# II. ASSESSMENT OF WATER QUALITY

## A. WATERBORNE POLLUTANTS ARISING FROM THE MAINLAND

### *A.1. Pertinent Mainland Coastline*

The Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz and Anacapa) are separated from the mainland by the Channel. Of these four islands, Anacapa is closest to the mainland; ~24 km separate East Anacapa and Port Hueneme, near the city of Oxnard. The north shores of San Miguel, Santa Rosa and Santa Cruz are ~50-65 km from the mainland coast. Runoff from the mainland directly enters the Channel from numerous small coastal streams that drain the southern slopes of the Santa Ynez mountains and from the mouths of the Ventura and Santa Clara Rivers. Santa Barbara is situated ~64 km from the nearest mainland point, Palos Verdes Point, in Los Angeles County. All five of the islands are subject to Bight-scale processes and current regimes. Coastal water quality from the west entrance of the Channel, at Point Conception, to the east entrance of the Channel, at Port Hueneme, is most directly relevant to the four northern Channel Islands. Owing to its southerly location outside of the Channel, Santa Barbara is more likely to be affected by coastal water quality from Point Mugu to (at a minimum) the mouth of the Los Angeles River.

### *A.2. Water quality jurisdictions*

Water quality in California is regulated by the California Water Resources Control Board. The state is divided into the following nine Regional Water Quality Control Boards (Regional Boards):

Region 1: North Coast WQCB
Region 2: San Fransisco Bay WQCB
Region 3: Central Coast WQCB
Region 4: Los Angeles WQCB
Region 5: Central Valley WQCB
Region 6: Lahontan WQCB
Region 7: Colorado River Basin WQCB
Region 8: Santa Ana WQCB
Region 9: San Diego WQCB

The stretch of coastline most likely to deliver pollutants to Channel Islands National Park (north to south, from Point Conception to Los Angeles Harbor) is contained in Regions 3 and 4.

Region 3. Surface waters from Region 3 are assigned to 16 smaller areas referred to as *Hydrologic Unit*s (HUs). Two of these HUs are pertinent to this report: *South Coast HU 15* (which includes mostly first order streams draining the coastal mountains from Point Arguello to Carpinteria) and *HU 16* (which includes San Miguel, Santa Rosa and Santa Cruz) (Figure 15).

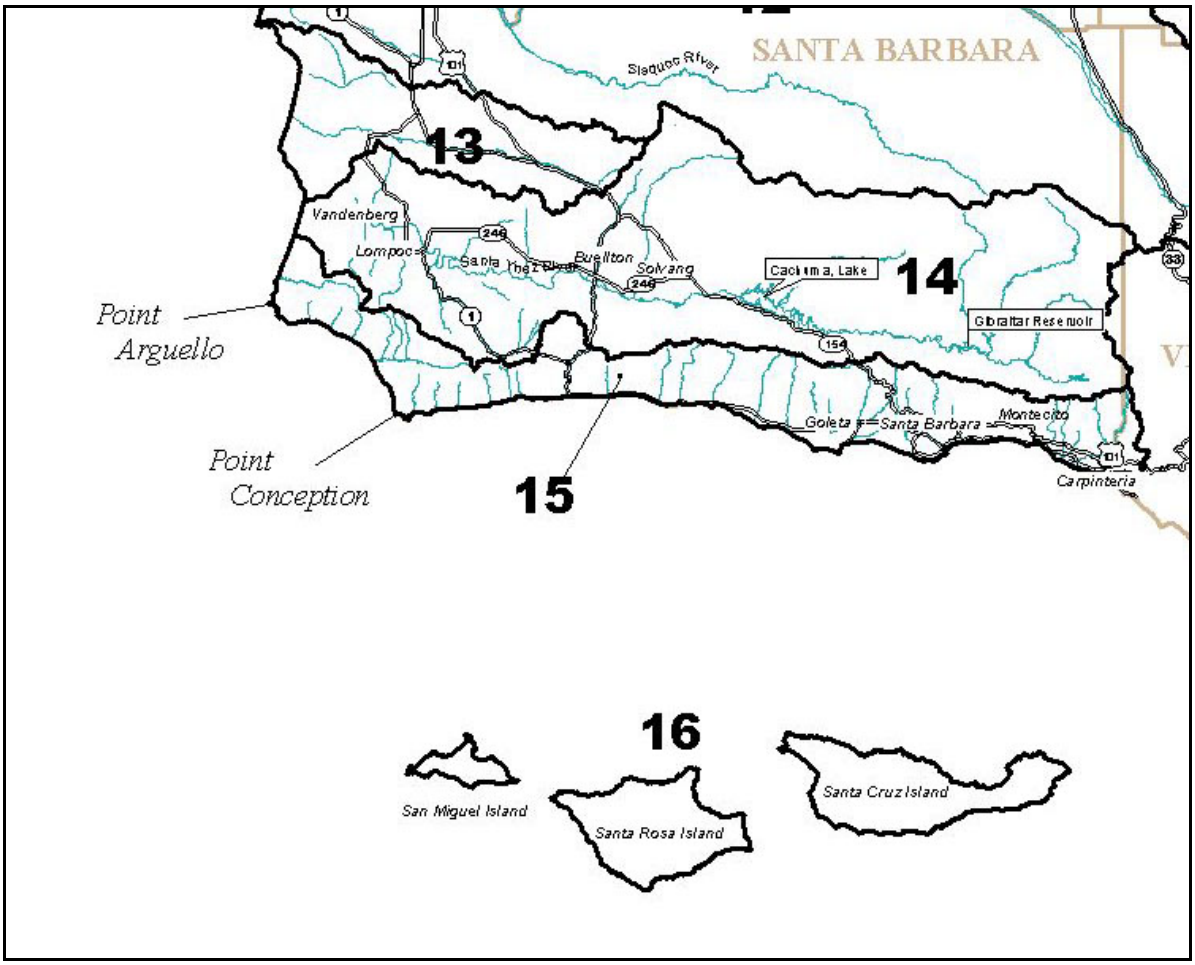



Figure 15. Southernmost Hydrologic Units in Region 3. Hydrologic Unit 15 (*"Central Coast"*) contains coastal streams that empty into the Santa Barbara Channel. Hydrologic Unit 16 contains surface waters on San Miguel, Santa Rosa and Santa Cruz Island (downloaded, and modified 8/2005 from www.waterboards.ca.gov/centralcoast/images/reg3map_001.jpg).

Region 4. Surface waters from Region 4 are assigned to one of ten *Watershed Management Areas* (WMAs) (Figure 16). State lists of 303(d) water quality limited segments and NPDES permits are developed for individual WMAs. Two of the islands in the Park (Anacapa and Santa Barbara) fall under the jurisdiction of Region 4, and constitute the "Channel Islands WMA". Storm flow from three other WMAs of Region 4 are especially pertinent as potential direct sources of pollution in the Channel:

(1) Misc. Ventura Coastal WMA (which is a collection of first order coastal streams, three harbors and one lake),
(2) Ventura River WMA, and
(3) Santa Clara River WMA.

Four other WMAs of Region 4 are pertinent as sources of pollutants to the coastal ocean in the vicinity of Santa Barbara Island:

(1) Calleguas Creek WMA,
(2) Santa Monica Bay WMA,
(3) Dominguez Channel WMA, and
(4) Los Angeles River WMA.

Owing to some development on Catalina, San Clemente and San Nicolas Islands, the Channel Islands WMA is also included in discussions below.

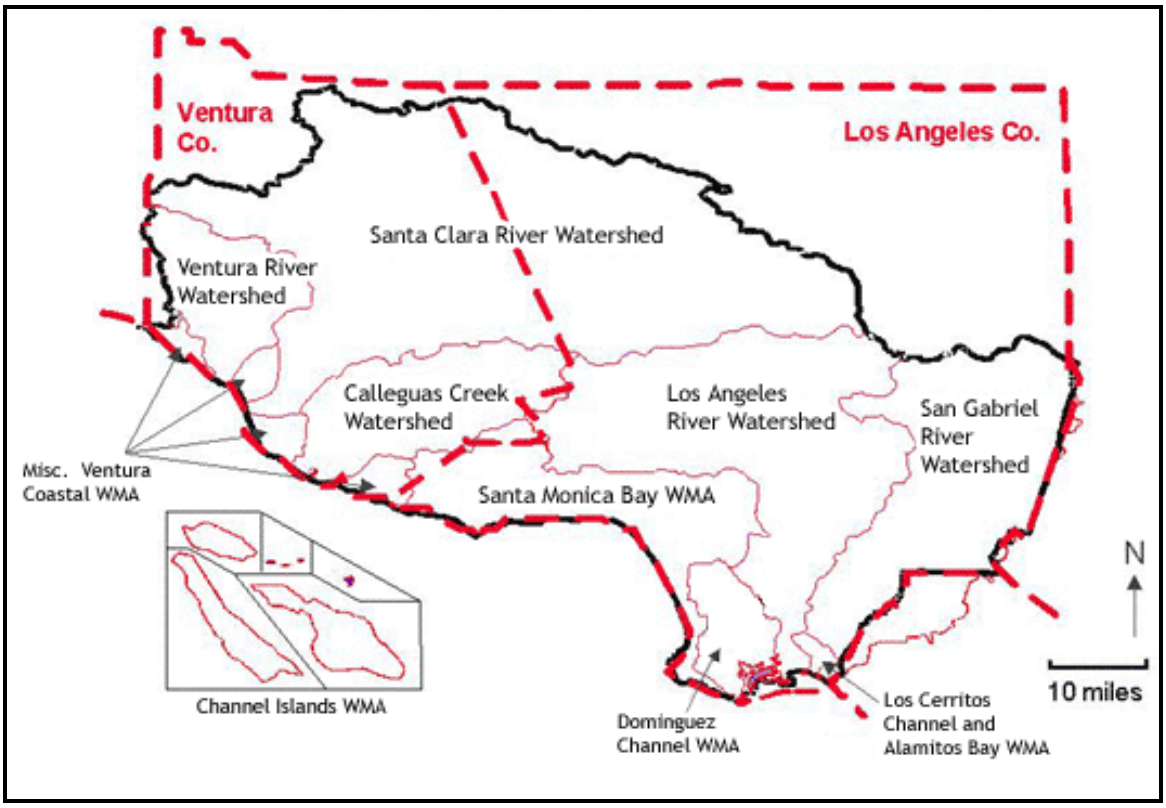



Figure 16. Division of Region 4 into Watershed Managements Areas (WMAs). Map was obtained from the Region 4 website: (http://www.waterboards.ca.gov/losangeles/html/programs/regional_programs.html#Watershed)

### *A.3. Point sources on Mainland*

#### a. State permitted discharges to waterways (NPDES permitees)

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Industrial, municipal, and other facilities must obtain permits if their discharges go directly into surface waters. In California, the NPDES permit program is administered by the State. The permits contain limits on what can be discharged, monitoring and reporting requirements, and other provisions. Pollutants include dredged soil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes,

biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste. Point source means any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container. It also includes vessels or other floating craft from which pollutants are or may be discharged. By law, the term "point source" also includes concentrated animal feeding operations, which are places where animals are confined and fed. By law, agricultural stormwater discharges and return flows from irrigated agriculture are not "point sources".

NPDES waste water permits are either *individual* or *general*. An individual permit is specifically tailored to an individual facility. These are developed based on the type of activity, nature of discharge, and receiving water quality. Individual permits are further categorized into *Major* or *Minor* dischargers. *Major* dischargers are either (1) Publically Owned Waste Water Treatment Works (POTWs) with a yearly average flow of over 0.5 million gallons per day (MGD), (2) industrial sources with a yearly average flow of over 0.1 MGD, or (3) those with lesser flows but with acute or potential adverse environmental impacts. *Minor* dischargers are all other dischargers that are not categorized as Major. A *general permit* is an NPDES permit that covers several facilities that have the same type of discharges and are located in a specific geographic area (such as oil platforms, see Section II.B.2). A general permit applies the same or similar conditions to all dischargers covered under the general permit. Table 7 lists all permittees that discharge treated sewage directly into the ocean in the pertinent coastal areas.

### b. POTW discharges: Historic and current threats

The major souces of pollutants in the Bight in the early 1970s were POTWs. In a notorious example, prior to 1971, the White's Point Outfall on the Palos Verdes Shelf (see JWPCP in Table 7) was the conduit for massive DDT and PCB release into the coastal ocean. Between 1947 and 1971, Montrose Chemical Corp. of California's Torrance manufacturing plant, seven miles inland, dumped about 1,800 tons of DDT and an undisclosed amount of PCBs into the Los Angeles County sewer lines, which terminate at the White's Point Outfall (see Section II.B.1). Owing to improved treatment, source control, and pretreatment, cumulative pollutant loads from POTWs have declined several fold - even orders of magnitude for some dischargers. For example, between 1971 and 1996, the percentage of combined wastewater flow by Bight POTWs subjected to secondary treatment rose from 10% to 49% (Schiff et al. 2000). This has resulted in recovery for some marine biota over the last 30 years. Fish diseases (such as fin rot and epidermal tumors) were common in the 1970s, but now are at background levels. Kelp beds near large sewage outfalls that were only a fraction of their historical extent in 1970 have experienced exceptional recruitment. Reductions in kelp extent to 1970 levels are currently only observed during El Niño events, such as during 1987-1988 (Schiff et al. 2000). Largely as a result of reductions in emissions from POTWs in the Bight, suspended solids and BOD decreased by 50%, heavy metals decreased by 90%, and chlorinated hydrocarbons decreased by 99%, in discharges to the ocean between 1971 and 1996. Consequently, urban runoff (stormwater) in the Bight now contributes significantly more suspended solids, nitrate, phosphate, chromium, copper, lead, nickel and zinc than discharges from small and large POTWs combined (Table 8). The main source of lead is oil platform discharges, and the main source of mercury is power plant discharges. PCBs are no longer detected in POTW discharges in the Bight (Schiff et al. 2000).

**Summary**. Appendix E lists all major, minor, and general NPDES wastewater discharge permits issued in coastal watersheds (as of 9/2005) from Point Conception to the mouth of the Los Angeles River. Owing to the enormity of the list, the specific contaminants associated with each permit, and reported violations from specific facilities, are not provided in the appendix. A north to south trend of increasing urbanization and industrialization - and increasing numbers of potential point-sources of pollution - is evident, however, following even a casual inspection of the list.

Table 7. POTW outfalls from treatment plants that discharge directly to the ocean from Point Conception to the mouth of the Los Angeles River.[a]

| POTW (NPDES#) | Treatment processes | distance from shore (feet) | depth (feet) | Comments |
|---|---|---|---|---|
| **Region 3, Unit 15** | | | | |
| Goleta CA0048160 | Primary and secondary blended w. disinfection | 5800 | 90 | An upgrade to full secondary treatment is planned under a settlement for 2014. Treats sewage from Goleta, UC Santa Barbara, some of Santa Barbara County, Santa Barbara Municipal Airport |
| Santa Barbara CA0048143 | Secondary with disinfection | 8720 | 79 | Up to 4.3 MGD can be recycled |
| Montecito CA0047899 | Secondary with disinfection | 1550 | 22 | |
| Summerland CA0048054 | Secondary with disinfection | 740 | 19 | Tertiary, except when filters are being changed |
| Carpinteria CA0047364 | Secondary with disinfection | 1000 | 25 | |
| **Region 4** | | | | |
| Oxnard CA0054097 | Secondary | 5280 | 48 | |
| Hyperion (Los Angeles City) CA0109991 | Secondary | 10,000 | 200 | 2 additional outfalls used in emergencies. Some wastewater reclaimed and reused. Treats dry weather storm water runoff. Los Angeles, Beverly Hills, San Fernando, W. Hollywood, Santa Monica, Inglewood, Universal City, Alhambra, Pasadena, S. Pasadena, Culver City, and El Segundo |
| JWPCP LA County CA0053813 "White's Point Outfall" | Blended primary and secondary with disinfection | 10,000 | 200 | Called the White's Point Outfall. **Significant source of DDT** to Palos Verdes Shelf during 1950s-70s when Montrose Chemical Company operated - one of the nation's largest producers of DDT. Legacy effects from DDT contamination in this area are predicted to persist for another century[b]. |
| Terminal Island (LA City) CA0053856 | Tertiary with disinfection | | outer LA Harbor | This plants treats wastewater from domestic sources and heavy industry. Reuse is being practiced. Terminal Island in the Los Angeles-Long Beach Harbor, communities of Wilmington, San Pedro and a portion of Harbor City. |
| Avalon CA0054372 | Secondary | 400 | 130 | City of Avalon on Catalina Island |
| NALF, San Clemente Island WWTP | Secondary | | | Treats waste from a US Navy Auxiliary Landing Field |

[a]Information on distances and depths, and some comments, obtained from "Heal the Ocean - "Ocean Wastewater Discharge Inventory for the State of California", report by Heal the Ocean to the California Ocean Protection Council, March 2005

[b]Distribution and Fate of Contaminated Sea-floor Sediment on the Shelf Offshore Los Angeles, introduction to USGS research at White's Point, and links to publications http://walrus.wr.usgs.gov/pv/. White's Point is discussed in Section II.B.1.

### *A.4. Non-Point Source Water Pollution from Mainland*

#### a. State Storm Water Program

The 1987 Water Quality Act requires the EPA to issue NPDES permits for the several categories of stormwater discharges. This is an effort to regulate non-point source pollution generated by runoff from land and impervious areas such as paved streets, parking lots, and building rooftops during precipitation. Through the Regional Boards, the SWRCB issues NPDES permits to government and private entities for storm water discharges. This process is distinct from the issuance of NPDES permits for *waste water* discharges. Three different types of storm water permits are issued: municipal, construction and industrial. Once permits are issued, the permittees are obligated to certain monitoring and reporting procedures and to carrying out best management practices to limit contamination of storm flow with sediment and other contaminants.

Construction Permits. Owing to Stormwater Phase II Final Rule of 1999, operators of small construction sites (1-5 acres of disturbed area) became required to obtain a NPDES permit and develop a Storm Water Management Program (SWMP). Dischargers whose projects disturb one or more acres of soil, or whose projects disturb less than one acre but are part of a larger common plan of development that in total disturbs one or more acres, are required to obtain coverage under the General Permit for Discharges of Storm Water Associated with Construction Activity (Construction General Permit, 99-08-DWQ). Construction activity subject to this permit includes clearing, grading and disturbances to the ground such as stockpiling, or excavation, but does not include regular maintenance activities performed to restore the original line, grade, or capacity of the facility.

Industrial Permits. The federal storm water regulations, Code of Federal Regulations Section 122.26(b)(14), require the following facilities to obtain industrial stormwater permits:

1. Facilities subject to storm water effluent limitations guidelines, new source performance standards, or toxic pollutant effluent standards (40 CFR Subchapter N);
2. Manufacturing facilities;
3. Mining/oil and gas facilities;
4. Hazardous waste treatment, storage, or disposal facilities;
5. Landfills, land application sites, and open dumps that receive industrial waste;
6. Recycling facilities such as metal scrap yards, battery reclaimers, salvage yards, automobile yards;
7. Steam electric generating facilities;
8. Transportation facilities that conduct any type of vehicle maintenance such as fueling, cleaning, repairing, etc.;
9. Sewage treatment plants;
10. "Light industries" where industrial materials, equipment, or activities are exposed to storm water.

Table 8. Total mass emissions of selected pollutants from several sources to coastal ocean in the Southern California Bight. Table adapted from Schiff et. al. (2000).

| Constituent | Total Load | Percent of Total Load | | | | | |
|---|---|---|---|---|---|---|---|
| | | Urban Runoff | Large POTWs | Small POTWs | Industrial Facilities | Power Plants | Oil Platform |
| Year of estimate | | 1994-1995 | 1997 | 1995 | 1995 | 1995 | 1990 |
| Flow | | 21.36 | 11.19 | 1.44 | 0.17 | 65.81 | 0.04 |
| Suspended solids (mt) | 674 200 | 88.76 | 10.90 | 0.29 | 0.05 | 0.01 | «0.01 |
| BOD (mt) | 140 541 | - | 98.19 | 1.68 | 0.13 | «0.01 | «0.01 |
| Oil and grease (mt) | 19 922 | - | 96.37 | 2.32 | 0.45 | 0.14 | 0.72 |
| Nitrate-N (mt) | 9224 | 95.41 | 2.87 | 1.65 | - | 0.07 | - |
| Nitrite-N (mt) | 151 | - | 84.11 | 15.89 | - | - | - |
| Ammonia-N (mt) | 45 898 | 1.96 | 90.06 | 7.84 | 0.12 | 0.01 | - |
| Organic N (mt) | 5880 | - | 99.00 | 1.00 | - | - | - |
| Phosphate (mt) | 4702 | 61.68 | 38.32 | - | - | - | - |
| Total P (mt) | 1841 | - | 100.0 | - | - | - | - |
| Cyanide (kg) | 8026 | - | 80.99 | 18.71 | «0.01 | «0.01 | 0.30 |
| Arsenic (kg) | 5723 | - | 87.37 | 6.67 | 4.11 | 1.00 | 0.86 |
| Cadmium (kg) | 2085 | - | 47.01 | 21.68 | 0.21 | 30.94 | 0.16 |
| Chromium (kg) | 38 396 | 76.05 | 18.23 | 3.65 | 0.25 | 1.05 | 0.78 |
| Copper (kg) | 149 464 | 58.61 | 35.46 | 4.53 | 0.03 | 1.31 | 0.06 |
| Lead (kg) | 51 349 | 76.53 | 4.67 | 4.64 | 0.03 | 2.29 | 11.83 |
| Mercury (kg) | 262 | - | 8.39 | 4.19 | 0.03 | 85.38 | 2.02 |
| Nickel (kg) | 91 572 | 63.67 | 32.53 | 2.96 | 0.15 | 0.01 | 0.69 |
| Selenum (kg) | 9212 | - | 84.67 | 8.48 | 6.85 | «0.01 | «0.01 |
| Silver (kg) | 6031 | «0.01 | 89.54 | 10.38 | 0.01 | _0.01 | 0.07 |
| Zinc (kg) | 443 437 | 71.35 | 19.39 | 3.57 | 0.24 | 4.17 | 1.27 |
| Phenols (kg) | 166 643 | - | 97.57 | 0.02 | 0.84 | «0.01 | 1.57 |
| Chlorinated | 2900 | - | 96.55 | 3.45 | «0.01 | «0.01 | - |
| Nonchlorinated | 94 966 | - | 99.83 | 0.17 | «0.01 | «0.01 | - |
| Total DDT (kg) | 3 | - | 91.18 | 8.82 | «0.01 | «0.01 | - |
| Total PCB (kg) | «0.1 | - | - | - | - | - | - |

Municipal Permits. The Municipal Storm Water Permitting Program regulates storm water discharges from municipal separate storm sewer systems (MS4s). MS4 permits were issued in two phases. Under *Phase I*, which started in 1990, the Regional Boards have adopted NPDES storm water permits for medium (serving between 100,000 and 250,000 people) and large (serving 250,000 people) municipalities. Most of these permits are issued to a group of co-permittees encompassing an entire metropolitan area. These permits are reissued as they expire.

Under *Phase II*, which started in 1999, MS4s serving less than 100,000 people must obtain a NPDES permit, called a General Permit for the Discharge of Storm Water from Small MS4s (WQ Order No. 2003-0005-DWQ). Included as MS4s are smaller municipalities, including non-traditional small MS4s (governmental facilities such as military bases, public campuses, and

prison and hospital complexes). The permit must describe how the regulated entity will identify and implement a range of Best Management Practices into an effective SWMP that reduces the discharge of pollutants to the maximum extent practicable (MEP). MEP is the performance standard specified in Section 402(p) of the Clean Water Act. SWMPs include public education and outreach; illicit discharge detection and elimination; construction and post-construction; and good housekeeping for municipal operations. In general, medium and large municipalities are required to conduct chemical monitoring, though small municipalities are not.

Region 3. As of 9/2005, no Phase I municipal stormwater permits had been issued in HU 15 (as of 9/2005, Salinas was the only Phase I municipal permittee in Region 3). The following Phase II municipal permits have been applied for, or approved, in HU 15:

- Isla Vista (applied)
- Carpinteria (approved)
- Santa Barbara, City (applied)
- Summerland (applied)
- Goleta (applied)
- Santa Barbara County (applied)
  The permit includes the urbanized unincorporated areas of the county on the South Coast, in the Santa Ynez Valley, and in the Orcutt area of the Santa Maria Valley. In May 2004 the County of Santa Barbara released its Draft Storm Water Management and Discharge Control Ordinance as required by the Phase II storm water regulations.

Region 4. As of 9/2005, the following Phase I municipal stormwater permits had been issued in Region 4:

- City of Long Beach (NPDES #CAS004003)
- County of Los Angeles and the Incorporated Cities Therein except the City of Long Beach (NPDES #CAS004001)
- Ventura County (NPDES #CAS004002)
  This permittee is a partnership of the County of Ventura, Ventura County Flood Control District, and the Cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura (Ventura), Santa Paula, Simi Valley, and Thousand Oaks.

### b. Contaminants present in mainland water bodies draining to ocean.

303(d) Listed Water Bodies. California's SWRCB and the nine Regional Boards are responsible for monitoring, assessment, and reporting under Clean Water Act Sections 303(d) and 305(b) for the State of California. The State Board and Regional Boards cooperate in developing Section 305(b) and Section 303(d) listing reports. *For the purposes of this report, the 303(d) lists provide an indication of the overall levels of pollution in the coastal watersheds in the vicinity of the Park, and the diversity of contaminants present in waterbodies drain into the ocean along the pertinent stretch of coastline*. Appendix F provides a complete list of all pertinent 303(d) listed waters, and reported impairments, from Regions 3 and 4. Types of impairments reported from Region 3 (HUs 15-16) and Region 4 are summarized in Tables 10 and 11, respectively.

Table 9. Categorization of NPDES permits from Point Conception to the mouth of the Los Angeles River (as of 9/2005). Owing to their temporary nature, the number of active Construction Stormwater Permits in any jurisdiction changes frequently.

| Hydrologic Unit | Waste Water Permits | Storm Water Permits |
|---|---|---|
| Region 3 Hydrologic Units | | |
| Unit 15 | Major: 6 includes. 5 POTWs<br>Minor: 1 | Municipal: 1 (Carpinteria)<br>Industrial: 37<br>Construction: 62 |
| Unit 16 | none | none |
| Region 4 WMAs | | |
| Southern Channel Islands | Major: 1 (Catalina Island)<br>Minor: 4 | Industrial: 5<br>Construction: 1 |
| Misc. Ventura | Major: 4 1 POTW and 2 generating stations<br>Minor: 9<br>General: 11 | Industrial: 82<br>Construction: 92 |
| Ventura River | Major: 1 POTW discharging to middle reach, upgraded to tertiary treatment<br>General: 6 | Industrial: 37<br>Construction: 13 |
| Santa Clara River | Major: 4 POTWs (one discharging to estuary, one to middle reaches, two into upper watershed)<br>Minor: 11<br>General: 15 | Industrial: 114<br>Construction: 317 |
| Calleguas Creek | Major: 5 (all POTWs)<br>Minor: 6<br>General: 13 | Municipal: 1<br>Industrial: 73<br>Construction: 276 |
| Santa Monica Bay | Major: 7 includes 3 POTWs (two direct ocean discharges), one refinery, 3 generating stations<br>Minor: 21<br>General: 158 | Industrial: 87<br>Construction: 220 |
| Dominguez Channel and Los Angeles/Long Beach Harbors | Major: 9 includes 1 POTW, 2 generating stations, 5 refineries<br>Minor: 48<br>General: 0 | Industrial: 399<br>Construction: 134 |
| LA River | Major: 144 includes 4 POTWs<br>Minor: 23<br>General: 114 | Municipal: 2<br>Industrial: 1336<br>Construction: 436 |

**sources of data:**
Region 3:
SWRCB Stormwater Site, Construction Permit Database (http://swrcbnt3.swrcb.ca.gov/stormwater/search/ConSearch.asp),
Industrial Permit Database (http://swrcbnt3.swrcb.ca.gov/stormwater/search/IndSearch.asp)
Municipal Permit Database (http://www.swrcb.ca.gov/stormwtr/municipal.html)
Region 4: watershed management site: http://www.waterboards.ca.gov/losangeles/html/programs/regional_programs.html#Watershed

According to current 303(d) lists, coastal watersheds in Region 3 are much less polluted than in Region 4. The majority of the pollutants in Region 3 are pathogens (unspecified), fecal coliform, or total coliform in stream segments, stream mouths, or beaches. Toxicants (priority organics and metals) were only reported from two water bodies (Carpinteria Marsh and Goleta Slough). Most of the contamination in Region 4 originates south of the Santa Clara River watershed. No toxicants were reported from the Ventura River watershed, although there were bacterial and nutrient exceedances in some reaches. The Santa Clara River watershed was also affected by nutrient and bacterial contamination, but only one toxicant was reported from the watershed (toxiphene, in the river's estuary). Although most of the NPDES waste water permittees in the Misc. Ventura WMA discharge into coastal streams, no exceedances were reported in lotic systems in this hydrologic unit. Instead, contamination with metals and other toxicants was reported for Channel Island Harbor, Port Hueneme, and McGrath Lake, which are situated in the Oxnard Plain south of both Ventura and the mouth of the Santa Clara River. According to the CA 303(d) lists, no impaired waters occur on any of the Channel Islands (Unit 16 in Region 3,

plus Channel Islands WMA in Region 4), including all of the islands within the Park, plus Catalina, San Clemente and San Nicolas Islands.

Table 10. Types of impairments in 303(d) listed waters (coastal streams, beaches and sloughs) in Region 3, Hydrologic Unit 15 (vicinity of city of Santa Barbara to the Ventura County line). No impairments were reported for Unit 16 (San Miguel, Santa Rosa and Santa Cruz Islands). See Appendix F for the complete list of 303(d) listed segments from this part of the coast.

| |
|---|
| Fecal Coliform |
| Low DO |
| Metals |
| Nutrients |
| Pathogens |
| Priority Organics |
| Total Coliform |
| Unknown toxicity |

Owing to high numbers of point sources and permitted discharges, and the wide range of contaminants in surface waters from the Calleguas Creek WMA southward, it is very likely that mainland runoff entering the coastal ocean from Point Mugu to the mouth of the Los Angeles River is much more polluted than runoff north of Point Mugu. Mainland runoff *directly* entering the Channel (which occurs from Port Hueneme to Point Conception) should carry a smaller load of pollutants than mainland runoff south of the Channel. Santa Barbara Island is most directly offshore from the Palos Verdes Point, at the southern end of Santa Monica Bay. To the extent that pollutants can be transported 36 miles from the shore to Santa Barbara Island, contaminants from many of the hydrologic units of Region 4 represent potential threats to water quality in the Park (but see Section II.A.6). During synoptic flow regimes that transport water from the Bight offshore of Los Angeles County poleward into the Channel (*Relaxation* and *Flood West* regimes, see Section I.B.1) pollutants from Region 4 are potentially transported into the Channel. For these reasons, summary discussions of the overall condition of surface waters in each of the pertinent WMAs of Region 4 are provided in Appendix G. These discussions provide some guidance in setting priorities for addressing the risks to the Park represented by dry weather or wet weather flow from the principal drainages in Region 4.

Table 11. Types of impairments in 303(d) listed waters (streams, rivers, beaches, channels, sloughs, harbors, bays, lakes) in Region 4 from the Ventura County/Santa Barbara County line to the mouth of the Los Angeles River. See Appendix F for the complete list of 303(d) listed segments from this part of the coast.

| | | |
|---|---|---|
| aldrin (tissue) | enteric viruses | PCBs (tissue & sediment) |
| algae | eutrophic | PCBs (tissue) |
| aluminum, total | eutrophic trash | pesticides |
| ammonia | exotic vegetation | pH |
| beach closures | fecal coliform | reduced tidal flushing |
| benthic comm. effects | fish barriers | scum/foam-unnatural |
| boron | fish consumption advisory | sediment toxicity |
| cadmium | habitat alteration | sedimentation/siltation |
| cadmium (sediment) | hexachlorocyclohexane (HCH) (tissue) | Selenium |
| cadmium, dissolved | hydromodification | Selenium, total |
| ChemA* (tissue) | Lead | shellfish harvesting advisory |
| chlordane (sediment) | Lead (in sediment) | silver (sediment) |
| chlordane (tissue - fish consumption advisory) | Lead (sediment) | specific conductance |
| chlordane (tissue & sediment) | Lead (tissue) | sulfate |
| chlordane (tissue) | Lead, dissolved | swimming restrictions |
| chloride | Low DO | Tetrachloroethylene/PCE |
| chlorpyrifos (tissue) | low DO/organic enrichment | total dissolved solids |
| chromium (sediment) | Mercury | toxaphene |
| coliform | Mercury (sediment) | toxaphene (tissue & sediment) |
| coliform, fecal | Mercury (tissue) | toxaphene (tissue) |
| copper | nickel | toxaphene (tissue) |
| copper (sediment) | Nickel (sediment) | toxicity |
| copper (tissue & sediment) | nitrate (NO3) | trash |
| copper, dissolved | nitrate + nitrite | Trichloroethylene/TCE |
| dacthal (sediment) | nitrogen | Zinc |
| DDT | nutrients (algae) | Zinc (sediment) |
| DDT (fish consumption advisory) | odors | Zinc (tissue & sediment) |
| DDT (sediment) | oil | zinc, dissolved |
| DDT (tissue & sediment) | organophosphorus pesticides | |
| DDT (tissue) | PAHs | |
| debris | PAHs (sediment) | |
| Dichloroethylene/1,1-DCE | PAHs (tissue & sediment) | |
| dieldrin (sediment) | pathogens | |
| dieldrin (tissue) | PCBs | |
| endosulfan (tissue & sediment) | PCBs (fish consumption advisory) | |
| endosulfan (tissue) | PCBs (sediment) | |

### *A.5. Contamination and Toxicity in Storm Plumes*

Episodic storms, typically occurring late fall through early spring, contribute up to 95% of the annual runoff volume and pollutant load in the Bight (Schiff et al. 2000). Current estimates of mass emissions for the southern California region indicate stormwater discharges of many constituents rival, and often exceed, those from combined point sources (e.g. nitrate, phosphate, chromium, copper, lead, nickel and zinc (Table 8). More than 60% of the southern California shoreline exceeds water contact standards for bacteria following wet weather events. However, Ahn et al. (2005) discovered that severe bacterial contamination in the surf zone from stormwater discharged from the Santa Ana River (south of Los Angeles) was limited to a fairly small stretch of the beach (<5 km on either side of the river). They postulated that the spatial confinement of the contamination resulted from physical transport processes (e.g., dilution by rip cell-mediated exchange of water between the surf zone and offshore) or nonconservative processes (e.g., the removal of fecal indicator bacteria from the surf zone by die-off or sedimentation) (Ahn et al. 2005).

