SWAMP
Surface Water Ambient Monitoring Program

Final Technical Report | 2011

Assessment of Surface Water Quality and Habitat in Agricultural Areas of the Central Coast of California, and Associated Risk to the Marine Environment

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List of Acronyms

C	Celcius
CCAMP	Central Coast Ambient Monitoring Program
CCLEAN	Central Coast Long-term Environmental Assessment Network
CCRWQB	Central Coast Regional Water Quality Control Board
CCWQP	Central Coast Water Quality Preservation Inc.
CDFG	California Department of Fish and Game
CDPH	California Department of Public Health
CENCOOS	Central California Ocean Observing System
CMP	Cooperative Monitoring Program for Agriculture
CWA	Clean Water Act
DDT	Dichloro diphenyl trichloroethane
DPR	Department of Pesticide Regulation
kg	kilograms
LC50	Lethal concentration to 50% of test organisms
LOBO	Land/Ocean Biogeochemical Observatory
MPA	Marine Protected Area
MPN	Most Probable Number
mg/L	millograms per liter
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
OEHHA	Office of Environmental Health Hazzard Assessment
OP	Organophosphate
PCB	Polychlorinated Biphenols
QAMP	Quality Assurance Management Plan
QAPP	Quality Assurance Project Plan
SCCOOS	Southern California Ocean Observing System
SLOSEA	San Luis Obispo Science and Ecosystem Alliance
SWRCB	State Water Resources Control Board
TDS	Total Dissolved Solids
TIE	Toxicity Identification Evalution
TMDL	Total Maximum Daily Load
TU	Toxic Unit – Concentration in sample divided by LD50
UCSC	University of California at Santa Cruz
USEPA	United States Environmental Protection Agency

Executive Summary

Several important areas of the California Central Coast region are severely degraded by high levels of nitrates in surface and ground water, toxicity to test organisms, pesticides in surface water and sediment that exceed toxic thresholds, and other water quality concerns. Benthic invertebrate communities in these areas, and their associated habitat, are also degraded. These areas are generally dominated by very intensive agricultural activities. Areas with a high percentage of row crop agriculture are particularly associated with surface waters that have high levels of nitrate, turbidity, and toxicity.

This report summarizes water, sediment, biological and habitat conditions of agricultural areas of the Region. It also examines the history of legacy pollutants (used both for agricultural and other uses) in the marine environment, and evaluates Central Coast Marine Protected Areas for their relative risk of impact from chemicals currently associated with agricultural activities. The information in this report is intended to support regulatory and management decisions associated with the regulatory program for agriculture in the Central Coast.

This report relies on data collected by the Central Coast Ambient Monitoring Program (the monitoring program for the Central Coast Water Board) and the Central Coast Cooperative Monitoring Program for Agriculture (the monitoring program for the irrigated agricultural industry). Both programs maintain high levels of quality assurance and data quality documentation, as defined by the State Water Board's Surface Water Ambient Monitoring Program requirements.

Notable study findings are summarized below:

Surface Water Quality

- Surface water bodies in the lower Salinas and Santa Maria areas, both areas of intensive agricultural activity, are the most severely impacted of the Region. Evaluated through a multi-metric index of water quality, 82 percent of the most degraded sites in the Central Coast Region are in these agricultural areas.

Nitrate

- The 2010 List of Impaired Waterbodies includes forty-seven Central Coast waterbodies that have drinking water beneficial uses impaired by nitrate pollution. Sixty-eight percent of these nitrate listings occur in our three major agricultural watersheds: Lower Salinas area (15 waterbodies), Pajaro River watershed (5 waterbodies) and lower Santa Maria area (12 waterbodies).
- Twenty-seven percent of all sites from CCAMP and CMP have average nitrate concentrations that exceed the drinking water standard, and approximately 60 percent exceed the level identified to protect aquatic life. Several of these water bodies have average nitrate concentrations that exceed the drinking water standard by five-fold or more.
- Some of the most seriously polluted water bodies include the Tembladero Slough system (including Old Salinas River, Alisal Creek, Alisal Slough, Espinosa Slough, Gabilan Creek and Natividad Creek), the Pajaro River (including Llagas Creek, San Juan Creek, and Furlong Creek), the lower Salinas River (including Quail Creek, Chualar Creek and Blanco Drain), the lower Santa Maria River (including Orcutt-Soloman Creek, Green Valley Creek, and Bradley Channel),

and the Oso Flaco watershed (including Oso Flaco Lake, Oso Flaco Creek, and Little Oso Flaco Creek).

Toxicity and Pesticides

- Toxicity is widespread in Central Coast waters, with sixty-five percent of all waterbodies monitored for toxicity showing some measure of lethal effect. Twenty-nine waterbodies are on the proposed 2010 Clean Water Act, Section 303(d) List of Impaired Waters because of sediment and/or water toxicity.
- Ninety percent of severely toxic sites are in agricultural areas of the lower Santa Maria and Salinas/Tembladero watershed areas.
- A number of small creek drainage systems are toxic nearly every time they are sampled. Researchers collaborating with CCAMP have shown that these small drainages can cause toxic effects in downstream river systems that damage benthic invertebrate communities.
- Water column invertebrate toxicity has been primarily associated with high concentrations of diazinon and chlorpyrifos pesticides; sediment toxicity has been associated with chlorpyrifos and pyrethroid pesticide mixtures.
- Agricultural use of pyrethroid pesticides in the Central Coast Region and associated toxicity are among the highest in the state. In a statewide study of four agricultural areas conducted by the Department of Pesticide Regulation (DPR), the Salinas study area had the highest percent of surface water sites with pyrethroid pesticides detected (85 percent), the highest percent of sites that exceeded levels expected to be toxic (42 percent), and the highest rate (by three-fold) of active ingredients applied (113 lbs/acre).

Turbidity

- Agricultural waste discharges contribute to sustained turbidity with many sites heavily influenced by agricultural waste discharges exceeding 100 NTUs as a median value. For comparison, most CCAMP sites have a median turbidity level of under 5 NTUs. Resulting turbidity greatly exceeds levels that affect the ability of salmonids to feed. Many of these more turbid sites are located in the lower Santa Maria and Salinas-Tembladero watersheds.

Water Temperature

- Lack of shading in creek channels modified for agricultural purposes can cause water temperatures to exceed levels that are healthy for salmonids. Several high temperature areas are in major river corridors that important provide rearing and/or migration habitat for salmonids. These include the Salinas, Santa Maria, and Santa Ynez rivers.

Habitat and Benthic Infauna

- Benthic macroinvertebrate assemblages are degraded in areas with heavy agricultural activity, reflecting poor water quality and/or degraded aquatic habitat. Aquatic habitat is often poorly shaded and stream bottom habitat is dominated by fine sediment.
- The lower Salinas area and lower Santa Maria watershed score low for common measures of benthic macroinvertebrate community health and aquatic habitat health.
- Unstable, bare dirt and tilled soils, highly vulnerable to erosion and stormwater runoff, are common directly adjacent to surface waterbodies in agricultural areas.

Trends

- Nitrate concentrations in areas that are most heavily affected are not improving significantly or in any widespread manner and in a number of sites in the lower Salinas/Tembladero and Santa Maria watershed areas appear to be getting worse in the last few years.
- Nitrate concentrations in some drainages in the Santa Barbara area are improving (such as Bell Creek, which supports agricultural activities) and on Pacheco Creek in the Pajaro watershed. A few other areas where significant technical assistance has occurred are also improving (e.g. Quail and Chualar creek) in either nitrate concentration, load, or both.
- Some locations in the lower Salinas and Santa Maria areas show increasing nitrate concentrations over the past five years of the CMP. However, flow volumes have declined at some of these sites, so at these locations nitrate loads may actually be improving in spite of upward trends in concentrations;
- Dry season flow volume is declining in some areas of intensive agriculture, implying reductions in tailwater volume;
- Detailed flow analysis by the CMP showed that 18 of 27 sites in the lower Salinas and Santa Maria watersheds had statistically significant decreases in dry season flow over the first five years of the program;
- CCAMP monitoring has detected declining flows at other sites elsewhere in the Region, likely because of drought;
- Several sites along the main stem of the Salinas River showed significant increases in turbidity during the dry season; significant decreases in turbidity were seen at two locations in the Santa Maria watershed.
- One CCAMP monitoring site on the Salinas Reclamation Canal (309JON) shows statistically significant improvement in survival of invertebrate test organisms in water.

Marine Protected Areas

- Several Marine Protected Areas (MPAs) along the Central Coast are at risk of pollution affects from sediment and water discharges leaving river mouths. Three of the MPAs, Elkhorn Slough, Moro Cojo Slough and Morro Bay, are estuaries that receive runoff into relatively enclosed systems. In two of these MPAs (Moro Cojo Slough and Elkhorn Slough), nitrates, pesticides and toxicity are documented problems.
- Research in the Monterey Bay area has shown that discharge of nitrate from the Salinas and Pajaro river systems can increase the initiation and development of phytoplankton blooms, and some of these blooms have resulted in the deaths of hundreds of sea birds.
-

Data and Information Gaps

- The timeframe and frequency of data collection, especially for toxicity, limit the evaluation of statistical trends for some water quality parameters at this time, but significant trends are beginning to be detected in some locations.
- Flow information and water quality data are not reported for agricultural waste discharges from individual farms, so direct conclusions cannot be drawn relating

- In most Marine Protected Areas, there is no monitoring of sediments that carry pesticides in attached forms. Without this information it is difficult to determine if these pesticides, carried downstream attached to sediments and discharged to the ocean, are harming marine life.
- Additional research will increase understanding of the effects of nutrient discharges from rivers to nearshore ocean waters.

1.0 Introduction

This report summarizes water, sediment, biological and habitat conditions of agricultural areas of the Central Coast of California. From the standpoint of water quality, it focuses particularly on nitrate and several other contaminants that are directly associated with agricultural activities, as well as on toxicity to test organisms in both water and sediment collected in agricultural areas. It also examines the history of legacy pollutants (used both for agricultural and other uses) in the marine environment, and evaluates Central Coast Marine Protected Areas for their relative risk of impact from chemicals currently associated with agricultural activities.

This report relies on data collected by the Central Coast Ambient Monitoring Program (the Surface Water Ambient Monitoring Program (SWAMP) for the Central Coast Water Board) and the Central Coast Cooperative Monitoring Program for Agriculture (the monitoring program for the irrigated agricultural industry in the Central Coast). The information in this report was originally used to support regulatory and management decisions associated with the regulatory program for agriculture in the Central Coast, particularly associated with the 2011 renewal of the "Conditional Waiver of Waste Discharge Requirements of Irrigated Agricultural Waste Discharges" or "Agricultural Order". The report has been further developed for use as a SWAMP assessment report on the status of water quality in agricultural areas of the Central Coast Region.

2.0 Background

The California Central Coast Water Board oversees water quality concerns in the Central Coast Region, which encompasses almost 300 miles of coastline, from southern San Mateo County to northern Ventura County, and includes all of Santa Cruz, San Benito, Monterey, San Luis Obispo, and Santa Barbara Counties. Its many natural resources include two National Marine Sanctuaries, a National Estuary, numerous Areas of Special Biological Concern, and the first of the State's Marine Protected Areas. The Central Coast Region varies dramatically in climate and topography, ranging from arid plains in the east to foggy redwood forests along the northern coastal slopes. The larger watersheds end in broad river valleys with mild coastal climates that support rich and productive agricultural lands (Figure 1).

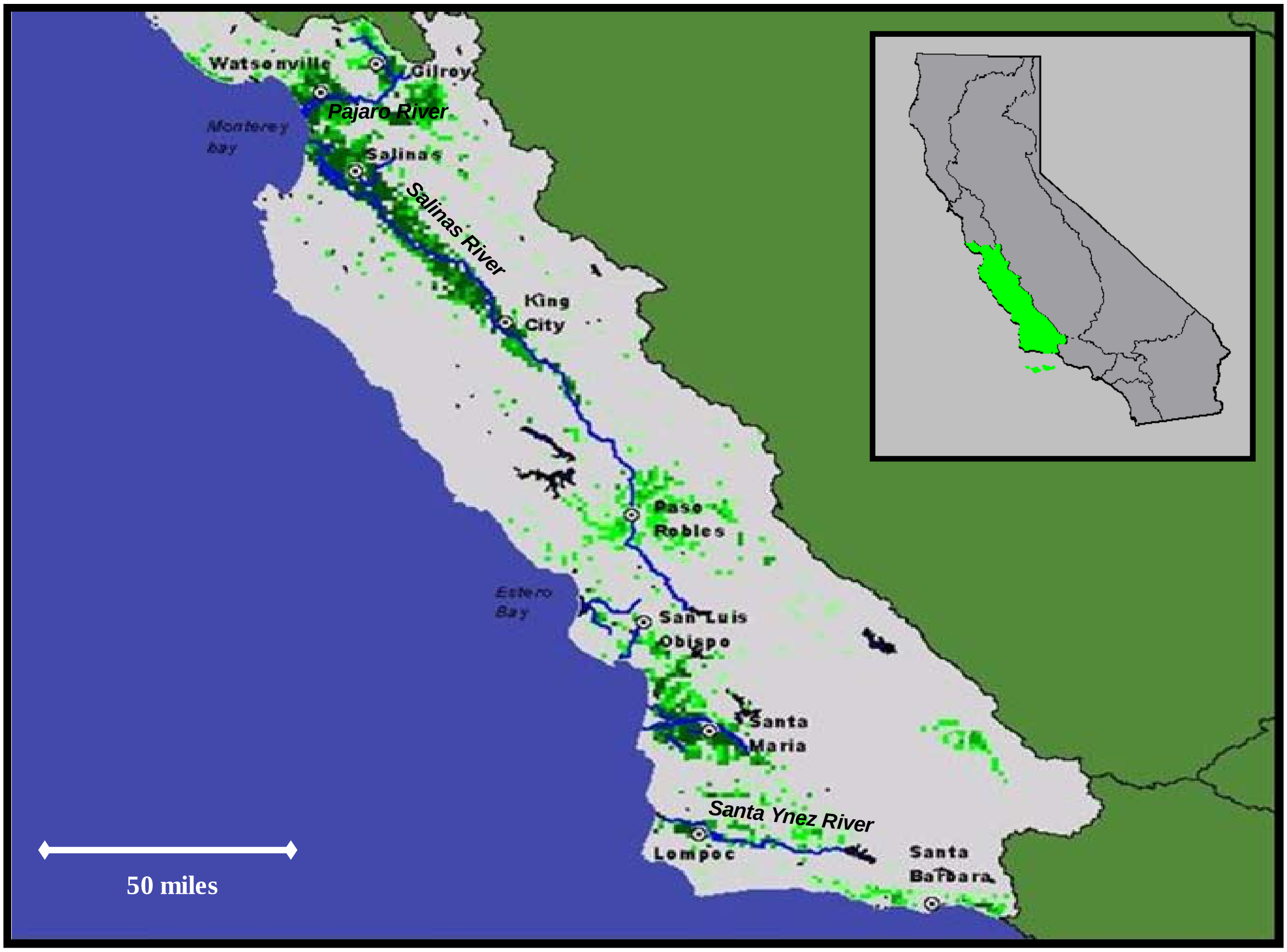


Figure 1. Map of the Central Coast Region (with California inset)

AGRICULTURAL AREAS ARE INDICATED IN GREEN SHADING. MAJOR URBAN AREAS AND WATER BODIES ARE SHOWN.

The Central Coast Region's diverse landscape includes row crops, orchards and vineyards, rapidly expanding urban areas, and many miles of paved roadways. The Central Coast is among of the most productive agricultural regions in the nation, with a gross production value of more than six billion dollars. Agriculture in Monterey County alone is a 3.4 billion dollar industry that supplies 80 percent of the nation's lettuce and nearly the same percentage of artichokes. The mild climate can support three or even four crops per year in some areas. The major watershed areas in the Region are shown in Table 1, along with area and percent of irrigated agricultural crops.

Hydrologic Unit	Total Sq. Km.	Row Crops Sq. Km (%)	Vineyards and Orchards Sq. Km (%)	Small Grains Sq. Km (%)
Santa Cruz Coast (304)	1036	1.7 (0.2%)	2.7 (0.3%)	0.8 (0.1%)
Pajaro (305)	3602	127.7 (3.5 %)	126.0 (3.5%)	1.6 (0.04%)
Elkhorn Slough (306)	477	95.2 (20.0%)	0.8 (0.2%)	0 (0.0%)
Carmel (307)	837	4.9 (0.6%)	0.6 (0.1%)	1.1 (0.1%)
Salinas (309)	8684	695.3 (8.0%)	67.2 (0.8%)	45.6 (0.5%)
Big Sur and San Luis Obispo (308 and 310)	2782	55.6 (2.0%)	10.8 (0.4%)	6.7 (0.2%)
Soda Lake (311)	1280	23.8 (1.9%)	0.2 (0.01%)	25.1 (2.0%)
Santa Maria (312)	1772	109.2 (6.2%)	28.5 (1.6%)	6.4 (0.4%)
San Antonio (313)	561	16.5 (2.9%)	17.3 (3.1%)	1.6 (0.3%)
Santa Ynez (314)	2344	76.3 (3.3%)	13.7 (0.6%)	8.5 (0.4%)
Santa Barbara Coast (315)	990	13.0 (1.3%)	27.2 (2.7%)	3.1 (0.3%)
Estrella River (317)	2524	32.2 (1.3%)	19.7(0.8%)	57.8 (2.3%)

Table 1. Agricultural land in major watershed areas (hydrologic units) of the Central Coast Region

SQUARE KILOMETERS (SQ. KM.) AND PERCENT OF LANDS IN AGRICULTURE ARE SHOWN FOR EACH HYDROLOGIC UNIT. LAND USE DATA IS FROM THE NATIONAL LAND COVER DATASET (2001). SOME ACREAGES HAVE CHANGED SINCE THIS ANALYSIS (E.G. VINEYARDS HAVE EXPANDED IN THE SALINAS VALLEY).

The Central Coast is a region of unique habitat areas, significant biodiversity, and many sensitive natural habitats and species of concern. In some areas agricultural discharges are threatening or impacting these resources and beneficial uses. Pesticides and nutrients that are applied to the land make their way into drainages, creeks and rivers, and ultimately the ocean, and are causing serious damage to water resources of the area. In addition, Central Coast residents depend in large part upon groundwater as their drinking water source. Fresh water stream systems are an important source of recharge for groundwater in many areas.

California Porter-Cologne Water Quality Control Act (1970) established nine Regional Boards and the State Water Resources Control Board, which implement water planning, policy, regulatory and enforcement activities for the State of California. The Central Coast Water Board is the principle agency responsible for regulating discharges to waters of the State in the Central Coast Region. The Discharges from agriculture are regulated by the Central Coast Board under a “Conditional Waiver of Waste Discharge Requirements”, or “Agricultural Order”. The program requires that monitoring data be collected in order to ascertain progress towards meeting conditions of the Waiver, and requires periodic revision and renewal of conditions.

The Central Coast Ambient Monitoring Program (CCAMP) is the Central Coast Water Board’s regional monitoring program, funded in part by the State Water Resources Control Board’s Surface Water Ambient Monitoring Program (SWAMP). CCAMP has been in place since 1998, and has collected data from throughout the Region in two full annual rotations of monthly data collection through our five major watershed areas. CCAMP has also collected monthly trend monitoring data at river mouth trend monitoring sites since 2001. CCAMP data provided evidence of water quality problems associated with irrigated agriculture during development of the first Central Coast Agricultural Order in 2004. The Order specified monitoring that led to development of the Central Coast Cooperative Monitoring Program for Agriculture (CMP). The CMP is managed by an agricultural non-profit organization, Central Coast Water Quality Preservation Inc. The CMP data focuses monitoring in agricultural areas with impaired waters while CCAMP monitors throughout the Region. The CMP has collected over five years (ongoing from 2005) of baseline data from 50 long-term trend monitoring sites in agricultural areas, as well as additional data from a number of follow-up monitoring studies. The 2005 Ag Order required that CMP sites be located in waters impaired by agricultural pollutants; as a result, the CMP dataset is heavily focused on monitoring in problem areas. The CMP has developed several summary reports, summarizing the findings of their long-term monitoring program, as well as of follow-up activities. The reports have looked in depth at flow variability in channels dominated by agricultural discharge, organophosphate pesticide concentrations associated with water column toxicity, detailed characterization of source areas for constituents of concern and most recently, sediment pesticide concentrations associated with sediment toxicity.

Both CCAMP and the CMP maintain full documentation of quality assurance data and operate under SWAMP approved quality assurance documents. Data is comparable in terms of analytical methods, field methods, and data management. All data is delivered electronically to the California Environmental Data Exchange Network (CEDEN) and to the California Integrated Assessment for support of Clean Water Act 303(d) and 305(b), and so is publically available.

In this report we examined data from the CMP (2005 – 2009) and CCAMP (1998 – 2009) to develop an assessment of water quality in agricultural areas throughout the

Region. We also evaluated both sets of data for evidence of water quality change. Finally, we assessed potential risk of agricultural chemicals impacting the nearshore marine environment, particularly Marine Protected Areas.

Additional documentation, including references and access to data, charts, related documents and maps, can be found in the Appendices, the CCAMP web site (www.ccamp.org) and on the CCAMP Ag Assessment wiki (http://www.ccamp.net/ag/index.php/Main_Page).

3.0 Methods

Both the CCAMP and CMP monitoring programs use similar field and analytical methods, as identified by the SWAMP program. Sampling locations for both programs are often located at public bridge crossings because of all-weather public access and because of private property issues. A map of CCAMP and CMP sites is shown in Figure 2. CCAMP watershed monitoring sites are placed at safe access locations along the main stem of each major creek and river, typically upstream of each major tributary input, and also at the lower end of major tributaries. CCAMP watershed sites are sampled monthly for a year on a five year rotational schedule. CCAMP also samples thirty-three long-term coastal confluence trend sites continuously on a monthly basis. Water column toxicity sampling is conducted once in the wet season, and once in the dry season at a subset of sites. Sediment toxicity and benthic invertebrate bioassessment are sampled once in Spring at a subset of sites.

CMP sites are usually at the lower ends of smaller tributaries in areas dominated by agricultural activity, or on stream reaches at the lower end of agricultural areas. CMP sites are selected to reduce or eliminate influences from other land uses, to the extent possible. CMP samples all of its 50 sites on a continuous monthly basis for conventional water quality. Water column toxicity sampling is conducted each year, twice in the wet season, twice in the dry season. Sediment toxicity and benthic invertebrate bioassessment are sampled once in Spring.

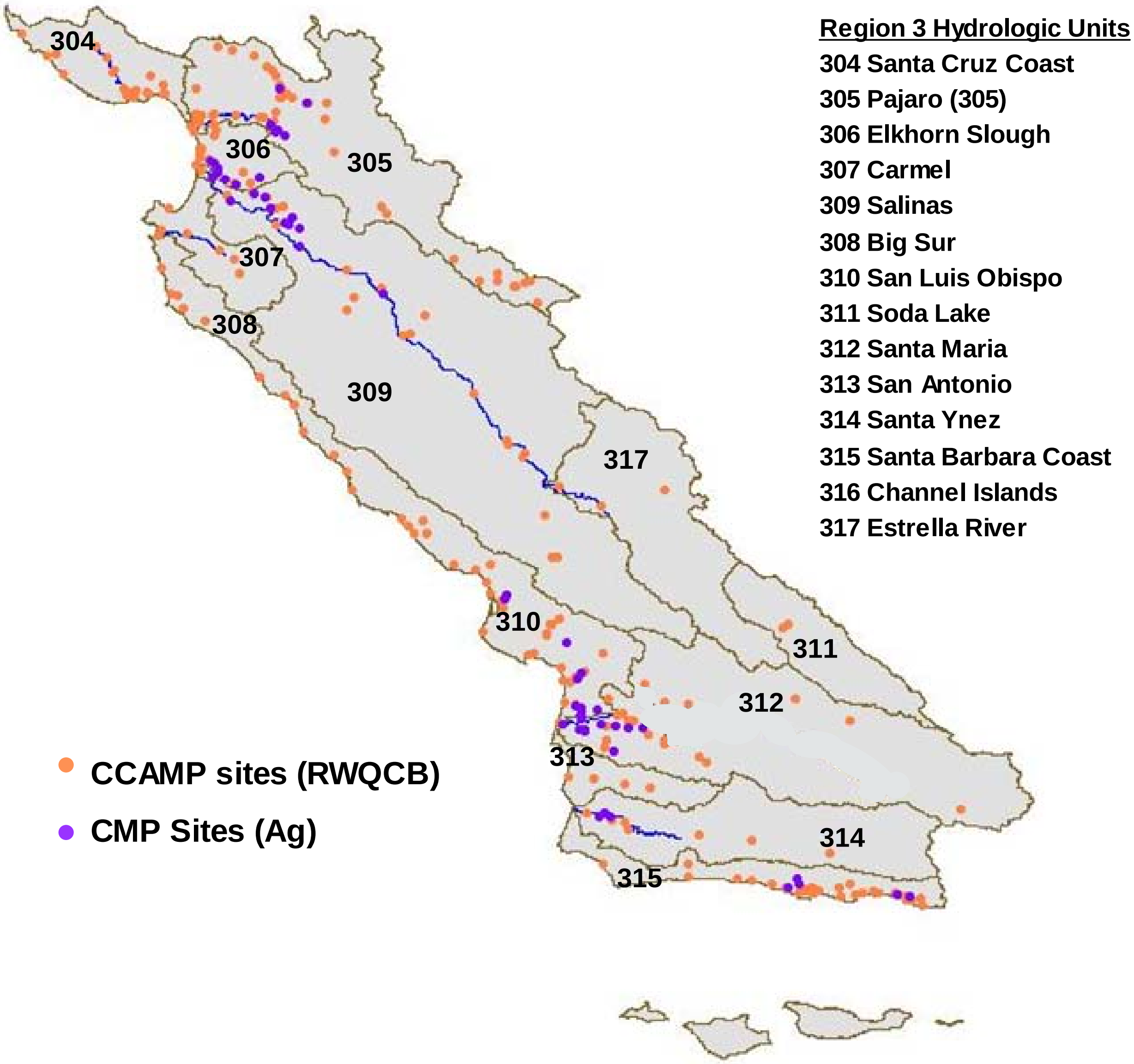


Figure 2. Map of monitoring sites for the Central Coast Ambient Monitoring Program (CCAMP) and the Cooperative Monitoring Program for Agriculture (CMP).

CMP SITES ARE SHOWN IN PURPLE. NOT ALL SITES ARE LONG-TERM TREND MONITORING SITES; SOME ARE WATERSHED ROTATION OR FOLLOW-UP MONITORING SITES. HYDROLOGIC UNIT NUMBERS ARE ALSO INDICATED.

Conventional Water Quality

Conventional water quality sampling is conducted following the protocols outlined in CCAMP Standard Operating Procedures (Puckett, 2002). Analytes used by the two monitoring programs, along with methods and reporting limits are shown in Table 2. Proper chain of custody documentation is maintained for all samples as described in the SWAMP QAMP (Puckett, 2002).

Hydrolab probes (DS4a) are calibrated prior to and following each sampling event. Probes are calibrated using laboratory certified standards for pH, conductivity and turbidity, and are air calibrated for dissolved oxygen. Calibration data is used to evaluate instrument performance. The SWAMP QAMP has defined +/- 20% difference as the maximum allowable variation between the calibration standard and post calibration measurement of the standard (Puckett, 2002, Appendix C).

A blind field duplicate sample is collected at least once per sampling trip, and at a rate of at least 5% of samples. Data from duplicates is compared to original samples and evaluated using the SWAMP maximum for relative percent difference of 25% (Puckett 2002, Appendix C).

The quality control measures employed by the contract laboratory are also evaluated using SWAMP criteria. These measures include but are not limited to matrix spike recovery, laboratory control samples, calibration control samples, method blanks and lab duplicates. Data is flagged according to SWAMP standard language and disposition is identified if qualified, estimated, or rejected.

