January 31, 2018

Annual Report:

Central Coast Long-term Environmental Assessment Network

REGIONAL MONITORING PROGRAM

2016–2017

Lead Agency:
Carmel Area Wastewater District
3945 Rio Road
Carmel-by-The-Sea

cclean

Applied Marine Sciences, 911 Center St. Suite A, Santa Cruz, CA 95060

2016-2017 Annual Report: Central Coast Long-term Environmental Assessment Network

REGIONAL MONITORING PROGRAM

Submitted to:

California Water Board
Central Coast Region
895 Aerovista Place, Suite 101
San Luis Obispo, CA 93401

Submitted by:

911 Center Street, Suite A
Santa Cruz, CA 95060

January 31, 2018

Table of Contents

1.0 EXECUTIVE SUMMARY 1

2.0 PROGRAM BACKGROUND 6

3.0 REPORT ORGANIZATION AND SCOPE 11

4.0 RESULTS FOR PROGRAM OBJECTIVES 18

4.1 WHAT ARE THE STATUS AND LONG-TERM TRENDS IN THE QUALITY OF NEARSHORE WATERS, SEDIMENTS, AND ASSOCIATED BENEFICIAL USES? 18

4.1.1 Status and Trends of POPs and Nutrients in River Waters 19

4.1.1.1 Conclusions 25

4.1.1.2 Recommendations 25

4.1.2 Status and Trends of POPs and Nutrients in Open Ocean Waters 26

4.1.2.1 Conclusions 29

4.1.2.2 Recommendations 32

4.1.3 Status and Trends of Pollutants in Mussels 32

4.1.3.1 Conclusions 34

4.1.3.2 Recommendations 34

4.1.4 Status and Trends of Bacteria in Receiving Waters 37

4.1.4.1 Conclusions 39

4.1.4.2 Recommendations 40

4.1.5 Status and Trends of POPs in Sediments of Monterey Bay 42

4.1.5.1 Conclusions 42

4.1.5.2 Recommendations 44

4.2 WHAT ARE THE MAJOR SOURCES OF CONTAMINANTS TO NEARSHORE WATERS? 44

4.2.1 Sources of Nutrients to Monterey Bay 44

4.2.1.1 Conclusions 48

4.2.1.2 Recommendations 48

4.2.2 Sources of POPs to Monterey Bay 49

4.2.2.1 Conclusions 51

4.2.2.2 Recommendations 51

4.2.3 Relationships Between POP Sources and Water Quality Impairments 52

4.2.3.1 Correlations between the Pajaro River and North Monterey Bay 55

4.2.3.2 POP Profiling in Ocean Waters Without Ocean Plan Exceedances 56

4.2.3.3 POP Profiling in Ocean Waters with Ocean Plan Exceedances 57

4.2.3.4 POP Profiling in Potential POP Sources 60

4.2.3.5 Conclusions 76

4.2.3.6 Recommendations 77

4.3 WHAT ARE THE EFFECTS OF WASTEWATER DISCHARGES ON NEARSHORE WATERS? 77

4.3.1 Conclusions 78

4.3.2 Recommendations 78

5.0 REFERENCES CITED 79

Table of Figures

FIGURE 1. WATER YEAR 16 (WY 16) BROKEN DOWN INTO SAMPLING SEASONS. 13
FIGURE 2. LOCATIONS OF CCLEAN SAMPLING SITES FOR MUNICIPAL WASTEWATER EFFLUENT, OPEN OCEAN WATER, RECEIVING WATER, SEDIMENT, MUSSELS, AND RIVERS..... 16
FIGURE 3. TEMPORAL PATTERNS IN THE DAILY FLOW RATE (L/D) OF THE PAJARO RIVER (DATA COLLECTED FROM THE USGS GAUGE AT THE CHITTENDEN) AND IN DAILY RAINFALL (MM/D) OVER THE COURSE OF THE CCLEAN PROGRAM. 19
FIGURE 4. TEMPORAL PATTERNS IN CONCENTRATIONS OF POPS (NG/L) IN THE DRY VERSUS WET SEASONS IN THE PAJARO RIVER OVER THE COURSE OF THE CCLEAN PROGRAM. 20
FIGURE 5. TEMPORAL PATTERNS IN CONCENTRATIONS OF PBDES (NG/L) IN THE PAJARO RIVER SINCE MEASUREMENTS BEGAN IN 2006 (WY 6)..... 21
FIGURE 6. TEMPORAL PATTERNS IN CONCENTRATIONS OF NITROGEN IN THE FORM OF AMMONIUM (BLUE SYMBOLS) AND NITRATE (RED SYMBOLS) SINCE 2010 (WY 10) IN THE PAJARO RIVER. 22
FIGURE 7. CONCENTRATIONS IN NG/L OF A) FIPRONIL, B) FIPRONIL SULFIDE, AND C) FIRPONIL SULFONE MEASURED IN THE SAN LORENZO, PAJARO, SALINAS, AND CARMEL RIVERS IN WATER YEARS 15 AND 16. 23
FIGURE 8. PYRETHROID CONCENTRATIONS IN NG/L OF A) PERMETHRIN, B) BIFENTHRIN, C) CYPERMETHRIN, AND D) FENPROPATHRIN IN THE SAN LORENZO, PAJARO, SALINAS, AND CARMEL RIVERS IN WATER YEARS 15 AND 16..... 24
FIGURE 9. TEMPORAL PATTERNS IN CONCENTRATIONS OF A) PCBS, B) DIELDRIN, C) CHLORDANES, D) DDTS AND E) PAHS AT TWO OPEN WATER SITES IN MONTEREY BAY. 27
FIGURE 10. TEMPORAL PATTERNS IN CONCENTRATIONS OF PBDES IN NORTH (NMB) AND SOUTH (SMB) MONTEREY BAY IN THE DRY AND WET SEASONS. 28
FIGURE 11. TOXICITY EQUIVALENCY QUOTIENTS OF PCBS MEASURED AT TWO OPEN WATER SITES IN MONTEREY BAY SINCE 2012..... 29
FIGURE 12. ANNUAL TREND OF PAJARO RIVER FLOWS COMPARED WITH POP CONCENTRATIONS IN MONTEREY BAY (AVERAGE OF THE SOUTH AND NORTH MONTEREY BAY STATIONS) EXPRESSED AS THE DIFFERENCE (DELTA) BETWEEN THE ANNUAL MEAN AND LONG-TERM MEAN CONCENTRATION FOR EACH POP..... 30
FIGURE 13. SAME AS FIGURE 12 BUT FOR DIFFERENT POPS. A) DELTA PAJARO RIVER FLOWS, B) DELTA PCBS, C) DELTA CHLORDANES, C) DELTA PBDES. 31
FIGURE 14. CORRELATIONS BETWEEN FLOW DATA FROM THE PAJARO RIVER (MEASURED AT THE CHITTENDEN USGS GAGE STATION) AND SATELLITE-DERIVED TURBIDITY DATA FOR MONTEREY BAY, WHERE SPATIAL PIXELS WITH P VALUES > 0.05 ARE DEPICTED. 33
FIGURE 15. CONCENTRATIONS OF A) PCBS, B) DIELDRIN, C) CHLORDANES, D) DDT, AND E) PBDES IN MUSSEL TISSUE NORMALIZED TO WET WEIGHT (NG/G WW) FROM FIVE CCLEAN SITES IN MONTEREY BAY (WATER YEARS 6-16)..... 35
FIGURE 16. LIPID-WEIGHT CONCENTRATIONS OF PCBS, DIELDRIN, CHLORDANES, DDTS, AND PBDES MEASURED IN MUSSELS DURING THE WET SEASON FROM 5 CCLEAN SITES ALONG THE MONTEREY BAY COAST. 36
FIGURE 17. FIB ABUNDANCES (MOST PROBABLE NUMBER (MPN) OF BACTERIA PER 100 ML) FOR WATER YEARS 10-16 CORRESPONDING WITH YEARS 2010-2017 FROM M1W, SANTA CRUZ, AND WATSONVILLE RECEIVING WATER SITES..... 38
FIGURE 18. ANNUAL GEOMETRIC FIB MEANS OF MOST PROBABLE NUMBER OF BACTERIA PER 100 ML, AT STATIONS FAR- AND NEAR-FIELD FROM DISCHARGE AT THREE RECEIVING WATER SITES (MONEREY, SANTA CRUZ, AND WATSONVILLE) FOR THE WATER YEARS 10-16 (REPRESENTING YEARS 2010-2017). 40
FIGURE 19. TIME COURSE (2014-2017) OF MONTHLY SAMPLING OF A) PAJARO RIVER FLOW (L/D), B) PAJARO RIVER FECAL COLIFORM LOAD (MPN/D) CALCULATED FROM CONCENTRATION, AND C) FECAL COLIFORM CONCENTRATION (MPN/100 ML) AT THE WATSONVILLE NEAR-FIELD RECEIVING WATER SITE IN MONTEREY BAY..... 41
FIGURE 20. MEAN CONCENTRATIONS OF POPS IN SEDIMENTS FROM INNER BAY AND OUTER BAY SAMPLES..... 43
FIGURE 21. MEAN EFFLUENT FLOW RATE, LITERS PER DAY (L/D), FOR WATER YEARS 2-16 (REPRESENTING YEARS 2002-2017) BY CCLEAN DISCHARGERS. 45
FIGURE 22. NUTRIENT LOADS OVER TIME (WY 2-WY 16) BY SEASON (DRY AND WET) AND BY DISCHARGER (CAWD, WATSONVILLE, SANTA CRUZ, M1W). 47
FIGURE 23. NITROGEN (N) LOADING (KG/D) FROM THE PAJARO RIVER COMPARED WITH WASTEWATER EFFLUENT FROM THE CITY OF WATSONVILLE OVER THE PAST 4 WATER YEARS DURING THE A) DRY SEASON AND B) WET SEASON..... 48
FIGURE 24. COMBINED ANNUAL LOADS OF PYRETHROIDS AND FIPRONILS FROM ALL RIVERS AND ALL WASTEWATER SOURCES DISCHARGING INTO THE OCEAN IN THE MONTEREY BAY AREA. 49
FIGURE 25. LOADS OF POPS (G/YEAR) FROM ALL RIVERS COMBINED AND ALL WASTEWATER DISCHARGES COMBINED INTO THE OCEAN IN THE MONTEREY BAY AREA. 52

Figure 26. Mean daily wet-season loads of POPs from the San Lorenzo, Pajaro, and Salinas rivers. 54
Figure 27. Profiles of background, non-exceeding POP concentrations (a) and percentage of summed concentrations (b) for dry-season and wet-season ocean samples collected at North Monterey Bay. 58
Figure 28. Profiles of POP concentrations for ocean samples collected at North Monterey Bay with concentrations of DDT, dieldrin, PCBs, and chlordanes exceeding their Ocean Plan objectives. 59
Figure 29. Profiles of POP concentrations (a) and percentage of summed concentrations (b) for sediment samples collected from Santa Cruz (SC) Inner Harbor and Moss Landing (ML) Harbor in 2016 and 2017 and mean dry-season and wet-season loads from the Pajaro River (n = 8 dry season, 6 wet season) in samples not associated with exceeding ocean samples. 61
Figure 30. Profiles of POP percentages in ocean samples collected at North Monterey Bay with PCB exceedances of the Ocean Plan objective (a) and profiles of POP percentages in sediment samples from SC and ML and mean contemporaneous loads from the Pajaro River (b) 62
Figure 31. Profiles of POPs in Santa Cruz and Moss Landing harbor sediments and ambient sediments collected along the 80-m contour in 2015, 2016, and 2017 at two sites in northern Monterey Bay. 63
Figure 32. Profiles of DDTs in ocean samples with >5x exceedances of PCBs, in samples with exceedances for DDT and dieldrin, and in samples without exceedances. 64
Figure 33. Mean loads (a, c note log scale) and mean percentages of loads (b, d) of DDTs from the Pajaro River (n = 15) and Salinas River (n = 4) into northern Monterey Bay. 66
Figure 34. Profiles of concentrations (a) and percentage (b) of DDTs in non-exceeding ocean samples from North Monterey Bay. 67
Figure 35. Profiles of DDT compounds in ocean samples from North Monterey Bay that exceeded the Ocean Plan objective for DDTs. 68
Figure 36. Percentage of DDD in summed DDTs in samples without exceedances, in ocean samples with >5x exceedances of PCBs, and in ocean samples with exceedances for DDT 68
Figure 37. Profiles of POPs in wet-season ocean samples exceeding the Ocean Plan for DDTs (a) and contemporaneous loads from the Salinas River and Pajaro River (b) 69
Figure 38. Profiles of DDTs in wet-season ocean samples exceeding the Ocean Plan for DDTs (a) and contemporaneous loads from Salinas River and the Pajaro River (b) 70
Figure 39. Mean profiles of POPs and DDTs in wet-season samples from Pajaro River and Salinas River. 71
Figure 40. Profiles of POPs and DDTs in contemporaneous wet-season samples from North Monterey Bay (a and c) and Pajaro River (b and d) when ocean samples exceeded the Ocean Plan objective for DDT and when ocean samples did not exceed the objective for DDT. 72
Figure 41. Profiles of DDT isomers in agricultural soils from Santa Cruz and San Benito counties sampled in 1985 compared to wet-season loads from the Pajaro River sampled since 2002. 75

Table of Tables

Table 1. Laboratories and agencies participating in the CCLEAN program. 7
Table 2. Original elements of the CCLEAN program. 8
Table 3. POP groups emphasized in this report 12
Table 4. Sampling matrices, sites, frequency, techniques, parameters sampled, analytical methods, reporting limits, applicable water-quality stressors, and relevant program objectives for CCLEAN during the 2016–2017 program period. 14
Table 5. Dates, volumes and numbers of samples collected for CCLEAN in 2016–2017 17
Table 6. Concentrations of regulated (California Toxics Rule - CTR) pollutants in the Pajaro River and San Lorenzo River with CTR numeric criteria. 21
Table 7. Pyrethroid and Fipronil water quality criteria developed by Central Valley Water Board and removal efficiencies by wastewater treatment. 25
Table 8. PCB homolog concentrations and percent contribution of homologs to total PCB concentration in ocean samples from Monterey Bay. 26
Table 9. USEPA human health alert levels for wet-weight concentrations (ng/g) of chemical contaminants in fish and shellfish for two categories of consumers. 33

TABLE 10. OCEAN PLAN MONTHLY OBJECTIVES (ITALICS), ANNUAL GEOMETRIC MEANS, MEDIANS AND SINGLE SAMPLE MAXIMA FOR INDICATOR BACTERIA (MPN/100 ML OR CFU/100 ML) IN RECEIVING WATERS ADJACENT TO OCEAN OUTFALLS FOR THREE CCLEAN WASTEWATER DISCHARGERS DURING WY 16. 37
TABLE 11. WET SEASON SIX-MONTH MEDIAN CONCENTRATIONS (MG/L) AND LOADS (KG/D) OF AMMONIUM IN CCLEAN WASTEWATER EFFLUENT DISCHARGES FOR WY 16 AND NPDES PERMIT LIMIT FOR EACH DISCHARGER 44
TABLE 12. SUM OF ANNUAL LOADS OF TOTAL N (NH_4^+ + NO_3^- + UREA-N), AMMONIUM-N (NH_4-N), NITRATE-N (NO_3-N), UREA-N, PHOSPHATE-P (PO_4^{3-}) AND SILICA IN EFFLUENT DISCHARGED BY FOUR CCLEAN PARTICIPANTS. 46
TABLE 13. CONCENTRATIONS AND MAXIMUM DAILY LOADS OF REGULATED (OCEAN PLAN) POLLUTANTS IN MEASURED CCLEAN WASTEWATER DISCHARGES (WITH NPDES PERMIT LIMITS FOR EACH DISCHARGER) DURING WY 16. 50
TABLE 14. AVERAGE ANNUAL LOADS (G/YEAR) OF POPS BETWEEN 2001-2017 FROM COMBINED WASTEWATER AND RIVER DISCHARGES. 51
TABLE 15. THE MASS OF SEDIMENTS PERMITTED FOR DREDGING AND DISPOSAL FROM MOSS LANDING (ML) HARBOR AND SANTA CRUZ (SC) INNER HARBOR BETWEEN 2004 AND 2014. 55
TABLE 16. CORRELATIONS BETWEEN LOADS OF INDIVIDUAL POPS FROM THE PAJARO RIVER AND THEIR RESPECTIVE CONCENTRATIONS AT THE NORTH MONTEREY BAY SITE AND BETWEEN POPS WITHIN OCEAN SAMPLES. 56
TABLE 17. CORRELATIONS BETWEEN POPS IN OCEAN SAMPLES FROM NORTH MONTEREY BAY 56
TABLE 18. DATES AND CONCENTRATIONS OF POPS AT OR ABOVE OCEAN PLAN OBJECTIVES AT NORTH MONTEREY BAY SINCE 2004. 57
TABLE 19. WET-SEASON PAJARO RIVER LOADS (I.E., RIVER = G/DAY) FOR DDTS, DIELDRIN, CHLORDANES, AND PCBS, FOR EACH SAMPLING EVENT, WITH CORRESPONDING OCEAN CONCENTRATIONS (I.E., OCEAN = NG/L; PG/L FOR PCBS) AT NORTH MONTEREY BAY. 74

Central Coast Long-term Environmental Assessment Network

2016–2017 Annual Report

1.0 Executive Summary

The Central Coast Long-term Environmental Assessment Network (CCLEAN) annual report incorporates the results from 2016–2017 with historic data. Major findings are as follows:

Status and Trends of POPs and Nutrients in River Waters: Concentrations of the legacy pesticides dieldrin, chlordanes, and DDTs, as well as PCBs, continue to exceed the CTR criteria for human consumption of water and organisms in the Pajaro River in the wet season. In contrast, concentrations of nitrogen sources have steadily decreased in the wet season and reached their lowest level compared with the past five years. In the past two years, contaminants of emerging concern (CECs), such as fipronils, have been consistently detected above guidance levels in the San Lorenzo River, and pyrethroids have been consistently detected in the Pajaro and Salinas Rivers with concentrations of bifenthrin and cypermethrin measured above guidance levels. It is not clear whether these CECs will continue to increase in concentration over time or not. Measurements elsewhere in California tend to be sporadic in nature and are focused on toxicities rather than trends.

Recommendations: Sampling of rivers for legacy POPs and for contaminants of emerging concern should continue in order to improve our understanding of the potential impact of river discharges on beneficial uses in Monterey Bay, and to provide comparisons for evaluating effects of the discharges from the POTWs.

Status and Trends of POPs and Nutrients in Open Ocean Waters: Water column POP concentrations in Monterey Bay appear to either be related to wet season water run-off or to other non-weather related factors. In the former category are dieldrin and DDTs, which had the highest recorded concentrations this past wet season compared with the long-term mean concentration measured by CCLEAN. Concentrations of both these POPs exceeded the Ocean Plan for the first time since 2012. Concentrations of PAHs also demonstrated an increase this past wet season. In contrast with dieldrin and DDTs, concentrations of PCBs and chlordanes did not increase this past wet season despite record flow from rivers such as the Pajaro. Concentrations of both these compounds demonstrated highest concentrations in the dry seasons of 2010 and 2012. Exceedances of the Ocean Plan water quality objective for PCBs have occurred in nearly every ocean sample collected by CCLEAN since 2008; new evidence suggests especially high pulses of PCBs have been associated with releases of materials from anaerobic environments. High PBDE concentrations have also occurred sporadically in Monterey Bay but are not easily associated with a particular locale or event.

Recommendations: Sampling of POPs in open ocean waters should continue in order to document the status and trends of beneficial uses in Monterey Bay, and to document the effects of pollutant sources on ocean water quality.

Status and Trends of Pollutants in Mussels: Concentrations of PCBs and the legacy pesticides dieldrin, chlordanes, and DDTs increased sharply this year over recent years at The Hook, both on a wet-weight and a lipid-weight basis. The sharp increase in mussel body burdens on a wet-weight basis at this site exceeded human health alert levels for all three legacy pesticides (dieldrin, chlordanes and DDTs) as well as for PCBs. Moreover, concentrations of PCBs, dieldrin, and chlordanes at The Hook were the highest ever measured in mussel tissue at any site under the CCLEAN program.

> **Recommendations:** Mussel sampling provides a valuable sentinel for detection of temporal trends in contaminants coming from the land into the nearshore marine ecosystem. It should continue as part of CCLEAN at its current annual frequency.

Status and Trends of Bacteria in Receiving Waters: A second year with strong wet-season precipitation and river flow resulted in record FIB concentrations in Monterey receiving waters and in FIB concentrations similar to, or greater than, the previous year in Watsonville and Santa Cruz receiving waters. These increases in FIB concentrations were for the most part similar between near- and far-field measurements and therefore could not be systematically associated with discharges from the CCLEAN participants. As such, the combined wastewater discharges from the three CCLEAN participants does not appear to cause impairments to water contact recreation above that associated with loading of FIBs from nearby rivers such as the Pajaro River. Exceedances of the single sample maxima for fecal coliform and *Enterococcus* in Watsonville receiving waters in the month of January were associated with an exceptionally high load of FIBs from the Pajaro River which discharges in the vicinity of the Watsonville wastewater outfall. Data contributed by the monitoring programs of individual CCLEAN stakeholders indicate relatively low concentrations of FIB from most POTWs throughout the reporting period.

> **Recommendations:** Monitoring of FIB concentrations should continue in Monterey Bay receiving waters as well as in the Pajaro River. Moreover, loads of FIBs from the Pajaro should continue to be estimated in order to track the effects of non-wastewater sources on receiving water FIB concentrations.

Status and Trends of POPs in Sediments: Concentrations of all POPs measured in Monterey Bay sediments were greater in the Outer Bay samples compared with Inner Bay samples. The only exception was dieldrin, which had the same concentration in both Inner and Outer Bay sediment samples. Concentrations of most POPs have decreased over time since sediment sampling began under the CCLEAN program; this year the decrease appeared to have leveled off as concentrations were similar to last year's. An important exception to this trend was PCBs, which are increasing in concentration in both Inner and Outer Bay sediments.

Three new sediment sites were added this year in order to further investigate potential sources of elevated PCBs in Monterey Bay, which previously have been correlated with disposal of dredged materials. Dredging occurs both in the Santa Cruz Inner Harbor and Moss Landing Harbor and very fine-grained spoils that conform to contaminant and toxicity limitations are deposited at the SF-14 dumping site at the southern border of the Monterey

Canyon. Evaluation of the 2016 POP data from these three additional sediment sites demonstrated that Moss Landing Harbor sediments were the most contaminated compared with any of the other sites measured under CCLEAN.

> **Recommendations:** Annual sediment sampling should continue until the source of high PCBs in Monterey Bay can be more definitively determined.

Sources of Nutrients to Monterey Bay Waters: Since the start of the CCLEAN monitoring program, loads of nutrients discharged by each participating agency has either remained consistent or declined. Nutrient loads from effluent are typically greater than that from rivers in the dry season but less in the wet season. This past wet season, flows in the Pajaro River were at a record high driving the annual load of nitrogen to 20,385 kg N/day from the Pajaro River compared with 262 kg N/day from Watsonville effluent.

> **Recommendations:** Continue to monitor nutrient concentrations in effluent and in Rivers in order to assess their effect on beneficial uses in Monterey Bay. For the coming year, an in-depth analysis of the impact of nutrient discharge from effluent and rivers on phytoplankton biomass development in the nearshore region is recommended. An inter-laboratory calibration exercise should be conducted to confirm the proficiency of local and agency laboratories for analysis of nutrients at relevant ocean concentrations.

Sources of POPs to Monterey Bay Waters: Estimated loads of most POPs remain much greater from rivers than from wastewater. This year, loads of POPs from rivers were at a record high compared with past years, including the load of PBDEs, which has been higher from rivers than wastewater in the last two years. Loads of pyrethroids and fipronils increased dramatically this year compared with last year, both from wastewater and from rivers, underscoring the importance of continuing to monitor the trend of these CECs.

> **Recommendations:** Continue to monitor concentrations of legacy POPs as well as the newly emerging pyrethroids and fipronils.

Relationships Between POP Sources and Water Quality Impairments: Exceedances of Ocean Plan objectives for DDTs, dieldrin, chlordanes, and PCBs at North Monterey Bay have different sources. DDTs and dieldrin appear to have a similar source, which is different from the source(s) for chlordanes and PCBs. Ocean concentrations of DDTs and dieldrin were highly correlated, as were the ocean concentrations of chlordanes and PCBs.

The link between DDTs and dieldrin includes co-occurrence of wet-season exceedances, including in February 2017, when loads for both were the highest ever recorded by CCLEAN from the Pajaro River. Ocean concentrations of summed DDTs and dieldrin also were significantly correlated with loads from the Pajaro River and there were similarities of POP and DDT compound profiles in exceeding ocean samples and contemporaneous loads from the Pajaro River. These results are consistent with the Pajaro River being a source of DDTs and dieldrin that have exceeded Ocean Plan water quality objectives in wet-season samples, although effects of discharges from the Salinas River on ocean exceedances cannot be ruled out.

Comparisons of mean POP and DDT profiles between wet-season ocean samples with and without exceedances of DDT water quality objectives revealed that exceeding samples had profiles very similar to those for the Pajaro River, whereas non-exceeding samples were different from the Pajaro River. This result also suggests the Pajaro River as a source of DDTs that exceeded water quality objectives. Moreover, the exceeding ocean samples at the North Monterey Bay ocean site were not uniformly associated with the highest loads from the Pajaro River, which suggests that detections of wet-season DDT Ocean Plan exceedances at North Monterey Bay are related to oceanographic phenomena that transport more or less concentrated river water past the site, and that the actual rate of exceedance during the wet season is higher than what CCLEAN has detected.

DDT isomer profiles obtained from historic soil data collected in 1985 from agricultural fields in the Pajaro River watershed were compared to isomer profiles for wet-season loads in the Pajaro River. This comparison found that 95% of the variation in wet-season DDT isomer profiles from the Pajaro River was explained by the DDTs measured in 1985. This indicates erosion of agricultural soils is the likely source of DDTs in wet-season samples from the Pajaro River and, by extension, causes exceedances of water quality objectives in the ocean. The infrequent dry-season DDT and dieldrin exceedances are unrelated to river discharges and coincided with exceedances for chlordanes and PCBs.

The link between chlordanes and PCBs is less obvious than that between DDTs and dieldrin. PCBs have exceeded the Ocean Plan objective in 19 out of 22 samples collected at North Monterey Bay since 2004. Five of these exceedances were >5 times above the Ocean Plan objective. Three out of four chlordane Ocean Plan exceedances at North Monterey Bay co-occurred with extreme PCB exceedances. The fourth chlordane exceedance occurred in February 2017 during the highest chlordane load measured by CCLEAN from the Pajaro River. The highest chlordane concentration measured at North Monterey Bay coincided with the an extreme event in September 2012, in which the highest concentration of PCBs was measured at that site, as well as exceedances of Ocean Plan objectives by DDTs and dieldrin. The PCB concentration in this sample, which was based on quantification of 71 of the total 209 PCB congeners, was 40 times higher than the Ocean Plan objective. This sample also contained the third highest concentrations of both DDTs and dieldrin measured at North Monterey Bay. The profiles of POPs in this, and other samples that exceeded the PCB Ocean Plan objective, were similar to two out of four profiles of surficial sediment collected by CCLEAN in Santa Cruz Inner Harbor and Moss Landing Harbor. The profile of DDT compounds in the September 2012 and October 2014 samples from North Monterey Bay that exceeded the PCB Ocean Plan objective indicated the DDTs in the samples came from sources with anaerobic antecedent conditions, such as deep sediments. We conclude that, although extreme river flows can lead to Ocean Plan exceedances for chlordanes, most chlordane exceedances and all PCB exceedances are unrelated to river discharges and tend to not co-occur with exceedances of DDTs or dieldrin.

Recommendations: Every effort should be made to restore POP sampling in the Pajaro River, as well as the Salinas River. The impact of river discharges on ocean water quality needs to be documented through regular sampling, especially in the wet season. In this

regard, discussions with agricultural interests and water quality managers should be undertaken to explore funding opportunities. Continuation of sediment sampling in Moss Landing Harbor and Santa Cruz Small Craft Harbor is also essential. With additional samples, future analytical approaches are under investigation that could better discern similarities between ocean concentrations of POPs and contaminant profiles from various possible sources.

What are the Effects of Wastewater Discharges on Nearshore Waters: CCLEAN data continue to provide evidence of a sustainable environment in the Monterey Bay region with its regulated wastewater discharges. CCLEAN's approach to implementing regional science and regulation-driven planning continues to benefit the participants, stakeholders along the Central Coast, and the regulatory authorities.

Recommendations: CCLEAN should continue to describe the status and trends of beneficial uses in Monterey Bay and seek ways to describe the roles, if any, of wastewater discharges in impairments and enhancements to beneficial uses, while also identifying other sources of water quality impairments.

2.0 Program Background

The complexity of environmental issues affecting nearshore marine waters today have led to general agreement that their protection is only possible by implementing regional approaches to monitoring and resource management. Nearshore waters are affected by point-source discharges, storm runoff, rivers, agriculture, discharges from ships, and atmospheric deposition. At the same time, many marine resources are diminishing under pressure from increasing usage. In the late 1990s, multiple agencies in the Monterey Bay area began working toward implementation of a regional approach to monitoring watersheds and coastal waters.

CCLEAN is a long-term monitoring program committed to environmental stewardship that has been designed by program participants to fulfill several regulatory objectives. CCLEAN is currently funded by the City of Santa Cruz, 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 California Regional Water Quality Control Board, Central Coast Region (Water Board). 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 monitoring. In addition, it represents a significant portion of their contributions to their communities' efforts at sustainability of their coastal environments. However, CCLEAN is also the current mechanism by which the Water Board fulfills part of its obligations under a monitoring framework developed to provide an ecosystem-based Water Quality Protection Program for the Monterey Bay National Marine Sanctuary. The monitoring framework evolved to fulfill the Water Board's obligations to the Management Plan for the Sanctuary. The Sanctuary's Management Plan includes a Memorandum of Agreement among 8 federal, state, and regional agencies (including the Water Board). The Water Board's framework for partial fulfillment of this Water Quality Protection Program is the Central Coast Ambient Monitoring Program (CCAMP). This multidisciplinary program includes sampling in watersheds that flow into coastal regions, in estuarine coastal confluences, and at coastal sites. The goal of CCAMP is to "collect, assess, and disseminate scientifically based water quality information to aid decision-makers and the public in maintaining, restoring, and enhancing water quality and associated beneficial uses." CCLEAN is the only program measuring persistent organic pollutants (POPs) and contaminants of emerging concern (CECs) in ocean water 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 goals of the CCLEAN program are: 1) To fulfill the regulatory requirements of the stakeholders in complying with continued analyses of the effects of the location and discharge into the receiving waters of the Central Coast, and 2) to assist stakeholders in maintaining, restoring, and enhancing nearshore water and sediment quality to support associated beneficial uses in the Central Coast Region, including recreation, wildlife habitat and biological communities. During the initial formation of CCLEAN, program participants decided that it should use high-quality data to address the following questions and objectives:

- What are the status and long-term trends in the quality of nearshore waters, sediments, and associated beneficial uses?
    - Do nearshore waters and sediments comply with the Ocean Plan?
- What are the major sources of contaminants to nearshore waters?
- What are the effects of wastewater discharges in nearshore waters?
- Develop a long-term database on trends in the quality of nearshore waters, sediments and associated beneficial uses.
- Ensure that the database is compatible with other regional monitoring efforts and regulatory requirements.
- Ensure that data are presented in ways that are understandable and relevant to the needs of stakeholders.

To answer these questions and to meet the program objectives, CCLEAN relies on a diverse team of scientists from several organizations (Table 1) and a range of sample matrices and parameters as originally developed by the CCLEAN program (Table 2).

Table 1. Laboratories and agencies participating in the CCLEAN program.

Organization	Location	Responsibilities
Applied Marine Sciences	Santa Cruz, CA	Program direction, data analysis, reporting
Kinnetic Laboratories	Santa Cruz, CA	Field sampling, data reporting
Axys Analytical	Sydney, British Columbia	POP analyses in all matrices
Physis Laboratories	Anaheim, CA	Pyrethroids and fipronils in water
Ramboll-Environ	Port Gamble, WA	Sediment sampling
Moss Landing Marine Laboratories	Moss Landing, CA	Sorting and identification of benthic organisms
City of Santa Cruz Environmental Laboratory	Santa Cruz, CA	Nutrients and bacteria in water
City of Watsonville Laboratory	Watsonville, CA	Nutrients and bacteria in water
Monterey One Water Laboratory	Marina, CA	Nutrients and bacteria in water
Sonoma County Department of Health	Santa Rosa, CA	Bacterial analysis in tissues

Analysis of data employs various graphical and statistical approaches, as well as comparisons of data with numeric and narrative objectives, guidelines and alert levels from the Ocean Plan (State Water Resources Control Board 2009), Central Coast Basin Plan (Central Coast Water Board 2017), California State Mussel Watch Program (California State Mussel Watch Program 2003), California Office of Environmental Health Hazard Assessment (Office of Environmental Health Hazard Assessment 2003), USEPA, and the National Oceanic and Atmospheric Administration (Long et al. 1998; Long et al. 2000). Much of the focus of CCLEAN has been on determining the sources, loads to the ocean, and effects of legacy contaminants. Most of these are POPs whose uses have been banned for 30–40 years, yet continue to be broadly detected in the environment at concentrations that are sometimes toxic. Moreover, due to their chemical characteristics, they often accumulate in animals, with concentrations increasing higher in the food chain. For example, it has been suggested that killer whales along the coast of British

Columbia have accumulated body burdens of PCBs that are exceeding probable toxic levels (Hickie et al, 2007).

CCLEAN participants have adaptively managed the program based on findings and emerging issues of concern in water quality management. This adaptive management has included both additions and reductions in program elements, including dropping analytes that have consistently either not been accumulated by mussels or have remained consistently below water quality objectives without evidence of upward trends. The original program elements are described in Table 2.

Table 2. Original elements of the CCLEAN program.