Direct measurements of chemical contaminants in offshore storm plumes are scarce. However, storm drain discharges in Southern California have been shown to be toxic to marine and freshwater organisms and this toxicity persists to some degree as discharge plumes spread through coastal receiving waters (Jirik et al. 1998). Toxicity tests, measuring the ability of sea urchin sperm to fertilize eggs, were conducted on stormwater collected from Ballona Creek and surface water of storm plumes in the Santa Monica Bay (Bay et al. 2003). Toxicity was present whenever plume water contained at least 10% creek water. Toxicity was detected at a maximum of 4 km offshore after a 2-year storm in Feb. 1996. Dissolved zinc, and occasionally dissolved copper, were found to be at toxic levels in undiluted stormwater from Ballona Creek, and postulated to be the constituents responsible for much of the toxicity in tests conducted on plume water. Overall, dissolved constituents were responsible for more toxicity than particle-bound constituents in creek water. However, particle-bound toxicity was relatively more important in plume water at sea than it was in creek water upstream of the mouth. Zinc was similarly implicated in toxicity tests of Chollas Creek stormwater in the San Diego Bay (Schiff et al. 2003).

### *A.6. Likelihood that Mainland Storm Plumes enter the Park*

#### a. Mainland storm plumes that enter the Channel

Otero & Siegel (2004) evaluated four years (Oct. 1997-Jun. 2001) of Advanced Very High Resolution Radiometer (AVHRR) and Sea-viewing Wide-Field-of-View sensor (SeaWiFS) data for the Channel. Normalized water-leaving radiance at 555 nm, or *LwN(555)*, was used as a proxy for suspended sediment to delineate plumes at sea produced by mainland runoff. The annual cycle for mean monthly LwN(555), computed by Otero & Siegel (2004) for the whole period, is presented in Figure 17. It shows that most sediment enters the coast between Ventura and Oxnard (owing to the mouths of the Ventura and Santa Clara Rivers), and that, on average, February is the month during which sediment plumes penetrate furthest offshore into the Channel toward Anacapa and Santa Cruz.

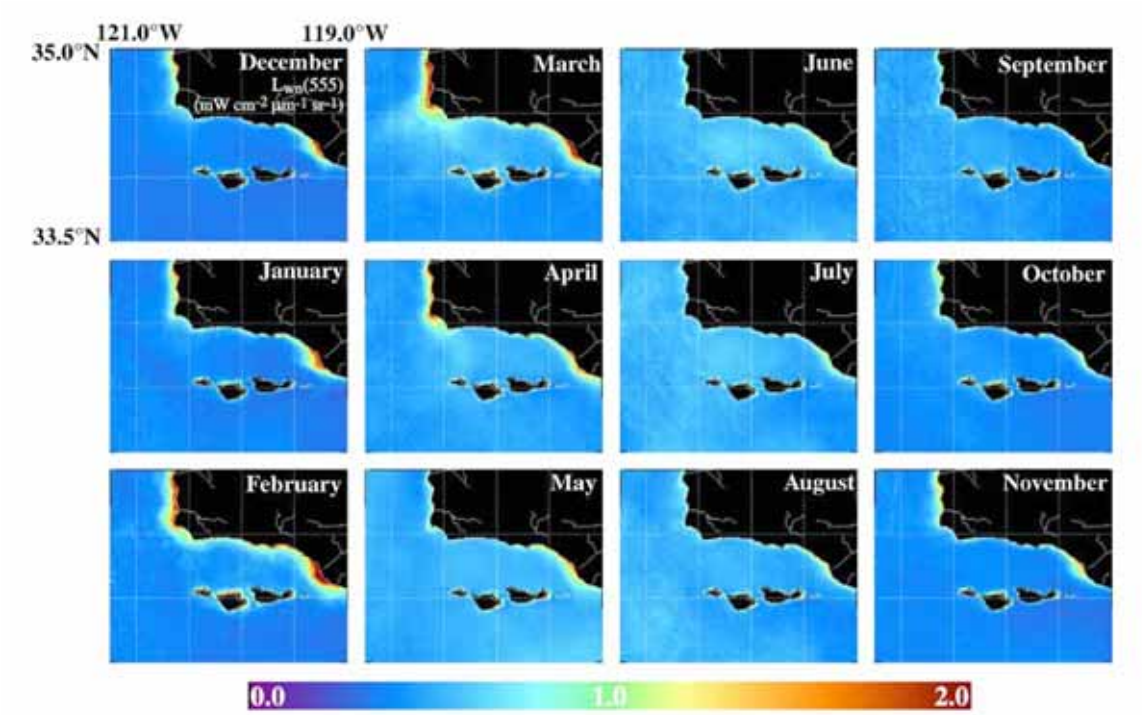



Figure 17. LwN(555) monthly mean annual cycle computed from all available images. Images above are composites of all data from each month. The monthly mean annual cycle is computed from October 1997 to June 2001 (Otero & Siegel 2004).

Salinity in the well-mixed freshened surface layer (*hypopycnal plume*) produced by the Santa Clara River ranges from 30.0-33.0 psu, and is <10 m deep (Warrick et al. 2005). Over 90% of the sediment entering the ocean is lost from the water column within ~1 km of the mouth of the Santa Clara River during discharge events. In contrast, the hypopycnal surface plume is advected (initially by discharge inertia in a well defined jet, and subsequently by wind and currents) at least an order of magnitude further away from the river mouth (Warrick et al. 2004a). Annually recurring storms (~2-year events) produce jets extending ~10 km offshore. However, remotely sensable fine suspended sediments ordinarily extend further away from the river mouth than the salinity anomalies (Dave Siegel, Professor, Department of Geography, UCSB, pers. comm.). Large sediment plumes, covering >20% of the Channel, occur about once per year (Warrick et al. 2004a). Less frequent, larger storms (~10-year events) can produce plumes extending ~30 km into the Channel (Warrick et al. 2004b) (Figure 18). Growth of phytoplankton, especially at the leading edge of sediment plumes, can interfere with retrievals of suspended sediment signals, such that remotely sensed data may exaggerate the area of sediment plumes to some degree (Libe Washburn, Professor, Department of Geography, UCSB, pers. comm.).

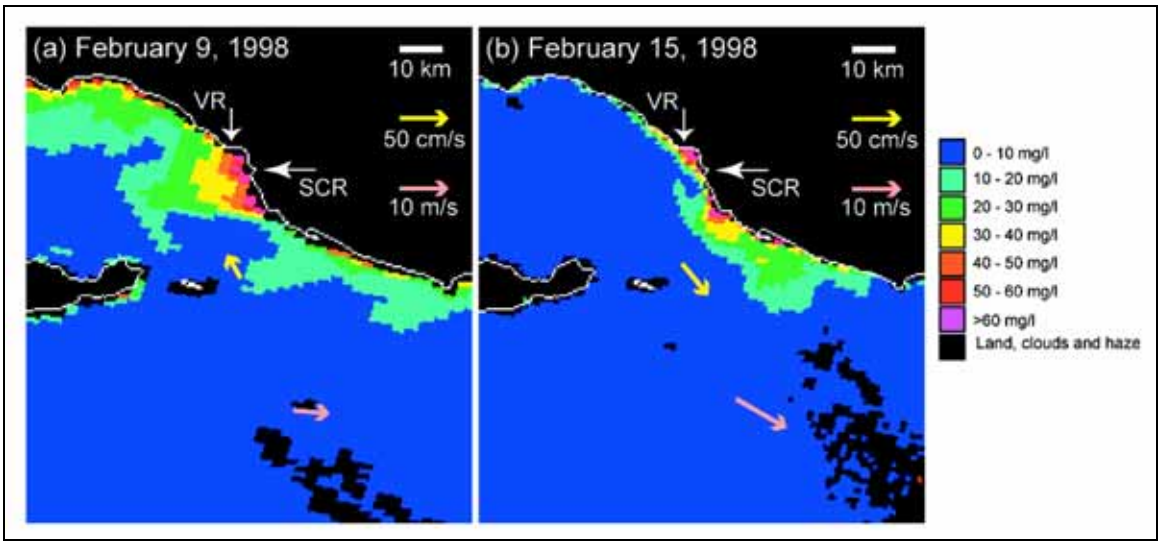



Figure 18. Suspended sediment concentrations retrieved from SeaWiFS images during two large storms (~10-year storms) in Feb. 1998. Pink arrows are mean wind vectors and yellow arrows are mean surface currents measured at NOAA and UC San Diego operated buoys, respectively (Warrick et al. 2004b).

Despite the occurrence of extensive surface sediment plumes in 1997 (Mertes et al. 1998), transects of salinity from Goleta Point (near Santa Barbara) to Santa Rosa Island (UCSB Plumes & Blooms project) did not reveal freshened water extending into the Channel at that time (see Figure 39 on page 125, salinity data are examined in detail in Section II.C.8.b). In Feb. 1983, after 25 cm of rain in the previous month, a large plume generated by the combined outflow of the Ventura and Santa Clara Rivers was 10 km long and 25 km wide (Mertes et al. 1998; image not shown here, but plume was smaller than the one in Figure 18(a) above). A similar amount of rain (28 cm) fell during Feb. 2004 in the Santa Ynez Mountains behind the city of Santa Barbara (San Marcos Pass station data-Santa Barbara Flood Control District), and yet by the end of Feb. 2004, cross shelf surface salinity anomalies were not detected in the Channel (at least not along the Plumes & Blooms transect for that month, see Figure 38a). The capability of fine suspended sediments to be advected beyond the zone of reduced surface salinity in storm plumes raises the possiblity that fine-particle-bound contaminants have a longer reach than dissolved contaminants after discharge events. Indeed, it may be that 25 to 50-year rain events (such as occurred in the winter of 2004/2005) are necessary to observe significant dilution of ocean water across the whole channel (see Section II.C.8)

Nezlin et al. (2005) evaluated six years (1997-2003) of SeaWiFS images of river plumes generated by storms of different sizes in the Ventura area, and created contour plots of the frequency of occurrence of pixels that exceeded the threshold signal for suspended sediment (Figure 19). These results show that storms >2.5 cm are required before plumes spread along the local coast as far north as Santa Barbara Point.

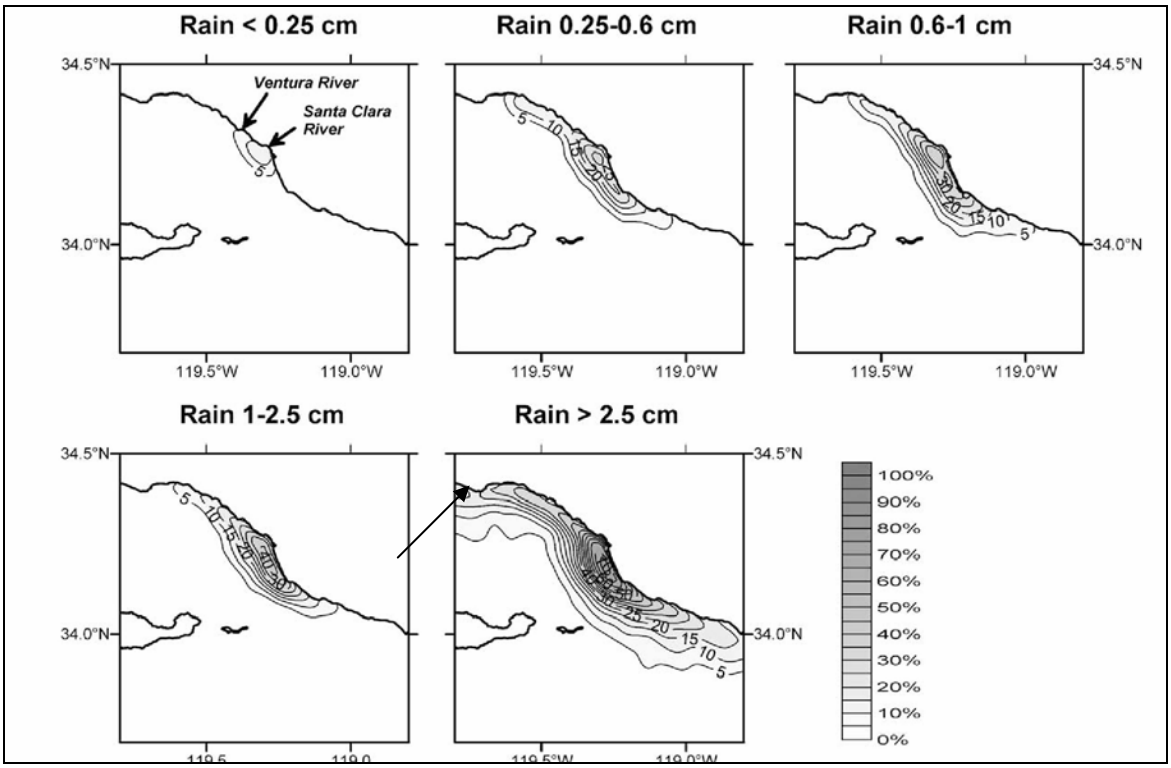



Figure 19. The areas occupied by freshwater plume after rainstorms of different magnitude in the Ventura region. The isolines indicate the percentage of satellite images with nLw555>1.3 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$; the resulting grids were smoothed by 5-km cosine-filter (Nezlin et al. 2005). The arrow points to Santa Barbara Point, which is near the start point of the cross channel transects conducted by the Plumes & Blooms project of UCSB (see Section II.C.8).

The Santa Clara and Ventura River watersheds are the largest watersheds that drain into the Channel, amounting to 71% and 9.8%, respectively, of the total watershed area discharging into the Channel (Warrick et al. 2005). Their combined output produces the largest plumes in the Channel (Mertes et al. 1998). Conditions in these two watersheds will have the maximum influence on which kinds of contaminants from the mainland could eventually be advected into Park waters surrounding the Northern Channel Islands during discharge events.

### b. Mainland storm plumes that enter the ocean south of the Channel.

**Santa Monica Bay**. Storm plumes were studied during three wet seasons (95/96 to 97/98) in Santa Monica Bay (Washburn et al. 2003, Bay et al. 2003). There, runoff plumes from single rainfall events of < 2 cm have cross-shelf length scales of 4–7 km, along-shore scales of at least 10 km, vertical scales of about 10 m, and persist for at least three days after a storm (Bay et al. 1998, Washburn et al. 2003). As was done for the Ventura area, Nezlin et al. (2005) created contour plots of the frequency of plume occurrence for different sized storms in the Santa Monica Bay (Figure 20). Even after storms in the largest size category (>2.5 cm), sediment plumes rarely extend in the cross-shelf direction outside of the bay.

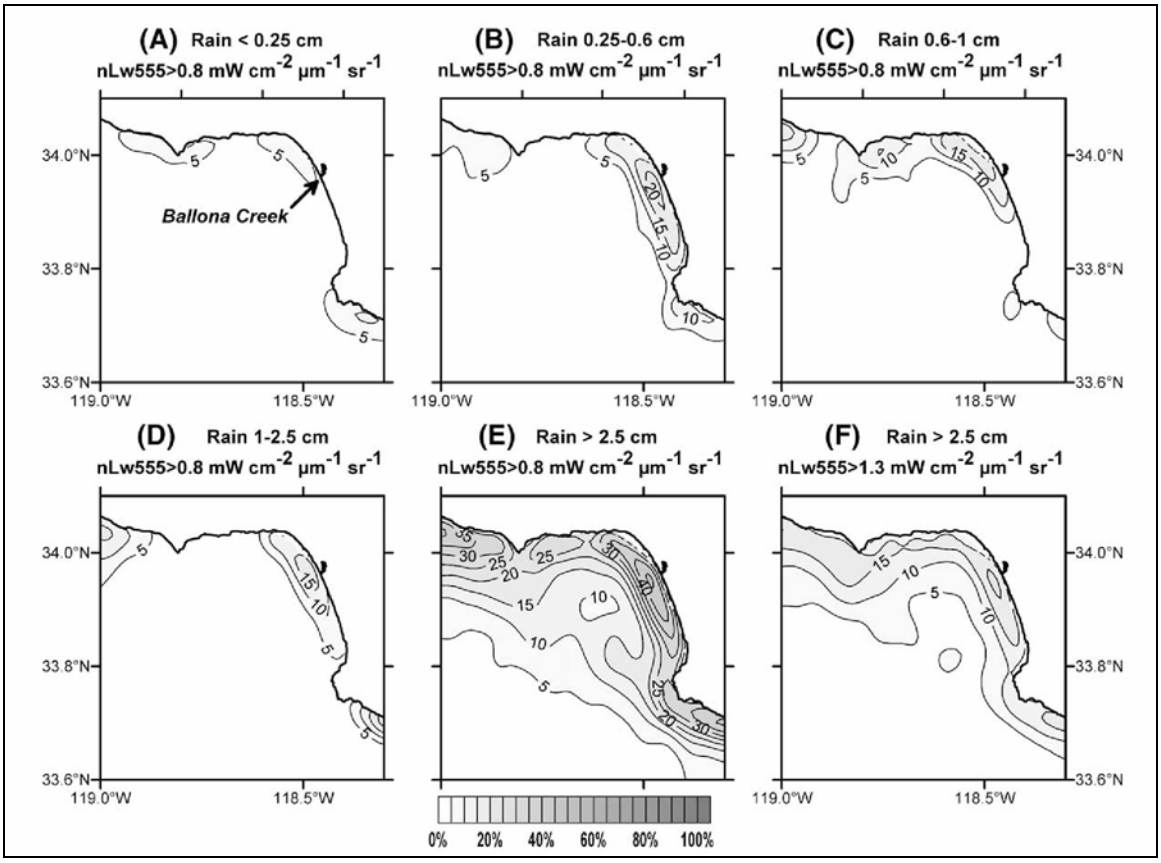



Figure 20. The areas occupied by freshwater plumes after rainstorms of different magnitude in Santa Monica Bay. The isolines indicate the percentage of satellite images with nLw555>0.8 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$ (A–E) and nLw555>1.3 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$ (F); the resulting grids were smoothed by 5-km cosine-filter. No plumes with nLw555>1.3 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$ were detected after rainstorms <2.5 cm (Nezlin et al. 2005).

**San Pedro Shelf.** Nezlin & DiGiacomo (2005) used 628 SeaWiFS images to delineate suspended sediment plumes originating from the San Pedro Shelf from 1997 to 2003. They discovered that even the smallest precipitation events in this area result in sediment plumes. Furthermore, almost all of the rainwater precipitated over the watersheds of the Dominguez Channel and the Los Angeles, San Gabriel and Santa Ana Rivers was discharged to the coastal ocean during the events they analyzed. Tidal circulation had an insignificant influence on plume area (i.e., did not contribute to offshore advection). Local winds did not influence the plumes in this area. When the San Pedro plumes extended several km offshore, they were typically entrained into a cyclonic eddy dominant in this region, bending the leading edge soutward and inshore (Nikolay Nezlin, Scientist, SCCWRP, pers. comm.). However, a statistical analysis of all plumes in their series showed no preference in the direction of plume propagation poleward or equatorward (Nezlin et. al. 2005). As was done for Ventura and Santa Monica Bay, Nezlin et al. (2005) generated contour plots of the frequency of occurrence of suspended sediment on the San Pedro Shelf according to storm size (Figure 21). These data show that even large plumes are very unlikely to extend offshore as far as Catalina Island, and even less likely to reach Santa Barbara Island.

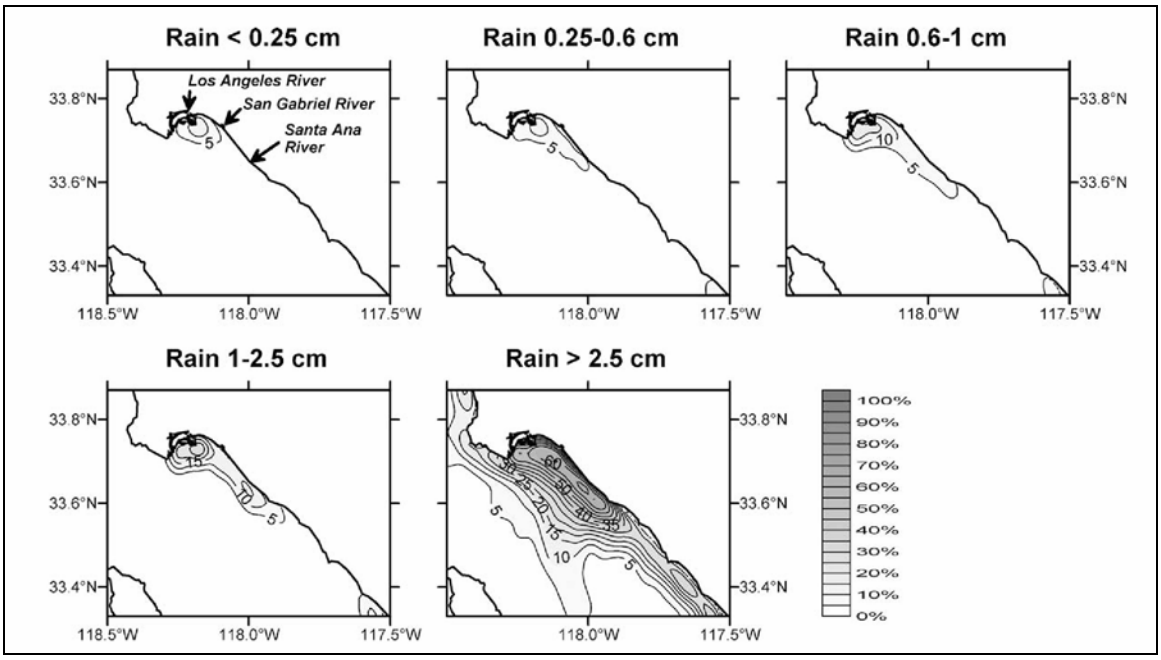



Figure 21. The areas occupied by freshwater plumes after rainstorms of different magnitude over San Pedro Shelf. The isolines indicate the percentage of satellite images with nLw555>1.3 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$; the resulting grids were smoothed by 5-km cosine-filter (Nezlin et al. 2005).

A discharge event in late Feb. 1998 produced the largest plume in the 1997-2003 series of images for San Pedro Shelf (Figure 22). The Los Angeles River and Dominguez Channel (which constitute the southern-most watersheds judged pertinent for this report) would have contributed to this storm plume. Although this particular plume was advected equatorward (and entrained in an eddy), the suspended sediment signal reaches the tip of Catalina Island on Feb. 26, 1998. Santa Barbara Island is about twice as far from the mainland as is Santa Catalina Island. Most sediment plumes in this region will have smaller cross-shelf length scales than the one shown in Figure 22, and are unlikely to extend to Santa Barbara Island.

Watershed conditions in Region 4 (Appendix G) and the lists of pollutants and stressors in Regions 3 and 4 (Tables 10 and 11), indicate that terrestrial runoff from Point Mugu southward potentially carries a wider range, and higher concentrations, of dissolved and particulate contaminants than runoff that directly enters the Channel. If constituents in stormwater from these southerly drainages were advected poleward into the Channel, they might present a greater threat to Park biota than constituents from streams and rivers that directly enter the Channel from watersheds in Santa Barbara and Ventura areas. Poleward flow through the east entrance of the Channel is one of two alternating Channel-scale patterns of circulation that are common during winter ("Flood West" mode, see Figure 8). During spring and fall, poleward flow into the Channel ("Relaxation" mode, see Figure 8) is one of the three Channel-scale patterns of circulation that occur in a repeating sequence roughly every 16 days. Storm-derived contaminants from drainages south of the Channel may have the greatest chance of reaching Park waters if torrential winter rains co-occur with, or are quickly followed by, the winter "Flood West" circulation regime. However, based on the information above, by the time such

contaminants were advected to Park waters, they would no longer comprise part of a discernable storm water plume, and should be very dilute, if even detectable.

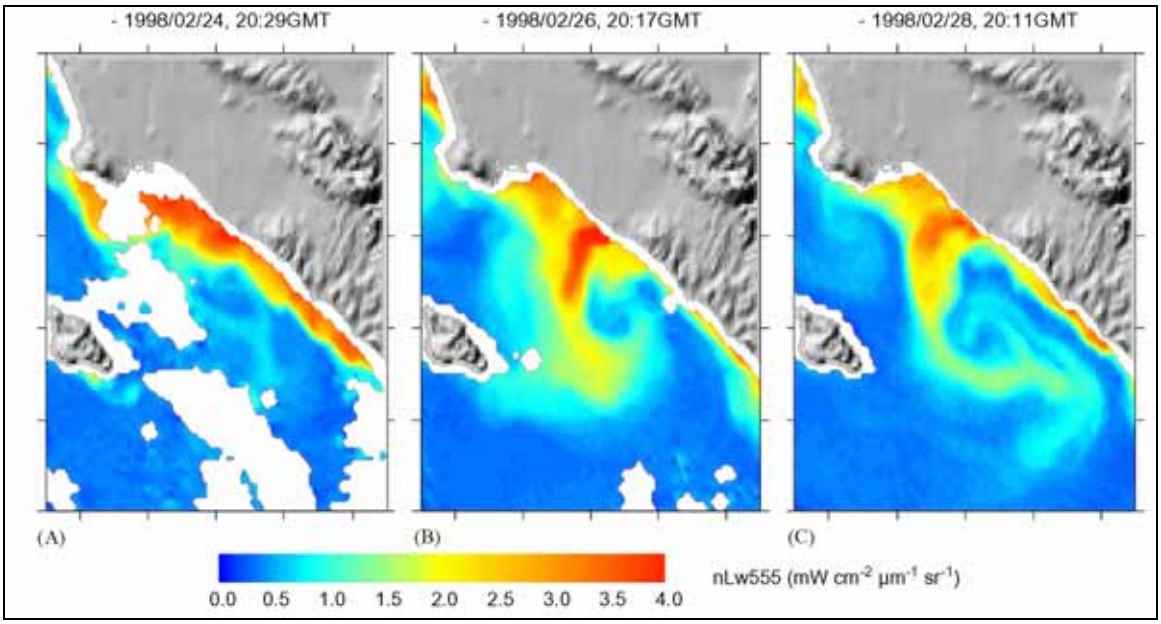



Figure 22. Sediment plume produced on the San Pedro Shelf after an El Niño related storm in 1998. Normalized water-leaving radiance at 555 nm (nLw(555) calculated from SeaWiFS images was used to delineate the plume. Torrential rains (4.2-6.1 cm/day) fell for three days from 2/23/98 to 02/25/98. Figure is from Nezlin & DiGiacomo (2005).

Summary of threats posed by storm plumes to Park waters. Based on plume toxicity, and the limited offshore extent of hypopycnal surface plumes, it seems extremely unlikely that acutely toxic levels of stormwater pollutants would reach any of the five islands in the Park during mainland runoff events. However, fine sediments that are transported to Park waters, and settle there, may, over time, contribute to contaminant loads in sediments and sublethal accumulation of toxicants in benthic organisms and fish. To date, sediments in the Park have not been found acutely toxic to benthic amphipods in survival tests (Bay et al. 2005 - see below). However, sentinel mussels in Park waters have detectable levels of a suite of organic contaminants and trace metals, including some high levels of zinc (see Section II.C.9). The extent to which this reflects exposure to contaminants transported directly to the Park in seawater or suspended sediment *versus* indirect transfer of contaminants from coastal sediments to the Park through the marine food web (see below), is an open question.

## B. Offshore Sources of Pollutants

### *B.1. Polluted Ocean Sediments*

Comprehensive surveys of sediment chemistry and sediment toxicity throughout the Bight were conducted in 1994, 1998, and 2003 by the Southern California Coastal Water Research Project (SCCRWP), and are referred to herein as Bight '94, '98, and '03, respectively. Unfortunately, sediment samples were not evaluated from the Channel Islands in Bight '94 and '98 - although

multiple sites were included in the Channel in an area of sediments bounded by 200 m isobath and the mainland shore. Bight '03 included a number of sediment sites from depths of 30-120 m at the Channel Islands. At the time of this writing, the full results of the Bight '03 toxicity tests were available, but only partial results from the Bight '03 sediment chemistry survey were published.

**a. Geographic patterns of sediment contamination.**

Results of sediment chemistry and toxicity from the Bight '94 and Bight '98 surveys were very similar. Nearly 90% of the Bight sediments had evidence of anthropogenic contamination by at least one chemical. Almost 50% of the Bight is contaminated by at least one trace metal. Total DDT was the most widespread anthropogenic contaminant; approximately 82% of the Bight area (roughly 2,878 $km^2$) contained measurable quantities of this persistent pesticide. Based on the best available DDT-specific sediment quality guidelines, less than 1% of Bight sediments contain concentrations of total DDT expected to cause chronic or acute toxicity to benthic organisms. The highest levels of DDTs were found in stations near the Palos Verdes Peninsula, an area that has historically been known to have high levels of contaminants. Notably high levels of total DDT were also found in LosAngeles/Long Beach Harbor. The highest levels of PCBs were found on the Palos Verdes Shelf and in Los Angeles/Long Beach Harbor. Although sediment contaminants were widespread, less than 1% of the Bight contained contaminants at concentrations presenting a high risk of acute toxicity[11] for benthic organisms. Where biological exceedances occurred, they were usually for total DDT. Most Bight sediments had healthy benthic communities, and were not acutely toxic based on amphipod survival tests[12]. Bight '03 tests revealed that sediments near Park islands were not acutely toxic to amphipods (Figures 23-24).

Geographic patterns of sediment contamination revealed by Bight '94, and '98 are summarized below (discussion adapted from Shiff & Gossett 1998, Noblet et al. 2003). They provide guidance to Park managers regarding which sediment locations near the mainland pose the greatest *indirect* threats to the Park. They also indicate whether river plumes are producing contaminant hot spots near the mainland. Partial results of the Bight '03 sediment chemistry survey (Schiff et al. 2006) were publically available at the time of this writing, and are only summarized for the Channel Islands. For brief explanations of contaminant categories, see Section II.C.9 (Mussel Watches).

[11] acute = sufficient to cause severe biological harm or death soon after a single exposure or dose

[12] Amphipods are often used in sediment tests because they are among the first species to disappear from benthic communities impacted by pollution (Bay et al. 1998).

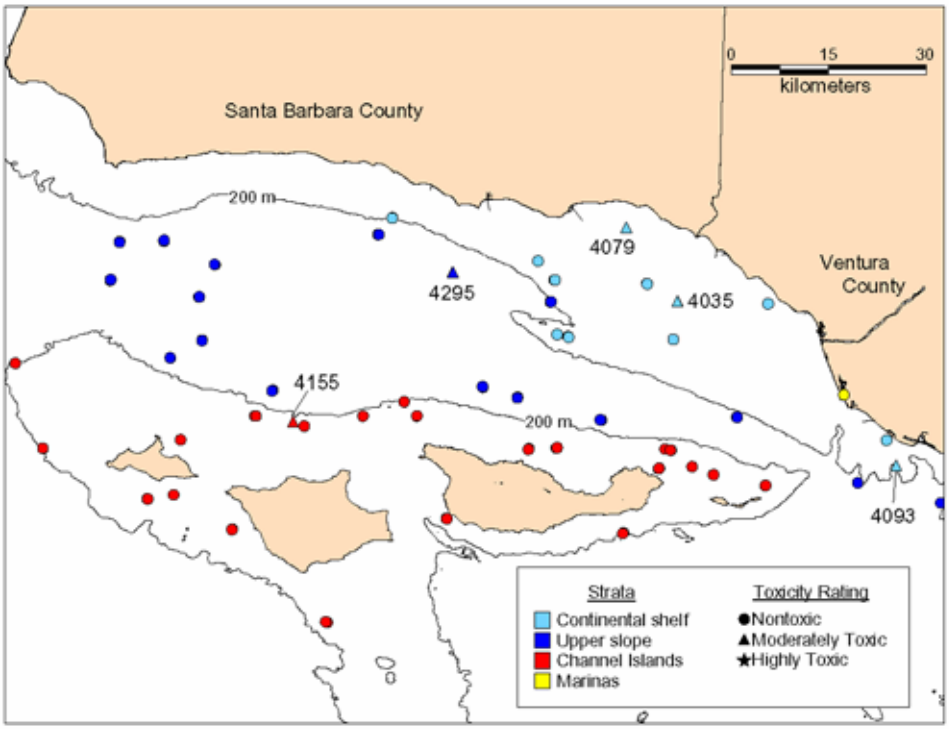



Figure 23. Bight '03 sediment toxicity results for stations in the Channel area. Results are from 10-day sediment exposure survival tests using the amphipod *Eohaustorius estuarius* (Bay et al. 2005).

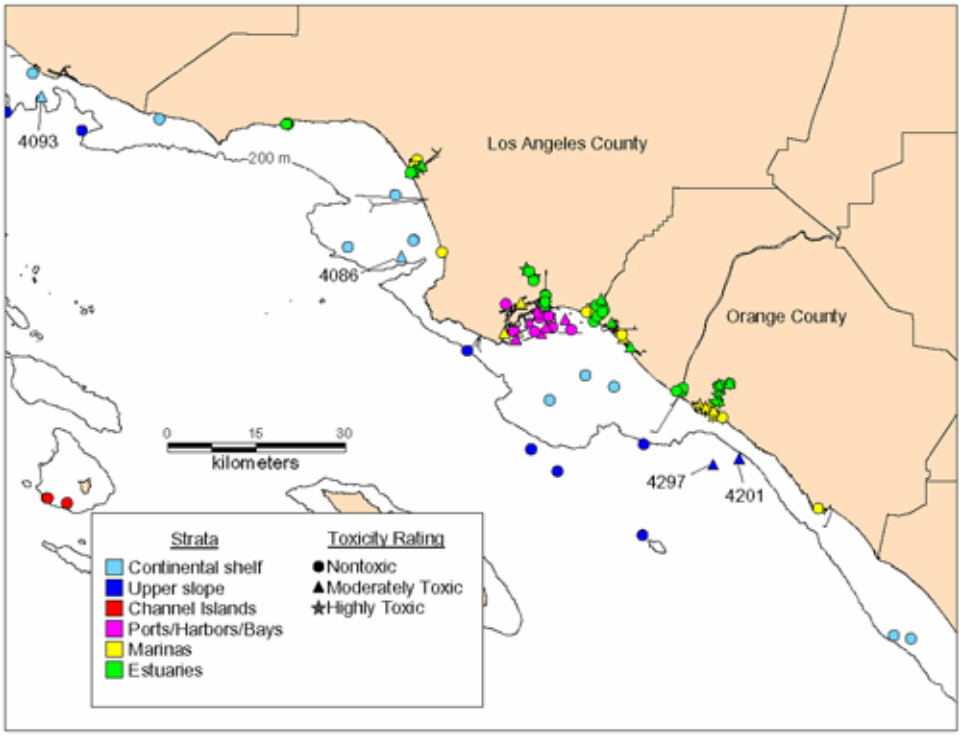



Figure 24. Bight '03 sediment toxicity results for stations nearest Santa Barbara Island. Results are from 10-day sediment exposure survival tests using the amphipod *Eohaustorius estuarius* (Bay et al. 2005).

### *Channel Islands (Bight '03 only)*

With the exception of antimony and nickel, trace metal concentrations in sediments at the Channel Islands were the lowest in the Bight. However, cadmium and nickel exceeded NOAA's ERL in 18.8% and 9.4% of the Channel Island samples, respectively. DDT was detected in sediments at the islands, and the mean for the Channel islands (1.6 µg DDT/kg ) was a little higher than the mean for small POTWs (1.2 µg DDT/kg). Thirty-four percent of the stations evaluated at the islands had DDT levels that fell between NOAAs ERL and ERM (Shiff et al. 2006). PCBs were near detection limits in Channel Island sediments, and total chlordane was not detected. Polycyclic aromatic hydrocarbons (PAHs) were relatively high in sediments at the islands (area weighted mean 338 ± 69.6 ng/g). The Channel Islands stations represented 8% of the geographic area sampled in Bight '03 and contained 7.8% of the total mass of PAH residue measured (compared to 0.4% and 0.9% of the total mass for DDT and PCBs, respectively). The molecular signature of the PAH residues in the island sediment samples (i.e., the relative distribution of low vs high molecular weight PAH homologs) was more congruent with petrogenic sources than with combustion byproducts (such as from the transportation sector). This suggests that PAHs in sediments at the islands originate from offshore oil and gas facilities and/or the natural hydrocarbon seeps at the islands and in the Channel.