Rapid Bioassessment

CCAMP and CMP staff collect benthic macroinvertebrates (BMIs) and assess associated habitat following SWAMP Bioassessment Standard Operating Procedures and quality assurance requirements. All BMI samples are processed and identified to the lowest possible taxon following California Aquatic Macroinvertebrate Laboratories Network taxonomic standards. Samples are collected during base-flow conditions during the index period of April through July. Sampling reaches are selected in association with conventional water quality monitoring sites.

Analyte	Program	Method	Reporting Limit
Nitrate as N	CCAMP	EPA 300.0	0.1 mg/L
Nitrite as N	CCAMP	EPA 353.2	0.01 mg/L
Nitrate + Nitrite	CMP	SM 4500-P	0.1 mg/L
Total Ammonia as N	CCAMP/CMP	EPA 350.1	0.1 mg/L
Total Phosphorus as P	CCAMP	EPA 365.4	0.06 mg/L
Orthophosphate as P	CCAMP/CMP	EPA 365.1	0.01 mg/L
Total Dissolved Solids	CMP	EPA 160.1	10.0 mg/L
Fixed Dissolved Solids	CCAMP	EPA 160.4	5.0 mg/L
Volatile Dissolved Solids	CCAMP	EPA 160.4	5.0 mg/L
Total Suspended Solids	CCAMP	EPA 160.2	10 mg/L
Fixed Suspended Solids	CCAMP	EPA 160.4	0.5 mg/L
Volatile Suspended Solids	CCAMP	EPA 160.4	1.0 mg/L
Chlorophyll a (ug/L)	CCAMP/CMP	Optical sensor	2 ug/L
Hardness as CaCO3	CCAMP	SM 2340B	1 mg/L
Calcium	CCAMP	EPA 200.7	0.05 mg/L
Magnesium	CCAMP	EPA 200.7	0.02 mg/L
Boron, dissolved	CCAMP	EPA 200.7	0.01 mg/L
Sodium	CCAMP	EPA 200.7	0.1 mg/L
Chloride	CCAMP	EPA 300.0	0.35 mg/L
Total and Fecal Coliform	CCAMP	25-tube dilution	NA
E. coli	CCAMP	Colilert	NA

Table 2. Laboratory analytes and typical methods and reporting limits

Water Toxicity

Sampling for toxicity to fathead minnow larvae (Pimephales promelas), water fleas (Ceriodaphnia dubia), and algae (Selenastrum capricornatum) occurs at all CMP sites twice in the dry season and twice in the wet season. For CCAMP, toxicity samples are collected only once in the dry season and once in the wet season at a subset of sites. Toxicity testing is performed at the University of California Davis Marine Pollution Studies Laboratory at Granite Canyon (UCD-GC) for CCAMP and at Pacific Ecorisk for the CMP. All tests are conducted according to US EPA (1994) protocols. Water quality parameters including conductivity, hardness, alkalinity, pH, dissolved oxygen, and ammonia are measured at the beginning of each test. Field duplicate samples for toxicity are tested to estimate the variability in results associated with sampling and laboratory procedures. All toxicity tests include both positive and negative controls. Details of toxicity testing methods can be found in the SWAMP QAMP (Puckett 2002, Appendix F) and the CMP QAPP (CCWQP, 2006).

Sediment Chemistry and Toxicity

Bed sediment samples are collected targeting fine-grained sediments within the wetted creek channel. A pre-cleaned Teflon™ scoop is used to collect the top 2 cm of sediment from multiple locations at the site. Samples are homogenized thoroughly and aliquoted into pre-cleaned, pre-labeled sample jars (glass or polyethylene, as appropriate) for organic chemical, metal or toxicological analysis. Ten-day sediment toxicity testing is conducted using Hyalella azteca (EPA 2000). Endpoints recorded after ten days are survival and growth (as dry weight). Sediment toxicity QA procedures include field duplicates and positive and negative controls. Details on bed sediment sampling and toxicological analytical procedures are outlined in the SWAMP QAMP (Puckett 2002, Appendix D) and the CMP QAPP (CCWQP, 2006).

4.0 Surface Water Status

Overall Status

We have summarized overall water quality status of all sites and subwatersheds monitored through the CCAMP and CMP programs using a multi-metric approach that combines and scores several parameters into a water quality index. The rules for scoring are based on percentile ranking relative to water quality criteria or guideline values, and are described in detail in Appendix A. We have used the same rules to score sites, waterbodies, and watersheds. The water quality index includes water temperature, unionized ammonia, water column chlorophyll a, total dissolved solids (TDS), nitrate-nitrite (as N), orthophosphate, turbidity, and dissolved oxygen. We scored each parameter into one of five categories: good condition (green), slightly impacted (yellow), impacted (red), and very impacted (dark red). Unscored areas are white. Most of the unscored areas are in upper watershed areas. Sites which have naturally elevated salt concentrations (either those in tidal areas or those associated with saline basins) were removed from consideration for total dissolved solids. We have created a separate index for toxicity. The rules for interpretation of toxicity data are also described in Appendix A. Maps of water quality and toxicity index results (scored for small watersheds using Federally defined (HUC12) boundaries) are shown in Figures 3 and 4.

These summary indices confirm that two areas of our region stand out in terms of severity of impact using multiple measures of water quality. These are 1) the lower Salinas watershed and tributaries, Tembladero Slough-Salinas Reclamation Canal watershed and Moro Cojo Slough (hereafter referred to as the “lower Salinas area”) and 2) the lower Santa Maria watershed and tributaries, and lower Oso Flaco Creek (hereinafter referred to as the “lower Santa Maria area”). These are both areas of intensive agricultural activity. We have evaluated the water quality index at 250 individual sites. Of the 51 sites that score lowest (poorest) (less than 40 out of 100 possible points), 82% are in these two areas. Similar results are seen for the toxicity index, where all of the lowest scoring sites (less than 40 out of 100 points) fall in the lower Santa Maria and Salinas areas. Several other areas in the Region are also in poor condition. These include the lower Santa Ynez River (heavily influenced by a point source discharge), and the San Juan Creek and Watsonville Slough areas of the Pajaro River watershed (heavily influenced by agricultural activities).

Some of the most impacted sites in the Region drain directly to sensitive estuarine habitat. Flows from the Salinas Reclamation Canal move into the Old Salinas River and on an incoming tide into Elkhorn Slough, a Marine Protected Area and National Estuarine Research Reserve. Orcutt Creek provides the primary flow into the Santa Maria Estuary in the dry season. This estuary is critical habitat for endangered Snowy plovers, threatened steelhead trout, and other sensitive species. Both the Salinas Reclamation Canal and Orcutt Creek are two of the most impaired waterbodies

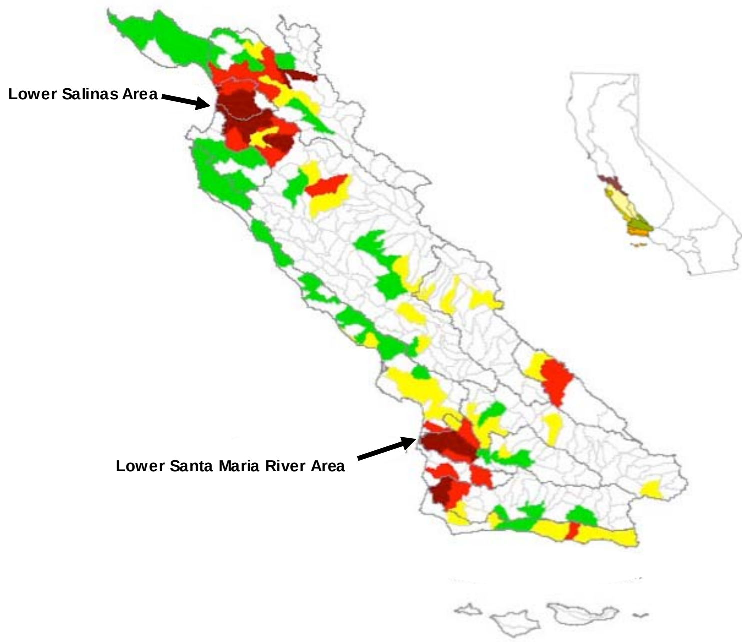


Figure 3. Water Quality Index
CENTRAL COAST REGION HUC 12 WATERSHEDS ARE SCORED, WITH GREEN BEING GOOD, YELLOW SLIGHTLY IMPACTED, RED IMPACTED AND DARK RED SEVERELY IMPACTED

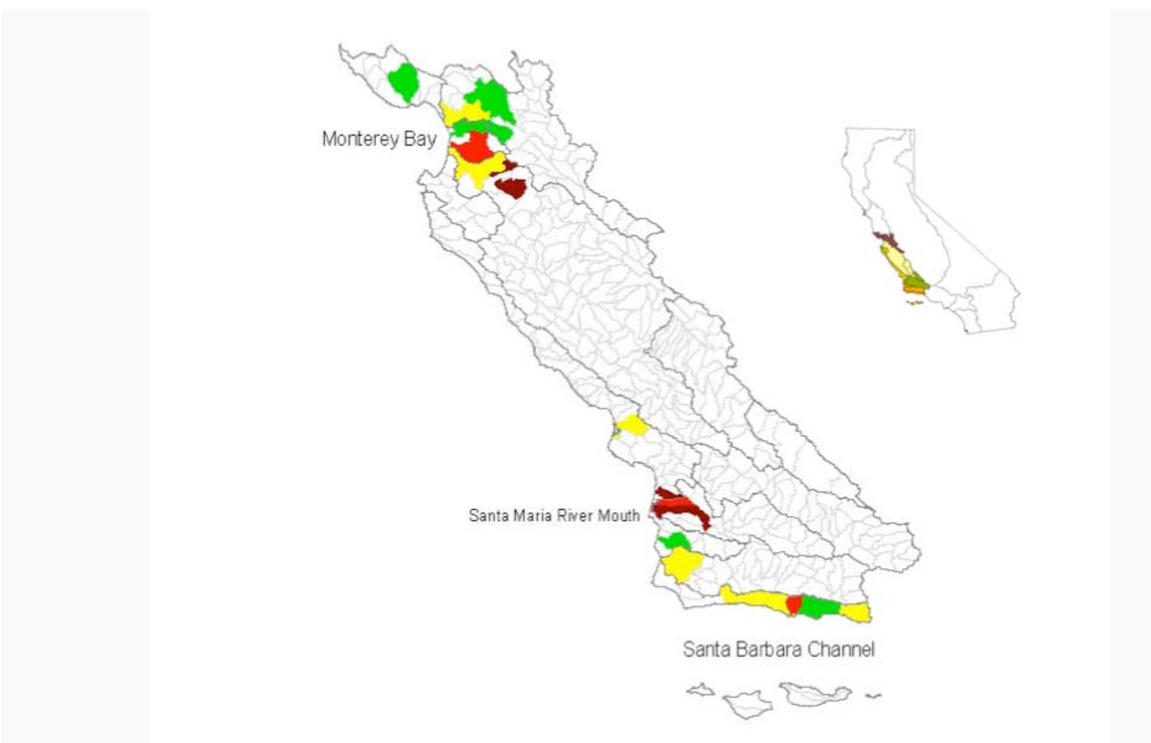


Figure 4. Toxicity Index
CENTRAL COAST REGION HUC 12 WATERSHEDS ARE SCORED, WITH GREEN BEING GOOD, YELLOW SLIGHTLY IMPACTED, RED IMPACTED AND DARK RED SEVERELY IMPACTED

in the Region, with persistent toxicity, extremely high nitrate concentrations, and turbidity that is elevated year-round (25 NTUs or higher).

The Central Coast 2010 List of Impaired Waters includes 704 listings. This is the list of waterbodies not meeting water quality standards that is developed every two years pursuant to Section 303(d) of the Clean Water Act. The List is based on a uniform assessment of all data collected through 2006, including data from CMP, CCAMP, and several other sources and is the most comprehensive evaluation of data conducted in the State for this purpose. Of the 704 impaired waterbody listings in the Central Coast Region, 77 are in the lower Santa Maria area, and include fifteen different pollutants and twelve waterbodies; Orcutt Creek and the Santa Maria River have the most listings. One-hundred and seventeen listings are in the lower Salinas watershed area, with 19 different pollutants and 16 waterbodies; the lower Salinas River, the Salinas Reclamation Canal, and Quail Creek (an agricultural tributary to the Salinas River) have the most listings (CCRWQCB, 2009). Maps of 2010 303(d) listings in Region 3 for toxicity, chlorpyrifos, diazinon, nitrate, turbidity, water temperature and un-ionized ammonia are found in Appendix B.

Evaluation of Key Parameters

Nitrate - The California Department of Public Health (CDPH) drinking water standard is 10 mg/L Nitrate-N. This standard is also adopted by the Central Coast Water Board as a water quality objective to protect for municipal and domestic water supply (CCRWQCB, 2006). This standard protects against Methemoglobinemia, or “blue baby syndrome”. Other public health concerns have also been linked to nitrate in drinking water, including incidence of bladder cancer and non-Hodgkin’s lymphoma (Ward, et al., 1996; Weyer, 2001). The drinking water standard is not intended to protect aquatic life and Water Board staff estimates that 1 mg/L nitrate-N or lower is necessary to protect aquatic life beneficial uses from biostimulation (Worcester, et al., 2010). For the purposes of this discussion, we have used the drinking water standard only.

Nitrate is arguably the most serious and widespread of all pollution problems in the Central Coast Region. The 2010 List of Impaired Waterbodies (CCRWQCB, 2009) includes forty-seven Central Coast waterbodies that have drinking water beneficial uses impaired by nitrate pollution. Sixty-eight percent of these nitrate listings occur in our three major agricultural watersheds: Lower Salinas area (15 waterbodies), Pajaro River watershed (5 waterbodies) and lower Santa Maria area (12 waterbodies). Other notable listings fall in small drainages in areas of intensive agriculture or greenhouse activity along the Santa Barbara coast, including Arroyo Paredon, Franklin Creek, Bell Creek, Los Carneros and Glen Annie creeks. A map of the waterbodies that are listed for nitrate pollution on the 2010 List are shown in Figure 5, along with location of irrigated agricultural land. Figure 6 shows the associated monitoring sites that have supported the listings, scored according to nitrate rules in Appendix A.

In combination, the CCAMP and CMP monitoring programs have collected over 7000 nitrate samples at 250 sites. A summary of data from these programs, by major watershed (Hydrologic Unit), is shown in Figure 7, where box plots represent the minimum, 25th percentile, median, 75th percentile, and maximum data values collected. Several watershed areas rarely or never exceed 1 mg/L (the guideline value used by the Central Coast Region to screen for aquatic life protection (Worcester, et al., 2010)). These include the Santa Cruz Coast (304), Carmel (307), and Big Sur (308). None of these watersheds have significant amounts of commercial agricultural activity. For a number of watersheds, the 75th percentile exceeds the drinking water standard. This means that at least 25% of samples collected in these watersheds violate this criterion. These include Pajaro (305), Elkhorn Slough (306), San Antonio (314), Santa Ynez (314), and Santa Barbara Coast (315). Two watersheds have data distributions that show very high levels of impairment. These include the Salinas (309) and the Santa Maria (312), where the median value (or at least 50% of samples collected) violated the drinking water standard.

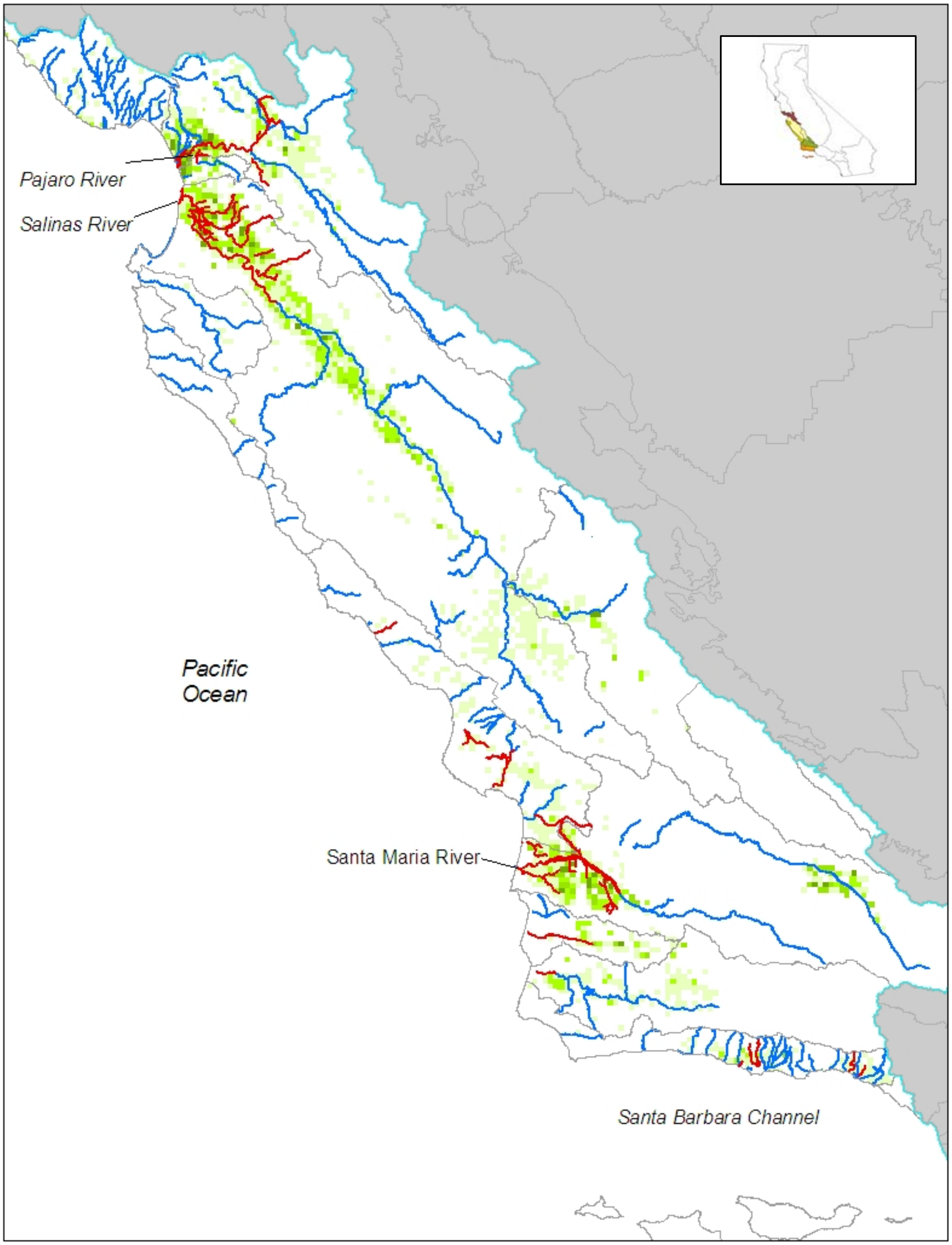


Figure 5. 2010 303(d) Listings for Nitrate in Region 3

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY NITRATE SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.

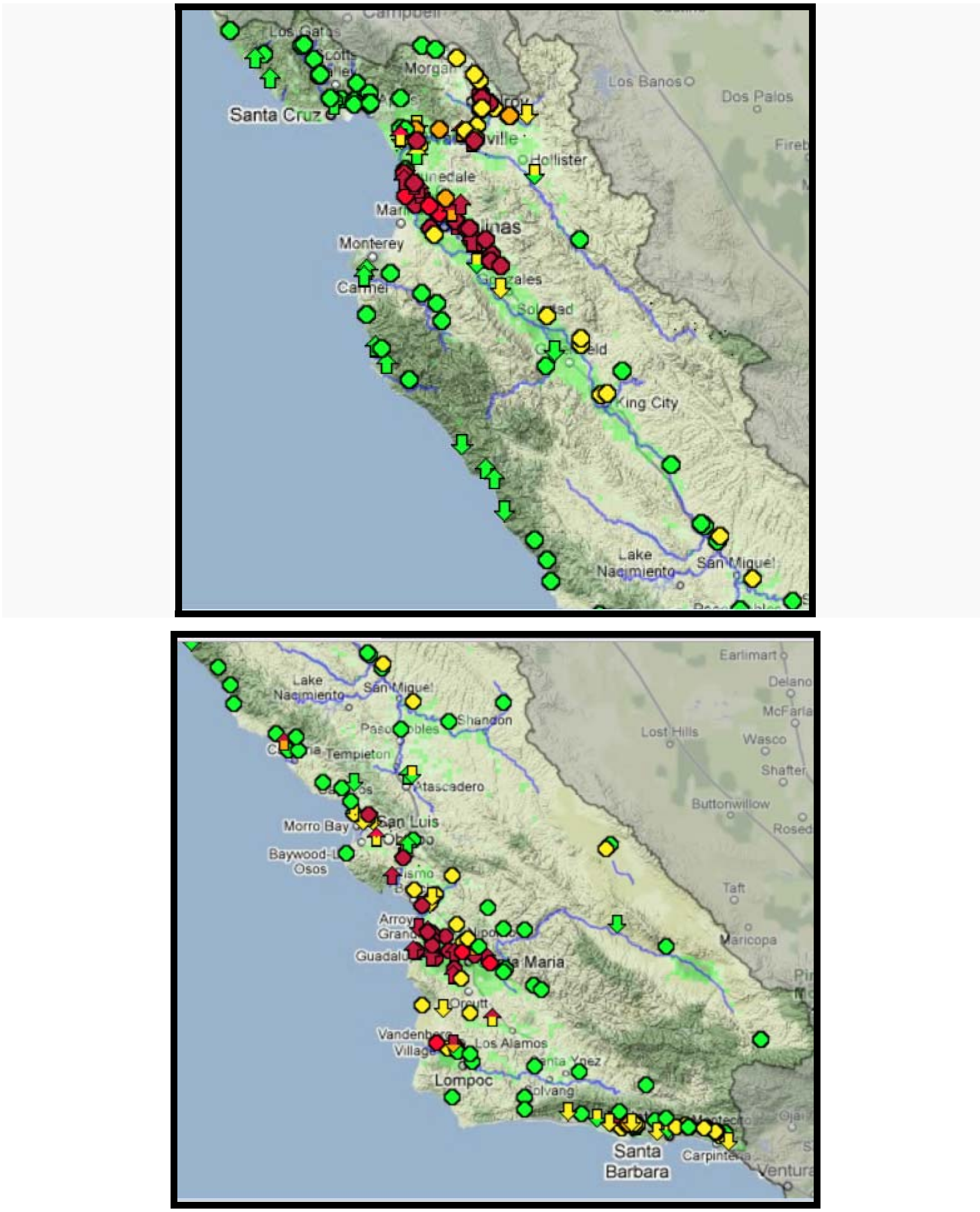


Figure 6. Nitrate (mg/L) at Central Coast Region CCAMP and CMP sites

MAPS ARE TAKEN FROM THE CCAMP WEBSITE (WWW.CCAMP.ORG)
SCORED ACCORDING TO NITRATE RULES WHERE:
IF 90TH PERCENTILE <= 1 THEN SITE COLOR = GREEN
IF 90TH PERCENTILE > 1 AND 90TH PERCENTILE <= 10 THEN SITE COLOR = YELLOW
IF 75TH PERCENTILE <= 10 AND 90TH PERCENTILE > 10 THEN SITE COLOR = ORANGE
IF 75TH PERCENTILE > 10 AND MEDIAN <= 10 THEN SITE COLOR = RED
IF MEDIAN > 10 THEN SITE COLOR = DARK RED

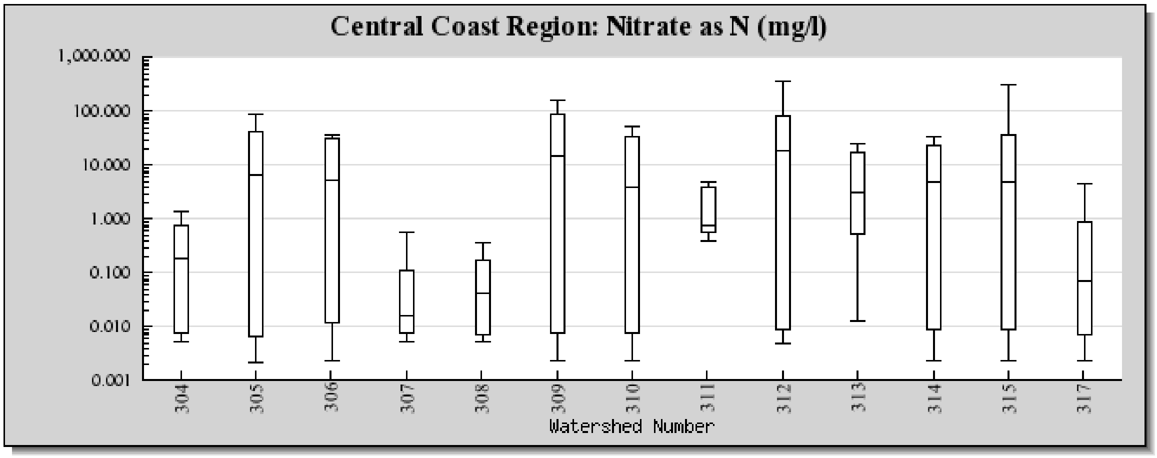


Figure 7. Nitrate (mg/L) at Central Coast Regional Hydrologic Units

BOX PLOTS REPRESENT MINIMUM, 25TH PERCENTILE, MEDIAN, 75TH PERCENTILE, AND MAXIMUM CONCENTRATION OF SAMPLES COLLECTED IN EACH HYDROLOGIC UNIT. WATERSHEDS ARE ORGANIZED FROM NORTH TO SOUTH, AND REPRESENT SANTA CRUZ COAST (304), PAJARO (305), ELKHORN SLOUGH (306), CARMEL (307), BIG SUR (308), SALINAS (309), SAN LUIS OBISPO COAST (310), SODA LAKE (311), SANTA MARIA (312), SAN ANTONIO (313), SANTA YZNEZ (314), SANTA BARBARA COAST (315), ESTRELLA (317).

Twenty-seven percent of all sites evaluated have nitrate-N concentrations that exceed the drinking water standard on average. Several of these sites have average nitrate concentrations that exceed the standard by five-fold or more. The top twenty worst sites in the Region from the standpoint of nitrate concentrations are shown in Table 3. These sites are typically in areas dominated by irrigated agricultural activity. Acres and percent of area in row crop agriculture, both in the immediate catchment and in the upstream watershed, are indicated (based on National Land Cover Database, 2001). On average, 48.4 percent of the immediate catchment area in which these sites are located are in row crop agriculture, and 27.1 percent (also on average) of the watershed area upstream of each site are in row crop agriculture. Other land uses can contribute to elevated nitrate concentrations, including orchards and vineyards, greenhouses and nurseries (prevalent in the Franklin Creek watershed), and urban landscapes. However, most of the worst quality sites in the Central Coast Region are in areas dominated by row crop agriculture, either in the near vicinity of the site or in the upstream watershed area.