Sampling Sites	Parameters Sampled at Each Site	Frequency of Sampling
Water Sampling 4 wastewater discharges (Santa Cruz, Watsonville, Monterey, Carmel) in effluent and 4 rivers (San Lorenzo, Pajaro, Salinas, Carmel)	30-day flow proportioned samples using automated pumping equipment, solid-phase-extraction (particle filter + XAD resin) techniques for persistent organic pollutants (POPs); screen effluent for reproductive endocrine disruption activity	Twice per year (wet season and dry season)
	Grabs of effluent for ammonia and nitrate, turbidity, temperature, conductivity, pH, urea, orthophosphate, dissolved silica and total suspended solids	Monthly
30-ft contour sites for Santa Cruz, Watsonville, and Monterey One Water	Grabs for total and fecal coliform, *enterococcus*	At least monthly
2 background sites	30-day time-integrated samples using automated pumping equipment and solid-phase-extraction (particle filter + XAD resin) techniques for: POPs, nitrate, ammonia, urea, orthophosphate and dissolved silica, total suspended solids, temperature, conductivity, pH, total and fecal coliform, *enterococcus*	Twice per year (wet season and dry season)
10 coastal streams from Waddell Creek to Big Sur River	Nutrients and bacteria	Monthly
Sediment Sampling 3 sites along the northern bight in outer 3 sites in inner Monterey Bay along 80-m contour,	Single samples for benthic infauna, POPs, total organic carbon and grain size	Every 5 years in the fall
Mussel Sampling 5 rocky intertidal sites	1 composite of 30-40 mussels for POPs, total and fecal coliform, and *enterococcus*	Twice per year (wet season and dry season)

Major milestones in the evolution of the program have included the following:

2005–2006 – Commissioned an external peer review by independent consultant Dr. Brock Bernstein;

2006–2007 – Stream sampling was eliminated due to implementation of monthly sampling by the Central Coast Water Board as part of its Coastal Confluences Ambient Monitoring Program

(CCAMP); mussel sampling frequency was reduced to an annual wet-season index period; measurements of Diazinon, Chlorpyrifos and alkylated PAHs were eliminated; measurements of the flame retardants polybrominated diphenylethers (PBDEs); non-stick coatings perfluorinated compounds (PFCs) were added; and effluent POP data began to be used for NPDES permit compliance;

2007–2008 – POP sampling at the Salinas and Carmel River mouths was discontinued so that program participants would not be required to fund sampling of constituents that they could not control;

2008–2009 – Sediment sampling near the mouths of the Pajaro and Salinas rivers was performed in an attempt to track high concentrations of legacy pesticides back to their sources, measurement of dioxins/furans began in water and wastewater samples;

2009–2010 – A modified EPA assay was implemented to determine the measure of specific reproductive endocrine disrupting activity in effluent wastewater from participating agencies. The study was peer-reviewed by Golder Associates and repeated testing was recommended; sediment sampling was reduced to 6 of the 8 historic CCLEAN sites and the frequency of sediment sampling was reduced to every 5 years;

2011–2012 – measurement of PFCs was discontinued due to infrequent detections in mussels and sediment;

2012–2013 – In order to better determine sources of elevated PCB concentrations in Monterey Bay, analysis of PCBs in water and effluent samples was expanded from the 70 congeners historically measured by CCLEAN to all 209 PCB congeners;

2013–2014 – CCLEAN began collaborating with agencies that discharge stormwater into Areas of Special Biological Significance (ASBS) by sharing data from the mussel bioaccumulation monitoring performed by CCLEAN. ASBS stormwater dischargers provided funding to include additional analytes required by their program (i.e., antibiotics and other anthropogenic compounds particularly indicative of human influence, such as caffeine), as well as an additional site at Point Reyes National Seashore. CCLEAN also performed a pilot study during the dry-season where effluent from Santa Cruz and Watsonville, as well as waters from the San Lorenzo and Pajaro Rivers, were sampled to determine the feasibility of using flow-proportioned high-volume sampling to monitor pyrethroid pesticides in wastewater and rivers.

2014–2015 – Due to poor pyrethroid recoveries in the 2013–2014 screening exercise, high-volume water sampling in 2014–2015 utilized separate sampling media for pyrethroids and other POPs. After sampling was completed for other POPs, new sampling media were installed in the sampling equipment to collect samples for pyrethroids. Moreover, in the wet-season samples, the dissolved phase and particulate phase were extracted and analyzed separately from the XAD resin and particle filter, respectively.

2015–2016 – Based upon poor recoveries of pyrethroids and fipronils from high-volume water sampling media, collection of six-liter grab samples over three-day periods began for analysis of

these compounds in rivers and wastewater. Also, earlier CCLEAN annual reports documented frequent ocean PCB concentrations above the California Ocean Plan water quality objective and statistical links between ocean PCB concentrations in Monterey Bay and permitted volumes of dredged material from local harbors. In order to better understand linkages between sediments and water quality, sediments collected in fall 2015 were analyzed with high-resolution methods for all 209 PCB congeners. Preliminary review of chemistry data from sediment samples collected in fall 2015 revealed many more PCB congeners than previously observed. These high-resolution data afforded the opportunity to compare the composition of sediment PCBs with the composition of PCBs in ocean waters to further examine linkages between the two matrices.

2016–2017 – In order to better understand the spatial and temporal variation in sediment PCBs, the current program year included sediment sampling at each of the six CCLEAN sites, as well as in Moss Landing and Santa Cruz harbors, and at the approved dredge disposal site in Monterey Bay. These samples were analyzed for PCBs and chlorinated pesticides using high-resolution methods.

3.0 Report Organization and Scope

This report analyzes the 2016–2017 results in a manner designed to improve the efficiency of the CCLEAN program and guide management actions to reduce impairments of beneficial uses associated with discharges of POPs, nutrients and fecal indicator bacteria (FIBs) to the ocean. Graphical and statistical presentations emphasize six POP groups that have either been associated with beneficial use impairments in previous CCLEAN reports, or are contaminants of emerging concern (CECs) that currently are not regulated by the Ocean Plan or NPDES waste discharge permits (Table 3). While CCLEAN measures more compounds in several of these groups than are regulated by the Ocean Plan (Table 3), comparisons between Ocean Plan water quality objectives and concentrations measured in Monterey Bay are based only on those POPs that are covered by the Ocean Plan (Table 3). The Ocean Plan currently regulates only commercial mixtures of PCBs called Aroclors. Different Aroclors were developed for different uses and each Aroclor contained different amounts of the individual PCB compounds (i.e., PCB congeners 1 through 209). While some of the PCB congeners reported by CCLEAN were not detected in the Aroclors regulated by the Ocean Plan (Frame et al. 1996), these congeners co-elute with other more widely detected congeners and are included here in ocean PCB concentrations and are presented in the graphs of the PCB trends. As CCLEAN historically measured only 71 out of a possible 209 PCB congeners, the concentrations of PCBs reported here are probably conservative.

The sampling of discharges from rivers ceased to be a formal part of the CCLEAN program in 2007. Nevertheless, the City of Watsonville and the City of Santa Cruz continue to support measurement of POPs in the Pajaro River and San Lorenzo River, respectively, and those data have are presented in a separate section on the Status and Trends of POPs and Nutrients in Rivers with the permission from each city. This year, precipitation and river flows were exceptionally high in the wet season compared with past wet seasons since sampling began under the CCLEAN program and data have been included demonstrating the trend in river flows over time in a number of places in this report.

In 2011, sediment sampling was shifted from observation of status and trends to trends only (see Section 2). As such, sampling was reduced to every five years and was last performed in 2015. However, following recent re-analysis of water column PCB data demonstrating that these increased concentrations were potentially associated with dredging event, the CCLEAN steering committee resolved to go back to sampling sediments for POP analysis every year. In addition, three new sediment sites were added for the first time this year. These include a site in Santa Cruz Harbor, a site in Moss Landing Harbor and a site in the vicinity of a site where sediments dredged from both Santa Cruz and Moss Landing Harbors are deposited.

Table 3. POP groups emphasized in this report.

POP Group	Compounds Measured by CCLEAN	Compounds covered under the Ocean Plan
PAHs Reporting Limits:	Polynuclear aromatic hydrocarbons: Biphenyl, Naphthalene, 1-methylnapthalene, 2-methylnapthalene, 2,6-dimethylnapthalene, 2,3,5-trimethylnapthalene, Acenaphthene, Acenaphthylene, Anthracene, Dibenzothiophene, Fluorene, Phenanthrene, 1-methylphenanthrene, Benz(a)anthracene, Chrysene, Fluoranthene, Pyrene, Benzo(a)pyrene, Benzo(e)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Dibenz(a,h)anthracene, Perylene, Benzo(ghi)perylene, Indeno(1,2,3-cd)pyrene	acenaphthylene, anthracene,1,2-benzanthracene (Benz(a)anthracene), 3,4-benzofluoranthene (Benzo(b)fluoranthene), benzo[k]fluoranthene, 1,12-benzoperylene (Benzo(ghi)perylene), benzo[a]pyrene, chrysene, dibenzo[ah]anthracene, fluorene, indeno[1,2,3-cd]pyrene, phenanthrene and pyrene
DDTs	o,p'-DDT, p,p'-DDT = (1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) o,p'-DDD, p,p'-DDD = (1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane) o,p'-DDE, p,p'-DDE = (1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene)	o,p'-DDT, p,p'-DDT = (1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) o,p'-DDD, p,p'-DDD = (1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane) o,p'-DDE, p,p'-DDE = (1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene)
Dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4α,5,6,7,8,8α-octahydro-1,4-endo,exo-5,8-dimethanonaphthalene	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4α,5,6,7,8,8α-octahydro-1,4-endo,exo-5,8-dimethanonaphthalene
Chlordanes	trans-Chlordane, cis-Chlordane, trans-Nonachlor, cis-Nonachlor, Oxychlordane, Heptachlor, Heptachlor epoxide	
PCBs	Polychlorinated biphenyls: congener numbers = all 209 congeners in water; congeners 5, 8, 18, 20, 21, 28, 31, 33, 43, 44, 49, 52, 56, 60, 61, 66, 69, 70, 73, 74, 76, 80, 86, 87, 89, 90, 93, 95, 97, 99, 101, 105, 106, 110, 111, 113, 115, 116, 117, 118, 127, 128, 132, 138, 139, 141, 147, 149, 151, 153, 156, 158, 160, 163, 164, 168, 170, 174, 177, 180, 181, 182, 183, 187, 190, 194, 195, 196, 201, 203 in tissues	The sum of chlorinated biphenyls whose analytical characteristics resemble those of Aroclor-1016, Aroclor-1221, Aroclor-1232, Aroclor-1242, Aroclor-1248, Aroclor-1254 and Aroclor-1260 (All CCLEAN congeners are included)
Dioxins/ Furans[2]	TCDD, 2,3,7,8-; PeCDD, 1,2,3,7,8-; HxCDD, 1,2,3,4,7,8-; HxCDD, 1,2,3,6,7,8-; HxCDD, 1,2,3,7,8,9-; HpCDD, 1,2,3,4,6,7,8-; OCDD, 1,2,3,4,6,7,8,9-; TCDF, 2,3,7,8-; PeCDF, 1,2,3,7,8-; PeCDF, 2,3,4,7,8-; HxCDF, 1,2,3,4,7,8-; HxCDF, 1,2,3,6,7,8-; HxCDF, 1,2,3,7,8,9-; HxCDF, 2,3,4,6,7,8-; HpCDF, 1,2,3,4,6,7,8-; HpCDF, 1,2,3,4,7,8,9-	
PBDEs[1]	Polybrominated diphenyl ethers: congener numbers = 7, 8, 10, 11, 12, 13, 15, 17, 25, 28, 30, 32, 33, 35, 37, 47, 49, 51, 66, 71, 75, 77, 79, 85, 99, 100, 105, 116, 119, 120, 126, 128, 138, 140, 153, 154, 155, 166, 181, 183, 190, 203, 206, 207, 208, 209	
Pyrethroids[1]	Allethrin, Bifenthrin, Cyfluthrin, Cyhalothrin - total lambda, Cypermethrin, Danitol (Fenpropathrin), Deltamethrin/Tralomethrin, Esfenvalerate, Fenvalerate, Fluvalinate, Permethrin-cis, Permethrin-trans, Tetramethrin	
Fipronils[1]	Fipronil, Fipronil desulfinyl, Fipronil sulfide, Fipronil sulfone	

[1] = Currently not regulated by the California Ocean Plan.

[2] = Measured in wastewater only

Program monitoring activities during water year 16 (WY 16) = July 1, 2016 – June 30, 2017 and their relationship to program objectives are shown in Table 4. Figure 1 illustrates the program or water year with its associated sampling seasons (dry and wet). Sampling sites are shown in Figure 2 and the dates of sampling are shown in Table 5. All sampling methods have been described in previous CCLEAN reports (CCLEAN 2007) and are also listed in Table 4. Also in this year's report, CCLEAN continues the conservative approach of calculating sums of analytes (e.g., PAHs, DDTs, PCBs, etc.), in which individual analytes whose reported values have received the SWAMP QA code of "JA" (i.e., peak detected, but did not meet quantification criteria, result reported represents the estimated maximum possible concentration) are excluded from summed concentrations.

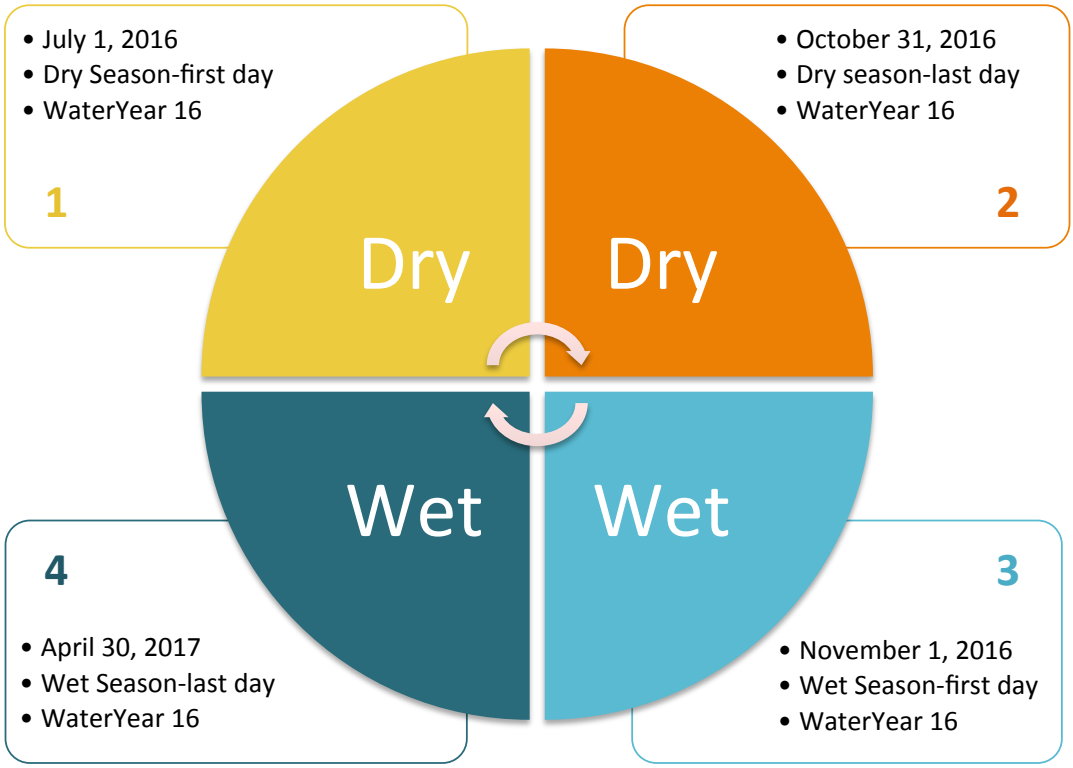

Figure 1. Water Year 16 (WY 16) broken down into sampling seasons. Dry season (starting July 1, 2016 and ending October 31, 2016) marked in orange and the wet season (starting November 1, 2016 and ending April 30, 2017) marked in blue.

Table 4. Sampling matrices, sites, frequency, techniques, parameters sampled, analytical methods, reporting limits, applicable water-quality stressors, and relevant program objectives for CCLEAN during the 2016–2017 program period.

Sample Matrix	Sampling Frequency	Sampling Technique	Parameter sampled	Analytical Method	Reporting Limits	Applicable Water Quality Stressors and Program Objectives
Effluent – Santa Cruz Watsonville M1W CAWD	Two times per year (wet and dry season)	30-day flow proportioned samples using automated pumping and solid-phase-extraction (particle filter + XAD resin)	PAHs	AXYS MLA-021 Rev 12	<1 ng/L	Sources, loads, trends, effects and permit compliance for: POPs
			DDTs	AXYS MLA-007 Rev 13	<1 ng/L	
			Dieldrin	AXYS MLA-028 Rev 06	<1 ng/L	
			Chlordanes	AXYS MLA-007 Rev 13	<1 ng/L	
			PCBs	AXYS MLA-010 Rev 11	<1 pg/L	
			Dioxins/Furans	AXYS MLA-017 Rev 20	<1 pg/L	
			PBDEs	AXYS MLA-033 Rev 06	<1 pg/L	
		Three-day, six-liter composites	Pyrethroids	EPA 625	<1 ng/L	Trends of: Emerging POPs of concern
			Fipronils	EPA 625	<1 ng/L	
	Weekly	Grab	Ammonia	SM4500	0.1 mg/L	Sources, loads, trends and permit compliance for: Nutrients
			Nitrate	EPA 300.0	0.1 mg/L	
			Silica	EPA 300.0	0.1 mg/L	
			Ortho-Phosphate	EPA 300.0	0.1 mg/L	
			Urea	Mulvenna 1992	0.01 mg/L	
Influent – Watsonville	Once per year (dry season					Efficiency of: POP removal
Rivers – San Lorenzo Pajaro	Two times per year (wet and dry season)	30-day flow proportioned samples using automated pumping and solid-phase-extraction (particle filter + XAD resin)	PAHs	AXYS MLA-021 Rev 12	<1 ng/L	Sources, loads, trends, effects and permit compliance for: POPs
			DDTs	AXYS MLA-007 Rev 13	<1 ng/L	
			Dieldrin	AXYS MLA-028 Rev 06	<1 ng/L	
			Chlordanes	AXYS MLA-007 Rev 13	<1 ng/L	
			PCBs	AXYS MLA-010 Rev 11	<1 pg/L	
			PBDEs	AXYS MLA-033 Rev 06	<1 pg/L	
Rivers – San Lorenzo Pajaro Salinas Carmel		Three-day, six-liter composites[1]	Pyrethroids	EPA 625	<1 ng/L	Trends of: Emerging POPs of concern
			Fipronils	EPA 625	<1 ng/L	
		Grab	Ammonia	EPA 350.1	0.03 mg/L	Effects of: Nutrients
			Nitrate	EPA 353.2	0.01 mg/L	
			Silicate	FIA analysis	0.01 mg/L	
			Ortho-Phosphate	EPA 365.1	0.01 mg/L	

Monterey Bay – (Receiving water) Santa Cruz Watsonville M1W	Monthly (weekly for Santa Cruz receiving water)	Grab	Total coliform	SM 9222B	2	Sources, trends, effects and permit compliance for: Fecal Indicator Bacteria (FIB) pathogen indicators
			Fecal coliform	SM 9222D	2	
			Enterococcus	SM 9230C	1/10	
Monterey Bay – (Open water) North South	Two times per year (wet and dry season)	30-day flow proportioned samples using automated pumping and solid-phase-extraction (particle filter + XAD resin)	PAHs	AXYS MLA-021 Rev 12	<1 ng/L	Sources, loads, trends, effects and permit compliance for: POPs
			DDTs	AXYS MLA-007 Rev 13	<1 ng/L	
			Dieldrin	AXYS MLA-028 Rev 06	<1 ng/L	
			Chlordanes	AXYS MLA-007 Rev 13	<1 ng/L	
			PCBs	AXYS MLA-010 Rev 11	<1 pg/L	
			PBDEs	AXYS MLA-033 Rev 06	<1 pg/L	
		Grab	TSS			
			FIBs	EPA 1604	2 CFU/100ml	Trends of: FIBs
			Ammonia	EPA 350.1	0.03 mg/L	Effects of: Nutrients
			Nitrate	EPA 353.2	0.01 mg/L	
			Silica	FIA analysis	0.01 mg/L	
			Ortho-Phosphate	EPA 365.1	0.01 mg/L	
			Urea	Mulvenna 1992	0.01 mg/L	
	Every 5 years	Database satellite ocean color imagery	Chlorophyll *a*			
Sediments – Bathymetric sites (6) along the 80m contour in Monterey Bay	Annually in the dry season starting 2016, every five years previously	Sediment Grab	DDTs	AXYS MLA-028 Rev 06	<1 ng/g	Status, effects and alert level comparisons for POPs
			Dieldrin	AXYS MLA-028 Rev 06	<1 ng/g	
			Chlordanes	AXYS MLA-028 Rev 06	<1 ng/g	
			PCBs	AXYS MLA-010 Rev 11	<1 pg/g	
			PBDEs	AXYS MLA-033 Rev 06	<1 pg/g	
			Grain size	SM 2560 D v21		
			TOC	EPA 9060		
Mussels – Rocky intertidal sites (5) in Monterey Bay	Annually in the wet season	1 composite of 30-40 mussels for POPs	Lipid content	AXYS MLA-007 Rev 13	<1 ng/g	Status, trends, effects and alert level comparisons for: POPs Pathogen indicators
			DDTs	AXYS MLA-007 Rev 13	<1 ng/g	
			Dieldrin	AXYS MLA-007 Rev 13	<1 ng/g	
			Chlordanes	AXYS MLA-007 Rev 13	<1 ng/g	
			PCBs	AXYS MLA-007 Rev 13	<1 ng/g	
			PBDEs	AXYS MLA-033 Rev 06	<1 ng/g	

[1]= Pyrethroid/fipronils sampled from effluent are comprised of 3x2L 24 hr composites; sampled from San Lorenzo and Pajaro Rivers are comprised of 6x1L bottles, and sampled from Salinas and Carmel Rivers are comprised of 3x2L 24 hr composites.

Figure 2. Locations of CCLEAN sampling sites for municipal wastewater effluent, open ocean water, receiving water, sediment, mussels, and rivers.

Table 5. Dates, volumes and numbers of samples collected for CCLEAN in 2016–2017.

Season	Site	Matrix	Start Date	Ending Date	Liters[1]
Effluent Sampling					
Dry	Santa Cruz	Effluent	August 15, 2016	September 20, 2016	253-318 (6)
Dry	Watsonville	Effluent	August 15, 2016	September 20, 2016	379 (6)
Dry	One Water	Effluent	August 15, 2016	September 27, 2016	265 (6)
Dry	CAWD	Effluent	August 15, 2016	October 4, 2016	255 (6)
Wet	Santa Cruz	Effluent	January 24, 2017	March 22, 2017	274 (6)
Wet	Watsonville	Effluent	January 23, 2017	February 21, 2017	292 (6)
Wet	One Water	Effluent	January 23, 2017	February 16, 2017	344 (6)
Wet	CAWD	Effluent	January 23, 2017	February 27, 2017	272 (6)
Dry	Watsonville	Influent	August 15, 2016	September 20, 2016	252 (6)
River Sampling					
Dry	San Lorenzo	River	August 15, 2016	September 16, 2016	312 (15)
Dry	Pajaro River	River	August 15, 2016	September 16, 2016	264 (16)
Dry	Salinas River	River	(September 19, 2016)	(September 21, 2016)	(6)
Dry	Carmel River	River	(September 19, 2016)	(September 21, 2016)	(6)
Wet	San Lorenzo	River	January 24, 2017	February 7, 2017	343-372 (15)
Wet	Pajaro River	River	January 23, 2017	February 24, 2017	253 (16)
Wet	Salinas River	River	(February 27, 2017)	(March 1, 2017)	(6)
Wet	Carmel River	River	(February 27, 2017)	(March 1, 2017)	(6)
Open Water Sampling					
Dry	North	Monterey Bay	August 22, 2016	September 29, 2016	250
Dry	South	Monterey Bay	August 22, 2016	September 29, 2016	250
Wet	North	Monterey Bay	January 31, 2017	March 2, 2017	250
Wet	South	Monterey Bay	January 31, 2017	March 2, 2017	250
Mussel Sampling					# Mussels[2]
Dry	Scott Creek	Mussel Tissue		February 22, 2017	46/30
Dry	Laguna Creek	Mussel Tissue		February 22, 2017	48/30
Dry	The Hook	Mussel Tissue		February 22, 2017	46/30
Dry	Fanshell Overlook	Mussel Tissue		February 22, 2017	44/30
Dry	Monterey Creek	Mussel Tissue		February 22, 2017	47/30
Dry	Carmel River B.	Mussel Tissue		February 22, 2017	44/30

[1] = Numbers in parentheses are volumes collected for analysis of pyrethroids and fipronils.

[2] = Number of mussels submitted to Axys Analytical lab / Number of mussels submitted to the County of Sonoma

4.0 Results for Program Objectives

4.1 What are the status and long-term trends in the quality of nearshore waters, sediments, and associated beneficial uses?

This question has historically been at the center of the CCLEAN program. It embodies the environmental stewardship of the program participants by ensuring availability of data to guide management actions that might be needed to protect marine waters into which they are permitted to discharge wastewater. Answering questions about trends in the quality of nearshore waters, sediments, and associated beneficial uses requires high-quality long-term POP, nutrient and FIB data that have been provided by CCLEAN since 2001. Ascribing trends in the quality of open ocean waters, sediments and beneficial uses to potential contaminant sources or processes requires estimates of historic and current-use POP and nutrient loads to the ocean.

Several elements of the CCLEAN program provide data that enable assessment of both the status and trends in the quality of ocean waters, sediments and associated beneficial uses (see Table 4). These include sampling of rivers for POPs and inorganic nitrogen concentrations, nearshore receiving waters for FIBs, open ocean waters for POPs, FIBs and dissolved inorganic nutrients; sediments for POPs and benthic infauna; and mussels for POPs. Analysis of status involves comparisons with the objectives, guidelines and alert levels, including the Ocean Plan, described in Section 2. Through these comparisons, analysis of status also documents compliance with applicable regulatory guidelines, which can indicate contaminant effects. Analysis of trends also involves statistical tests to determine whether measured parameters are changing over time.

The analyses in this section are focused on particular contaminants that previously have been associated in CCLEAN reports either with exceedances of Ocean Plan water quality objectives or human health alert levels. These include the following:

- PCBs, dieldrin, chlordanes, and DDTs in nearshore waters (i.e., exceeded 30-day average in Ocean Plan for the protection of human health)
- Dieldrin, DDT, and PCBs in mussels (i.e., exceeded U.S. Environmental Protection Agency [EPA] human health alert level for subsistence and recreational fishers).

All of these exceedances were discussed in previous reports (CCLEAN 2008; CCLEAN 2011; CCLEAN 2012; CCLEAN 2015). In addition to these previously noted POP exceedances, this consideration of status and trends also includes analysis of FIBs and dissolved inorganic nutrient concentrations in ocean waters. Because the increasing use of a number of CECs in the Monterey Bay watershed, measurements of these in potential sources such as river water and effluent has also been added to CCLEAN in the past two years. All of these data are presented and discussed in the following sections.

4.1.1 Status and Trends of POPs and Nutrients in River Waters

CCLEAN has consistently measured concentrations of POPs such as PCBs, dieldrin, chlordanes, DDTs and PBDEs, and nutrients such as ammonium and nitrate, in the Pajaro River. Flows in the Pajaro River this past wet season, produced by record precipitation, were the highest recorded in the CCLEAN program's history (Fig. 3). These high flows from the Pajaro River and other rivers discharging into Monterey Bay affected processes and beneficial uses in Monterey Bay in a number of ways that will be discussed in the following sections of the report.

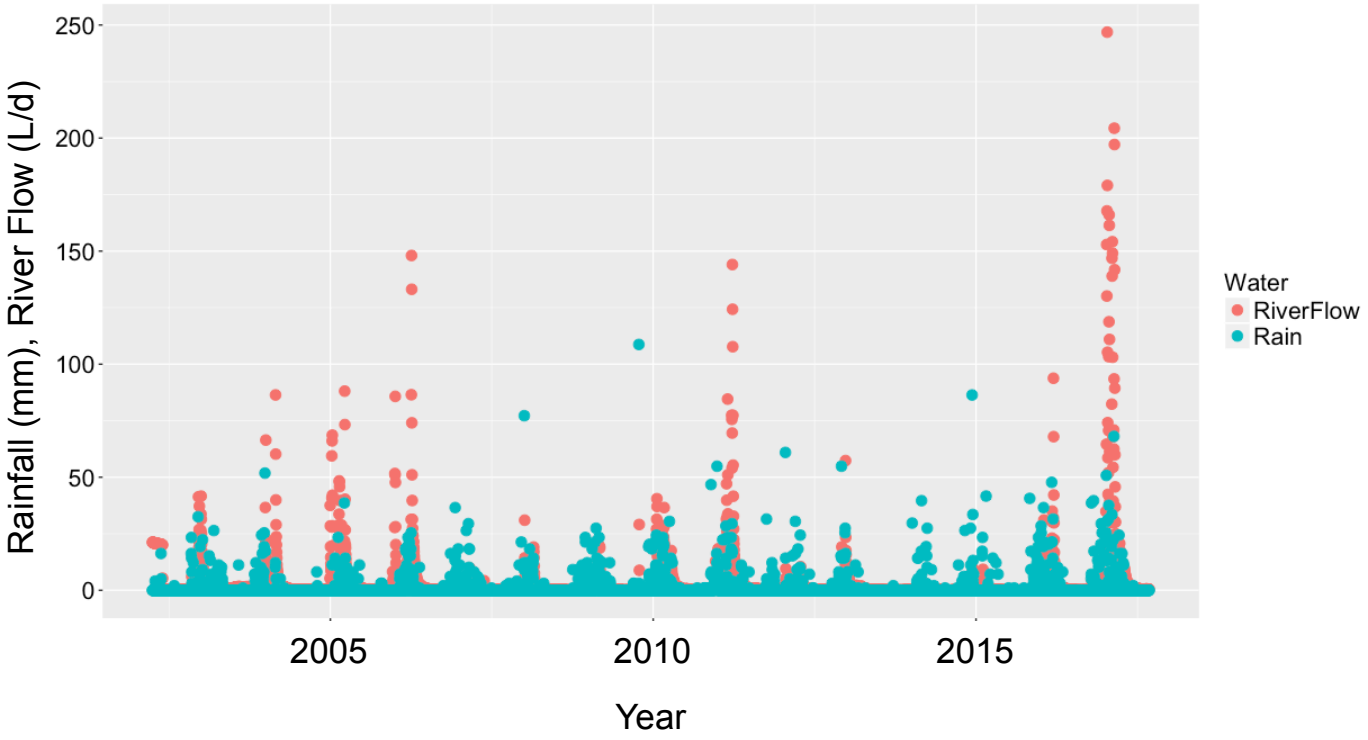

Figure 3. Temporal patterns in the daily flow rate (L/d) of the Pajaro River (data collected from the USGS gauge at the Chittenden) and in daily rainfall (mm/d) over the course of the CCLEAN program.

While discharge volume was greater than typical in the Pajaro River, concentrations of POPs in the river were not greater than typical for this past wet season (Fig. 4). Historically, concentrations of POPs in the Pajaro River have been greater in the wet season compared with the dry seasons (Fig. 4). And, similar to previous years, concentrations of dieldrin, PCBs, chlordanes and para-DDTs in the Pajaro River exceeded the California Toxics Rule (CTR) limits for human consumption of organisms in the wet season (Table 6, Fig. 4). Concentrations of PCBs also exceeded the CTR in the wet season sample from the San Lorenzo River (Table 6).

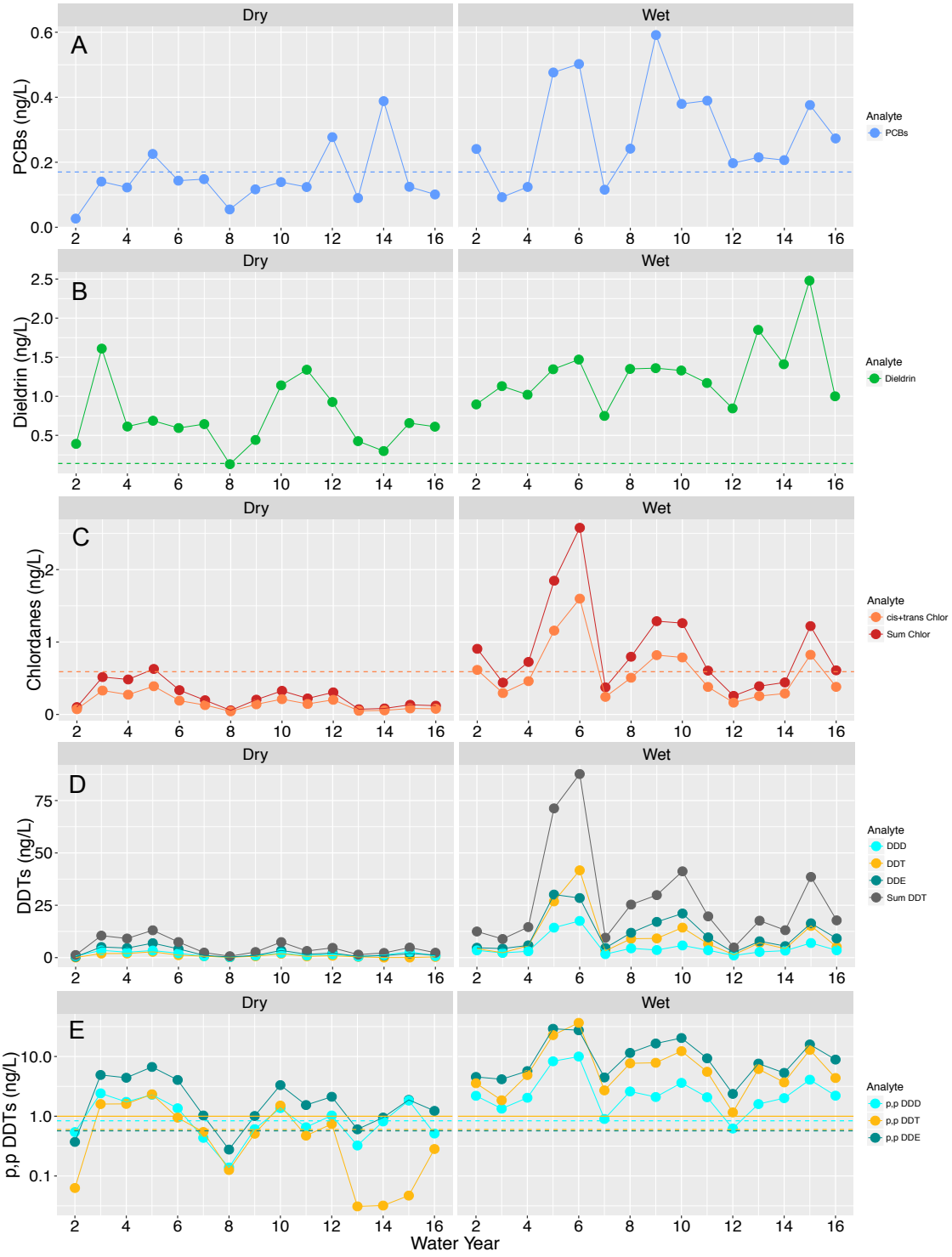

Figure 4. Temporal patterns in concentrations of POPs (ng/L) in the dry versus wet seasons in the Pajaro River over the course of the CCLEAN program. Dashed lines represent the California Toxics Rule Criteria for human consumption of organisms and solid lines represent the California Toxics Rule Criteria for aquatic life. A) PCBs, B) dieldrin, C) chlordanes including sum of all chlordanes (sum Chlor) and only the cis- and trans-chlordanes (cis+transChlor), D) DDTs including individual DDT compounds and sum of all DDTs, E) para-DDTs only.