### *Santa Barbara Channel*

With very few exceptions, concentrations of metals and organic contaminants measured during Bight '98 in sediments from sites in the Channel were below background concentrations. Inspection of figures in Noblet et al. (2003) indicates that silver, nickel, zinc, lead, copper and chromium were above background concentrations (and thus judged anthropogenically enriched) at 1, 1, 2, 2, 2, and 9 sampling sites, respectively, shoreward of the northern 200 m isobath in the Channel.

### *Santa Monica Bay*

The extent of sediment contamination inside of Santa Monica Bay was much greater relative to the extent of contamination outside of Santa Monica Bay. One hundred percent of the area inside of Santa Monica Bay was enriched in at least one sediment contaminant. Fifty percent of the area inside the bay contained sediment concentrations of at least one constituent that exceeded screening thresholds for potentially adverse biological effects. TOC, TN, cadmium, chromium,copper, lead, mercury, nickel, silver, zinc, total DDT, and total PCB were significantly higher inside than outside of the bay. Mean sediment concentrations for these constituents were 50% to 1,000% higher inside than outside of the bay. Organic constituents contaminated large areas of Santa Monica Bay (98%). Total DDT was responsible for most of the exceedances of thresholds for biological effects, although PCBs also contaminated nearly three-quarters (72%) of the Bay sediments.

### *Bays and Harbors, generally*

The highest sediment concentrations for most target analytes were found in bays and harbors. Although bays and harbors constituted only about 6% of the area, they contained 22% of total Bight-wide contamination. The most elevated contaminants inbays and harbors were copper, lead, zinc, mercury, chlordanes, PAHs, and PCBs.

### *POTW Outfall Areas*

Approximately 87% of the total POTW outfall area was anthropogenically enriched compared to 90% of the area distant from POTW outfalls at similar depths (25-100 m). Mean TOC and TN content were higher in sediments near POTW outfall areas than distant from them, however, the difference was not significant. Likewise, mean concentrations of cadmium, chromium, and lead were higher in sediments near POTW outfalls than areas distant from them, but not significantly different. Concentrations of copper, mercury, silver, total DDT, and total PCB were significantly higher in sediments nearest POTW outfalls compared to sediments farther away; mean sediment concentrations were higher by a factor of 100% to 1,000% for these constituents. Much of this is reflective of historically deposited DDT and PCB in areas near outfalls for two POTWs: the Hyperion Wastewater Treatment Plant and Joint Water Pollution Control Plant (the latter referred to as the *White's Point*, or *White Point* outfall, see Table 7). In contrast, sediment concentrations of arsenic, nickel, and zinc were higher distant from POTW outfall areas than areas closer; mean concentrations of arsenic and nickel were significantly higher.

### *Stormwater Discharge Areas*

Weighted mean sediment concentrations in areas near stormwater discharges were higher for every constituent measured compared to sediments farther from stormwater discharges. Mean TOC and TN contents of these stormwater-influenced sediments were 50% higher than sediments farther from stormwater discharges. The greatest disparity between stormwater discharge areas and shallow water areas more distant was the enrichment of trace metals, in particular, cadmium, chromium, copper, lead, and zinc. Ten percent of the stormwater discharge area was enriched in at least one trace metal to the point where biological effects may occasionally occur. Although the trace metal concentrations averaged 60% higher in sediments near stormwater discharges, only copper concentrations were significantly higher there than in sediments farther away. Mean concentrations of total DDT and total PCB were only marginally higher near stormwater discharges than mean sediment concentrations farther away. The areas affected by river discharges make up about 1% of the Bight, but contribute an estimated 1.3% of the total contamination.· In the river discharge zones, only the mass contributions of lead (1.2%), chlordanes (7.4%) and PAHs (1.5%) were in excess of their proportional area contributions to the Bight.

## b. The White's Point Outfall

### *History of White's Point*

As indicated above, the shelf sediments off the coast of the Palos Verdes Peninsula comprise the most significant source of total DDT and PCBs in the region near the Park. From 1947 until 1971, the Montrose Chemical Corp. plant, in the City of Torrance discharged DDT manufacturing waste, containing an estimated 1,800 tons of DDT, through Los Angeles County's ocean outfall from the Joint Water Pollution Control Plant (JWPCP), commonly referred to as the *White's Point Outfall*, or the *White Point Outfall* (Shiff & Gossett 1998). Although the discharges to public sewers ended in 1971, the Montrose plant continued to manufacture DDT until 1982. In addition to discharges from the JWPCP outfalls, DDT was also introduced into the Bight through direct ocean dumping of acid sludge that originated from the Montrose facility

(Figure 25). It is estimated that between 1947 and 1961, barrels of acid sludge containing 350 to 700 metric tons of DDTs were dumped into the San Pedro Basin off of Catalina Island by the California Salvage Company (NRT 2005). The barrels were punctured at sea to make them sink, which undoubtedly released large amounts of DDTs to surface waters (NRT 2005).

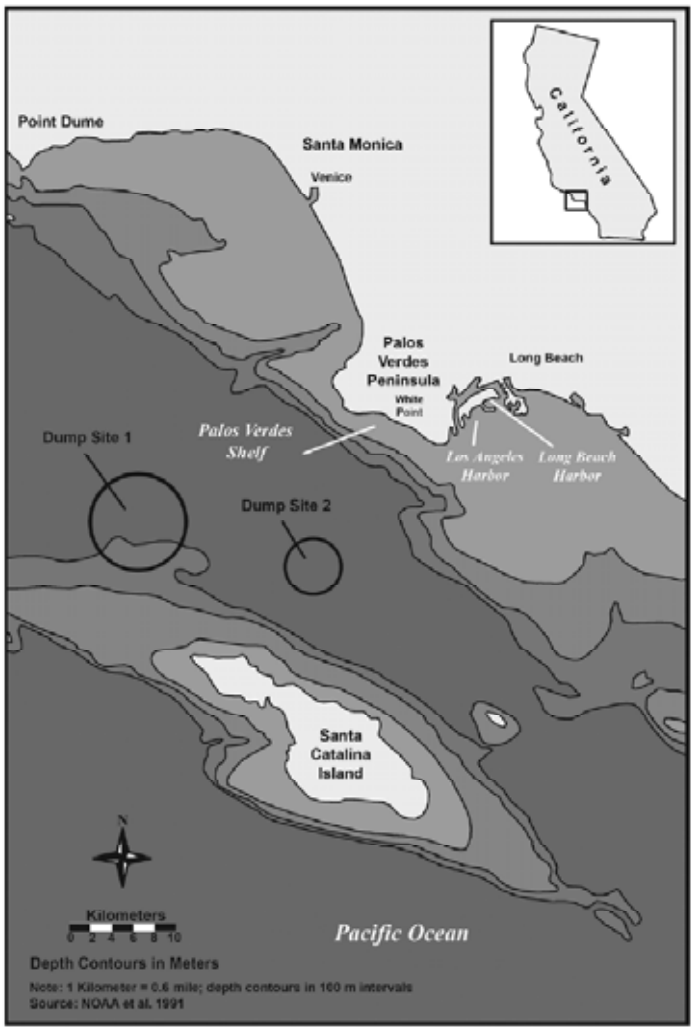



Figure 25. Location of the Montrose Chemical Corporation's DDT ocean dump sites (NRT 2005).

In 1992 and 1993, surveys by the USGS found that more than 100 metric tons of DDTs and 10 metric tons of PCBs remained in ca. 9 million cubic meters of contaminated sediment over a 44 square kilometer area of both the continental shelf and continental slope off the Palos Verdes peninsula, although DDT-contaminated sediment also extends northward into Santa Monica Bay and to the southeast (EPA 2003). The highest concentrations of DDTs and PCBs were near the mouth of the White's Point outfall (Figure 26). The contaminated sediment ranges in thickness from 5 cm to >60 cm. On the continental shelf, where most of the contamination resides, the contaminated sediments are in water 30 to 100 m deep, with the highest concentrations along the 60 m isobath. Bight '94 results showed that elevated concentrations of DDTs and PCBs in bottom sediments extended from the Palos Verdes Shelf into Santa Monica Bay.

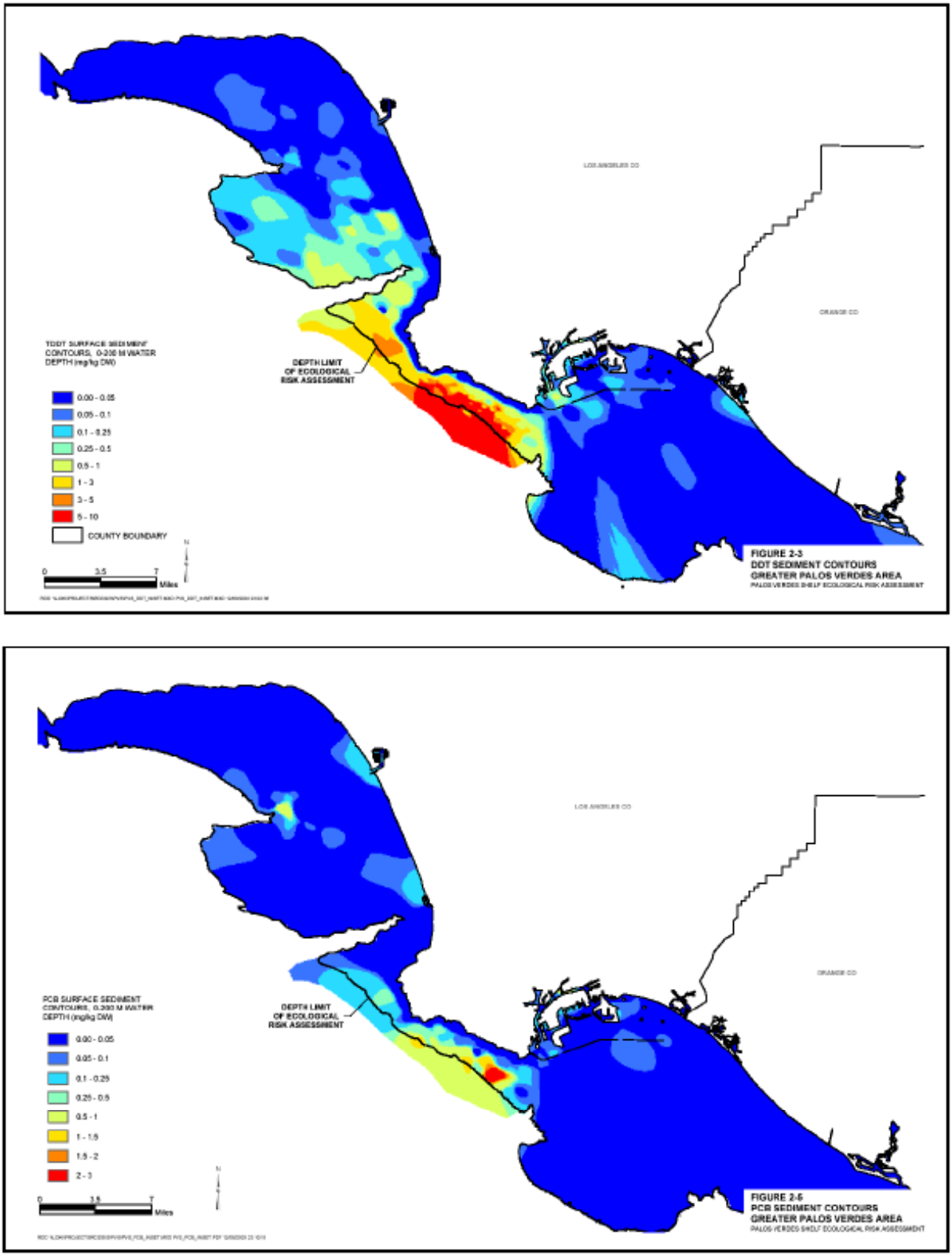



Figure 26. DDT contours (top) and PCB contours (bottom) in sediments of the greater Palos Verdes Shelf area (NRT 2005).

## Pollutants detected in Park biota

**Molluscs.** Organic contaminants, including DDTs and PCBs, and elevated levels of trace metals have been detected in sentinel mussels at a variety of sites in the Park, and at Catalina Island, during State-run and NOAA-run mussel watch programs. These results, in particular, indicate that contaminants originating outside Park boundaries eventually occupy the water column at the Park, and are evaluated in detail in Section II.C.9.

**Fish**. Only one published study was located in which organic contaminants were measured in fish taken from the Channel Islands (Brown & Steinert 2003), although a figure in Connolly & Glazer (2002) shows that DDE was detected in kelp bass at Anacapa and Santa Barbara (the figure cites a 1987 report by RW Risebrough, submitted to the SWRCB, as the source of the data points). Brown & Steinert (2003) measured quantities of fluorescent aromatic compounds (FACs), which are metabolites of PAHs, in fish bile from Pacific sanddabs (*Citharichthys sordidus*) collected by otter trawl in 1998 from 11 stations near San Miguel, Santa Cruz, Anacapa and Santa Barbara at depths between 31 to 202 m. Channel Island sanddabs contained far less (up to an order of magnitude) FACs than California halibut collected in mainland bays and harbors (Figures 27-28). As noted above, the molecular signature of PAHs in Channel Island sediment samples suggests a petrogenic, rather than a pyrogenic origin for these compounds (Shiff et al. 2006). Thus the PAHs in sediments, fish, and mussels (for the latter, see Section II.C.9) may be resulting from the offshore oil operations (or natural oil seeps), rather than from the combustion of fuels on the mainland or in the shipping lanes.

Many common sport fish caught from the ocean in the Los Angeles area have levels of DDTs and PCBs high enough that the State of California has issued health advisories to limit or avoid consumption of these fish when caught at certain coastal locations in Los Angeles and Orange Counties. In addition, because of especially high levels of DDTs and PCBs in the white croaker, the State has banned commercial fishing for white croaker in the vicinity of the Palos Verdes Shelf. The affected fish are as follows:

<u>limited consumption advised (one meal every two weeks)</u>

| | |
|---|---|
| sculpin | black croaker |
| white seaperch | California corbina |
| barred surfperch | Queenfish |
| calico surfperch | rubberlip seaperch |
| pile perch | shiner perch |
| black perch | walleye surfperch |
| rainbow seaperch | silver surfperch |
| dwarf perch | spotfin surfperch |
| striped seaperch | water column surfperches |
| kelp perch | all rockfish (*Sebastes*) |
| kelp bass | |

<u>no consumption advised</u>
white croaker

**Pinnipeds.** Concentrations of p,p'-DDE and PCBs in the blubber of sea lions from San Miguel have been measured in three separate studies: DeLong et al. (1973), Gilmartin et al. (1976), and Costa et al. (1994); the reader is directed to these sources for more detail. Connolly & Glaser (2002) modeled the relationship between p,p'-DDE body burdens in female sea lions from San Miguel and regional prey contaminant levels and determined that the more highly contaminated lactating females must have consumed prey with levels of DDE only found in fish from the Palos Verdes Shelf and the Santa Monica Bay.

**Avifauna.** DDT, and its final metabolite DDE, were strongly implicated in the decline of two federally-listed endangered species in the Park (the California brown pelican and the bald eagle, [*Haliaeetus leucocephalus]*), and in the loss of peregrine falcons (*Falco peregrinus*) from the Park. On the West coast of North America, the only breeding colonies of California brown pelicans occur in the Park (on Anacapa, Prince Island [an islet off San Miguel], and Santa Barbara), and in Mexico on islands off the coast of Baja California. The colonies in the Park almost disappeared in the 1970's, owing to egg-shell thinning and hatching failure. Historically, bald eagles were a resident breeding species on all of the California Channel Islands, with roughly 35 eagle nest sites existing earlier in this century (Kiff 2000). After the 1972 ban on DDT use, bald eagle populations rebounded across the U.S., except in Southern California. Breeding bald eagles on Catalina are still reproductively impaired and are not self-sustaining. Kiff (1980) and Hunt (1994) present evidence for 15 documented pairs of peregrines on the California Channel Islands during the first half of the century and estimate that between 20 and 30 pairs nested on the Channel Islands prior to 1945. The population of peregrine falcons on the Channel Islands was eliminated between the mid-1940s and the early 1960s due to shooting, harvest for falconry, egg collecting, and DDT contamination (Kiff 2000).

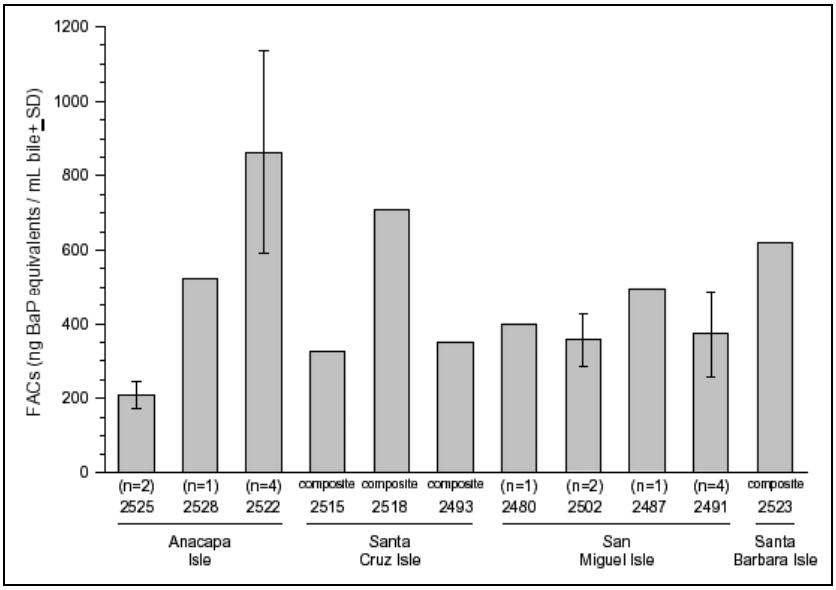



Figure 27. Concentration of bile FACs in Pacific sanddab from Channel Islands stations. *n* = number of fish at a given station (Brown & Steinert 2003).

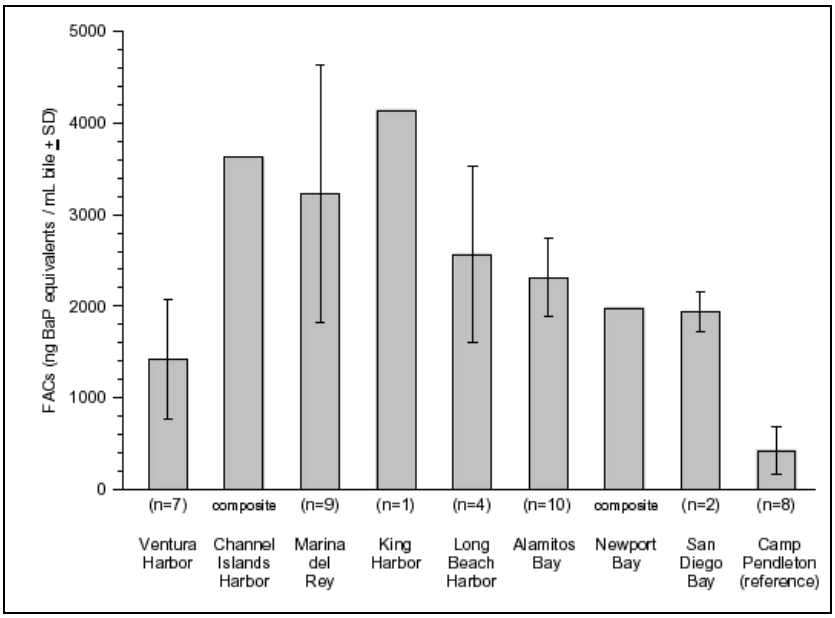



Figure 28. Concentration of bile FACs in California halibut for mainland bay and harbor locations, and the Camp Pendleton reference site. Camp Pendleton fish were collected in 1999, while the fish from the other locations were collected in 1998. *n* = number of fish at a given location (Brown & Steinert 2003).

## The Montrose Settlement

The former Montrose plant property was named a federal Superfund site in 1989, and the affected region of the shelf has been designated the Montrose/Palos Verdes Shelf Contaminated Sediment Superfund Site (EPA 2003). As a result of a federal and state lawsuit filed in 1990, a settlement was reached with Montrose Chemical Corp. and three other companies that ran the DDT plant (Aventis Crop Science USA, Chris-Craft Industries Inc. and Atkemix Thirty Seven Inc.). Under the terms of four separate settlement agreements, Montrose and the other defendants agreed to pay $140.2 million plus interest to the federal and state governments. Of this amount, the USEPA and the California Department of Toxic Substances Control received $66.25 million, the Natural Resource Trustees (NRT) for the Montrose case received $63.95 million, and $10 million of "swing money" was earmarked for EPA response actions, although the swing money may instead go to natural resource restoration, depending on the outcome of the EPA's ongoing remedial investigation (NRT 2005). Of the ~$73 million awarded to the NRT, $30 million is earmarked to restore natural resources, and $43 million will be used to clean up the DDT left in the ocean. As of 9/2005, a pilot study of the efficacy of capping the polluted sediments was underway.

## Avifauna recovery

In 1980, the Institute of Wildlife Studies, the USFWS, and the CF&G initiated a program to reintroduce bald eagles to Catalina Island. Montrose settlement money has funded recent years of this program. Between 1980 and 1986, 33 chicks from wild nests were brought to the island, reared on artificial nest platforms, and released. Several of these eagles have survived and formed nesting pairs. However, none of their eggs have been hatched normally to date, as the eggshells were too thin for normal incubation, would have broken under the weight of the adults, and the embryos would have suffered water loss through the thin eggshells (NRT 2005). From

1989 to 2005, the population was maintained by collecting the eggs, transporting them to the San Francisco Zoo for artificial incubation, and re-introducing the chicks back to the nests. In 2005, an incubation facility was built on the Catalina, and the eggs were hatched on-site. Beginning in 2002, the Montrose Settlements Restoration Program, in partnership with NPS, decided to reintroduce bald eagles to the northern Channel Islands, and brought on the Institute of Wildlife Studies as the cooperator. Every summer through 2006, a dozen eaglets from Alaska or the San Francisco Zoo will be transferred to screened hack towers on the island. The chicks typically remain in the towers for a month before the tower gates are lifted. The juvenile eagles released on the islands will be monitored for DDT exposure and ability to reproduce over a five to seven year period. Because eagles generally first breed between 4-5 years of age, the initial results of breeding are expected in 2007-2008. As of 2005, about 23 released eagles remain on Santa Cruz and the other Northern Channel Islands, along with a pair of eagles that were raised in captivity on Catalina Island, and flew to Santa Cruz. On April 12, 2006, a chick was successfully hatched on Santa Cruz by the pair of eagles that flew in from Catalina Island. As of this writing, an additional chick was hatched from a second nest on Santa Cruz in 2006.

California brown pelicans are showing signs of recovery in the Park. In 2002, the number of nests and fledglings produced by the southern California nesting population was estimated at 6,440 and 3,220 individuals, respectively. From 1983-2002, nest attempts have ranged from 628 to 6440, and fledglings produced has ranged from 372 to 6390 (Gress et al. 2003). This is in sharp contrast to the early 1970's in which there were only about 100 nest attempts.

The peregrine falcon has made a dramatic recovery in the Park since 1975, in large part due to an active release program conducted by the Santa Cruz Predatory Bird Research Group. Artificial incubation of thin-shelled eggs removed from wild nests and a captive breeding program provided source birds for the release program. Between 1985 and 1993, six peregrine falcon hatchlings were released at sites on San Miguel, and 17 hatchlings were released on Catalina Island (NRT 2005). The minimum breeding age for peregrine falcons is two years. In 1987, the first reestablished peregrine falcon pair was recorded on San Miguel. In 1989, active nests were recorded on Anacapa and Santa Cruz (Hunt 1994). Between 8 and 10 pairs were noted on the Northern Channel Islands between 1992 and 1994 (Hunt 1994). In 2004, approximately 21 peregrine falcon pairs were occupying breeding territories on six of the eight Channel Islands (PBRG 2004). The majority of the pairs (18 of 21) occur on the Northern Channel Islands, and 3 pairs occur on the Southern Channel Islands (2 pairs were recently confirmed on Catalina and 1 on Santa Barbara). Although peregrine falcons now appear to be self-sustaining on the Northern Channel Islands, they have not fully recovered to historical levels throughout the Channel Islands. In addition, data collected in 1992 indicated that contamination in the food web was still at sufficient levels to result in substantial eggshell thinning for peregrine falcons on the Channel Islands.

### c. Ocean Dumps

In addition to the Montrose ocean dump sites near Catalina Island, the Channel region contains several sites that were used for dumping of wastes from the 1940's through 1960's. Two sites, one in the vicinity of the Santa Lucia Bank and another south of Santa Cruz Island, have been identified as locations formerly designated for U.S. chemical munitions dumping (Ugoretz 2002). A site southeast of Santa Barbara Island might have been used as an explosives dumping

area and a location offshore of Port Hueneme might contain 3,100 containers of low-level radioactive waste at a depth of 4,750 m (Polgar et al. 2005). Active dredge material discharge sites are located in the Los Angeles/Long Beach area which are contributing to contaminant loads (e.g. levels of certain heavy metals, PCBs, PAHs) in area sediments (Steinberger et al. 2000). All three of the currently designated dredge material disposal sites are located in depths greater than 200m, which reduces the extent to which contaminants from these sites will be advected out of the basin (Shiff et al. 2006).

### *B.2. Offshore Oil and Gas Facilities*

#### a. Location of Platforms

There are 19 oil and gas platforms located off the coast of Santa Barbara and Ventura Counties (Figure 29). Twenty-two fields have been discovered in the Santa Barbara Channel, and two fields in the offshore Los Angeles Basin (MMS 2001). Most of the oil platforms in the channel are 15 to 25 miles from the Sanctuary boundary, but Platform Gail is just over 6 miles from Anacapa Island. In addition to the existing operations, there are 37 federal and 5-6 state leases that may be developed over the next 25-40 years.

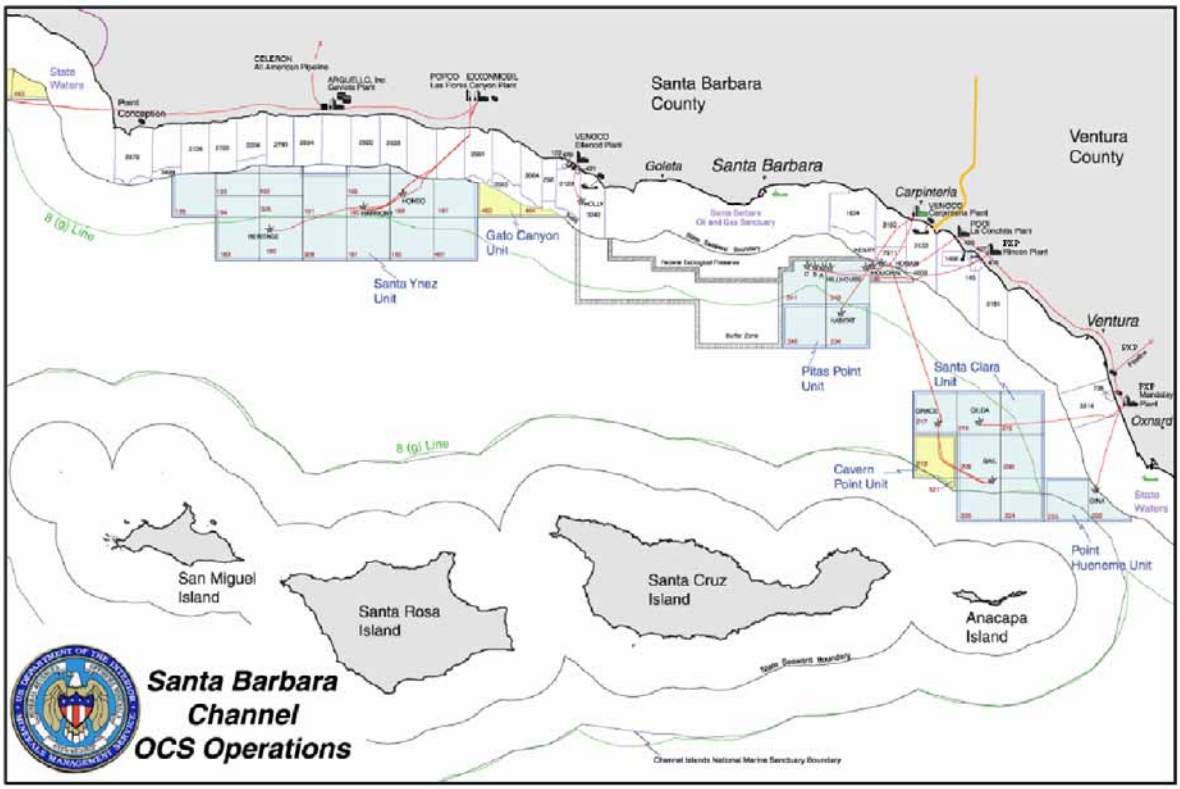



Figure 29. Location of federal and state offshore leases, and active oil and gas platforms, in the Santa Barbara Channel (from http://www.mms.gov/omm/pacific/lease/maps.htm).

**b. Oil Spills**

**The Santa Barbara Oil Spill of 1969.** On Jan 28, 1969, an 80,000-barrel oil spill occurred at Union Oil Platform A, six miles off the coast of Summerland, 64 miles south of the city of Santa Barbara. Eight hundred square miles of ocean were impacted, and 35 miles of mainland coastline were coated with oil up to six inches thick. Rescuers counted >3,600 dead seabirds, and a large numbers of poisoned seals and dolphins were removed from the shoreline (Clarke & Hemphill 2002). Most of the dead birds were grebes and loons, followed by waterfowl (presumably largely scoters), cormorants, and pelicans (Straughan 1971). Western Grebes accounted for nearly 41 percent (176) of a sample of 432 birds whose species were known. In addition, gulls, alcids (mostly Common Murres), shorebirds, and herons are known to have been oiled and died. By February 3, a large oil slick had surrounded Anacapa Island and was encircling the eastern end of Santa Cruz Island. During February 5-13, CF&G divers established 14 transects around the islands: 4 at Anacapa and 10 at Santa Cruz (Straughan 1971). The transects extended from the high tide line to a depth of ca. 50 ft. Short term impacts observed at the islands are summarzied below:

> Extent of Oil. Oil slicks were observed in slight to moderate amounts around both islands, particularly on both sides of the middle of Anacapa Island. These slicks of coalesced oil droplets formed dense patches up to 1/4 inch in thickness which extended seaward from the shore for several hundred feet. Beached oil adhered to the intertidal rocks and driftwood in patches several hundred feet long. These patches were up to 20 feet wide, and were in lumps up to 1/2 inch thick. Patches were most common on the north side of the middle of Anacapa Island and on Santa Cruz Island at Punta Arena, Yellowbank Anchorage, Smugglers Cove, and Scorpian Anchorage. At Santa Cruz Island, major concentrations of floating oil were observed in the kelp canopy at Scorpion Anchorage and in the nearshore waters between Sandstone Point and Middle Anchorage. On the north shore of Anacapa, numerous oil droplets were suspended in the water column from shore seaward about 100 feet. These droplets appeared to be adhering to organic detritus, wood chips and grass, which had washed into the sea during the recent rains. Although visible in the surge zone throughout the water column, the droplets did not adhere to the substrate, plants or animals.
>
> Birds and pinnipeds. Several dead birds were observed in the kelp canopy at Scorpion Anchorage and three dead surf scoters were observed on the beach. About 35 California sea lions, coated with oil, but in no apparent distress, were observed at Sandstone Point. Another group, about 300, observed in the vicinity of Coche Point, had no evidence of oil on them.
>
> Intertidal zone. In Feb., some plants and animals in the intertidal area, from the splash zone to just below low tide, were coated with varying amounts of oil. The black abalone, Haliotis cracherodii ; gooseneck barnacles, Pollicipes polynerus; and numerous other intertidal animals as well as the algae, Hesperophycus harveyanus, Pelvetia fastigiata, and surf grass, P. torreyi, were heavily coated with oil at Punta Arena. Surf grass at Anacapa Island was heavily coated with oil when the initial survey was made on February 5, 1969. By February 14, 1969, the plants were free of oil.
>
> Subtidal zone. Subtidal plants and animals appeared untouched by the oil. Oil was observed on the surface canopy of many of the kelp beds, but most of this oil could be easily shaken off. During a storm that followed, the kelp beds were cleaned by the rough waters. Topsmelt, Atherinops afinis, would swim up under the coalesced floating oil and investigate its lower surface.
>
> Recovery. Surveys in Apr. 1969 and Feb. 1970, indicated that invertebrates appeared to remain viable and healthy, surf grass and algae had recovered, fish were free from oil and showed no signs of starvation due to oil on prey items.

**Other oil spills.** Since 1969, there have been 843 small oil spills off southern California (Table 12). However, only one spill resulted in documented seabird mortality: the 163-barrel Platform Irene pipeline spill off Point Arguello in 1997, which resulted in the loss of more than 700 birds

(McCrary et al. 2003). Natural oil seepage from the Coal Oil Point seep field (see Section II.B.3) releases as much as 100 barrels of oil per day (Libe Washburn, Professor, Dept. of Geography, UCSB, pers. comm.), although the volume appears to be decreasing over time (see Section II.B.3). Birds and pinnipeds apparently avoid the resulting slicks, as they do not result in oiled or beached animals.