Though overall acreage of irrigated agriculture can serve as an indicator of risk for nitrate contamination, it can't predict locally-scaled impacts. We have observed that discharges from even a single operation can greatly influence stream nitrate concentrations. Prefumo Creek in the San Luis Obispo watershed provides an example of this. The only significant irrigated row crop operation in the lower watershed,

Site Tag	Site Location	Major Watershed	Mean (mg/L as N)	Max (mg/L as N)	Acres row crop in near vicinity	Acres (%) row crop in upstream watershed
312ORN	Orcutt-Solomon North Fork tributary near sand plant	Santa Maria	93.7	380	498 (66.1%)	1,800 (73.3%)
312BSR	Oso Flaco Creek and Bonia School Rd.	Santa Maria	68.2	99.2	4,065 (39.2%)	4,071 (38.9%)
305MVR	San Juan Creek at Mission Vineyard Road	Pajaro	64.4	78.9	1,073 (16.8%)	1,073 (16.8%)
309BLA	Blanco Drain below pump	Salinas	62.8	130	209 (16.1%)	144,825 (6%)
312GVS	Green Valley Creek at Simas Rd.	Santa Maria	60	260	1,137 (67.3%)	8,221 (37.3%)
312OSR	Oso Flaco Creek at Highway 1 (south RR trestle)	Santa Maria	50.4	95.9	4,065 (39.2%)	4,071 (38.9%)
305PRR	San Juan Creek at Prescott Road	Pajaro	50	61.4	930 (36.8%)	2,083 (13.3%)
312ORI	Orcutt Solomon Creek @ Highway 1	Santa Maria	49.6	91.8	100 (80%)	10,568 (18.8%)
309SOS	Chualar Creek, South Branch at Old Stage Road	Salinas	43	49	1,107 (73.0%)	1,107 (73.0%)
309UQA	Quail Creek @ Old Stage Road	Salinas	43	106	547 (30.2%)	547 (5.6%)
309ASB	Alisal Slough at white barn	Salinas	42.4	94.8	659 (89.1%)	2,751 (70.7%)
312OFN	Little Oso Flaco Creek	Santa Maria	39.3	62	-	-
315FMV	Franklin Creek at Mountain View Ln.	Santa Barbara Coast	39.1	322	93 (5.5%)	93 (5.5%)
312MAB	Main Street Ditch at Bonita School Rd.	Santa Maria	38	61.5	5,326 (31.1%)	5,326 (31.1%)
312OFC	Oso Flaco Creek @ Oso Flaco Lake Road	Santa Maria	37.5	70.3	-	-
312GVT	Orcutt Creek at Brown Rd.	Santa Maria	36.8	61.8	172.6 (29.4%)	845 (6.16%)
309NOS	Chualar Creek, North Branch at Old Stage Rd.	Salinas	35.1	51	1,209(83.4%)	6,644 (35.4%)
305FUF	Furlong Creek @ Fraiser Lake Rd.	Pajaro	34.2	89.1	814 (28.4%)	2,680 (4.7%)
309ESP	Espinosa Sdlough upstream from Alisal Slough	Salinas	33.6	84.8	44 (93.4%)	20,338 (27.8%)
309NAD	Natividad Creek upstream from Salinas Reclamation	Salinas	32.6	150	111 (51.3%)	516 (9.2%)

Table 3. Sites with highest nitrate concentrations in Region 3

PERCENT AND ACREAGE OF LAND IN ROW CROP AGRICULTURE IS INDICATED, BOTH FOR CATCHMENT AND UPSTREAM WATERSHED (NLCD, 2001).

immediately adjacent to the Prefumo Creek monitoring site, was taken out of production in 2006. Nitrate-N concentrations on the creek were typically around 30 mg/L when first sampled by CCAMP in 2002. Recent sampling through 2010 shows concentrations routinely under 10 mg/L, a statistically significant decline of 64.3%. Daily loads of nitrate have also declined dramatically, from a high of nearly 400 kg/day to approximately 10 kg/day, based on monthly sampling (Figure 8). Recently (in 2010), the land was put back into production, though with an organic operation. Future data will provide an excellent comparison of two very different sets of farming practices.

Orcutt Creek in the Santa Maria watershed has the most serious nitrate pollution in the Region, with one site averaging 94 mg/L and peaking at 380 mg/L (as N). This creek drains directly into the Santa Maria Estuary, an important wildlife area. In a flow analysis completed by the CMP (CCWQP, 2009f), Orcutt-Solomon Creek was shown to typically flow between 4 and 10 cubic feet per second, including during summer months. This is a high summer flow for the size and location of this system. The flow increases through agricultural areas in the lower watershed, where the dominant discharge is from agricultural land (CCWQP, 2008b). Nitrate concentrations in the estuary downstream of this drainage are virtually always over the drinking water standard and have exceeded 50 mg/L at times.

Another sensitive estuarine area in the Central Coast Region is impacted by nitrate discharge from adjacent agricultural drainages. The Old Salinas River and Tembladero Slough are surrounded by wetland habitat and drainage from these systems directly impact two Marine Protected Areas, Moro Cojo Slough and Elkhorn Slough. These areas are discussed in more detail in Section 4 on marine impacts.

Some of the sites in Table 3 have relatively low flow in the summer time (in the vicinity of one to two cfs or less). Examples of highly polluted systems of this nature include Furlong Creek and San Juan Creeks in the Pajaro system, Quail and Chualar Creeks in the Salinas system, and Green Valley Creek in the Santa Maria system. Most fresh waterbodies in the Region with a few exceptions are required to support the Central Coast Region's municipal drinking water standard (10 mg/L NO3-N), so regardless of loading, these small system are in serious violation of Central Coast objectives.

Several major waterbodies that support important resources and diverse beneficial uses routinely violate the drinking water standard. These include the Pajaro River (in its mid-reaches), the lower Salinas River, and lower Santa Maria River. These are the three largest watersheds in the Central Coast Region. These systems support important drinking water and groundwater recharge beneficial uses, as well as multiple uses associated with aquatic life support, and nitrate concentrations are severely impairing these uses. Though there are multiple land uses in these watersheds, the areas of impairment are associated with substantial irrigated agricultural activity.

Urban land uses appear to be contributing less significantly to nitrate concentrations than are surrounding agricultural lands. The City of Salinas is a major urban area permitted for stormwater discharges with a Phase 1 National Pollutant Discharge Elimination System Municipal Permit. The City drains to several waterbodies that are tributary to Tembladero Slough. The Salinas Reclamation Canal, one of the most polluted systems in the Region, travels from agricultural land through the City of Salinas and then back through agricultural land to Tembladero Slough. Site 309ALG is upstream of the City, 309ALU is at the upper edge of the City, 309ALD is downstream of the City, and 309JON is farther downstream, once again within agricultural influence. Nitrate concentrations at these sites average 19.9, 14.0, 7.9, and 15.6 mg/L (N), respectively. Concentrations at the lower end of the City are significantly lower ($p=0.0013$) than concentrations entering the City, and lower than those farther downstream once the drainage travels back through agricultural land. However, stormwater discharge data indicate the City is still a nitrate source, and Water Board staff have already identified and eliminated one urban discharge with elevated nitrate concentrations. CMP follow-up work in this area found some nitrate loading from the urban area in winter months, but little contribution during the rest of the year (CCWQP, 2008b).

The San Lorenzo River receives stormwater runoff from one of the Central Coast's larger cities, Santa Cruz. This river also has numerous septic systems in the upper watershed. There is almost no irrigated agriculture in the San Lorenzo watershed, in fact, according to the National Land Cover Database (2001) there is none. The highest nitrate concentration measured in the San Lorenzo River at its coastal confluence site (304LOR) in almost ten years of monthly monitoring is 1.4 mg/L nitrate-N. Other urban areas are adjacent to creeks and rivers without causing substantial increases in nitrate concentrations. Atascadero, Paso Robles, Cambria, and Carmel are examples. Along the highly urbanized Santa Barbara coast, several sites that are upstream of most urban influences but below intensive agricultural activity show serious nitrate impacts. These include CMP sites on Franklin, Bell, and Glen Annie creeks (with site averages of 17.7, 21.8, and 34.3 mg/L nitrate-N, respectively). Other highly urbanized creeks in the same area but with less upstream agricultural activity, such as

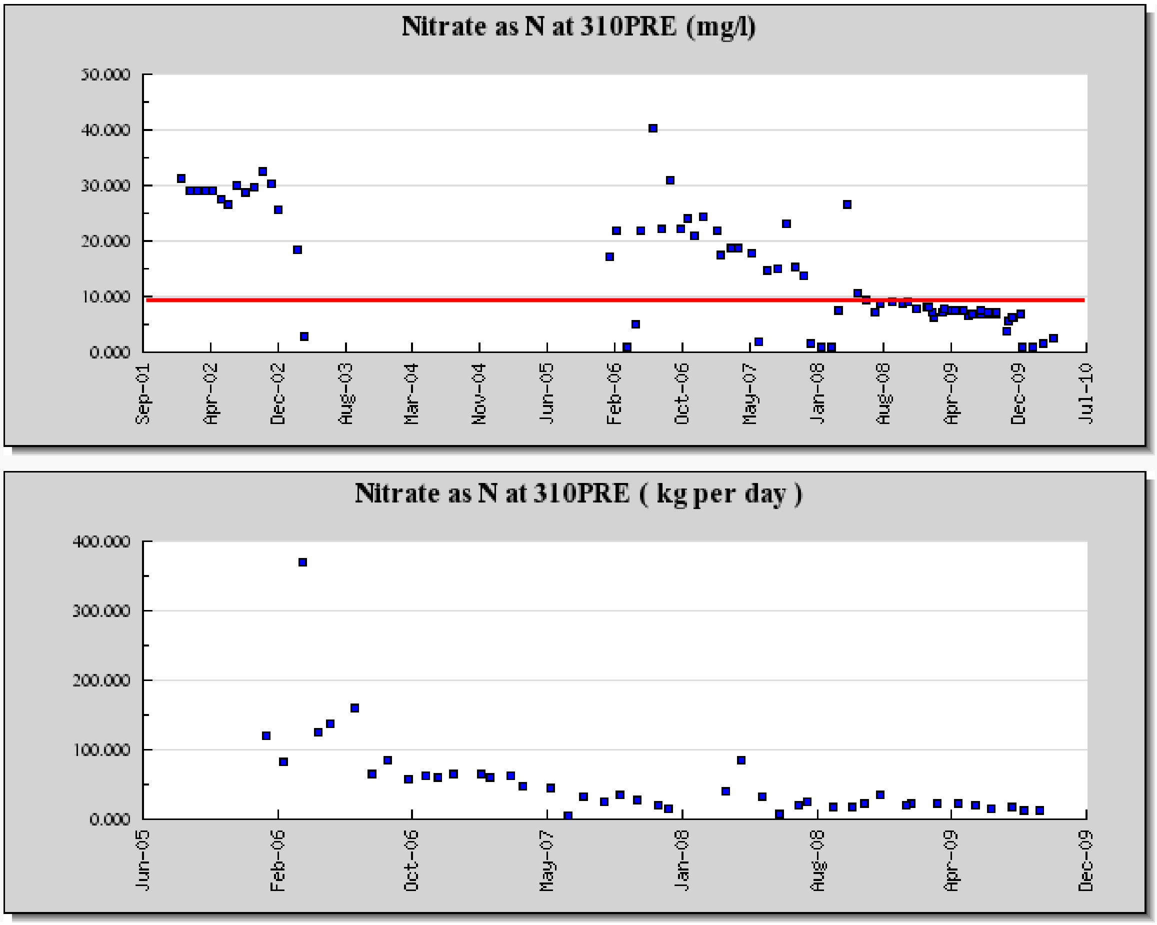


Figure 8. Nitrate-N Concentrations (mg/L) and Daily Loads (kg/day) at Prefumo Creek

LAND TAKEN OUT OF AGRICULTURAL PRODUCTION IN 2006. FLOW DATA NOT AVAILABLE PRIOR TO 2006. RED LINE INDICATES DRINKING WATER STANDARD.

Mission Creek, are much less impacted by nitrate (typically under 2.0 mg/L nitrate-N). Major urban influences on in-stream nitrate concentrations in the Central Coast Region are primarily downstream of wastewater discharges. For example, San Luis Obispo Creek (310SLV) and the Santa Ynez River (314SYF) have site averages of 17.9 and 10.9 mg/L nitrate-N (respectively) below treatment plant discharges.

With a few exceptions, most sites in the Central Coast Region that are considered in “good condition” according to the rules established in Appendix A (average nitrate concentrations under 1.0 mg/L nitrate - N) have wet season nitrate averages that are higher than dry season averages. Of the 81 sites evaluated with means less than 1.0 mg/L, 80% have average dry weather nitrate concentrations that are lower than wet weather nitrate concentrations. Increased concentrations in winter at these typically pristine sites may result when rain water moves nutrients off of the land into surface waters. Conversely, most sites that are considered in "slightly impacted" or worse condition (average nitrate concentration greater than 1.0 mg/L- N) have dry season averages that are higher than their wet season averages. This can result where irrigation discharges (or in some areas surfacing contaminated groundwater) are a primary source of water. In winter, water sources to stream systems are primarily from storm water, not from irrigation runoff. Of the 133 sites with elevated nitrate concentrations, 79% have average dry weather nitrate concentrations that are higher than average wet weather nitrate concentrations. Where average concentrations exceed 30 mg/L nitrate-N, 89% of sites have dry weather concentrations that are higher than wet weather concentrations.

Time-series data from sites with substantial agricultural influence typically show a strong pattern of seasonality, with dry season concentrations much higher than wet season concentrations. An example of this is seen on the Salinas River at Davis Road (309DAV) (Figure 9), where average wet weather nitrate concentration is 7.32 mg/L NO3-N and average dry season concentration is 18.12 mg/L NO3-N.

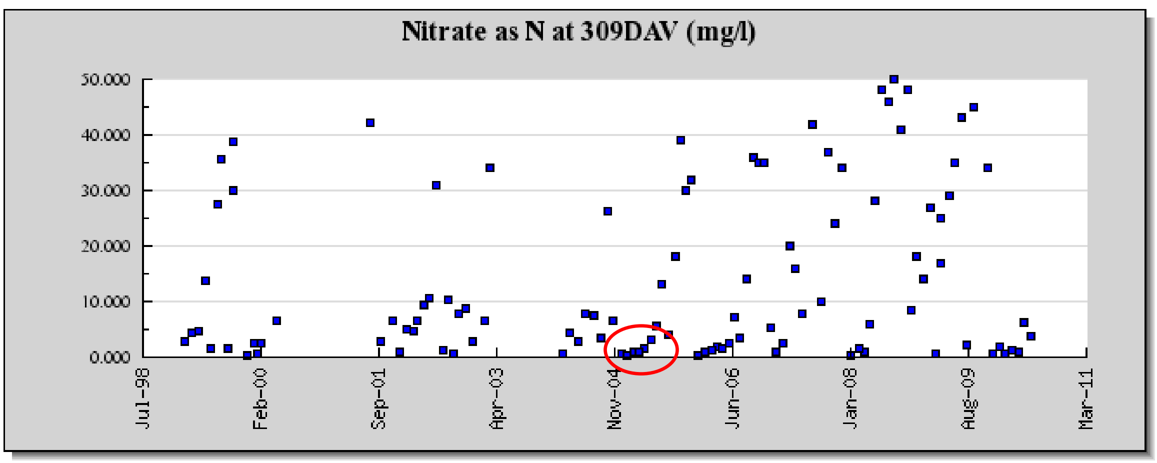


Figure 9. Time series of nitrate-N concentrations (mg/L) on the Salinas River at Davis Road (309DAV)

AN EXAMPLE OF LOW WINTER NITRATE CONCENTRATIONS IS CIRCLED IN RED

Toxicity and Pesticides

Both the CMP and CCAMP programs rely heavily on toxicity bioassays to screen for chemical problems. Neither program tests directly for pesticides as part of routine monitoring. The levels of toxicity to test organisms found in ambient waters of the

Central Coast far exceed anything allowed in permitted point source discharges to surface waters. The California Toxics Rule allows only one acute and one chronic toxic hit every three years on average for permitted discharges to surface waters. We have drainages in agricultural areas of the Region that are toxic to test organisms nearly every time they are measured.

Region-wide, CCAMP and the Cooperative Monitoring Program have conducted toxicity monitoring in 80 streams and rivers in the Region. The CMP sites are particularly data-rich, with four samples collected per year since the mid 2000’s (twice during wet weather, twice during irrigation season). At 16% of all sites, no toxic effects were observed whatsoever. Some measure of lethal effects (as opposed to growth or reproduction) has been observed at 65% of the waterbodies monitored. CCAMP does not sample for toxicity at all sites, but rather at sites in areas of most intensive land use (either because of agricultural or urban actiities). CMP sites are only located in impaired waters associated with agricultural activity (though even these sites may have unavoidable urban influences). Though 65% of waterbodies sampled have shown lethal effects, these waterbodies tend to be located in areas where toxicity is most likely to occur. Nevertheless, toxicity is a widespread problem in the Central Coast Region (Figure 9).

CCAMP and the CMP undertake several types of toxicity monitoring. Water is sampled for toxicity to an invertebrate species (usually *Ceriodaphnia dubia*), a fish species (usually *Pimephales promelas*), and an algae (usually *Selenastrum capricornutum*). Sediment is sampled for toxicity to an invertebrate (*Hyalella azteca*). Different tests are indicative of different types of problems. For example, sediment toxicity usually indicates chemicals that adhere to sediment, such as pyrethroid pesticides. Water toxicity is typically indicative of more soluble chemicals, like diazinon. Some chemicals, like chlorpyrifos, can create toxic effects in both sediment and water. Some pesticides are more toxic to fish than other chemicals are, again like some of the pyrethroid pesticides. Toxicity to algae may imply presence of herbicides. Detailed information on toxicity sampling, references, past research findings, and toxicity references is available in Appendix C.

A number of published studies have already linked invertebrate toxicity in the Central Coast to chlorpyrifos and diazinon (in water) and to chlorpyrifos and pyrethroids (in sediment) (Anderson et al., 2003; Anderson et al., 2006a; Anderson et al., 2006b, Anderson et al., 2010). A summary of this work can be accessed in "Toxicity Research Findings" in Appendix C. Staff has used data collected by these researchers, by CCAMP and by the CMP to evaluate all Central Coast waters for impairment based on toxicity. As a result, fifteen waterbodies are on the 2010 List of Impaired Waters for both water column and sediment toxicity, and an additional 14 waterbodies are on the List for water toxicity alone. The majority of these listings are in the lower Salinas River (12 listings) and the lower Santa Maria River (10 listings). Figure 10 shows the location of waterbodies listed for toxicity in the Central Coast Region. In addition, the List includes 13 listings for Diazinon, and 26 listings for Chlorpyrifos. The Santa Maria and Oso Flaco watershed area has 5 chlorpyrifos listings, and 2 diazinon listings. The Salinas area has 7 chlorpyrifos listings and 8 diazinon listings. In combination, 73% of all toxicity listings and 56% of organophosphate pesticide listings are in these two priority areas.

Acute water column toxicity to Ceriodaphnia (invertebrate) was found at 50% of sites sampled, and 36% of all sites were severely toxic. Of these severely toxic sites (defined by rules described in Appendix A), 90% are in the lower Santa Maria and Salinas areas. Fifteen sites have been toxic to invertebrates in water tests virtually every time they are sampled; the majority of these (13 sites) are in the lower Salinas area.

CMP conducted follow-up studies at agricultural sites in the lower Salinas and Santa Maria watersheds to clarify the sources of the extensive water column invertebrate toxicity identified by the program in those two high priority areas. The first follow-up study documented a strong relationship between concentrations of diazinon and chlorpyrifos pesticides and water column toxicity in the lower Salinas and Santa Maria rivers (CCWQP, 2008a). These findings verify those of Hunt et al. (2003) and Anderson et al. (2003, 2006). Organophosphate (OP) pesticides were found at all agricultural program sites at least once and at 70% of the sites on all four sampling events. Although seven different organophosphate chemicals were detected, only chlorpyrifos and diazinon were at concentrations sufficient to cause acute toxicity. In this study, 53% of all samples collected were acutely toxic, and 39% of samples had OP concentrations high enough to explain the toxicity. In 35 of the 38 samples with 100% mortality, the mortality was explainable by elevated concentrations of OP pesticides. Diazinon was most commonly elevated in the Salinas watershed, whereas chlorpyrifos was more typically elevated in the Santa Maria watershed.

The second follow-up study (CCWQP, 2010a) included sampling projects in 2007 and 2008, some conducted in collaboration with Dow Agrosciences. This study had similar findings as the first, although it included sampling from areas outside the Salinas and Santa Maria areas, and sampled for a broader suite of pesticides and herbicides. This study also found that diazinon and chlorpyrifos were very commonly encountered at sites in the Salinas and Santa Maria areas, and were most commonly detected at levels likely to cause toxicity, but it also found malathion and methylmyl at concentrations that could cause toxicity. Malathion detections were common, and at times at levels known to be toxic, which was never found in the first study. This report also found that outside the Salinas and Santa Maria areas, OPs were not consistently detected (though the sample size was small). The second follow-up report noted a decline in maximum concentrations of diazinon and chlorpyrifos in the Salinas area, and in chlorpyrifos in the Santa Maria area. Other pesticide maximums had increased, including dimethoate and malathion in the Salinas area, and diazinon, cichlorvos, dimethoate and malathion in the Santa Maria area (though in some cases only slightly). These observations are anecdotal, and do not support trend analysis.

According to the 2006 Department of Pesticide Regulation (DPR) Pesticide Use Report, many more pounds of diazinon are applied in Monterey County than elsewhere in the Region (or State), particularly to leafy vegetable crops. Chlorpyrifos is applied most heavily to broccoli, but also to wine grapes, in both Monterey and Santa Barbara counties. Statewide use of OP pesticides in both agricultural and non-agricultural applications has dropped significantly over the past 10 years, from a high of over 17 million pounds to under 5 million pounds. The applications of diazinon and chlorpyrifos have declined statewide by more than half (DPR, 2007). In a recent DPR study (Starner, 2009) of diazinon use in the Central Valley, Imperial Valley and Central Coast, the Salinas Valley was found to account for 45 to 50 percent of all statewide use during spring and summer months, and irrigation season use was characterized as "very high", with most applications on lettuce. Detection frequencies were greater than 95% in the Salinas area. This study did not find diazinon use to be declining in the Salinas and Pajaro areas. Diazinon use in the Santa Maria area was considered moderate.

Sediment toxicity is also prevalent in agricultural areas of the Central Coast Region, with 64% of all sites sampled showing some toxicity (measured as survival), and all but three of the most toxic 23 sites occurring in the lower Salinas and Santa Maria watersheds. Based on several published studies, sediment toxicity appears to be highly related to pyrethroid pesticides and chlorpyrifos, at least in the lower Salinas and Santa Maria rivers (Anderson, et al., 2006a, 2006b, 2010; Phillips, et al, 2006). In a comparative study of lagoon water quality in the Pajaro, Salinas and Santa Maria systems, the Santa Maria River lagoon proved to be particularly toxic (Anderson et al., 2010), with persistent toxic concentrations of pyrethroid and organophosphate pesticides and depauperate benthic communities in lagoon sediments.

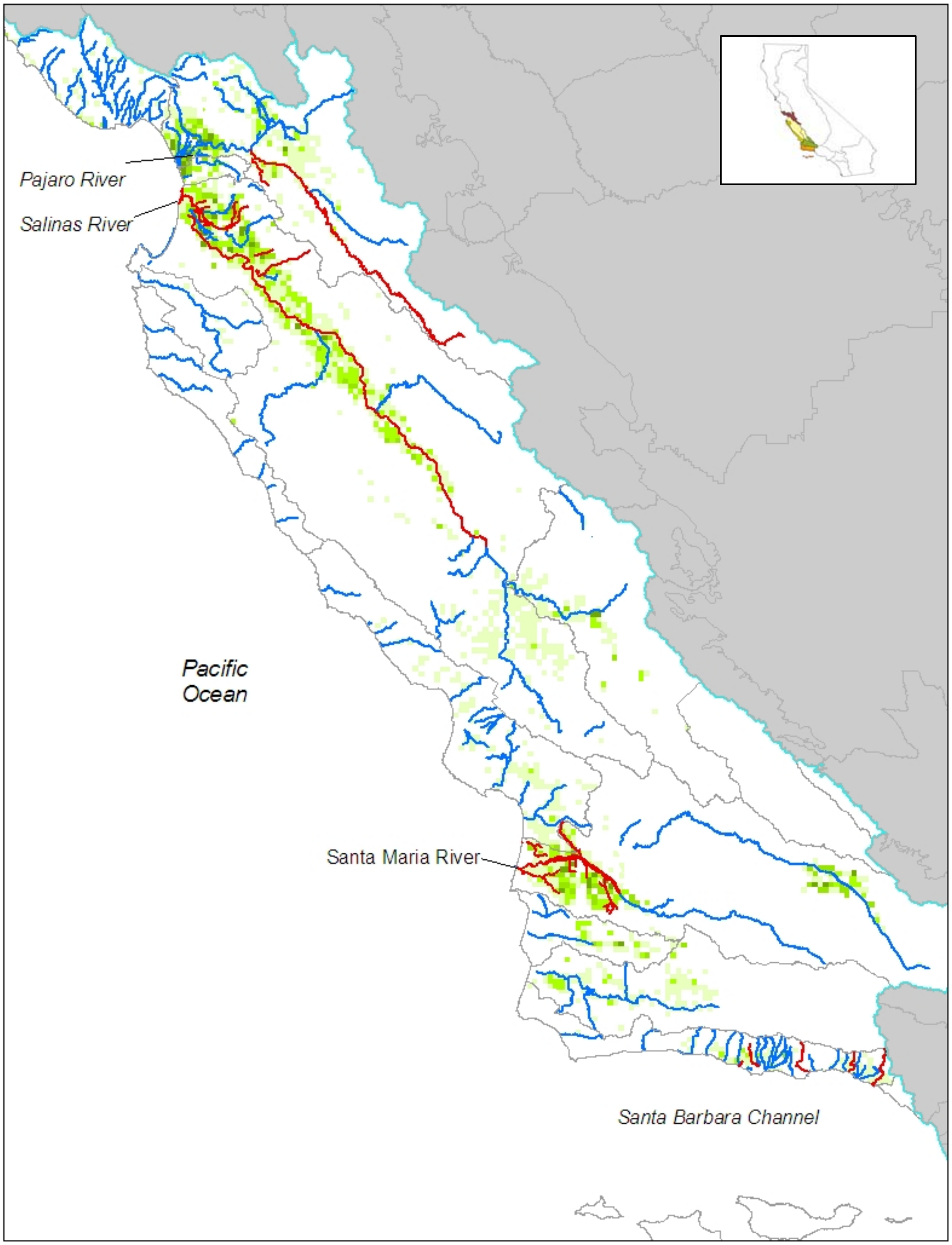


Figure 10. 2010 303(d) Listings for Sediment and Water Toxicity

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY TOXICITY SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.

Ng et al. (2008) describes finding significant toxicity in sediments coming out of agricultural land above the City of Salinas, as well as within the City limits, and shows that urban chemical signatures were somewhat different than those from agricultural areas. In a statewide study of four agricultural areas (Salinas, Sacramento, San Joaquin, and Imperial valleys), conducted by the Department of Pesticide Regulation, the Salinas study area had the highest percent of sites with pyrethroid pesticides detected (85%), the highest percent of sites that exceeded levels expected to be toxic (42%), and the highest rate (by three-fold) of active ingredients applied (113 lbs/square mile) (Starner, 2006). More details on this research, and references to additional technical papers, can be found in Appendix C.

Toxicity to algal and fish test organisms is less commonly encountered in the Central Coast region than toxicity to invertebrates. Overall, lethal effects for fish were the least frequently encountered toxic effect. Acutely toxic effects to fish were found at 28.5% of sites sampled, and 6.5% of sites were very toxic. The CMP found repeated toxicity to fish in several tributaries in the Santa Maria watershed and at several sites along the main stem of the Salinas River, from Greenfield to Spreckels. Several other sites had more than one toxic sample, including Prefumo Creek (310PRE) in San Luis Obispo and Tequisquita Slough (305TSR) in the Pajaro watershed (CCWQP, 2010a).

Toxic effects to algae were found at 44% of sites, with 11% of sites severely toxic. Toxicity to algae shows a different pattern than most other contaminants examined in this report. In addition to toxicity in the lower Salinas and Santa Maria areas, algal toxicity was also prevalent in some of the Santa Barbara area streams (Glenn Annie, Franklin, Bell), the Pajaro watershed (Furlong Creek, San Juan Creek, lower San Benito River, Pajaro River at Murphy's Crossing, and Harkins and Watsonville sloughs), and in the lower Santa Ynez River. This may suggest other sources than runoff from irrigated agricultural fields, such as roadway maintenance, creek channel clearing, or other activities involving herbicides. CCAMP field staff has observed direct spraying of herbicides on agricultural channels for weed abatement purposes.