Table 6. Concentrations of regulated (California Toxics Rule - CTR) pollutants in the Pajaro River and San Lorenzo River with CTR numeric criteria.

Source & Date	PCBs209 ng/L	4,4'-DDT ng/L	4,4'-DDE ng/L	4,4'-DDD ng/L	Chlordanes ng/L	Dieldrin ng/L	Benzo(b)fluoranth ng/L
CTR criteria	0.17	0.59	0.59	0.83	0.57	0.14	4.4
Pajaro River							
Sept-16	0.10	0.28	1.23*	0.51	0.12	0.61*	0.08
Feb-17	0.27*	4.37*	8.88*	2.21*	0.61*	1.00*	1.37
San Lorenzo River							
Sept-16	0.12	0.01	0.04	0.01	0.07	0.05	0.15
Feb-17	0.41*	0.11	0.16	0.04	0.31	0.06	1.15

* = Exceeds CTR.

[1] = Detected, not quantified

In contrast with the aforementioned POPs, PBDEs are not regulated. However, concentrations of PBDEs have been measured in the Pajaro River on an annual basis since 2006 (Fig. 5). Concentrations of nitrogen, including ammonium and nitrate, have also been measured in the Pajaro River and are presented in Figure 6. In the Pajaro River, nitrate is the primary source of nitrogen; since WY 13 higher concentrations have been measured in the wet season compared with the dry season (Fig. 6).

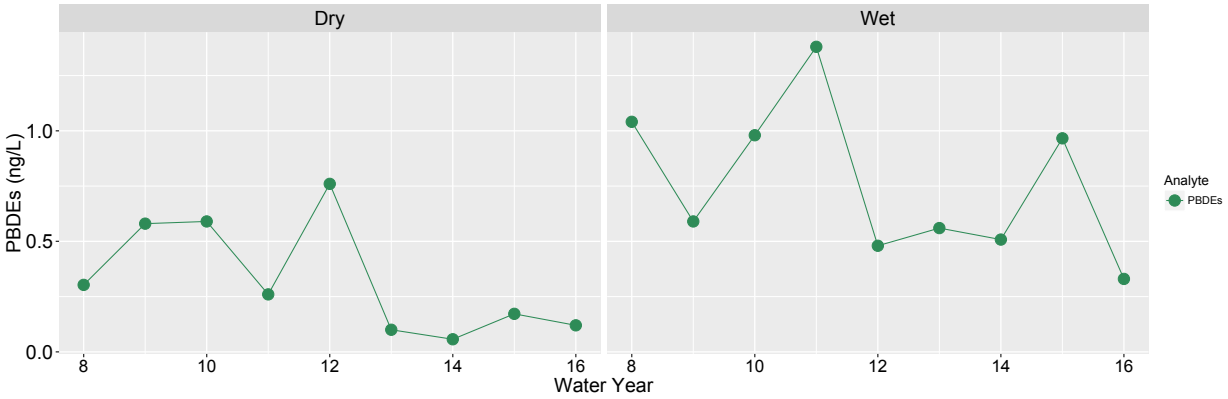

Figure 5. Temporal patterns in concentrations of PBDEs (ng/L) in the Pajaro River since measurements began in 2006 (WY 6).

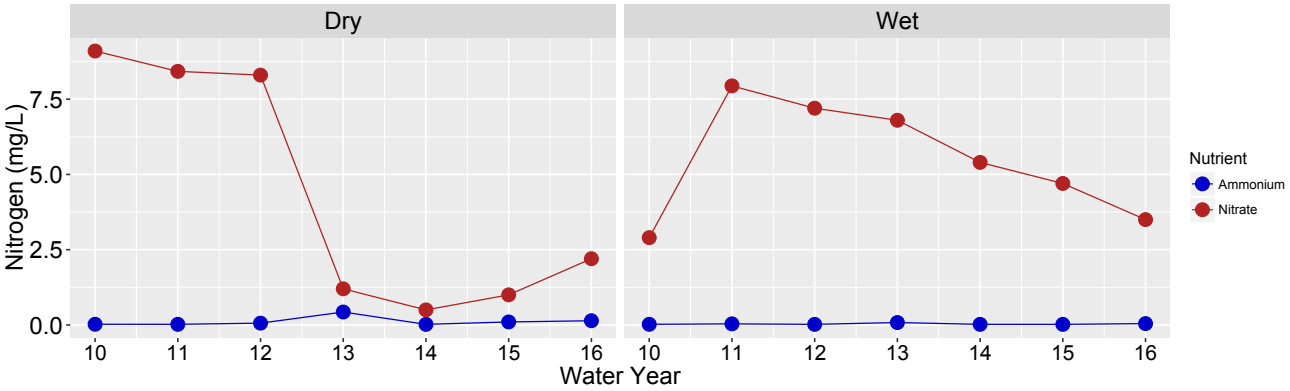

Figure 6. Temporal patterns in concentrations of nitrogen in the form of ammonium (blue symbols) and nitrate (red symbols) since 2010 (WY 10) in the Pajaro River.

The CCLEAN program is in its second year of measuring the fipronils and pyrethroids in four rivers discharging into Monterey Bay, including the San Lorenzo River, the Pajaro River, the Salinas River, and the Carmel River (Figs 7, 8). These CECs are broad-spectrum insecticides that were first approved for use in the United States the 1990's since which time they have increasingly being used in agriculture, as pest control, and for consumer use including as pet flea treatments (Amweg et al. 2005).

With respect to the three fipronil derivatives measured under CCLEAN, fipronil was the most consistently detected in all four rivers and during both seasons (Fig. 7a). Fipronil sulfide was detected only in the dry season in the San Lorenzo and the Pajaro Rivers (Fig. 7b), but in both locations it was detected above both the acute and chronic guidance levels (Fig. 7b, Table 7). This year, fipronil sulfone was detected in three rivers in the dry season at concentrations above the chronic guidance level; in the Pajaro River it was also detected in the wet season as well above the chronic guidance level (Fig. 7c). Since CCLEAN started sampling for CECs, pyrethroids have principally detected in two rivers, the Pajaro and the Salinas Rivers (Fig. 8). This year, concentrations of biphenthrin exceeded the acute guidance level by more than 3-fold in the dry season in the Salinas River and exceeded the chronic guidance level in the wet season in the Pajaro River (Fig. 8B). The concentration of cypermethrin exceeded the chronic guidance level in the Salinas River this year (Fig. 8c) and fenopathrin was detected both last year and this year in the wet season in the Pajaro River (Fig. 8d).

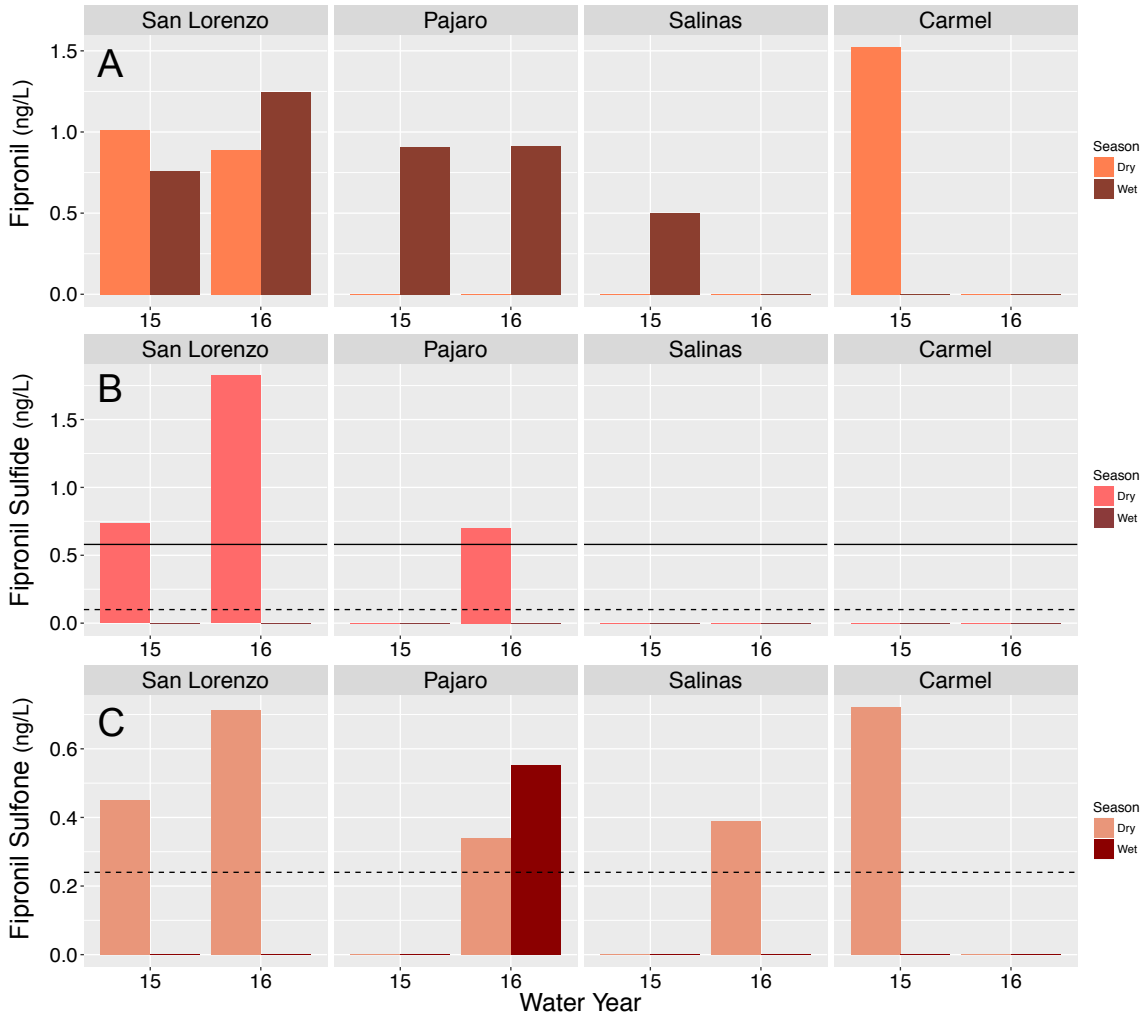

Figure 7. Concentrations in ng/L of A) fipronil, B) fipronil sulfide, and C) firponil sulfone measured in the San Lorenzo, Pajaro, Salinas, and Carmel rivers in water years 15 and 16.

Comparison of influent and effluent concentrations of pyrethroids and fipronils revealed high removal efficiencies of the wastewater treatment process. All the pyrethroids measured here were removed with efficiencies of 99-100% whereas fipronils were removed with efficiencies of 85-95% (Table 7). These removal rates are similar to those reported by Parry and Young (2013), whose results suggested that <6% of pyrethroids remain in the dissolved phase with substantial portions being associated with dissolved organic matter and very small particles <0.8 μm.

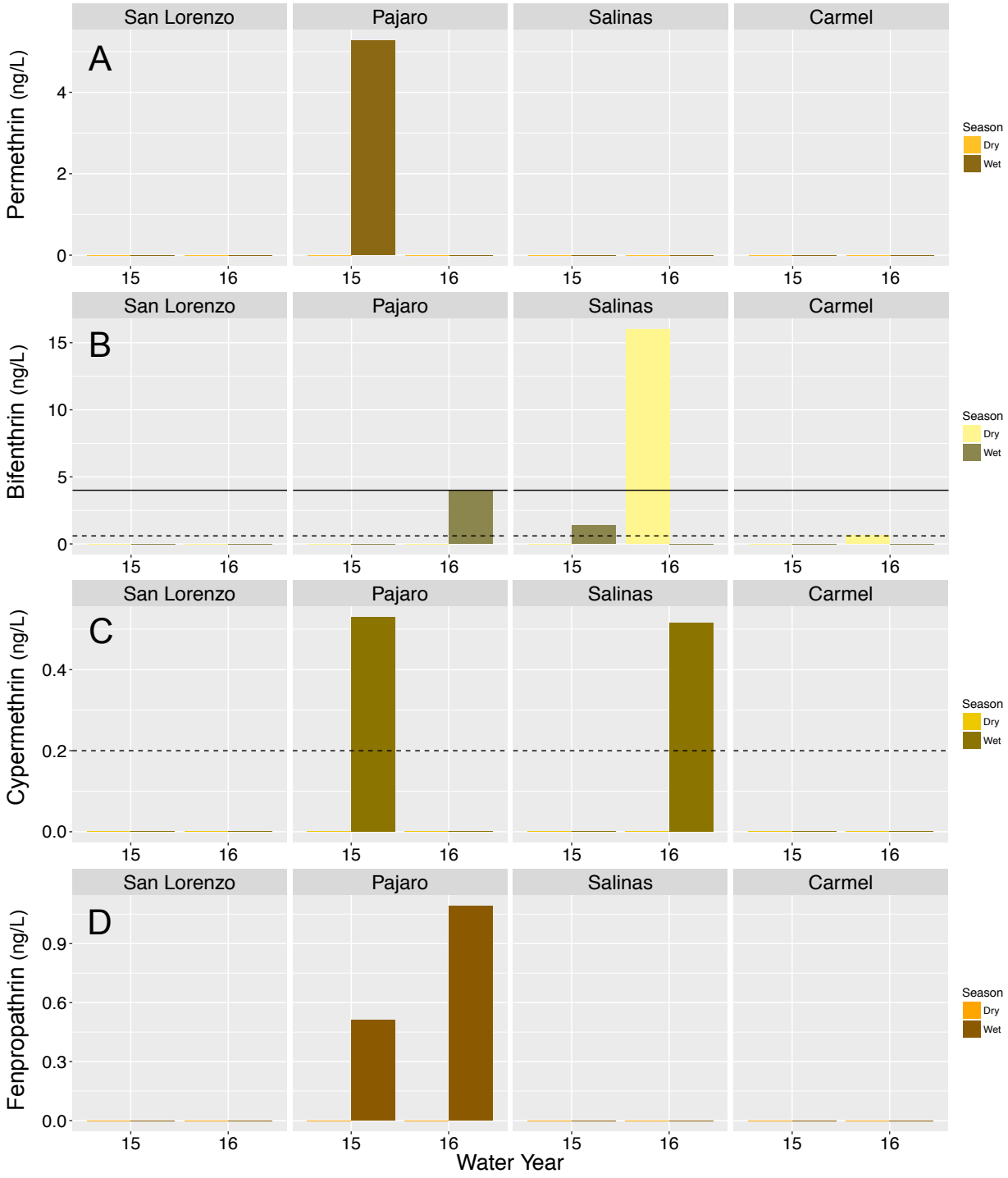

Figure 8. Pyrethroid concentrations in ng/L of A) permethrin, B) bifenthrin, C) cypermethrin, and D) fenpropathrin in the San Lorenzo, Pajaro, Salinas, and Carmel rivers in water years 15 and 16. Dashed lines indicate proposed chronic criteria and solid lines indicate proposed acute criteria.

4.1.1.1 Conclusions

Concentrations of the legacy pesticides dieldrin, chlordanes, and DDTs, as well as PCBs, continue to exceed the CTR criteria for human consumption of organisms in the Pajaro River in the wet season. In contrast, concentrations of nitrogen sources have steadily decreased in the wet season and reached their lowest level compared with the past five years. In the past two years, fipronils have been consistently detected above guidance levels in the San Lorenzo River and pyrethroids have been consistently detected in the Pajaro and Salinas Rivers with concentrations of bifenthrin and cypermethrin measured above guidance levels. It is not clear whether these CECs will continue to increase in concentration over time or not. Measurements elsewhere in California tend to be sporadic in nature and are focused on toxicities rather than trends (Domagalski et al. 2010, Weston et al. 2014, Weston et al. 2015). Early results suggest that many pyrethroids and fipronils are acutely toxic to aquatic animals (Amweg et al. 2005, Domagalski et al. 2010, Weston et al. 2014).

Table 7. Pyrethroid and Fipronil water quality criteria developed by Central Valley Water Board and removal efficiencies by wastewater treatment.

Pesticide	**Chronic** 4-day average 1x per 3 years, ng/L	**Acute** 1-hour average 1x per 3 years, ng/L	**Removal Efficiency (%)** Based on City of Watsonville
Bifenthrin[1]	0.6	4	98.9
Cypermethrin[2]	0.2	1	99.4
Permethrin[3]	2	10	100.0
Fipronil[4]	2.2	14	90.8
Fipronil sulfide[4]	0.1	0.58	94.9
Fipronil sulfone[4]	0.24	1.3	85.6

[1] = From Palumbo et al (2010),[2] = From Fojut et al (2011a), [3] = From Fojut et al (2011b) ,[4] = From Bower and Tjeerdema (2016); draft criteria.

4.1.1.2 Recommendations

Sampling of rivers for legacy POPs and for contaminants of emerging concern should continue in order to improve our understanding of the potential impact of river discharges on beneficial uses in Monterey Bay, and to provide comparisons for evaluating effects of the discharges from the POTWs.

4.1.2 Status and Trends of POPs and Nutrients in Open Ocean Waters

CCLEAN has previously identified several POPs with concentrations that have been near or above their respective Ocean Plan objectives in Monterey Bay. These include PCBs, chlordanes, dieldrin, DDTs and PAHs. PBDEs are also considered here because they are chemically very similar to PCBs, they have serious consequences for human health (Windham et al, 2015), and a 2006 ban of certain forms in California has resulted in declines in some areas (Sutton et al, 2014). In addition, exceptionally high concentrations were measured in women's breast tissue in the San Francisco Bay area (Windham et al, 2010), which is not far from Monterey Bay.

PCBs vary substantially in concentration from year to year (Fig. 9A). The highest concentration measured in CCLEAN's sampling history was in the dry season of 2012 followed by the dry season of 2010. Smaller peaks in PCB water column concentrations occurred in the dry season of 2014 and the wet season of 2016. This variation in water column PCB concentrations does not appear to be linked with river discharges or runoff from land during wet years, indicated by the low concentration of PCBs in the 2017 wet season (Fig. 9A) despite high river flows and rainfall (Fig. 3). Rather, the pattern of infrequent high PCB concentrations has been associated with disposal of dredged material in Monterey Bay (CCLEAN, 2014, 2015).

Table 8. PCB homolog concentrations and percent contribution of homologs to total PCB concentration in ocean samples from Monterey Bay.

SMB September 2016			**NMB September 2016**		
Homolog	Concen (ng/L)	Percent (%)	Homolog	Concen (ng/L)	Percent (%)
MonoCB	0.0035	5.7	MonoCB	0.0037	5.6
DiCB	0.0183	29.8	DiCB	0.0197	29.9
TriCB	0.0186	30.2	TriCB	0.0197	29.9
TetraCB	0.0104	16.9	TetraCB	0.0103	15.7
PentaCB	0.0052	8.5	PentaCB	0.0060	9.1
HexaCB	0.0023	3.7	HexaCB	0.0029	4.4
HeptaCB	0.0008	1.3	HeptaCB	0.0010	1.5
OctaCB	0.0016	2.6	OctaCB	0.0016	2.4
NonaCB	0.0008	1.3	NonaCB	0.0009	1.4
DecaCB	0	0.0	DecaCB	0	0.0
SMB March 2017			**NMB March 2017**		
Homolog	Concen (ng/L)	Percent (%)	Homolog	Concen (ng/L)	Percent (%)
MonoCB	0	0.0	MonoCB	0	0.0
DiCB	0.0127	20.4	DiCB	0.0098	18.7
TriCB	0.0179	28.7	TriCB	0.0144	27.4
TetraCB	0.0113	18.1	TetraCB	0.0089	17.0
PentaCB	0.0066	10.6	PentaCB	0.0061	11.6
HexaCB	0.0041	6.6	HexaCB	0.0053	10.1
HeptaCB	0.0020	3.2	HeptaCB	0.0026	5.0
OctaCB	0.0051	8.2	OctaCB	0.0036	6.9
NonaCB	0.0024	3.8	NonaCB	0.0016	3.0
DecaCB	0.0003	0.5	DecaCB	0.0002	0.4

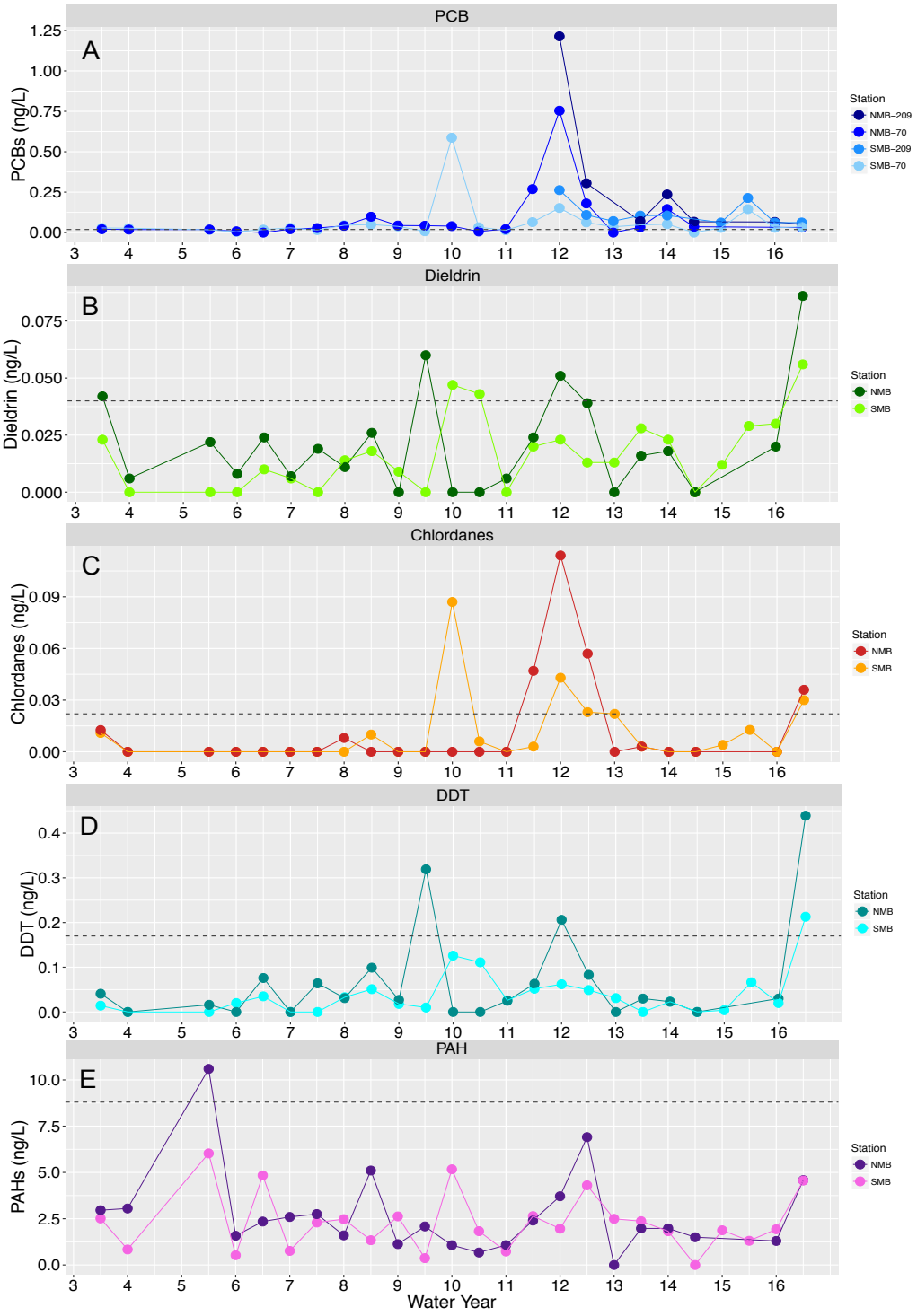

Figure 9. Temporal patterns in concentrations of A) PCBs, B) dieldrin, C) chlordanes, D) DDTs and E) PAHs at two open water sites in Monterey Bay. Dashed horizontal lines indicate the Ocean Plan water quality objective for each POP. PCB concentrations are shown for Monterey Bay with 70 and 209 congeners measured. NMB=North Monterey Bay; SMB-South Monterey Bay. NMB/SMB-209=209 PCB congeners; NMB/SMB-70=70 PCB congeners.

Even though PCB concentrations were lower this past water year compared with previous years, the summed concentrations at both CCLEAN sites in Monterey Bay, calculated with both 70 and 209 congeners, were still above the Ocean Plan objective of 0.019 ng/L as they have been in all 64 samples save eight (Fig. 9A). Of the 209 PCB congeners measured in the 2016–2017 project year, the dominant congeners were the triCB, diCB and tetraCB congeners, together comprising 63-77% of the total PCB pool, depending on season and location in Monterey Bay (Table 8). Higher percentages of summed PentaCB through DecaCB homologs in the wet season (33% – 37%) compared to the dry season (17% – 19%) suggest greater concentrations of suspended sediments because homologs with greater numbers of chlorines have a greater affinity for sediments than do homologs with fewer chlorines.

In contrast with concentrations of PCBs, the concentrations of dieldrin were the highest measured since the inception of CCLEAN at both North and South Monterey Bay in the 2017 wet season (Fig. 9B). These concentrations exceeded the ocean plan objective of 0.04 ng/L and were greater than previous peaks observed in the 2010 and 2012 dry seasons. The concentrations of chlordanes were also elevated in ocean water in the 2017 wet season, exceeding the ocean plan objective of 0.022 ng/L, but remaining several-fold lower than peak concentrations detected in the 2010 and 2012 dry seasons (Fig. 9C). The pattern for DDTs was similar to dieldrin, in that the greatest concentrations detected since the inception of CCLEAN occurred in the 2017 wet season. These high concentrations exceeded the ocean plan objective of 0.17 ng/L, as well as previous peaks measured in the dry and wet seasons of 2010 and 2012 (Fig. 9D). In contrast with the aforementioned POPs, PAHs did not exhibit a pattern that is obviously associated with weather or dredging (Fig. 9E). The concentration this past wet season increased above the last wet season but was lower than measurements on five past occasions. Moreover, the highest measured concentration of PAHs occurred in the wet season of 2006, a year that did not produce peak concentrations for any other POP measured in the CCLEAN program (Fig. 9).

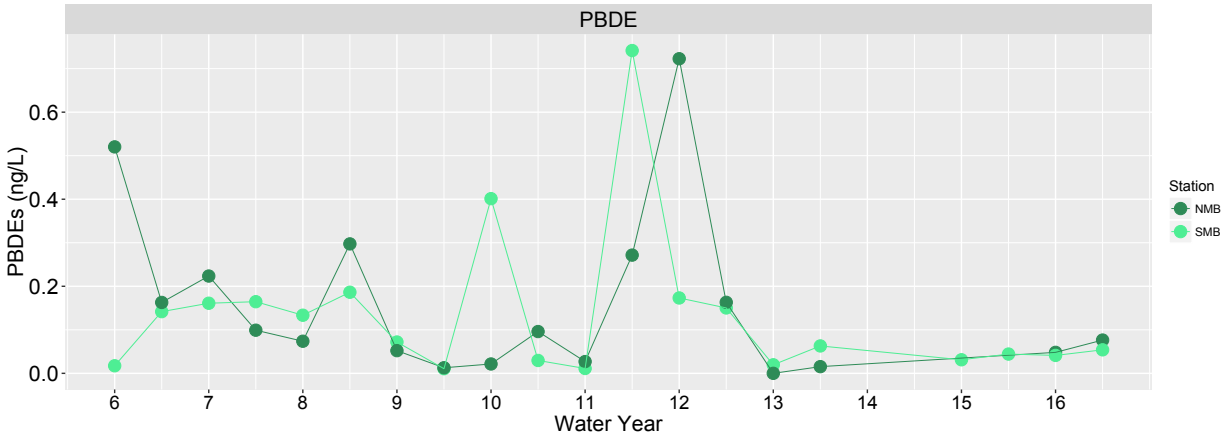

Figure 10. Temporal patterns in concentrations of PBDEs in north (NMB) and south (SMB) Monterey Bay in the dry and wet seasons.

PBDEs have displayed spatial and temporal patterns in Monterey Bay similar to those for PCBs with peak concentrations in the dry seasons of 2010 (South Monterey Bay) and 2012 (North Monterey Bay). Water column PBDE concentrations also peaked in the wet season of 2012 but they did not for PCBs (Figure 9A and Figure 10). Concentrations of PBDEs in the water column were low this past wet season, similar to PCB concentrations, suggesting that increases in concentrations are not associated with precipitation or riverine discharge.

Toxicity Equivalency Factors (TEFs), similar to those used to calculate the toxicity of Dioxin/Furan mixtures, have been developed for 12 dioxin-like PCB congeners (Van den Berg, 2006; USEPA, 2010). These TEFs are based on the chemical and toxicity similarities between the PCB congeners and Dioxins/Furans. Each of the 12 congener concentrations is multiplied by its corresponding TEF; these factors are summed over all 12 congeners to provide a Toxicity Equivalency Quotient (TEQ). PCB TEQs, calculated using all 209 PCB congeners, demonstrated a notable decrease between 2012 and 2015 and has remained relative low since 2015 (Fig. 11). Compared with last year there has been a slight increase but the TEQ for dioxin-like PCBs remained below the Ocean Plan objective in WY 16 (2016-2017, Fig. 11).

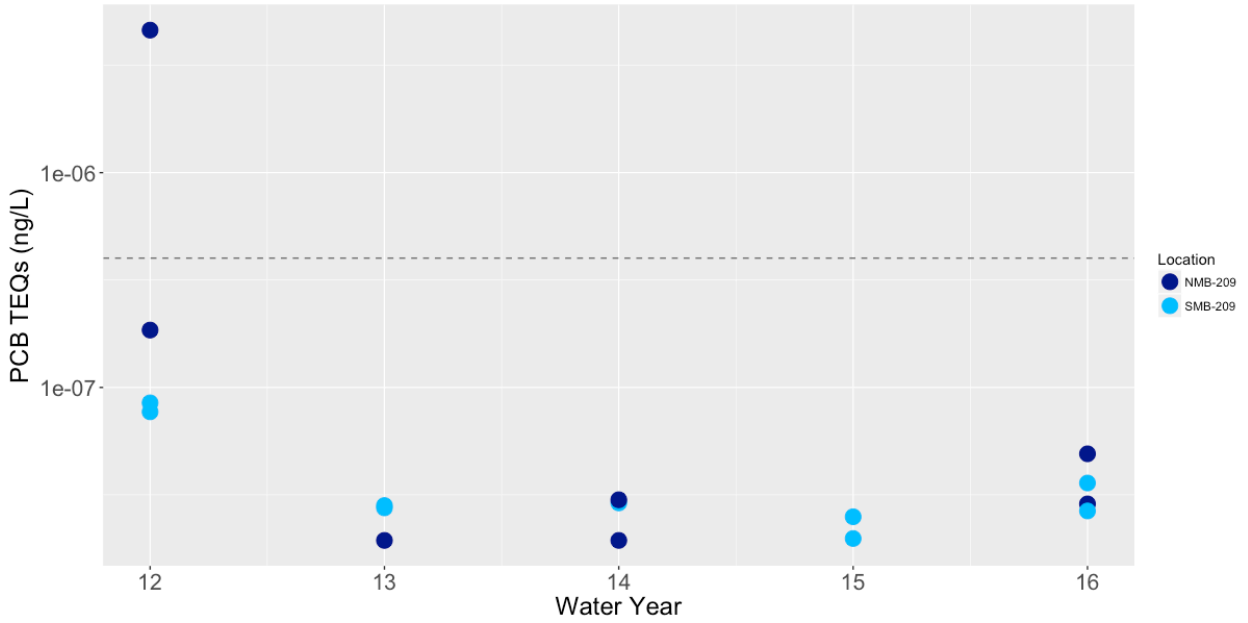

Figure 11. Toxicity Equivalency Quotients of PCBs measured at two open water sites in Monterey Bay since 2012. Horizontal line indicates Ocean Plan objective for the Dioxin/Furan Toxicity Equivalency Quotient (TEQ).