Table 12. Crude, diesel, or other hydrocarbon spills (volume in barrels) recorded off southern California in the MMS Pacific OCS Region, from 1969 to 1999. Note that the data cover an area larger than the Santa Barbara Channel. Table is from McCrary et al. 2003.

| | ≤ 1 bbl | | > 1 bbl < 50 bbl | | ≥ 50 bbl | | Total | |
|---|---|---|---|---|---|---|---|---|
| Year | No. | Volume | No. | Volume | No. | Volume | No. | Volume |
| 1969 | 0 | | 0 | | 2 | 80,900.0 | 2 | 80,900.0 |
| 1970 | 0 | | 0 | | 0 | | 0 | |
| 1971 | 0 | | 00 | | 0 | | 0 | |
| 1972 | 0 | | 0 | | 0 | | 0 | |
| 1973 | 0 | | 0 | | 0 | | 0 | |
| 1974 | 0 | | 0 | | 0 | | 0 | |
| 1975 | 1 | 0.1 | 0 | | 0 | | 1 | 0.1 |
| 1976 | 3 | 1.1 | 1 | 2.0 | 0 | | 4 | 3.1 |
| 1977 | 11 | 2.2 | 1 | 4.0 | 0 | | 12 | 6.2 |
| 1978 | 4 | 1.2 | 0 | | 0 | | 4 | 1.2 |
| 1979 | 5 | 1.7 | 1 | 2.0 | 0 | | 6 | 3.7 |
| 1980 | 11 | 4.9 | 2 | 7.0 | 0 | | 13 | 11.9 |
| 1981 | 21 | 6.0 | 10 | 75.0 | 0 | | 31 | 81.0 |
| 1982 | 24 | 3.2 | 1 | 3.0 | 0 | | 25 | 6.2 |
| 1983 | 56 | 7.7 | 3 | 6.0 | 0 | | 59 | 13.7 |
| 1984 | 65 | 4.7 | 3 | 36.0 | 0 | | 68 | 40.7 |
| 1985 | 55 | 9.3 | 3 | 9.0 | 0 | | 58 | 18.3 |
| 1986 | 39 | 5.5 | 3 | 12.0 | 0 | | 42 | 17.5 |
| 1987 | 67 | 7.5 | 2 | 11.0 | 0 | | 69 | 18.5 |
| 1988 | 47 | 3.7 | 1 | 2.0 | 0 | | 48 | 5.7 |
| 1989 | 69 | 4.1 | 3 | 8.0 | 0 | | 72 | 12.1 |
| 1990 | 43 | 3.6 | 0 | | 1 | 100.0 | 44 | 103.6 |
| 1991 | 51 | 5.8 | 1 | 10.0 | 1 | 50.0 | 53 | 65.8 |
| 1992 | 39 | 1.2 | 0 | | 0 | | 39 | 1.2 |
| 1993 | 32 | 0.7 | 0 | | 0 | | 32 | 0.7 |
| 1994 | 18 | 0.4 | 2 | 33.0 | 1 | 50.0 | 21 | 83.4 |
| 1995 | 25 | 0.9 | 1 | 1.4 | 0 | | 26 | 2.3 |
| 1996 | 39 | 0.9 | 1 | 5.0 | 1 | 150.0 | 41 | 155.9 |
| 1997 | 20 | 2.5 | 0 | | 1 | 163.0 | 21 | 165.5 |
| 1998 | 29 | 1.0 | 0 | | 0 | | 29 | 1.0 |
| 1999 | 22 | 0.5 | 1 | 10.0 | 0 | | 23 | 10.5 |
| **Total** | **796** | **80.4** | **40** | **236.4** | **7** | **81,413.0** | **843** | **81,729.8** |

### c. Permitted Discharges from Oil & Gas Platforms

**Nature of Discharges.** Certain types of ocean discharges are allowed from offshore oil and gas platforms off the coast of Southern California under NPDES General Permit No. CAG280000. Owing to the location of these facilities in federal waters, this permit was issued by the U.S.EPA Region 9, instead of the State. The permitted discharges include:

Drilling Fluids and Cuttings
Produced Water

Well Treatment, Completion and Workover Fluids
Deck Drainage
Domestic and Sanitary Waste
Blowout Preventer Fluid
Desalination Unit Discharge
Fire Control System Water
Non-Contact Cooling Water
Ballast and Storage Displacement Water
Bilge Water
Boiler Blowdown
Test Fluids
Diatomaceous Earth Filter Media
Bulk Transfer Material Overflow
Uncontaminated water
Water Flooding Discharges
Laboratory Waste
Excess Cement Slurry
Muds, Cuttings and Cement at Sea Floor
Hydrotest Water
$H_2S$ Gas Processing Waste Water

During the drilling process, water- or oil-based lubricants and cleaners combine with rock and other drilling wastes to form slurries. These slurries, or drilling muds, are composed of water or oil and clays (e.g. barite and bentonite), or polymers, as well as heavy metals, traces of hydrocarbons and organophosphates (Polgar et al. 2005). Drilling muds and cuttings (solid byproducts from the drilling process) are discharged from the platforms. The wastes settle over the ocean floor adjacent to the platforms and contribute to the formation of large debris mounds. Barium, in the form of barite (barium sulfate) is a non-toxic additive in drilling muds. Owing to the fact that barium was 150 times more concentrated in discharged drilling fluid than in the sea floor, Coats (1994) used barium as a tracer in sediment trap deployments to track the dispersal of drilling fluid from drilling platforms off the coast of Point Arguello. Drilling solids were detected in traps 3.5 and 6.8 km from the platforms. The support activities associated with oil production are also sources of potential water quality degradations. Although support activities to the platforms are often coordinated, the numbers of transports required to change crews and restock supplies include >1300 ship and >1800 helicopter transports per year (Polgar et al. 2005).

### Produced water

How generated. Produced water is the water extracted along with oil during oil production. Produced water consists of naturally occurring groundwater or seawater that is injected into the wells during the extraction process. Large volumes of produced water are often generated during pumping because many oil deposits reside in or around groundwater aquifers. The MMS estimated a yearly average of 330 million gallons produced per platform in the Channel (MMS 2001). As a reservoir of oil is emptied, produced waters constitute a growing percentage of the total material pulled up from a well, potentially reaching 98% (Polgar et al. 2005). Each platform sends an emulsion of gas, oil, and produced water to a tank for separation of the gas. The gas is used for fuel, sent to shore, or re-injected. The emulsion may be sent to shore for processing or some or all processing may occur on the platform. Processing of the emulsion removes impurities (including the produced water) and results in oil of a quality to be accepted into a pipeline for transport to a refinery. Produced water removed at a platform can be

reinjected into wells and/or discharged overboard. Ten of the platforms in the Channel regions discharge produced water on site (MMS 2001). Produced water removed in onshore facilities can be can be discharged through submarine outfalls and/or sent to a platform offshore for injection or overboard discharge.

Contaminants in Produced Water. Produced water contains many contaminants including hydrocarbons, heavy metals, and chemical additives such as corrosion inhibitors to prevent damage to refinery equipment (Higashi et al. 1992). Weekly measurements of oil and grease, and quarterly measurements of metals, phenols, and other constituents in produced water are required under the General NPDES Permit for offshore oil lease permitees. Produced water can contain PAHs (e.g. benzene, toluene, naphthalene, phenols), metals (e.g. As, Cr, Ni, Ag, Cd, Cu, Pb, Se, Ba), cyanides, ammonia, organosulfur compounds (in particular, thiocarboxylic acids and novel thiopyranones), organopolysulfides, and inorganic forms of sulfur, such as sulfides, thiosulfates, and polysulfides (Raimondi & Boxshal 2002; and results from MMS Contract No. 14-35-0001-30761: Characterization of Organic Constituent Patterns at a Produced Water Site / Barium Relations to Bioeffects of Produced Water). Phenol, cyanides and nickel are commonly reported in discharge monitoring reports (Panzer 1999). However, according to estimates by Shiff et al. (2000), with the exception of lead, combined total mass emissions of trace metals, and many other constituents, from oil platforms is dwarfed by combined total mass emissions from large POTWs in the region (Table 8).

Toxicity of Produced Water. Until recently it was believed that the most significant biological impacts of produced water resulted from solids released with the discharge, which quickly settle out of the plume (Washburn et al. 1999). However, several studies indicate the toxicity of dissolved constituents in produced water. Key findings concerning potential deleterious effects of produced water in the Channel region are summarized below:

- Raimondi & Schmitt (1992): Survivorship, settlement, metamorphosis and viability of pre-competent red abalone larvae were directly correlated with distance from a near shore produced water outfall up to at least a distance of 1 km from the diffuser. Impacts extended to the 100-500 m isobaths surrounding the diffusers. The diffuser was ca. 1 m above the sea floor in 12 m of water off the mainland coast near Carpinteria.
- Raimondi & Boxshal (2002): Behaviors (swimming, settlement, metamorphosis) of larvae of bryozoans, ascidians, sea stars and red abalone were altered by exposure to produced water in laboratory experiments. These sublethal effects were accompanied by little mortality. In some cases, the changes in behavior may have been due to a narcotic effect of the produced water, as larvae regained normal behaviors after placement in clean, filtered seawater.
- Osenberg et al. (1992): Growth rates, general condition and tissue production of mussels was decreased within 1000 m of the same diffuser described above. Benthic invertebrate species composition was altered within 100 m of the diffuser.
- Krause et al. (1992), Krause (1993): Reproductive success of purple sea urchins was inversely proportional to produced water concentrations in egg fertilization tests. Egg fertilization was reduced by 10% in water containing as little as 0.0001% produced water (dilution factor of $10^6$:1).
- Washburn et al. (1999) In fall and winter, when density stratification is weak, plumes of produced water from the diffuser described above may extend through most of the water column, and plumes may surface. Plumes are trapped below the surface in spring and summer and intermittently in winter owing to freshwater runoff during winter storms. Plumes are rarely within 2 m of the bottom. Considering the results of Krause (1992), the authors concluded that measurable toxic effects may extend beyond 1 km from the diffuser.

Dilution of Produced Water. Industry estimates of expected dilutions of produced water at the edge of a 100-m mixing zone range from 500 to >3000:1 (EPA 2004). Washburn et al. (1999) report smaller dilution factors (100 and 500:1 at 80 m distance in summer and winter, respectively) for produced water entering shallow water (12 m deep) through a coastal outfall diffuser. At 1 km distance from the outfall, dilution factors ranged from 4000 to 400,000:1. USEPA assessments of acute toxicity from produced water discharged (using data from the Gulf of Mexico) indicate that a dilution of approximately 140:1 is needed to dilute discharge below acutely toxic levels (EPA 2004). Based on dilution factors calculated for two example California platforms, acute toxicity would be confined to distances of <12.5 m or <7.5 m from the outfalls. Using data for three California species (unidentified in the source cited), the USEPA contends that chronic toxicity would be encountered within 30-35 m from California platform outfalls (EPA 2004). Based on the information above, and given that the oil platforms nearest to the Park are ~10 km from Anacapa (the nearest island), it is apparent that acute or chronic toxicity arising from produced water discharges does not reach Park boundaries. Although they would be extremely dilute tens of kilometers from their sources, do constituents from oil and gas platforms accumulate in the Park ecosystem? PAHs in bottom fish (Section II.B.1), mussels (Section II.C.9), and sediments (see Section II.B.1) in the Park *may* constitute far field effects of oil platform discharges. However, a sophisticated biochemical approach would be necessary to separate the hydrocarbon signal from offshore oil and gas operations from that produced by prolific natural hydrocarbon seeps close to the islands themselves and elsewhere in the Channel (see Section II.B.3).

**Pollutants detected in fish and invertebrates at oil platforms**

The wide range of ocean discharges from offshore oil platforms raises the possibility that invertebrates and fish that reside at platforms may accumulate sub-lethal concentrations of contaminants[13]. If so, they might serve as entry points for contaminants into the Park food web.

Fish. Oil platforms in the Channel serve as nursery habitat for a suite of rockfish and other fish species, often have higher densities of fish than nearby natural outcrops (Figure 30), and can serve as *de facto* fishing reserves, owing to the avoidance of them by commercial fishermen using gear that could be snared by the platform (Love et al. 1999a,b; 2003, 2005; Schroeder & Love 2004, Love & Westphal 1990). Although fish densities are not elevated at every platform, in general, canary, copper, flag, greenblotched, greenspotted, greenstriped, halfbanded, and vermilion rockfishes; bocaccio; cowcod; widow rockfish young-of-the-year; painted greenling and all life history stages of lingcod are more abundant at platforms than at natural outcrops (Love et al. 2003). The main diet of California sea lions consists of anchovies, sardines, whiting, mackerel, rockfish and market squid. Although sea lions spend time at oil platforms, they have not been directly observed persuing fish in the vicinity of the platforms (Donna Schroeder, Associate Researcher, UCSB, pers. comm.). Harbor seals are frequently seen at depths of several hundred feet around platforms, behavior which is suggestive of fish pursuit (Milton Love, Professor, Dept. Ecology, Evolution & Marine Biology, UCSB, pers. comm.). Cormorants may be catching juvenile rockfish (widow, blue, bocaccio, olive and squarespot) and blacksmith, when recruitment classes for these species are large (Donna Schroeder, Associate

[13]An exhaustive review of oil platform fauna was not conducted for this report.

Researcher, UCSB, pers. comm.). Piscivorous sea birds and pinnipeds may be more likely to forage at platforms when pelagic species (sardines, anchovies) are in their vicinity.

Figure 30. Photo showing extremely high densities of young bocaccio and vermillion rockfish at Platform Gilda in the Santa Barbara Channel during Oct. 2003 (photo by Donna Schroeder, Marine Science Institute, UCSB)

Bascom et al. (1976) sampled liver, muscle, kidney, gonad, and whole soft tissues from rockfishes, crabs, and mussels from rocky reef control sites and Platforms Hazel and Hilda in the Channel. Two hundred thirty-two samples were analyzed for trace metals (cadmium, chromium, copper, lead, molybdenum, nickel, silver, vanadium, and zinc). Concentrations of trace metals were not different between control and impact sites, with the exception of vanadium in rockfishes which was significantly higher. Vanadium levels were not toxic at the levels measured. Concentrations of hexane-extractable materials, volatile solids, copper, and zinc showed no obvious anomalies near the platforms. Hydrocarbons were not detectable in the mussels or crabs regardless of collection site, but very high in the rockfish. Owing to gas chromatographic fingerprints, the authors concluded that the hydrocarbons in the rockfish were biogenic, rather than from petroleum. The MMS is currently funding studies of platform rockfish body burdens (Dr. Milton Love at UCSB, is the grantee). Initial funding is for measurements of tissue concentrations of heavy metals (including mercury). PAHs and PCBs may be measured later in archived tissue samples (Ann Bull, Minerals Management Service, pers. comm.). At the time of this writing (1/2006), results of this study were not available.

Epibiota Epibiota (e.g., mussels, barnacles, bryozoans, anenomes, scallops) grow prolifically on offshore platforms, resulting in large shell mounds at the base of the structures. Approximately 85% of the statewide commercial mussel production originates on offshore oil platforms

(Ugoretz 2002). For many years, the locally based company Ecomar (now out of business) harvested up to 500,000 lbs per year of Mediterranean mussels, rock scallops, and oysters from Platform Holly and other oil platforms in the Channel, for sale to area restaurants. Commercial shellfish harvesters in California must be certified by the California Department of Health Services, a process which requires testing only for bacteria and paralytic shellfish toxin. Initially, Ecomar had to translocate batches of mussels to a "clean" site away from the platforms and compare the contaminant loads (most likely fecal coliform) between the mussels taken from the platforms and those at the clean site. After a year of testing there was little if any difference between mussels at the two sites and Ecomar was certified to harvest directly from the platforms and sell to the public (John Richards, Marine Advisor, Sea Grant Extension Program, UCSB, pers. comm.)

### *B.3. Natural Oil Seeps*

Oil and gas escapes naturally from seep fields at several locations in the Channel region, including at sites within the Park (Hostetler et al. 2004). The seep field at Coal Oil Point off the mainland coast is the most prolific seep field in the region (Figure 31) and is among the largest and best documented seeps in the world (Quigley et al. 1999), releasing approximately 100,000 $m^3$ of gas (Leifer et al. 2003) and more than 100 barrels of oil per day (Libe Washburn, Professor, Dept. of Geography, UCSB, pers. comm.). The nearshore seeps at Coal Oil Point are predominantly oil exuded directly from the outcrop of the Monterey Formation exposed in the axis of the Coal Oil Point anticline. Further offshore, seepage passes through overlying Sisquoc Formation cap rock and includes both oil and gas. Oil slicks produced by the Coal Oil Point seep were mapped by side aperature radar (SAR) imagery from 1995-1998 by DiGiacomo et al. (2004). Their image set included an oil slick that extended 50 km in the alongshore direction that was 100 $km^2$ in area, as well as a slick that was entrained 15 km offshore. Cross-shore entrainment of slicks was seaward or landward, depending on how the slick interacted with surface eddies. Oil slicks from the Coal Oil Point seep field would have to be entrained ca. 50 km in the cross-shore direction before entering the Park.

There is evidence that oil extraction at Platform Holly (Figure 29) has decreased the areal extent and volume of natural seepage at the Coal Oil Point seep field. Sonar backscatter can be used to measure the extent of plumes of bubbles in seep fields. Using transects of sonar data from 1973 and 1996, Quigley et al. (1999) discovered a 50% decrease in seepage area at Coil Oil Point that was accompanied by a decline, since 1989, in the volume of gas being collected in underwater seep tents.

Active, unmapped seeps occur near the shores of the Channel Islands. Hostetler et al. (2004) used chromatographic signatures to examine the possible origins of 128 tar balls deposited on the beaches at Santa Cruz, Santa Rosa, San Miguel and the mainland. They were able to assign the tar balls to four chemically distinct seepage sources - at least one of which may be releasing tar from sites separated by as much as 60 km. Most of the tar balls collected on Park islands originated from seeps near the islands. The dominant shallow seepage around the Channel Islands appeared to originate off Fraser Pt. on Santa Cruz and accounted for about 65% of the sample set. Tar balls originating from Channel Island seeps were transported as far north as Pt. Reyes and as far south as San Diego.

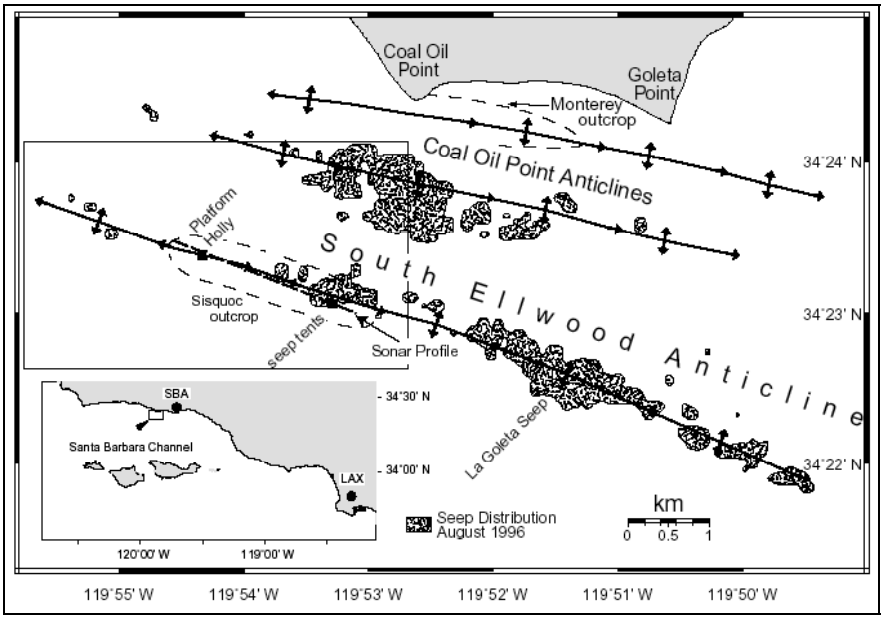



Figure 31. Coal Oil Point hydrocarbon seep area. Fault locations and anticline/syncline pairs in Monterey and Sisquoc Formations of northern Santa Barbara Channel shelf determine seep distribution. Mapped distribution of seepage is from 3.5 kHz sonar survey during August 1996 (Quigley et al. 1999).

### *B.4. Shipwrecks*

An inventory of over 140 shipwrecks dating from 1853 to 1980 has been documented in the Sanctuary (Ugoretz 2002). To date, about 20 sites have been located (Appendix H) and include Chinese junks, Russian and Mexican sailing ships, American coastal traders and Gold Rush-era steamships. In 1987, the Pacbaroness (540 ft) collided with an automobile freighter and sank offshore near Point Conception with approximately 80,000 lbs of copper powder concentrate onboard (the auto carrier did not sink). Although this shipwreck has not been identified as a source of pollution, settling and corrosion of the sunken vessel could lead to releases of copper in the future. Furthermore, the Pacbaroness sank with 30,000 gallons of remaining bunker fuel (Polgar et al. 2005).

### *B.5. Water Quality Threats posed by Large and Small Vessel Traffic*

A good review of the potential threats to Sanctuary water quality posed by large vessel and small vessel traffic appears in a recent report: Polgar et al. (2005). For details, and sources of data therein, the reader is directed to this report which was available online in Jan. 2006 at: http://www.edcnet.org/ProgramsPages/pressrelease.html.

Special concerns associated with vessel categories are listed below:

<u>Large Vessels: Container Ships, Bulk and Cargo Ships, Oil Tankers</u>

- Pass through the east end of the Sanctuary, and approach Park boundaries around Anacapa, via the southbound international shipping lane
- Frequency: ~20 per day
- Potential Releases: bilge water, ballast water, diesel exhaust

Cruise Ships

- Anchor off of the City of Santa Barbara, do not enter the Park
- Frequency: ~ 2 per year
- Potential Releases: bilge water, diesel exhaust, large volumes of untreated sewage, black and gray water, and hazardous wastes from on-board facilities for dry cleaning, photo-developing, etc., anthropogenic debris

Commercial Fishing Vessels, Commercial Passenger Fishing Vessels (CPFVs), Whale watching Vessels

- Enter the Sanctuary and the Park
- Potential Releases: bilge water, diesel fuel spils, faulty operation of Type I or Type II marine sanitation devices or releases from Type III-holding tanks, anthropogenic debris, discarded fishing gear, leaching of copper or tributyltin from anti-fouling paint on hulls (tributyltin only from vessels > 75 m in length).

Recreational Motor Boats and Sailboats

- Enter the Sanctuary and the Park, use Park anchorages
- Potential discharges: untreated sewage from Type III marine sanitation devices, bilge water, anthropogenic debris, diesel fuel spils, leaching of copper from anti-fouling paint on hulls.

According to Polgar et al. (2005), the Sanctuary plans to monitor large vessel traffic using an Automated Identification System base station on Santa Cruz, which tracks the identities, position and cargo types of large vessels using legally required identification transponders. Weekly, since August 1997, Sanctuary staff conduct aerial surveys of commercial and recreational vessels (location, number, type) as part of the Sanctuary Aerial Monitoring Spatial Analysis Program. Spatial patterns of Park use by commercial and recreational fishermen, sightseeing boats, and kayakers are discussed in Sections III.B. and III.C.

Since the writing of Polgar et al. (2005), new legislation, the California Clean Coast Act of 2005 (SB 771), took effect on Jan. 1, 2006, which targets discharges from "oceangoing ships" (private, commercial, government, or military vessel of 300 gross registered tons) and cruise ships. Discharges of (1) hazardous waste, (2) oily bilgewater, (3) "other waste" (dry-cleaning, photographic film-developing and medical), and (4) graywater, are now prohibited within state marine waters. The SWRCB will request the Administrator of NOAA to extend these prohibitions to California's four national marine sanctuaries (Cordell Bank, Gulf of the Farallones, Monterey Bay, and Channel Islands).

## C. WATER QUALITY WITHIN THE PARK

### *C.1. State designated beneficial uses or classifications of Park waters*

State designated beneficial uses of upland waters on Park islands are:

- Municipal drinking water supply
- Agriculture (Santa Rosa creeks only)
- Contact & noncontact water recreation
- Warmwater habitat
- Wildlife habitat
- Preservation of rare & endangered species

State designated beneficial uses of coastal waters at Park islands are:

- Contact and noncontact water recreation
- Navigation
- Marine habitat
- Shellfish harvesting
- Commercial and sport fishing
- Rare, threatened or endangered species
- Wildlife habitat
- Areas of special biological significance (see below)

<u>State Water Quality Protection Areas (SWQPA)</u>

Authorized by Assembly Bill 2800, SWQPAs are marine or estuarine areas designated to protect marine species or biological communities from an undesirable alteration in natural water quality, including, but not limited to, "areas of special biological significance" (ASBS) designated by the SWRCB through its water quality control planning process. The Park is fully contained within two SWQPAs:

**ASBS No. 17**, within Region 3, includes the waters surrounding San Miguel, Santa Rosa, and Santa Cruz Islands to a distance of one nautical mile offshore, or to the 300-ft isobath, *whichever is the greatest*.

**ASBS No. 22**, within Region 4, includes the waters surrounding Santa Barbara and Anacapa Islands to a distance of one nautical mile offshore, or to the 300-ft isobath, *whichever is greatest*.

An ASBS designation implies the following requirements:

- Discharge of elevated temperature wastes in a manner that would alter water quality conditions from those occurring naturally will be prohibited.
- Discharge of discrete, point source sewage or industrial process wastes in a manner that would alter water quality conditions from those occurring naturally will be prohibited.
- Discharge of waste from nonpoint sources, including but not limited to storm water runoff, silt, and urban runoff, will be controlled to the extent practicable. In control programs for waste from nonpoint sources, Regional Boards will give high priority to areas tributary to ASBS.

### *C.2. 303(d) listed water quality limited segments*

There are no 303(d) listed water bodies or segments in the Park.

### *C.3. Streams and Riparian Corridors*

#### a. Stream Sampling History

Stream water quality data are available for only one site on Santa Cruz (in 1993), and none on San Miguel. On Santa Rosa, streams in several canyons (Figure 32) were sampled with varying frequency from 1993-1998, and again in 2002 and 2005. Until recently, streams and riparian zones on Santa Rosa were impacted by almost two centuries of livestock grazing (see Section I.A.5 for a history of livestock operations). Starting in the early 1800's, sheep ranching was conducted by Spanish occupants on Santa Rosa. In 1902, the island was converted to cattle grazing by the Vail & Vickers Co. In addition, Roosevelt elk and kaibab mule deer were introduced in the late 1920s to support a commercial hunting operation. Vail & Vickers Co. was allowed to continue its cattle operation for 18 years after Santa Rosa became part of the Park. A settlement agreement between the NPS, the SWRCB, Vail & Vickers Co. and the National Parks & Conservation Association resulted in the removal of the cattle in 1998. The commercial hunting operation for deer and elk continues under a special use permit that is due to expire in 2008, although the NPS may allow the continued hunting of elk and deer until 2011, at which time all elk and deer will be removed from the island.

Owing to a paucity of water developments, the cattle on Santa Rosa used, and substantially damaged, the riparian areas (Wagner et al. 2004). Cattle use of streams and riparian areas increased substantially during the hotter summer months. From 10/1993 to 5/1998 water quality monitoring of three streams on Santa Rosa was conducted in Lobo Canyon, Water Canyon and Quemada Canyon. During this period, water quality standards for turbidity, microbial content, nutrients, and pH were exceeded frequently (Table 13). In May, 1995, the Central Coast RWQCB (Region 3) issued Cleanup and Abatement Order 95-064 in response to non-point source pollution caused by grazing and road management practices on Santa Rosa. That year, an assessment of riparian corridor functionality was conducted by staff from the Park, the NPS Water Resources Division, the U.S. Forest Service, and the Bureau of Land Management, in 10 stream reaches on the island, partly in order to assist with recommendations to alter cattle management (Wagner et al. 2004; see Section I.C.1. for details). Instead, in 1998, the NPS eliminated cattle on the island. During July - Sept. 2002, the streams in Lobo, Water and Quemada Canyons were resampled monthly for physical, chemical, and biological parameters in order to assess the consequences of cattle removal on water quality and riparian health. The assessment of riparian corridor vegetation, geomorphology, and functionality was repeated in 2004 (Wagner et al. 2004). A road inventory was conducted to determine the condition of all stream crossings on the island and assess the effect road management activities were having on stream conditions.

Figure 32. Stream sampling sites on Santa Rosa Island. Station numbers are those used in Table 13.

Stream sampling history for the Park, and water quality exceedances, are summarized in Table 13. With the exception of three sites (CHIS0011, CHIS 0013, CHIS 0001), time series plots of physical, chemical, and bacteriological parameters, and tables including data from 1993-2002 are available in CINP (2002b); a subset of these figures are presented in Appendix I. For this report, all available individual observations were compared to EPA "water quality criteria for aquatic life" (pH, DO), EPA and state criteria for "freshwater recreational contact" (total coliform and fecal coliform bacteria), state water quality "objectives for inland surface waters" (turbidity, DO and high pH), and EPA "suggested criteria" for TN and TP in streams and rivers of the "Xeric-West Ecoregion". Through 1998, total coliform and fecal bacteria frequently exceeded standards for recreational water contact at every site where they were measured (Appendix I). Turbidity exceedances were common during 1993-1998, and also observed at three sites post-cattle removal (Appendix I). pH was intermittently higher than 8.3 (CA upper limit) and occasionally higher than 9.0 (EPA upper limit). TN and TP frequently exceeded EPA-recommended levels before cattle removal (Appendix I).

### b. Effects of cattle removal on stream water quality on Santa Rosa

In CINP (2002b), the 2002 ("post-removal") results were compared to average results for the same stations from 1993-1998 ("pre-removal"). Only pre-removal data obtained during summer months (Jul.-Sep.) were used in the comparisons. Stream discharge was significantly lower in 2002 at five of the stream sites compared to pre-removal mean values. However, this result was ascribed to unusually low precipitation on Santa Rosa in 2002 (62% below normal), rather than to phenomena associated with cattle removal. In fact, owing to the removal of grazers, and the recovery of riparian zones on Santa Rosa (see more below), many seasonal streams are reportedly experiencing a longer period of flow (Kate Faulkner, Chief of Natural Resources, Channel Islands National Park, pers. comm.). Post removal stream temperatures (relative to air temperature) were significantly lower at six sites than pre-removal stream temperatures. Cooler water temperatures are probably resulting from the recovery of riparian vegetation, and consequent streambed shading (Wagner et al. 2004). The two sites where this change was not observed were (1) where the stream bed was sharply incised in bedrock, and lacked a riparian zone, and (2) at a spring (where pre-removal temperatures were unaffected by a lack of riparian vegetation). Post-removal, TSS was 100% lower at two of the three sites where it was measured, and both of these sites were also cooler. However, post-removal *turbidity* was significantly higher than pre-removal turbidity at two of the six cooler stream locations, and not significantly different at three others. CINP (2002b) expresses more confidence in the results for TSS than for turbidity - citing low flows and sediment resuspension as having interfered with turbidity measurements (although presumably not with water sampling for TSS). Results for dissolved nutrient concentrations appear unambiguous; TP was no longer detected and TN was 89%-100% lower, post-removal. Two sites (both near the stream mouths in Water Canyon and Lobo Canyon) displayed signficantly lower mid-day dissolved oxygen levels during the post-removal survey. This result may indicate a reduction in within-stream photosynthesis following post-removal reductions in dissolved nutrients CINP (2002b), although measurements of periphytic algal biomass are not available to support this hypothesis. Total coliform bacteria were 73%-82% lower and fecal coliform bacteria >98% lower at two of the sites where measured, and unchanged at the third site (in both former cases, the changes were significant).

Table13. Stream sampling history for Channel Islands National Park. Sites in drainages are listed from highest (upstream) to lowest (downstream) in the drainage. (Whether or not exceedances were observed in 2005 was not known at time of writing)

| Stream Sampling Site | Latitude Longitude | NPS station in Horizon Report | other site names | parameters measured | Sampling Era[a] | list of years sanpled (# obs) | types of Water Quality Exceedances observed during Sampling Era[b] |
|---|---|---|---|---|---|---|---|
| **Quemada Canyon - Santa Rosa Island** | | | | | | | |
| Clapp Springs- head of San Augustine Canyon - diverted to Vail & Vickers Ranch and into Quemada Canyon | 33.951087 | CHIS0012 | Clapp Springs | temp, pH | pre-removal | 1993 (5) | Turbidity-EPA |
| | -120.060005 | | | conductivity | | 1994 (16) | pH (high)-EPA |
| | | | | salinity | | 1995 (5) | DO |
| | | | | turbidity, DO | | 1996 (7) | |
| | | | | | | 1997 (2) | |
| | | | | | | 1998 (1) | |
| | | | | | post-removal | 2002 (3) | Turbidity-EPA |
| | | | | | | 2005 (1) | |
| Quemada Canyon-50 m below ranch water development | 33.954588 | CHIS0011 | | temp, pH | pre-removal | 1993 | Turbidity-EPA |
| | -120.056255 | | | conductivity | | 1994 | |
| | | | | salinity | | others?[c] | |
| | | | | turbidity, DO | | | |
| Quemada Canyon near Las Cruces Corral | 33.965727 | CHIS0007 | Quemada #2 (2002) | temp, pH | pre-removal | 1993 (5) | Turbidity-EPA |
| | -120.034365 | | | conductivity | | 1994 (16) | pH (high)-CA, EPA |
| | | | | salinity | | 1995 (5) | |
| | | | | turbidity, DO | | 1996 (7) | |
| | | | | | | 1997 (2) | |
| | | | | | | 1998 (1) | |
| | | | | | post-removal | 2002 (3) | none |
| | | | | | | 2005 (1) | |

| Stream Sampling Site | Latitude Longitude | NPS station in Horizon Report | other site names | parameters measured | Sampling Era[a] | list of years sanpled (# obs) | types of Water Quality Exceedances observed during Sampling Era[b] |
|---|---|---|---|---|---|---|---|
| Quemada Canyon near Old Ranch Canyon Corral | 33.970142<br>-119.998253 | CHIS0006 | Quemada #3 (2002) | temp, pH<br>conductivity<br>salinity, turbidity<br>DO, TN, TP, TSS, TDS<br>total coliform<br>fecal coliform | pre-removal | 1993 (6)<br>1994 (19)<br>1995 (8)<br>1996 (7)<br>1997 (2)<br>1998 (1) | Turbidity<br>TN<br>TP<br>total coliform<br>fecal coliform |
| | | | | | post-removal | 2002 (8)<br>2005 (1) | none |
| Quemada Canyon -half mile from stream mouth | 33.964421<br>-119.983142 | CHIS0005 | Quemada #4 (2002) | temp, pH<br>conductivity<br>salinity<br>turbidity, DO | pre-removal | 1993 (6)<br>1994 (11)<br>1995 (7)<br>1996 (7)<br>1997 (2)<br>1998 (1) | pH (high)-CA, EPA<br>Turbidity |
| | | | | | post-removal | 2002 (3)<br>2005 (1) | Turbidity |
| **Water Canyon Drainage - Santa Rosa Island** | | | | | | | |
| Water Canyon - below Army Camp | 33.964421<br>-120.053920 | CHIS0010 | Water #2 (2002) | temp, pH<br>conductivity<br>salinity<br>turbidity, DO | pre-removal | 1993<br>1994<br>others? | none |
| | | | | | post-removal | 2002<br>(flow only)<br>2005 (1) | |

| Stream Sampling Site | Latitude Longitude | NPS station in Horizon Report | other site names | parameters measured | Sampling Era[a] | list of years sanpled (# obs) | types of Water Quality Exceedances observed during Sampling Era[b] |
|---|---|---|---|---|---|---|---|
| Water Canyon - adjacent to corral | 33.978587 | CHIS0009 | Water #3 (2002) | | pre-removal | 1993 (6) | Turbidity |
| | -120.049642 | | | temp, pH | | 1994 (20) | pH (high)-CA, EPA |
| | | | | conductivity | | 1995 (7) | TN |
| | | | | salinity | | 1996 (6) | TP |
| | | | | turbidity | | 1997 (2) | total coliform |
| | | | | DO, TN, TP, TSS, TDS | | 1998 (1) | fecal coliform |
| | | | | total coliform | post-removal | 2002 (7) | Turbidity |
| | | | | fecal coliform | | | pH (high)-CA |
| | | | | | | 2005 (1) | |
| Water Canyon - below NPS campground | 33.992059 | CHIS0008 | Water #4 | temp, pH | pre-removal | 1993 (6) | Turbidity |
| | -120.045225 | | | conductivity | | 1994 (19) | pH (high) CA |
| | | | | salinity | | 1995 (7) | total coliform |
| | | | | turbidity | | 1996 (7) | fecal coliform |
| | | | | DO, TSS, TDS | | 1997 (2) | |
| | | | | total coliform | | 1998 (1) | |
| | | | | fecal coliform | post-removal | 2002 (5) (bacteria not done) | pH (high) CA |
| **Lobo Canyon Stream - Santa Rosa Island** | | | | | | | |
| Lobo Canyon - 100 m upstream fr Smith Highway | 34.002087 | CHIS0013 | | temp, pH | pre-removal | 1993 | none |
| | -120.087365 | | | conductivity | | 1994 | |
| | | | | salinity | | others? | |
| | | | | turbidity, DO | | | |

| Stream Sampling Site | Latitude Longitude | NPS station in Horizon Report | other site names | parameters measured | Sampling Era[a] | list of years sanpled (# obs) | types of Water Quality Exceedances observed during Sampling Era[b] |
|---|---|---|---|---|---|---|---|
| Lobo Canyon - below Smith Highway | 34.005253 | CHIS0014 | Lobo #3 | temp, pH | pre-removal | 1993 (6) | Turbidity |
| | -120.090699 | | | conductivity | | 1994 (19) | TN |
| | | | | salinity | | 1995 (7) | TP |
| | | | | turbidity | | 1996 (7) | total coliform |
| | | | | DO, TN, TP, TSS, TDS | | 1997 (2) | fecal coliform |
| | | | | | | 1998 (1) | |
| | | | | total coliform | post-removal | 2002 (7) | none |
| | | | | fecal coliform | | 2005 (1) | |
| Lobo Canyon - near lower end of cattle exclosure | 34.017420-120.097865 | CHIS0015 | Lobo #4 | temp, pH | pre-removal | 1993 (6) | Turbidity |
| | | | | conductivity | | 1994 (19) | |
| | | | | salinity | | 1995 (7) | |
| | | | | turbidity, DO | | 1996 (7) | |
| | | | | TN (once, post-removal) | | 1997 (2) | |
| | | | | | | 1998 (1) | |
| | | | | | post-removal | 2002 (4) | Turbidity, TN |
| | | | | | | 2005 (1) | |
| **Santa Rosa Island** - Arlington Canyon, La Jolla Vieja Canyon, Verde Canyon, Windmill Canyon, Tecelote Canyon, Wreck Canyon - | | | | temp, pH | post removal | 2005 (1) | |
| | | | | conductivity | | | |
| | | | | salinity | | | |
| | | | | DO, TN, TP, TSS, | | | |
| | | | | total coliform | | | |
| | | | | fecal coliform | | | |

| Stream Sampling Site | Latitude Longitude | NPS station in Horizon Report | other site names | parameters measured | Sampling Era[a] | list of years sanpled (# obs) | types of Water Quality Exceedances observed during Sampling Era[b] |
|---|---|---|---|---|---|---|---|
| **Santa Cruz Island**-Joyce Springs Canyon Mouth | 34.008781<br>-119.554726 | CHIS0001 | | temp, conductivity,<br>TSS | | 1993<br>others? [a] | data not inspected |

[a]Pre- and post-removal refers to the removal of cattle by the Vail & Vickers ranch from Santa Rosa Island in Sept. 1998.