Other Parameters of Concern

Turbidity - Turbidity in a healthy creek system in the Central Coast Region is typically very low during the dry season (under 5 NTU), and though it can be elevated during rain events it typically drops back down to low flow conditions relatively rapidly.

For example, all coastal confluence sites in the relatively undisturbed 308 Hydrologic Unit (Big Sur Coast) have turbidity levels that remain below 5 NTU as a median, with most sites closer to 1 NTU.   These sites also typically remain under 20 NTUs at the 90th percentile. These conditions exist in spite of watershed disturbance from wildfire, because sediment typically moves into stream systems only during active rain events.

Waters that exceed 25 NTUs can reduce feeding ability in trout (Sigler et al., 1984). Elevated turbidity during the dry season is an important measure of discharge across bare soil, and thus can serve as an indicator of systems with heavy tailwater discharge. Many of the sampling sites in areas dominated by agricultural activities have sustained turbidity throughout the dry season, in some cases greatly exceeding 100 NTU as a median.

CCAMP staff evaluated whether sustained turbidity was present at monitoring sites by examining median turbidity values. Ninety-three percent of all sites with a median turbidity value exceeding 100 NTUs were in the lower Salinas and Santa Maria areas. The worst of these sites, on Chualar Creek (309NOS) had a median value which exceeded 3000 NTUs, the limit of the turbidity probe. Waters listed as impaired by turbidity on the 2010 303(d) List are shown in Figure 11.

Water Temperature - Water temperature becomes elevated when creeks are not adequately shaded and solar exposure is high. Low flow and wide sandy stream bottoms also contribute to water heating. Twenty-one degrees Celsius is considered at the upper end of the optimal range to support steelhead trout (Moyle, 1976). Though water temperature is problematic in many of the same areas of the lower Salinas and Santa Maria as other parameters examined, there are several additional areas of concern. These include the lower Santa Ynez and tributaries, middle reaches of the Salinas watershed, and several smaller creek systems like Huasna, Jalama and San Lorenzo Creek. Waters listed as impaired by water temperature on the 2010 303(d) List are shown in Figure 12.

Riparian cover helps maintain water temperatures. As an example, Orcutt Creek has lost most of its shading in its lower reaches as a result of channel modification in agricultural areas. It is one of the many waterbodies that are listed as impaired by high temperatures on the 2010 303(d) List of Impaired Waters. Unlike some small drainages, flows remain relatively high (typically ranging between 4 and 10 cubic foot/second (cfs)) through the summer (CCWQP, 2009f). Agricultural discharges to the creek are commonly observed by field staff in this reach. In spite of higher flow, temperatures frequently range between 20 and 25^{o}C in summer months. Upstream, where vegetation is still intact (312ORB) but flow is lower (with baseflow usually less than 1 cfs), temperatures typically remain under 20°C. Similarly, in the next major watershed to the south, temperatures on lower San Antonio Creek typically stay below 20°C in spite of much lower instream flow. The riparian corridor on San Antonio creek is mature and intact (CCAMP, 2010a).

Un-ionized Ammonia - Water quality impairment associated with ammonia is nowhere near as widespread in the Central Coast Region as is that associated with nitrate. However, when ammonia is elevated it can be extremely toxic to fish, particularly to salmonids, and thus is of considerable concern. Un-ionized ammonia is the most toxic form of ammonia; it increases in concentration relative to ammonium as pH and temperature increases. The general objective for un-ionized ammonia in the Central Coast Water Quality Control Plan is set at a level that is protective of salmonid populations (EPA, 1999). All but two of the 26 sites most impaired by un-ionized ammonia are in the lower Salinas and Santa Maria watersheds, although several sites in the Pajaro watershed are also in serious condition (at Miller's Canal (305FRA), San Juan Creek (305SJA), and Tequisquita Slough (305TSR)). Nineteen waterbodies are listed as impaired because of elevated un-ionized ammonia concentrations; the majority of these are located in the lower Santa Maria River (7 listings) and lower Salinas River (8 listings) in areas heavily impacted by agriculture. Waters listed as impaired by un-ionized ammonia on the 2010 303(d) List are shown in Figure 13.

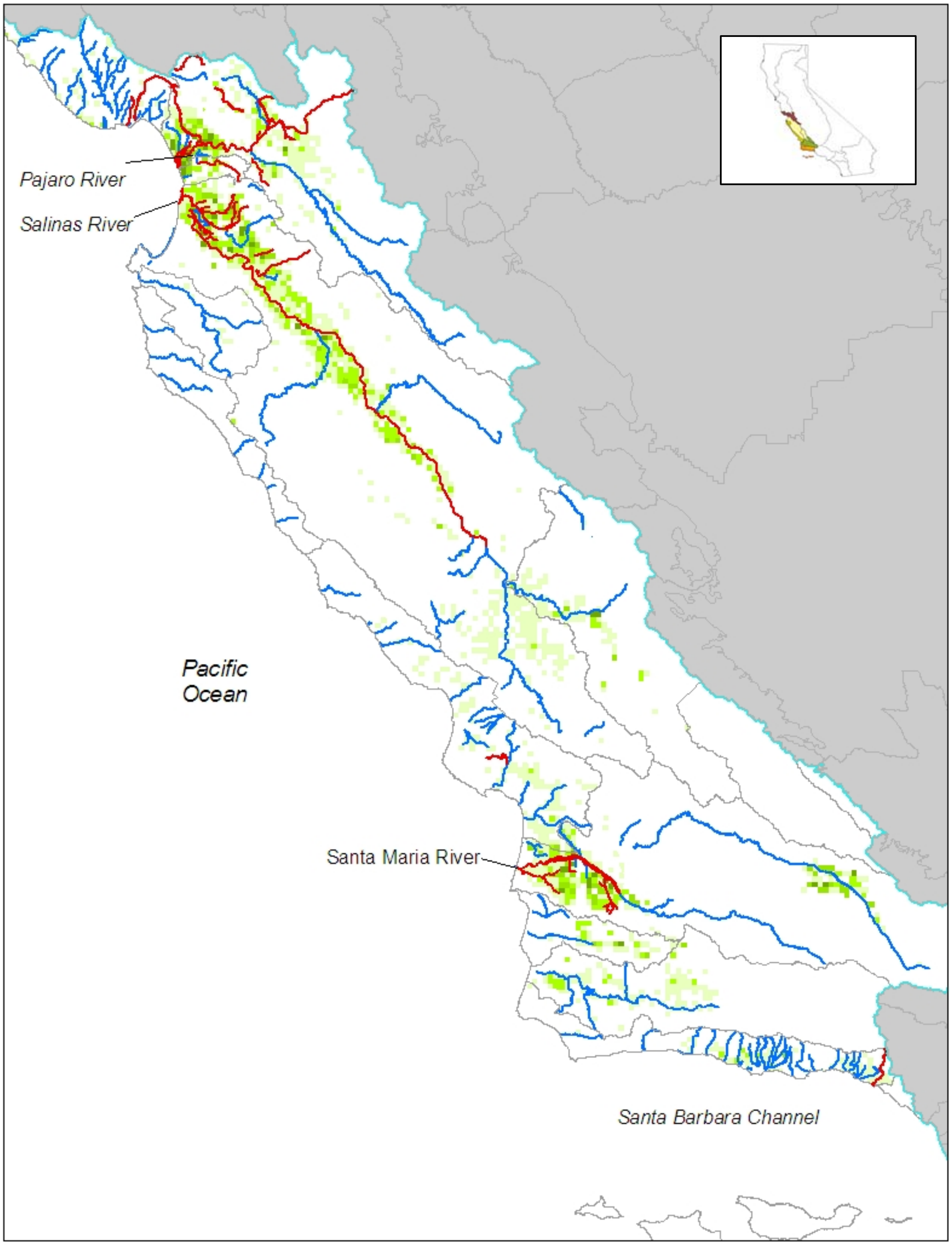


Figure 11. 2010 303(d) Listings for Turbidity (NTU)

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY TURBIDITY SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.

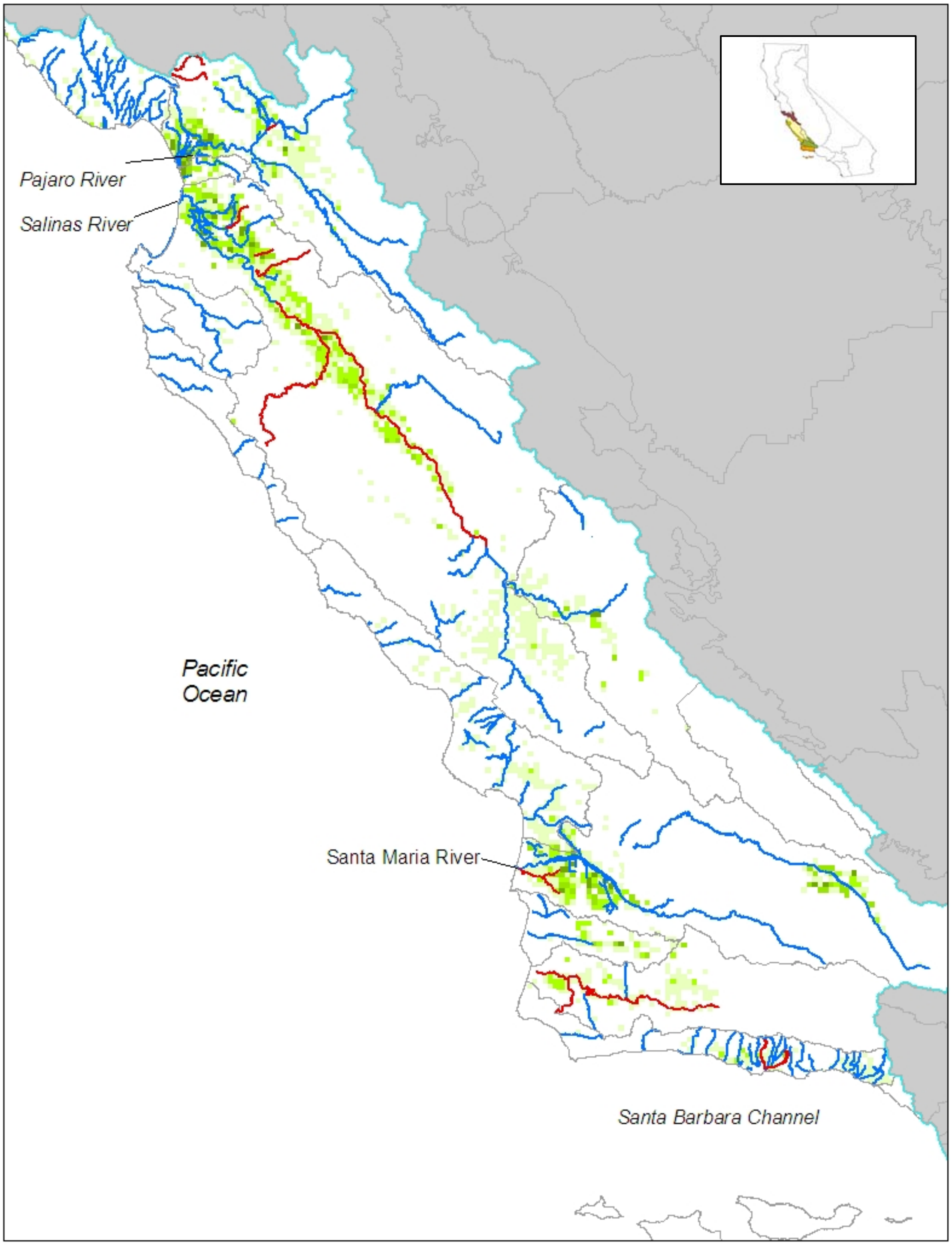


Figure 12. 2010 303(d) Listings for Water Temperature(C)

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY WATER TEMPERATURE SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.

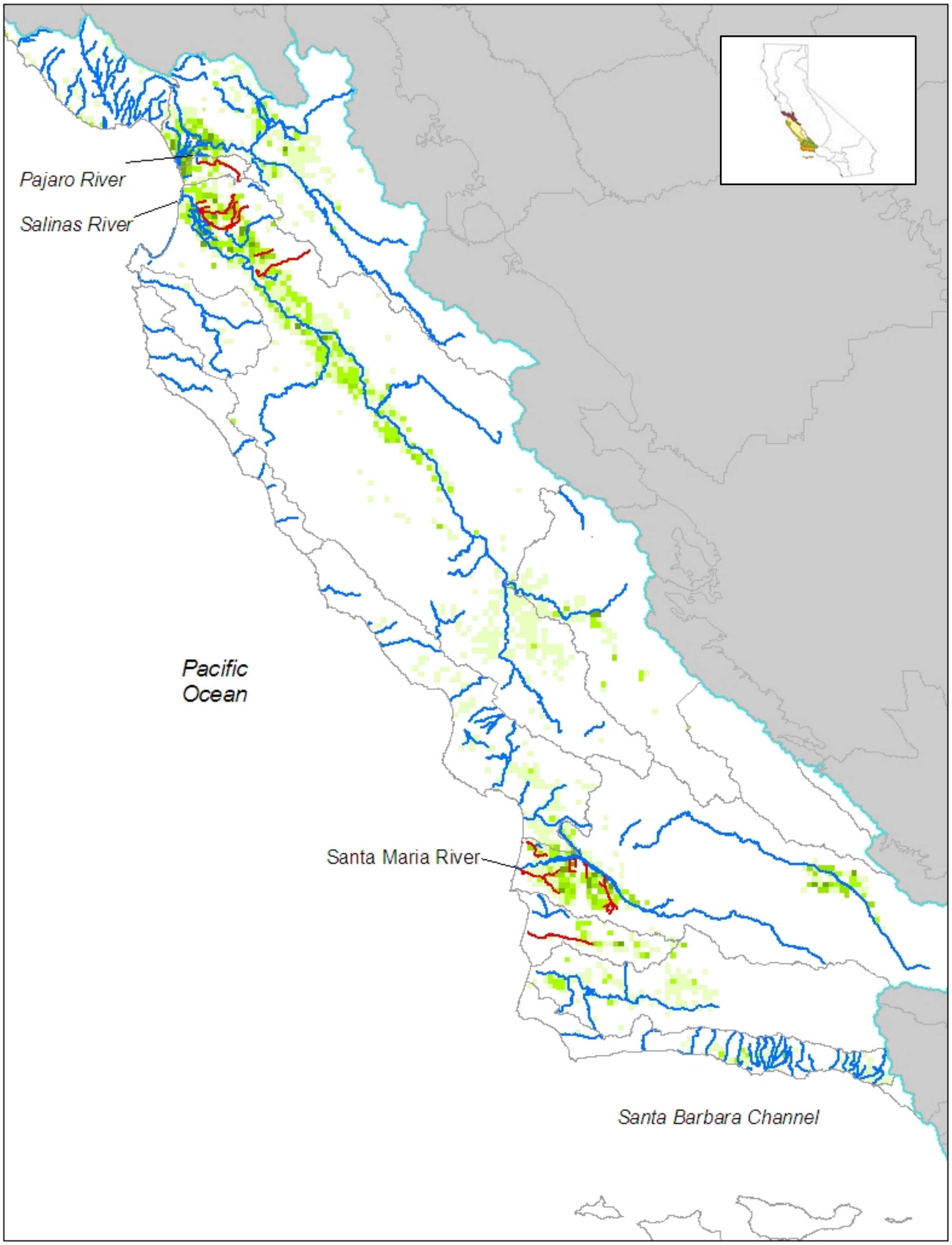


Figure 13. 2010 303(d) Listings for Un-ionized Ammonia (mg/L as N)

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY UN-IONIZED AMMONIA SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.

Water Quality Trends

Time is required to show change in environmental data, because of the inherent variability in the environment, seasonality, and because changes in land management do not necessarily result in immediate water quality change. Both CWP and CCAMP are designed to allow for detection of statistical trends over time at the sub-watershed scale. Placement of sites at the lower end of tributary watersheds allows managers to relate changes in water quality to specific actions taken by growers or other dischargers in specific drainage areas. Both programs monitor fixed sites on a monthly basis. This design provides sufficient sample size to eventually allow for trend detection, although it can take five or more years to show change, depending on the variability of the data and the amount of change. However, we have been able to show statistically significant change at a number of sites.

Our ability to detect change in stream systems and associate it with changes in land management is often confounded by climatic variability. For example, during the period of record for the CMP program, winters of 2004-05, 2005-06, 2009-10, and 2010-11 were wetter than average years, and 2006-07, 2007-08, and 2008-09 were considered drought years. Increased instream flows can dilute chemical concentrations resulting in lower concentrations, but may at the same time increase loading of the chemical (concentration times flow), and the opposite may also be true. In wet years, increased movement of fines and associated pollutants during winter months may result in increased concentrations of some pollutants during the wet season, but lower concentrations during the dry season (and again, the opposite may also be true). Any trends in concentration or loading should be considered this context. For these reasons, it is important to evaluate change at trend sites over longer time periods and multiple climatic patterns for both concentration and load, to understand the basis for observed trends.

The CCWQP developed a briefing on trends associated with CMP data (CCWQP, 2009a). They employed a non-parametric approach that evaluated data for overall trends and for trends in dry and wet season data. They found that 18 of 27 sites in the lower Salinas and Santa Maria watersheds showed statistically significant decreases in dry season flow over the first five years of the program. Most of these sites are in areas heavily influenced by irrigated agriculture, so it is possible that flows dropped in response to reductions in agricultural tailwater volume or other discharges.

This analysis included data from 2005 through 2009. During this same period, significant declines in flow were seen at other sites in the Region not influenced by agricultural discharges, presumeably because of changes in climatic conditions from above average rainfall years to drought years. So, though these initial trends observed by the CMP were encouraging, they can not be conclusively attributed to reductions in tailwater volume.

The CMP analysis showed two sites in the lower Santa Maria area with significant improvements in nitrate concentration (Green Valley Creek (312GVS) and Oso Flaco Creek (312OFC). Both of these sites also showed declining flow, implying a significant load reduction has occurred. These trends are not confirmed by more recent CCAMP change analysis. The CMP analysis also found that concentrations at two sites were getting worse (Natividad Creek (309NAD) in both wet and dry seasons, and Salinas River at Chualar (309SAC) during the wet season only).

The CMP analysis also evaluated turbidity for change. In pristine systems turbidity is typical only during rain events. In some sites heavily dominated by tail water, turbidity is elevated throughout the summer. Four sites on the main stem of the Salinas River (from Greenfield to Spreckels) were identified with significant increasing trends in turbidity during the dry season. Decreasing turbidity trends were noted at sites on Main Street Canal and Bradley Channel in the Santa Maria watershed.

CCAMP has evaluated change using a simple two group comparison (t-test) with transformations to address non-normal data distributions, and also using a Mann-Kendall non-parametric trend analysis. We looked for concurrence between the two tests for compelling evidence of change. A number of sites show change over the period of time they have been sampled. We have included evidence of change as arrow icons in our CCAMP website mapping approach (www.ccamp.org), also visible in Figure 6.

The most notable area-wide improvements in nitrate concentrations are occurring along the Santa Barbara coastline. A number of drainages monitored there are showing statistically significant improving trends, though only two of these sites are heavily impacted by agricultural activities (315BEL, 315FRC). Other sites that are improving and that have considerable agricultural influence include San Antonio Creek (313SAI), Chorro Creek (310CCC), and Prefumo Creek (310PRE). It should be noted that discharges to Chorro Creek have changed recently due to upgrade of the California Men's Colony treatment plant that discharges to the creek. Also, the single agricultural operation on the Prefumo Creek drainage was halted awaiting urban development (discussed above). Changes on these two creeks are likely impacted by these actions.

Franklin Creek in Santa Barbara County is a highly polluted waterbody that is showing trends in the right direction. In this case, the area where the nitrate problem arises is dominated by nurseries and greenhouses. In 2002, nurseries in the watershed were required by the Central Coast Water Board to cease discharging to the creek or obtain an NPDES permit. All growers opted to cease discharging. Since that time, average concentrations have dropped significantly, from around 30 mg/L to approximately 20 mg/L (as N) (Figure 14). Further progress may be impaired by groundwater surfacing near the sampling site that is high in nitrates from activities in the watershed.

Our analysis of nitrate data indicates that a number of sites in poor condition are getting significantly worse in terms of concentrations, not better. These locations include three sites on Orcutt Creek (312ORB, 312ORC,312ORI), the Santa Maria Estuary (312SMA), Old Salinas River (309OLD), and Arroyo Grande Creek (310ARG). Most of these sites are located in the lower Salinas and Santa Maria watersheds, our high priority areas for TMDL development. However, some sites are showing statistically significant reductions in flow volumes, which have implications for overall load. For example, nitrate concentrations at Orcutt Creek (312ORC), just above the point where it enters the Santa Maria Estuary, have increased significantly since CCAMP sampling began in 2000 (Figure 15). CMP data also shows a statistically significant decline in flow at this site since the Cooperative Monitoring Program for Agriculture began monitoring there in 2005 (Figure 16). Instantaneous loads are trending downward but are not

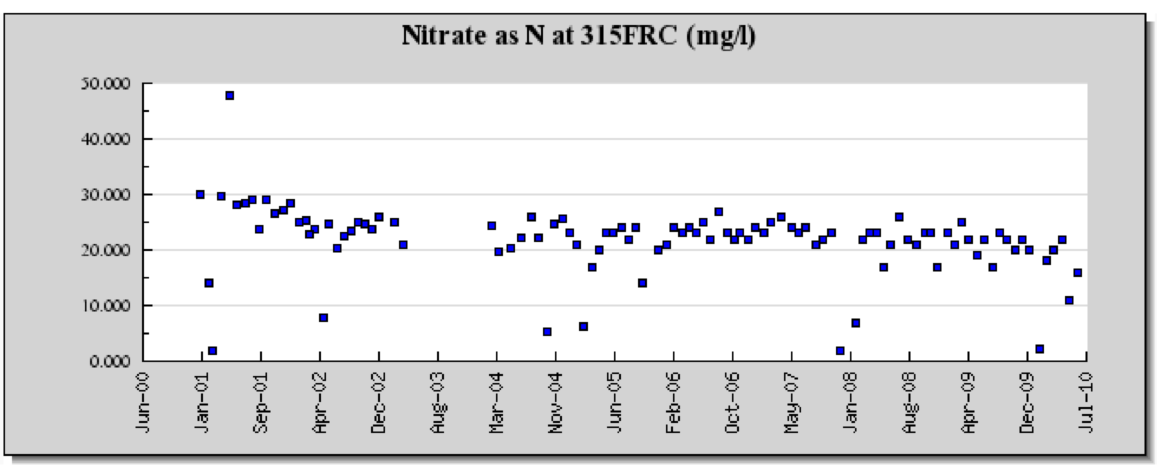


Figure 14. Nitrate-N Concentrations (mg/L) at Franklin Creek (2001-10)

WATER BOARD ORDER TO CEASE DISCHARGING OCCURRED IN 2002. DECREASE IS STATISTICALLY SIGNIFICANT (p = 0.0054).

significant. Other locations that show a significant reduction in nitrate load include Quail Creek (309QUA), Green Valley Creek (312GVS), Espinosa Slough (309ESP) and Blanco Drain (309BLA), all in the lower Salinas and Santa Maria areas. Note that this analysis includes both dry and wet season data. Two sites show clear evidence of increasing turbidity. These include the Santa Maria River at the estuary (312SMA) (Figure 17) and the Prefumo Creek site (310PRE) where nitrate has improved and agricultural operations were ceased. There is a considerable amount of new construction in this watershed which could contribute sediment to the creek. Several sites on the Pajaro River system show significant decreases, including two sites on the main stem (305THU and 305CHI) and one on lower Llagas Creek (305LLA).

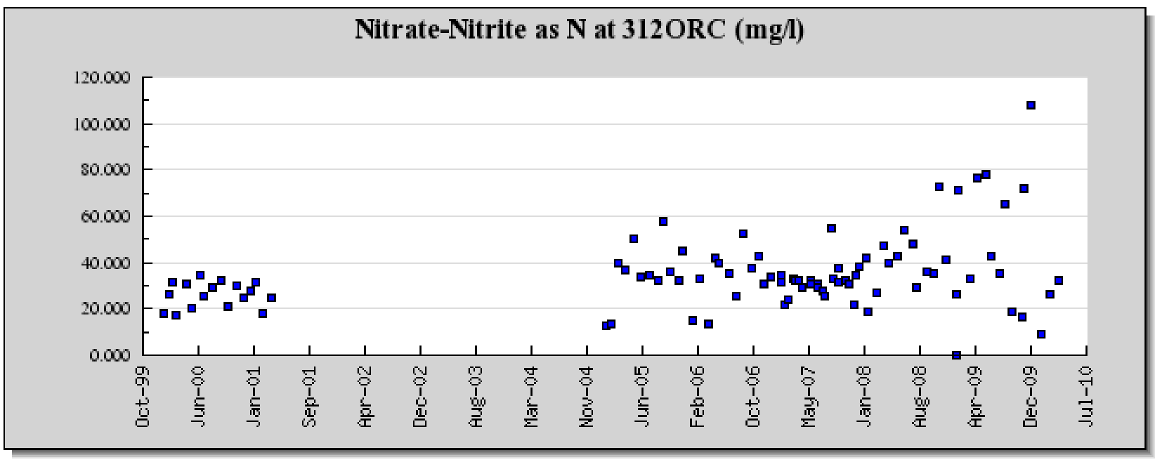


Figure 15. Nitrate (mg/L-N) at Orcutt Creek (312ORC)
DATA IS PRIMARILY FROM CMP, BUT INCLUDES EARLY CONCENTRATION DATA FROM CCAMP (2000)

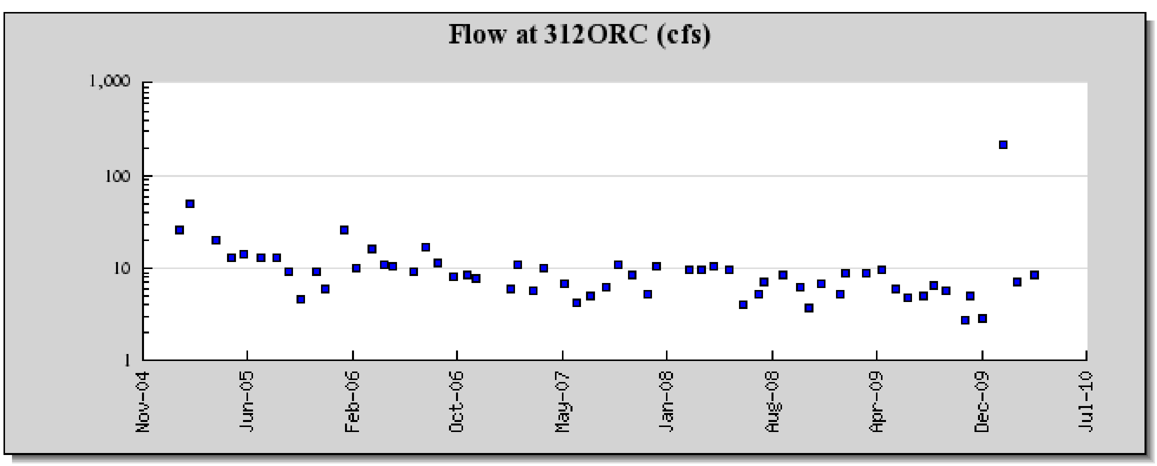


Figure 16. Flow (cubic feet per second) at Orcutt Creek (312ORC)
FLOW DATA IS FROM CMP; FLOW IS ON LOG SCALE

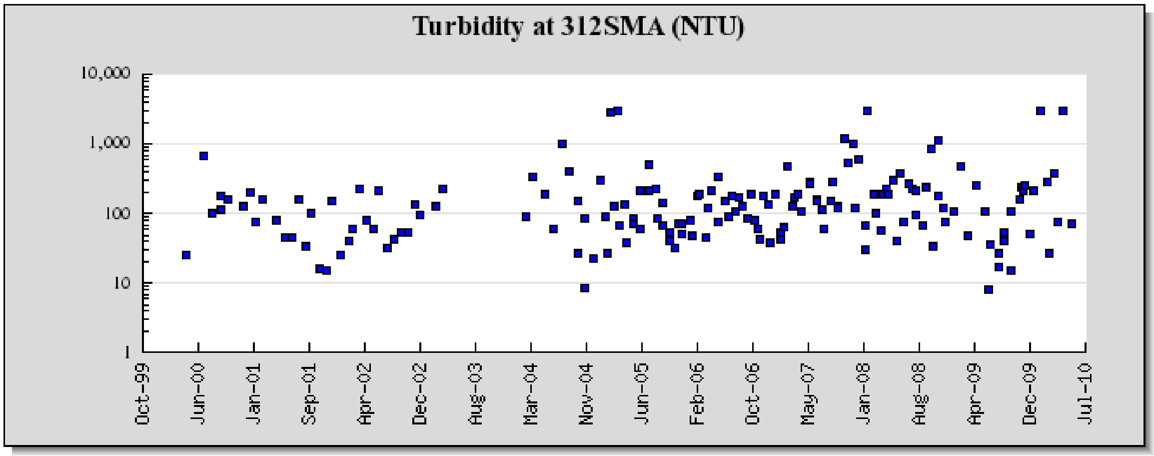


Figure 17. Increasing turbidity (NTU) at the Santa Maria Estuary
DATA FROM BOTH CCAMP AND CMP. NOTE THAT TURBIDITY (NTUS) VALUES ARE EXPRESSED ON A LOG SCALE

Because toxicity is sampled less frequently (four times per year) than other parameters (monthly) through the CMP, statistical change in toxicity is less likely to be detected than in conventional parameters. A few sites show indications of improvement in water toxicity to invertebrates, including Espinosa Slough (309ESP) and the Salinas Reclamation Canal at Jon Rd (309JON). The Espinosa Slough site has extremely toxic sediment, and diminishing toxicity in water may reflect a change from use of soluble organophosphate pesticides like diazinon to less soluble pesticides like pyrethroids (which are more toxic in sediment). Toxicity to fish appears to be getting worse on the Salinas River at Gonzalez (309SAG), and improving on the Santa Ynez River above Lompoc (314SYL). Algal toxicity appears to be improving at a few sites, including the lower San Benito River (305SAN) and lower Orcutt Creek (312ORC). Some changes may be verified statistically as sample count increases.