4.1.2.1 Conclusions

POP water column concentrations in Monterey Bay appear to either be related to wet season water run-off (Fig. 12A), or to other non-weather related factors. In the former category are dieldrin and DDTs, which had the highest recorded concentrations this past wet season compared with the long-term mean concentration measured by CCLEAN in Monterey Bay (Fig. 12B-C). Concentrations of both these POPs exceeded the Ocean Plan for the first time since 2012. Concentrations of PAHs also demonstrated an increase this past wet season; past peaks

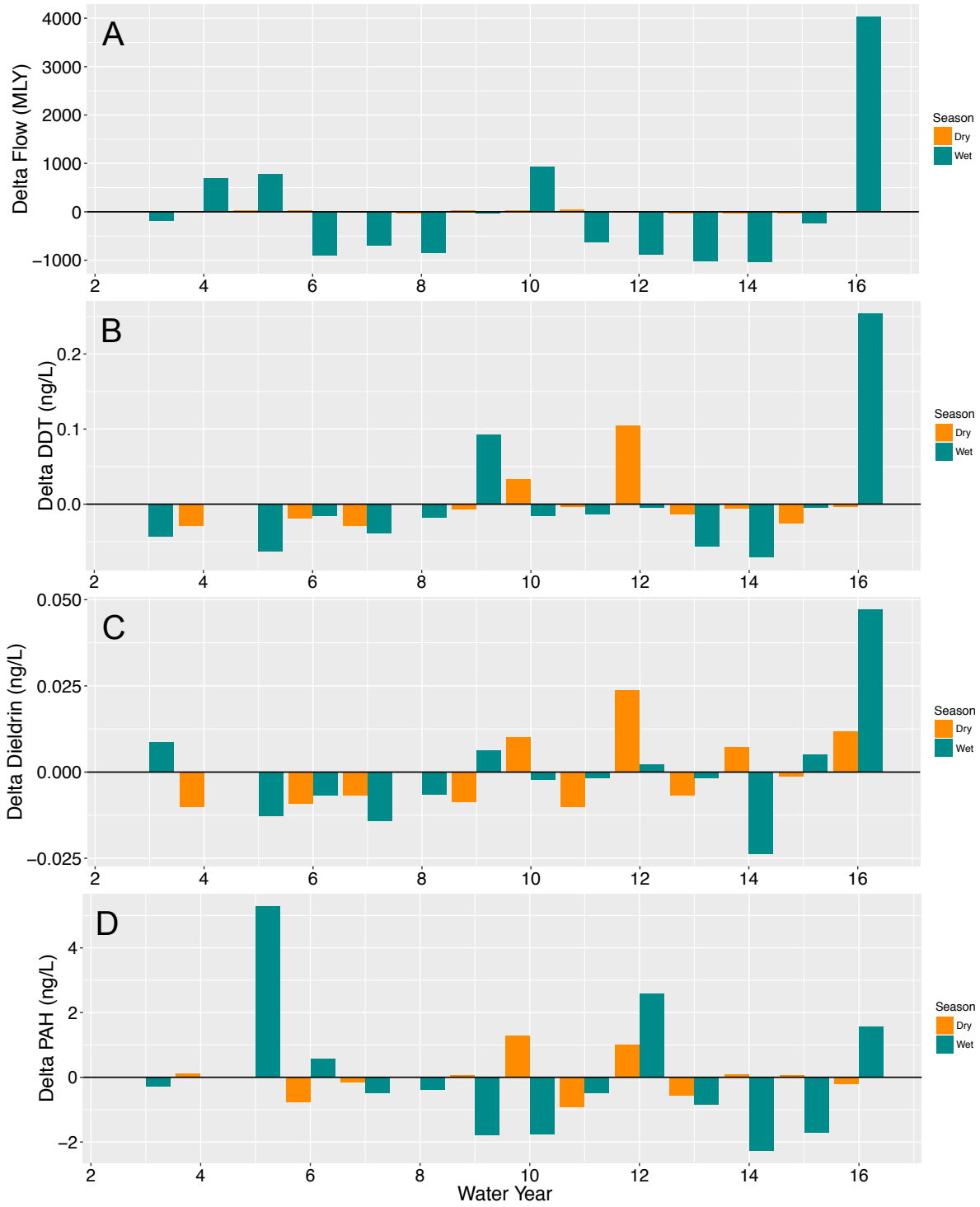

Figure 12. Annual trend of Pajaro River flows compared with POP concentrations in Monterey Bay (average of the South and North Monterey Bay stations) expressed as the difference (delta) between the annual mean and long-term mean concentration for each POP. A) Pajaro River delta flow (Chittenden USGS gage station daily flows summed over the dry and wet seasons minus the dry and wet season long-term sum means), B) delta DDTs, C) delta dieldrin, and D) delta PAHs.

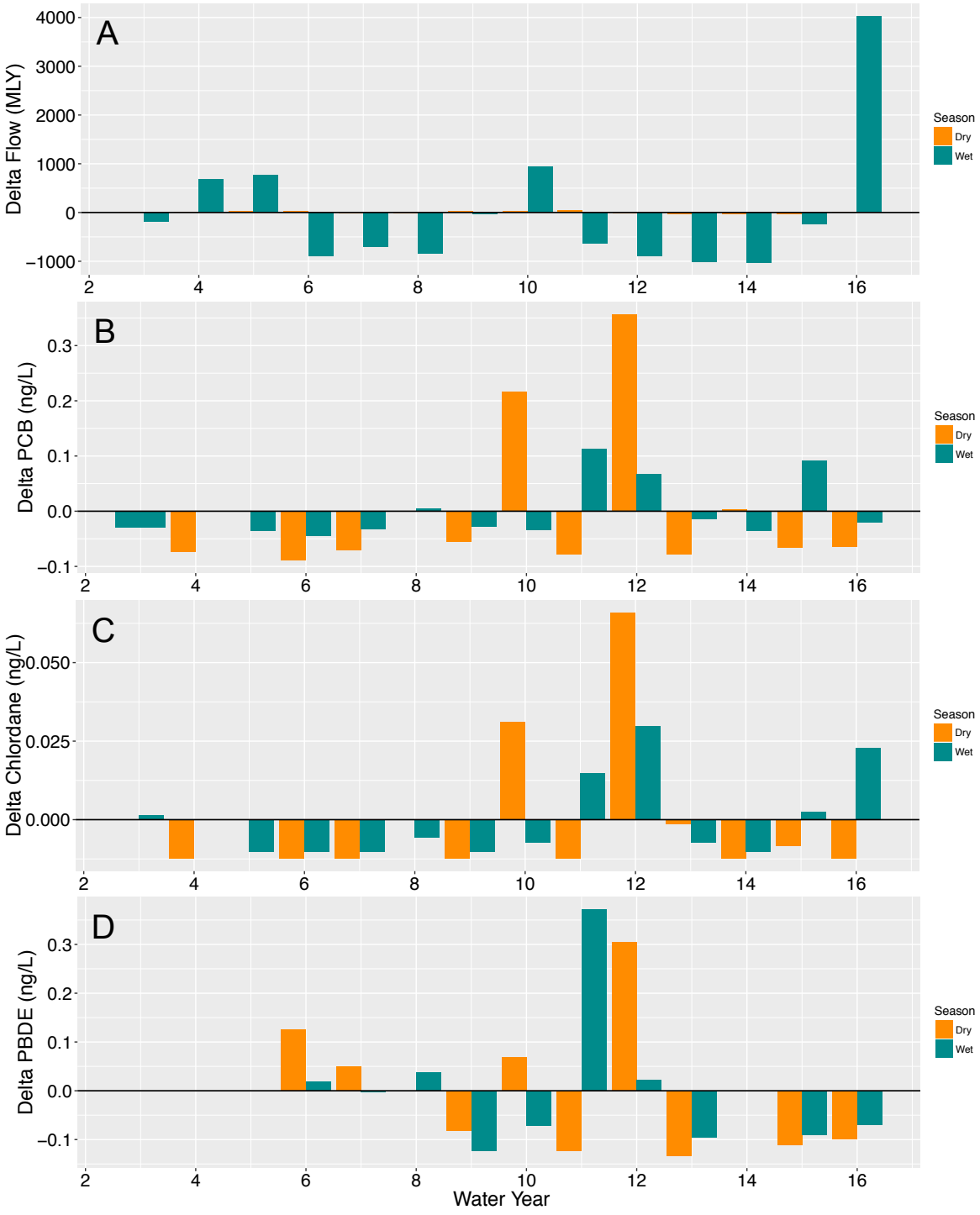

Figure 13. Same as Figure 12 but for different POPs. A) Delta Pajaro River flows, B) delta PCBs, C) delta chlordanes, C) delta PBDEs.

have also occurred during wet seasons but not in years when river flows have deviated significantly and positively from the long-term average (Fig. 12A, D).

In contrast with dieldrin and DDTs, PCBs can be classified as POPs whose concentrations did not increase this past wet season despite record flow from rivers such as the Pajaro (Fig. 13). For example, PCBs demonstrated highest concentrations in the dry seasons of 2010 and 2012 (Fig. 13B). Exceedances of the Ocean Plan water quality objective for PCBs have occurred in nearly every ocean sample collected by CCLEAN since 2008; new evidence for a linkage between high pulses of water column PCBs and dredging in Monterey Bay is shining the spotlight on a potential path to reduce the occurrence of these events.

Chlordanes also demonstrated highest concentrations in the dry seasons of 2010 and 2012, as well as a smaller increase this past wet season, compared with its long-term mean concentration in Monterey Bay (Fig 13C), exceeding the ocean plan objectives in all three cases. Lastly, PBDEs which became an environmental and human health concern only within the last 20 years have decreased in concentration in California water bodies, including San Francisco Bay, following state legislation limiting their uses since 2004. PBDEs are typically associated with urban sources and the peaks in PBDE concentrations that have occurred sporadically in Monterey Bay and are not easily associated with a particular locale or event (Fig. 13D).

4.1.2.2 Recommendations

Sampling of POPs in open ocean waters should continue in order to document the status and trends of beneficial uses in Monterey Bay, and to document the effects of pollutant sources on ocean water quality.

4.1.3 Status and Trends of Pollutants in Mussels

Concentrations of POPs in mussels at CCLEAN sites have generally been highest at the Hook and Laguna Creek. Both of these sites are situated along the northern coastline of Monterey Bay and are typically in the path of the Pajaro River plume, as illustrated by the correlation between satellite derived turbidity data in Monterey Bay with Pajaro River flow (Fig. 14). This suggests that POPs, potentially associated with particulate matter discharged from the Pajaro River, are accumulated by the mussels at these two sites, particularly at the Hook.

POPs associated with mussel tissue measured under CCLEAN are compared with human health alert levels for concentrations of contaminants shellfish and fish published by the USEPA. These concentrations are risk-based alert levels that are based on the amounts of tissue that are predicted to be eaten, which are called the subsistence and recreational fisher alert levels (Table 9; EPA 2000). These alert levels are indicated in the following figures, as appropriate.

Whereas concentrations of most POPs had been declining since around 2009, the 2017 wet season witnessed a sharp spike in concentrations of most POPs at both the Hook and Laguna Creek sites (Fig. 15). For example, mussel tissue PCB concentrations on a wet-weight basis increased 2.6-fold at the Hook and exceeded the OEHHA Fish Contaminant alert level of 2.5 ng/g (Fig. 15A).

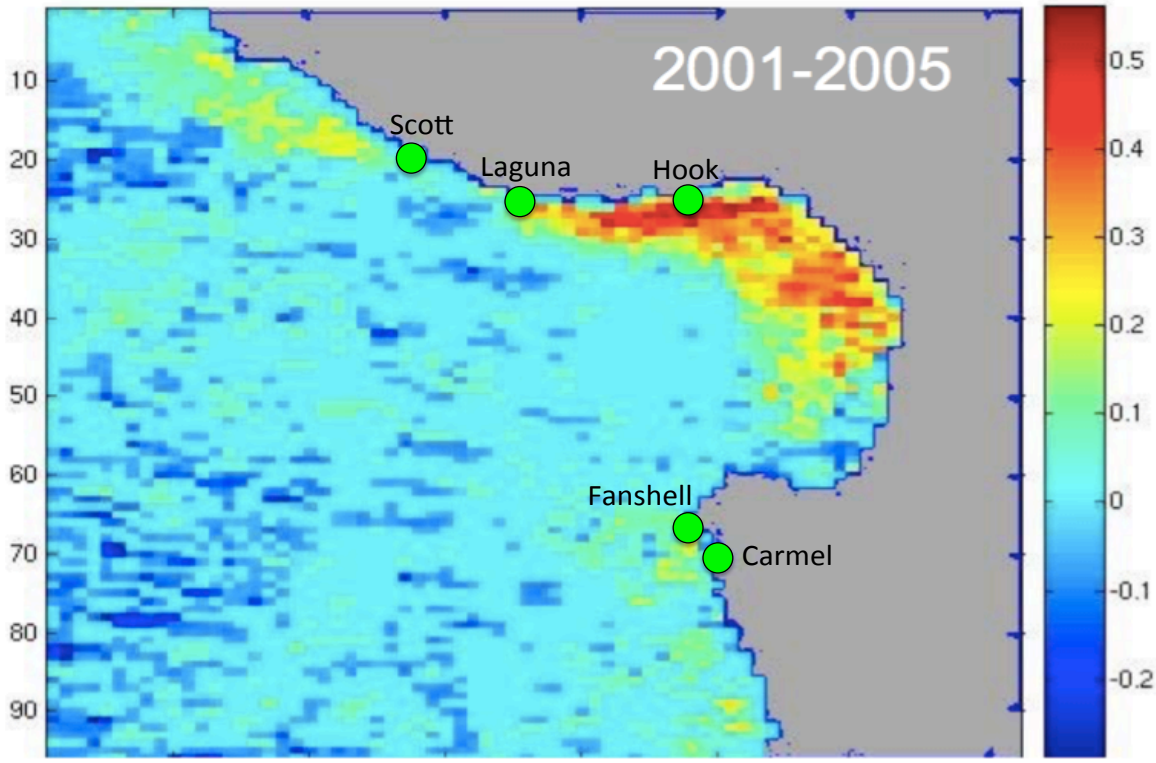

Figure 14. Correlations between flow data from the Pajaro River (measured at the Chittenden USGS gage station) and satellite-derived turbidity data for Monterey Bay, where spatial pixels with p values > 0.05 are depicted. Using the individual correlation coefficients, significant pixels were averaged between the years 2001-2005. Color scale on the right indicates correlation coefficients. Mussel sampling stations, represented by green circles, are overlaid on the map. Map and data from Kudela 2015.

Interestingly, PCB concentrations remained relatively similar to previous years at the other sites including Laguna Creek (Fig. 15A). The legacy pesticides dieldrin, chlordanes and DDTs also increased sharply in concentrations at the Hook this year and exceeded human alert levels (Fig. 15B-D). Concentrations of these POPs also increased at the Laguna Creek site compared with the past seven years but not enough to exceed human health alert levels (Fig. 15B-D). Mussel tissue concentrations of these same POPs did not increase substantially at the other sites sampled (Fig. 15B-D), potentially due to their distance from the Pajaro River plume (Fig. 14).

Table 9. USEPA human health alert levels for wet-weight concentrations (ng/g) of chemical contaminants in fish and shellfish for two categories of consumers.

Contaminant	Recreational Fishers[1]	Subsistence Fishers[2]
Chlordanes	114	14.0
DDTs	117	14.4
Dieldrin	2.5	0.307
PCBs	20	2.45

[1] = Consumption rate 17.5 g/day, body weight 70 kg, cancer risk factor 10^{-5}, life span 70 years

[2] = Consumption rate 142.4 g/day, body weight 70 kg, cancer risk factor 10^{-5}, life span 70 years

Consistent with providing data on the effects of POPs on beneficial uses, CCLEAN has presented mussel data on a wet-weight basis (Fig. 15) as human health alert levels are based on wet-weight concentrations. However, because most POPs are lipid-soluble, tracking trends of contaminant concentrations in organisms is often based on concentrations normalized to lipid content (i.e., ng POP per g of lipid), which gives a better estimate of the actual burden of POPs being carried by the organisms. Consequently, lipid normalizations were performed for concentrations of PCBs, dieldrin, chlordanes, and DDTs in mussels to parallel those POPs that are most problematic in Monterey Bay waters (Fig. 16). PBDEs are also considered here because of their chemical similarity to PCBs and their consequences for human health (Windham et al, 2015).

As with the trends for mussel POP data on a wet-weight basis, the lipid-normalized tissue concentrations for PCBs, dieldrin, chlordanes, DDTs and PBDEs exhibited a reversal of the downward trends observed in recent years (Fig. 16). This reversal was particularly strong for PCBs, chlordanes and DDTs (Fig. 16A, C, D), and less so for dieldrin and PBDEs (Fig. 16B, E), measured at the Hook and at Laguna Creek. At the Hook, lipid-normalized concentrations of DDTs and chlordanes doubled this year compared with concentrations measured last year, exhibiting concentrations of chlordanes similar to those measured in 2011 and 2005, and exceeding all concentrations of DDTs measured in the past at this site (Fig. 16A, C).

4.1.3.1 Conclusions

Concentrations of PCBs and the legacy pesticides dieldrin, chlordanes, and DDTs increased sharply this year over recent years at The Hook, both on a wet-weight and a lipid-weight basis. The sharp increase in mussel body burdens on a wet-weight basis at this site exceeded human health alert levels for all three legacy pesticides (dieldrin, chlordanes and DDTs) as well as for PCBs. Moreover, concentrations of PCBs, dieldrin, and chlordanes at The Hook were the highest ever measured in mussel tissue at any site under the CCLEAN program.

4.1.3.2 Recommendations

Mussel sampling provides a valuable sentinel for detection of temporal trends in contaminants coming from the land into the nearshore marine ecosystem. It should continue as part of CCLEAN at its current annual frequency.

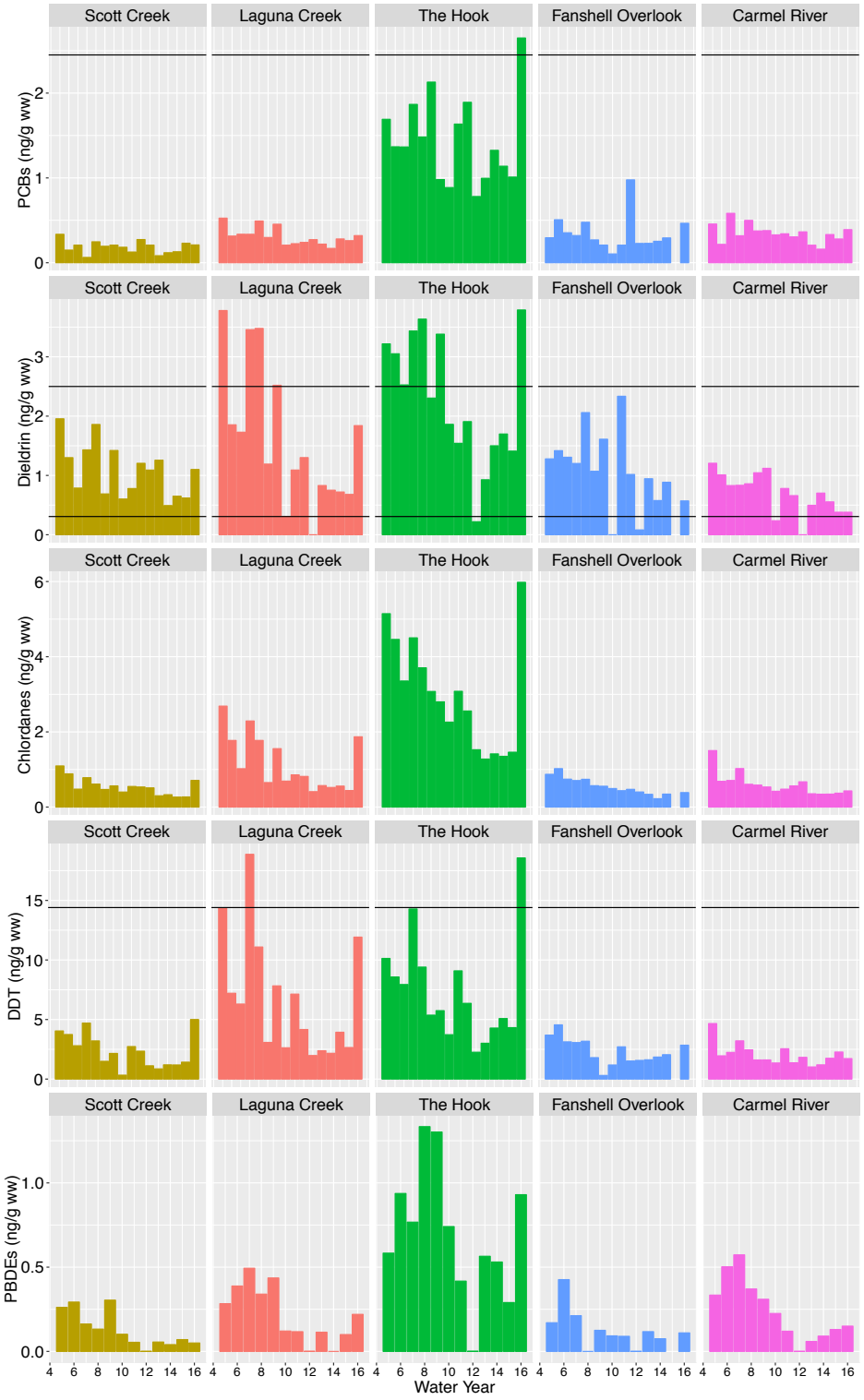

Figure 15. Concentrations of A) PCBs, B) dieldrin, C) chlordanes, D) DDT, and E) PBDEs in mussel tissue normalized to wet weight (ng/g ww) from five CCLEAN sites in Monterey Bay (water years 6-16). Grey lines represent human health alert levels.

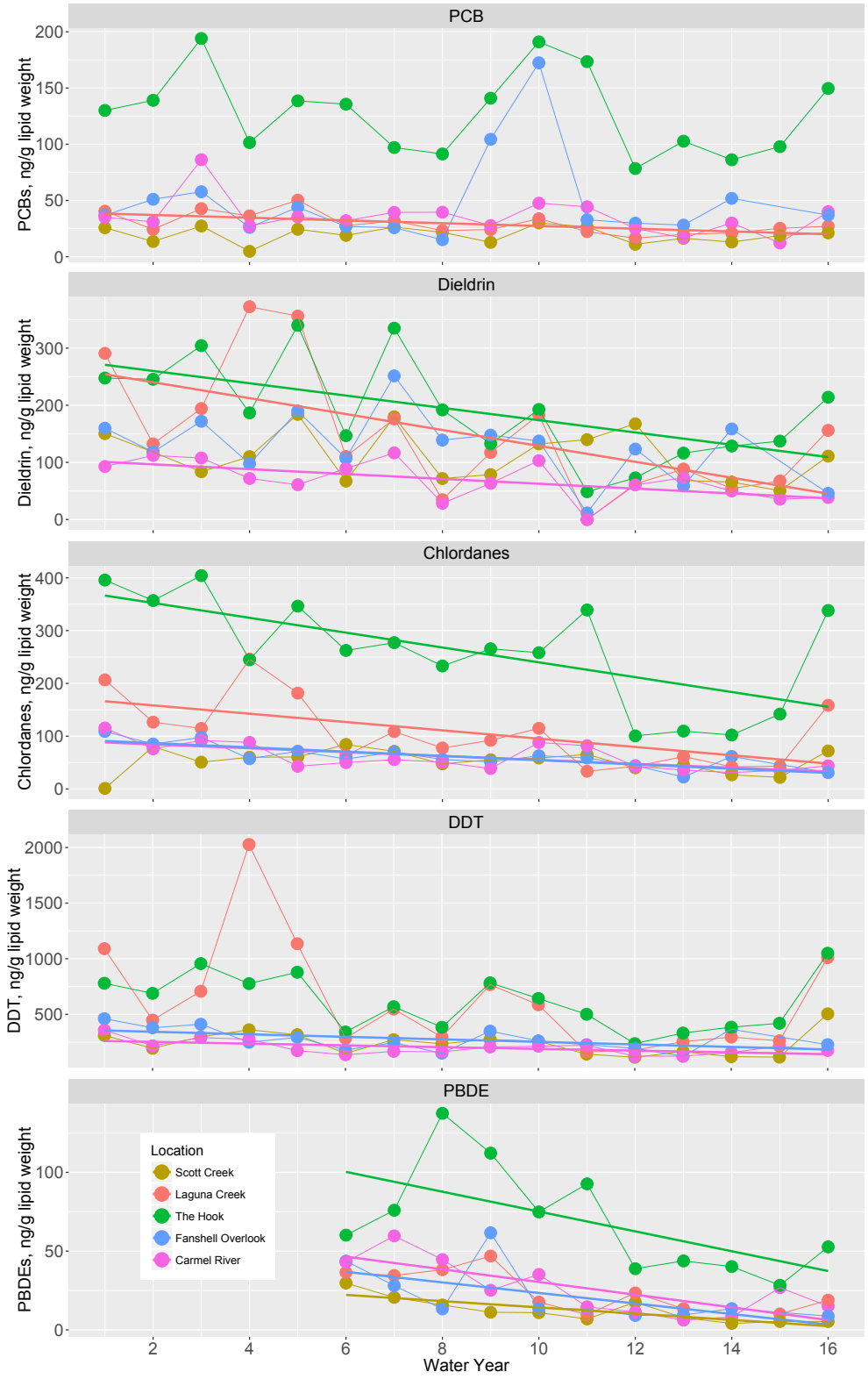

Figure 16. Lipid-weight concentrations of PCBs, dieldrin, chlordanes, DDTs, and PBDEs measured in mussels during the wet season from 5 CCLEAN sites along the Monterey Bay coast. Statistically significant (p = <0.05) declines are indicated by trend lines.

4.1.4 Status and Trends of Bacteria in Receiving Waters

The Ocean Plan limits the bacterial concentrations in ocean waters designated for use in water-contact recreation. These objectives, noted in Table 10 below, are presented as 30-day (monthly) geometric means, single sample maxima, and as the ratio of fecal to total coliform (FC/TC). The sampling frequency of FIBs under the CCLEAN program is not high enough to calculate monthly geometric means at two of the three wastewater discharge sites, therefore annual geometric means are calculated instead and compared with the Ocean Plan monthly objectives (Table 10).

This past sampling year witnessed unusually strong precipitation and river discharges (Figure 3). Correspondingly, FIB concentrations collected under the CCLEAN program increased at all three receiving water locations (Santa Cruz, Watsonville, and Monterey). For example, this past year Monterey and Watsonville receiving water total coliform concentrations were the highest and second highest, respectively, compared with the past six years (Fig. 17A). Despite high total coliform abundances, the single sample maximum of 10,000 per 100 ml was not exceeded at any of the receiving water sites (Table 10). Using the single sample maximum values, the FC/TC ratio was greater than 0.1 in all cases suggesting either that total coliform values were underestimated (as was the case for Watsonville this year), or that fecal coliform abundances are relatively high during peak occurrences.

Table 10. Ocean Plan monthly objectives (italics), annual geometric means, medians and single sample maxima for indicator bacteria (MPN/100 ml or CFU/100 ml) in receiving waters adjacent to ocean outfalls for three CCLEAN wastewater dischargers during WY 16. Exceedances in bold lettering.

		Recreational Waters			Shellfish Harvesting	
Agency	**Site**	**TC[1]**	**FC[2]**	**Entero[3]**	**TC[1]**	**FC[2] (proposed)**
		Geometric Means			Medians (Shellfish)	
Ocean Plan Objective[4]		*1,000*	*200*	*35*	*70*	*14*
Santa Cruz	A (far)	4.43	1.87	1.54	5.5	1
	G (near)	2.27	0.95	1.05	2	0.5
Watsonville	A (far)	4.21	2.03	3.20	1	1
	D (near)	4.23	3.69	3.44	1	1
M1W	A (far)	3.35	2.43	1.14	2	1.5
	B (near)	5.27	2.92	1.33	3	1.5
		Single Sample Maxima			% >230	FC/TC Ratio
Ocean Plan Objective		*10,000*	*400*	*104*	*10*	*0.1*
Santa Cruz	A (far)	308	205	55	2.9	**0.67**
	G (near)	84	21	12	0	**0.25**
Watsonville	A (far)	>1600	350	**364**	7.7	**0.22**
	G (near)	>1600	**540**	**233**	7.7	**0.34**
M1W	A (far)	700	240	36	8.3	**0.34**
	B (near)	700	350	43	8.3	**0.50**

[1] = Total coliform, [2] = Fecal coliform, [3] = Enterococcus, [4] =30-day Geometric Means.

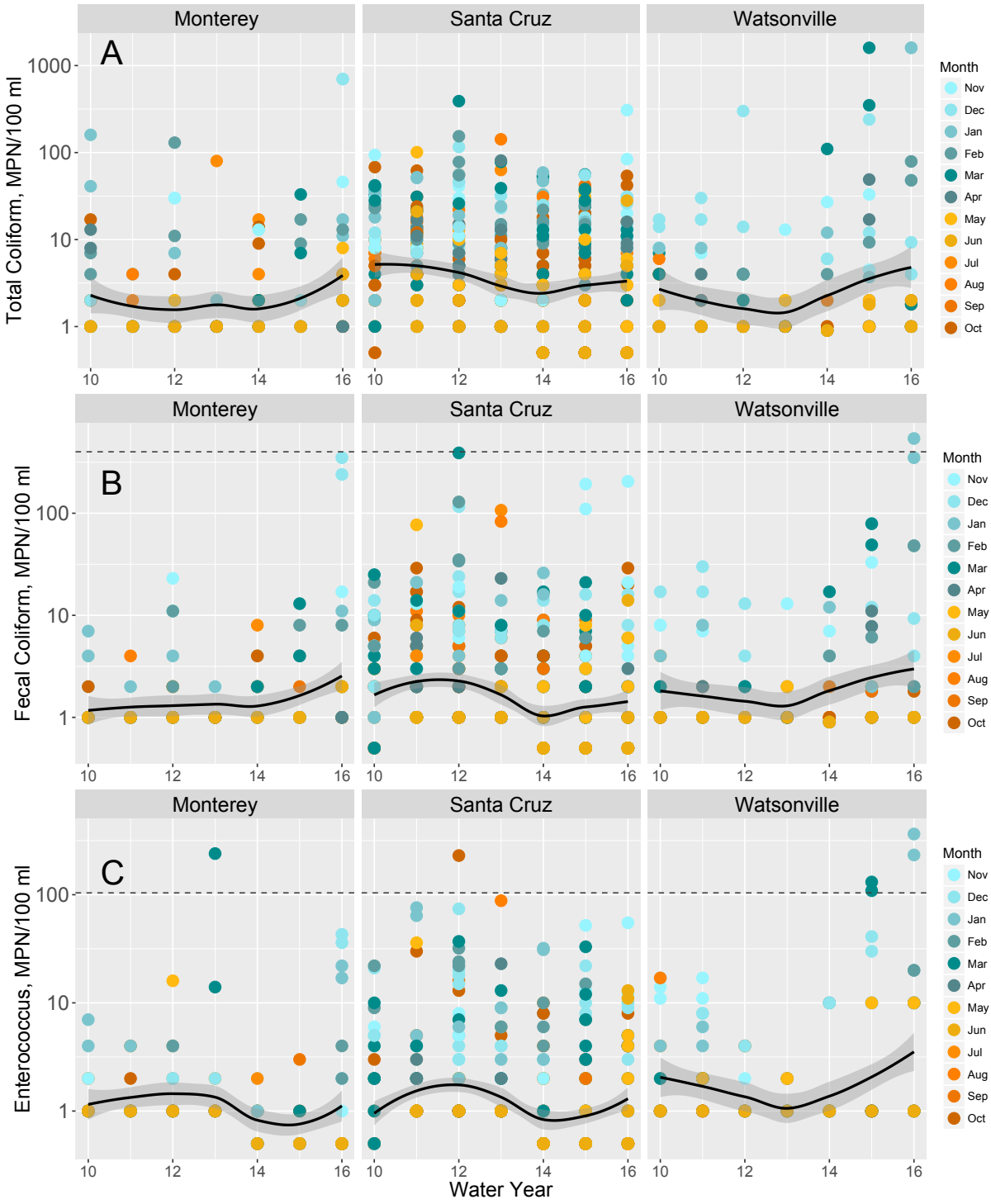

Figure 17. FIB abundances (most probable number (MPN) of bacteria per 100 ml) for water years 10-16 corresponding with years 2010-2017 from M1W, Santa Cruz, and Watsonville receiving water sites. A) Total Coliform abundances, B) Fecal Coliform abundances, and C) *Enterococcus* abundances. Dashed lines indicate the Ocean Plan single sample maximum. Teal symbols represent wet season months and orange symbols represent dry season months. Black line displays a loess fit ± standard error (shaded area).

High wet-season fecal coliform abundances were also measured in Monterey and Watsonville receiving waters this past year (Fig. 17B). For the month of January, the fecal coliform abundance at the Watsonville near-field receiving water site exceeded the single sample maximum of 400 per 100 ml (Fig. 17B, Table 10. *Enterococcus* abundance also exceeded the single sample maximum of 104 per 100 ml both near- and far-field in Watsonville receiving waters for the month of January (Fig. 17C, Table 10. There was also an increase in the *Enterococcus* trend this past year driven by increases in the wet-season *Enterococcus* concentrations at all three receiving water sites (Fig. 17C).

FIB concentrations collected monthly (at Monterey and Watsonville receiving water sites) or weekly (at Santa Cruz receiving water sites) were used to calculate annual geometric means of the FIBs for each site. Increases in the annual geometric means of total coliforms and fecal coliforms occurred at two of the three receiving water locations this year. The total coliform geometric mean increased 3.5-fold far-field, and 2-fold near-field, over the previous year in Monterey receiving waters. The Monterey near-field total coliform geometric mean of 5.3 was the highest compared with the other two receiving water locations where total coliform means were not substantially different compared with the previous year (Fig. 18A). Near-field and far-field fecal coliform geometric means were close to double that of the previous year in Monterey receiving waters (Fig. 18B). In Watsonville receiving waters there was an increase in near-field and a decrease in far-field fecal coliform geometric means compared with the previous year (Fig. 18B). The *Enterococcus* geometric mean was also greater both near-and far-field in Monterey receiving waters, and far-field in Watsonville receiving waters, compared with the previous year (Fig. 18C). Compared with Monterey and Watsonville receiving waters, Santa Cruz receiving water FIB annual geometric means were not very different from the previous year (Fig. 18). Here, small increases in the geometric means of total coliform and *Enterococcus* occurred at the far-field receiving water site (Fig. 18A, C).

4.1.4.1 Conclusions

A second year with strong wet-season precipitation and river flow (Fig. 19A) resulted in record FIB concentrations in Monterey receiving waters and in FIB concentrations similar to, or greater than, the previous year in Watsonville and Santa Cruz receiving waters. It is important to note that these increases in FIB concentrations are for the most part similar between near- and far-field measurements and therefore cannot be systematically associated with discharges from the CCLEAN participants. As such, the combined wastewater discharges from the three CCLEAN participants do not appear to cause impairments to water contact recreation above that associated with loading of FIBs from nearby rivers such as the Pajaro River (Fig. 19B). Exceedances of the single sample maxima for fecal coliform and *Enterococcus* in Watsonville receiving waters in the month of January were associated with an exceptionally high load of FIBs from the Pajaro River which discharges in the vicinity of the Watsonville wastewater outfall (Fig. 19A-C). With respect to total coliform bacteria, exact concentrations at the Watsonville receiving water sites were not determined for this month, only that they exceeded 1600 at both near- and far-field receiving water sites (Table 10).