[b]Water Quality Criteria from the EPA or from CA-RWQCB-Region 3 (Inland Surface Water Quality Objectives in Basin Plan, Region 3)

- Total Coliform: EPA: 1000 MPN/100ml (geometric mean)
- Fecal Coliform: 200 MPN/100 ml (geometric mean), 400 MPN/100ml (single sample)
- Turbidity: 50 FTU/NTU
- DO-EPA: <4.0 mg/L
- DO-CA: <5.0 mg/L
- pH (low) EPA&CA: < 6.5
- pH (high) EPA: >9.0, CA: >8.3
- TP: >0.022 mg/L (EPA recommended criteria for rivers and streams in xeric west)
- TN: >0.38 mg/L (EPA recommended criteria for rivers and streams in xeric west)

[c]Period of observations reported in 1999 inventory of water quality data for the Park ("Horizon Report", NPS 1999) . Based on sampling history reported in CINP (2004) for the other Santa Rosa sites, there may be other observations at the site that are not included in the Horizon Report.

### *C.4. Vernal pools*

Water quality has been examined only once in vernal pools in the Park (Furlong 1996). In April, 1995, some basic measurements were made during a survey of 12 vernal pools on Santa Rosa (Table 14). Pools on the west end of the island were being used by cattle at that time. Turbidity was high (80 to >1000 NTU) in these pools, however, no corresponding measurements were made in pools on the east side of the island that were apparently less impacted, or unimpacted, by cattle. Water temperature ranged from 11.8 to 18.5°C, and pH ranged from 7.37-8.55. Water quality in the generally deeper vernal pools on the east end of the island was not evaluated. However, macroinvertebrate diversity was higher in pools on the east end, primarily owing to higher numbers of insect taxa.

Table 14. Santa Rosa vernal pool information from an April, 1995, survey (Furlong 1996).

| | Pocket Field Pools | | | | | | Water Canyon Pool | Skunk Point Pools | | | | Abalone Rock Pool |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | | 1 | 2 | 3 | 4 | |
| estimated size* | L | L | L | M | S | S | L | M | S | M | M | L |
| Depth (cm) | 55 | 35 | 35 | 10 | 35 | 20 | 60 | 60 | 45 | 150 | 80 | 40 |
| Bank characteristics** | G,L | M,G | M,G | M | M | L | C,L | D,L | D,L | D,L | D,L | L |
| Cattle Impact | H | H | H | H | H | M | N | N | N | N | N | O |
| Clarity (subjective score) | S | S | S | T | T | T | S | C | C | C | C | C |
| Turbidity (NTU) | 111 | 260 | 80 | >1000 | >1000 | >1000 | | | | | | |
| Water temp. °C | 11.8 | 12.1 | 13.4 | 16.7 | 16 | 18.5 | | | | | | |
| pH | 8.55 | 7.94 | 7.97 | 7.86 | 7.64 | 7.37 | | | | | | |
| Salinity (%) | 0.08 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | | | | | | |
| Dissolved O2 (mg/l) | 11.1 | 9.73 | 9.52 | 8.65 | 8.27 | 7.21 | | | | | | |
| | | | | | | | | | | | | |
| Crustatcean Taxa | 1 | 2 | 3 | 3 | 2 | 2 | 5 | 1 | 2 | 3 | 2 | 3 |
| Insect Taxa | 5 | 8 | 6 | 7 | 6 | 2 | 7 | 17 | 14 | 10 | 13 | 17 |

*L > 3000 $m^2$; M >1500 $m^2$; S <1500 $m^2$ (estimated)
**M = mud, G=introduced grasses, L=littoral species, D=dune vegetation
***H=high impact observed/assumed, O=occasional impact assumed, N=no or rare impact assumed

### *C.5. Groundwater*

No principal aquifers underlie the islands of the Park (Planert and Williams 1995) and groundwater from the mainland does not discharge into the Park. A search of the USGS ground water site inventory yielded no well water, test bore, or other ground water data for the Park (Santa Barbara Channel Island HUC 18060014). The Park maintains wells on Santa Cruz (at Prisoner's Harbor and Scorpion Bay), on Santa Rosa (in Windmill Canyon), and on San Miguel (in Nidever Canyon). Other than bacterial levels, water quality is not monitored at these sites (Kate Faulkner, Chief of Natural Resources, Channel Islands National Park, pers. comm.). In July, 2005, a network of 18 shallow groundwater wells was installed in the coastal wetland at

Prisoner's Harbor on Santa Cruz in order to monitor the water table in anticipation of restoration work there (Noon 2005). No data from these wells was available at the time of this writing. However, owing to the *Eucalyptus* stands on the riparian terrace at this site, these wells provide an opportunity to study any future changes in the water table, should restoration work include removal or reduction of *Eucalyptus*.

### *C.6. Lagoons and coastal wetlands*

The only lagoons and wetlands that are studied in the Park are on Santa Rosa. A monitoring protocol for Santa Rosa lagoons was created in 1990 (Dugan et al. 1990), and three lagoons have been sampled with variable frequency since then: Old Ranch House Canyon Lagoon, Old Ranch Canyon Lagoon and Oat Point Lagoon (variably called a lagoon or a wetland, Dugan and Hubbard, 1990). Lagoon monitoring by Park staff takes place in conjunction with sandy beach monitoring and occurred in 1994 (Richards 1996), 1995 (Richards and Lerma 1996), 1997 (Lerma and Richards 2000), 1999 (Lerma et al. 2001), 2000 (Lerma and Richards 2002), and 2004 (Richards 2004) (Figure 11). Physical measurements are water depth, secchi depth, salinity (surface and 10 cm) and water temperature. No chemical measurements are made. The main water input to the lagoons is berm overwash, which can change the volume and areal extent of the lagoons during single tidal cycles. An ephemeral freshwater seep sometimes lowers surface salinity in part of Old Ranch House Lagoon. Freshwater inputs from creek inflow cause the other two lagoons to be brackish some of the time. Oat Point Lagoon does not receive creek water, is always hypersaline, and fills with either rainfall or berm overwash (Dan Richards, Marine Biologist, Channel Islands National Park, pers. comm.). Old Ranch Canyon Lagoon and Oat Point wetland are susceptible to complete drying. The lagoons are usually 5-10°C warmer than the ocean. The lagoons were sampled with greatest frequency from 1988-1990. During that time, salinity ranged from ~40 to ~150 ppt at Oat Point and from 0 to ~50 ppt in Old Ranch Canyon Lagoon. Overall, salinity ranges from 0 to >200 ppt at the three lagoons (Dugan and Hubbard 1990).

### *C.7. Beach water*

Water quality at Park beaches or anchorages is not monitored by the Park. Between 5/26/2005 and 9/5/2005, Santa Barbara Channelkeeper, an area non-profit organization, sampled total coliform, *E.coli* and *Enterococcus* in ocean water (surface grab samples) at several anchorages around the eastern end of Santa Cruz and at Anacapa. The following anchorages were sampled (each more than once, for a sample set of 34 grab samples):

| **Santa Cruz** | **Anacapa** |
|---|---|
| Coches Prietos | Landing Cove |
| Little Scorpion | Frenchy's Cove |
| Big Scorpion | |
| Seals | |
| Prisoners | |
| Pelican | |
| Smugglers | |
| Cueva Valdez | |
| Diablo | |
| Frys | |
| Yellowbanks | |

Total coliforms were high only twice, on July 2, 2005 at Pelican and Yellowbanks anchorages (933 and 6488 MPN/100 ml, respectively). The state standard for total coliform for ocean water contact recreation is a runnning average of 1000 MPN/100 ml, with no single, verified, sample being >10,000 MPN/100ml. *E. coli* and *Enterococcus* were each detected in only four samples during the summer, and *E. coli* was only high on one occasion (813 MPN/100 ml, at Pelican Anchorage on July 2, 2005). These higher values were attributed to high numbers of boats at most anchorages on the 4th of July weekend-especially at Pelican and Smugglers/Yellowbanks anchorages (Jessica Altstatt, Science Director, Santa Barbara Channelkeeper, pers. comm.). Fourteen boats were counted at Pelican Anchorage that weekend (which is crowded for that site) and 23 boats were anchored at Yellowbanks (which is a roomier anchorage).

### *C.8. Ocean water quality*

#### a. Sources of Oceanographic Data from Park waters

Four oceanographic research programs measure oceanographic parameters at regular intervals near, or within, Park waters. These are summarized below. The Park has temperature logger data from some kelp forest monitoring sites dating back to about 1985. In addition, for the last decade, year-round temperature logger data has been collected at 16 sites.

**Santa Barbara Coastal Long-Term Ecological Research Project (LTER)** The LTER, which was initiated in 2000, is headquartered at the University of California, Santa Barbara (UCSB) and is part of the National Science Foundation's Long-Term Ecological Research Network. The LTER collects hydrographic and biological data four times per year during Channel-wide surveys (Figure 33), principally to determine how oceanographic processes influence material transport to and from mainland kelp forests. During each cruise, an undulating towed vehicle called a Scanfish is deployed to obtain high resolution, two-dimensional maps of temperature, salinity, beam attenuation at 660 nm (a measure of water turbidity), and chlorophyll from the surface to ~100 meters depth. Cross-channel transects of CTD (conductivity/ temperature/depth instrument) profiles along the Scanfish tracks provide vertical profiles of the same water properties measured by the Scanfish, but from the surface to the sea floor. Nutrient and particle concentrations, and primary production rates, are derived from bottle samples obtained during the CTD surveys. Other instruments attached to the CTD measure optical properties used to characterize the particle fields and dissolved components of the water column. Spatial variation in currents is measured continuously during the cruises with ship-board instrumentation. Local area SeaWiFS and AVHRR images are collected and analyzed as part of the LTER program in collaboration with joint funding from NASA. This imagery provides 1-km scale synoptic views of ocean chlorophyll concentrations (Chl) and sea surface temperature (SST). Co-registered five-day composite fields for SST and Chl are created on a routine basis for the Channel.

**UCSB Plumes & Blooms Project**. The Blooms & Plumes project (PnB) is a joint collaboration among UCSB faculty, student and staff researchers at the Institute of Computational Earth System Science, NOAA researchers at the Coastal Services Center (Charleston, SC) and the Sanctuary. Since 1996, twice-monthly research cruises have taken place from the shelf waters north of Santa Rosa island to Goleta Point on the mainland (Figure 33). Measurements include temperature and salinity, ocean color spectra, water column profiles of red light transmission and chlorophyll fluorescence, and depth profiles of nutrients from bottle samples. PnB and LTER

cruises are frequently combined.

**CalCOFI.** The California Oceanic Cooperative Fisheries Investigations (CalCOFI) are a partnership of the CF&G, the NOAA Fisheries Service and the Scripps Institution of Oceanography (Scripps). The organization was formed in 1949 to study the ecological aspects of the collapse of the sardine populations off California. Today its focus has shifted to the study of the marine environment off the coast of California and the management of its living resources. Since 1949, hydrographic and biological data of the California Current System have been collected on CalCOFI cruises. The 54+ year hydrographic time-series includes temperature, salinity, oxygen and phosphate observations. In 1961 nutrient analysis expanded to include silicate, nitrate and nitrite; in 1973, chlorophyll was added; in 1984, $C_{14}$ primary productivity incubations were added. Currently, two to three week cruises are conducted quarterly. Scripps and NOAA provide equally in terms of ship time, personnel, and other cruise-related costs. On each cruise a grid of 66 stations off Southern California is occupied (Figure 33).

**PISCO.** The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) is a research consortium involving marine scientists from Oregon State University, Stanford University, UCSB, and UC Santa Cruz. PISCO was established in 1999 primarily with funding from the David and Lucile Packard Foundation. Among other things, PISCO studies recruitment processes and other factors that pattern communities of fish, invertebrates and algae at the Northern Channel Islands (and along the U.S. Pacific Coast). With respect to water quality, PISCO collects continuous measurements of temperature, and current speed and direction using moored instruments at various sites at the Channel Islands[14].

[14] PISCO data were not utilized in this report.

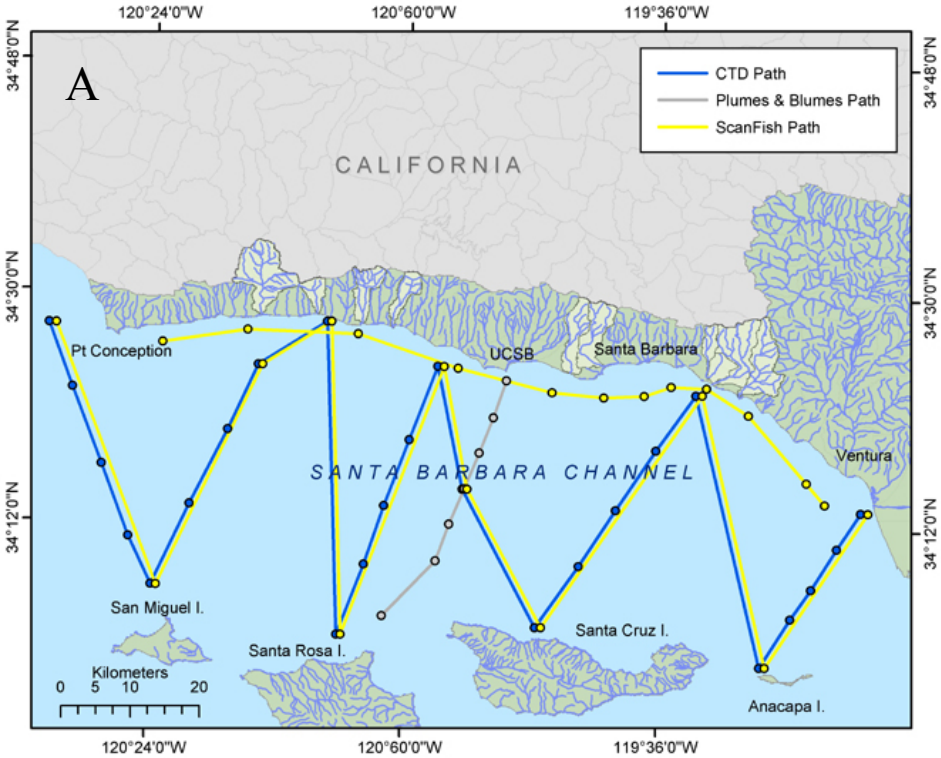
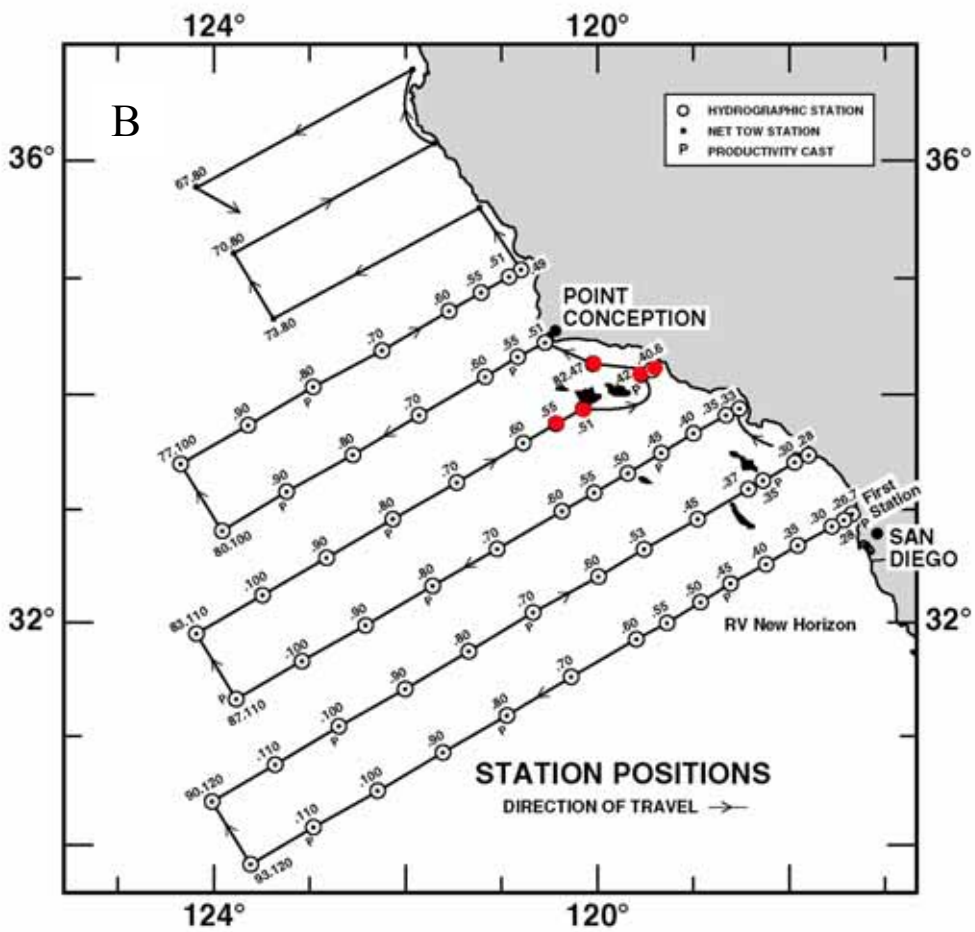



Figure 33. Oceanographic cruise sampling locations in the Santa Barbara Channel.

(A) Location of LTER grid stations(points along the labeled CTD path) and PnB transect stations.




(B) Location of CalCOFI grid stations. Selected CalCOFI salinity data for the stations highlighted in red are examined in this report.

**b. What do oceanographic data reveal about the reach of mainland storm plumes in the vicinity of the Park?**

Anthropogenic marine water pollution is unstudied at the Park. Measurements of synthetic organic contaminants or inorganic toxicants (metals) are lacking for Park waters. Natural phenomena (such as upwelling, currents, seasons, El Niño/La Niña cycles, and multidecadal climatic shifts) contribute to regional dynamics in SST, nutrient supply, and primary productivity. Consequently, standard oceanographic measurements (such as temperature, salinity, DO, dissolved nutrients, and chlorophyll-a) do not indicate *per se* whether or not water quality at the Park is compromised. However, in some cases, salinity data can be used to examine whether mainland storm plumes (and, presumably, associated contaminants) are advected all the way to the Park after major runoff events. Fine suspended sediments from mainland runoff usually penetrate further offshore than the surface salinity anomalies created by hypopycnal river plumes (Dave Siegel, Professor, Department of Geography, UCSB, pers. comm.). This implies that the dissolved constituents and fine particle-bound constituents of storm plumes are not transported in equivalent fashion away from the mainland. Average ambient coastal salinity in the region is 33.4 ± 0.1 psu, while river plumes produced by storms in the region have salinities in the range of 30.0-33.0 psu (Warrick et al. 2004b). Sea urchin fertility tests indicate that, at least in the Santa Monica Bay, water in storm plumes at sea must contain at least 10% of undiluted river water to be toxic (Section II.A.5). According to Warrick et al. (2005), plume water containing 12% river water corresponds to a decrease in salinity of approx. 4 psu from ambient seawater salinity. This implies that, in this region, the salinity of storm plume water at seas may need to be as low as 30.0 psu before it contains enough terrestrial runoff to represent an immediate threat to sensitive aquatic biota (i.e., acute toxicity). In real time, water quality in the Park is probably not affected by mainland runoff so long as the islands remain outside the zone of decreased salinity produced by major terrestrial runoff events. Below, selected salinity data from the LTER, PnB and CalCOFI research programs are examined to see whether surface salinity anomalies from mainland storm plumes extend far enough into the Santa Barbara Channel to reach Park waters.

**Examination of salinity data from LTER and PnB.**

Raw bottle sample data from all twelve LTER ocean grid cruises (2001 onward) was obtained in Nov. 2005. Salinity profiles for stations closest to the Park were plotted and inspected for evidence of discharge events of sufficient magnitude to reduce salinity in Park waters. For the dates on which LTER cruises were co-conducted with the more frequent bi-monthly PnB transects, salinity data were also plotted for the two PnB transect stations that lie closest to the Park (PnB7- on shelf waters near Santa Rosa, and PnB6 - nearest Santa Cruz). Combined LTER/PnB cruises coincided twice with stormflow events that influenced water close to the mainland: on 2/26/2004 when a storm plume was observed off of the Ventura coast, and during the Jan. 2005 cruise, after weeks of above-normal rainfall had occurred in the area (monthly rainfall totals with 25 to 50-year return intervals). For this reason, for both of these runoff events, salinity profiles obtained near each of the islands were compared to those obtained nearest the mainland (LTER station called "Ventura Plume" on 2/26/2004 , LTER grid station #25 off Ventura Harbor on 1/25/2005; and PnB transect station #1 off Goleta Point on 2/29/2004

and 1/25/2005). During these two discharge periods, surface salinity was sharply stratified near the mainland coast, and minimum surface values were 32.59 and 30.07 psu (on 2/26/2004 and 1/25/2005, respectively).

**San Miguel.** Salinity data for San Miguel are from LTER grid station #5. Salinity profiles from this site indicate that surface salinity was never stratified near San Miguel during the twelve LTER cruises, and salinity was not low enough on any of the sampling occasions to indicate dilution of San Miguel waters with terrestrial runoff (Figure 34).

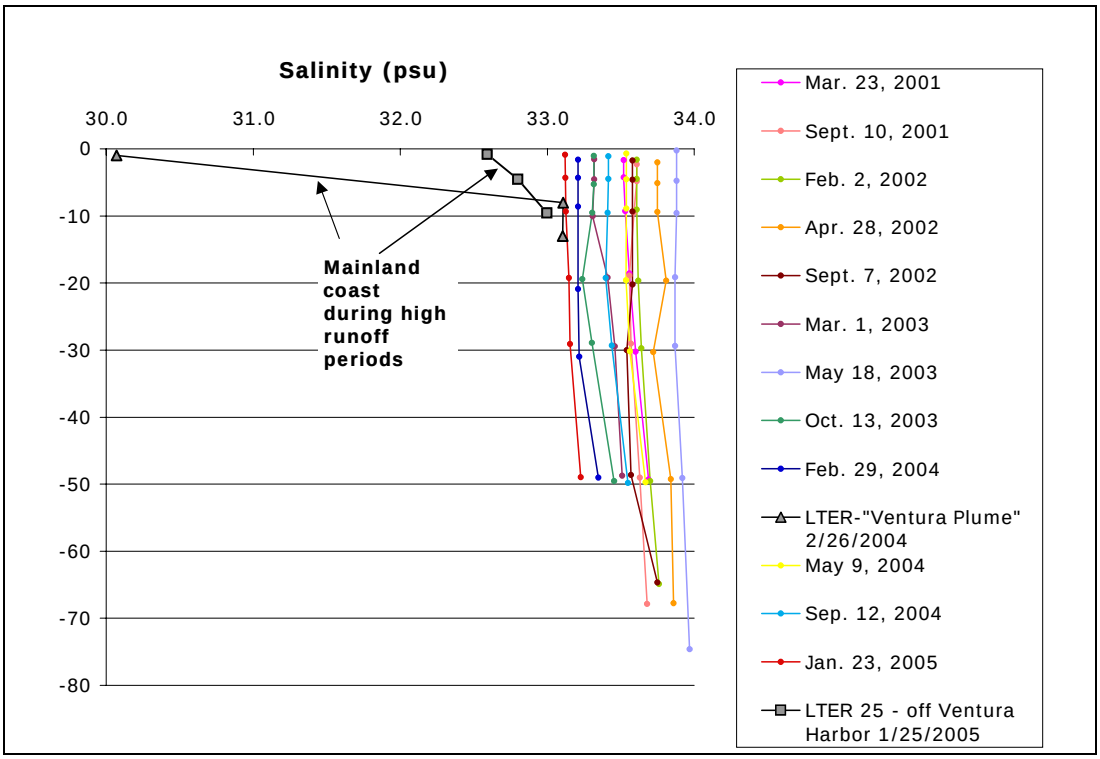
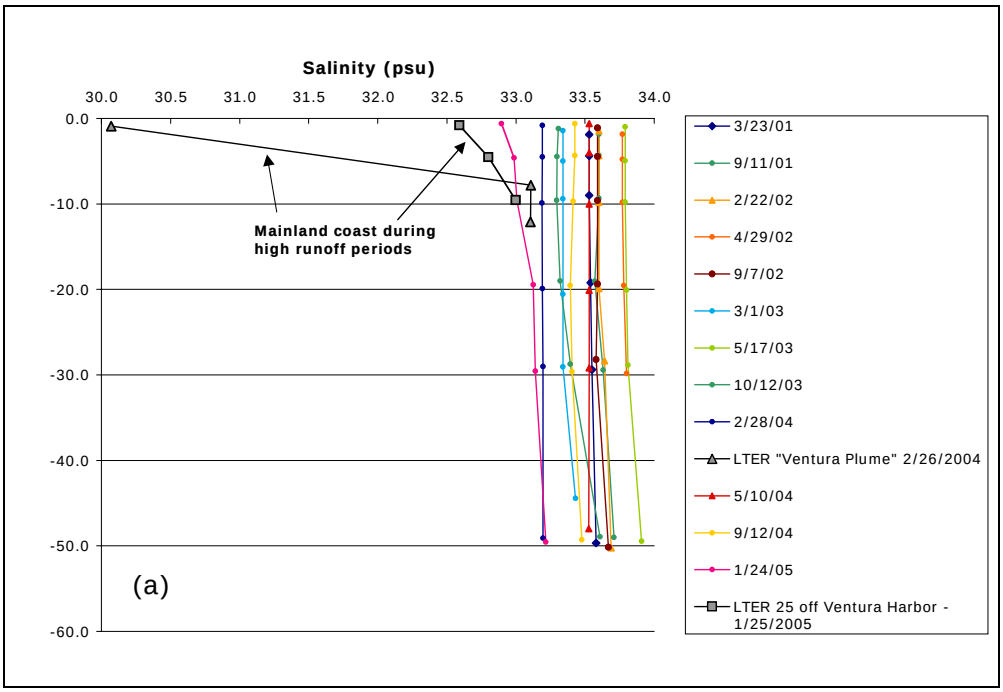



Figure 34. Salinity profiles near San Miguel Island. Data are from bottle samples collected at LTER grid station #5. For comparison, surface salinity at LTER stations nearest the mainland are included from two cruises that coincided with high terrestrial discharge.

**Santa Rosa.** Salinity data for Santa Rosa are from LTER grid station #10 and PnB transect station #7. Salinity profiles from 1/24/2005 at both stations indicate reduced surface salinity in Park waters near the island (Figure 35). However although a storm plume from the Santa Clara River was present off Ventura on 2/26/2004, surface water near Santa Rosa was not freshened by terrestrial runoff at that time.



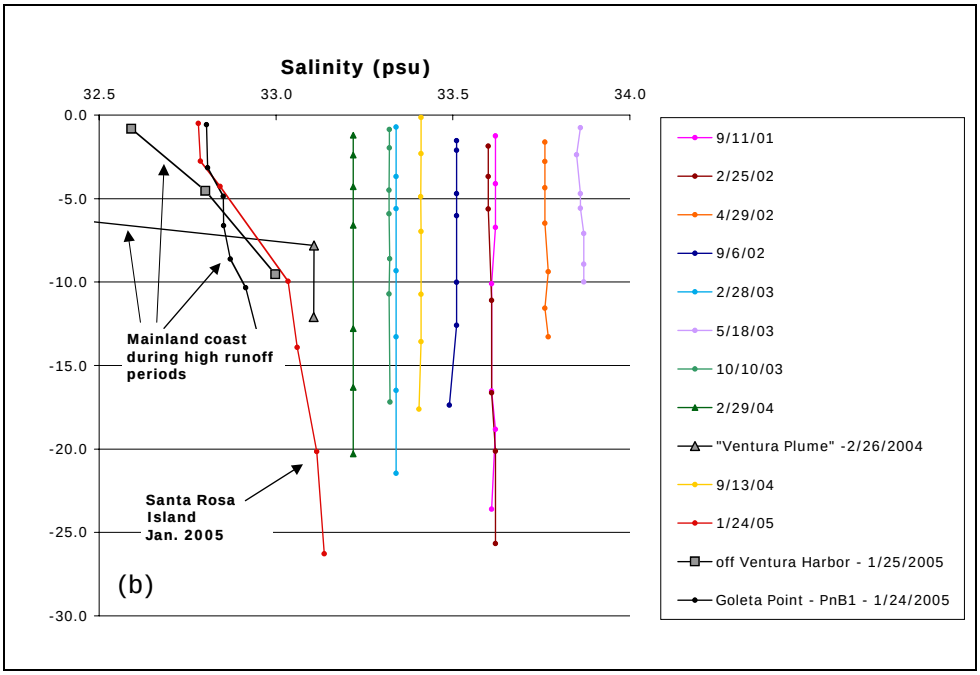
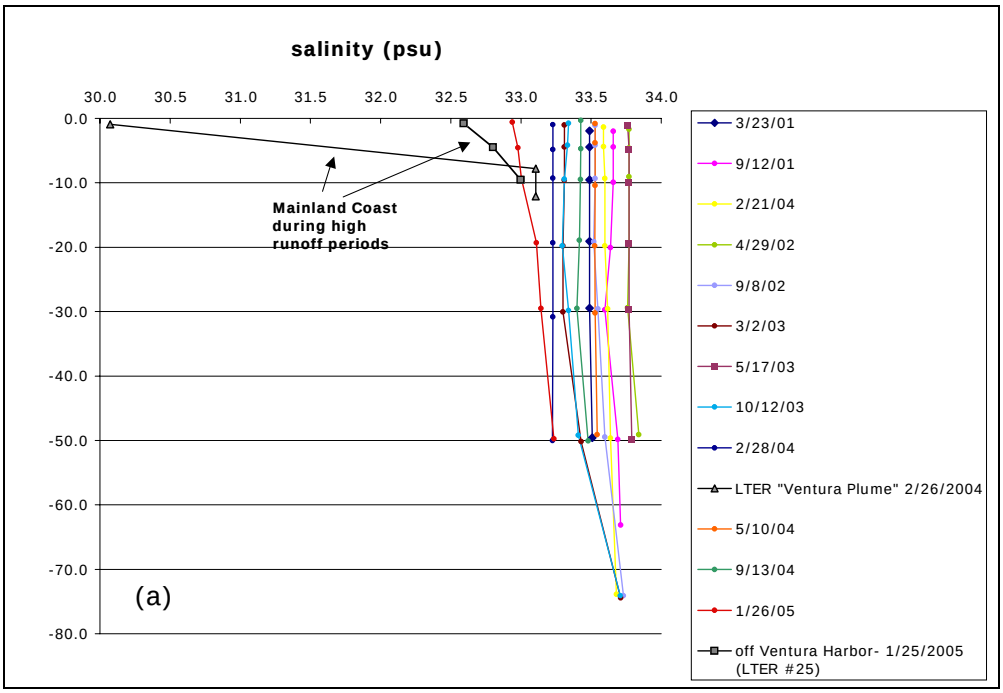




Figure 35. Salinity profiles near Santa Rosa Island. (a) Bottle sample salinity from LTER grid station #10. For comparison, surface salinity at LTER stations nearest the mainland are included from two cruises that coincided with high terrestrial discharge. (b) Bottle sample salinity from PnB station 7. Mainland station data from PnB1 (Goleta Point), and two LTER stations, are included.

**Santa Cruz.** Salinity data for Santa Cruz are from LTER grid station #16 and PnB transect station #6. As was the case for Santa Rosa, salinity profiles from Jan. 23-26, 2005 indicate reduced surface salinity near the island (Figure 36). However, although a storm plume from the

Santa Clara River was present off Ventura on 2/26/2004, surface water near Santa Cruz was not freshened by terrestrial runoff at that time.