5.0 Biological and Habitat Health

The National Clean Water Act requires that water quality standards protect the physical, chemical, and biological integrity of our Nation's waters. State Water Resources Control Board programs are moving aggressively towards adopting biocriteria for regulatory use in permits issued throughout the State. Biocriteria will include numeric requirements for maintenance of the invertebrate communities that dwell in stream bottom substrate. Though biocriteria will not be established state-wide until 2013 or later, invertebrate metrics from impacted areas can still be compared to metrics in relatively clean locations to assess overall condition. The species composition within invertebrate communities reflects comprehensive stream health, both in terms of habitat quality and water quality. Both the CCAMP and CMP programs have collected benthic macro-invertebrate data as part of their monitoring programs. This data collection includes a detailed analysis of habitat at the monitoring site. Because sites are selected for ease of access, habitat scores are not necessarily reflective of all habitats in the sampled area, but can still give an indication of local conditions.

The Southern California Index of Biotic integrity was developed incorporating data from Central Coast streams and is applicable in this area (Ode, et al., 2005). However, it was developed for perennial streams and is most appropriate for use in higher gradient system. We have examined several component metrics that are commonly used in assessment of benthic health, including overall taxa diversity, and number of “EPT” taxa (which are considered sensitive to water and habitat quality and include the mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) groups).

High quality sites monitored by CCAMP (including sites in upper Big Sur River, Big Creek, upper San Simeon Creek and Arroyo de la Cruz) have comparatively high overall diversity (with more than forty taxa in a sample), and numerous EPT taxa (over 20 taxa in a sample). Additional characteristics of these high quality sites include excellent water quality and stable, diverse habitat (well established and mature riparian corridor and in-stream habitat with a mix of substrates including gravel, cobble and woody debris).

Benthic macro-invertebrate community composition reflects poor water quality and lack of habitat at sites in areas with heavy irrigated agricultural activity. Table 4 provides a comparison of sites in the lower Salinas and Santa Maria areas to sites farther upstream and to high quality sites. In the lower Salinas and Santa Maria areas, common measures of BMI community health and habitat health score low compared to upper watershed monitoring sites and other high quality sites in the Central Coast Region. Overall taxa diversity is much lower, EPT taxa are completely absent from many sites, and substrate is dominated by sand or fines with little or no boulders, cobbles or gravels. Percent canopy cover is low (<10%) or absent and the riparian habitat typically does not have a diverse structure that includes woody vegetation with understory (CCWQP,2009b; CCWQP,2009c; CCWQP,2009d ; CCWQP, 2009e).

	Total Taxa Diversity	EPT Taxa Diversity	Instream Substrate	Riparian Canopy
Highest Quality Sites	> 40	> 20	Mixed gravel, cobble, woody debris	Mature trees with understory
Lower Salinas area	3 - 27, with one exception	0 - 6	> 90% sand and fine sediment	Typically (for 8 of 13 sites) < 5% canopy cover, dominated by non-woody plants
Lower Santa Maria watershed	6 - 16, with one exception	0	> 85% sand and fine sediment	Typically < 10 % canopy cover, dominated by non-woody plants
Upper Salinas watershed	26 - 43	6 - 17	Mixed sand, gravel, cobble	Mature trees with understory
Upper Santa Maria watershed	25 - 44	5 - 18	<25% fines, dominated by gravel and cobble	Mature trees with understory

Table 4. Summary of Typical Biological and Habitat Conditions in various areas of Region 3

CMP AND CCAMP DATA THROUGH 2009

Upper Salinas and Santa Maria watershed sites are more similar to highest quality CCAMP sites, with diverse benthic communities and relatively high numbers of EPT taxa. Habitat at upper watershed sites is also in better condition with a greater diversity of substrates including a mix of sand, gravel and cobbles. The riparian corridor is typically well established, with mature trees and understory vegetation at all sites.

These findings indicate that streams in areas of heavy agricultural use areas are typically in very poor condition in terms of benthic community health and that habitat in these areas is often poorly shaded, lacking woody vegetation, and heavily dominated by fine sediment. Invertebrate community composition is sensitive to degradation by both habitat and water quality. In some cases, the fine sediment dominating stream substrate is likely the largest influence on benthic community composition, but in areas where sediment and water toxicity is common, chemical impacts to native communities are also probable. Heavily sedimented stream bottoms can result from the immediate discharge of sediment from nearby fields, the loss of stable, vegetated stream bank habitat, the channelization of streams and consequent loss of floodplain, as well as from upstream sources.

6.0 Risk of Impact to the Marine Environment from Agricultural Activities

Legacy Impacts from Past Chemical Use

A number of monitoring and research efforts over the years have shown that chemicals leaving the land can cause environmental impacts in the marine environment. For example, the Central Coast Long-term Environmental Assessment Network (CCLEAN) has shown that concentrations of dieldrin in open ocean waters of Monterey Bay at times exceed Ocean Plan objectives, dieldrin concentrations in mussels collected along the shoreline of the Bay can exceed OEHHA Human Health alert levels, concentrations of dieldrin in nearshore sediments in the Bay at times exceed NOAA Effects Range Low concentrations, and concentrations of dieldrin leaving Pajaro and Salinas Rivers and entering Monterey Bay can exceed California Toxics Rule criteria (CCLEAN, 2007). Dieldrin was a chemical used widely in agricultural applications from 1950 - 1974, but also in termite and mosquito control up into the early 1980s. It has been banned for many years because of its bioaccumulating properties. Nevertheless, it is clearly still impacting the nearshore ocean environment in measureable ways.

CCLEAN also showed that the loading of several legacy pesticides was far higher from rivers than from wastewater discharges. The combined river loads of DDT and dieldrin were 394 and 41 times higher than the loads from wastewater discharges, respectively, in data collected between 2001 and 2006. Also, the combined loads from the Pajaro and Salinas Rivers, our major agricultural watersheds in Monterey Bay, represented over 95% of river loads of DDT, dieldrin, and endosulphan. Clearly, chemicals that have been applied in past agricultural applications can and do impact the marine environment.

There are other examples of legacy chemicals, common applied in past agricultural applications, found in nearshore areas. Recent research off of Central Coast waters has documented elevated levels of several organochlorine pesticides in sea otter tissue (Miller et al., 2007). Sea otters are voracious consumers of marine invertebrates and bioaccumulate the contaminants found in their food source. Dugan (2005) found elevated levels of organochlorine pesticides in sandcrabs from several locations along the Central Coast, with significantly elevated concentrations of DDT in sand crab tissues collected off of the Santa Maria river mouth. Concentrations at this location declined with distance from the river mouth, implying a river source, and were very similar in magnitude to those documented in sand crabs in the same location in the 1970's (Burnett, 1971 in Dugan, 2005).

Granite Canyon Marine Pollution Studies Laboratory researchers (Anderson et al., 2006, 2010) found elevated levels of DDT and more currently applied agricultural chemicals in the lower Santa Maria river and its estuary, along with significant invertebrate toxicity and impoverished benthic communities, and tracked high levels of chemicals moving from agricultural stream discharges (specifically, Orcutt Creek and tributaries) into the lagoon. Moss Landing Harbor is listed as a Toxic Hot Spot because of high levels of legacy chemicals that have entered from upstream sources, primarily the Salinas Reclamation Canal/Tembladero Slough watershed. (SWRCB, 1998). The drainages that enter Moss Landing Harbor are some of the most polluted in our Region, with documented toxicity and chemical pollution from nitrates and pesticides that originate in great part from the intensive agricultural activities in the area (though it should be noted that the City of Salinas drains to this watershed and research has shown the City is likely contributing to the toxicity problem (Westin, 2008)).

Though the chemicals used in the Region have changed over the years, the contamination problem persists. It is clear from research findings associated with legacy pesticides that chemicals can and have been applied in quantities sufficient to cause harm in the marine environment. Most currently applied chemicals are not known to bioaccumulate in tissue the way that some of the legacy pesticides have. However, a recent study of central coast lagoons found measureable levels of organophosphate and pyrethroid pesticides in lagoon fish in the Santa Maria estuary (Anderson, et al., 2010). Some pesticides, such as pyrethroids, are known to attach to sediments and persist in a relatively stable form in the aquatic environment where they can cause sediment toxicity. Therefore, we should view current chemical applications, particularly pyrethroids that show stability in the aquatic environment, as potential risks to marine aquatic health.

Risk to Marine Protected Areas

In 2007, the California Fish and Game Commission adopted regulations to create a new suite of Marine Protected Areas in the Central Coast of California, the first to be adopted for the State. These preserves are intended to implement the State's Marine Life Protection Act Program, to conserve and enhance the State's marine resources. The Marine Protected Areas of the Central Coast include the originally designated MPAs, and more recently, Areas of Special Biological Significance designated in the Central Coast Basin Plan (which include Pt. Lobos, the Carmel and Pacific Grove area, and Ano

Nuevo). Detailed maps of these areas can be found on the California Department of Fish and Game website, and the CDFG map of Central Coast MPAs is shown in Figure 18.

SMCA = state marine conservation area SMP = state marine park
SMR = state marine reserve SMRMA = state marine recreational management area

Figure 18. California Central Coast Marine Protected Areas

FIGURE IS TAKEN FROM CDFG MARINE PROTECTED AREAS WEB SITE

Many of the Central Coast Marine Protected Areas are located in relatively remote areas, such as along the Big Sur coastline. However, several are located in areas which are more likely to be impacted by sediment and water discharges leaving the land. Two of the MPAs, Elkhorn Slough and Morro Bay, are estuaries which receive fresh water runoff into relatively enclosed systems. Another is Moro Cojo Slough, which is a brackish water slough that receives direct discharge of agricultural return water and has serious water quality problems.

We have identified and ranked the eight MPA areas most likely to be impacted by agricultural chemicals in Table 5. The MPA ranking is qualitative, but considers technical data and associated models related to MPA proximity to polluted discharges, size of discharges, loading of pollutants, predicted area of plume influence, and current patterns. Other MPAs, because of their locations offshore of smaller, more remote watersheds, are all considered to be at low risk for impacts from agriculture. More detailed comments on highest risk MPAs are found in Appendix D. In considering how to rank potential impacts from agriculture, we have primarily considered loadings of nitrates and potential loadings of pyrethroid pesticides.

MPAs at highest risk for impact include Moro Cojo and Elkhorn Slough, because of their proximity to agricultural activities, the direct inputs of agricultural return waters, and documented evidence of nutrient over-enrichment and toxicity to aquatic life. Nitrate, pesticides and toxicity are documented problems at these locations, and these two MPAs are already included as part of the Moss Landing Toxic Hot Spot designation (BPTCP, 1998).

Nutrient Loading - The Moro Cojo and Elkhorn Slough MPAs are directly impacted by nutrients, which are found in these estuaries at levels that are not protective of aquatic life. Monterey Bay Aquarium Research Institute has collected chemical sensor data from a number of in-situ probes in Elkhorn Slough. This data shows nitrate concentrations in the center of Elkhorn Slough exceeding 3 mg/L NO3-N, and even higher concentrations (often over 20 mg/L NO3-N) near the mouth of the Slough that receives drainage from Tembladero Slough and the Old Salinas River. Though Moro Cojo Slough concentrations are typically under 1 mg/L NO3-N, it has exceeded 5 mg/L. It routinely violates Basin Plan un-ionized ammonia objectives. Both sloughs are highly tidal and influenced by elevated concentrations in the Tembladero and Old Salinas River systems.

Other MPAs may be impacted by nitrate more indirectly, for example by increased frequency of toxic algal blooms. Current research indicates that nutrient discharges from rivers may be important drivers of toxic plankton blooms during periods when ocean upwelling is not dominant (Lane, 2009). Toxic phytoplankton blooms appear to be increasing in frequency and possibly in toxicity over the years, and researchers are evaluating whether anthropogenic sources of nutrients from rivers and wastewater could be contributing to this increase. Recent research shows that *Pseudo-nitzschia* bloom magnitude and the toxicity of those blooms can vary according to availability of different forms of nitrogen (Howard, et al., 2007), with nitrate, ammonium and urea all increasing growth rate, but showing differential levels of toxicity, with urea causing the most toxicity.

CCAMP staff has developed estimates of loading to the ocean using nitrate concentration data along with modeled daily flow discharges from coastal confluences. We have provided CCAMP discharge and nutrient loading data over a ten-year period (2000 – 2009) to U.C. Santa Cruz researchers, who have evaluated the effects of river and wastewater sources relative to upwelling on daily and weekly time scales in the Monterey Bay area (Lane, 2009; Lane, et al., in review). This research shows a clear onshore to offshore gradient in nitrate load influence from rivers, and also shows overall increasing trends in loading from rivers, whereas nitrate loading from upwelling shows no trends. Also, the ratios of nitrate to other nutrients coming from the Pajaro and Salinas rivers are extreme when compared to other sources in the area (other streams and rivers, upwelling, wastewater) and other rivers. As an example, the Mississippi River has a nitrogen:phosphorus ratio of 15. The Salinas ratio is over 3000. Ninety-five percent of river loading to the Bay comes from the Pajaro and Salinas rivers. The study estimates that river nitrate loading has exceeded that of wind-driven upwelling in 28% of daily load estimates within the study period. This work suggests that nutrient discharges from rivers can increase the initiation and development of phytoplankton blooms in the Monterey Bay area.

Researchers at the Monterey Bay Aquarium Research Institute have documented plankton bloom initiation two years in a row (2007 and 2008) in lower salinity waters directly adjacent to the nutrient enriched Moss Landing (Chapin et al., 2004) and Pajaro River discharges (Lane, 2009; Lane, et al., in review), following first flush events. These blooms have then evolved into very large red tides, particularly in 2007 (Ryan J., 2009). This red tide killed hundreds of sea birds in the affected area. (Jessup, et al, 2009)

Pesticide Loading - We suggest that pesticides which attach to sediments (such as synthetic pyrethroids and chlorpyrifos) represent the highest risk to the marine environment, compared to other, more soluble pesticides. These chemicals tend to be more persistent in the environment than are soluble chemicals. In addition, fine-grained sediments can accumulate in specific areas as a result of current and wave patterns. This means that chemicals traveling attached to sediments can also accumulate in those areas. The intense mixing that occurs in the marine environment will quickly dilute more soluble chemicals (such as diazinon) and greatly reduce their concentrations once they leave the vicinity of the shoreline. In confined MPAs, such as Moro Cojo Slough, soluble pesticides like diazinon are clearly of concern.

CCAMP has monitored pesticide concentrations in the water column routinely. Because we do not monitor sediment discharge in storm events, we do not have a reliable estimate of sediment loading to the ocean for our coastal watersheds. Recently, the Surface Water Ambient Monitoring Program Stream Pollution Trends Program (SPoT) began monitoring sediment chemistry and toxicity at eleven of our coastal confluences, which will provide data about which rivers discharge sediment with toxic properties.

However, we can make professional judgments about the level of risk of pesticide toxicity to individual MPAs. We have approached the potential for impacts from pesticides by evaluating watershed applications (pounds) of pesticides known to attach to sediment. This approach assumes that some percentage of these pesticides run off of the land into our waterways. Though this assumption will not be equally true for all growers and all watersheds, it provides a way to assess areas of greatest exposure risk. We have used information on MPA proximity to river mouths and current patterns to assess which MPAs are likely at risk.

The Department of Pesticide Regulation Pesticide Use Report reports the pounds of specific pesticides applied for commercial applications throughout the State, using the Public Lands Survey System as its geographic basis. We have used the U.S.G.S. National Hydrography Dataset to "route" upstream applications of pesticides to each of our river mouth monitoring sites. This provides us with the pounds of pesticides applied in the watershed above each site (excluding pounds applied by private homeowners). Obviously, only a fraction of the total pesticides applied make their way into stream and river systems and then to the ocean. However, total pounds applied can be used to assess which rivers have the potential to discharge sediment with toxic properties. In terms of straight poundage applied, the Salinas, Pajaro, and Santa Maria watersheds are the highest risk watersheds in the Region (and also the largest). For total pyrethroid chemicals in 2007, 10,000 pounds were applied in the Santa Maria watershed, 8,600 pounds in the Pajaro watershed, and 25,000 pounds in the Salinas watershed. For chlorpyrifos, 30,296 pounds were applied in the Santa Maria watershed, 10,299 pounds in the Pajaro watershed, and 37,389 pounds in the Salinas watershed. These numbers far exceed the outputs of any other watershed in the Region. The Salinas numbers do not include the additional extensive applications in the Old Salinas River watershed. In addition to relatively high overall poundage, the rate of pesticide application is comparatively high, particularly in the Salinas area where Starner (et al., 2006) noted it was over three-fold higher in terms of pounds of active ingredients applied per acre than other agricultural areas in the study. This can affect runoff risk. Because the Salinas, Pajaro, and Old Salinas Rivers all drain to Monterey Bay, this area in total receives by far the largest loads of pesticides of any area in our Region. Long (2005) ranks the aquatic toxicity of pyrethroids as high to extremely high, and chlorpyrifos as extremely high.

MPA	**Severity of Agricultural Discharge**	**Proximity of MPA to discharge plume(s)**	**Size of Discharge**	**Overall Risk to MPA from Agriculture**
Moro Cojo Slough	Extremely High	Extremely High	Low	Extremely High
Elkhorn Slough	Very High	Extremely High	Medium	Very High
South Santa Ynez River Mouth (Vandenburg)	Medium	High	Medium	Medium
Monterey Bay – Soquel Canyon	Very High	Very Low	Very High	Medium
Monterey Bay – Portuguese Ledge	Very High	Very Low	Very High	Medium
Morro Bay	Low-Medium	Very High	Low-Medium	Low-Medium
Carmel Bay	Low	High	Medium	Low
Pacific Grove, Edward F. Ricketts, and Asilomar	Low	Low	Low	Low

Table 5. Marine Protected Areas Risk Matrix

7.0 Conclusions

This evaluation includes a large amount of data from two well-documented and reliable monitoring programs, the Water Board's Central Coast Ambient Monitoring Program and the agricultural community's Cooperative Monitoring Program for Agriculture. We have found that many of the same areas that showed serious contamination from agricultural pollutants five years ago at the initiation of the Central Coast Regulatory Program for Agriculture are still seriously contaminated. We have seen evidence of improving trends in some parameters in some areas. However, we are not seeing widespread improvements in nitrate concentrations in areas that are most heavily impacted, and in fact a number of sites in the lower Salinas and Santa Maria watersheds appear to be getting worse, at least in terms of concentration.

Invertebrate toxicity remains common in both water and sediment. Statistical trends in toxicity are not generally apparent, in part because of smaller sample sizes, but a few sites show indications of improvement. Very high summer turbidity values is common in many agricultural areas; this implies that water is being discharged over bare soil and is moving into creek systems from sources other than storm water. Dry season turbidity is getting worse along the main stem of the Salinas River, an important migratory corridor for the threatened steelhead trout. High turbidity limits the ability of fish to feed. Bioassessment data shows that creeks in areas of intensive agricultural activity have impaired benthic communities, with reduced diversity and few sensitive species. Associated habitat is often poorly shaded and has in-stream substrate dominated by fine sediment.

In general, we find poor water quality, biological and physical conditions in many waterbodies located in, or affected by, agricultural areas in the Central Coast Region, with the most serious problems located in the lower Salinas and Santa Maria areas. We have found that these problems are not only affecting the biological integrity of fresh water systems in the vicinity, but also some of the Marine Protected Areas to which they drain. Though some improving trends are apparent at some monitoring locations, trends are not widespread and much improvement is needed to begin to meet water quality standards. The many impaired water bodies in agricultural areas remain impaired, with few delistings and many recent additions to the 303(d) List. The Central Coast Water Board is currently renewing the Agricultural Order regulating irrigated agriculture. As a result of the findings in this analysis which generally find that conditions remain severely impacted in spite of requirements of the 2005 Order, staff are proposing changes to the Order that will focus additional monitoring and accountability in highest risk areas, will require additional measures to protect groundwater recharge areas and riparian habitat, and will continue trend monitoring requirements with the intention of showing positive change in the coming years.

8.0 References

Anderson, B.S., Hunt, J.W., Phillips, B.M., Nicely, P.A., de Vlaming, V., Connor, V., Richard, N., Tjeerdema, R. 2003a. Ecotoxicologic impacts of agriculture drainwater in the Salinas River (California, USA). Environmental Toxicology and Chemistry. 22: 2375-2384.

Anderson, B.S., Hunt, J.W., Phillips, B.M., Nicely, P.A., de Vlaming, V., Connor, V., Richard, N., Tjeerdema, R.S. 2003b. Integrated assessment of the impacts of agricultural drainwater in the Salinas River (California, USA). Environmental Pollution 124: 523-532

Anderson, B.S., Nicely, P., Gilbert, K., Kosaka, R., Hunt, J.W., Phillips, B.M. 2004. Overview of /freshwater and marine toxicity tests. Prepared for *Office of Environmental Health Hazard Assessment,Reproductive and Cancer Hazard Assessment Section, Ecotoxicology Unit.*

Anderson, B.S., Phillips, B.M., Hunt, J.W., Richard, N., Connor, V., Tjeerdema, R.S. 2006a. Evidence of pesticide impacts in the Santa Maria River watershed (California, USA). Environmental Toxicology and Chemistry. 25:1160-1170.

Anderson, B.S., Phillips, B.M., Hunt, J.W., Richard, N., Connor, V., Tjeerdema, R.S. 2006b. Identifying primary stressors impacting macroinvertebrates in the Salinas River (California, USA): relative effects of pesticides and suspended particles. Environmental Pollution. 141: 402-408.

Anderson, B.S., Hunt, J.W., Phillips, B.M., Tjeerdema, R.S. 2007. Navigating the TMDL process: sediment toxicity. Report # 02-WSM-2; Water Environment Research Foundation, Alexandria, VA.

Anderson, B, B. Phillips, J. Hunt, K. Siegler, J. Voorhees, K. Smalling, K. Kuivila. 2010. Watershed-Scale Evaluation of Agricultural BMP Effectiveness in Protecting Critical Coastal Habitats: Final Report on the Status of Three Central California Estuaries. Central Coast Water Board Grant Agreement No. 06-352-553-0.

Burnett R. 1971. DDT residues: Distribution of concentration in Emerita analoga (Stimpson) along the coast of California. Science 174: 606-608.

California Department of Pesticide Regulation (DPR). 2006 Pesticide Use Report, Indexed by Chemical. November, 2007.

California Department of Pesticide Regulation (DPR). 2007 Pesticide Use Report, Indexed by Chemical. November, 2008.

Central Coast Long-term Environmental Assessment Network (CCLEAN). January 31, 2007. 2001 – 2006 Program Review. Prepared for Central Coast Regional Water Quality Control Board. San Luis Obispo, CA. Prepared for Central Coast Regional Water Quality Control Board. San Luis Obispo, CA.

Central Coast Ambient Monitoring Program (CCAMP) 2010a. http://www.ccamp.info/_2010/view_data_01.php Web data summaries of CCAMP and CCWQP data.

Central Coast Regional Water Quality Control Board (CCRWQCB). Water Quality Control Plan – Central Coast Basin. September 8, 1994 and subsequent amendments.

Central Coast Regional Water Quality Control Board (CCRWQCB), 2009. Fact Sheets Documenting 303(d) Listing Decisions. http://www.waterboards.ca.gov/centralcoast/water_issues/programs/tmdl/303d/appendix_f.shtml

Central Coast Water Quality Preservation Inc. (CCWQP). 2006. Quality Assurance Project Plan (QAPP) for Monitoring for the Region 3 Conditional Ag Waiver Cooperative Monitoring Program. Prepared by S. Clark and S. Ogle, Pacific Ecorisk.

Central Coast Water Quality Preservation Inc. (CCWQP). 2008a. Phase 1 Follow-up Water Quality Monitoring: Organophosphate Pesticide Sampling Final Data Report. May 19, 2008

Central Coast Water Quality Preservation Inc. (CCWQP). 2008b. Follow-up Monitoring Report: Water Quality Results from Upstream Monitoring, 2008. Revised September 2010.

Central Coast Water Quality Preservation Inc. (CCWQP). 2009. Supplemental Water Quality Monitoring for Organophosphate Pesticides and Aquatic Toxicity. May 28, 2009.

Central Coast Water Quality Preservation Inc, (CCWQP). 2009a. Preliminary Cooperative Monitoring Trend Analysis Brief, October 19, 2009. http://www.ccamp.org/ccamp/documents/TrendAnalysisBrief_v2.pdf

Central Coast Water Quality Preservation Inc. (CCWQP). 2009b. Central Coast Cooperative Monitoring Program: 2005 Bioassessment Monitoring. Pacific Ecorisk, Fairfield, CA. Revised April 2010.

Central Coast Water Quality Preservation Inc. (CCWQP). 2009c. Central Coast Cooperative Monitoring Program: 2006 Bioassessment Monitoring. Pacific Ecorisk, Fairfield, CA. Revised April 2010.

Central Coast Water Quality Preservation Inc. (CCWQP). 2009d. Central Coast Cooperative Monitoring Program: 2007 Bioassessment Monitoring. Pacific Ecorisk, Fairfield, CA. Revised April 2010.

Central Coast Water Quality Preservation Inc. (CCWQP). 2009e. Central Coast Cooperative Monitoring Program: 2008 Bioassessment Monitoring. Pacific Ecorisk, Fairfield, CA. Revised April 2010.

Central Coast Water Quality Preservation Inc. (CCWQP). 2009f. Final Follow-up Water Quality Monitoring Report: Continuous Monitoring of Flows. August 14, 2009. Revised September, 2010.

Central Coast Water Quality Preservation Inc. (CCWQP). 2010a. Central Coast Region Conditional Waiver Cooperative Monitoring Program Follow-up Monitoring Report: Organophosphate Monitoring at Phase II Sites 2009. April 6, 2010.