4.1.4.2 Recommendations

Monitoring of FIB concentrations should continue in Monterey Bay receiving waters as well as in the Pajaro River. Moreover, loads of FIBs from the Pajaro should continue to be estimated in order to track the effects of non-wastewater sources on receiving water FIB concentrations.

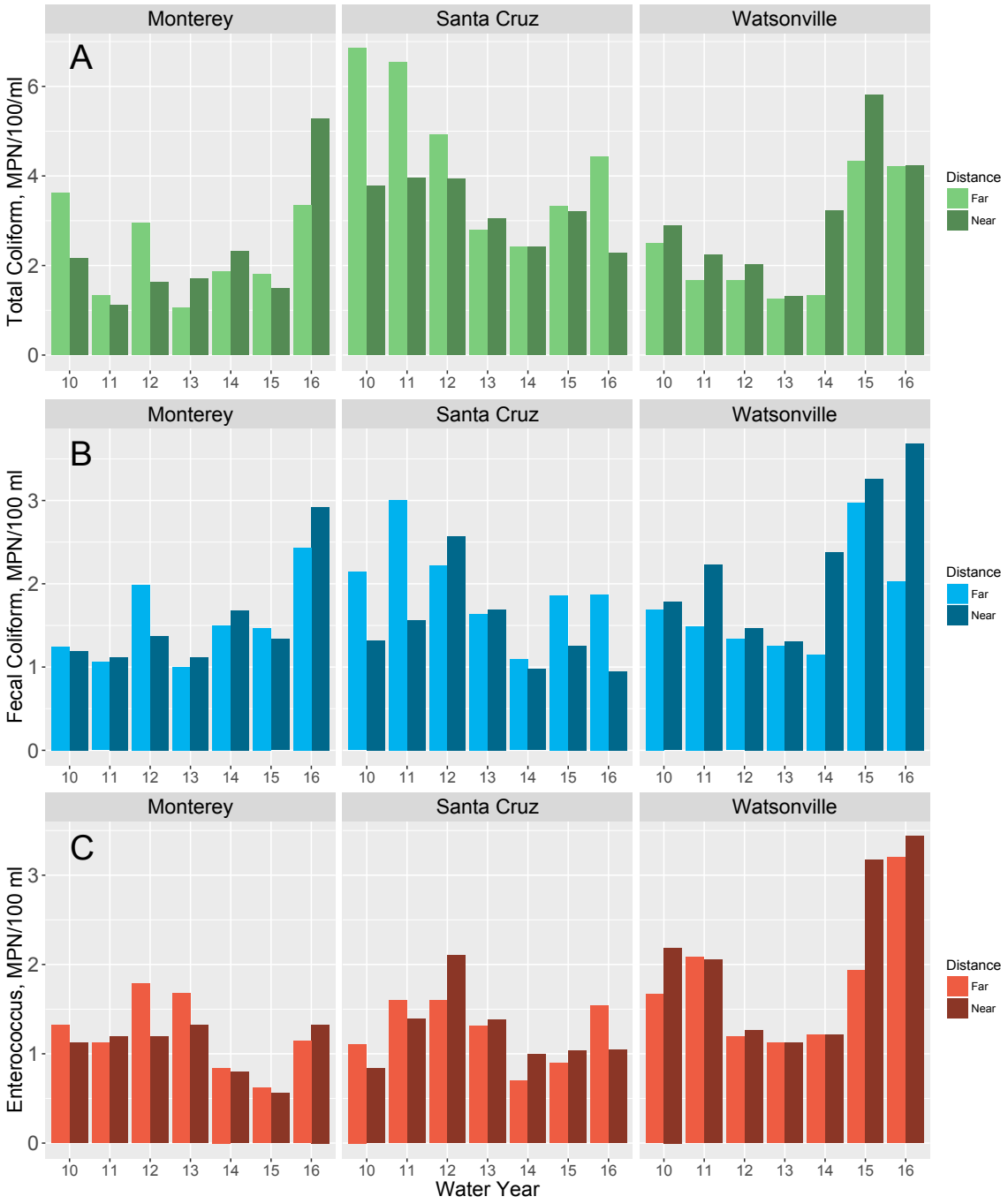

Figure 18. Annual Geometric FIB means of most probable number of bacteria per 100 ml, at stations far- and near-field from discharge at three receiving water sites (Monerey, Santa Cruz, and Watsonville) for the water years 10-16 (representing years 2010-2017). A) Total Coliform means, B) Fecal Coliform means, and C) Enterococcus means.

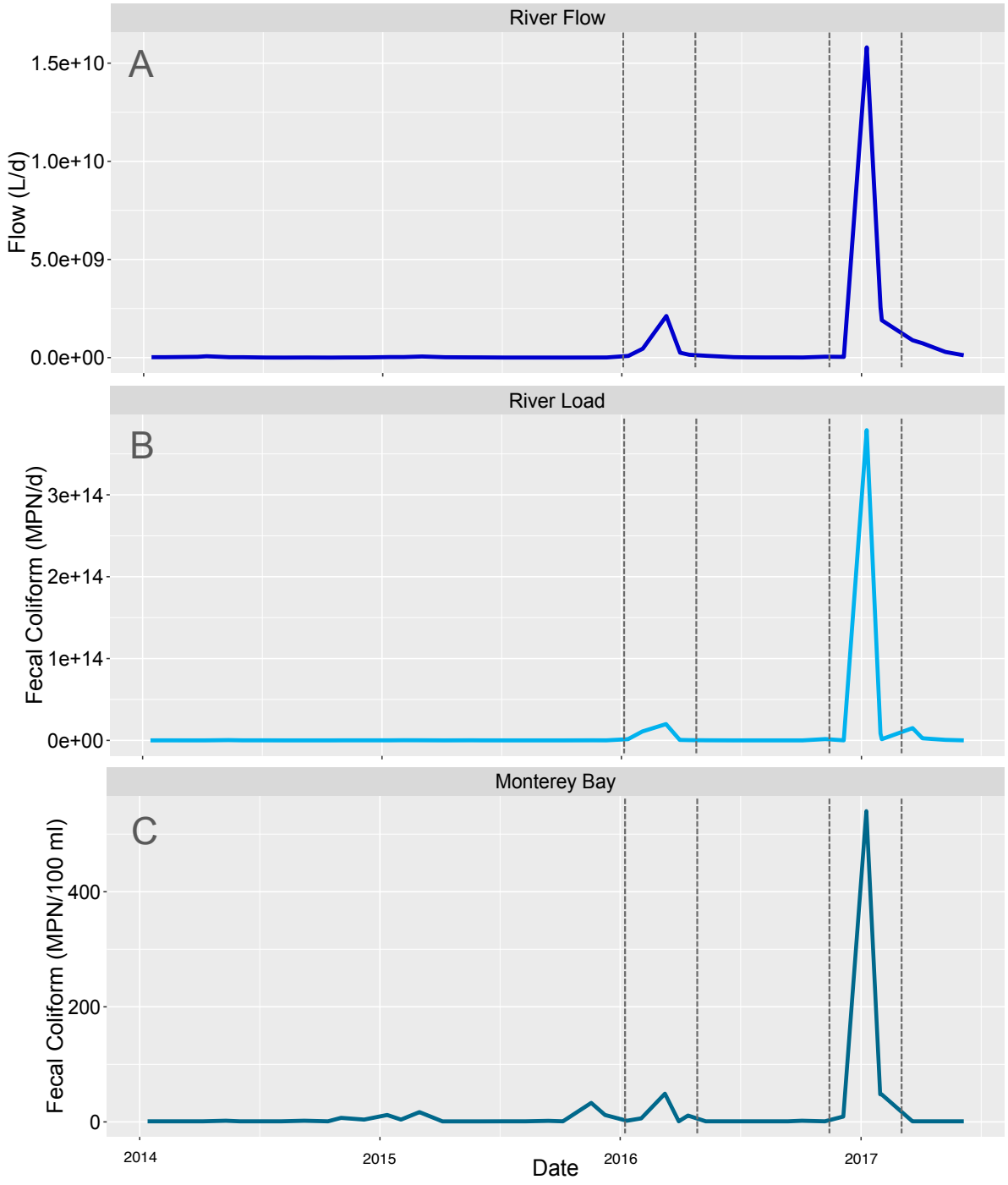

Figure 19. Time course (2014-2017) of monthly sampling of A) Pajaro River flow (L/d), B) Pajaro River fecal coliform load (MPN/d) calculated from concentration, and C) fecal coliform concentration (MPN/100 ml) at the Watsonville near-field receiving water site in Monterey Bay. Grey dashed lines indicate periods of strong flow and high volume discharge of the Pajaro River.

4.1.5 Status and Trends of POPs in Sediments of Monterey Bay

While sediment and benthic community sampling was conducted annually through 2010, it has occurred every five years since then. Starting in 2016, sampling of sediment chemistry was increased to every year which is reflected in this year's data analysis and presentation. In order to present the entire time course since 2001, the data are presented every five years until 2015 and presented every year thereafter. Another change instituted this sampling year was the addition of three new sediment collection sites, one in Santa Cruz Harbor, one in Moss Landing Harbor, and one in the Monterey Canyon at site SF-14 (Fig. 2). Data from these sites have not been collected before as part of the CCLEAN program and is presented separately. As in last year's CCLEAN report, the data have been grouped into Outer Bay samples (all the SedRef sites, Figure 2) and Inner Bay samples (SedDep sites, Figure 2). This grouping of samples enabled examination of broad spatial variation in long-term trends.

An interesting finding in this year's PCB data was an increase in sediment concentrations in both Outer and Inner Bay samples over the last year. The Outer Bay PCB concentration reached above 0.9 µg per Kg dw sediment, an increase of 50% over the previous year (Fig. 20A). Despite this increase, this concentration was low compared with that measured in Moss Landing Harbor sediments (Fig. 20A). Levels of PCBs were 6 and 12-fold greater in Moss Landing Harbor sediments than in Outer and Inner Bay sediments, respectively, and 30 and 44-fold greater than Santa Cruz Harbor and Site SF-14 sediments, respectively. In contrast with PCBs, concentrations of chlordanes in the historical sediment sites sampled by CCLEAN did not increase but remained at relatively low concentrations in Inner and Outer Bay samples (Fig. 20B). As was the case for PCBs, concentrations of chlordanes and dieldrin were greater in Moss Landing Harbor sediments than any other sampled sediments (Fig. 20B, C). Chlordanes were 140-186 times more concentrated in Moss Landing Harbor than in Santa Cruz Harbor or SF-14 sediments, and 41-84 times more concentrated in Moss Landing Harbor sediments than in Outer or Inner Bay sediments (Fig. 20B). In contrast with the aforementioned POPs, Moss Landing Harbor sediments had lower DDT concentrations compared with the Outer Bay sediment sites, but similar to the Inner Bay sites (Fig. 20D).

4.1.5.1 Conclusions

This year concentrations of all POPs were greater in the Outer Bay samples compared with Inner Bay samples. The only exception was dieldrin which had the same concentration in both Inner and Outer Bay sediment samples. Concentrations of most POPs have decreased over time since sediment sampling began under the CCLEAN program; this year the decrease appeared to have leveled off as concentrations were similar to last year's. An important exception to this trend was PCBs which are increasing in concentration in both Inner and Outer Bay sediments.

Three new sediment sites were added this year in order to further investigate potential sources of elevated PCBs in Monterey Bay, particularly during dredging events. Dredging occurs both in the Santa Cruz Inner Harbor and Moss Landing Harbor and the spoils are deposited at the SF-14 dumping site at the southern border of the Monterey Canyon. Evaluation of the POP data from these three additional sediment sites demonstrated that Moss Landing Harbor sediments were the most contaminated compared with any of the other sites measured under CCLEAN and

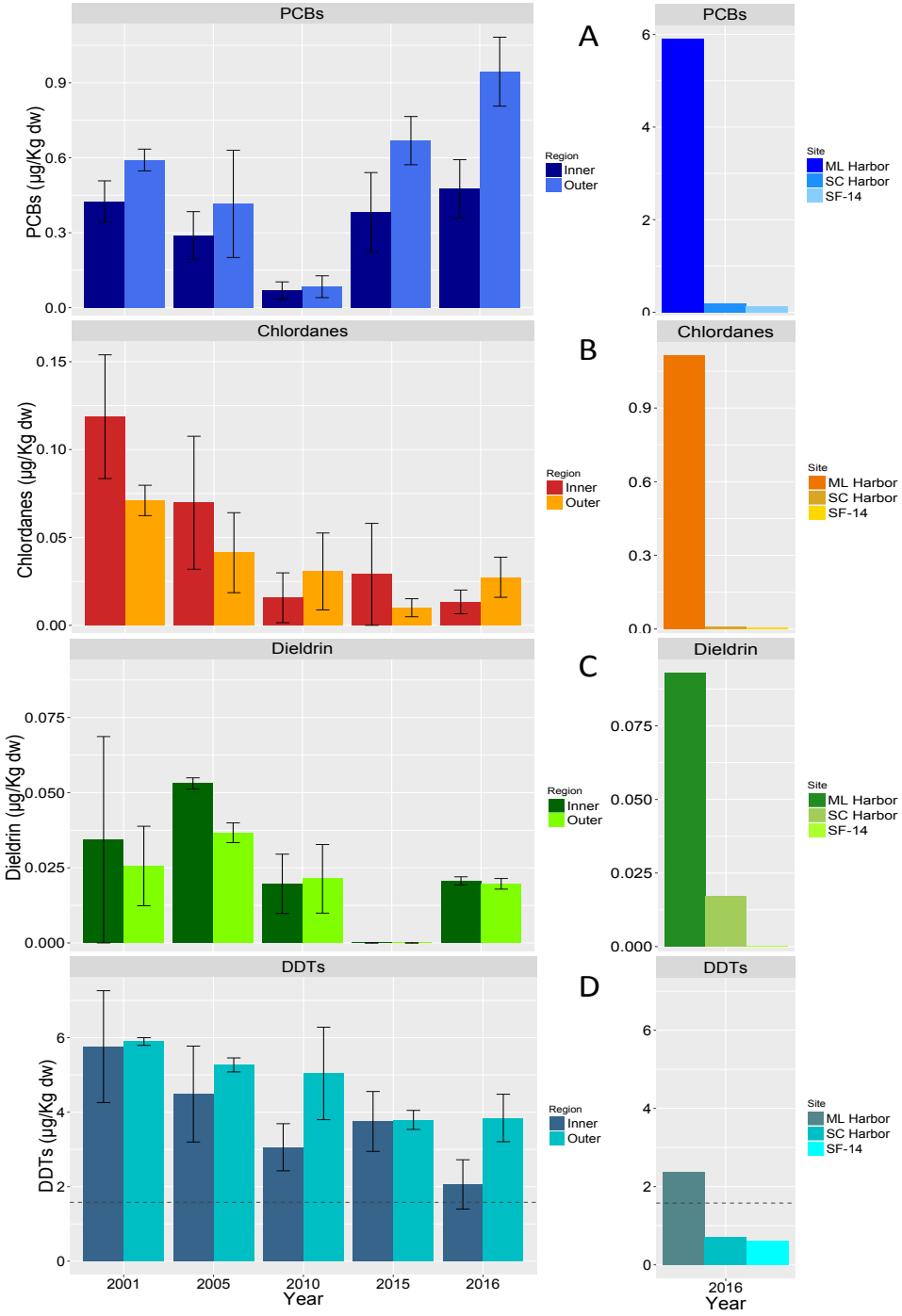

Figure 20. Mean concentrations of POPs in sediments from Inner Bay and Outer Bay samples. Very low concentrations of PCBs in 2010 were due to the inadvertent use of low-resolution analytical methods. Horizontal dashed line is NOAA Effects Range Low concentration. Error bars= standard error of the mean.

cannot not be ruled out as the source of the episodically high POP concentrations in the water column of Monterey Bay.

4.1.5.2 Recommendations

Annual sediment sampling should continue until the source of high PCBs in Monterey Bay can be more definitively determined.

4.2 What are the major sources of contaminants to nearshore waters?

4.2.1 Sources of Nutrients to Monterey Bay

CCLEAN participants have been measuring concentrations of a number of different nutrients, including ammonium-nitrogen (N), nitrate-N, urea-N, orthophosphate phosphorus (P) and silica, in their effluent streams for the duration of the program. Here we present inter-annual and seasonal variations in effluent-associated nutrient loads discharged into Monterey Bay over the course of 14 years. For the past water year (WY 16) we also compare effluent-associated nutrient loads with riverine nutrient loads.

Table 11. Wet season six-month median concentrations (mg/L) and loads (kg/d) of ammonium in CCLEAN wastewater effluent discharges for WY 16 and NPDES permit limit for each discharger. The NPDES permit for City of Santa Cruz does not require load limits.

	Watsonville		Monterey		Carmel	
Unit	WY 16	Permit	WY 16	Permit	WY 16	Permit
mg/L	13	51	43	88	11	73
kg/d	295	2313	2725	9798	45	816

Of the nutrients discharged by CCLEAN participants, only ammonium is regulated. On average, ammonium constitutes >70% of the dissolved N load from the combined effluent discharged by CCLEAN participants into Monterey Bay. For WY 16, ammonium loads from wastewater effluent were generally between 10% and 50% of the maximum daily load limits established in dischargers' NPDES permits (Table 11). The total N load discharged by CCLEAN participants into Monterey Bay averages 1,014,462 kg N per year while the load of phosphorus (P) from orthophosphate averages 172,700 kg P per year and the N:P ratio of the combined effluent discharged is 5.9 (Table 12). The load of silica averages 1,198,656 kg per year and is close in magnitude to the N load (Table 12).

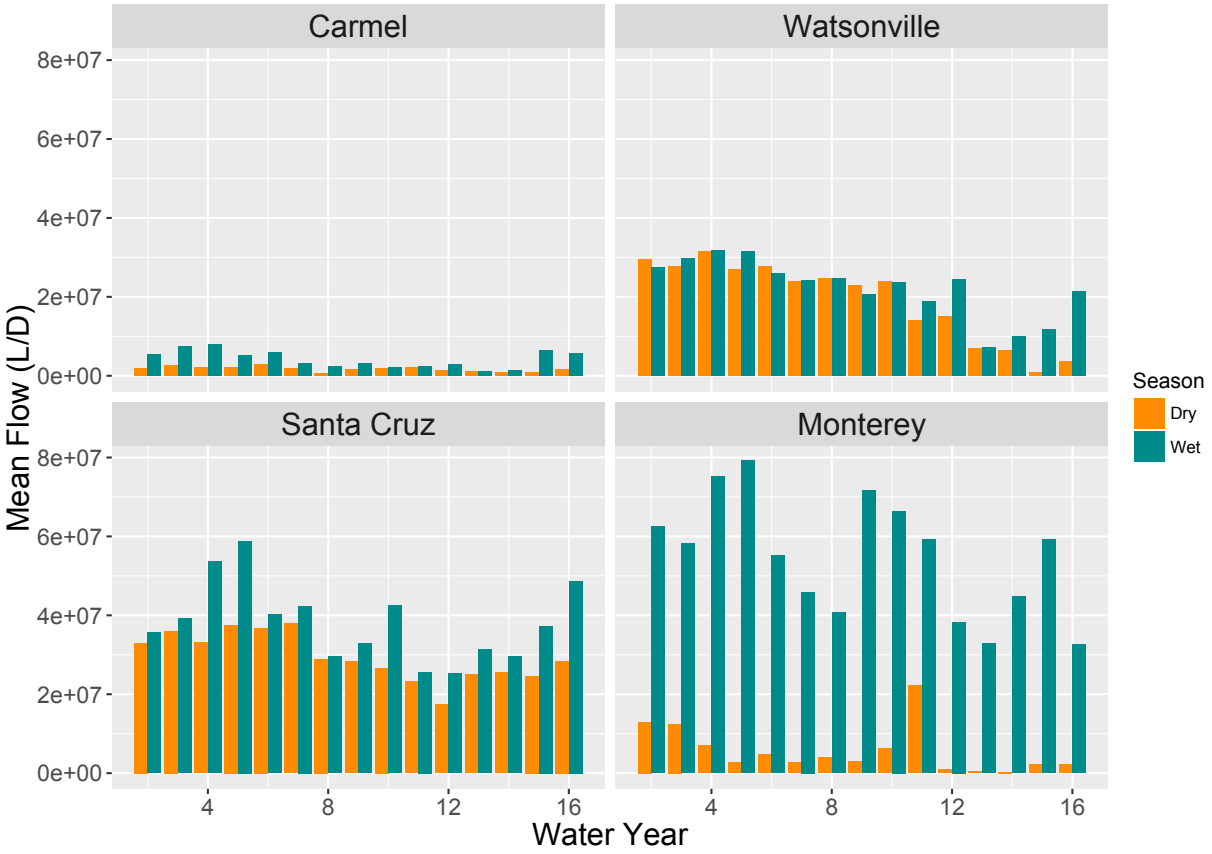

Figure 21. Mean effluent flow rate, liters per day (L/D), for water years 2-16 (representing years 2002-2017) by CCLEAN dischargers. Dry season and wet season mean flows calculated from the 30-day CCLEAN sampling period in each season. Orange bars represent dry season and teal bars represent wet season.

Effluent discharge (L/d) varies widely with discharger but is fairly similar between the dry and wet season, with the exception of M1W discharge (Fig. 21). M1W reclaims water in the dry season, as does Watsonville since 2013, producing much less discharge in the dry compared with the wet season (Fig. 21). Carmel reclaims water in both the dry and wet seasons and has the lowest effluent discharge rate and therefore discharge volume of the four CCLEAN dischargers (Fig. 21).

Nutrient loads closely follow effluent discharge rates and volumes, with the smallest loads typically being discharged by Carmel and the greatest loads being discharged by Santa Cruz and M1W (Fig. 22). Loads of nutrients from effluent are similar between the wet season and dry season for all the dischargers with the exception of M1W where flows are much greater in the wet season compared with dry season (Fig. 21, 22).

Loads of ammonium (NH_4^+) from Carmel consistently average 43 kg N/d while loads of ammonium from Watsonville have decreased steadily from 533 kg N/d in 2006 to 88 kg N/d in 2015 (Fig. 22A). This past year (WY 16) witnessed a spike in the Watsonville wet season NH_4^+

load reversing this declining trend (Fig. 22A). While NH_4^+ loads from Santa Cruz have remained fairly consistent around 739 kg N/d, they have increased in M1W driven by increasing wet season loads in the last four years (Fig. 22A), reaching an annual average of 1309 kg N/d this year. Current NH_4^+ loads from M1W are similar to NH_4^+ loads in the past (WY 4-10). Nitrate (NO_3^-) represents a smaller fraction of the total N discharged (15-20%) than NH_4^+ for all the dischargers, with the exception of Carmel. In Carmel where nitrate NO_3^- represents the majority of N discharged, loads of NO_3^- have steadily increased to average 77 kg N/d. Loads of NO_3^- have either remained consistent or declined over time for all other dischargers (Fig. 22B). Loads of phosphate (PO_4^{3-}) and silica have either remained consistent over time or decreased. In particular, loads of both PO_4^{3-} and silica have declined substantially over time in Watsonville discharge (Fig. 22C, D).

Table 12. Sum of annual loads of total N ($NH_4^+ + NO_3^- +$ urea-N), ammonium-N (NH_4-N), nitrate-N (NO_3-N), urea-N, phosphate-P (PO_4^{3-}) and silica in effluent discharged by four CCLEAN participants. Overall annual means (water years 2-16, n=15) are noted in the bottom row. The percent of various N sources comprising total N discharge are in noted in the three rightmost columns. The mean nutrient element discharge ratios are as follows: Si:N=1.2 and N:P=5.9.

Year	Total N (kg/yr)	NH_4^+-N (kg/yr)	NO_3^--N (kg/yr)	Urea -N (kg/yr)	Silica (kg/yr)	PO_4^{3-}-P (kg/yr)	NH_4^+ (%)	NO_3^- (%)	Urea (%)
WY02	1,056,171	889,697	161,554	4,920	1,511,146	NA	84.2	15.3	0.5
WY03	983,257	830,948	146,282	6,027	1,442,364	292,109	84.5	14.9	0.6
WY04	1,217,016	953,418	258,303	5,295	1,651,933	453,108	78.3	21.2	0.4
WY05	1,053,792	722,227	327,574	3,991	1,495,875	311,677	68.5	31.1	0.4
WY06	1,088,692	898,804	184,030	5,858	1,247,975	153,503	82.6	16.9	0.5
WY07	998,779	548,821	447,803	2,155	1,382,129	172,480	54.9	44.8	0.2
WY08	855,838	661,982	190,436	3,420	1,073,910	141,004	77.3	22.3	0.4
WY09	1,124,686	805,370	315,588	3,728	1,247,749	136,679	71.6	28.1	0.3
WY10	1,358,373	817,508	537,249	3,616	1,295,195	135,274	60.2	39.6	0.3
WY11	1,077,496	515,445	558,813	3,238	1,204,432	105,482	47.8	51.9	0.3
WY12	877,313	406,207	468,774	2,332	818,872	99,834	46.3	53.4	0.3
WY13	710,072	540,168	167,511	2,393	727,750	95,776	76.1	23.6	0.3
WY14	814,027	610,255	201,379	2,393	812,334	95,573	75.0	24.7	0.3
WY15	975,911	772,470	200,811	2,630	959,851	103,001	79.2	20.6	0.3
WY16	1,025,510	826,845	195,430	3,235	1,108,321	122,301	80.6	19.1	0.3
Mean:	1,014,462	720,011	290,769	3,682	1,198,656	172,700	71.1	28.5	0.4

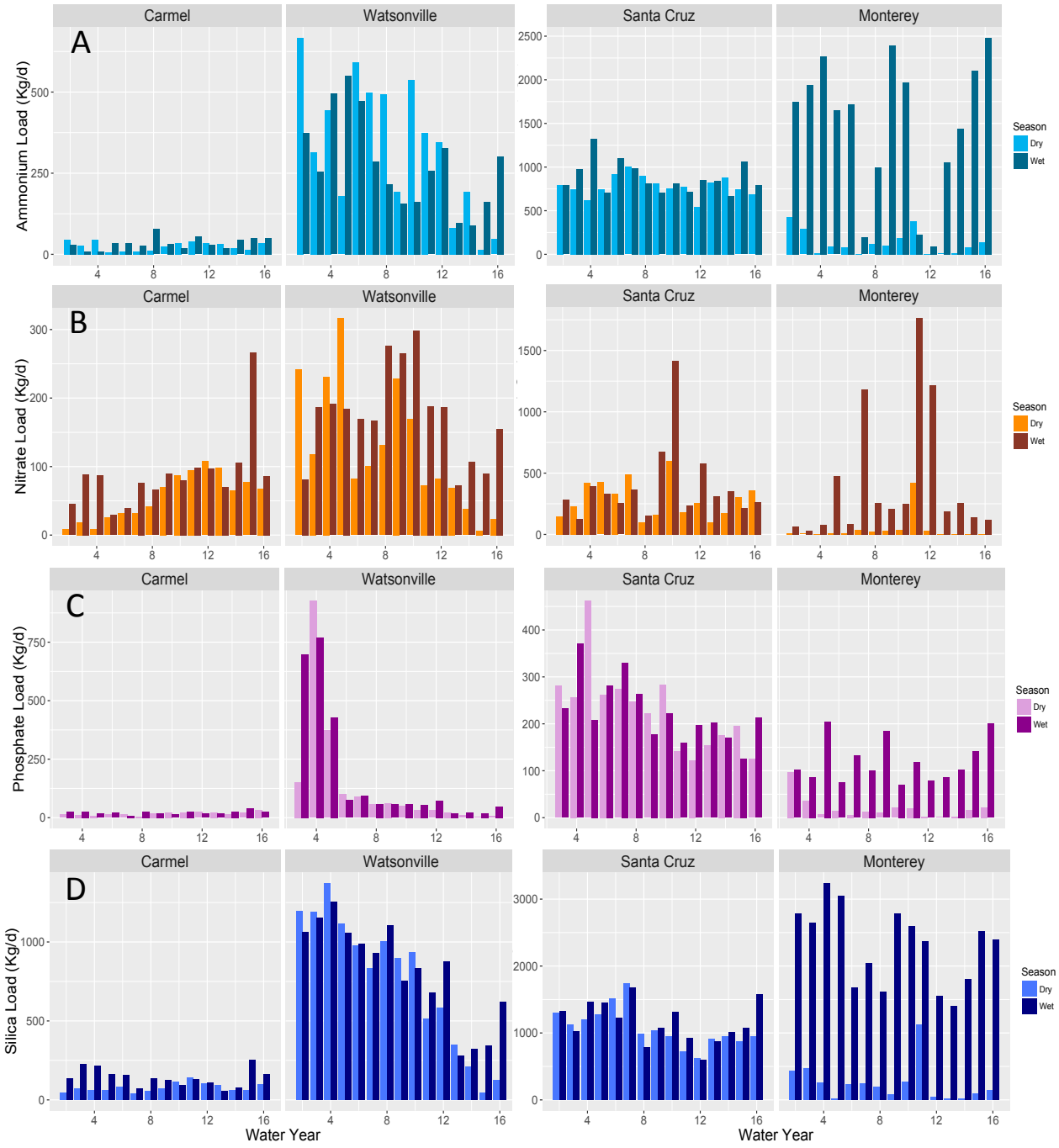

Figure 22. Nutrient loads over time (WY 2-WY 16) by season (dry and wet) and by discharger (CAWD, Watsonville, Santa Cruz, M1W). A) Time course of ammonium loads (kg/d), B) time course of nitrate loads (kg N/d), C) time course of phosphate loads (kg P/d), and D) time course of silica loads (kg/d).

Because CCLEAN participants have consistently measured concentrations of nutrients and POPs in the Pajaro River, a local comparison of nutrient loads between the Pajaro River and Watsonville effluent was performed (Fig. 23). Over the past four years, loads from the Pajaro

River have been 4-fold less than loads from Watsonville effluent during the dry season (Fig. 23). However, in the wet season this pattern is reversed with N loading from the Pajaro River typically being greater than that from effluent (Fig. 23, B). Particularly in wet years, N loading from the Pajaro can be 2 to 80-fold greater than from Watsonville effluent (Fig. 23B).

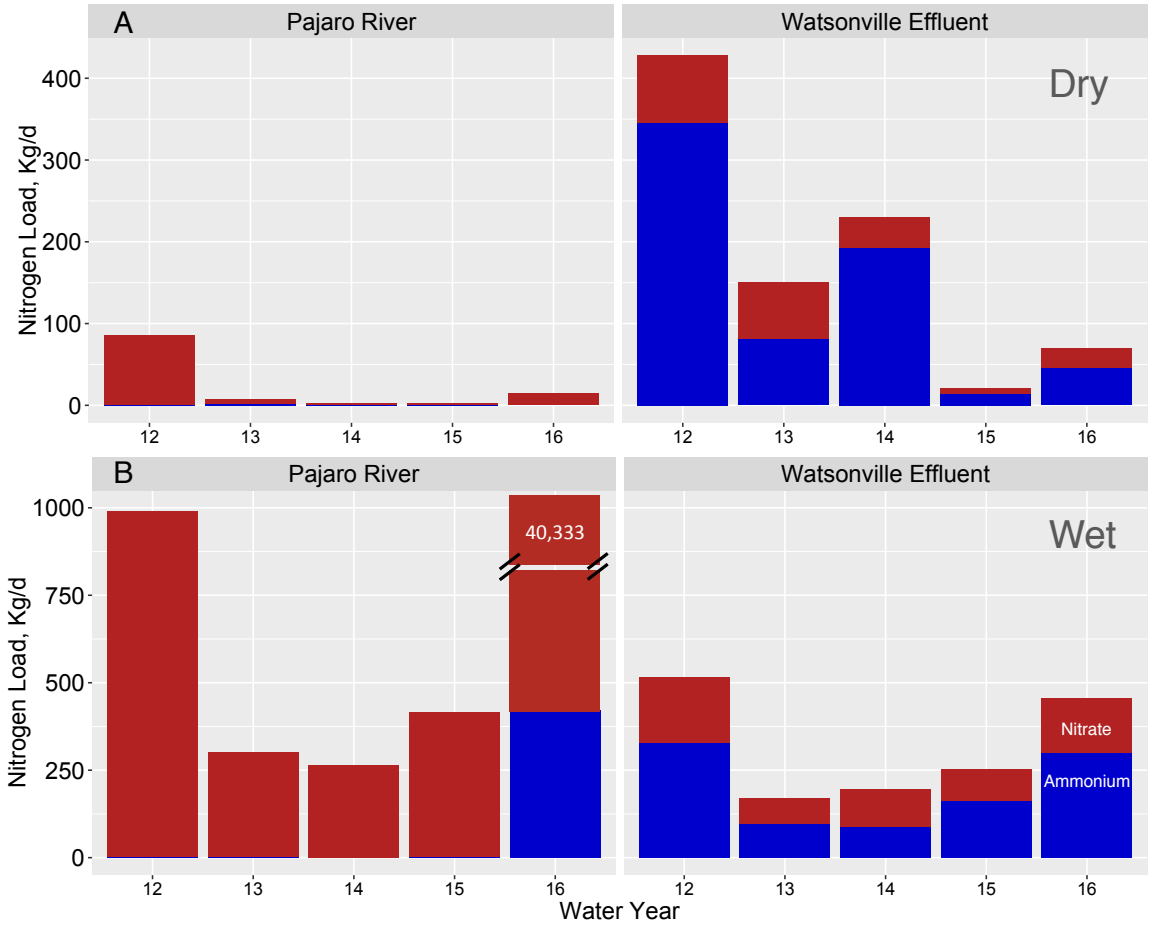

Figure 23. Nitrogen (N) loading (kg/d) from the Pajaro River compared with wastewater effluent from the city of Watsonville over the past 4 water years during the A) dry season and B) wet season. Blue color represents ammonium-N and red represents nitrate-N.