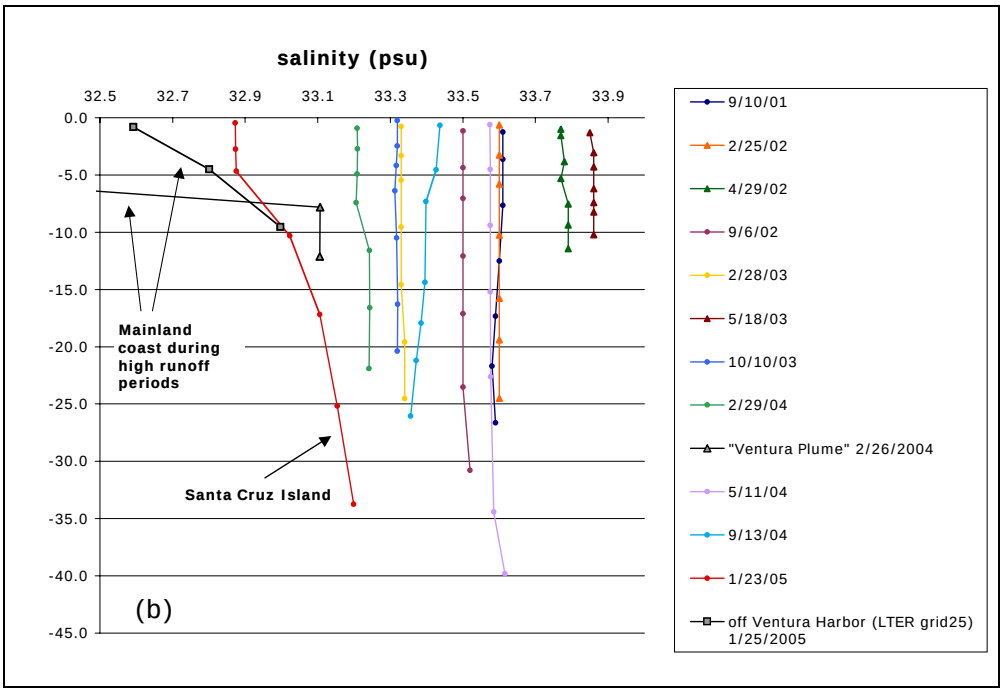
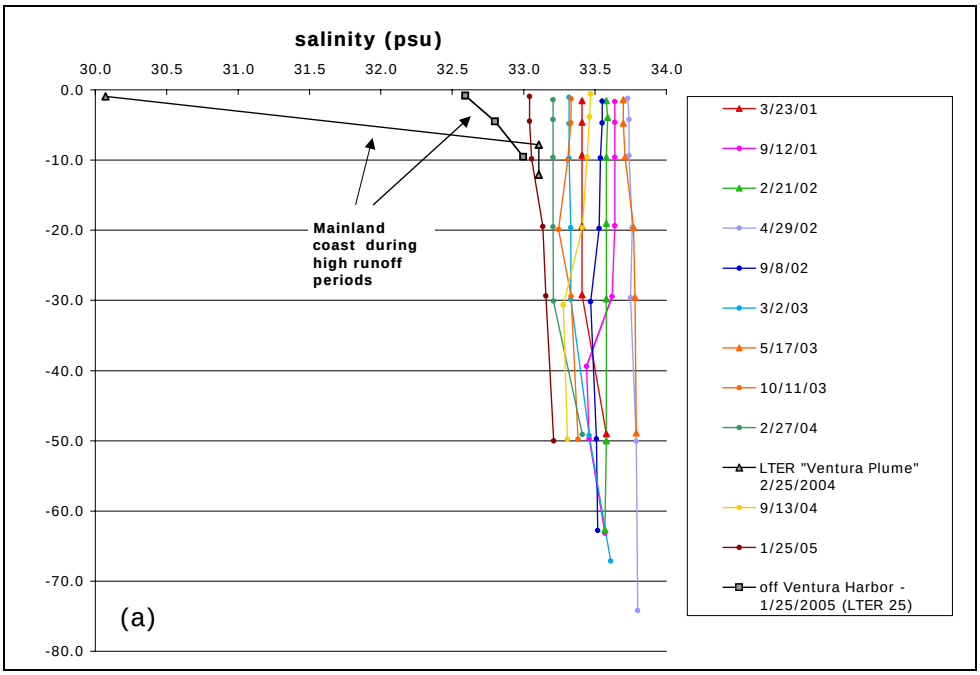




Figure 36. Salinity profiles near Santa Cruz Island. (a) Bottle sample salinity from LTER grid station #16. For comparison, surface salinity at LTER stations nearest the mainland are included from two cruises that coincided with high terrestrial discharge. (b) Bottle sample salinity from PnB station 6. Mainland station data from PnB1 (Goleta Point), and two LTER stations, are included.

**Ancacapa.** Salinity data for Anacapa are from LTER grid station #21. The salinity profile from 1/25/2005 indicated slightly reduced surface salinity near the island (Figure 37). However, although a storm plume from the Santa Clara River was present off Ventura on 2/26/2004, surface water near Anacapa was not freshened by terrestrial runoff at that time.



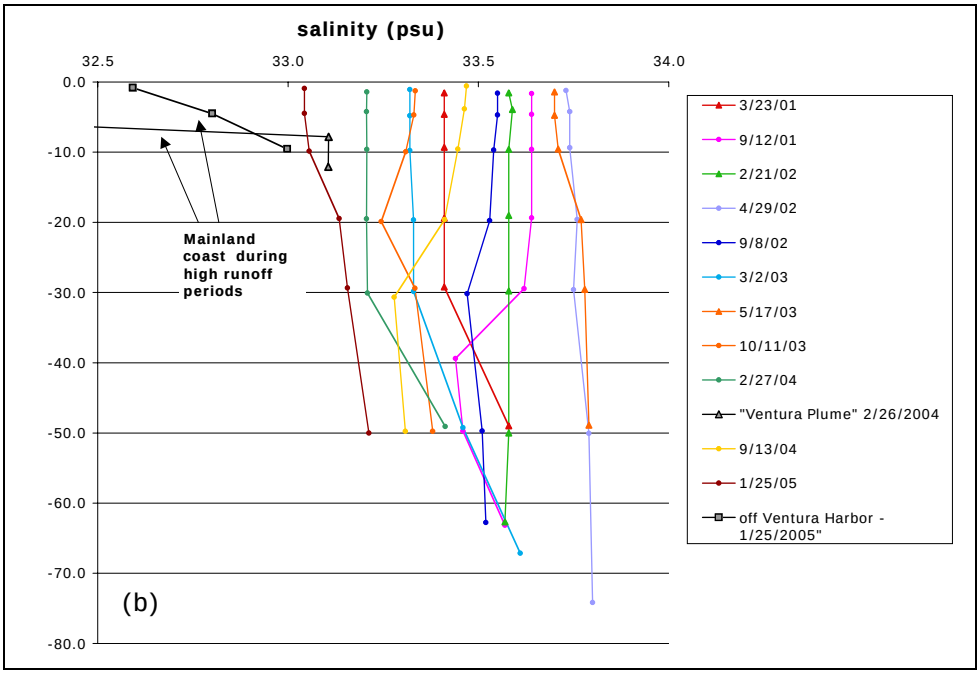
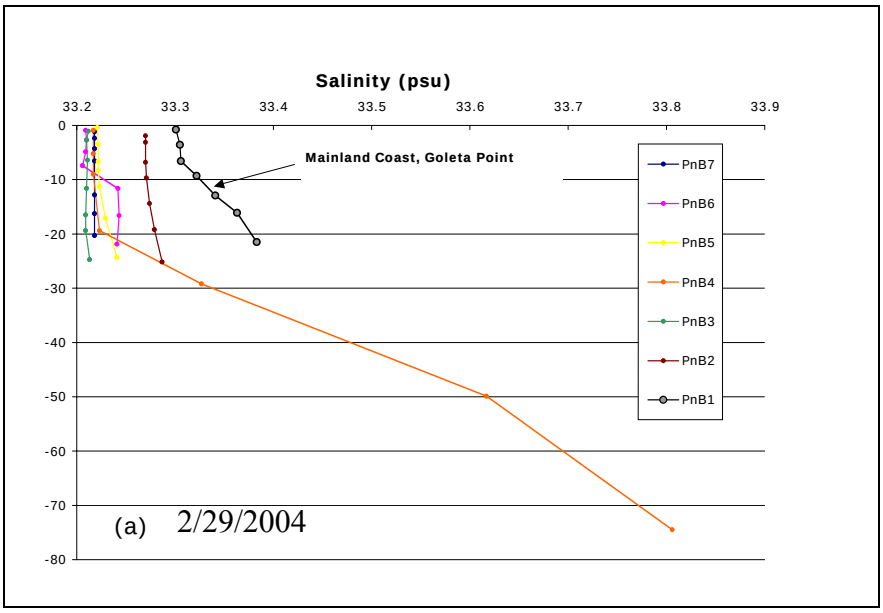




Figure 37. (a) Salinity profiles near Anacapa Island. Data are from bottle samples collected at LTER grid station #21. For comparison, surface salinity at LTER stations nearest the mainland are included from two cruises that coincided with high terrestrial discharge. (b) As in (a), but with truncated X-axis.

**Two cross-channel PnB salinity transects examined.** The results described above do not indicate whether pronounced surface salinity anomalies near Santa Rosa and Santa Cruz Islands, and slight anomalies near Anacapa, on Jan. 24-25, 2005 were localized phenomena (produced by island runoff) or whether they extended across the whole Channel. In order to address this question, salinity profiles were plotted from bottle data for cross-Channel PnB transects (which extend from the mainland coast at Goleta Point to Santa Rosa - see Figure 40) on Feb. 29, 2004 and Jan. 23, 2005 (Figure 38).



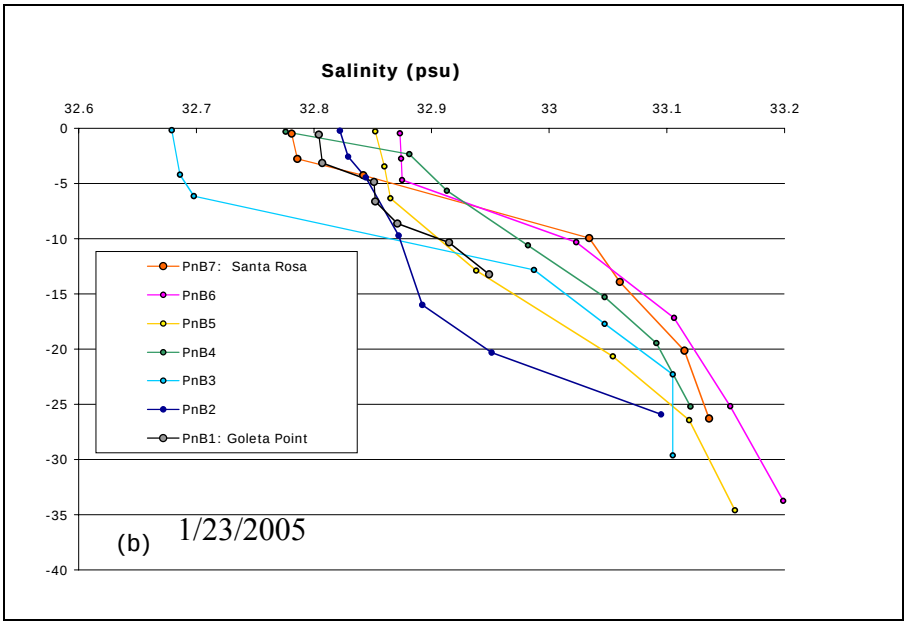




Figure 38. Salinity from bottle samples during PnB cross-Channel transects on 2/29/2004 (a), and 1/23/2005 (b). Note that the y-axes have different scales in (a) and (b).

On 2/29/2004, the surface ocean off of Goleta Point was slightly stratified, however, salinities were not as low (e.g., <33.0 psu) as those observed in hypopycnal plumes from the Santa Clara River. This suggests that the hypopycnal plume observed off the coast at Ventura a few days earlier (on 2/26/2004) did not extend far enough to the west in the Channel to influence stations along the PnB transect. The PnB salinity profile nearest Santa Rosa shows no stratification on 2/29/2004. However, in Jan. 2005 (after monthly rainfall totals with 25 to 50-year return intervals), freshened seawater extended from the mainland all the way out to Santa Rosa and Santa Cruz (Figure 38b). Interestingly, surface salinity at San Miguel did not appear to be influenced by this major event (Figure 34).

Plots of raw data from CTD casts from 103 PnB cross channel transects, covering the period 1996 to 2002, are publically available at: ftp://ftp.icess.ucsb.edu/pub/PnB/plots. Inspection of all of these plots uncovered no cases in which PnB cruises coincided with surface salinity <33.0 psu across the whole Channel, such as was observed on Jan. 23-25, 2005. Apparently, the only time (other than Jan. 2005) when PnB cruises detected freshened water all the way across the Channel was during the 1998/99 El Nino (Figure 39) - however surface salinity in the ocean during these storms was not much less than 33 ppt (Dave Siegel, Professor, Dept. of Geography, UCSB, pers. comm.). Salinity data from a May 5, 1998, PnB cruise (CTD casts, Figure 40) most strongly resemble the Jan. 23, 2005 results, although salinity was lower across the surface of the Channel on the latter date.

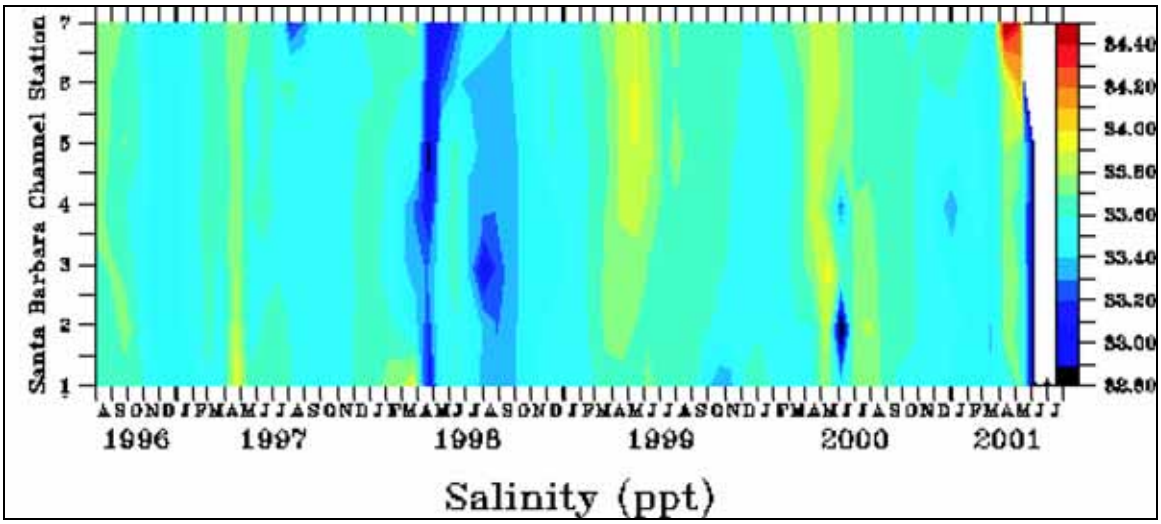



Figure 39. Time series for surface salinity from PnB transects from the mainland (station 1 at bottom) to shelf waters off of Santa Rosa Island (station 7 at top) from August 1996 to July 2001 (figure was provided by D. Siegel, UCSB).

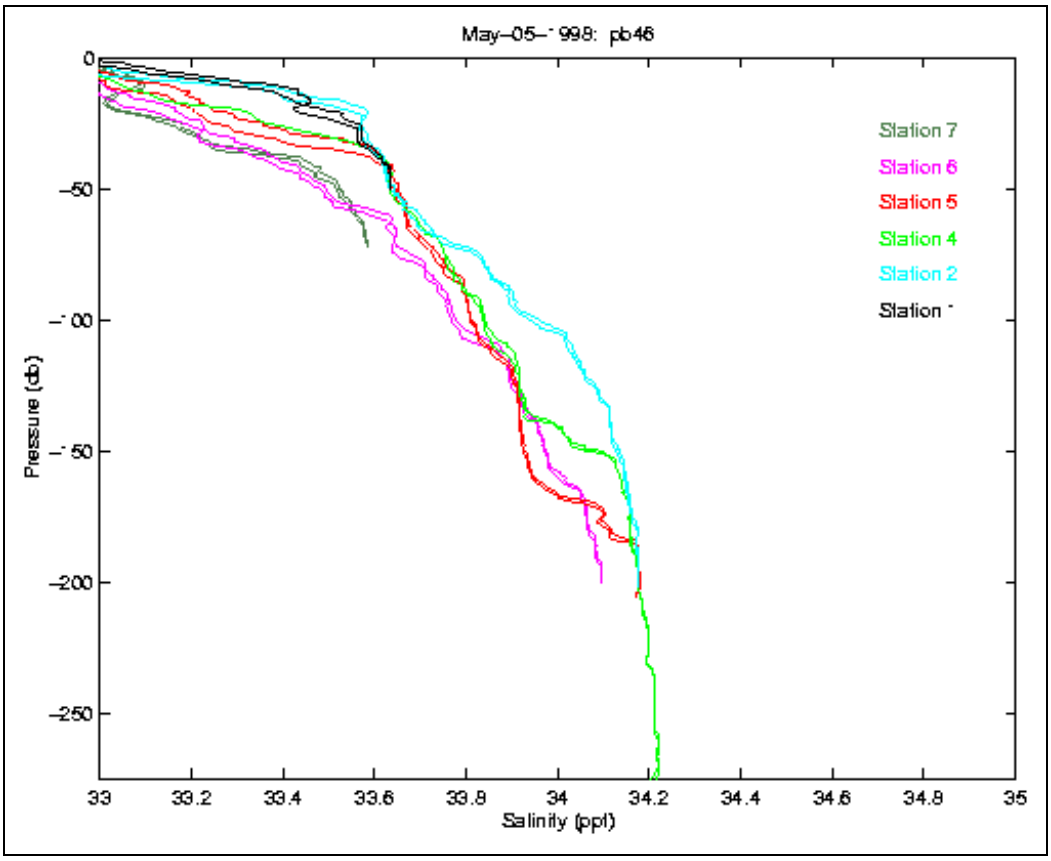
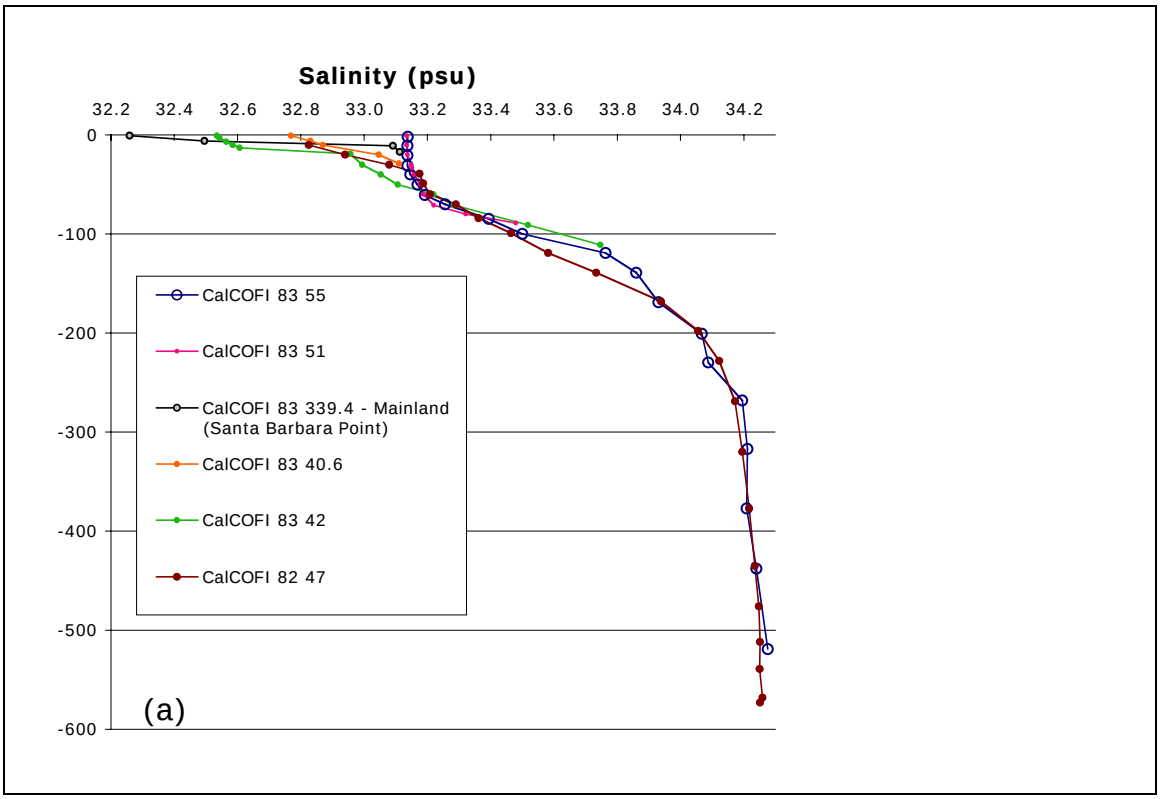



Figure 40. Salinity profiles from a May 5, 1998, PnB Channel transect. Station 1 (black) is at the mainland (Goleta Point) and Station 7 (dark green) is on shelf waters off Santa Rosa Island. Rainfall during April, 1998, was 4.2 cm in the mountains behind Santa Barbara, which represents a monthly total with a 10-year return interval. Figure was obtained at ftp://ftp.icess.ucsb.edu/pub/PnB/plots/seriesplots/

**Examination of CalCOFI salinity data.** One CalCOFI station (station 83.51) is close to the south shore of Santa Rosa (Figure 33). Because Channel-scale events are less likely to influence water quality on the south shore of Santa Rosa, compared to the shelf waters north of the island, this CalCOFI station provides an opportunity to examine whether runoff from Santa Rosa itself creates a localized hypopcynal plume during periods of high rainfall. For this report, salinity profiles from station 83.51 were inspected for every CalCOFI cruise from the early 1980s to 2005. None of the cruises detected surface salinity <33.0 psu at this station. CalCOFI cruise #0501 took place in mid Jan. 2005, close to when the PnB transect revealed freshened water across the surface of the Channel (as in Figure 38b). In Figure 41, salinity profiles from cruise #0501 from the two CalCOFI stations nearest the south shore of Santa Rosa (stations 83.55, 83.51) are compared to those from four stations *inside* the Channel and near the mainland coast (stations 83.42, 83.40.6, 83.33.9, 82.47).



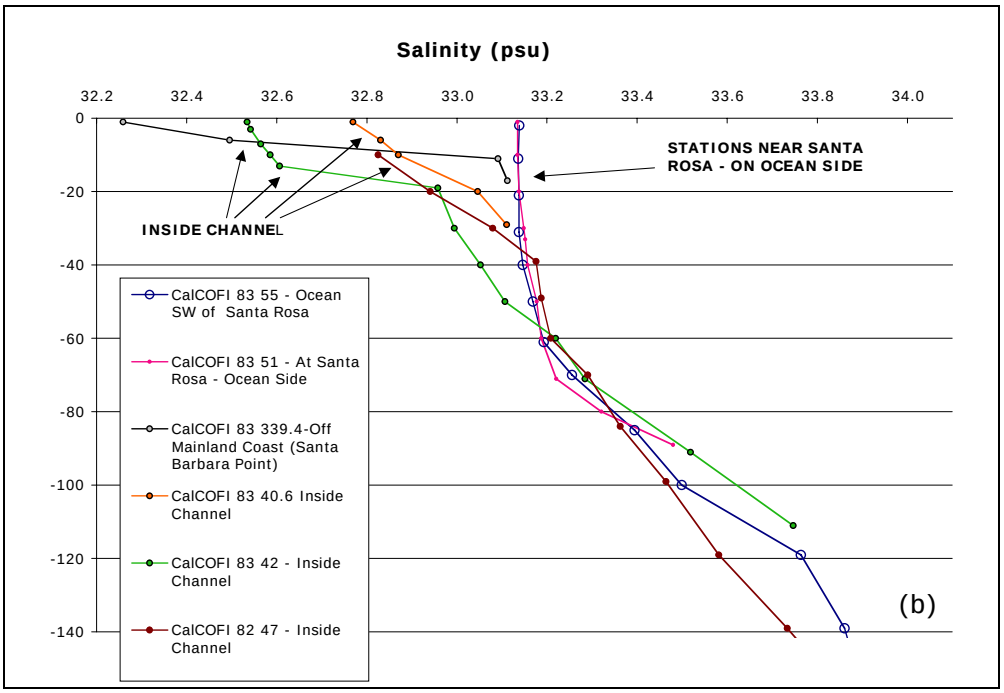




Figure 41. (a) Salinity profiles from CalCOFI cruise #0501. Stations shown were sampled on Jan. 15, 2005; (b) as in (a) for the top 140 m of the water column.

The CalCOFI profiles south of Santa Rosa were obtained to a depth of more than 500 m. Considering this depth range, a pycnocline is evident at ca. 100 m (Figure 41a). This feature is consistent with deep water profiles obtained by PnB from CTD casts across the Channel (data not presented here). However, there is no sign of a hypopycnal surface plume at CalCOFI stations 83.55 and 83.51, such as might occur if stream runoff from Santa Rosa itself (or the islands as a group) was creating a large, localized plume encircling the islands. In contrast to this result, surface salinity was sharply stratified, with surface values below 33.0 psu, at every CalCOFI station *inside* the Channel on that date, including the station in shelf waters north of Santa Rosa (Figure 41). Together with the Jan. 2005 data from LTER and PnB projects discussed above, these CalCOFI data suggest that in January, 2005, mainland runoff could have contributed to decreased salinity near the northern coasts (Channel side) of Santa Rosa, Santa Cruz and Anacapa. These data imply that during periods such as Jan. 2005 (after weeks of rainfall levels with 25- to 50-year return intervals) Park waters might become diluted with discharge from the mainland.

No data were obtained to confirm whether or not a surface sediment plume associated with mainland discharge extended to Park waters in Jan. 2005. The exercise above is intended as an example of how salinity data could be used by the Park to evaluate the likelihood that *dissolved constituents* in mainland runoff reach Park waters during runoff events. The data at hand suggest that extraordinary rainfall (≥25-year events) may be required before Park waters become diluted with mainland runoff. Whether or not detectable quantities of mainland-derived contaminants are present in the water near the islands during these unusual events is unknown. Other evidence, such as remote sensing data of ocean color, may be most useful to determine the reach of fine suspended sediments from the mainland into the Park. Whether the infrequent arrival of mainland-derived suspended sediments in Park waters poses a threat to Park biota is unknown.

### c. Remotely sensed observations of water quality in the Park.

**Suspended sediment.** Sediment export from Park islands was examined using 26 years of remote sensing data, and related to watershed geomorphology and nearshore bathymetry (Mertes et al. 1998). Because the major drainages on Santa Rosa radiate toward the ocean from a central highland, the higher order streams on Santa Rosa have longer streams lengths and greater vertical descents, than same-order streams on Santa Cruz. Consequently, sediment is more efficiently transferred to the ocean by streams on Santa Rosa than on Santa Cruz. During large rain events (such as a 10-year storm on Feb. 15, 1998, Figure 42) suspended sediments can surround much of Santa Rosa, without any influence from mainland storm plumes. However, many of the largest watersheds on Santa Rosa drain into shallow coastal waters, where resuspension of marine sediments also produces surface sediment plumes that can be decoupled from discharge events (Mertes et al. 1998). This complicates efforts to associate sediment concentrations in water around Santa Rosa with terrestrial sediment output.

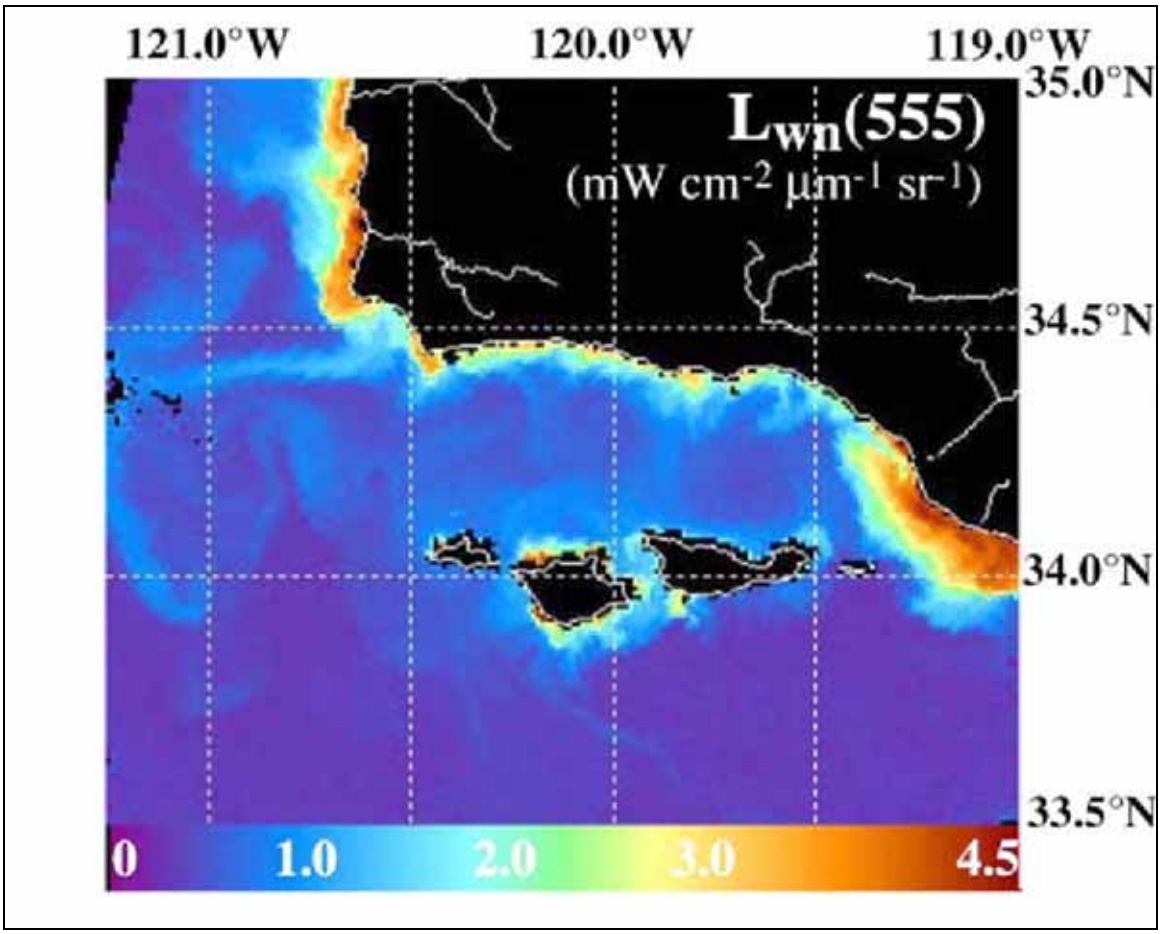



Figure 42. Image of suspended sediment concentrations (based on LwN(555) during a runoff event on February 15, 1998. This was the second largest discharge event from October 1997 to June 2001. Figure is from Otero and Siegel (2004).

The likelihood that a sediment plume will occur at any particular location in the region is illustrated in Figure 43. The northern and eastern shores of Santa Rosa and San Miguel, and the east end of Santa Cruz, are where suspended sediment is most frequently detected in the Park by AVHRR and SeaWiFS data.

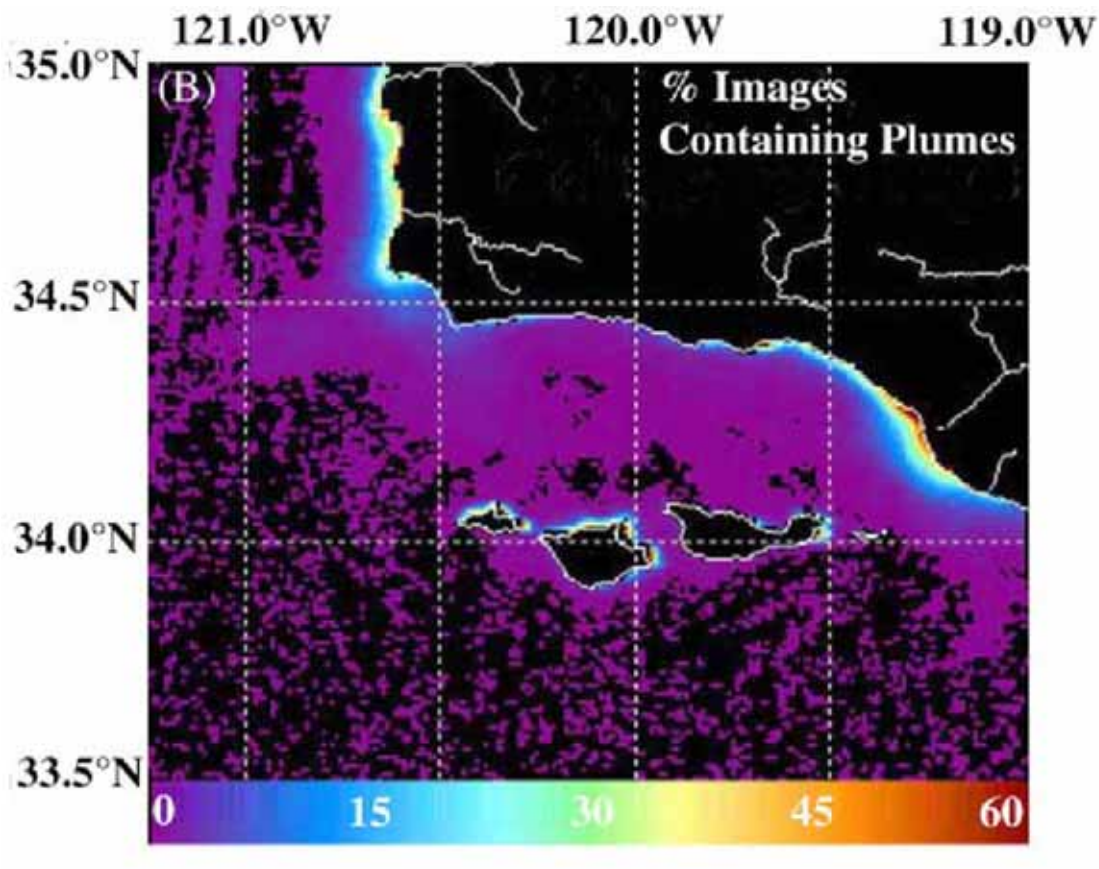



Figure 43. Map showing the frequency of surface sediment plumes by location, based on normalized water-leaving radiance at 555 nm, or LwN(555). Frequency for each pixel is the percentage of AVHRR and SeaWiFS images from October 1997-June 2001 in which LwN(555) > 1.3 mW/cm2/µm/sr. Figure is adapted from Figure 8 in Otero and Siegel (2004).

**Regional Chlorophyll Dynamics.** Regionally, chlorophyll concentrations in the Channel are controlled by nutrient availability, and are inversely related to SST - which reaches its minima during coastal upwelling events in the western portion of the Channel (Figure 44). The primary nutrient supply is created by coastal upwelling in the western portion of the Channel (Atkinson et al. 1986, Hayward and Venrick 1998). Upwelled waters from near Point Conception typically flow south and often enter the SBC (Jones et al. 1988). The resulting phytoplankton biomass is concentrated in the upper 25m of the water column, and subsurface maxima are rarely observed (Venrick 1998). Temporal fluctuations of mixed-layer chlorophyll within the Channel are well correlated with nearby stations outside of the channel (Hayward and Venrick, 1998), indicating that biological processes within the Channel are regulated, in part, by Bight-scale processes. However, elevated nearshore chlorophyll values along the mainland coast from December to February are poorly related to SST (Otero and Siegel 2004). The *year-round* nature of elevated chlorophyll in the vicinity of the Santa Clara River (see Figure 44) led Warrick et al. (2005) to contend that riverine input of nutrients is insufficient to explain consistently high nearshore phytoplankton biomass in the eastern Channel. Furthermore, nutrient concentrations behave conservatively with respect to salinity in river plumes, resulting in dispersal of dissolved nutrients tens of km away from river mouths during large runoff events (Warrick et al. 2005).