Central Coast Water Quality Preservation Inc. (CCWQP). 2010b. Central Coast Cooperative Monitoring Program, 2005 – 2008 Water Quality Report. Prepared by Larry Walker and Assoc.

Central Coast Water Quality Preservation Inc. (CCWQP). 2010c. Cooperative Monitoring Program 5-Year Evaluation Report: Monitoring Program Effectiveness and Efficiency. December 23, 2010.

Central Coast Water Quality Preservation Inc. (CCWQP). 2010d (draft). Central Coast Region Conditional Waiver Cooperative Monitoring Program Follow-up Monitoring Report: Pesticides and Toxicity to Hyalella azteca in Sediments, 2010. In Draft.

Chapin, T.P., J.M. Caffrey, J.W. Jannasch, L.J. Coletti, J.C. Haskins, and K.S. Johnson. 2004. Nitrate Sources and Sinks in Elkhorn Slough, California: Results from Long-term Continuous In-situ Nitrate Analyzers. Estuaries 27(5):882-894.

Dugan, J. Monitoring of Coastal Contaminants Using Sand Crabs. 2005. Prepared for Central Coast Regional Water Quality Control Board. Marine Science Institute UCSB, California Department of Fish and Game.

Howard, M. D. Armstrong, W. P. Cochlan, N. Ladizinsky, R. M. Kudela. 2007. Nitrogenous preference of toxigenic Pseudonitzschia australis from field and laboratory experiments. Harmful Algae 6:206-217.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Tjeerdema, R.S., Puckett, H.M., and deVlaming, V. 1999. Patterns of aquatic toxicity in an agriculturally dominated coastal watershed in California. *Agriculture, Ecosystems, and Environment* 75: 75-91.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Nicely, P.A., Tjeerdema, R.S., Puckett, H.M., Stephenson, M., Worcester, K., deVlaming, V. 2003. Ambient toxicity due to chlorpyrifos and diazinon in a Central California Watershed. Environmental Monitoring and Assessment. 82: 83-112.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Tjeerdema, R.S. 2005. Salinas River sediment toxicity survey. California State Water Resources Control Board and Central Coast Regional Water Quality Control Board.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Tjeerdema, R.S., Richard, N., Connor, V., Worcester, K., Angelo, M., Bern, A., Fulfrost, B., Mulvaney, D. 2006. Spatial relationships between water quality and pesticide applications in agricultural watersheds. Environ Monit Assess. 121:245-262.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Largay, B., Watson, F., Harris, K., Hanson, E., Beretti, M., Schafer, R., Brown, K., Bern, A.L. 2007. Effectiveness of agricultural management practices in reducing concentrations of pesticides associated with toxicity to aquatic organisms. Data Summary and Final Report. Central Coast Regional Water Quality Control Board, San Luis Obispo, CA.

Hunt, J.W., Anderson, B.S., Phillips, B.M., Tjeerdema, R.S., Largay, B., Beretti, M., and Bern, A. 2008. Use of toxicity identification evaluations to determine the pesticide mitigation effectiveness of on-farm vegetated treatment systems. Environmental Pollution. 156: 348 - 358.

Jessup, D. A. , M.A. Miller, J.P. Ryan, H.M. Nevins, H. A. Kerkering, A. Mekebri, D.B. Crane, T.A. Johnson, R.M. Kudela. 2009. Mass Stranding of Marine Birds Caused by a Surfactant-Producing Red Tide, PLoS ONE (2):e4550.doi:10.1371/journal.pone.0004550. Online.

Lane, J.Q., D.M. Paradies, K.R. Worcester, R. M. Kudela. Description of freshwater eutrophic sources to Monterey Bay, California, with categorization according to nutrient ratio characteristics. Poster presentation at Coastal and Estuarine Research Federation (CERF) Conference, Portland, OR, Nov 2 – 5, 2009.

Lane, J.Q., D.M. Paradies, K. R. Worcester, R.M. Kudela. In review. Assessment of river discharge as a source of nitrate-nitrogen to Monterey Bay, California. Journal of Limnology and Oceanography.

Miller, M., E. Dodd, M. Ziccardi, D. Jessup, D. Crane, C. Dominik, R. Spies, D. Hardin. June 30, 2007. Persistent Organic Pollutant Concentrations in Southern Sea Otters (Enhydra lutris nereis) Patterns with Respect to Environmental Risk Factors and Major Causes of Mortality. California Department of Fish and Game (CDFG)-Office of Spill Prevention and Response, Wildlife Health Center, University of California, Davis. Applied Marine Sciences.

Moyle, Peter. 1976. Inland Fisheries of California. University of California Press, Berkeley, CA. 405 pp.

Ng, C. M., D. P. Weston, J. You, M.J. Lydy. In Press. Patterns of pyrethroid contamination and toxicity in agricultural and urban stream segments. Department of Integrative Biology, University of California, Berkeley, California.

Ode, P.R., A.C. Rehn and J. T. May. 2005. A Quantitative Tool for Assessing the Integrity of Southern California Coastal California Streams. Environmental Management 35(4):493-504.

Phillips , B.M., Anderson, B.S., Hunt, J.W., Huntley, S., Tjeerdema, R.S., Kapellas, N., Worcester, K. 2006. Solid-phase sediment toxicity identification evaluation in an agricultural stream. Environmental Toxicology and Chemistry. 25: 1671-1676.

Phillips, B.M., Anderson, B.S., Hunt, J.W., Nicely, P.A., Kosaka, R., de Vlaming, V., Connor, V., Richard, N., Tjeerdema, R.S. 2004. *In situ* water and sediment toxicity in an agricultural watershed. Environmental Toxicology and Chemistry. 23:435-442.

Puckett, M. California Department of Fish and Game. 2002. Quality Assurance Management Plan (QAMP)for the State of California's Surface Water Ambient Monitoring Program (SWAMP). Prepared for the California State Water Resources Control Board, Division of Water Quality. Sacramento, CA.

Ryan, J. 2009. Video news from Monterey Bay Aquarium Research Institute. http://www.mbari.org/news/homepage/2009/ryan-blooms/ryan-blooms.html.

Sigler, et al. 1984. Transactions of the American Fisheries Society 113: 142 – 150.

Sparling, D.W., G. Fellers. 2007. "Comparative toxicity of chlorpyrifos, diazinon, malathion and their oxon derivatives to larval Rana boylii ". *Environmental Pollution*, 147 (3), p.535-539, June, 2007.

Starner, K. and K. Kelley. 2004. Pyrethroid concentrations in surface water and bed sediment in high agricultural use regions of California. California Department of Pesticide Regulation. Sacramento, CA 95812

Starner, K., J. White, F. Spurlock and K. Kelley. 2006. Pyrethroid Insecticides in California Surface Waters and Bed Sediments: Concentrations and Estimated Toxicities. California Department of Pesticide Regulation, Sacramento, Calif.

Starner, K., J. White, F. Spurlock and K. Kelley. 2008 Assessment of Pyrethroid Contamination of Streams in High-Use Agricultural Regions of California. American Chemical Society Symposium Series, Vol. 991.

Starner, K. October 8, 2009. Spatial and Temporal Analysis of Diazinon Irrigation-Season Use and Monitoring Data. California Deparment of Pesticide Regulation, Sacramento, CA. 42 pp.

State Water Resources Control Board (SWRCB). 1998. Chemical and biological measures of sediment quality in the Central Coast Region. Final Report. Division of Water Quality. Bay Protection and Toxic Cleanup Program. Sacramento, CA.

United States Environmental Protection Agency (USEPA). 1999 Update of Ambient Water Quality Criteria for Ammonia. EPA #822R99014.

Ward, M. H., S.D. Mark, K.P. Cantor. 1996. Drinking Water Nitrate and the Risk of Non-Hodgkin's Lymphoma. Journal of Epidemiology and Community Health. 7:465-471.

Waters, T.F. 1995. Sediment in streams; sources, biological effects, and control. American Fisheries Society monograph. 0362-1715 (7). 251 p.

Weyer, P. 2001. Nitrate in Drinking Water and Human Health. http://www.agsafety and healthnet.org/Nitrate/pdf

Worcester, K.R., D.M. Paradies, M Adams. 2010. Interpreting Narrative Objectives for Biostimulatory Substances for California Central Coast Waters. Surface Water Ambient Monitoring Program Technical Report. State Water Resources Control Board. Sacramento, CA 95812.

Appendix A. Rules for Scoring Parameters

Each parameter is scored for each site according to the rules described below. Green is good, yellow shows some evidence of a problem, red definitely has a problem, and dark red has a serious problem. Water quality indices are scored by combining parameter scores, where Green = 3, Yellow = 2, Red = 1, and Dark Red = 0, and then scores are percentile ranked so that 100 is a site where all parameters are in good shape (all parameters are green) and 0 is a site where all parameters are in serious condition.

Parameter rules vary depending on characteristics of data and the desired emphasis. For example, storm events during the wet season can drive elevated turbidity (to a great extent a natural phenomenon), but tailwater discharges during the dry season can also drive elevated turbidity. The turbidity rule is designed to emphasize persistence in the data. Consequently, the turbidity parameter is scored dark red when the 25th percentile exceeds a value of concern (this means that 75% or more of the data is over this value). Several other parameters, such as toxicity or nitrate, are scored dark red when the 75th percentile of the data exceeds a criterion or guideline value (this means that 25% of the data or more is over a limit of concern). Note that use of the 90th percentile, instead of the maximum value, prevents a single outlier from determining status.

Water Quality Index

Nitrate-Nitrite (as N) (mg/L)

1 mg/L is a guideline value to protect aquatic life (Worcester et al., 2010); 10 mg/L is the Basin Plan standard to protect drinking water (CCWRQCB, 1994)

- If the 90th percentile <= 1 then the status = Green
- If the 90th percentile > 1 and the 90th percentile <= 10 then the status = Yellow
- If the 75th percentile <= 10 and the 90th percentile > 10 then the status = Orange
- If the 75th percentile > 10 and the median <= 10 then the status = Red
- If the median > 10 then the status = Dark Red

Water Column Chlorophyll *a* (ug/L)

15 ug/L and 40 ug/L are guideline values adapted from cold and warm water standards used in North Carolina and Oregon. 40 ug/L is the guideline value adopted for 303(d) listing by the Central Coast Region

- If the 90th percentile <= 15 then the status = Green
- If the 90th percentile > 15 and the 90th percentile <= 40 then the status = Yellow
- If the 75th percentile <= 40 and the 90th percentile > 40 then the status = Orange
- If the 75th percentile > 40 and the median <= 40 then the status = Red
- If the median > 40 then the status = Dark Red

Turbidity (NTU)

25 NTU is the guideline value adopted for 303(d) listing by the Central Coast Region, and supported by Sigler et al., 1984

- If the 75th percentile <= 25 then the status = Green
- If the 75th percentile > 25 and the median <= 25 then the status = Yellow
- If the median > 25 and the 25th percentile <= 25 then the status = Orange
- If the 25th percentile > 25 and the 75th percentile <= 250 then the status = Red
- If the 25th percentile > 25 and the 75th percentile > 250 then the status = Dark Red

Un-ionized Ammonia (mg/L)

0.025 mg/L is a General Basin Plan standard. Other values are based on CCAMP data distribution, and are typical of good water quality (<0.01 mg/L), or very poor water quality (> 0.1 mg/L)

- If the 90th percentile <= 0.01 then the status = Green
- If the 90th percentile > 0.01 and the 90th percentile <= 0.025 then the status = Yellow
- If the 90th percentile > 0.025 and the 75th percentile <= 0.025 then the status = Orange
- If the 75th percentile > 0.025 and the 90th percentile < 0.1 then the status = Red
- If the 75th percentile > 0.025 and the 90th percentile > 0.1 then the status = Dark Red

Water Temperature (degrees C)

21 C is the evaluation guideline used to protect the Cold Freshwater Habitat beneficial use and is supported by Moyle 1976. Other values are based on CCAMP data distribution, and are typical of good water quality (<18 C), or very poor water quality (> 25 C)

- If the 90th percentile <= 18 then the status = Green
- If the 90th percentile > 18 and the 90th percentile <= 21 then the status = Yellow
- If the 75th percentile <= 21 and the 90th percentile > 21 then the status = Orange
- If the 75th percentile > 21 and the 90th percentile <= 25 then the status = Red
- If the 75th percentile > 21 and the 90th percentile > 25 then the status = Dark Red

Dissolved Oxygen (mg/L)

This rule is expressed as mg/L diverging outside of the desirable range of 7 to 13 mg/L. 7 mg/L is a Basin Plan objective for protecting cold water habitat; 13 mg/L has been identified as the upper range of desirable conditions in the Central Coast application of Numeric Nutrient Endpoints (Worcester, 2010). So, for example, if 90% of measurements fall within the desired range of 7 - 13 mg/L, the status is green, if 90% of the measurement fall within 1 mg/L of the desired range the status is yellow.

- If the 90th percentile = 0 then the status = Green
- If the 90th percentile > 0 and the 90th percentile <= 1 then the status = Yellow
- If the 90th percentile > 1 and the 90th percentile <= 2 then the status = Orange
- If the 90th percentile > 2 and the 75th percentile <= 2 then the status = Red
- If the 75th percentile > 2 then the status = Dark Red

Total Dissolved Solids (mg/L)

Saline, tidal, and marine sites are excluded from this rule. This rule is based on limits set to protect agriculture in the Central Coast Basin Plan (1994) (Table 3-3 and 3-4).

- If the 75th percentile <= 500 then the status = Green
- If the 75th percentile > 500 and the 75th percentile <= 1000 then the status = Yellow
- If the 75th percentile > 1000 and the 90th percentile <= 2000 then the status = Orange
- If the 75th percentile > 1000 and the 75th percentile <= 2000 and the 90th percentile > 2000 then the status = Red
- If the 75th percentile > 2000 then the status = Dark Red

Ortho-Phosphate (as P) (mg/L)

0.12 mg/L is a screening value identified in Williamson (1994)

- If the 90th percentile <= 0.12 then the status = Green
- If the 75th percentile <= 0.12 and the 90th percentile > 0.12 then the status = Yellow
- If the 75th percentile > 0.12 and the median <= 0.12 then the status = Orange
- If the median > 0.12 and the 25th percentile <= 0.12 then the status = Red
- If the 25th percentile > 0.12 then the status = Dark Red

Toxicity Index

Note: the Toxicity Index is only scored for sites that have data for more than one species. For the purposes of this index, we have used "percent of control" between the sample and the control test. For example, if sample survival is 63% and control survival is 91%, the percent of control is 63/91 * 100 or 69.2%. When only one sample is toxic, we distinguish between samples which show some toxicity, where the test is 50 to 80% of the control, and samples that are quite toxic, where the test is less than 50% of the control.

- If the minimum >= 80 then the status = Green
- If the minimum < 80 and the minimum >= 50 then the status = Yellow
- If the minimum < 50 and the 25th percentile >= 80 then the status = Orange
- If the 25th percentile < 80 and the median >= 80 then the status = Red
- If the median < 80 then the status = Dark Red

For small sample counts (three or fewer):

- If Minimum > 80 Then status = Green (No samples toxic)
  If Minimum <= 80 and Minimum > 50 Then status = Yellow (Some toxicity)
  If Minimum < 50 And Median >= 80 Then status = Red
- If Minimum < 50 And Median < 80 Then status = Dark Red (At least two samples are toxic and one of them is quite toxic)

Coliform Index

Fecal Coliform (MPN/100mL)

400 MPN/100 ml is the Basin Plan standard to protect for Water Contact Recreation (CCRWQCB, 1994)

- If the 90th percentile <= 400 then the status = Green

- If the 75th percentile <= 400 and the 90th percentile > 400 then the status = Yellow
- If the 75th percentile > 400 and the median <= 400 then the status = Orange
- If the median > 400 and the 25th percentile <= 400 then the status = Red
- If the 25th percentile > 400 then the status = Dark Red

E. coli (MPN/100mL)

235 MPN/100 ml is the evaluation guideline adopted for 303(d) listing by the Central Coast Region to protect for Water Contact Recreation, and is supported by USEPA Ambient Water Quality Criteria for Bacteria (1986)

- If the 90th percentile <= 235 then the status = Green
- If the 75th percentile <= 235 and the 90th percentile > 235 then the status = Yellow
- If the 75th percentile > 235 and the median <= 235 then the status = Orange
- If the median > 235 and the 25th percentile <= 235 then the status = Red
- If the 25th percentile > 235 then the status = Dark Red

Total Coliform (MPN/100mL)

10000 MPN/100 ml is a California Ocean Plan standard and is used here as a screening value for fresh water. This value is also used in other countries to protect for Waterbody Contact Recreation.

- If the 90th percentile <= 10000 then the status = Green
- If the 75th percentile <= 10000 and the 90th percentile > 10000 then the status = Yellow
- If the 75th percentile > 10000 and the median <= 10000 then the status = Orange
- If the median > 10000 and the 25th percentile <= 10000 then the status = Red
- If the 25th percentile > 10000 then the status = Dark Red

Appendix B. Maps of 2010 303(d) listings

MAP 1. 2010 303(D) LISTINGS FOR ALL TOXICITY

MAP 2. 2010 303(D) LISTINGS FOR WATER TOXICITY

MAP 3. 2010 303(D) LISTINGS FOR SEDIMENT TOXICITY

MAP 4. 2010 303(D) LISTINGS FOR CHLORPYRIFOS

MAP 5. 2010 303(D) LISTINGS FOR DIAZINON

MAP 6. 2010 303(D) LISTINGS FOR NITRATE-N

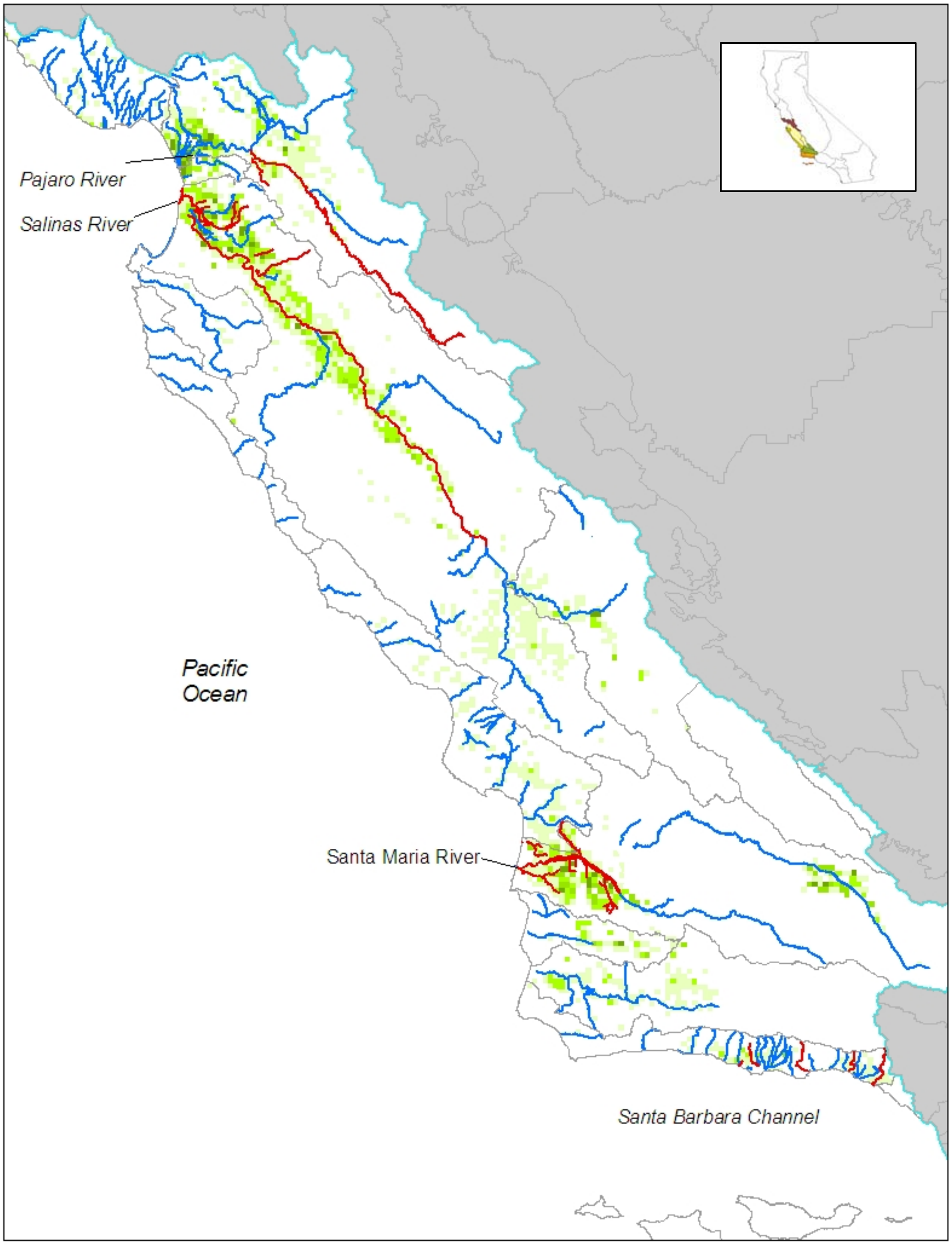
MAP 7. 2010 303(D) LISTINGS FOR NITRATE-N IN THE MONTEREY BAY AREA

MAP 8. 2010 303(D) LISTINGS FOR NITRATE-N IN SOUTHERN REGION 3

MAP 9. 2010 303(D) LISTINGS FOR TURBIDITY

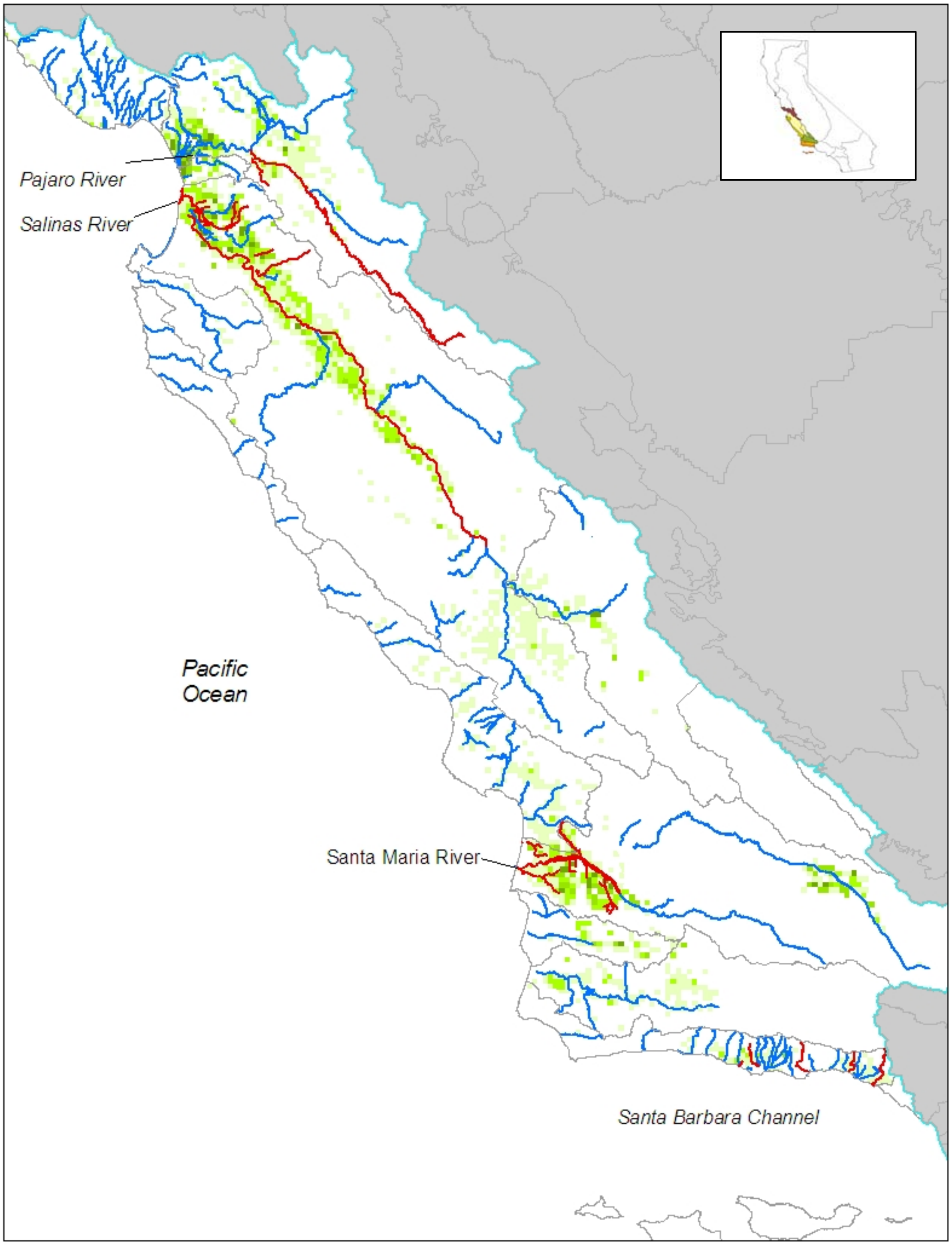
MAP 10. 2010 303(D) LISTINGS FOR WATER TEMPERATURE

MAP 11. 2010 303(D) LISTINGS FOR UN-IONIZED AMMONIA



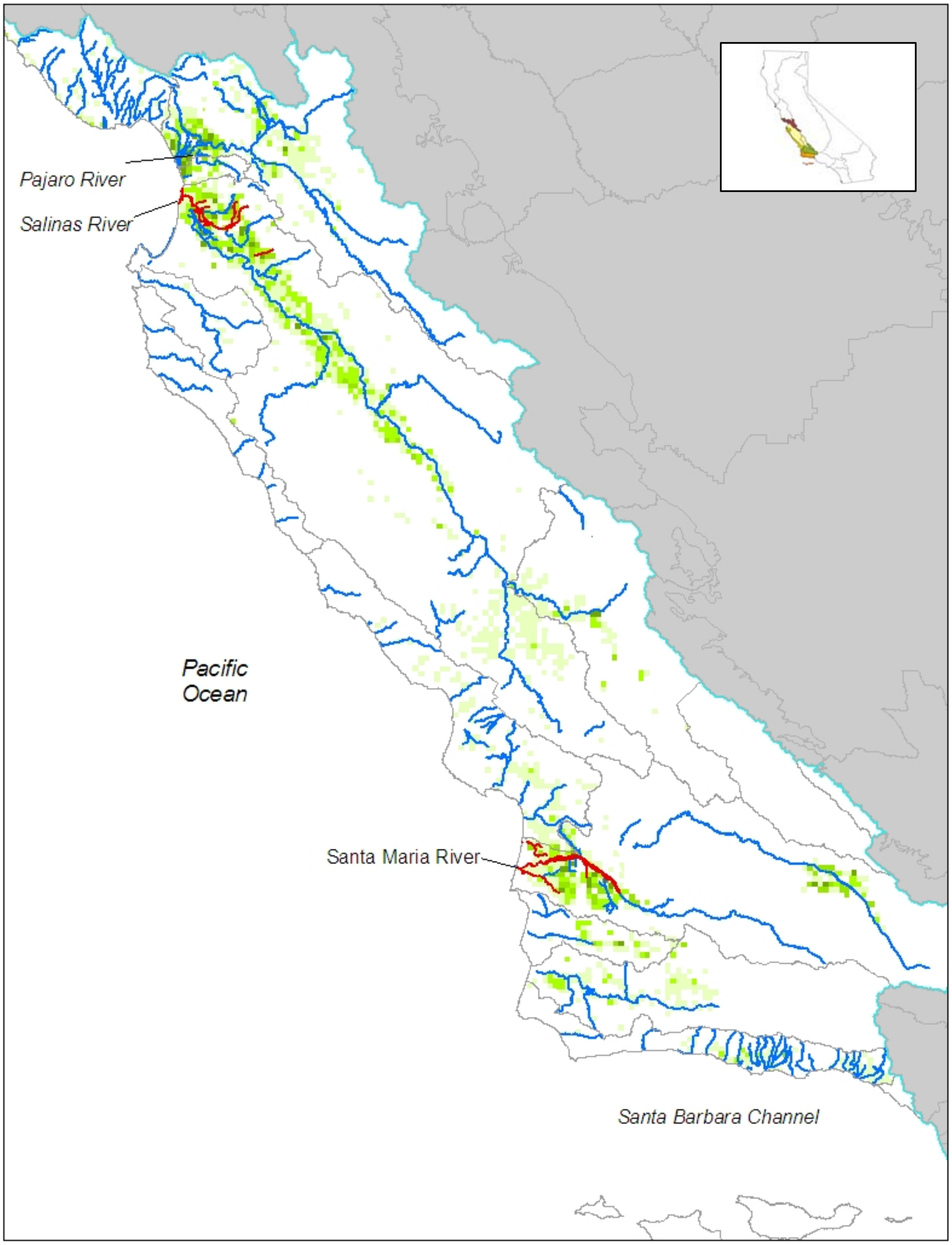
Map 1. 2010 303(d) Central Coast Listings for All Toxicity (includes data from sediment and water toxicity tests)