4.2.1.1 Conclusions

Since the start of the CCLEAN monitoring program, loads of nutrients discharged by each participating agency has either remained consistent or declined. Nutrient loads from effluent are typically greater than that from rivers in the dry season but less in the wet season. This past wet season, flows in the Pajaro River were at a record high driving the annual load of nitrogen to 20,385 kg N/day from the Pajaro River compared with 262 kg N/day from Watsonville effluent.

4.2.1.2 Recommendations

Continue to monitor nutrient concentrations in effluent and in Rivers in order to assess their effect on beneficial uses in Monterey Bay. For the coming year, an in-depth analysis of the

impact of nutrient discharge from effluent and rivers on phytoplankton biomass development in the nearshore region is recommended. An inter-laboratory calibration exercise should be conducted to confirm the proficiency of local and agency laboratories for analysis of nutrients at relevant ocean concentrations.

4.2.2 Sources of POPs to Monterey Bay

Pyrethroids and fipronils are currently not regulated but water quality criteria have been proposed by the Central Valley Regional Water Board (Table 7), and their concentrations in four rivers and four discharges have been measured successfully the past two years under CCLEAN. Most notable this year was the increase in loads compared with last year, both from wastewater and from rivers (Fig. 24). This increase was approximately 9-fold with for permethrin in wastewater, 2- and 6-fold for fipronil in wastewater and rivers, respectively, and 11-fold and 900-fold for fenopropoathrin and fipronil sulfone, respectively, in rivers. In addition, bifenthrin increased from no loading last year to a loading of >11,000 ng/L in the rivers this year (Fig. 24), associated with detections in the Pajaro and Salinas rivers (Fig. 8).

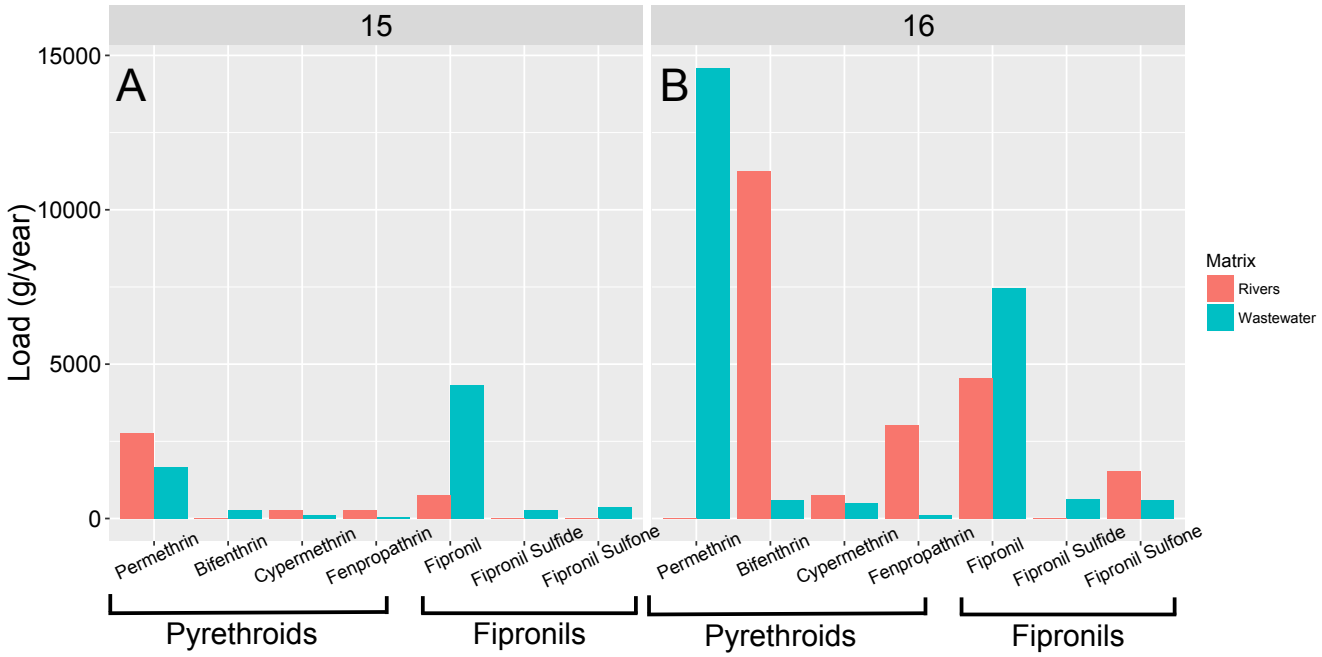

Figure 24. Combined annual loads of pyrethroids and fipronils from all rivers and all wastewater sources discharging into the ocean in the Monterey Bay area. A) Water year 15, B) water year 16.

This year-on-year increase was very large and it will be interesting to see if it persists next year or if this year was an anomaly. Although the increase in river load could be explained by heavy precipitation and run-off in the past wet season (Fig. 3), the increase in wastewater

effluent loads is more difficult to explain, as discharges typically do not change a great deal between years (Fig. 21).

CCLEAN continues to measure legacy POPs in wastewater and, as mentioned in Section 3.0, the City of Watsonville and City of Santa Cruz support POP sampling in the Pajaro River and San Lorenzo River, respectively. Wastewater concentrations and loads of regulated legacy POPs during WY 16 were generally substantially below concentrations and daily load limits established in dischargers' NPDES permits, with the exception of chlordane in Watsonville effluent in the wet season (Table 13).

CCLEAN has previously documented that rivers are the dominant sources of most contaminants discharged into ocean waters in the Monterey Bay area from either wastewater or rivers (CCLEAN 2007). For most POPs, cumulative loads discharged into the ocean from rivers have consistently been much greater than those from wastewater (Fig. 25). Since the cessation of CCLEAN POP monitoring in all rivers in 2007, total river POP loads have been estimated using average ratios of Pajaro River loads to those from the other rivers measured before 2007. With the re-initiation of POP sampling in the San Lorenzo River in 2013, the average ratios of the Pajaro and San Lorenzo combined to the other rivers have been used to estimate total loads from rivers. While cumulative loads of PAHs, DDTs, dieldrin, chlordanes, and PCBs from rivers have varied substantially through time, wastewater loads have been more stable and consistently much lower than those from rivers (Fig. 25). Average annual loads from rivers have exceeded those from wastewater for most POPs by factors ranging from 22 for PCBs and chlordanes to 542 for DDTs (Table 14). The one exception is loads of PDBEs from wastewater discharge which average 1.7 times greater than loads from rivers. However, the last two years PBDE loads from rivers have been greater than PBDE loads from wastewater (Fig. 25F). Due to high precipitation and river flows in the last 2 years, the annual river-based POP loads reached a high that has not been seen in the CCLEAN sampling program since 2010 (Fig. 25F).

4.2.2.1 Conclusions

Estimated loads of most POPs remain much greater from rivers than from wastewater. This year, loads of POPs from rivers were at a record high compared with past years, including the load of PBDEs, which has been higher from rivers than wastewater in the last two years. Loads of pyrethroids and fipronils increased dramatically this year compared with last year, both from wastewater and from rivers, underscoring the importance of continuing to monitor the trend of these CECs.

4.2.2.2 Recommendations

Continue to monitor concentrations of legacy POPs as well as the newly emerging pyrethroids and fipronils.

Table 13. Concentrations and maximum daily loads of regulated (Ocean Plan) pollutants in measured CCLEAN wastewater discharges (with NPDES permit limits for each discharger) during WY 16.

Source & Date	PCB_{209} ng/L *g/day*	PAH ng/L g/day	DDT ng/L g/day	HCH ng/L g/day	Chlordane ng/L g/day	Dieldrin ng/L g/day	Endosulfan ng/L g/day	Dioxin/Furan/ PCB TEQs g/day
Santa Cruz								
Permit	**2.66**	**1200**	**23.8**	**560**	**3.2**	**5.6**	**1260**	**5.5 E-4**
Sept-16	1.92 *0.05*	50.92 *1.44*	0.57 *0.02*	0.00 *0.00*	1.03 *0.03*	0.29 *0.01*	0.02 *0.001*	3.86E-04 *1.09E-05*
Feb-17	0.52 *0.03*	18.14 *1.00*	0.17 *0.01*	0.00 *0.00*	1.11 *0.06*	1.32 *0.07*	0.07 *0.004*	2.84E-05 *1.55E-06*
Watsonville								
Permit, ***Load***	**1.62** ***0.0735***	**748** ***33.97***	**14.45** ***0.655***	**340** ***15.4***	**1.96** ***0.089***	**3.4** ***0.15***	**770** ***34.9***	**3.32 E-4** ***1.51 E-5***
Sept-16	1.17 *0.01*	19.44 *0.10*	0.63 *0.003*	0.00 *0.00*	0.34 *0.002*	0.16 *0.001*	0.04 *0.0002*	5.79E-05 *3.04E-07*
Feb-17	3.09 *0.11*	29.29 *1.0*	3.81 *0.13*	0.00 *0.00*	11.18* *0.38**	1.70 *0.06*	0.13 *0.004*	1.92E-04 *6.53E-06*
M1W								
Permit, ***Load***	**2.774** ***0.3107***	**1284.8** ***143.79***	**24.82** ***2.781***	**292** ***264.9***	**3.358** ***0.376***	**5.84** ***0.635***	**1314** ***149***	**5.70 E-4** ***6.35 E-5***
Sept-16	0.66 *0.002*	35.14 *0.10*	0.97 *0.003*	0.00 *0.00*	1.22 *0.003*	0.40 *0.001*	0.34 *0.001*	1.02E-04 *2.90E-07*
Feb-17	0.48 *0.04*	25.47 *1.94*	0.74 *0.06*	0.00 *0.00*	0.60 *0.05*	0.48 *0.04*	0.52 *0.04*	4.28E-05 *3.26E-06*
CAWD								
Permit, ***Load***	**2.318** ***0.026***	**1073.6** ***12.25***	**20.74** ***0.236***	**488** ***5.4***	**2.806** ***0.032***	**4.88** ***0.054***	**1098** ***12.25***	**4.80 E-4** ***5.40 E-6***
Sept-16	0.64 *0.001*	78.42 *0.10*	0.17 *0.0002*	0.07 *8.66E-5*	0.94 *0.001*	0.97 *0.001*	0.21 *0.0003*	1.31E-04 *1.67E-07*
Feb-17	0.49 *0.005*	43.94 *0.45*	0.51 *0.005*	0.00 *0.00*	1.32 *0.01*	1.30 *0.01*	0.05 *0.0005*	3.28E-05 *3.39E-07*

Table 14. Average annual loads (g/year) of POPs between 2001-2017 from combined wastewater and river discharges.

	PAHs	PBDEs	PCBs	Dieldrin	Chordanes	DDTs
Rivers	32,810	214	391	519	607	7,049
Wastewater	1,226	372	18	12	28	13

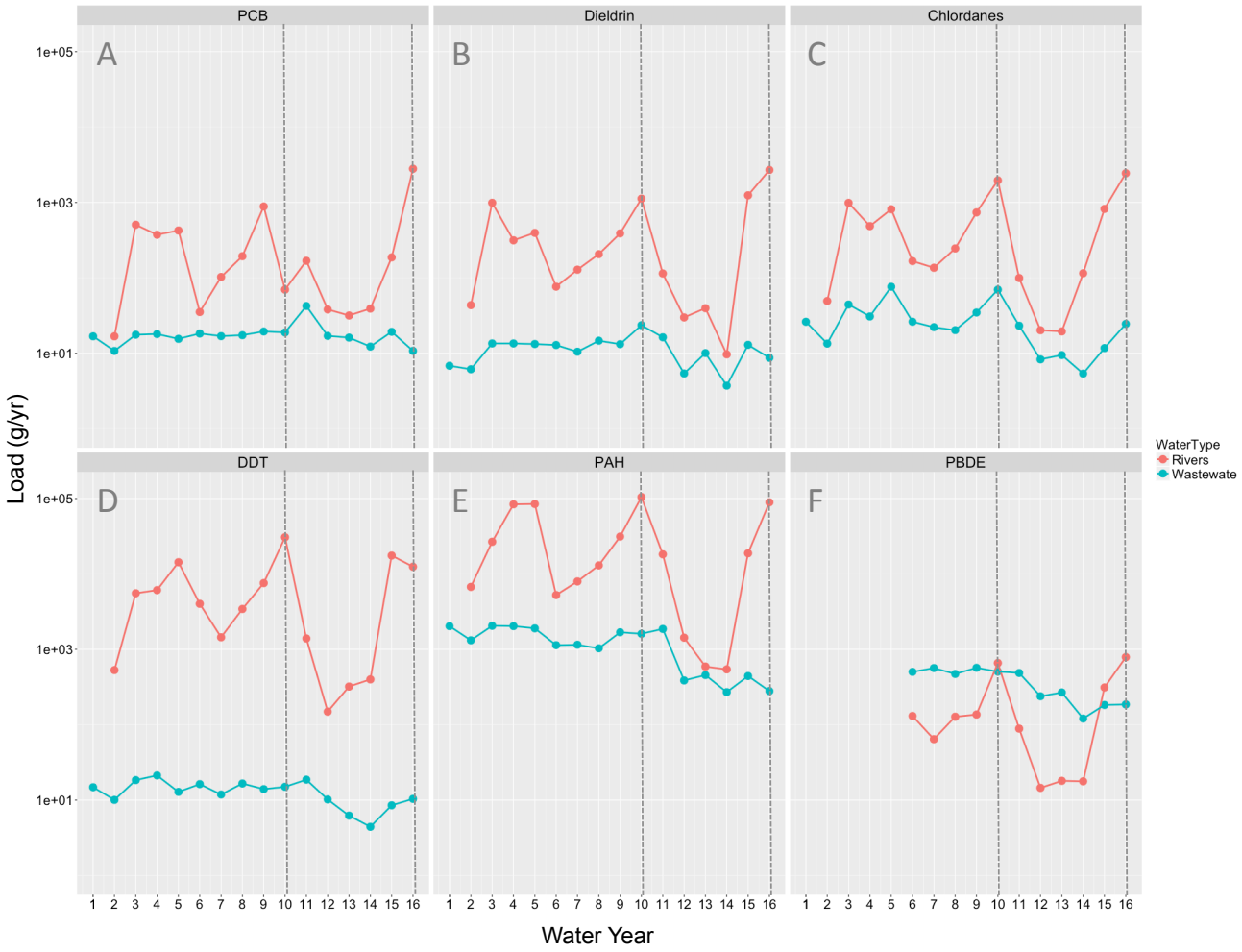

Figure 25. Loads of POPs (g/year) from all rivers combined and all wastewater discharges combined into the ocean in the Monterey Bay area. Sampling of all rivers but the San Lorenzo and Pajaro ceased in 2007 and the last 8 years are estimated from historic ratios of Pajaro River and San Lorenzo River to other rivers. A) PCBs; B) dieldrin; C) chlordanes; D) DDTs; E) PAHs; F) PBDEs. Vertical dashed lines indicate years of high precipitation.

4.2.3 Relationships Between POP Sources and Water Quality Impairments

The 2016 project year provided exceptional data for evaluating the effects of episodic high rainfall events on the concentrations of POPs in Monterey Bay. The very high rainfall and river flows in this year coincided with the highest concentrations of DDTs and dieldrin measured by CCLEAN in ocean water since the program began. Other POPs, such as chlordanes, exceeded Ocean Plan water quality objectives, but did not result in their highest ocean concentrations observed over the CCLEAN time series. This suggests that DDT and dieldrin concentrations correlate to precipitation and have different sources from other POPs.

Five different comparisons were applied to the entire set of CCLEAN data in an effort to more clearly demonstrate the relationships between POP sources and exceedances of Ocean Plan objectives for DDTs, dieldrin, PCBs, and chlordanes in Monterey Bay. These comparisons

involved 1) calculating the correlations between loads of POPs from potential sources and their corresponding concentrations in ocean samples, and 2) comparing source concentrations with concentrations in North Monterey Bay. In addition to correlations between concentrations in the ocean and potential sources, 3) correlations between POPs in the ocean, which can suggest a common source, 4) comparing percentages of DDTs, dieldrin, PCBs, and chlordanes in the summed concentrations of these POPs (i.e., % DDTs, % dieldrin, % PCBs, and % chlordanes in the sum of DDT + Dieldrin + PCBs + chlordanes), and 5) comparing the percentages of DDE, DDD, and DDT in summed DDTs, were compared among types of samples. Comparison of profiles of percentages, also called fingerprinting, is especially useful when there are large differences in concentrations among sample sets. For example, fingerprinting/profiling is used to match oil spills to a specific source, based on the percent compositions compared between the spilled petroleum and potential sources.

This examination of potential links between POP sources and exceedances of the Ocean Plan objectives focuses on the North Monterey Bay site for two reasons. First, we have documented the influence of river discharges on sea surface suspended particulate material in the northern bight of Monterey Bay (Figure 14). Second, we have a continuous 15-year time series of POP data collected from the Pajaro River, which discharges into the northern bight of the bay. Where appropriate, the limited data available from the Salinas River were also included in analyses of effects of river discharges on ocean water quality.

Determination of the potential sources to be considered in this analysis was based on historic CCLEAN load data. Loads from rivers are consistently orders of magnitude greater than those from wastewater for most POPs (Figure 25). Therefore, wastewater discharges were not considered to be significant sources and were not included in the present analyses. Moreover, higher flows (Figure 3) and higher concentrations (Figure 4 and Figure 5) in the Pajaro River during the wet-season indicate much higher daily loads than during the dry season and proportionally greater potential effects on ocean receiving waters. Comparisons of mean daily wet-season loads from the San Lorenzo, Pajaro, and Salinas rivers revealed large disparities (Figure 26). Mean daily wet-season loads of summed POPs in the Pajaro and Salinas rivers were 29 and 22 times greater, respectively, than in the San Lorenzo River (Figure 26). Based on these results, loads from the San Lorenzo River were also not considered to be significant sources and were not included in subsequent analyses.

During previous investigations by CCLEAN to determine sources of elevated PCBs in Monterey Bay, CCLEAN found correlations between increased ocean concentrations and potential disposal of dredged materials from Santa Cruz Inner Harbor and Moss Landing Harbor (CCLEAN, 2014, 2015). Data on volumes of material approved for dredging from Santa Cruz Inner Harbor and Moss Landing Harbor provided by USEPA (Brian Ross) indicated that approximately 95.5 x 10^6 kg of sediment, containing over 1.25 Kg of PCBs, was permitted for dredging in 2012 (Table 15). All dredged material from Santa Cruz Inner Harbor and Moss Landing Harbor that passes guidelines for toxicity and POP concentrations is permitted for disposal at a designated site in Monterey Bay (Figure 1, Site SF-14). Pursuant to the continuing search for sources of PCBs, CCLEAN has begun collecting annual samples of surficial sediment (i.e., the top 10 cm) from

Santa Cruz Inner Harbor (just below the Murray Street bridge) and Moss Landing Harbor (mid channel off Phil's restaurant). The samples collected in October 2016 and November 2017 are used in these analyses. Results based on these sediment samples should be considered with caution, because the locations sampled by CCLEAN may not be representative of the areas dredged, and CCLEAN samples included only surficial sediment, whereas dredged material includes much deeper sediments.

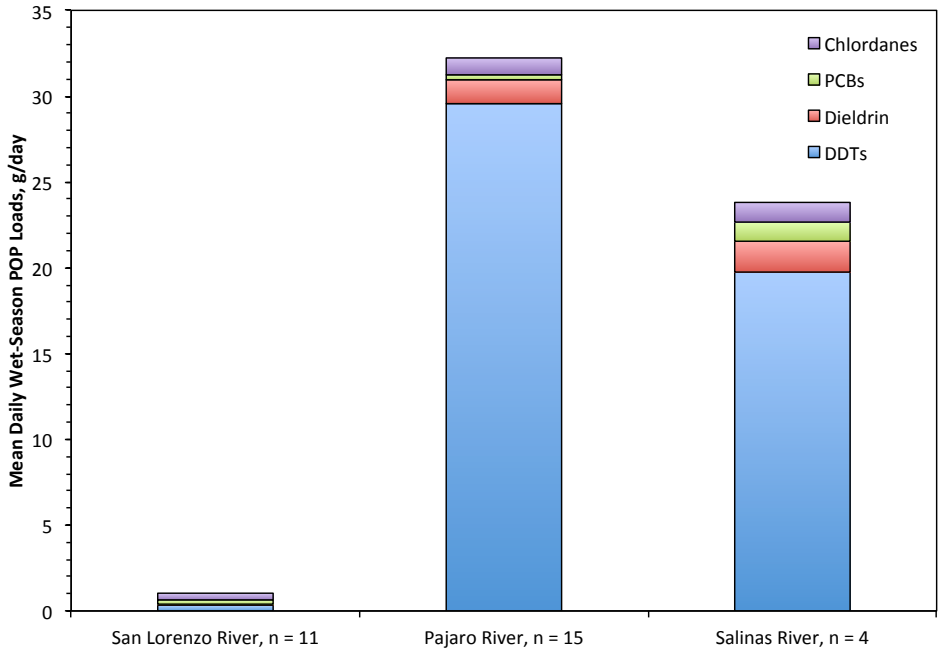

Figure 26. Mean daily wet-season loads of POPs from the San Lorenzo, Pajaro, and Salinas rivers.

Table 15. The mass of sediments permitted for dredging and disposal from Moss Landing (ML) Harbor and Santa Cruz (SC) Inner Harbor between 2004 and 2014.

Year	ML[1,2] Permitted Total Kg[4]	SC[1,3] Permitted Total Kg	Dredged Cumulative Kg	Estimated Cumulative Dredged PCBs, Kg[1]
2004	0	5,504,795	5,504,795	0.039
2006	0	12,232,878	12,232,878	0.086
2007	231,101,079	15,902,741	247,003,821	0.877
2008	0	5,691,958	5,691,958	0.057
2009	0	8,577,694	8,577,694	0.086
2010	0	13,012,112	13,012,112	0.232
2011	0	3,669,863	3,669,863	0.070
2012	86,373,903	9,129,397	95,503,300	1.255
2013	0	8,608,276	8,608,276	0.069
2014	0	22,433,874	22,433,874	0.191

[1] = Data obtained from USEPA (Brian Ross).
[2] = Moss Landing Harbor
[3] = Santa Cruz Inner Harbor.
[4] = Estimated assuming 1 yd^3 = 0.76455 m^3 and a dry sediment density of 1,600 Kg/m^3

4.2.3.1 Correlations between the Pajaro River and North Monterey Bay

General associations between ocean POP concentrations and loads from the Pajaro River were determined by calculating correlations between POP loads (g/day) from the Pajaro River and concentrations at the North Monterey Bay site (Table 16). There were statistically significant associations for ocean concentrations of DDTs and dieldrin, and river loads. The ocean concentrations of neither summed PCBs nor summed chlordanes were significantly correlated with river loads. These results suggest that the Pajaro River could be a source for DDT and dieldrin exceedances at North Monterey Bay, whereas the river is probably not a source for exceedances of PCBs and chlordanes. Moreover, significant correlations in ocean water were found between DDTs and dieldrin, and between chlordanes and PCBs (Table 17), suggesting distinct processes driving the fluctuations in each of these pairs of POPs. More detailed analysis of sources for each of these POPs was performed using comparisons of concentrations and percentages (POP profiling).

POP profiling began with examination of concentrations and percentages of DDT, dieldrin, PCBs and chlordanes in samples of ocean water that did not exceed Ocean Plan water quality objectives. This initial effort defined ambient conditions. Next, we examined POP profiles in ocean samples that exceeded Ocean Plan objectives, in order to discern the differences between ambient conditions and exceeding samples, across all POPs and not just exceeding

contaminants. This examination was intended to determine whether there were clues to the sources of the exceedances in non-exceeding contaminants. Third, we examined POP profiles in potential sources, such as the Pajaro River, Salinas River, and harbor sediments. Finally, we compared the profiles among samples that have exceeded the Ocean Plan objectives for any of the POPs and with the profiles from potential sources to determine whether sources could be identified.

Table 16. Correlations between loads of individual POPs from the Pajaro River and their respective concentrations at the North Monterey Bay site and between POPs within ocean samples. Bold *p* values indicate statistically significant correlations.

	River Loads vs Ocean Concentrations	
Compound	*r*	*P*
Sum of DDTs	0.5930	**0.0036**
Dieldrin	0.6304	**0.0017**
Sum of Chlordanes	-0.0463	0.8378
Sum of PCBs	-0.1689	0.4644

Table 17. Correlations between POPs in ocean samples from North Monterey Bay.

		Dieldrin	Chlordane	PCBs
DDTs	*r*	**0.9583**	0.1934	0.2128
	p	**<0.0000001**	0.3884	0.3544
Dieldrin	*r*		0.3609	0.3262
	p		0.0989	0.1490
Chlordanes	*r*			**0.6890**
	p			**0.000552**

4.2.3.2 POP Profiling in Ocean Waters Without Ocean Plan Exceedances

There were clear seasonal differences in concentrations and profiles of non-exceeding ocean POPs. Concentrations of DDTs and dieldrin were twice as high in wet-season samples as in dry-season samples from North Monterey Bay, whereas concentrations of PCBs and chlordanes did not differ between seasons (Figure 27a). were dominated by DDTs and had slightly higher concentrations of PCBs than of DDTs, followed by dieldrin and chlordanes, which exhibited similar concentrations (Figure 27a). Moreover, concentrations of PCBs were slightly higher than those of DDTs in dry-season samples. The differences between dry-season and wet-season samples in the composition of POPs are clearly evident when the percentages of DDTs, dieldrin, PCBs, and chlordanes in summed POP concentrations are compared (Figure 27b). The percentages for dieldrin and chlordanes did not change from dry season to wet season, whereas the percentages of DDTs and PCBs varied inversely to each other, with DDTs being higher in the wet season than the dry season and PCBs being higher in the dry season than in

the wet season. Ambient ocean conditions at North Monterey Bay can be summarized as having relatively consistent concentrations of PCBs and chlordanes, regardless of season, with substantially higher concentrations of DDTs and dieldrin in the wet season than in the dry season.

4.2.3.3 POP Profiling in Ocean Waters with Ocean Plan Exceedances

North Monterey Bay Ocean Plan exceedances for POPs, except PCBs, occurred predominantly in wet season samples (Table 18). PCB concentrations at the North Monterey Bay site exceeded the Ocean Plan objective in 19 out of 21 samples across both seasons since 2004, so we used only the ocean samples with the five highest PCB concentrations (i.e., >5 times the Ocean Plan objective). Hereinafter, only these five highest concentrations of PCBs are described as PCB exceedances. DDTs, dieldrin, and chlordanes were below their respective Ocean Plan objectives in most samples, with periodic large exceedances that usually co-occurred. The only dry season sample in which chlordanes, DDTs, and dieldrin exceeded their respective objectives was in September 2012. This sample also contained the highest concentrations of chlordanes and PCBs measured at the North Monterey Bay site. The greatest exceedances of DDTs and dieldrin occurred in February 2017.

Table 18. Dates and concentrations of POPs at or above Ocean Plan objectives at North Monterey Bay since 2004. Only PCB results >5 times the Ocean Plan objective are shown.

		Dry Season		Wet Season					
Compounds	Ocean Plan	Sep 2012	Oct 2014	Mar 2004	Mar 2009	Feb 2010	Mar 2012	Apr 2013	Feb 2017
Chlordanes, ng/L	0.023	0.114					0.057	0.057	0.036
DDTs, ng/L	0.17	0.206		0.169[1]		0.343			0.439
Dieldrin, ng/L	0.04	0.051		0.042		0.06			0.086
PCBs, pg/L	19	764	145		98.35		270	180	

[1] = Value is 0.001 ng/L below Ocean Plan objective

The POP profiles in ocean samples from North Monterey Bay that exceeded the Ocean Plan were initially examined to determine if there were any distinguishing features that that could inform subsequent analyses. The samples containing POPs that exceeded Ocean Plan objectives fell into two main groups. The first group included five samples in which PCBs exceeded the Ocean Plan objective, and also included exceeding concentrations of chlordanes in three out of the five samples. This group contains samples from September 2012, October 2014, March 2009, March 2012, and April 2013 (see Table 16 and Figure 28). The second group included three samples in which DDTs and dieldrin exceeded their objectives, but PCBs did not. These samples were collected in March 2004, April 2010, and April 2017 (see Table 16 and Figure 28).

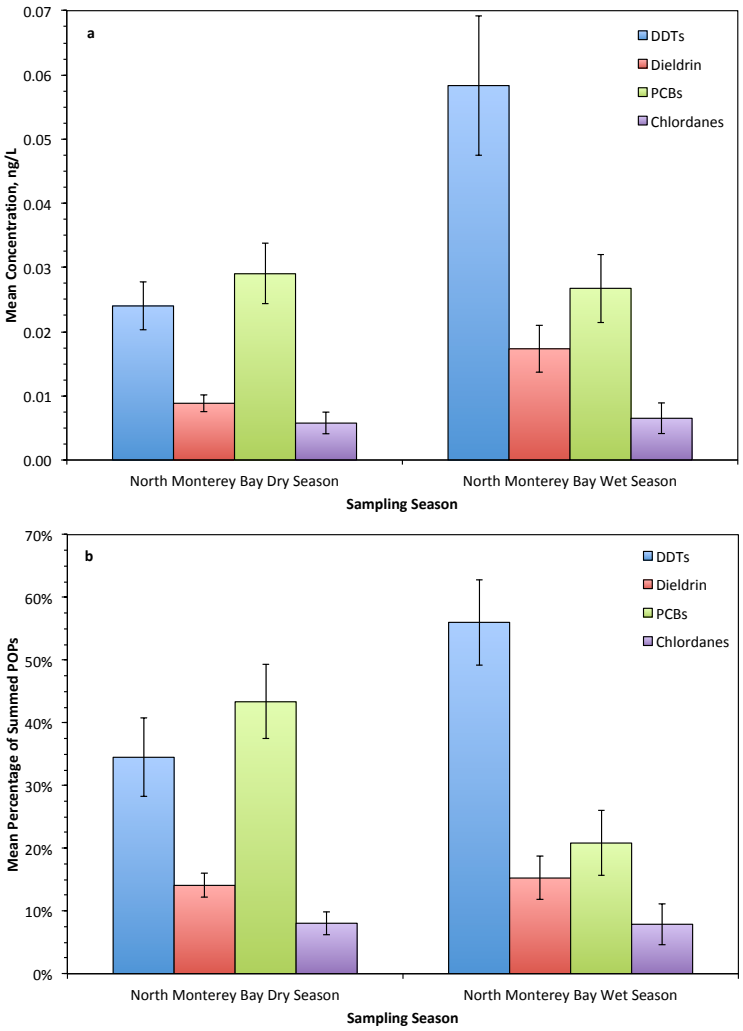

Figure 27. Profiles of background, non-exceeding POP concentrations (a) and percentage of summed concentrations (b) for dry-season and wet-season ocean samples collected at North Monterey Bay. n = 9 dry season, n = 12 wet season. Error bars = standard error of the mean.

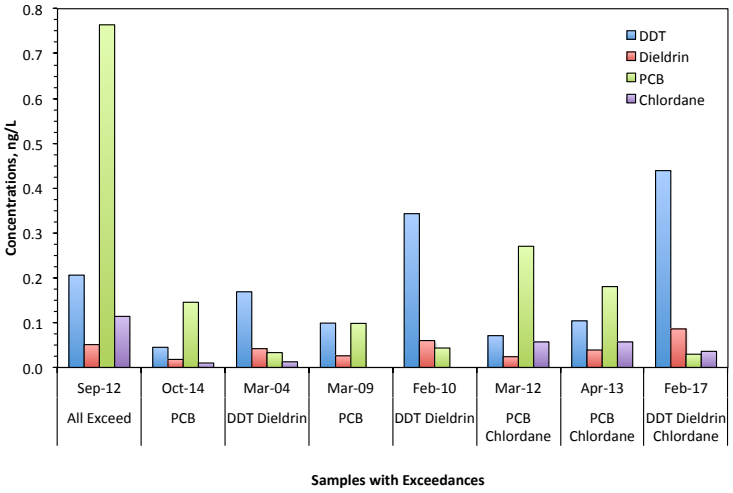

Figure 28. Profiles of POP concentrations for ocean samples collected at North Monterey Bay with concentrations of DDT, dieldrin, PCBs, and chlordanes exceeding their Ocean Plan objectives. The exceeding POPs are noted below the x-axis for each sampling date. Sep-12 and Oct-14 are dry-season samples and the others are wet-season samples.

Different POPs were in exceedance in North Monterey Bay depending on the sampling date (Figure 28). North Monterey Bay samples in which PCBs exceeded the Ocean Plan objective (occurring on September 2012, October 2014, March 2009, March 2012, April 2013) varied widely in their PCB concentrations (Figure 28), but were almost always dominated by PCBs. The highest PCB concentration occurred in September 2012 (Table 16 and Figure 28), which was 40 times the Ocean Plan objective. This dry-season event also included the greatest ocean chlordane concentration and the only dry-season exceedances by DDT and dieldrin measured at North Monterey Bay (Table 16). DDTs had the second highest, but much lower concentrations than PCBs, in all the samples with PCB exceedances, except for the March 2009 sample (Figure 28). In the March 2009 sample, DDTs and PCBs had equivalent concentrations. Chlordanes were not always detected in the extreme PCB-exceeding ocean samples.

The three North Monterey Bay samples that exceeded the DDT and dieldrin Ocean Plan objectives without PCB exceedances (March 2004, February 2010, and February 2017), exhibited similar patterns among POPs. In every case, DDTs had much higher concentrations than dieldrin, which had higher concentrations than PCBs and chlordanes (Figure 28). Only in the February 2017 sample did the concentration of chlordanes exceed that of PCBs.

The differences from ambient conditions exhibited by these exceeding samples varied between the two groups of exceeding samples. The PCB-exceeding samples differed from ambient conditions in having much higher concentrations of PCBs, and sometimes of chlordanes, regardless of season. The DDT-exceeding samples, which occurred mainly in the wet season, differed from ambient conditions in having higher concentrations of both DDT and dieldrin. The DDT-exceeding samples only exceeded the Ocean Plan once in the dry season and then the exceedance was accompanied by exceedances for PCBs and chlordanes, as well.