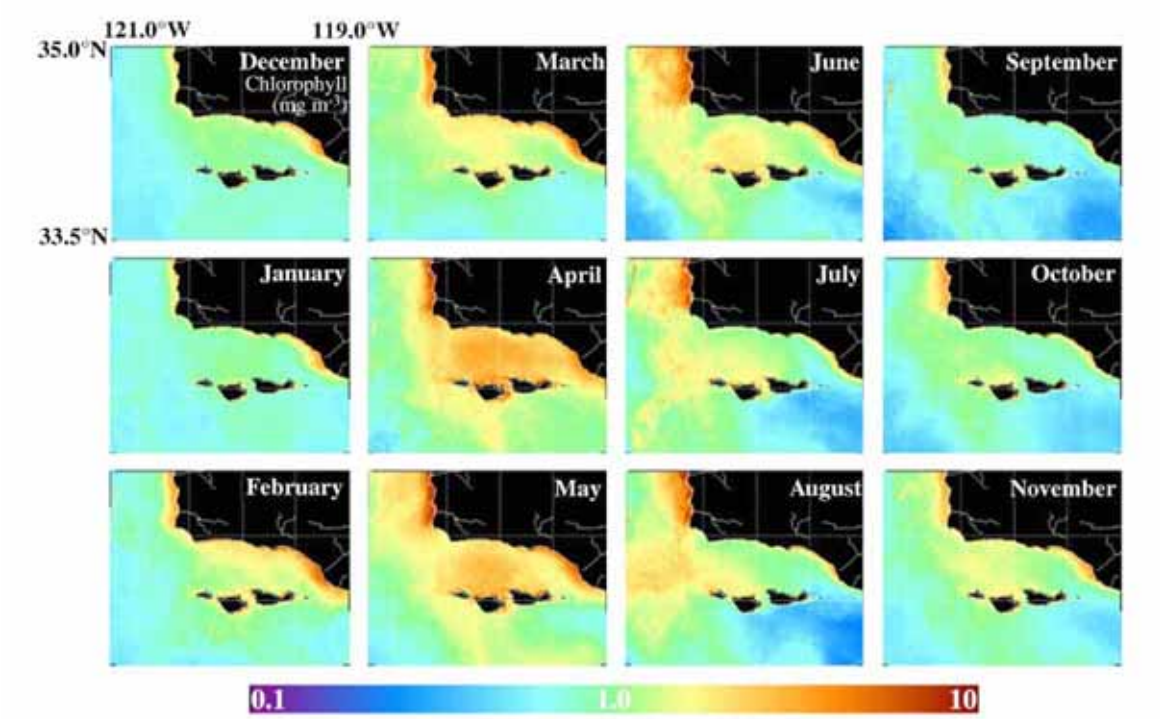



Figure 44. Annual cycle of mean monthly chlorophyll computed from AVHRR and SeaWiFS images from October 1997-June 2001 (Otero and Siegel 2004).

**Chlorophyll dynamics at the islands.** Satellite data indicate that nearshore bloom conditions are most frequent at Santa Rosa on either side of Brockway Point, in northern Bechers Bay, and around East Point (Figure 45). Determining whether blooms at these sites are related to local fluvial input, or to larger scale phenomena such as upwelling and Channel SST, requires a more sophisticated analysis than this report allows. However, during February, remotely sensed chlorophyll indices are higher on average in close proximity to Santa Rosa than they are further away from the island (Figure 44) - a phenomenon which precedes the March onset of upwelling and SST minima in the Channel (Figure 9). Terrestrial runoff contributes to the sediment plumes that are frequently observed in a narrow zone around the north/northeast shores of Santa Rosa (Figure 17). Based on historical sediment deposition rates in Old Ranch House Lagoon, on Santa Rosa, Cole and Liu (1994) reported that sediment deposition during the most intensive grazing period of 1887 to 1920 was 340 times higher than prior to 1800. Owing to ongoing recovery of riparian corridors on Santa Rosa since the removal of cattle in 1998, island streams are now transporting far less sediment, N, and P (CINP 2002b). Nevertheless, during 1997-2001 (a period which bracketed the removal of cattle) Santa Rosa was still the only island in the Park that frequently produced sediment plumes (Otero and Siegel 2004). As Santa Rosa continues to recover from decades of cattle grazing, it will be interesting to observe whether the frequency of sediment plumes, or bloom conditions, changes in waters surrounding this island. However, owing to the ease with which sediment is resuspended in the shallow bays surrounding Santa Rosa (Mertes et al. 1998), the frequency or persistence of sediment plumes at Santa Rosa may not be the most sensitive indicator of sediment export from streams on that island.

At San Miguel, bloom conditions are most prevalent in Simonton Cove, along the northwest end of the island out to Point Bennett, and off Cardwell Point (Figure 45). During July through August, San Miguel is more frequently encircled by cooler water produced by upwelling events near Pts. Arguello and Conception than are the other islands in the chain (Figure 9). Thus it may be less appropriate to try to link blooms at San Miguel with terrestrial influences from the island itself. Finally, bloom conditions appear to be more common surrounding east Santa Cruz than around west Santa Cruz (Figure 45) - making it tempting to invoke differences in the length of time since sheep removal (and degree of watershed recovery) as a factor contributing to nearshore chlorophyll dynamics.

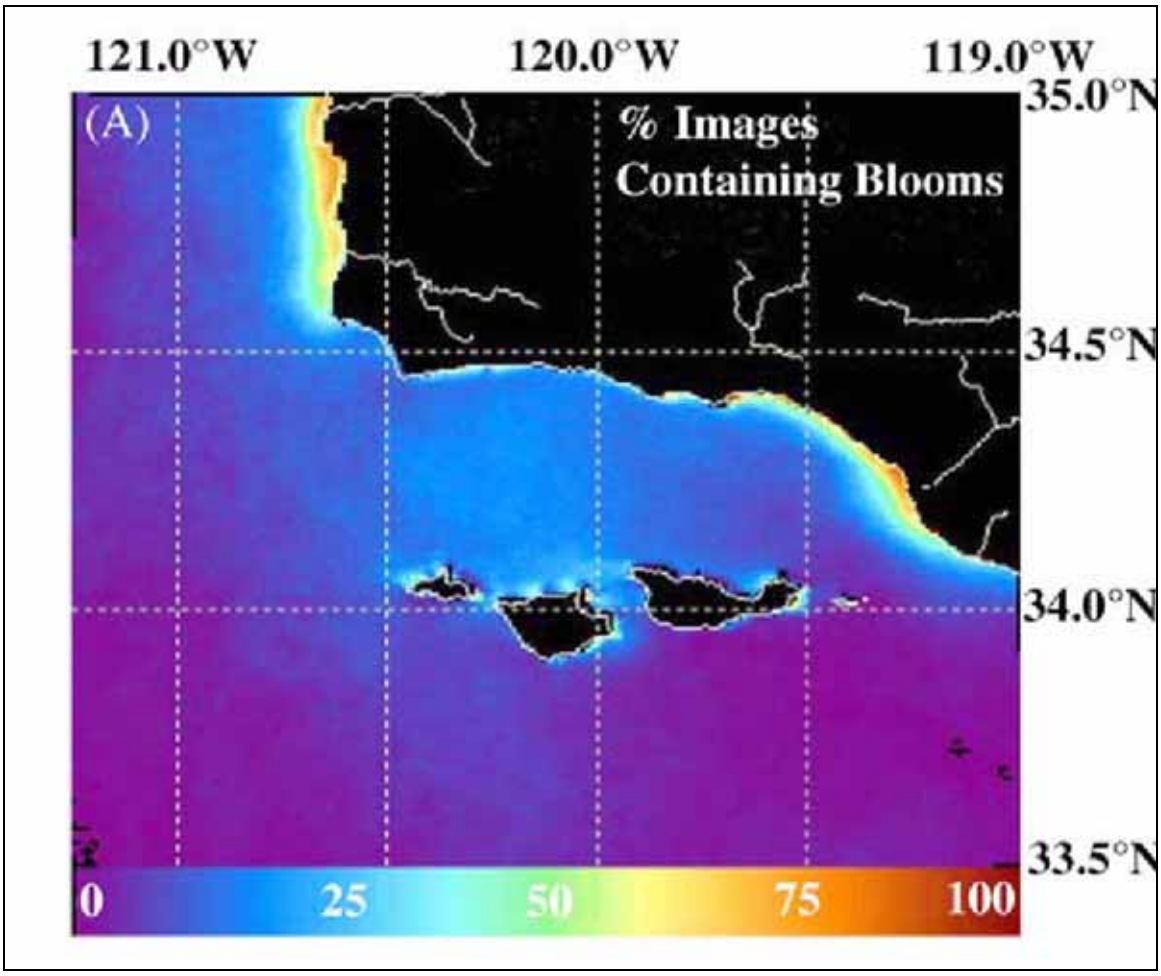



Figure 45. Map showing the frequency of bloom conditions in the region of Channel Islands National Park. Frequency for each pixel is the percentage of AVHRR and SeaWiFS images from October 1997-June 2001 when the chlorophyll index exceeded 2 mg/m3 (Otero and Siegel 2004).

### *C.9. Mussel Body Burdens in and near the Park*

**a. Overview of Mussel Watch Programs**

Contaminant levels have not been directly measured in sea water in the Park. However, sentinel mussels sampled over the years at Park islands provides indirect evidence for seawater contamination there. Presence of a contaminant in mussel tissue indicates that it resided at least part time in the water column of the Park's marine environment. It does not, however, indicate how the contaminant arrived in the Park, or in which other compartments of the marine habitat contaminants reside (e.g., sediment and other biota).

Figure 46. State and NOAA mussel sampling sites at the Northern Channel Islands.

**NOAA's Mussel Watch Project.** NOAA created the National Status & Trends (NS&T) Program to assess the influence of human activities on the quality of coastal and estuarine areas. In 1986 the NS&T Mussel Watch Project (NOAA-MWP) began to monitor spatial and temporal trends of chemical contamination by chemically analyzing mussels and oysters collected at fixed sites throughout the coastal United States. Owing to the fact that no single species of mollusc is common to all coasts, NOAA collects different species in different regions of the country: the blue mussel *Mytilus edulis* on the East Coast from Maine to Cape May, NJ; the American oyster *Crassostrea virginica* from Delaware Bay southward and throughout the Gulf of Mexico; the mussels *M. edulis and M. californianus* on the West Coast; the oyster *Ostrea sandvicensis* in Hawaii; the smooth-edged jewel box *Chama sinuosa* at the one site in the Florida Keys; the

mangrove oyster *Crassostrea rhizophorae* in Puerto Rico; and the zebra mussel *Dreissena polymorpha* at sites in the Great Lakes. Sampling stations were selected by NOAA to represent large areas rather than the small-scale patches of contamination commonly referred to as ‘‘hot spots’’. *To this end, no sites were knowingly selected near waste discharge points.* NS&T sampling sites are not uniformly distributed along the coast. Within estuaries and embayments, they average about 20 km apart, while along open coastlines the average separation is 70 km. Almost half of the sites were selected in waters near urban areas, within 20 km of population centers in excess of 100,000 people.

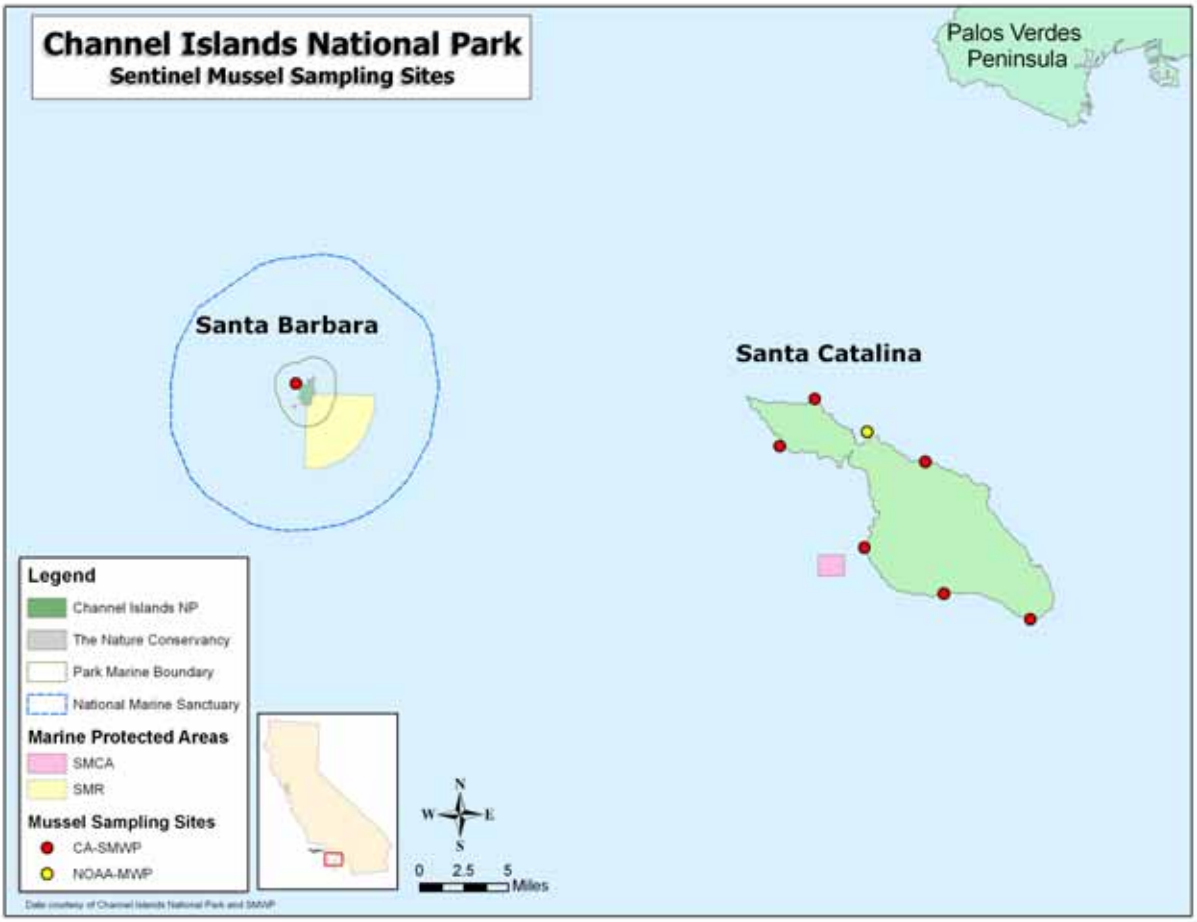



Figure 47. State and NOAA mussel sampling sites at Santa Barbara and Santa Catalina Islands.

Only three of the NS&T sites occur on islands in or near the Park: one each off of San Miguel (Tyler Bight), Santa Cruz (Fraser Point), and Catalina (Bird Rock) (Figures 46-47). Station locations are provided in Table 15. Mussels from San Miguel were sampled by NOAA only once, in 1988. Mussels from Santa Cruz and Catalina were sampled by NOAA from 1986-1988, 1990-1992, 1994, 1996, 1998, 2000, and 2002 (at the time of this writing, 2002 was the most recent year for which NOAA data were available).

Among the analytes measured in the NOAA-MWP are (1) chlorinated pesticides such as DDT (and its metabolites DDE and DDE), aldrin and dieldrin, chlordane (alpha-chlordane, trans-nonachlor, heptachlor, heptachlorepoxide), lindane (gamma-Hexachlorocyclohexane, "HCH")

and its metabolites, and mirex; (2) many other pesticides (such as diazinon, ethion, endosulfan, parathion, chlorpyrifos); (3) polychlorinated biphenyls (PCBs); (4) butyltin compounds (mono-, di-, and tri-butyltin); (5) trace metals; and (6) a suite of 23 polycyclic aromatic hydrocarbons (PAHs).

Several of these substances are now banned for use in the U.S. or California. For example, the pesticide lindane is banned in California, but elsewhere in the U.S. it is still widely prescribed for treating head lice and scabies, and is used on pets, livestock, fruits and vegetables, cotton, wool, and tobacco. Lindane is found in air, water and soil samples throughout the world - and is detected in mussels from the Channel Islands (Tables 16-18) - although not in high concentrations. All uses of DDT and dieldrin were banned in the U.S. in the 1970s. Chlordane use on U.S. crops ended in 1983, and its use for termite control effectively ended in 1988. However, residual chlordane persists in soil. Polychlorinated biphenyls (PCBs) are chlorinated compounds first used in the 1920s for a number of industrial purposes especially electrical transformers and capacitors. PCB use in the United States began being phased out in 1971, and a ban on new uses took effect in 1976. The compounds are still found in tissues and sediments because PCB-containing devices are still in use. Organotin (mono-, di-, and tributyltin) is found in molluscs because tributyltin has been used as an antifouling agent in the paint commonly used on boats and some underwater marine facilities. Its use on vessels under 75 feet long was banned in 1988 by the U.S. Organotin Anti-Fouling Paint Act (O'Connor 2002).

Although PAHs and trace metals (Cd, etc.) occur naturally, they can also be indicators of industrial pollution. PAHs are found in fossil fuels such as coal and oil, in creosote and asphalt, and are produced when organic matter burns. Nonetheless, a multitude of human activities, from coal and wood burning to waste incineration, create PAH compounds in excess of those that would exist naturally. In addition, human production, transport, and use of oil release more PAHs to the environment, on a globally averaged basis, than does natural seepage (NRC 1985). However, as discussed in Section II.B.3, prodigious natural oil seepage occurs in the vicinity of the Park, decreasing the likelihood that PAHs in the Park environment result from anthropogenic enrichment. There was a substantial decrease in the use of silver by the U.S. in the late 1970s owing to a decrease of silver use in the photographic industry. Lead concentrations were expected to decline in aquatic organisms following the ban of lead in gasoline. Transportation emissions accounted for over 80% of total lead emissions in 1970, and lead emissions declined by more than 98% from 1970-1980 (USEPA 1990)

**California State Mussel Watch Program.** For 26 years (1977-2003) the California State Mussel Watch Program (CA-SMWP) collected transplanted and resident mussels and clams from the waters of California's bays, harbors and estuaries. Statewide, samples were analyzed for one of more of the following types of contaminants: trace elements, pesticides, PCBs, and a suite of PAHs (although PAHs were never analyzed by the CA-SMWP in samples from the Channel Islands). In contrast with the NOAA-MWP, the CA-SMWP primarily targeted areas with known, or suspected, degraded water quality.

Over the lifetime of the program, mussels were sampled by the state at least once from 11 sites in or near the Park (Table 15): two on San Miguel , one each on Santa Cruz, Anacapa and Santa Barbara, and six on Catalina (Figure 46-47). Resident mussels from stations inside the Park were sampled only five times: twice in 1977 (several sites), twice in 1978 (several sites), and once in 2001 (Santa Cruz). Mussels transplanted to Anacapa for ca. 5 months were sampled

twice in 1980. Outside the Park, at Catalina, resident or transplanted mussels were sampled from six sites during one or more of the years 1977, 1978 and 1980. After a 13 year hiatus, mussels were sampled again at Catalina in 1993 (one site) and 1994 (one site). The only other CA-SMWP data from islands in or near the Park are from Santa Cruz in 2001. The CA-SWMP was discontinued after 2002 owing to budget cuts.

Table 15. Locations of mussel sampling stations for Channel Islands National Park and Santa Catalina Island. Stations from both the California State Mussel Watch Program (CA-SMWP) and NOAA's Mussel Watch Project are included. Coordinates are provided in both sexigesimal and decimal formats (the latter in parentheses).

| Station | Latitude | Longitude |
|---|---|---|
| **CA-SMWP Stations** | | |
| San Miguel Island/West (500) | 34 01 33 | 120 25 39 |
| | (34.0258) | (120.4275) |
| San Miguel Island/East (501) | 34 03 36 | 120 21 19 |
| | (34.0600) | (120.3553) |
| Santa Cruz Island (502) | 34 03 30 | 119 55 30 |
| | (34.0583) | (119.9250) |
| Anacapa Island (503) | 34 00 20 | 119 23 10 |
| | (34.0056) | (119.3861) |
| Santa Barbara Island (504) | 33 29 00 | 119 02 45 |
| | (33.4833) | (119.0458) |
| Santa Catalina Island/East (680) | 33 25 40 | 118 25 47 |
| | (33.4278) | (118.4297) |
| Santa Catalina Island/ West (681) | 33 28 41 | 118 32 19 |
| | (33.4781) | (118.5386) |
| Santa Catalina Island/ Ribbon Rock (682) | 33 26 20 | 118 34 20 |
| | (33.4389) | (118.5722) |
| Santa Catalina Island/ Ben Weston (683) | 33 21 24 | 118 29 16 |
| | (33.3567) | (118.4878) |
| Santa Catalina Island/ Silver Canyon (684) | 33 19 12 | 118 24 36 |
| | (33.3200) | (118.4100) |
| Santa Catalina Island/ Church West (685) | 33 17 59 | 118 19 30 |
| | (33.2997) | (118.3250) |
| **NOAA Mussel Watch Project Stations** | | |
| San Miguel Island/ Tyler Bight | 34 01 40 | 120 25 08 |
| | (34.028) | (120.419) |
| Santa Cruz Island/ Fraser Point | 34 03 29 | 119 55 12 |
| | (34.058) | (119.92) |
| Santa Catalina Island/ Bird Rock | 33 27 06 | 118 29 13 |
| | (33.45167) | (118.487) |

### b. Results for Channel Islands

Concentrations of contaminants measured by either the State or NOAA in mussels from sites within the Park are presented in Table 17 (Santa Cruz), and Table 16 (San Miguel, Anacapa and Santa Barbara). Owing to the long time series available, NOAA-MWP data are also presented for Catalina in Table 18. The CA-MWP sampling effort at Catalina was more sporadic. Although CA-MWP data for Catalina mussels were examined for exceedances (see below), concentrations are not presented in this report. Over the years, a wider array of organic contaminants was evaluated in samples from Santa Cruz and Catalina than from the other islands. The most complete time series for organics in mussels at the islands are NOAA's data for aldrin/dieldrin, chlordanes, DDT/DDE/DDD, lindane, hexachlorobenzene, mirex, PAHs, and PCBs at Santa Cruz and Catalina. The same suite of compounds was measured by NOAA in mussels from the Park only one other time - at San Miguel in 1988 (Table 16). Other pesticides were not evaluated by NOAA, nor the State, until 1996, and only every two years hence, providing a very short record for these analytes. Excluding aldrin, the organic compounds above were almost always detected in mussels at Santa Cruz, San Miguel and Catalina (Tables 16-18).

Table 16. Levels of contaminants in mussels from San Miguel, Santa Barbara and Anacapa Islands. All available data are included from California's State Mussel Watch Program (CA-SWMP) and the NOAA National Status & Trends (NS&T) Program's Mussel Watch Project (MWP). Values are based on dry weight. Null values indicate results below the limit of detection. Blanks indicate that the parameter was not analyzed. Values outlined in red exceed the national 85th percentile for that analyte, according to long term data from NOAA's MWP (see text). Shading indicates values that fall between the national 50th and 85th percentiles for that analyte (see text). Station locations provided in Table 15.

| Location | San Miguel (Tyler Bight) | San Miguel West (site 500) | San Miguel East (site 501) | Anacapa Island (site 503) | Anacapa Island (site 503) | Santa Barbara Island (site 504) |
|---|---|---|---|---|---|---|
| Program | NOAA | CA-SMWP | CA-SMWP | CA-SMWP | CA-SMWP | CA-SMWP |
| Year | 1988 | 1977-1978[a] | 1977 -1978[a] | 1977 -1978[a] | 1980 | 1977 -1978[a] |
| Type of Mussel | resident | resident | resident | resident | transplanted 5.1-5.9 mo.s | resident |
| **Organics (ppb dry wgt.)** | | | | | | |
| Total Chlordane[b] | 12.18 | | | | 11.1 | |
| Total DDT[c] | 188.33 | 305 | 49.7 | 30.0 | 43.1 | 33.6 |
| Total PAH[d] | 12.66 | | | | | |
| Total PCB[e] | 46.07 | 147.5 | 29 | 13.0 | 18.0 | 22.0 |
| Aldrin | 0.00 | | | | | |
| Dieldrin | 5.9 | | | | 2.8 | |
| Hexachlorobenzene | 0.28 | | | | 0.1 | |
| alpha HCH | | | | | 4.6 | |
| gamma HCH (Lindane) | 0.39 | | | | | |
| Mirex | 0.93 | | | | | |
| **Trace Elements (ppm dry wgt.)** | | | | | | |
| Aluminum | 130 | 58.45 | 17.78 | 31.14 | 152.35 | 91.53 |
| Arsenic | 20.33 | | | | | |
| Cadmium | 4.87 | 6.53 | 9.59 | 5.87 | 12.65 | 11.23 |
| Chromium | 1.6 | 1.65 | 1.50 | 1.65 | 1.02 | 2.01 |
| Copper | 6.43 | 5.15 | 4.13 | 4.30 | 5.100 | 4.63 |
| Iron | 153.33 | | | | | |
| Lead | 0.79 | 1.65 | 2.33 | 5.09 | 2.62 | 3.56 |
| Manganese | | 2.85 | 2.28 | 2.06 | 6.35 | 3.90 |
| Mercury | 0.57 | 0.55 | 0.12 | 0.15 | 0.27 | 0.13 |
| Nickel | 2.03 | 0.70 | 0.7 | 1.0 | 2.0 | 1.55 |
| Selenium | 3.47 | | | | | |
| Silver | | 0.22 | 0.65 | 4.27 | 0.439 | 0.95 |
| Zinc | 146.66 | 120.65 | 118.00 | 119.2 | 119.2 | 147.68 |

[a]Values are means for four sampling dates: 8/1/77, 12/3/77, 8/15/78, 11/18/78.

[b]Total Chlordane = (alphachlordane + transnonachlor + heptachlor + heptachlor-epoxide)

[c]Total DDT = (o,pDDE + p,pDDE + o,pDDD + p,pDDD + o,pDDT + p,pDDT)

[d]Total PAH = (1,6,7-trimethylnaphthalene, 1-methylnaphthalene, 2,6-dimehtylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(k)fluoranthene, benzanthracene, benzo(g,h,I)perylene, benzo-a-pyrene, benzo-b-pyrene, benzo-e-pyrene, benzo-k-flouranthene, biphenyl, chrysene, bibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, perylene, phenanthrene, pyrene)

[e]For Tyler Bight (NOAA site): Total PCB = ( 2) ∑(pcb8+pcb18+pcb28+ pcb52+pcb44+ pcb66 +pcb101+pcb105 +pcb138 +pcb118+pcb128+pcb153+pcb170+pcb180+pcb187+pcb195+pcb206+pcb209)

Table 17. Levels of contaminants in mussels from Santa Cruz Island. All available data are included from California's State Mussel Watch Program (CA-SWMP) and the NOAA National Status & Trends (NS&T) Program's Mussel Watch Project (MWP). Values are based on dry weight. Null values indicate results below the limit of detection. Blanks indicate that the parameter was not analyzed. Values outlined in red exceed the national 85th percentile; shading indicates values that fall between the national 50th and 85th percentiles (see text). All samples were from resident mussels. Station locations are provided in Table 15.

| | CA-SMWP site 502 | NOAA Fraser Point | | | | | | | | | | CA-SMWP site 502 | NOAA Fraser Point |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Analyte** | **1977-78[a]** | **1986** | **1987** | **1988** | **1990** | **1991** | **1992** | **1994** | **1996** | **1998** | **2000** | **2001** | **2002** |
| **Organics (ppb dry weight)** | | | | | | | | | | | | | |
| Aldrin | | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 |
| Organotins (DBT, TBT, MBT) | | | | | 0.00 | 14.60 | 10.21 | 17.26 | 8.66 | 8.12 | 5.97 | | 11.74 |
| Chlorpyrifos | | | | | | | | | 0.00 | 0.00 | 3.80 | 0.00 | 0.00 |
| cis-Nonachlor | | | | | | | | | 0.62 | 0.47 | 0.11 | 0.00 | 0.13 |
| Total Chlordanes[b] | | 5.32 | 5.33 | 4.13 | 5.16 | 0.77 | 2.27 | 7.46 | 4.96 | 1.67 | 3.46 | 1.3 | 3.38 |
| gamma-Chlordane | | | | | | | | | 1.65 | 0.55 | 0.53 | 0.00 | 0.50 |
| Chrysenes (C1,C2,C3,C4) | | | | | | | | 0.00 | 0.00 | 7.60 | 0.00 | | 0.00 |
| Total DDT[c] | 30.9 | 16.57 | 62.9 | 34.67 | 29.81 | 10.18 | 23.45 | 69.35 | 35.07 | 25.07 | 14.06 | 9.1 | 10.44 |
| Dacthal | | | | | | | | | | | | 0.00 | |
| Diazinon | | | | | | | | | | | | 0.00 | |
| Dibenzothiophenes (C1,C2,C3) | | | | | | | | 0.00 | 6.00 | 7.70 | 0.30 | | 0.10 |
| Dieldrin | | 2.27 | 2.67 | 2.37 | 0.00 | 0.32 | 2.18 | 2.06 | 2.34 | 2.55 | 2.31 | 2.9 | 2.02 |
| Endosulfan I | | | | | | | | | | | 0.26 | 0.00 | 0.00 |
| Endosulfan II | | | | | | | | | 1.84 | 0.00 | 0.11 | 0.00 | 0.05 |
| Endosulfan sulfate | | | | | | | | | | | 0.00 | 0.00 | 0.30 |
| Endrin | | | | | | 0.00 | 0.00 | 1.24 | 0.77 | 0.41 | 0.32 | 0.00 | 0.41 |
| Ethion | | | | | | | | | | | | 0.00 | |
| Ethylparathion | | | | | | | | | | | | 0.00 | |
| Fluorenes (C1,C2,C3) | | | | | | | | 0.00 | 0.00 | 11.90 | 0.00 | | 0.00 |
| alpha HCH | | | | | | | | | 1.21 | 0.63 | 1.26 | 1.0 | 0.94 |
| beta HCH | | | | | | | | | 0.78 | 0.38 | 0.63 | 0.00 | 0.61 |

| Analyte | CA-SMWP site 502 1977-78[a] | NOAA Fraser Point 1986 | 1987 | 1988 | 1990 | 1991 | 1992 | 1994 | 1996 | 1998 | 2000 | CA-SMWP site 502 2001 | NOAA Fraser Point 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| delta HCH | | | | | | | | | 0.19 | 0.06 | 0.00 | 0.00 | 0.00 |
| gamma HCH (lindane) | | 0.47 | 0.00 | 0.00 | 4.13 | 0.15 | 0.00 | 0.98 | 0.70 | 0.16 | 0.42 | 0.00 | 0.30 |
| Hexachlorobenzene | | 0.43 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.13 | 0.32 | 0.00 | 0.13 |
| C1-Fluoranthenes/pyrenes | | | | | | | | 0.00 | 0.00 | 3.80 | 0.00 | | 0.00 |
| Methylparathion | | | | | | | | | | | | 0.00 | |
| Methoxychlor | | | | | | | | | | | | 0.00 | |
| Mirex | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 | 0.22 | 0.00 | | 0.00 |
| Naphthalene (C1, C2, C3, C4) | | | | | | | | 7.42 | 0.00 | 24.60 | 7.10 | | 9.00 |
| Oxychlordane | | | | | | | | | 0.43 | 0.02 | 0.11 | 0.00 | 0.00 |
| Oxydiazon | | | | | | | | | | | | 0.00 | |
| Total PAH[d] | | 2026.67 | 0.00 | 0.00 | 9.05 | 41.75 | 118.75 | 36.31 | 34.60 | 58.30 | 23.20 | | 24.90 |
| Total PCB[e] | 16.0 | 5.60 | 3.85 | 11.20 | 7.69 | 1.00 | 17.74 | 50.82 | 40.36 | 33.64 | 22.88 | 14.0 | 8.70 |
| Phenanthrenes/anthracenes | | | | | | | | 0.00 | 0.00 | 13.70 | 4.20 | | 0.00 |
| Pentachloroanisole | | | | | | | | | 0.50 | 0.34 | 0.42 | | 0.53 |
| Pentachlorobenzene | | | | | | | | | | 0.00 | 0.00 | | 0.00 |
| 1,2,3,4-tetrachlorobenzene | | | | | | | | | | 0.19 | 0.11 | | 0.00 |
| 1,2,4,5-tetrachlorobenzene | | | | | | | | | | 0.00 | 0.00 | | 0.00 |
| Tetratributyltin | | | | | | | | | 0.00 | 0.00 | 0.00 | | 0.00 |
| Tetradifion | | | | | | | | | | | | 0.00 | |
| Toxaphene | | | | | | | | | | | | 0.00 | |
| **Trace Elements (ppm-dry weight)** | | | | | | | | | | | | | |
| Aluminum | 49.85 | 116.67 | 163.33 | 326.67 | 85.60 | 150.00 | 12.00 | 170.00 | 333.00 | 639.00 | 131.00 | 23.0 | 70.20 |
| Arsenic | | 19.67 | 39.67 | 40.00 | 32.17 | 28.00 | 27.80 | 23.30 | 25.40 | 19.00 | 19.50 | | 14.10 |
| Cadmium | 6.833 | 5.37 | 4.67 | 4.63 | 5.08 | 9.67 | 0.07 | 3.15 | 3.03 | 4.52 | 3.16 | 20.23 | 14.40 |
| Chromium | 1.515 | 1.93 | 1.73 | 1.50 | 1.63 | 2.73 | 2.75 | 2.09 | 4.60 | 4.39 | 1.69 | 2.24 | 1.79 |

| Analyte | CA-SMWP site 502 | NOAA Fraser Point | | | | | | | | | | CA-SMWP site 502 | NOAA Fraser Point |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1977-78[a] | 1986 | 1987 | 1988 | 1990 | 1991 | 1992 | 1994 | 1996 | 1998 | 2000 | 2001 | 2002 |
| Copper | 4.375 | 6.50 | 7.63 | 6.23 | 6.04 | 6.37 | 7.72 | 7.75 | 6.40 | 6.84 | 5.80 | 5.3 | 5.52 |
| Iron | | 453.33 | 310.00 | 313.33 | 163.40 | 533.33 | 250.00 | 210.00 | 765.00 | 1010.00 | 282.00 | | 122.00 |
| Lead | 1.583 | 1.09 | 0.85 | 0.70 | 0.99 | 0.92 | 0.02 | 0.80 | 0.30 | 0.84 | 0.48 | 1.10 | 1.94 |
| Manganese | 3.200 | 6.43 | 7.43 | | 2.93 | 8.93 | 8.90 | 7.20 | 5.90 | 14.90 | 11.20 | 2.6 | 2.90 |
| Mercury | 0.115 | 0.11 | 0.08 | 0.08 | 0.02 | 0.12 | 0.11 | 0.07 | 0.07 | 0.08 | 0.07 | 0.00 | 0.13 |
| Nickel | 1.150 | 2.63 | 3.30 | 2.97 | 2.03 | 2.47 | 0.65 | 1.37 | 1.50 | 2.93 | 1.78 | | 1.62 |
| Selenium | | 2.97 | 4.10 | 3.70 | 1.44 | 1.53 | 1.72 | 1.73 | 2.60 | 2.19 | 2.62 | | 1.34 |
| Silver | 1.017 | | | | 0.28 | 0.19 | 0.51 | 0.42 | 0.70 | 0.10 | 0.46 | 0.013 | 0.34 |
| Zinc | 121.225 | 153.33 | 193.33 | 180.00 | 160.00 | 166.67 | 190.00 | 180.00 | 151.00 | 175.00 | 158.00 | 131.3 | 223.00 |

[a]Values are means for four sampling dates: 8/1/77, 12/3/77, 8/15/78, 11/18/78.