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY TOXICITY SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



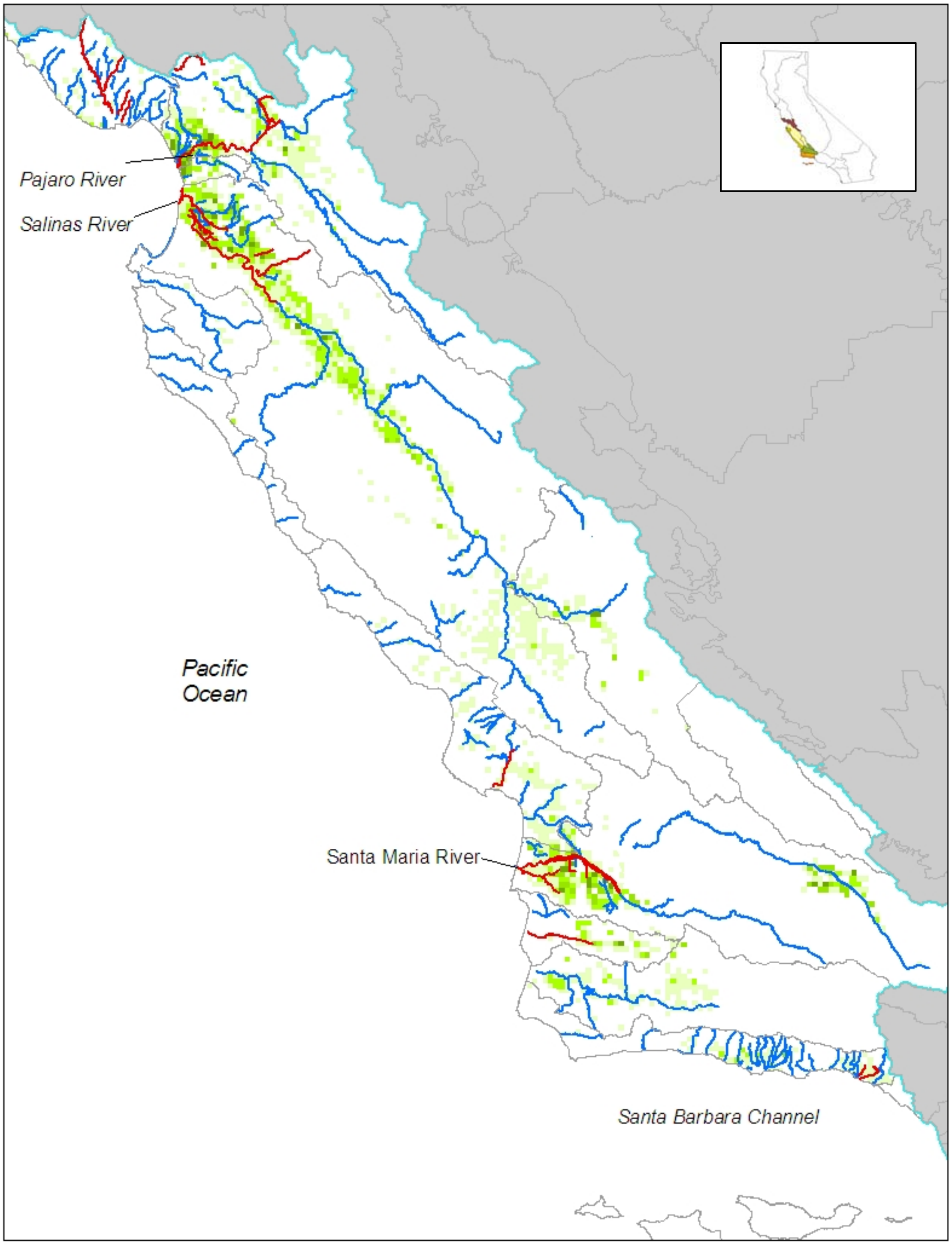
Map 2. 2010 Central Coast 303(d) Listings for Water Toxicity (includes data from invertebrates, fish and algae)

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY WATER TOXICITY SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



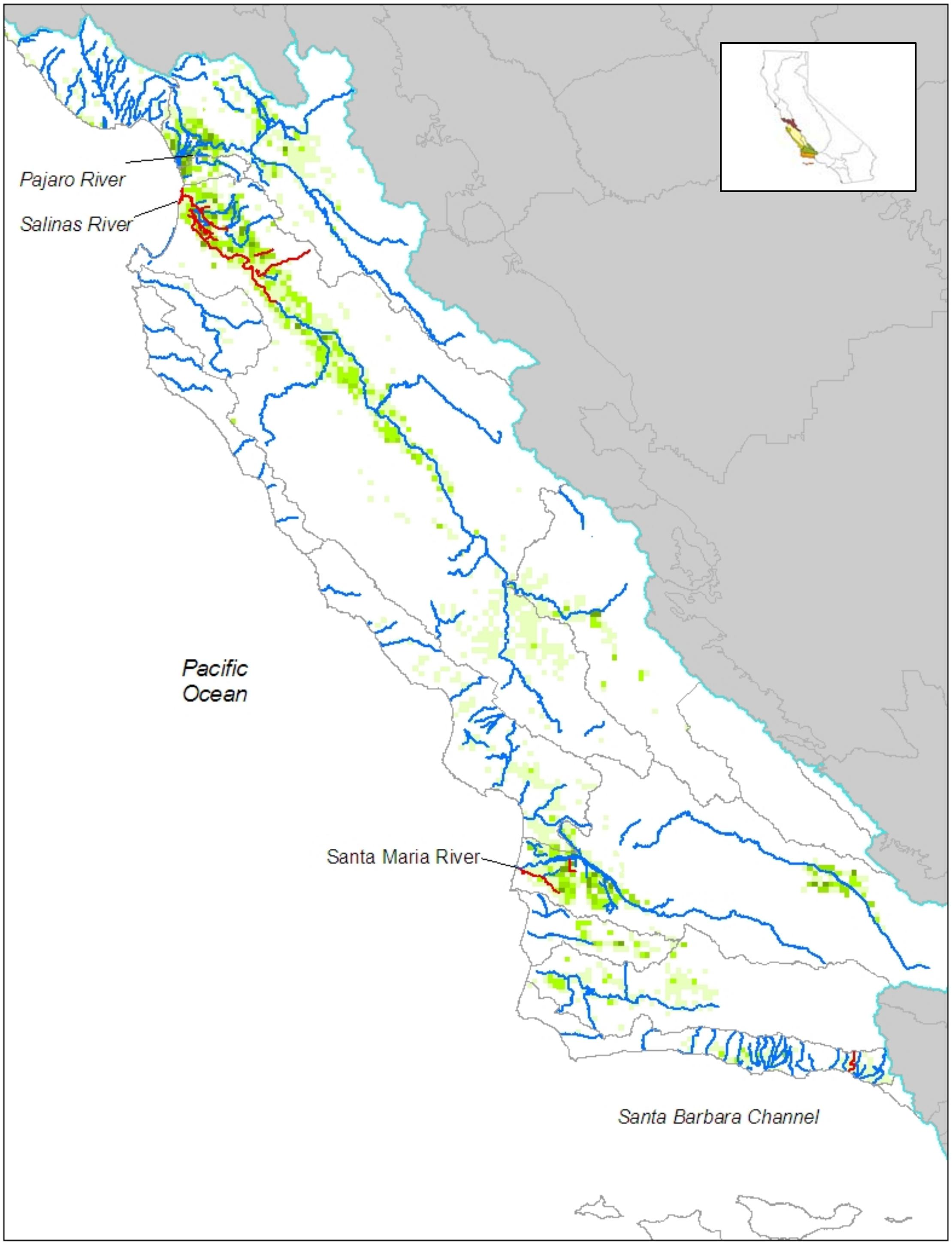
Map 3. 2010 Central Coast 303(d) Listings for Sediment Toxicity

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY SEDIMENT TOXICITY SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



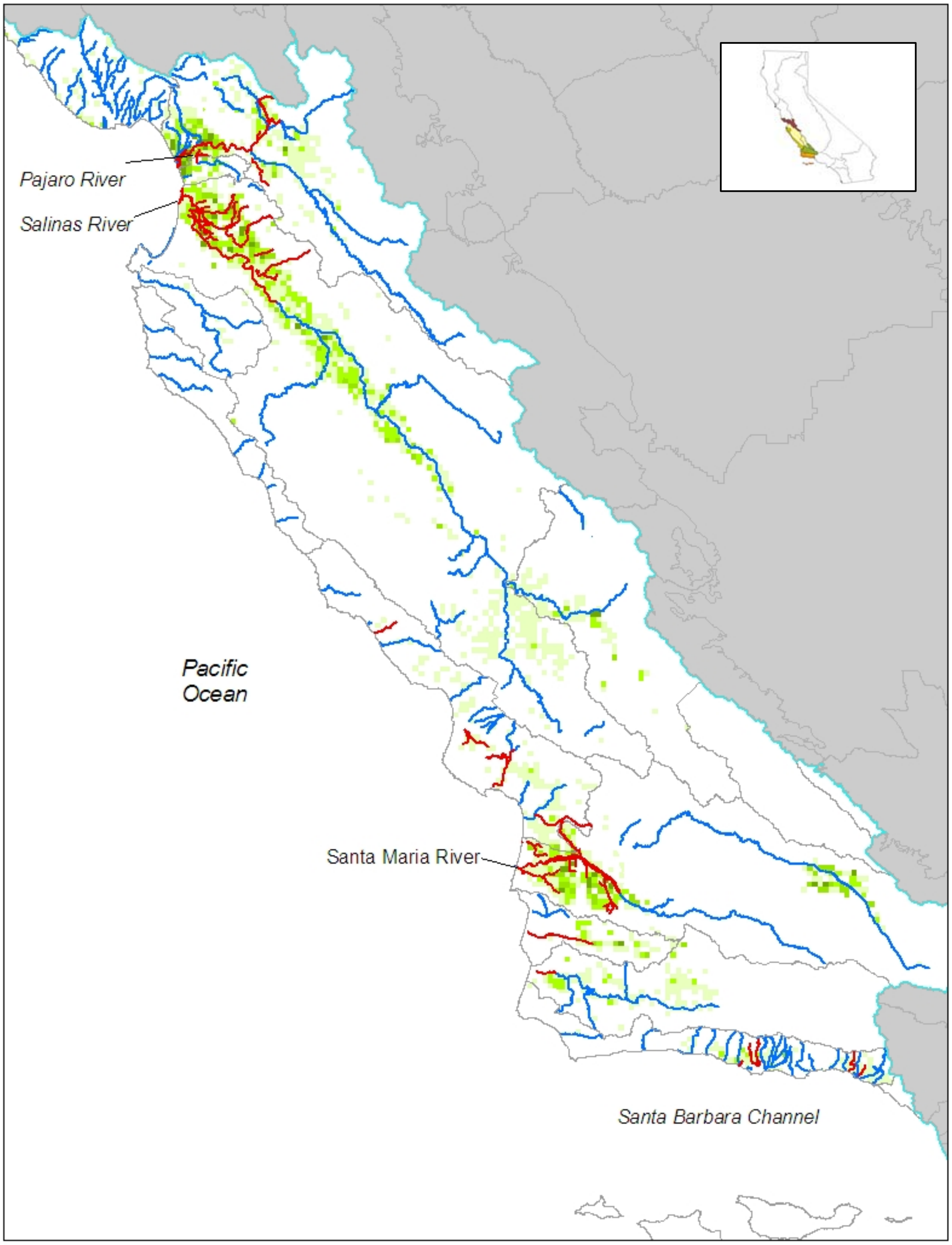
Map 4. 2010 Central Coast 303(d) Listings for Chlorpyrifos

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY CHLORPYRIFOS SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



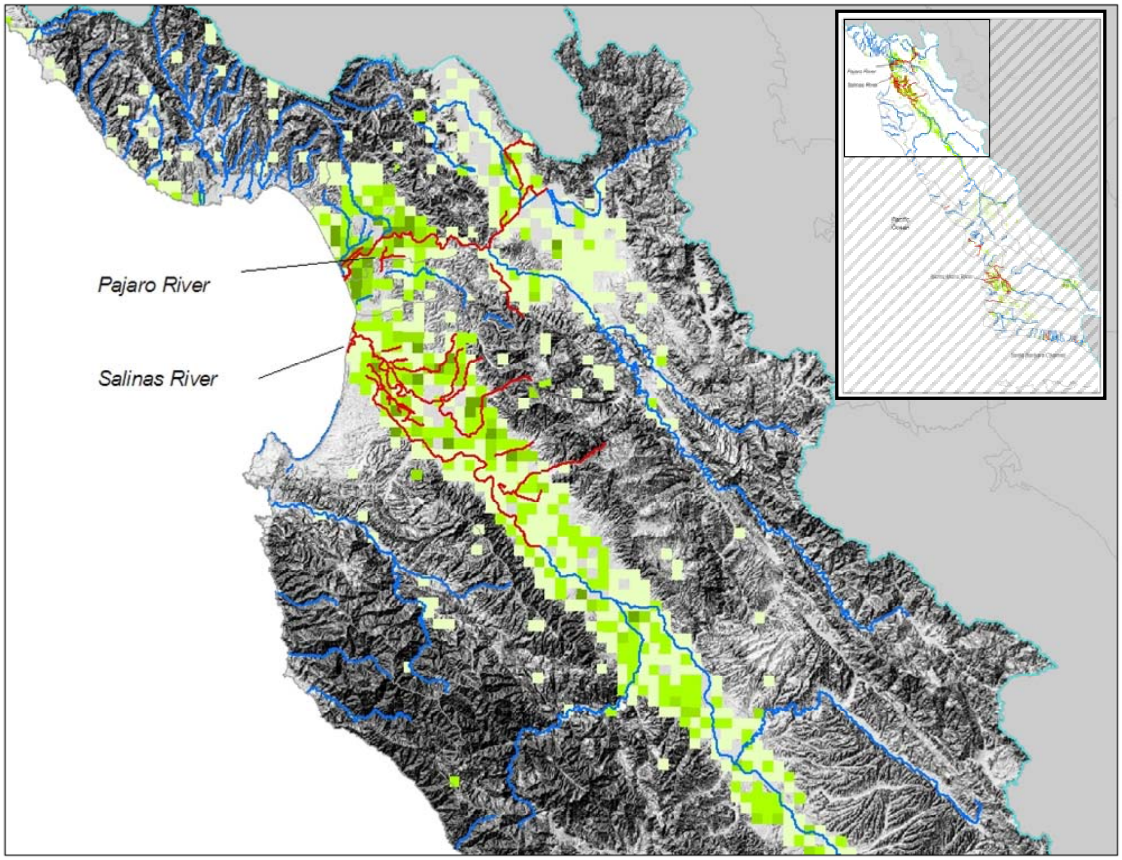
Map 5. 2010 Central Coast 303(d) Listings for Diazinon

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY DIAZINON SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



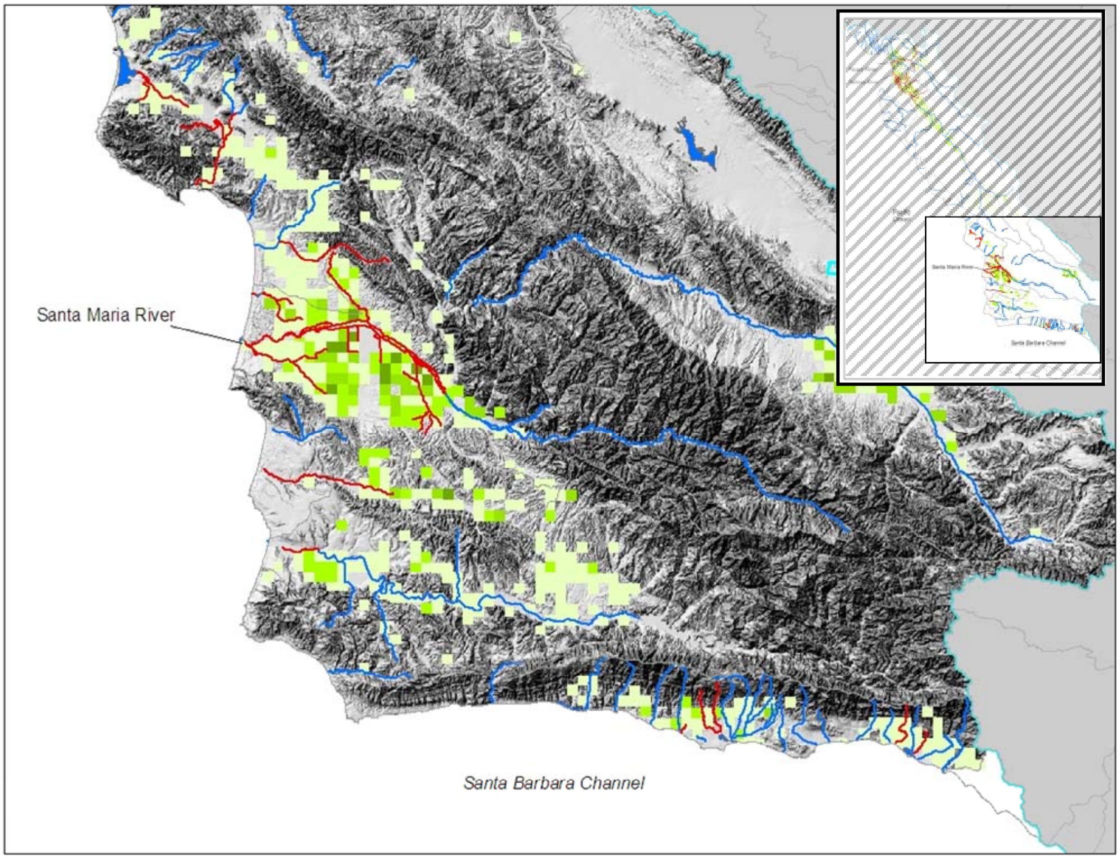
Map 6. 2010 Central Coast 303(d) Listings for Nitrate-N

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY NITRATE SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



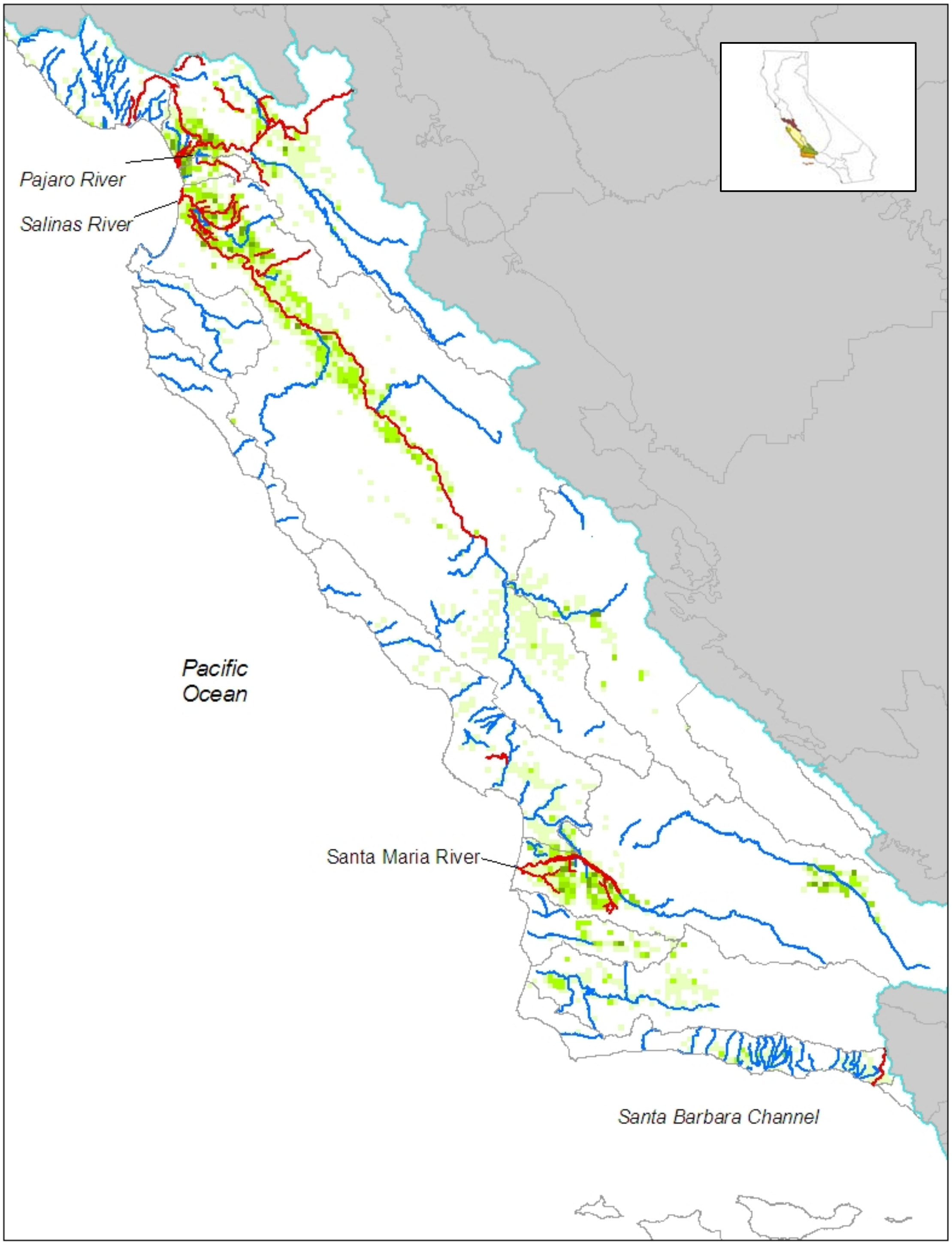
Map 7. 2010 303(d) Listings for Nitrate-N in the Monterey Bay Area, Including the Lower Salinas and Pajaro River Areas

MAJOR STREAM REACHES IN THE AREA ARE SHOWN, WITH REACHES IMPAIRED BY NITRATE SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



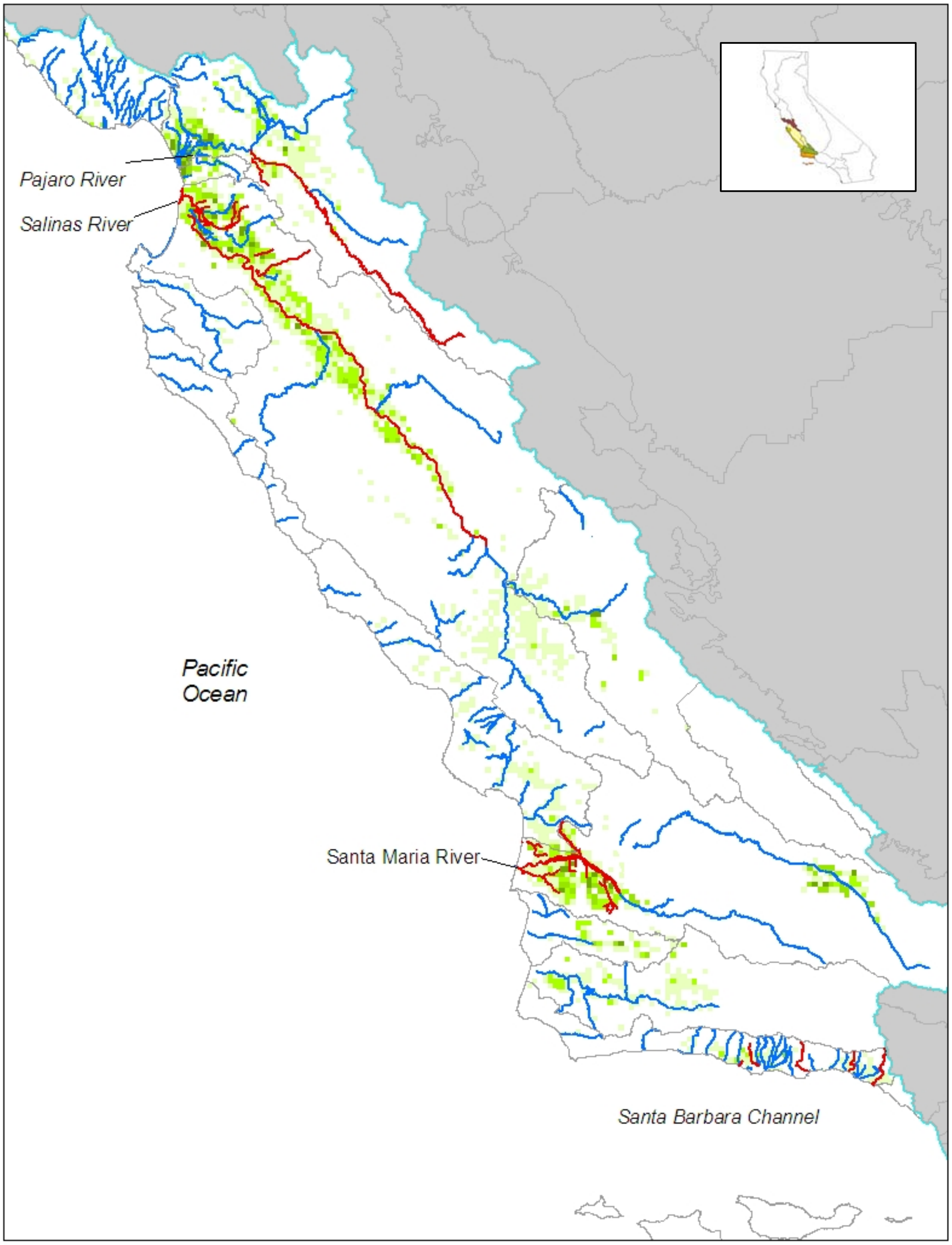
Map 8. 2010 303(d) Listings for Nitrate-N in Southern Region 3, Including the Lower Santa Maria River

MAJOR STREAM REACHES IN THE AREA ARE SHOWN, WITH REACHES IMPAIRED BY NITRATE SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



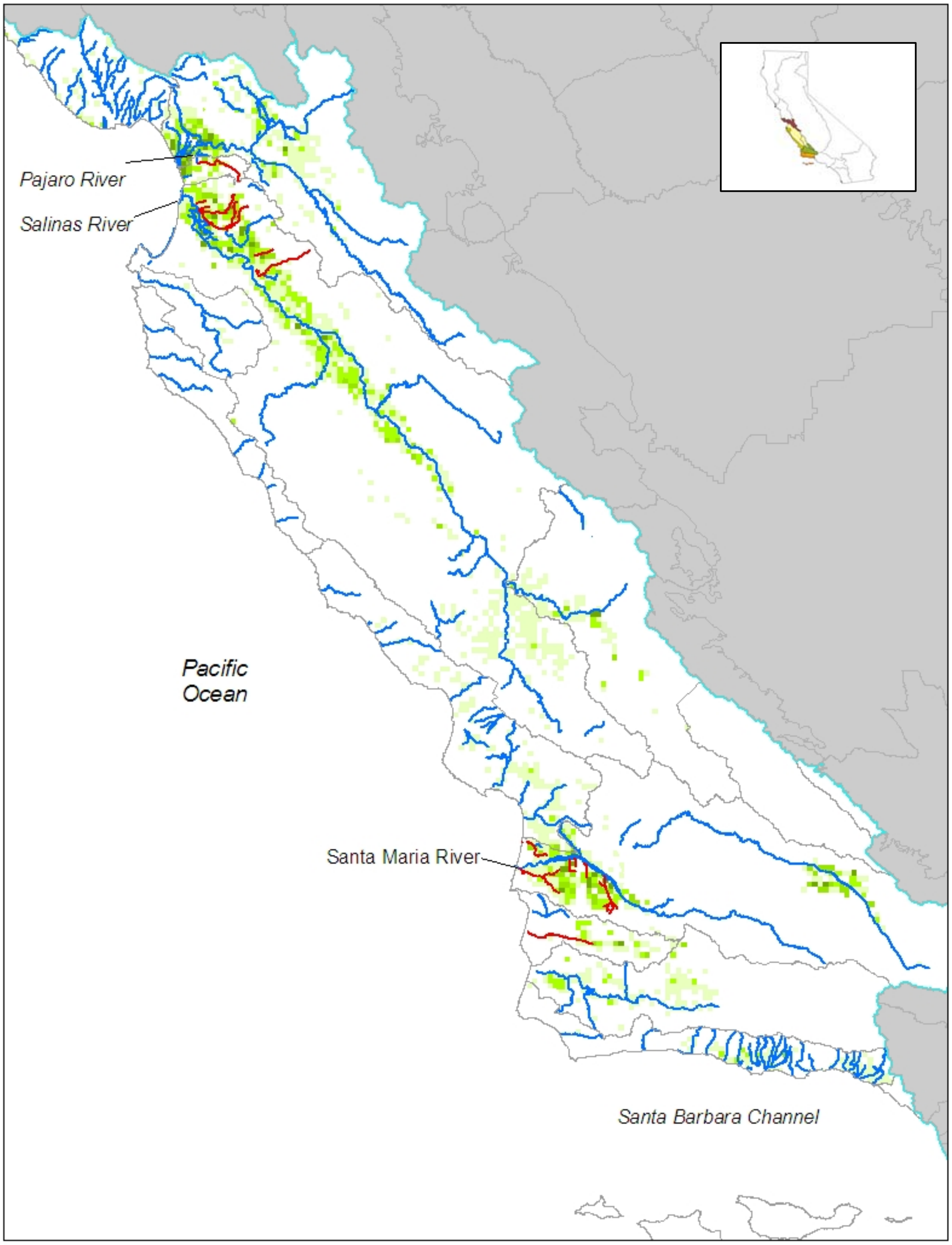
Map 9. 2010 303(d) Listings for turbidity in Region 3

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY NITRATE SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



Map 10. 2010 Central Coast 303(d) Listings for water temperature in Region 3

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY WATER TEMPERATURE SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.