4.2.3.4 POP Profiling in Potential POP Sources

There was substantial variation in POP concentrations in sediment samples from Santa Cruz Inner Harbor and Moss Landing Harbor between years (Figure 29a). Overall, concentrations in samples from both harbors were much higher in 2017 than in 2016 (Figure 29a). Moreover, the 2016 sample from Santa Cruz contained detectable concentrations of dieldrin but not chlordanes, whereas the converse was true in the 2017 sample. Mean daily loads from the Pajaro River in sampling periods not associated with exceeding ocean samples, which also contained PCB concentrations <5 times the Ocean Plan objective, were significantly higher in the wet season than in the dry season, with DDTs having the highest concentrations and PCBs the lowest concentrations in both seasons. Percentages for each POP in the summed POP concentrations for Santa Cruz and Moss Landing sediments were also very different between years, although either DDT or PCBs dominated all four samples (Figure 29b). The ranking of mean daily loads for POPs in the Pajaro River did not differ between seasons, with DDTs leading dieldrin, chlordanes, and PCBs, in order. The wet-season loads from the Pajaro River were enriched in DDTs (averaging 91%), relative to the other POPs.

The profiles of percentage of each POP in summed concentrations for the five PCB-exceeding samples from North Monterey Bay revealed similarities among the samples from September 2012, October 2014, March 2012 and April 2013 (Figure 30a). In these four samples, PCBs ranged from 47% – 67% and DDTs ranged from 17% – 27% of summed POPs. Dieldrin and chlordanes ranged from 4% – 10% and from 5% – 15%, respectively, of summed POPs (Figure 30b). The March 2009 sample contained equal percentages PCBs and DDTs (44%) and 12% for dieldrin. Chlordanes were not detected in this sample.

Comparisons of these ocean sample profiles with those from harbor sediment samples and the mean of loads from the Pajaro River revealed similarities between four of the ocean samples and two of the harbor sediment samples (Figure 30b). The profiles from the four sediment samples fell into two types, with two being dominated by PCBs and two being dominated by DDTs. The profiles in the 2017 sediment sample from Santa Cruz and the 2016 sample from Moss Landing were both similar to the profiles for ocean samples with PCB exceedances in that they were dominated by PCBs, with lesser percentages of DDTs. Chlordanes were detected in both of these sediment samples, with dieldrin not being detected in the Santa Cruz 2017 sample and constituting 1% of summed POPs in the Moss Landing 2016 sample (Figure 30b). The 2016 Santa Cruz and 2017 Moss Landing sediment samples were dominated by DDTs, followed by PCBs and dieldrin, with profiles that were similar to non-exceeding ocean samples and Pajaro River loads (Figure 30b and Figure 27b), except with higher percentages of PCBs. The mean percentages of each POP in daily loads from the Pajaro River samples that coincided with the extreme PCB exceedances were very similar among sampling periods, as indicated by narrow error bars. The profile from the river samples was similar to the profiles for the Santa Cruz 2016 and Moss Landing 2017 sediment samples (Figure 30b). The consistency among profiles from the Pajaro River and the differences between the river profiles and those from the

ocean samples with extreme PCB exceedances suggest that the river is not the cause of these exceedances.

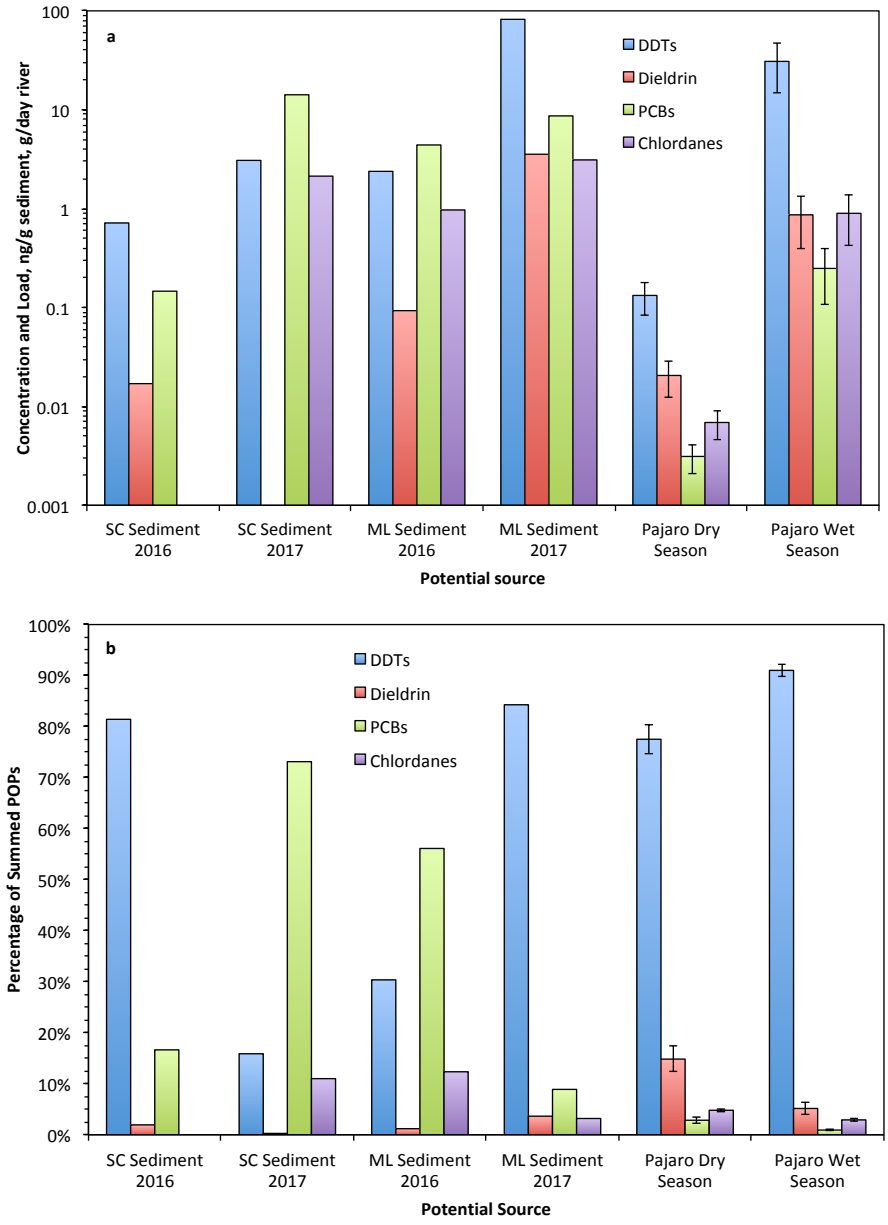

Figure 29. Profiles of POP concentrations (a) and percentage of summed concentrations (b) for sediment samples collected from Santa Cruz (SC) Inner Harbor and Moss Landing (ML) Harbor in 2016 and 2017 and mean dry-season and wet-season loads from the Pajaro River (n = 8 dry season, 6 wet season) in samples not associated with exceeding ocean samples. Error bars = standard error of the mean.

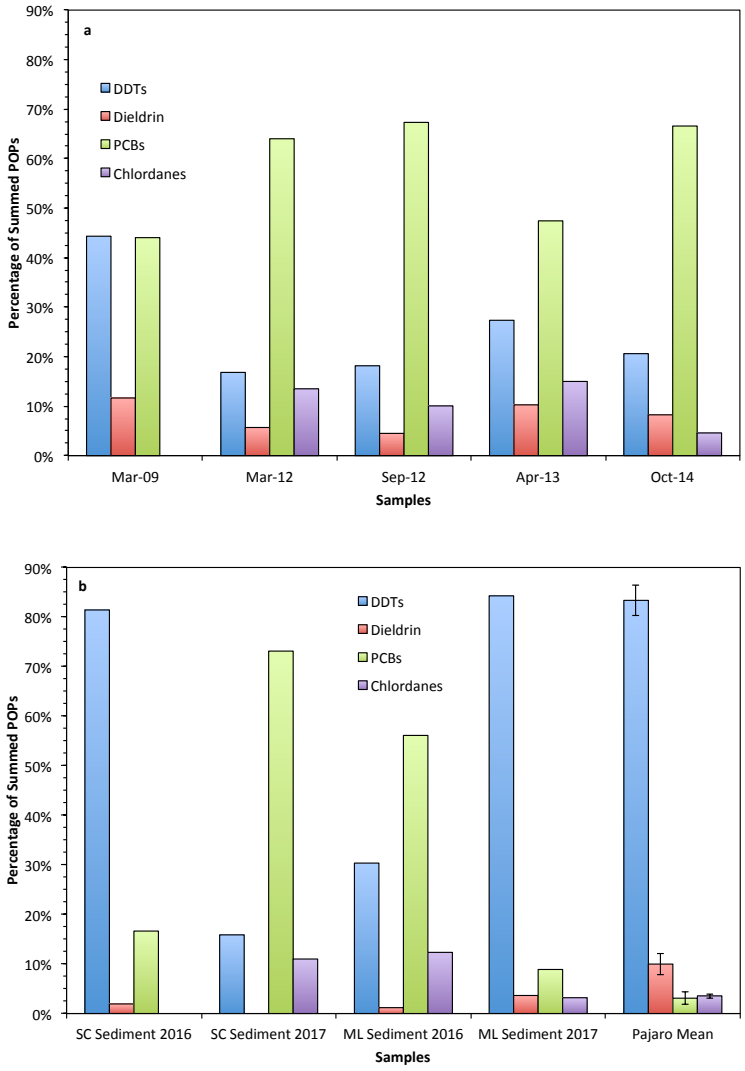

Figure 30. Profiles of POP percentages in ocean samples collected at North Monterey Bay with PCB exceedances of the Ocean Plan objective (a) and profiles of POP percentages in sediment samples from SC and ML and mean contemporaneous loads from the Pajaro River (b). Error bars = standard error of the mean.

The differences between years in the POP profiles from harbor sediments are probably due to a combination of factors. The harbors have historically been at the base of drainages containing various land uses, including agricultural and industrial activities. They require dredging partly because sediments from these watersheds continue to deposit, filling in the harbors and reducing draft depth for vessels. This means that the POP profiles in the surficial CCLEAN samples will vary depending on how recently dredging has occurred and the intensity of intervening storm runoff events since dredging was last performed. In order to investigate whether the inter-annual variation in harbor sediments also occurs in ambient Monterey Bay sediments, and whether resuspension of ambient sediments could be the source of elevated PCBs in ocean waters, we examined the mean POP profiles for two sites in northern Monterey

Bay (SedDep1 and SedDep2, see Figure 2) over the past three years (Figure 31). There was little difference in POP profiles between the two ambient sites and the narrow error bars indicate temporal stability, which shows that the variability observed in harbor sediments is not reflected in ambient sediments along the 80-meter contour. Moreover, the profiles at SedDep1 and SedDep2 are similar to the profiles for the 2016 SC sample and the 2017 ML sample, but they are dissimilar to the other harbor sediment samples and ocean water samples that exceeded the Ocean Plan PCB objective, indicating that resuspension of ambient sediments is not the source of extremely elevated PCBs in ocean waters. We infer that the source of extreme PCB exceedances is likely anaerobic, is very enriched in PCBs compared to background ocean waters and sediments, and also often contains high concentrations of chlordanes. While half of the sediment samples from harbors exhibited POP profiles consistent with these characteristics and with the profiles of ocean samples with extreme PCB concentrations, we have neither accurate PCB data for dredged materials, nor actual dates and volumes for dredge disposals in Monterey Bay. These missing data would be needed to definitively determine the relationship between disposal of dredged materials and elevated PCBs in Monterey Bay waters.

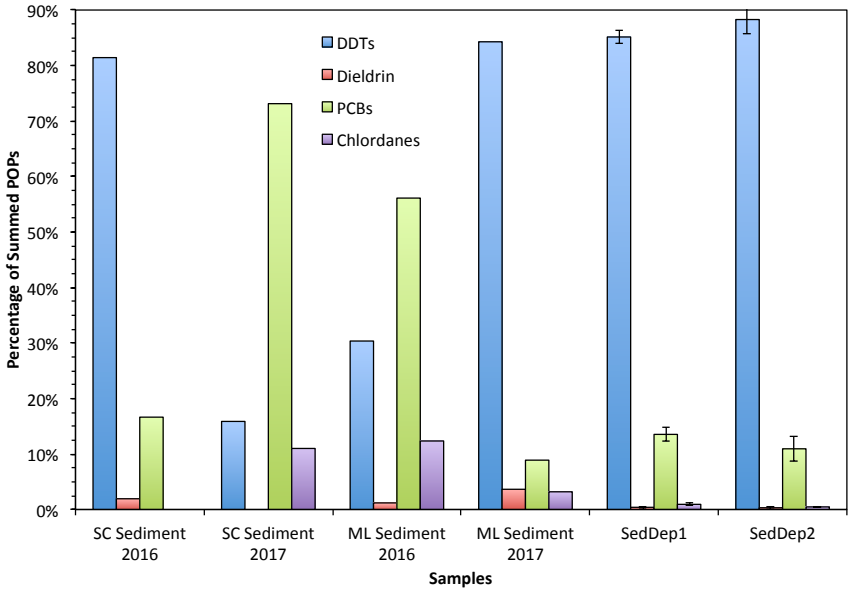

Figure 31. Profiles of POPs in Santa Cruz and Moss Landing harbor sediments and ambient sediments collected along the 80-m contour in 2015, 2016, and 2017 at two sites in northern Monterey Bay. Error bars = standard error of the mean.

The composition of DDTs in ocean samples with extreme PCB exceedances differed from those with DDT exceedances, and those without exceedances (Figure 32). The relative amount of individual DDT compounds in a sample can vary depending on the environment at the source of the sample. Summed DDTs include DDT, DDE, and DDD, each of which has p,p' and o,p' isomers. Chemically produced DDT, also called Technical DDT, typically consisted of 75% p,p' DDT, 15% o,p' DDT, 5% p,p' DDE and 5% other compounds (Zhang et al, 2009; Alamdar et al, 2014). In the environment, microbes reductively dechlorinate DDT into DDD under anaerobic

conditions and dehydrochlorinate DDT into DDE under aerobic conditions (Wedemeyer, 1966; Pereira et al, 1996; Corona-Cruz et al, 1999, Aislabie et al, 1997). In addition, DDD was produced as a pesticide, separate from DDT, and high concentrations in San Francisco Bay are thought to result from production and spillage at a facility in Richmond Harbor (Pereira et al, 1996). High percentages of DDD in summed DDTs can, therefore, indicate either anaerobic degradation of DDT or direct inputs of DDD from anthropogenic sources.

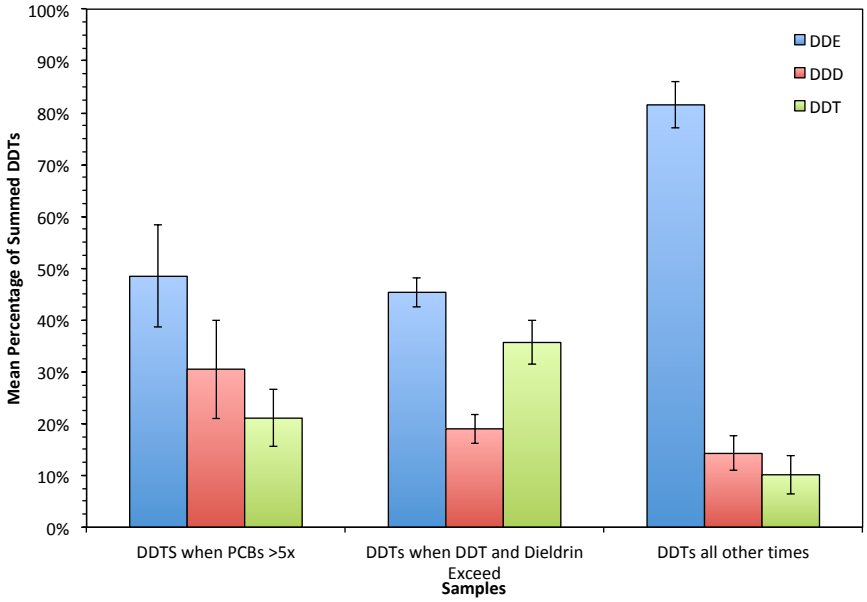

Figure 32. Profiles of DDTs in ocean samples with >5x exceedances of PCBs, in samples with exceedances for DDT and dieldrin, and in samples without exceedances. Error bars = standard error of the mean.

Samples in which PCB concentrations exceeded the Ocean Plan objective had higher percentages of DDD and DDT than did all other ocean samples. This suggests that extreme exceedances of the PCB Ocean Plan objective involved sources of DDTs that contained higher proportions of both undegraded DDT and DDD. DDTs in ocean samples with DDT exceedances averaged greater percentages of DDT than did non-exceeding samples, suggesting those exceedances arose from sources with less degraded DDTs than were measured in other ocean samples.

As shown above (Table 14), rivers flowing into Monterey Bay are major sources of DDT compounds. Profiles of DDTs from the Pajaro and Salinas rivers exhibit seasonal differences in the percentages of DDT compounds (Figure 33). Wet-season loads of DDTs were more than 100x greater than dry- season loads (Figure 33a, c), with dry-season loads generally <0.1 g/day. DDE had the greatest loads of the DDT compounds in both seasons and both rivers, and its percentage of summed DDTs was the same in both seasons (Figure 33b, d). The percentages of summed DDTs provided by DDD and DDT differed between seasons and between rivers. DDT percentages were greater than for DDD in wet-season loads from the Pajaro River, and the

converse was true in the dry season (Figure 33b). In the Salinas River, dry season loads also had higher percentages of DDD than DDT, whereas in wet-season loads the percentage of DDD was lower and the percentage of DDT was higher, compared to dry-season loads. The increased percentages of DDT in wet-season loads from both rivers are consistent with less-degraded DDT associated with terrestrial sediments being washed into the rivers by winter storms. In the dry season, runoff and river loads decrease and the contributions of DDD to summed DDTs increase, perhaps associated with discharges from subsurface tile drainage under agricultural fields.

The profiles of DDTs in ambient, non-exceeding ocean waters also exhibited seasonality (Figure 34). Concentrations of DDE and DDD averaged 2 to 3 times higher during the wet season than in the dry season, and DDT was never detected in dry-season samples without exceedances (Figure 34a). Moreover, concentrations of DDT in non-exceeding wet-season samples were similar to those for DDD. The dominance of DDTs by DDE in non-exceeding ocean samples was more pronounced than in loads from the Pajaro River (Figure 33b and Figure 34b), which could indicate aerobic degradation of DDT in the ocean.

Profiles of DDTs in the single dry-season ocean sample (Sep-12) from North Monterey Bay that exceeded the DDT Ocean Plan objective were different from the wet-season exceedances (Figure 35). Compared to the wet-season samples, the September 2012 sample was depleted in DDE and markedly dominated by DDD. Moreover, the September 2012 and October 2014 ocean samples that exceeded the Ocean Plan objective for PCBs (Table 16 and Figure 28) were unique in having higher percentages of DDD in summed DDTs than any of the other samples (Figure 36). The high percentage of DDD in these two samples is consistent with the DDTs coming from sources with anaerobic conditions, such as buried sediment.

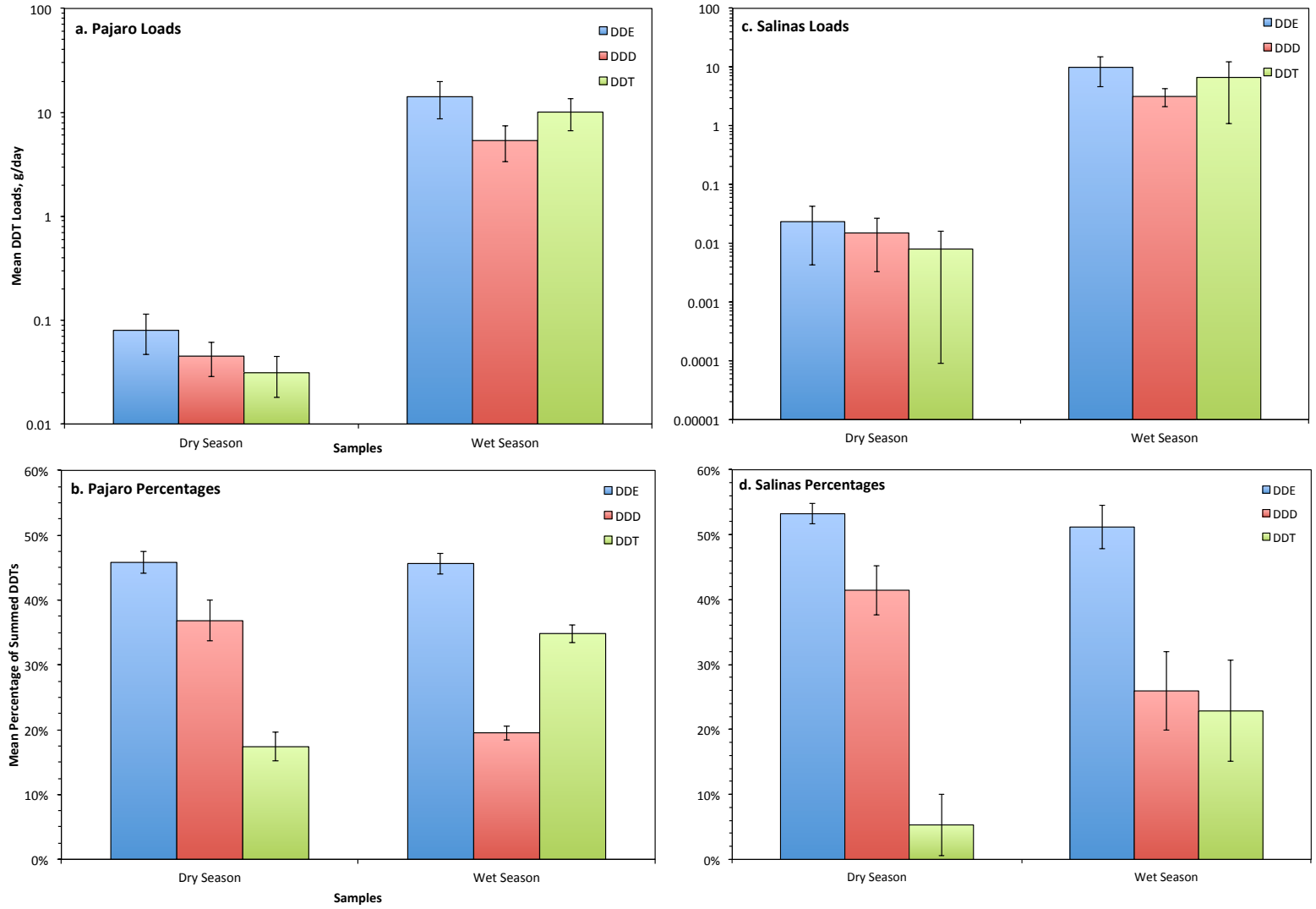

Figure 33. Mean loads (a, c note log scale) and mean percentages of loads (b, d) of DDTs from the Pajaro River (n = 15) and Salinas River (n = 4) into northern Monterey Bay. Error bars = standard error of the mean.

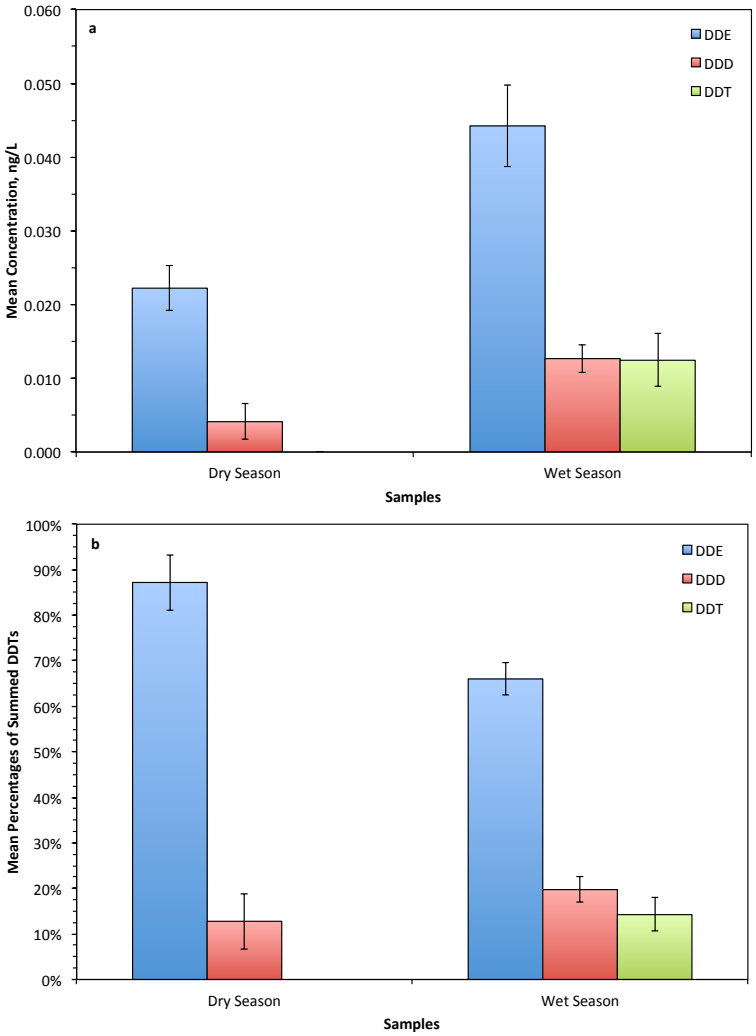

Figure 34. Profiles of concentrations (a) and percentage (b) of DDTs in non-exceeding ocean samples from North Monterey Bay. Error bars = standard error of the mean.

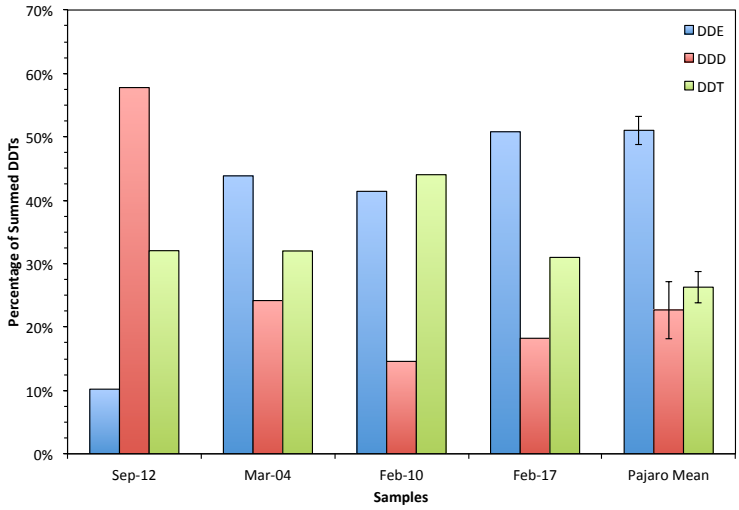

Figure 35. Profiles of DDT compounds in ocean samples from North Monterey Bay that exceeded the Ocean Plan objective for DDTs. Error bars = standard error of the mean.

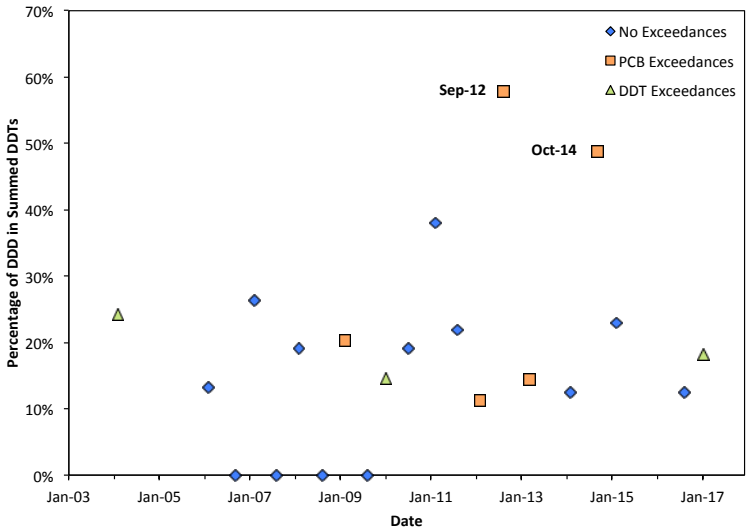

Figure 36. Percentage of DDD in summed DDTs in samples without exceedances, in ocean samples with >5x exceedances of PCBs, and in ocean samples with exceedances for DDT.

Exceedances of the Ocean Plan objective for DDTs and dieldrin at North Monterey Bay appear to be associated with discharges from rivers, except for one sample. As previously described, the September 2012 dry-season sample, which had exceedances for all four of the POP groups, was dominated by PCBs and also had unusual profiles of DDT compounds, which suggested that the DDTs came from material with anaerobic antecedent conditions. Profiles of POPs in wet-season samples from North Monterey Bay that exceeded Ocean Plan objectives for DDTs and dieldrin, but not for PCBs (Figure 37a), were very similar to contemporaneous loads from the

Salinas and Pajaro rivers (Figure 37b). The ocean sample from March 2004 was the only ocean exceedance for DDTs for which a contemporaneous sample was available from the Salinas River. In March 2004, the POP profiles for the Pajaro and Salinas rivers were very similar with DDT dominating, followed by dieldrin. This pattern was similar to that observed in the March 2004 ocean sample from North Monterey Bay. The POP profiles also were similar between Pajaro River loads and ocean samples in both February 2010 and February 2017.

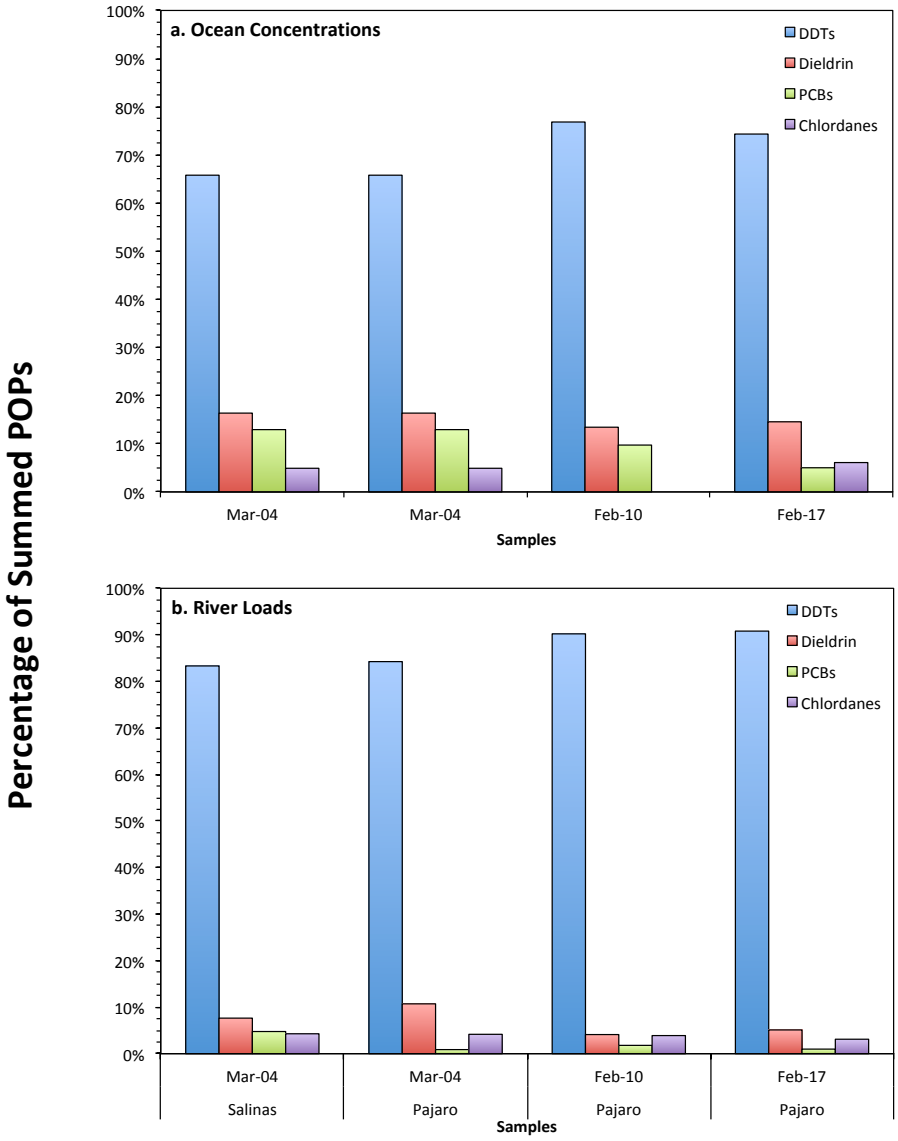

Figure 37. Profiles of POPs in wet-season ocean samples exceeding the Ocean Plan for DDTs (a) and contemporaneous loads from the Salinas River and Pajaro River (b).

There also were similarities in DDT profiles among wet-season DDT-exceeding samples from North Monterey Bay (Figure 38a) and contemporaneous loads from the Pajaro and Salinas rivers (Figure 38b). The correspondence between March 2004 ocean DDT profiles and loads from the rivers was poorer for the Salinas River than for the Pajaro River because the Salinas River DDTs included <10% DDD.