Map 11. 2010 Central Coast 303(d) Listings for un-ionized ammonia in Region 3

MAJOR STREAM REACHES IN THE CENTRAL COAST REGION ARE SHOWN, WITH REACHES IMPAIRED BY UN-IONIZED SHOWN IN RED. AREAS OF AGRICULTURAL ACTIVITY ARE SHOWN IN GREEN SHADING.

Appendix C. Information on Toxicity sampling, methods, and research findings

Background

Toxicity tests are used to determine if waters and streambed sediments are toxic to or produce detrimental physiological responses in aquatic life, conditions specifically prohibited in the Central Coast Basin Plan. At some concentrations, pollutants can kill test organisms, but at lower concentrations can cause sub-lethal effects (such as changes in rates of reproduction, growth, or other anomalies). Test organisms are exposed to water and sediment samples in a controlled laboratory environment, and survival, growth, and other measures are compared to the same measures in concurrent exposures to clean water or sediment (control test). Statistical comparisons are made between the test and control populations to determine whether the test matrix has had a significant effect.

A number of chemicals can cause toxicity to test organisms. Clearly, pesticides and herbicides are primary target groups, because they are formulated specifically to kill invertebrates or plant life. Over the past decade, toxicity testing in our Region has focused on organophosphate pesticides, particularly chlorpyrifos and diazinon, as these two chemicals have repeatedly shown toxicity to invertebrate test organisms. Because of the toxicity of these chemicals, the U.S. Environmental Protection Agency moved to ban both chemicals for sale for urban uses in 2000 and also restricted uses of these chemicals for some agricultural purposes. They are both still applied on row crops, such as broccoli, lettuce, cauliflower and spinach. Diazinon is a very soluble chemical, and therefore tends to have toxic effects in the water column only. Chlorpyrifos is less soluble and can be found at toxic concentrations in sediment as well.

Pyrethroids are a newer class of pesticides that are replacing diazinon and chlorpyrifos for both urban and agricultural uses. Different pyrethroid chemicals have different properties in water, including solubility, persistence and toxicity, but generally tend to attach to sediment particles as do the long banned organochlorine pesticides. Because of this, they are most likely to be detected using sediment chemistry and toxicity tests, rather than water tests. Some pyrethroids are very stable in water and can remain toxic for many months; others begin to break down in a matter of days. Permethrin is extremely stable, but is also the least toxic of the commonly used pyrethroids. The median concentration that is lethal to 50% of test organisms (the

“LC50”) for permethrin for Hyalella is 10.53 ug/g; for other common pyrethroids it ranges between 0.45 and 1.54 ug/g (Starner and Kelley, 2004). These LC50 values are very low because pyrethroids are highly toxic to amphipods and fish.

Because chemicals in groups like the organophosphate and pyrethroid pesticides can have additive effects, they are sometimes evaluated in total, using Toxic Units (TUs). A toxic unit is the pesticide concentration for a given sample, divided by its respective LC50. Toxic units for all measured chemicals can be summed to create a single value to represent the potential toxic effects of multiple chemicals with different toxicity thresholds. Typically, any value over 1 TU is likely to kill half of the exposed test organisms.

Many other pollutants can cause toxicity, including petroleum products and other organic pollutants and some metals, such as copper and mercury. Ammonia is toxic to fish and is routinely quantified in toxicity test procedures. Some chemicals cause sublethal effects as well as mortality. Tests that include embryo-larval development, like the Pimephales test, may be useful in situations where teratogenic (cancer-causing) chemicals are present, or where chemicals that cause endocrine disruption are present, and some standard tests have been adapted to better assess reproductive fitness and endocrine function (Anderson et al., 2003c).

Toxicity Methods

Typically, toxicity testing in fresh water systems of the Central Coast has included four species (with other species substituted in brackish or saline waters). Following the US Environmental Protection Agency (USEPA) methodology for Whole Effluent Toxicity testing, an invertebrate, a fish and an alga are used to test the water column and an invertebrate is used to test sediment samples. Multiple species are used because some are more sensitive to certain classes of pollutants than others. Either acute or chronic tests can be used. On the Central Coast, most tests in the ambient environment have been chronic tests. These tests are longer in duration and typically have other test “endpoints” in addition to mortality, such as growth or reproduction. Both acute and chronic tests can be used with a dilution series of a field sample to provide information on the magnitude of toxicity. ***Ceriodaphnia dubia***, a planktonic crustacean commonly called a water flea, is the most commonly used fresh water invertebrate test organism in the Central Coast. In addition to survival, 7-day chronic tests on *Ceriodaphnia* include number and size of broods. Invertebrates tend to be more sensitive to many pesticides, since pesticides are formulated to kill insects and other invertebrates. *Ceriodaphnia* has shown a particular sensitivity to organophosphate pesticides. ***Pimephales promelas***, the fathead minnow, is a standard vertebrate test organism. *Pimephales* is less sensitive to organophosphates, but can be impacted by other pollutants, including ammonia and pyrethroid pesticides. In 7-day chronic tests, larval *Pimephales* are evaluated for increases in weight as well as for survival. ***Selenastrum*** is an alga commonly used to test for toxic effects in water. The 96-hour test examines the rate of algal cell growth relative to a control sample. Algae are used to test for toxicity associated with herbicides and metals such as copper that are toxic to plants. However, when nutrient levels are high in the test water, the test sample can show higher growth rates than the control sample. To some extent this growth effect can confound test interpretation, but a toxic sample definitely indicates a problem. Streambed sediments are usually tested for toxicity with ***Hyalella azteca***, an “epi-benthic” amphipod (closely associated with the sediment – water interface). *Hyalella* is native to the Central Coast Region and other parts of California. The *Hyalella* chronic test measures both survival and growth in 10-day exposures.

To determine the chemical causes of observed toxicity, **Toxicity Identification Evaluations (TIE)** can be conducted. These are complicated weight-of-evidence procedures in which the field samples are manipulated to alter the ability of specific chemicals to affect organisms. For example, filtration can remove toxicants associated with particulates. Aeration can remove volatiles, solid-phase extraction can remove non-polar compounds, and piperonyl butoxide can block the toxic effects of organophosphate pesticides. Researchers progressively inactivate or enhance each chemical group, test for toxicity, and then where possible reintroduce the chemical group back into the sample, and retest for toxicity. In this way researchers generate multiple lines of evidence about the source of the toxicity. Some chemicals, such as diazinon, can be specifically identified; others, such as PCBs, can be identified to class.

Toxicity Research Findings

Researchers and monitoring programs have documented toxicity in Central Coast waters and sediment, using multiple test organisms in both agricultural and urban settings. A compilation of references on toxicity in the Central Coast Region, both from peer reviewed journals and from technical reports is summarized below, and most of these articles and reports can be found posted on the Water Board’s CCAMP website (www.ccamp.org/Reports).

Granite Canyon Marine Pollution Studies Laboratory - The Granite Canyon Marine Pollution Studies Laboratory has been studying issues associated with toxicity in marine and fresh waters of the Central Coast for the past decade. Granite Canyon researchers were originally affiliated with the University of California, Santa Cruz but became part of the U.C. Davis Department of Environmental Toxicology in 1998. CCAMP formed in 1998 and began collaborations with Granite Canyon in the Pajaro and Salinas watersheds, and when the State Board initiated the statewide Surface Water Ambient Monitoring Program (SWAMP), Granite Canyon became one of the primary contractor laboratories for toxicity testing through SWAMP.

Granite Canyon researchers initiated work in the Pajaro watershed in the mid-1990's (Hunt et al., 1999). In that study, they used *Neomysis mercedis*, a resident crustacean, as the invertebrate test organism in water toxicity bioassays. They found significant toxicity at all seven sites they sampled in the lower watershed, but found that toxicity was most prevalent in agricultural drains (78% of all samples) and tributary ditches (25% of samples), compared to the main stem river and estuary (11% of samples). Toxicity in the estuary was correlated with higher river flow. Several chemicals, including toxaphene and DDT (both banned organochlorine pesticides) and diazinon (a currently applied pesticide) were found at potentially toxic levels. TIE results indicated that multiple compounds were responsible for toxicity, and implicated non-polar compounds (such as organochlorine pesticides), and possibly polar compounds as the cause of toxicity.

The Granite Canyon team also spent several years working intensively in the Salinas watershed and surrounding area. In 1997 they worked through the State Water Resource Control Board's Bay Protection and Toxic Cleanup Program to evaluate toxicity in Tembladero Slough between the City of Salinas and Moss Landing Harbor. They tested both sediment and sediment pore water. All sites on the drainage had sediment that was toxic to invertebrates. High levels of DDT, dieldrin, and chlordane (all banned organochlorine pesticides) were found in sediments, generally decreasing in concentration from upstream to downstream. This study did not analyze for other pesticide groups (like organophosphates or pyrethroids). The Harbor was subsequently listed as one of two "toxic hot spots" in the Region because of high concentrations of organochlorine pesticides (SWRCB 1998).

The Granite Canyon group then began work in the Salinas watershed, where they found extensive water column toxicity to the invertebrate Ceriodaphnia in the lower watershed (Hunt et al., 2003). TIEs generally implicated chlorpyrifos and/or diazinon (i.e.

every toxic sample had concentrations of one or both of these chemicals sufficient to cause toxicity). 100% of samples taken from an agricultural tail water drain were toxic, and 87% of samples from a channel draining a mixed agricultural and urban watershed were toxic. Only 13% of samples from a tile drain were toxic and 11% of samples on the main stem were toxic. Other studies have noted lower toxicity from areas drained by tiles; it is likely that pesticides are removed from water as it filters through soil to the tile drains.

In a related study conducted at about the same time, the Granite Canyon group documented high levels of chlorpyrifos and diazinon leaving an agricultural drain (Quail Creek), and tracked those levels downstream in the Salinas River (Anderson et al., 2003). They documented high toxicity in water and sediment from both the drain and river and a concurrent impact on benthic macroinvertebrate communities where toxicity and chemical concentrations were highest. In this study, they had direct evidence relating measures of organophosphate pesticides to water column and sediment toxicity, and showed associated benthic invertebrate community degradation. TIEs indicated toxicity due to chlorpyrifos, but also indicated that a pyrethroid pesticide might contribute to toxicity. A subsequent dose-response study (Anderson et al., 2006) showed that several native invertebrates were sensitive to the levels of chlorpyrifos and permethrin (a pyrethroid) measured in the river system.

Granite Canyon studies in the Santa Maria watershed began in the early 2000s. Anderson et al. (2006) collected water and sediment samples for toxicity testing, chemical analyses, TIEs, and assessed benthic invertebrate communities from several sites, including one in the lower Orcutt Creek, and one in the Santa Maria River just downstream of Orcutt Creek, near where it becomes an estuary. Water samples from both of these sites were toxic to Ceriodaphnia, with high levels of chlorpyrifos (implicated by the TIE). Sediment sampling and subsequent TIEs from the same sites suggested chlorpyrifos and most likely a pyrethroid pesticide were responsible for observed sediment toxicity to Hyalella. Benthic invertebrate samples from these two sites were impacted relative to an upstream reference site, implying that toxicity and ecological damage are related. The researchers had few toxic samples at other sites evaluated in the study.

Phillips et al. (2006) evaluated sediment toxicity in Orcutt Creek in more detail. Several pesticides were present, including chlorpyrifos, DDT, and three pyrethroid pesticides (permethrin, esfenvalerate, and fenvalerate). Though individual concentrations were below documented toxic thresholds, many of these chemicals are known to have synergistic or additive effects. Also, only four pyrethroids were tested in this study; several others are applied in the watershed. TIE analysis indicated that one or more organic chemicals were responsible for toxicity, likely including a pyrethroid pesticide.

Hunt et al. (2005) evaluated the utility of pesticide–use reporting data for identifying sites at risk for toxicity, and examined whether nitrate concentrations could be used as a surrogate to identify sites at risk for toxicity. The study showed that there were significant correlations between intensity of pesticide application rates and in-stream toxicity, but that nitrate was not useful as a predictor of where toxicity might be found.

The Granite Canyon group has also done work in the Region on effectiveness of agricultural management practices (MPs) in reducing toxicity (Hunt et al., 2007 and 2008). These studies evaluated two types of vegetated treatment systems. Sediment and water toxicity testing and TIEs were used to evaluate the effectiveness of MPs in reducing concentrations of chemicals that caused toxicity. In one treatment system, inflows were toxic and contained toxic levels of chlorpyrifos (water and sediment) and permethrin (sediment). Significant reductions in chemical concentrations and toxicity were achieved at the outflow. The other system typically had water toxicity due to diazinon and sediment toxicity from lambda-cyhalothrin and cypermethrin (pyrethroids) at the inflow. Most pesticides were reduced in concentration at the outflow. Diazinon concentrations were less effectively reduced, likely because its high solubility limits absorption in the vegetated treatment system.

Surface Water Ambient Monitoring Program (SWAMP) - In 2006, SWAMP funded a statewide urban pyrethroid study that included a number of sites in the Central Coast. Granite Canyon researchers conducted the toxicity work for this study. Sites were selected to be representative of urban impacts only, to the extent possible. None of the ten sites initially screened in Region 3 showed toxicity, but more detailed follow-up testing found toxicity at three of five sites, though one may be influenced by greenhouses in the area. Pyrethroid chemistry analysis was conducted at two of these sites and found lambda-cyhalothrin and bifenthrin present. Pyrethroids are unusual in that they are more toxic at colder temperatures; this characteristic can be used as partial evidence that the chemical of interest is a pyrethroid. Many sites in the statewide study were more toxic at colder temperatures, implicating pyrethroids as a widespread cause of toxicity in urban streams.

U.C. Berkeley, Salinas Study - Dr. Don Weston (Integrative Biology Department of U.C. Berkeley) has worked on pyrethroid toxicity issues primarily in the Central Valley of California. In previous studies in the Central Valley, he has showed that homeowner use of insecticides and structural pest control by professional applicators can be responsible for a significant amount of toxicity in adjacent drainages. Some of the concentrations he detected in urban areas were many times more toxic than those he found in agricultural areas. The U.C. Berkeley group expanded their research on pyrethroid toxicity into three creeks draining through the City of Salinas (Ng et al., 2008). At all sites, including both urban and agricultural land uses, sediment toxicity was found with pyrethroid concentrations high enough to explain the toxicity (exceeding the LC50). Though there were not distinct differences between pesticide patterns in urban and agricultural areas, two pyrethroids, cyfluthrin and cypermethrin, tended to be typical of urban areas, while lambda-cyhalothrin tended to be found in agricultural areas. Other pyrethroids, bifenthrin and permethrin, were found in drainages associated with both land uses. In addition, chlorpyrifos contributed toxicity at one agricultural site.

California Department of Pesticide Regulation - In 2003, the Department of Pesticide Regulation (DPR) sampled agricultural dominated streams in the Salinas area for pyrethroid pesticides in sediment and water (Starner and Kelley, 2004 and Starner et al., 2004). Monitoring targeted fourteen sites and resulted in seventy-six total samples from the lower Salinas area. Starner et al. (2006) found 85% of sediment samples contained at least one pyrethroid pesticide and that 42% of samples exceeded one Toxic Unit (the sum of individual pesticide concentrations divided by their associated LC50s for Hyalella). In a statewide study of four agricultural areas conducted by the Department of Pesticide Regulation, the Salinas study area had the highest percent of sites with pyrethroid pesticides detected (85%), the highest percent of sites that exceeded levels expected to be toxic (42%), and the highest rate (by three-fold) of active ingredients applied (113 lbs/acre) (Starner, 2006).

In another study by Starner (2009) on diazinon use in the Central Valley , Imperial Valley and Central Coast, the Salinas area was found to account for 45 to 50 percent of all statewide use during spring and summer months, and irrigation season use was characterized as "very high", with most applications on lettuce. Detection frequencies were greater than 95% in the Salinas area. This study did not find diazinon use to be declining in the Salinas and Pajaro areas. Diazinon use in the Santa Maria area was considered moderate.

Appendix D. Marine Protected Areas (MPAs) at greatest risk for impacts from agricultural discharges

Extremely High Risk: Moro Cojo Slough

Moro Cojo Slough is a State Marine Reserve and a Marine Protected Area. This wetland area is surrounded by intensive agricultural activity. Staff has determined that it is the MPA at highest risk for impact from agricultural activities, and in fact it is already severely impaired. This slough, along with Elkhorn and Tembladero Sloughs and other waterbodies within the extensive wetland system, is designated as part of the Moss Landing Toxic Hot Spot, identified by the Bay Protection and Toxic Cleanup program in 1998. This original designation was primarily based on contamination by organochlorine pesticides. More recent data, collected by CCAMP and the CMP, suggest that organophosphate pesticides are causing water column toxicity. It is likely that herbicides are as well, given algae toxicity results. Based on chemical application patterns and research by Ng et al. (2008) in the area, sediment toxicity is likely caused by chlorpyrifos and/or pyrethroid pesticides.

Moro Cojo is sampled monthly by the CMP and on a five-year rotation by CCAMP. It has high levels of un-ionized ammonia and ortho-phosphate. Nitrate remains under the Drinking Water standard but always exceeds the screening value to protect for aquatic life uses (1 mg/L). Dissolved oxygen is low, dropping at times to a virtually anoxic condition. The CMP and CCAMP have documented invertebrate and algal toxicity here, in both sediment and water tests. Moro Cojo Slough is listed as impaired by pesticides, sedimentation, un-ionized ammonia, low dissolved oxygen, *E. coli*, Total coliform, and pH. Given the current toxicity evidence, it will likely be proposed for listing as impaired by toxicity in the future. This MPA is at extremely high risk for impacts from agricultural chemicals.

Very High Risk: Elkhorn Slough

Elkhorn Slough is identified as the MPA at second highest risk for impacts from agriculture and is one of the few for which data exists documenting impairment. Elkhorn Slough is currently listed as impaired due to pesticides and sedimentation. It is on the 2010 List as impaired by low dissolved oxygen, total coliform and pH. Low dissolved oxygen concentrations can occur when excessive nutrient enrichment causes algal growth that depletes water of its oxygen content. Nitrate loadings to Elkhorn Slough have been studied extensively by Ken Johnson at the Monterey Bay Aquarium Research Institute's Land/Ocean Biogeochemistry Observatory (LOBO), using sophisticated nitrate sensors deployed at numerous locations inside and outside the Slough:

'Nitrate sensors in the LOBO array reveal a persistent nitrate concentration increase that spans two orders of magnitude from the already rich waters of Monterey Bay to the tidal region of the Old Salinas River Channel. The nitrate concentrations in the old river channel are at nearly 100 times higher than the largest values found in the ocean. The extreme nitrate levels in runoff that enters Elkhorn Slough fuels such high primary production rates that shallow slough ponds have been described as "hyper-ventilating."' – From the MBARI website (http://www.mbari.org/twenty/LOBO.htm)

Dr. Johnson has shown that nitrate leaving the Old Salinas River Channel (which primarily receives input from Tembladero Slough and at times from the Salinas River) is moved up into Elkhorn Slough in an incoming tide. Toxicity testing of these drainages has shown significant water and sediment toxicity as well. Pesticides causing toxicity are presumably also transported into Elkhorn Slough on incoming tides. This MPA is at very high risk of impact from agricultural activities in the area.

Medium Risk: South Santa Ynez River Mouth

The South Santa Ynez River Mouth MPA is considered at medium risk for impacts from agricultural activities because of its proximity to a major river mouth with water quality problems. The Santa Ynez River is influenced by irrigated agriculture, but perhaps more so by a wastewater treatment plant discharge from the City of Lompoc. The Santa Ynez River is listed as impaired by nitrate, sodium, chloride, *E. coli*, fecal coliform, low dissolved oxygen, water temperature, and total dissolved solids.

Total applications of pyrethroid pesticides in the Santa Ynez watershed are low compared to those in Salinas, Pajaro, or Santa Maria watersheds. For example, total pounds of pyrethroid pesticides applied to the Santa Ynez watershed in 2007 were 2,188 pounds, compared to approximately 10,000 pounds in the Santa Maria watershed, 8,600 pounds in the Pajaro watershed, and 25,000 in the Salinas watershed. Though pollutant levels are not as severe as in some other agricultural areas, the location of the MPA immediately down coast from the river mouth allows discharge from the river to enter the MPA when coastal currents are moving south. Surface currents are heavily influenced by wind, and can be viewed on the Southern California Coastal Ocean Observatory

System website (SCCOOS Currents). This is a relatively high energy marine environment, suggesting significant mixing and higher substrate size, which should tend to minimize impacts.

Medium Risk: Monterey Bay

Two MPAs are designated in the deep waters of Monterey Bay. Though these MPAs are relatively distant from the shoreline, they are in the vicinity of the two largest river plumes in the Region (the Salinas and Pajaro Rivers), both of which are heavily influenced by agricultural activities in their respective watersheds. CCLEAN has found elevated levels of legacy pesticides (above California Ocean Plan limits) in open waters of Monterey Bay, and has also found concentrations of DDT in sediments at the 80-m contour to be associated with changes in some species abundance. These data imply that sediment-borne pesticides can be present at levels of concern in nearshore waters.

Monterey County has had the highest poundage of pyrethroid pesticides applied in the State (Starner, 2004), and overall, over 30,000 pounds of pyrethroids are applied annually to Salinas and Pajaro watersheds (DPR PUR, 2007). Chlorpyrifos can also attach to sediment particles and cause toxicity in sediment. Almost 50,000 pounds of chlorpyrifos are applied annually to the Pajaro and Salinas watersheds combined (DPR, 2007).

U. C. Berkeley researchers analyzed archived CCLEAN sediment samples (collected at sites along the 80-m contour) for pyrethroid pesticides and did not detect them (D. Hardin, pers. comm.). Though the sample count is small, this is encouraging data from the standpoint of impacts to these two MPAs. However, other research linking anthropogenic sources of nitrates to toxic plankton blooms may have implications for these MPAs. If river-sourced nitrate increases the frequency or toxicity of Pseudo-nitzchia blooms, MPAs in the Monterey area are at risk because of proximity to the large nitrate inputs from the Salinas and Pajaro rivers. UCSC research indicates that at some times nutrient discharges from rivers may be important drivers of toxic plankton blooms. This research shows that the ratios of nitrate to other nutrients coming from the Pajaro and Salinas rivers are extreme when compared to other sources (other streams and rivers, upwelling, and wastewater). Seasonal models show that nitrate concentrations and river discharge are significant predictors of blooms during periods of the year when upwelling is not dominant (Lane et al.,2009; Lane, in review).

Low-Medium Risk: Morro Bay

Morro Bay is a National Estuary that receives runoff from two creeks that have agricultural activity in their watersheds. Chorro Creek is listed as impaired by fecal coliform, E. coli, sedimentation and nutrients, and was delisted in 2010 for dissolved oxygen. Los Osos Creek is listed for fecal coliform, dissolved oxygen and nitrate. TMDLs are in place for these pollutants. Morro Bay itself is listed for pathogens, sedimentation (TMDLs in place), and low dissolved oxygen (2010 listing).

Overall, potential loading of agricultural pollutants is small relative to larger agricultural watersheds. For example, approximately 100 pounds of pyrethroid pesticides were applied in the Morro Bay watershed in 2007, compared to over 10,000 pounds in the Santa Maria watershed. Under 200 pounds of chlorpyrifos were applied in Morro Bay, compared to 30,000 pounds in the Santa Maria watershed (DPR Pesticide Use Report, 2007). The CMP site in Warden Creek is typically not toxic (with one toxic sample reported for algae and one for invertebrates).

The San Luis Obispo Science and Ecosystem Alliance (SLOSEA) has identified high levels of nonylphenol in fish in Morro Bay. This chemical is a potent endocrine disruptor, and numerous fish in the Bay have gonadal tumors, liver disease, and other irregularities that appear to be related to high tissue concentrations of this chemical. Pesticide formulations are one source of this chemical, though it is found widely in detergents, cosmetics, and other common products. SLOSEA researchers have found high levels of nonylphenol in wastewater and in septic discharges, as well as in other bays, including Tomales Bay.

The Chorro Creek Nutrient TMDL, adopted by EPA in 2007, identifies the California Men's Colony wastewater treatment plant discharge as the primary source of nutrients, and cropland as a secondary source to Chorro Creek. The Los Osos Nutrient TMDL (adopted by EPA in 2005) identifies cropland as the source of 86% of the nutrient load to Los Osos Creek. The thousands of septic systems in Los Osos are an additional source of nutrients to Morro Bay. Though agriculture is only one of several sources of nitrate entering Morro Bay, it definitely is a contributing source, and Morro Bay's recent listing as impaired by dissolved oxygen suggests that nutrient levels are contributing to eutrophic conditions in the Bay.

We have ranked Morro Bay as "low-medium" from the standpoint of risk from agricultural impacts. Agricultural pesticide application in the watershed is relatively low, with few toxic effects detected. Other sources, including septic systems and wastewater discharges probably contribute more significantly than agriculture to the eutrophic conditions in the Bay.