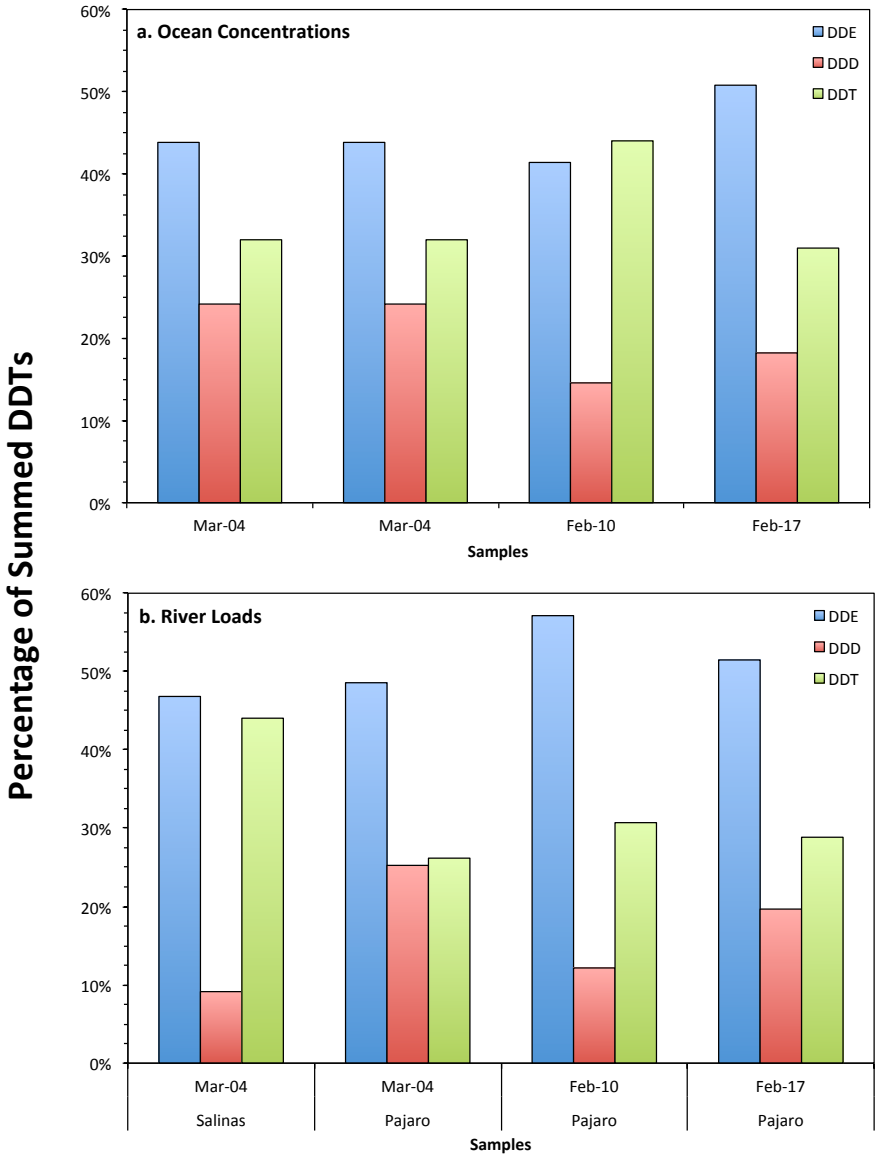

Figure 38. Profiles of DDTs in wet-season ocean samples exceeding the Ocean Plan for DDTs (a) and contemporaneous loads from Salinas River and the Pajaro River (b).

Analysis of all available wet-season samples from the Pajaro and Salinas rivers found unexpected differences in DDT profiles. Over all samples, loads from the Pajaro River had

higher proportions of DDT and lower proportions of dieldrin, PCBs and chlordanes than the Salinas River (Figure 39a). Moreover, mean DDT profiles differed between rivers in a way that was unlike the differences observed in the March 2004 sample (Figure 38b). Mean wet-season DDT loads from the Salinas River contained higher proportions of DDE and lower proportions of DDT than did those from the Pajaro River (Figure 39b).

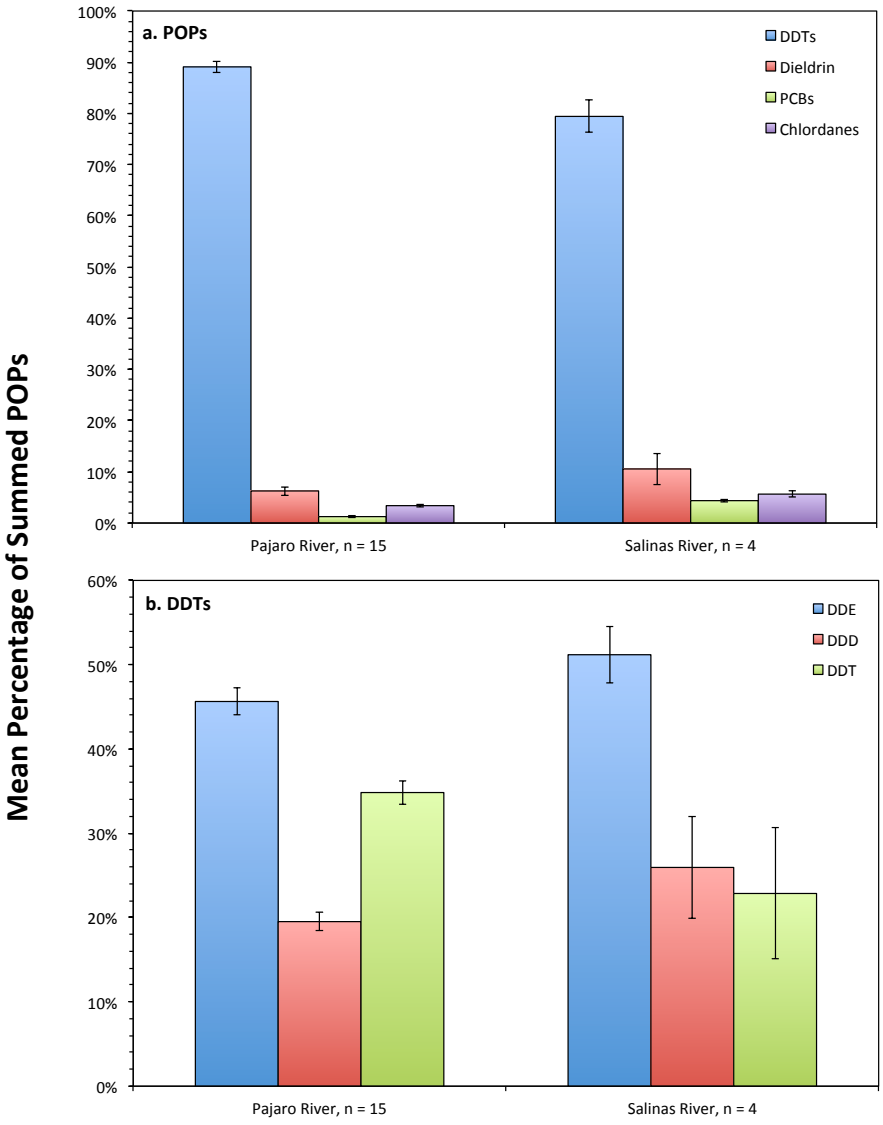

Figure 39. Mean profiles of POPs and DDTs in wet-season samples from Pajaro River and Salinas River. Error bars = standard error of the mean.

Comparisons of mean POP and DDT profiles in contemporaneous wet-season samples from the Pajaro River and the ocean at the North Monterey Bay site revealed clear differences between ocean samples that exceeded the DDT objective and those that did not (Figure 40). Exceeding

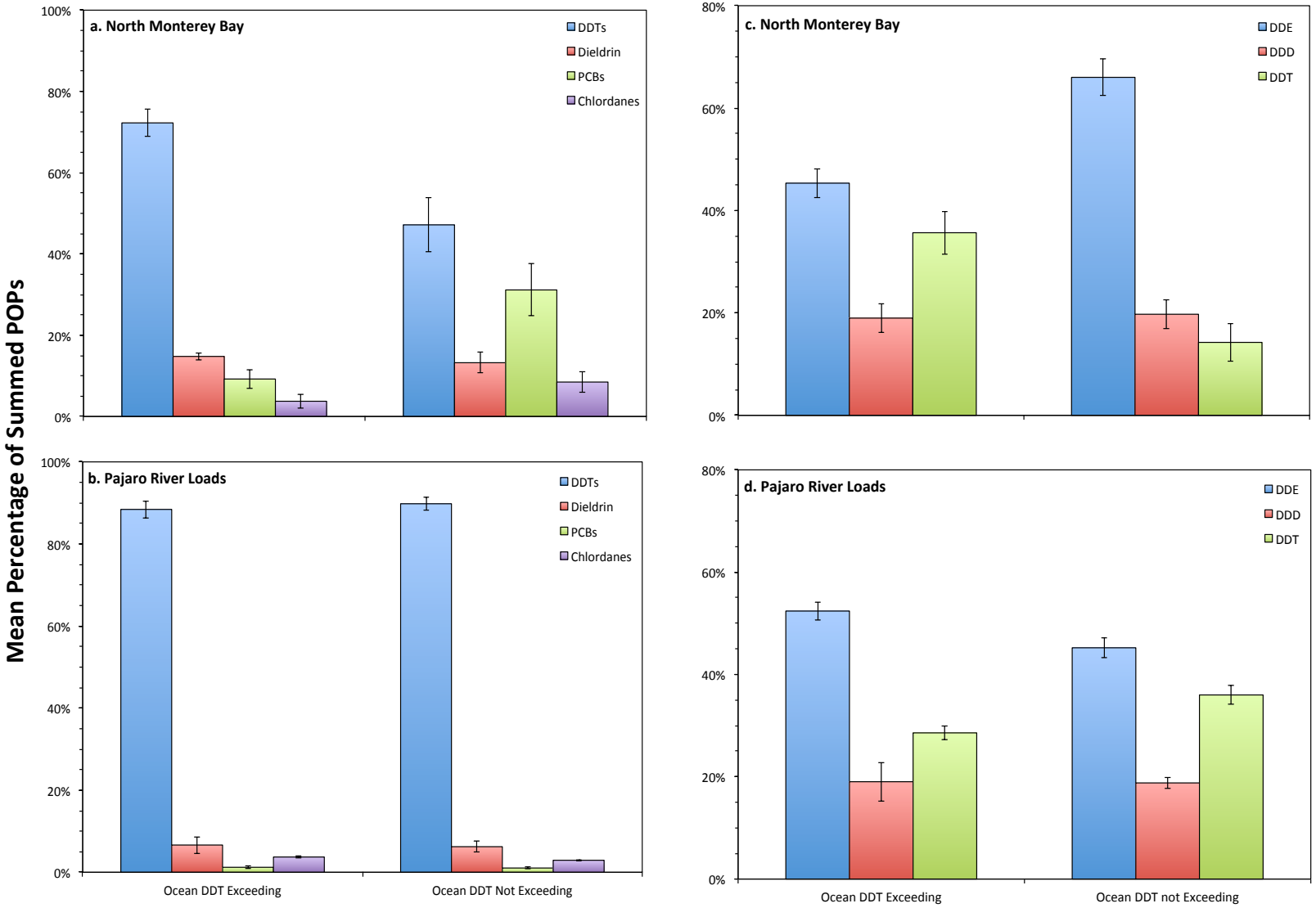

Figure 40. Profiles of POPs and DDTs in contemporaneous wet-season samples from North Monterey Bay (a and c) and Pajaro River (b and d) when ocean samples exceeded the Ocean Plan objective for DDT and when ocean samples did not exceed the objective for DDT. Error bars = standard error of the mean.

ocean samples had higher proportions of DDTs and lower proportions of PCBs than non-exceeding samples (Figure 40a). Conversely, profiles of POPs in Pajaro River loads did not differ between samples corresponding to ocean DDT exceedances and those that did not correspond to ocean DDT exceedances (Figure 40b). Exceeding ocean samples also had lower proportions of DDE and higher proportions of DDT in summed DDTs than did non-exceeding ocean samples (Figure 40c), whereas the DDT profiles were the same in Pajaro River loads corresponding to exceeding and non-exceeding ocean samples (Figure 40d). Pajaro River samples that did not correspond to exceeding ocean samples had higher mean proportions of DDT and lower mean proportions of DDE in summed DDTs than did loads corresponding to ocean exceedances (Figure 40d). These comparisons show that POP and DDT profiles in Pajaro River loads do not differ substantially between samples associated with and without DDT ocean exceedances, whereas ocean POP and DDT profiles do differ between samples that do and do not exceed the Ocean Plan objective for DDTs. Moreover, the mean profiles for exceeding ocean samples look much more like the river profiles than the non-exceeding ocean profiles, suggesting that ocean exceedances are associated with river discharges.

The results of this analysis of POP and DDT profiles in wet-season samples from North Monterey Bay that exceeded the Ocean Plan objective for DDTs are consistent with the significant positive correlations between ocean concentrations and loads from the Pajaro River for DDTs and dieldrin (Table 17). Profiles of POPs and DDTs in northern Monterey Bay appear to vary in response to changes in loads of POPs and DDTs discharged from the Pajaro River and perhaps also the Salinas River. In non-exceeding samples, concentrations of PCBs and chlordanes do not differ between wet season and dry season, whereas the concentrations of DDTs and dieldrin are higher in the wet season than in the dry season (Figure 27). Moreover, the highest concentration of DDTs in North Monterey Bay occurred during the wet season with the highest recorded DDT load from the Pajaro River, in February 2017.

Wet-season ocean waters in northern Monterey Bay probably exceed the Ocean Plan objective for DDTs more often that our results indicate. The loads of summed DDTs from the Pajaro River during the 3 wet-season exceedances at North Monterey Bay were the 1st, 5th, and 8th highest loads measured from the Pajaro River by CCLEAN (Table 19). The minimum wet-season daily load of DDT associated with an exceedance was 10.9 g/day. The other wet-season exceedances were associated with loads of 23.7 and 144.8 g/day. On other occasions, loads of 21.5, 23.7, 61.2, and 95.7 g/day were not associated with Ocean Plan exceedances. This suggests that detections of wet-season DDT Ocean Plan exceedances at North Monterey Bay are related to oceanographic phenomena that transport more or less concentrated river water past the site, and that our detection of a 25% rate of exceedance during the wet season is an underestimate of the actual rate.

Table 19. Wet-season Pajaro River loads (i.e., River = g/day) for DDTs, dieldrin, chlordanes, and PCBs, for each sampling event, with corresponding ocean concentrations (i.e., Ocean = ng/L; pg/L for PCBs) at North Monterey Bay. Bolded values equalled or exceeded Ocean Plan objectives.

	DDTs		Dieldrin		Chlordanes		PCBs	
Date	River	Ocean	River	Ocean	River	Ocean	River	Ocean
Mar-04	10.9	**0.169**[1]	1.382	**0.042**	0.538	0.013	0.113	**33.2**
Mar-06	61.2	0.091	1.155	0.022	1.585	0	0.418	**22.1**
Mar-07	21.5	0.076	0.360	0.024	0.631	0	0.119	MA[2]
Mar-08	4.45	0.079	0.351	0.019	0.175	0.005	0.054	**34.8**
Mar-09	10.7	0.099	0.572	0.026	0.337	0	0.102	**98.4**
Feb-10	23.7	**0.343**	1.077	**0.060**	1.020	0	0.469	**43.4**
Mar-11	95.7	0.029	3.087	0	2.927	0.009	0.881	7.81
Mar-12	4.20	0.071	0.250	0.024	0.129	**0.057**	0.083	**270.3**
Apr-13	0.402	0.104	0.070	0.039	0.021	**0.057**	0.010	**180.4**
Mar-14	1.00	0.040	0.105	0.016	0.022	0.014	0.008	**33.9**
Mar-15	1.25	0.035	0.134	0.023	0.042	0.011	0.012	**35.2**
Feb-17	144.8	**0.439**	8.142	**0.086**	4.958	**0.036**	1.567	**29.6**

[1] = Ocean Plan objective for DDT is 0.17 ng/L

[2] = Sample analyzed without high-resolution methods.

Dieldrin concentrations at North Monterey Bay were also likely influenced by oceanographic phenomena affecting the flow of river discharges past the ocean sampling location. The wet-season dieldrin exceedances occurred during the 1st, 3rd, and 5th highest dieldrin loads measured in the Pajaro River by CCLEAN (Table 19). The minimum dieldrin river load associated with an Ocean Plan exceedance was 1.077 g/day, with the other wet-season exceedances occurring when loads were 1.382 and 8.142 g/day. Loads of 1.155 and 3.087 g/day were not associated with Ocean Plan exceedances. As for DDTs, these results suggest the actual frequency of exceedances of the Ocean Plan objective for dieldrin is greater than reported here.

Historical data collected by the California Department of Food and Agriculture (now the Department of Pesticide Regulation) permitted a search for DDT sources in the Pajaro River watershed. In 1985, a study was commission by the California legislature to survey concentrations of DDTs that remained in agricultural soils and could be detected in fresh produce 13 years after their use was banned for agricultural purposes in 1972. The report was reprinted in 1991 by the Department of Pesticide Regulation (DPR) and is available on the DPR website (http://www.cdpr.ca.gov/docs/emon/pubs/ehapreps/eh06_85ddt.pdf). With the help

of county Agricultural Commissioners, fields were identified in 32 counties that had histories of moderate or high DDT usage. Four fields in both San Benito and Santa Cruz counties were sampled in April 1985. Ten 1-pint jars were collected along a diagonal line from one corner of the field for smaller fields (10–30 acres) and 50 feet from the edge of the field around the perimeter for larger fields. The 10 samples were composited and analyzed for all DDT isomers. With help from DPR staff, we obtained copies of the original chain-of-custody forms for samples collected in these two counties and used location information on the forms to identify data from fields within the Pajaro River watershed.

Profiles of DDT isomers in wet-weather loads from the Pajaro River were compared to profiles from Santa Cruz and San Benito counties (Figure 41). Similarity in the profiles of the Pajaro River and San Benito County sediments were evident. A stepwise liner regression using the sediment data as independent variables to explain variation in Pajaro River loads revealed that the San Benito County sediments explained 95% of the variation in the mean DDT isomer profiles for wet-season samples from the Pajaro River ($r^2 = 0.952$, $p < 0.001$). This means that the DDTs washed into the Pajaro River during wet weather have percentages of the 6 isomers that are very similar to DDTs measured in agricultural soils in the watershed in 1985, consistent with wet-season loads of DDTs arising largely from erosion of agricultural soils.

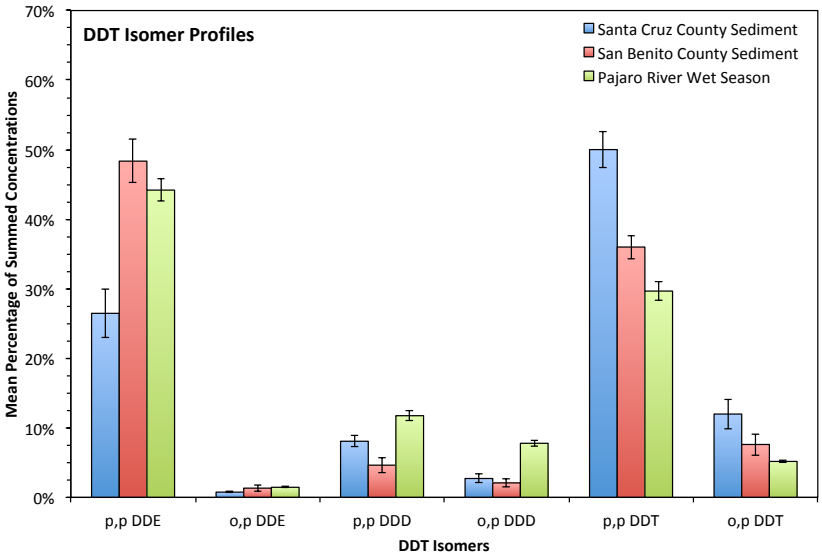

Figure 41. Profiles of DDT isomers in agricultural soils from Santa Cruz and San Benito counties sampled in 1985 compared to wet-season loads from the Pajaro River sampled since 2002. Error bars = standard error of the mean.

CCLEAN's findings of water quality exceedances in Monterey Bay are directly relevant to evidence that POPs discharged to the ocean are continuing to harm wildlife along the west coast of North America. For example, the Southern Resident Distinct Population Segment of killer whales was listed as endangered in 2005 due to a 20% decline in the population (NOAA, 2016) and exposure to high contaminant concentrations is one the primary threats identified

for the recovery of the population. The PCB concentrations in Southern Residents are above the threshold found to cause health problems in other captive marine mammals (Hickie et al, 2007) and two pods of the Southern Residents that have been observed feeding in Monterey Bay, also have high concentrations of DDTs (Krahn *et al*, 2009).

Another endangered species, the California Condor, is also being affected by legacy contaminants. This large bird, which was saved from extinction through a captive breeding program, has recently experienced low rates of hatching success in central California (Burnett *et al*, 2013). The failures in hatching success were linked to shell thinning, consistent with the known effects of DDT compounds, which were ingested by the birds through consumption of beach-cast California sea lion carcasses. Burnett *et al* (2013) predicted improved hatching success for the condors with attenuation of DDT concentrations in the coastal environment. Over the past several decades, such declines have been reported along the California coastline in mussels (Melwani *et al*, 2014) and in California sea lions (Kannan *et al*, 2004). CCLEAN data, however, have shown declines in DDTs in mussels over the past 15 years at only two sites (i.e., Fanshell Overlook and Carmel River Beach, Figure 16) and there have been no apparent trends in either ocean concentrations (Figure 9 and Figure 12) or river loads into Monterey Bay (Figure 25).

4.2.3.5 Conclusions

Exceedances of Ocean Plan objectives for DDTs, dieldrin, chlordanes, and PCBs at North Monterey Bay have different sources. DDTs and dieldrin appear to have a similar source, which is different from the source(s) for chlordanes and PCBs. Ocean concentrations of DDTs and dieldrin were highly correlated, as were the ocean concentrations of chlordanes and PCBs.

The link between DDTs and dieldrin includes co-occurrence of wet-season exceedances, including in February 2017, when loads for both were the highest ever recorded in the Pajaro River by CCLEAN. Ocean concentrations of summed DDTs and dieldrin also were significantly correlated with loads from the Pajaro River (Table 16). These results suggest the Pajaro River is a major source of DDTs and dieldrin that have exceeded Ocean Plan water quality objectives in wet-season samples. Similarity of DDT compound profiles in exceeding ocean samples and contemporaneous loads from the Pajaro River were also consistent with that river being a major source of the exceedances, although additional data from the Salinas River could show it to also be an important source of these legacy pesticides in northern Monterey Bay.

DDT isomer profiles obtained from historic soil data collected in 1985 from agricultural fields in the Pajaro River watershed were compared to isomer profiles for wet-season loads in the Pajaro River. This comparison found that 95% of the variation in wet-season DDT isomer profiles from the Pajaro River was explained by the DDTs measured in 1985. This suggests that erosion of agricultural soils is a likely source of DDTs in wet-season samples from the Pajaro River and contributes to exceedances of water quality objectives in the ocean. The infrequent dry-season DDT and dieldrin exceedances are unrelated to river discharges and coincided with exceedances for chlordanes and PCBs.

The link between chlordanes and PCBs is less obvious than that between DDTs and dieldrin. PCBs have exceeded the Ocean Plan objective in 19 out of 22 samples collected at North Monterey Bay since 2004. Five of these exceedances were >5 times above the Ocean Plan objective. Three out of four chlordane Ocean Plan exceedances at North Monterey Bay co-occurred with extreme PCB exceedances. The fourth chlordane exceedance occurred in February 2017 during the highest chlordane load measured by CCLEAN from the Pajaro River. The highest chlordane concentration measured at North Monterey Bay coincided with the an extreme event in September 2012, in which the highest concentration of PCBs was measured at that site, as well as exceedances of Ocean Plan objectives by DDTs and dieldrin. The PCB concentration in this sample, which was based on quantification of 71 of the total 209 PCB congeners, was 40 times higher than the Ocean Plan objective. This sample also contained the third highest concentrations of both DDTs and dieldrin measured at North Monterey Bay. The profiles of POPs in this, and other samples that exceeded the PCB Ocean Plan objective, were similar to two out of four profiles of surficial sediment collected by CCLEAN in Santa Cruz Inner Harbor and Moss Landing Harbor. The profile of DDT compounds in the September 2012 and October 2014 samples from North Monterey Bay that exceeded the PCB Ocean Plan objective indicated the DDTs in the samples came from sources with anaerobic antecedent conditions, such as deep sediments. We conclude that, although extreme river flows can lead to Ocean Plan exceedances for chlordanes, most chlordane exceedances and all PCB exceedances are unrelated to river discharges and tend to not co-occur with exceedances of DDTs or dieldrin.

4.2.3.6 Recommendations

Every effort should be made to restore POP sampling in the Pajaro River, as well as the Salinas River. The impact of river discharges on ocean water quality needs to be documented through regular sampling, especially in the wet season. In this regard, discussions with agricultural interests and water quality managers should be undertaken to explore funding opportunities. Continuation of sediment sampling in Moss Landing Harbor and Santa Cruz Inner Harbor is also essential. With additional samples, future analytical approaches are under investigation that could better discern similarities between ocean concentrations of POPs and contaminant profiles from various possible sources.

4.3 What are the Effects of Wastewater Discharges on Nearshore Waters?

CCLEAN continues to provide a scientifically valid, long-term assessment of nearshore waters that member agencies may impact by their permitted discharges. Over the past 15 years, CCLEAN has documented no clear adverse impacts on beneficial uses or on water quality indices along the Central Coast that may be attributable solely and directly to the publicly owned treatment work (POTW) facilities. The work design of CCLEAN has enabled resource managers and regulators in the area to apply its products to broader environmental assessments and makes CCLEAN and the participating agencies effective stewards of the coastal environment.

The methods used by the program to examine water quality issues have included an array of cutting-edge techniques. CCLEAN has employed effluent assays for endocrine disrupting

activity, applied statistical methods, and modeled the trajectories of wastewater discharges to determine associations between wastewater and exceedances of water quality objectives in ocean water. Despite the absence of demonstrable adverse effects, CCLEAN participants are consistent in their desire to implement excellent science for the protection of beneficial uses.

4.3.1 Conclusions

CCLEAN data continue to provide evidence of a sustainable environment in the Monterey Bay region with its regulated wastewater discharges. CCLEAN's approach to implementing regional science and regulation-driven planning continues to benefit the participants, stakeholders along the Central Coast, and the regulatory authorities.

4.3.2 Recommendations

CCLEAN should continue to describe the status and trends of beneficial uses in Monterey Bay and seek ways to describe the roles, if any, of wastewater discharges in impairments and enhancements to beneficial uses, while also identifying other sources of water quality impairments.

5.0 References Cited

Aislabie, J.M., N.K. Richards, H.L. Boul. 1997. Microbial degradation of DDT and its residues—A review. New Zealand Journal of Agricultural Research. 40:2, 269-282

Alamdar, A., J.H. Syed, R.N. Malik, A. Katsoyiannis, J.Liu, J. Li, K.C. Jones. 2014. Organochlorine pesticides in surface soils from obsolete pesticide dumping ground in Hyderabad City, Pakistan: Contamination levels and their potential for air–soil exchange. Science of the Total Environment. 470–471 (2014), 733–741.

Amweg, E. L., D. P. Weston, and N. Ureda. 2005. Use and Toxicity of Pyrethroid Pesticides in the Central Valley, California, USA. Environ. Tox. Chem. 24**:** 966-972.

Bower, J.C., R.S. Tjeerdema. 2016. Draft Water and Sediment Quality Criteria Report for Fipronil. Phase III: Application of pesticide water and sediment quality criteria methodologies. Department of Environmental Toxicology, University of California Davis.

Burnett, L.J., K.J. Sorenson, J. Brandt, E.A. Sandhaus, D. Ciani, M. Clark, C. David, J. Theule, S. Kasielke, R.W. Risebrough. 2013. 115(3): 477–491.

Central Coast Water Board. 2017. Water Quality Control Plan (Basin Plan). California Regional Water Quality Control Board, Central Coast Region

CCLEAN. 2007. 2001-2006 Program Overview. Central Coast Long-term Environmental Assessment Network, Santa Cruz, CA

CCLEAN. 2008. 2006-2007 Annual Report. Central Coast Long-term Environmental Assessment Network, Santa Cruz, CA

CCLEAN. 2011. 2009-2010 Annual Report. Central Coast Long-term Environmental Assessment Network, Santa Cruz, CA

CCLEAN. 2012. 2010-2011 Annual Report. Central Coast Long-term Environmental Assessment Network, Santa Cruz, CA

CCLEAN. 2014. 2012-2013 Annual Report. Central Coast Long-term Environmental Assessment Network, Santa Cruz, CA

CCLEAN. 2015. 2013-2014 Annual Report. Central Coast Long-term Environmental Assessment Network, Santa Cruz, CA

Corona-Cruz, A., G. Gold-Bouchot, M. Gutierrez-Rojas, O. Monroy-Hermosilla, E. Favela. 1999. Anaerobic-aerobic biodegradation of DDT (dichlorodiphenyl Trichloroethane) in soils. Bulletin of Environnmental Contamination and Toxicology. 63: 219–225.

Domagalski, J. L., Weston, D. P., Zhang, M. and M. Hladik. 2010. Pyrethroid insecticide concentrations and toxicity in streambed sediments and loads in surface waters of the San Joaquin Valley, California, USA. Environ. Toxicol. Chem. 29: 813-823.

Fojut, T.L., R. Mulligan, R.S. Tjeerdema. 2011a. Water Quality Criteria for Cypermethrin Phase III: Application of the pesticide water quality criteria methodology. Department of Environmental Toxicology, University of California Davis.

Fojut, T.L., C. Rering, R.S. Tjeerdema. 2011b. Water Quality Criteria for Permethrin Phase III: Application of the pesticide water quality criteria methodology. Department of Environmental Toxicology, University of California Davis.

Frame G.M., J.W. Cochran, S.S. Boedwadt. 1996. Complete PCB congener distributions for 17 Aroclor mixtures determined by 3 HRGC systems optimized for comprehensive, quanti.tative, congener-specific analysis. Journal of High Resolution Chromatography 19:

657-668

Hickie B.E., P.R. Ross, R.W. Macdonald, J.K.B. Ford. 2007. Killer whales (*Orcinus orca*) face protracted health risks associated with lifetime exposure to PCBs. Environ, Sci. Technol. 41:6613-6619.

Kannan, K., N. Kajiwara, B.J. LeBoeuf, S. Tanabe. 2004. Organochlorine pesticides and polychlorinated biphenyls in California sea lions. Environmental P;uution. 131 (2004) 425–434.

Krahn, M.M., M.B. Hanson, G.S. Schorr, C.K. Emmons, D.G. Burrows, J.L. Bolton, R.W. Baird, G.M Ylitalo. 2009. Effects of age, sex and reproductive status on persisten organic pollutant concentrations in "Southern Resident" killer whales. Marine Pollution Bulletin. 58 (2009) 1522–1529.

Long E.R., L.J. Field, D.D. MacDonald. 1998. Predicting toxicity in marine sediments with numerical sediment quality guidelines. Environmental Toxicology and Chemistry [Environ. Toxicol. Chem.]. 17: 714-727

Long, E.R., D.D. MacDonald, C.G. Severn, C.B. Hong. 2000. Classifying probabilities of acute toxicity in marine sediments with empirically derived sediment quality guidelines. Environmental Toxicology and Chemistry [Environ. Toxicol. Chem.]. 19: 2598-2601

Melwani, A.R., D. Gregorio, Y. Jin, M. Stephanson, G. Ichikawa, E. Siegel, D.Crane, G. Lauenstein, J.A. Davis. 2014. Mussel watch update: Long-term trends in selected contaminants from coastal California. Marine Pollution Bulletin. 81 (2014) 291–302.

NOAA Fisheries. 2016. Species in the Spotlight, Priority Actions: 2016–2020, Southern Resident Killer Whale DPS, *Orcinus orca*. January 2016

Palumbo, A.J., T.L. Fojut, S.M. Brander, R.S. Tjeerdema. 2010.Water Quality Criteria Report for Bifenthrin. Phase III: Application of the pesticide water quality criteria methodology. Department of Environmental Toxicology, University of California Davis.

Parry, E., T.M. Young. 2013. Distribution of pyrethroid insecticides in secondary wastewater effluent. Envirnmental Toxicologu and Chemsitry. 32(2): 2686-2694.

Pereira, W.E., F.D. Hostettler, J.B. Rapp. 1996. Distributions and Fate of Chlorinated Pesticides, Biomarkers and Polycyclic Aromatic Hydrocarbons in Sediments Along a Contamination Gradient from a Point-Source in San Francisco Bay, California. Marine Environmental Research. 41 (3) 219–314.

Sadaria, A.M., R. Sutton, K.D. Moran, J. Teerlink, J.V. Brown, R.U. Halden. 2016. Passage of fiproles and imidacloprid from urban pest control uses through wastewater treatment plants in northern California, USA. Environmental Toxicology and Chemistry. 9999 (9999): 1–10.

State Water Resources Control Board. 2009. California Ocean Plan. California Environmental Protection Agency, Sacramento, CA.

U.S. Environmental Protection Agency. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1 Fish Sampling and Analysis, Third Edition. Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, EPA 823-B-00-007, Washington, D.C.

U.S. Environmental Protection Agency. 2007. Survey of New Findings in Scientific Literature Related to Atmospheric Deposition to the Great Waters: Polychlorinated Biphenyls (PCB). U.S. Environmental Protection Agency Office of Air Quality Planning and

Standards Health and Environmental Impacts Division Climate, International and Multimedia Group Research Triangle Park, North Carolina, EPA-452/R-07-012, December 2007.

USEPA. 2010. Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin and Dioxin-Like Compounds. EPA/100/R-10/005. Risk Assessment Forum.

Van den Berg, M., L.S. Birnbaum, M. Denison, et al. 2006. The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds. Toxicological Sciences 93(2):223–241.

Wedemeyer, G. 1966. Dechlorination of DDT by *Aerobacter aerogenes*. Science. 152 (3722) 647.

Weston, D. P., Asbell, A. M., Lesmeister, S. A., Teh, S. J. and M. J. Lydy. 2014. Urban and agricultural pesticide inputs to a critical habitat for the threatened delta smelt (*Hypomesus transpacificus*). Environ. Toxicol. Chem. 33: 920-929.

Weston, D. P., Schlenk, D., Riar, N., Lydy, M. J. and M. L. Brooks. 2015. Effects of pyrethroid insecticides in urban runoff on Chinook salmon, steelhead trout, and their invertebrate prey. Environ. Toxicol. Chem. 34: 649-657.

Windham, G.C, S.M. Pinney, A. Sjodin, R. Lum, R.S. Jones, L.L. Needham, F.M. Biro, R.A. Hiatt, L.H. Kushi. 2010. Body burdens of brominated flame retardants and other persistent organohalogenated compounds and their descriptors in U.S. girls. Environmental Research 110(3): 251–257.

Windham, G.C., S.M. Phinney, R.W. Voss, A. Sjodin. F.M. Biro, L.C Greenspan, S. Stewart, R.A. HJiatt, L.H. Kushi. 2015. Brominated Flame Retardants and Other Persistent Organohalogenated Compounds in Relation to Timing of Puberty in a Longitudinal Study of Girls. Environmental Health Perspectives. 123 (10) 1046–1052.

Zhang, L., L. Dong, S. Shi, L. Zhou, T. Zhang, Y. Huang. 2009. Organochlorine pesticides contamination in surface soils from two pesticide factories in Southeast China. Chemosphere 77 (2009) 628–633.