[b]Total Chlordane = (alphachlordane + transnonachlor + heptachlor + heptachlor-epoxide)

[c]Total DDT = (o,pDDE + p,pDDE + o,pDDD + p,pDDD + o,pDDT + p,pDDT)

[d]Total PAH = (1,6,7-trimethylnaphthalene, 1-methylnaphthalene, 2,6-dimehtylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(k)fluoranthene, benzanthracene, benzo(g,h,I)perylene, benzo-a-pyrene, benzo-b-pyrene, benzo-e-pyrene, benzo-k-flouranthene, biphenyl, chrysene, bibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, perylene, phenanthrene, pyrene)

[e]For Frazer Point (NOAA site): during 1986-1987, Total PCB = ∑congeners: di-, tri-, tet-, pen-, hex-, hep- , oct-, non-. From 1988 onward, Total PCB = ( 2) ∑(pcb8+pcb18+pcb28+ pcb52+pcb44+ pcb66 +pcb101+pcb105 +pcb138 +pcb118+pcb128+pcb153+pcb170+pcb180+pcb187+pcb195+pcb206+pcb209)

Table 18. Levels of contaminants in mussels from Santa Catalina Island. Data are from the Bird Rock station in NOAA's National Status & Trends (NS&T) Mussel Watch Project (MWP). Values are based on dry weight. Null values indicate results below the limit of detection. Blanks indicate that the parameter was not analyzed. Values outlined in red exceed the national 85th percentile (see text). Shading indicates values that fall between the national 50th and 85th percentiles (see text). All samples were from resident mussels. Station location is provided in Table 15.

| | 1986 | 1987 | 1988 | 1990 | 1991 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Organics (ppb dry weight)** | | | | | | | | | | | |
| aldrin | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.65 | 0.00 | 0.00 |
| Butyltin (DBT, TBT, MBT) | | | | 19.84 | 0.00 | 17.67 | 22.6 | 10.8 | 7.02 | 5.604 | 11.735 |
| chlorpyrifos | | | | | | | | 0.46 | 0.00 | 0.203 | 0 |
| cis-nonachlor | | | | | | | | 0.6 | 1.06 | 0.203 | 0.649 |
| Total Chlordane[a] | 2.90 | 5.50 | 8.00 | 5.39 | 0.13 | 0.00 | 2.54 | 3.52 | 1.41 | 1.62 | 1.91 |
| gamma-chlordane | | | | | | | | 1.23 | 0.71 | 0.61 | 0.65 |
| Chrysene (C1,C2,C3,C4) | | | | | | | 0.00 | 4.40 | 3.80 | 0.00 | 0.00 |
| Total DDT[b] | 21.10 | 77.43 | 37.87 | 144.24 | 28.77 | 47.58 | 27.87 | 36.24 | 32.71 | 19.45 | 30.56 |
| Dibenzothiophene (C1,C2,C3) | | | | | | | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 |
| Dieldrin | 2.13 | 3.67 | 2.27 | 0.47 | 0.07 | 1.57 | 1.25 | 2.04 | 0.97 | 1.22 | 1.14 |
| endosulfan I | | | | | | | | 0.00 | | 0.27 | 0.00 |
| endosulfan II | | | | | | | | 0.51 | 0.04 | 0.00 | 0.00 |
| endosulfan sulfate | | | | | | | | | | 0.00 | 0.20 |
| endrin | | | | | 0.00 | 0.00 | 0.32 | 0.33 | 0.00 | 0.10 | 0.27 |
| Fluorene (C1,C2,C3) | | | | | | | 0.00 | 29.70 | 5.60 | 0.00 | 0.00 |
| alpha HCH | | | | | | | | 0.96 | 0.90 | 1.12 | 0.00 |
| beta HCH | | | | | | | | 1.20 | 0.68 | 0.41 | 0.42 |
| delta HCH | | | | | | | | 0.30 | 0.01 | 0.00 | 0.03 |
| gamma HCH (lindane) | 1.23 | 1.10 | 0.40 | 3.30 | 0.94 | 1.47 | 0.77 | 0.38 | 0.36 | 0.30 | 0.44 |
| Hexachlorobenzene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 | 0.15 | 0.20 | 0.34 |
| C1-fluoranthenes/pyrenes | | | | | | | 0.00 | 9.60 | 2.00 | 0.00 | 0.00 |
| Mirex | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Naphthalene (C1,C2,C3,C4) | | | | | | | 5.70 | 97.30 | 14.50 | 5.90 | 15.40 |

| | 1986 | 1987 | 1988 | 1990 | 1991 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| oxychlordane | | | | | | | | 0.32 | 0.49 | 0.10 | 0.00 |
| Total PAH[c] | 1824.00 | 0.00 | 4.67 | 32.99 | 31.27 | 121.06 | 20.92 | 159.40 | 24.50 | 27.20 | 35.60 |
| Total PCB[d] | 115.30 | 73.47 | 1.53 | 1.29 | 0.09 | 3.50 | 1.55 | 1.82 | 2.20 | 1.00 | 1.32 |
| phenanthrenes/anthracenes | | | | | | | 0.00 | 27.60 | 6.10 | 2.40 | 0.00 |
| pentachloroanisole | | | | | | | | 0.51 | 0.33 | 0.30 | 0.37 |
| pentachlorobenzene | | | | | | | | | 0.13 | 0.00 | 0.00 |
| 1,2,3,4-tetrachlorobenzene | | | | | | | | | 0.00 | 0.00 | 0.25 |
| 1,2,4,5-tetrachlorobenzene | | | | | | | | | 1.55 | 0.00 | 0.00 |
| tetratributyltin | | | | | | | | 0.00 | 0.00 | 0.00 | 0.00 |
| **Trace Elements (ppm-dry weight)** | | | | | | | | | | | |
| Aluminum | 22.67 | 65.67 | 153.33 | 75.10 | 42.67 | 240.00 | 36.30 | 194.00 | 645.00 | 36.40 | 8.82 |
| Arsenic | 16.00 | 22.67 | 18.33 | 12.41 | 19.33 | 13.92 | 16.50 | 13.20 | 14.10 | 12.50 | 10.30 |
| Cadmium | 3.40 | 4.63 | 6.63 | 4.38 | 2.83 | 1.20 | 2.44 | 2.74 | 4.47 | 5.96 | 4.10 |
| Chromium | 1.23 | 1.97 | 1.57 | 1.49 | 1.77 | 1.79 | 1.79 | 1.40 | 4.71 | 1.37 | 0.99 |
| Copper | 7.03 | 5.43 | 4.73 | 5.52 | 7.37 | 6.14 | 5.25 | 5.70 | 6.71 | 4.83 | 5.19 |
| Iron | 65.00 | 110.00 | 133.33 | 152.50 | 133.33 | 99.70 | 76.00 | 179.00 | 635.00 | 96.10 | 56.30 |
| Lead | 2.00 | 2.87 | 1.73 | 1.47 | 1.57 | 3.53 | 1.12 | 0.80 | 1.41 | 1.14 | 1.36 |
| Manganese | 4.17 | 6.23 | | 1.70 | 6.50 | 7.50 | 0.00 | 5.90 | 11.90 | 4.52 | 3.34 |
| Mercury | 0.14 | 0.18 | 0.14 | 0.02 | 0.11 | 0.10 | 0.08 | 0.15 | 0.12 | 0.07 | 0.10 |
| Nickel | 2.27 | 1.93 | 6.57 | 0.94 | 2.00 | 1.43 | 1.07 | 1.60 | 4.26 | 1.78 | 1.13 |
| Selenium | 3.87 | 5.47 | 3.80 | 3.31 | 3.13 | 2.52 | 2.17 | 3.70 | 2.64 | 2.72 | 2.84 |
| Silver | | | | 0.20 | 0.24 | 0.19 | 0.35 | 0.74 | 1.12 | 0.38 | 0.31 |
| Zinc | 133.33 | 166.67 | 130.00 | 126.67 | 126.67 | 130.00 | 120.00 | 121.0 | 91.40 | 118.00 | 116.00 |

[a]Total Chlordane = (alphachlordane + transnonachlor + heptachlor + heptachlor-epoxide)

[b]Total DDT = (o,pDDE + p,pDDE + o,pDDD + p,pDDD + o,pDDT + p,pDDT)

[c]Total PAH = (1,6,7-trimethylnaphthalene, 1-methylnaphthalene, 2,6-dimehtylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(k)fluoranthene, benzanthracene, benzo(g,h,I)perylene, benzo-a-pyrene, benzo-b-pyrene, benzo-e-pyrene, benzo-k-flouranthene, biphenyl, chrysene, bibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, perylene, phenanthrene, pyrene)

[d] Total PCB = ( 2) ∑(pcb8+pcb18+pcb28+ pcb52+pcb44+ pcb66 +pcb101+pcb105 +pcb138 +pcb118+pcb128+pcb153+pcb170+pcb180+pcb187+pcb195+pcb206+pcb209)

Statistical analyses were not performed on time series data from the NOAA-MWP. However, based on visual inspection, PCBs appear to be declining in mussels at both Santa Cruz and Catalina Islands from peak levels observed in 1986. (PCBs in Santa Cruz mussels temporarily rose in 1994, but have declined since then) (Figure 52). Also, lindane appears to be declining in mussels at both islands from peak values obtained in 1990 (Figure 49). Temporal trends in DDT levels in mussels are not evident (Figure 50). Much higher levels of PAHs were observed in mussels at both islands in 1986, than at any subsequent time (Figure 53).

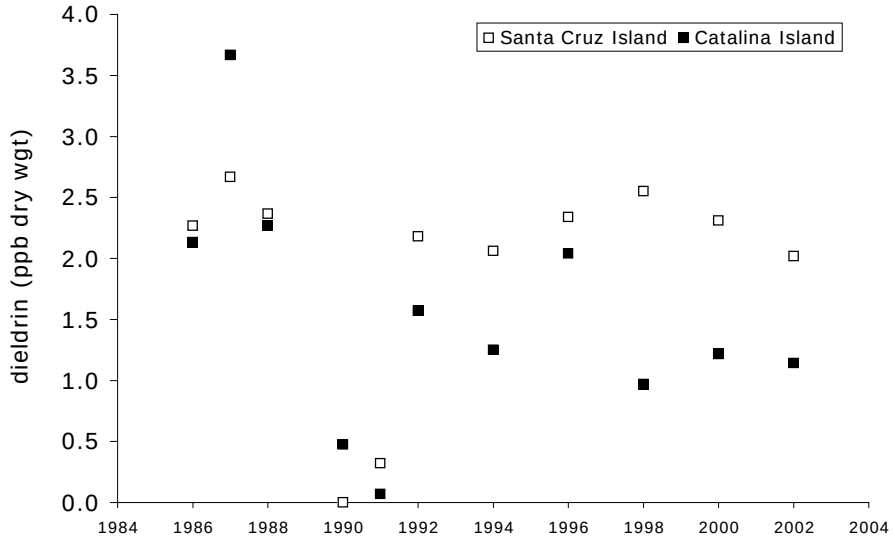



Figure 48. Dieldrin in mussels from Santa Cruz and Catalina Islands from 1986 to 2002. Data are from the NOAA-MWP.

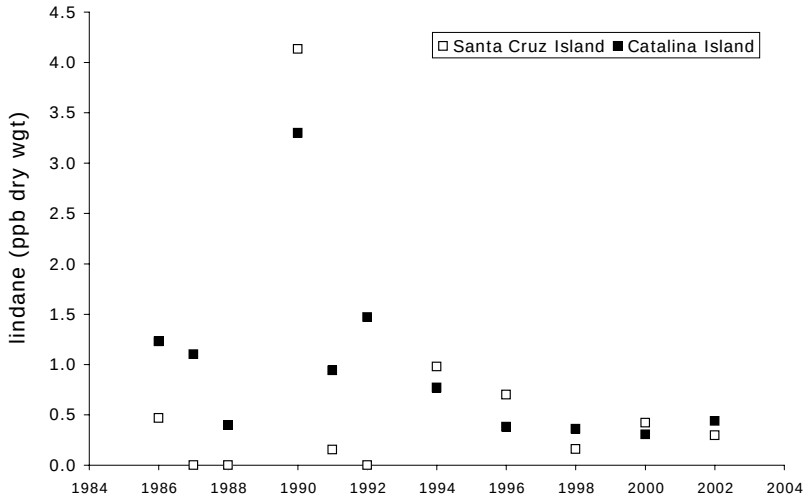



Figure 49. Lindane in mussels from Santa Cruz and Catalina Islands from 1986 to 2002. Data are from the NOAA-MWP.

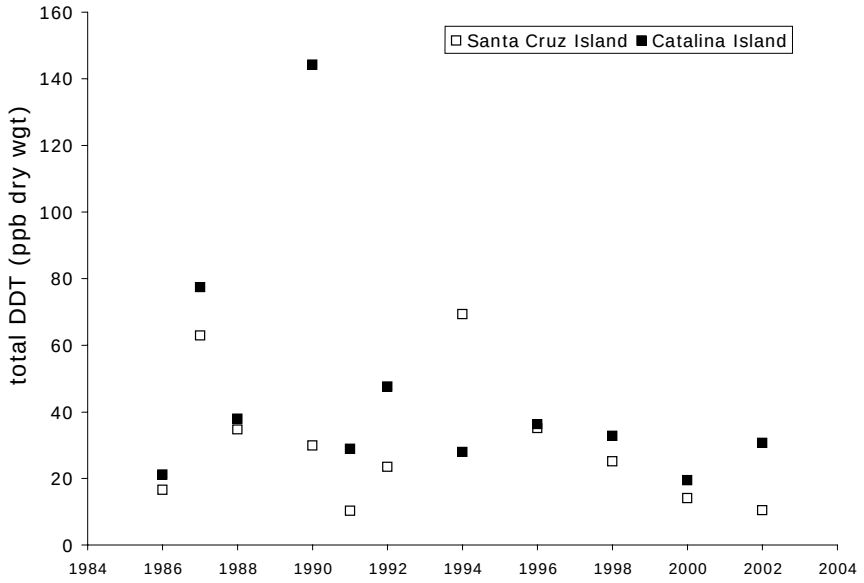



Figure 50. Total DDT in mussels from Santa Cruz and Catalina Islands from 1986 to 2002. Total DDT equalled 31 ppb in a 1978 sample of Santa Cruz mussels. Data are from the NOAA-MWP.

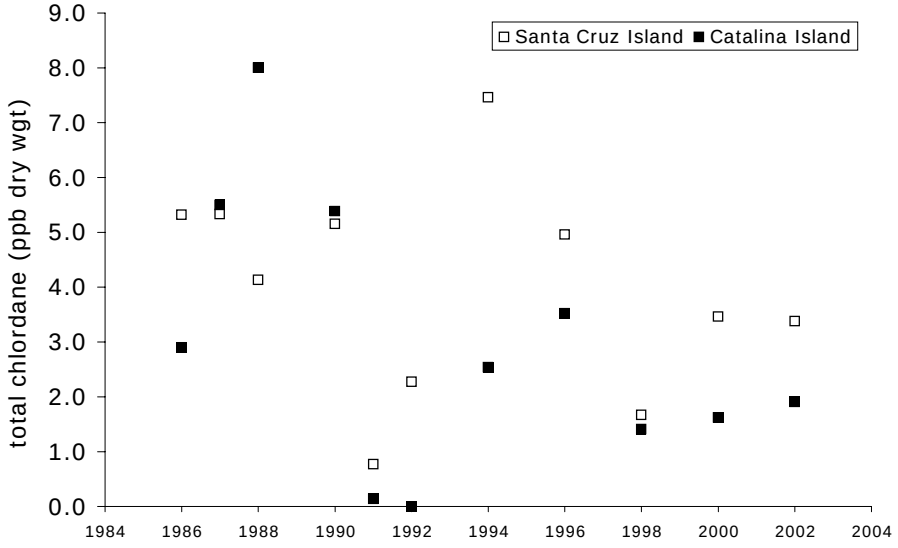



Figure 51. Total chlordane (alphachlordane + transnonachlor + heptachlor + heptachlor-epoxide) in mussels from Santa Cruz and Catalina Islands from 1986 to 2002. Data are from the NOAA-MWP.

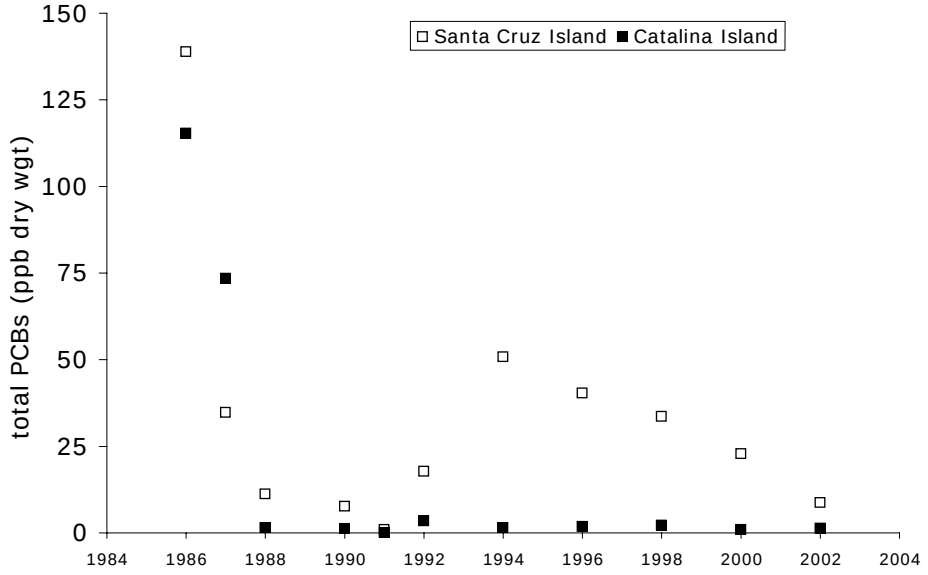



Figure 52. Total PCBs in mussels from Santa Cruz and Catalina Islands from 1986 to 2002. Data are from the NOAA-MWP.

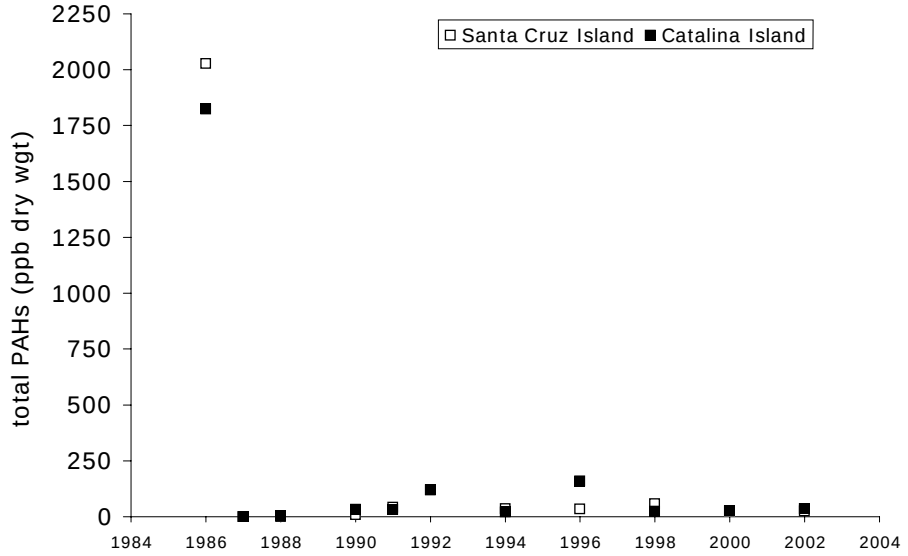



Figure 53. Total PAHs in mussels from Santa Cruz and Catalina Islands from 1986 to 2002. Data are from the NOAA-MWP.

In order to put the available results into perspective, the organic compounds and trace metal concentrations from all of the islands were compared to several criteria: (1) national 50th and 85th percentiles (from NOAA), (2) Maximum Tissue Residue Levels (from the SWRCB), and (3) California-wide Elevated Data Levels.

National 50th and 85th percentiles. O'Connor (2002) evaluated national trends in a long-term data set from the NOAA-MWP. Rather than force a mathematical distribution function on the data, central tendencies and variations were characterized by the 15th, 50th, and 85th percentiles among 214 site means measured in 1990 at marine sites. Contaminant concentrations based on dry weight were used in his analysis. The year 1990 was chosen as the basis for comparison because it was the year in which the most sites were sampled nationwide. Among the 238 marine sites included nationwide in NOAA-MWP, 24 of the sites were not sampled until 1991 or later and, according to O'Connor (2002), the percentiles calculated for 1990 data would change little if they were percentiles of site means calculated over all years. Following O'Connor (2002), both state and NOAA data from the islands were inspected for exceedances of the national 85th percentile concentrations in order to identify sites with "high" (terminology used below) concentrations of contaminants. For the purposes of this report, values falling between the national 50th and 85th percentiles reported by O'Connor (2002) are referred to in the following discussion as "above the national median".

Using this basis, three islands had high concentrations of total DDT in their mussels: San Miguel (in 1977, 1978, and 1988), Santa Cruz (in 1987, 1988, 1994, and 1996), and Catalina (1990). In addition, every island except Santa Cruz yielded mussel samples in which total DDT was above the national median. Total PAHs were especially high in mussels at Fraser Point on Santa Cruz in 1986. Levels of total PCBs and dieldrin were above the national median in mussels at San Miguel in 1977-78. Arsenic was above the national median, or high, in every sample from every island. Cadmium, chromium and lead were above the national median, or high, in 83%, 86% and 87% of island samples, respectively. Mercury, nickel, selenium, silver and zinc were frequently high or above the national median in island samples, although less consistently over time than the other elements above.

Maximum Tissue Residue Levels (MTRLs). The MTRLs were developed by SWRCB staff using human health water quality "objectives" from the 1997 *California Ocean Plan* and from the California Toxic Rule (40 CFR Part 131, May 18, 2000) as established in the *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California* (SWRCB 2000). The "objectives" are target concentrations of contaminants in ocean water, in ug/L, intended to that protect people from consumption of fish, shellfish, and water (the latter, freshwater only) that contain substances at levels which could result in significant human health problems. MTRLs (ppb wet weight) were calculated by multiplying these target ocean water concentrations with bioconcentration factors (L/kg) taken from the USEPA Draft Assessment and Control of Bioconcentratable Contaminants in Surface Waters (USEPA 1991). Rasmussen (2000) presents MTRLs for aldrin, total chlordane, total DDT, dieldrin, heptachlor, hexachlorobenzene, total PAHs, total PCBs, toxaphene. *Application of MTRLs for this report required tissue concentrations based on wet weight, which were obtained from the CA-SMWP, but not from the NOAA-MWP*. All available CA-SMWP data for Park islands and Catalina were inspected for MTRL exceedances for the organic contaminants and trace elements listed above; exceedances are indicated in Tables 19 and 20, respectively. Exceedances for total PCBs were widespread at the islands during 1977, 1978, and 1980. In addition, exceedances for total chlordane were observed at Anacapa (at one site), and Catalina (at two sites) in 1980. The MTRL for dieldrin was exceeded at Anacapa in 1980. The MTRL for total DDT was exceeded at San Miguel (at one site) every time mussels were sampled during 1977 and 1978.

Elevated Data Levels (EDLs). The EDL was introduced by SWRCB staff in 1983 as an internal comparative measure which ranks a given concentration of a particular substance with previous SMWP data. The EDL is calculated by ranking all of the results for a species and exposure condition (resident or transplant) and a given chemical from the highest concentration measured down to and including those records where the chemical was not detected. From this, a cumulative distribution is constructed and percentile rankings are calculated. The 85th percentile (EDL85) was chosen by the SWRCB as an indication that a chemical is "markedly elevated" from the median (Rasmussen 2000). The 85th percentile corresponds to measures used by the U.S. Fish and Wildlife Service in its National Contaminant Biomonitoring Program and would represent approximately one and one-half standard deviations from the mean, if the data were normally distributed. The 95th percentile (EDL 95) was chosen to indicate values that are "highly elevated" above the median. The 95th percentile would represent two standard deviations from the mean, if the data were normally distributed. *As with the MTRLs, EDLs were derived from wet weight concentrations, thus only CA-SMWP data were evaluated using EDLs.* For this report, island data were compared to the EDLs for organic contaminants and trace elements that were derived from combined statewide results from 1977-97, and which are reported in Rasmussen (2000). EDLs were available for the following organic contaminants: cis-chlordane cis-nonachlor, oxychlordane, trans-chlordane, total chlordane, total DDT, dieldrin, endosulfan I, total endosulfan, alpha HCH, gamma HCH (lindane), phenol, pentachlorophenol, and total PCBs. EDLs were available for all of the trace elements listed in Tables 16-18.

None of the available CA-SWMP results from the Channel Islands exceeded the EDL95 for any organic contaminant (Table 19). Total DDT and total PCB exceeded the EDL85 at San Miguel during 1977-78. Alpha-HCH and gamma-HCH (lindane) were each above the EDL85 in 1980 (at Anacapa and Catalina, respectively). Levels of cis-chlordane exceeded the EDL85 three times at Catalina, most recently in 1993. Highly elevated concentrations (>EDL95) of cadmium (Cd), lead (Pb) and chromium (Cr) were observed; in particular, Pb was consistently >EDL95 at one site on Catalina (Table 20). Elevated concentrations (>EDL85) of mercury, cadmium, and silver were observed sporadically at the islands.

Table 19. Exceedances for organic contaminant concentrations measured by the State Mussel Watch Program in mussels from Channel Islands National Park and Santa Catalina Island. Data for all available sample dates were evaluated. Exceedance criteria are based on wet weight (ppb), and were different for resident and transplanted mussels (see text). Values for DDT (ppb wet wgt) are given in parentheses. Total DDT in resident mussels from White's Point (station 617) was 170.8 ppb on 1/82, which exceeded the EDL95[c] for total DDT. Station locations are provided in Table 15 and shown in Figures 46-47.

| CA-SMWP station | Station # | Sample Date | Type | Exceedance Criteria EDL85[a] | EDL95[b] |
|---|---|---|---|---|---|
| San Miguel/West | 500 | 8/1977 | resident | Total DDT (65.8) | Total DDT (65.8) |
| | | 12/1977 | resident | Total DDT (31.6) | Total PCB |
| | | 8/1978 | resident | Total DDT (55.4) | Total DDT (55.4) |
| | | 11/78 | resident | Total DDT (22.9) | Total PCB |
| San Miguel/East | 501 | 7/77 | resident | Total PCB | ------ |
| | | 12/77 | resident | Total PCB | ------ |
| | | 8/78 | resident | Total PCB | ------ |
| | | 11/78 | resident | Total PCB | ------ |
| Santa Cruz Island | 502 | 8/77 | resident | Total PCB | ------ |
| | | 12/77 | resident | Total PCB | ------ |
| | | 8/78 | resident | Total PCB | ------ |
| | | 12/78 | resident | Total PCB | ------ |
| | | 3/01 | resident | ------ | ------ |
| Anacapa Island | 503 | 8/77 | resident | Total PCB | ------ |
| | | 12/77 | resident | Total PCB | ------ |
| | | 8/78 | resident | Total PCB | ------ |
| | | 11/78 | resident | Total PCB | ------ |
| | | 5/80 | transplant | total chlordane | ------ |
| | | 11/80 | transplant | total PCB | alpha-HCH |
| Santa Barbara Island | 504 | 7/77 | resident | total PCB | ------ |
| | | 12/77 | resident | total PCB | ------ |
| | | 8/78 | resident | total PCB | ------ |
| | | 12/78 | resident | total PCB | ------ |
| Santa Catalina Island/East | 680 | 8/78 | resident | total PCB | ------ |
| | | 12/78 | resident | total PCB | ------ |
| | | 12/80 | resident | total PCB, | gamma-HCH, |
| Santa Catalina Island/West | 681 | 7/77 | resident | total PCB | ------ |
| | | 12/77 | resident | total PCB | ------ |
| | | 8/78 | resident | total PCB | ------ |
| | | 12/78 | resident | total PCB | ------ |
| | | 3/94 | resident | ------ | ------ |
| Santa Catalina Island/ Ribbon Rock | 682 | 2/93 | resident | total chlordane, dieldrin | cis-chlordane |
| Santa Catalina Island/ Ben Weston | 683 | 12/80 | resident | total PCB, total chlordane | cis-chlordane |

[a]MTDL: Maximum Tissue Residue Level for Ocean Waters (see text)

[b]EDL85: 85th percentile for statewide CA-SMWP samples from 1977-1997.

[c]EDL95: 95th percentile for statewide CA-SMWP samples from 1977-1997.

Table 20. Exceedances for trace element concentrations measured by the State Mussel Watch Program in mussels from Channel Islands National Park and Santa Catalina Island. Data from all available sample dates was evaluated. Exceedance criteria are based on wet weight (ppb), and were different for resident and transplanted mussels (see text). Station locations are provided in Table 15 and Figures 46-47.

| CA-SMWP station | Station # | Sample Date | Mussel Type | Exceedance Criteria EDL85[a] | EDL95[b] |
|---|---|---|---|---|---|
| San Miguel/West | 500 | 8/1977 | resident | Hg | ------ |
| | | 12/1977 | resident | Hg | ------ |
| | | 8/1978 | resident | Cd | ------ |
| | | 11/1978 | resident | Hg | ------ |
| San Miguel/East | 501 | 7/1977 | resident | Cd | ------ |
| | | 12/1977 | resident | Cd | ------ |
| | | 8/1978 | resident | ------ | ------ |
| | | 11/1978 | resident | ------ | ------ |
| Santa Cruz Island | 502 | 8/1977 | resident | ------ | ------ |
| | | 12/1977 | resident | ------ | ------ |
| | | 8/1978 | resident | ------ | ------ |
| | | 12/1978 | resident | ------ | ------ |
| | | 3/2001 | resident | Cd | Cd |
| Anacapa Island | 503 | 8/1977 | resident | Ag | ------ |
| | | 12/1977 | resident | ------ | ------ |
| | | 8/1978 | resident | Ag, Pb | ------ |
| | | 11/1978 | resident | Ag | ------ |
| | | 12/1979 | resident | ------ | ------ |
| | | 5/1980 | transplant | Cd | Cd |
| | | 11/1980 | transplant | Cd | Cd |
| Santa Barbara Island | 504 | 7/1977 | resident | Cd | ------ |
| | | 12/1977 | resident | ------ | ------ |
| | | 8/1978 | resident | ------ | ------ |
| | | 12/1978 | resident | Cd | Cd |
| Santa Catalina Island/East | 680 | 8/1978 | resident | ------ | ------ |
| | | 12/1978 | resident | ------ | ------ |
| | | 12/1980 | resident | ------ | ------ |
| | | 12/1980 | transplant | ------ | ------ |
| Santa Catalina Island/West | 681 | 7/1977 | resident | Pb | Pb |
| | | 12/1977 | resident | Pb | Pb |
| | | 8/1978 | resident | Pb | Pb |
| | | 12/1978 | resident | Pb | Pb |
| | | 12/1979 | resident | Pb | Pb |
| | | 5/1980 | transplant | Al, Mn, Ni, Ag, Cr, Pb | Ag, Cr, Pb |
| | | 12/1980 | resident | Pb | Pb |
| | | 12/1980 | transplant | ------ | ------ |
| | | 9/1991 | resident | Pb | Pb |
| | | 3/1994 | resident | Pb | Pb |

| CA-SMWP station | Station # | Sample Date | Mussel Type | Exceedance Criteria EDL85[a] | EDL95[b] |
|---|---|---|---|---|---|
| Santa Catalina Island/Ribbon Rock | 682 | 12/1980 | resident | ------ | ------ |
| | | 9/1990 | resident | Zn | Zn |
| | | 2/1993 | resident | Pb, Cr | Cr |
| Santa Catalina Island/Ben Weston | 683 | 12/1980 | resident | Cr | Cr |
| Santa Catalina Island/Silver Canyon | 684 | 12/1980 | resident | Cr | ------ |
| Santa Catalina Island/Church Rock | 685 | 12/1980 | resident | ------ | ------ |

[a]EDL85: 85th percentile for statewide CA-SMWP samples from 1977-1997.

[b]EDL95: 95th percentile for statewide CA-SMWP samples from 1977-1997.

## Summary of sentinel mussel results for the Channel Islands

Trace elements. *Based on California distributions*, mussels in and near the Park have contained elevated levels of several metals in recent years (most frequently, Cd, Pb, Ag, and Cr). In addition, *compared to national distributions*, arsenic (As) has consistently been above the national median, and also "high", in mussels in or near the Park. High concentrations of some trace elements may represent entirely natural conditions (O'Connor 2002). When *groups* of sites in particular regions, rather than individual sites, show high concentrations of particular trace elements, a natural source is more likely. Some natural sources for Cd, Pb, Ag, and Cr have been identified in U.S. surveys. For example, the high As concentrations in southeast U.S. molluscs are probably due to phosphate deposits in that region (Vallette-Silver et al. 1999). The serpentine rocks of the Northwest are a source of both the Cr and Ni that are found at high levels in molluscs along that coast, and serpentine outcrops may be the source for the high Ni in oysters in the Mid-Atlantic (O'Connor 2002). Goldberg et al. (1983) and Farrington et al. (1983) suggested that the high Cd concentrations in mussels of Northern California may reflect the fact that the coastal water in that region upwells from the deep Pacific and that deep ocean waters are naturally enriched in Cd relative to surface waters. Whether or not the high levels of Cd, Pb, Ag and Cr in Park mussels are explained by upwelling, minerals in exposed bedrock, or some form of anthropogenic contamination, has not been investigated. Trace element concentrations evaluated by Lauenstein and Daskalakis (1998) indicated that between 1965 and 1993, more sites on the west coast of the U.S. experienced declines than increases in Ag, Cd and Pb in sentinel mussels. However, from 1986-2002, Ag, Cd and Pb in sentinel mussels at Santa Cruz have not shown decreasing trends (Table 17). In fact, the maximum levels of Cd and Pb measured by the NOAA-MWP in Santa Cruz mussels were obtained in 2001 and 2002, respectively. Interestingly, nationwide, high concentrations of As, Ni, Se and Cd in sentinel bivalves are inversely correlated with human population (O'Connor 2002), suggesting that hot spots for these trace elements are less likely being caused by anthropogenic pollution than are hot spots for other trace elements, such as Pb and Ag. This phenomenon suggests that natural explanations for high levels of As and Cd in Park mussels may be appropriate.

Organic contaminants. Among the islands, the highest DDT levels in the available record were found at San Miguel in 1977-78 - more recent data for the island are unavailable to indicate whether or not San Miguel remains a DDT hot spot. The above was true despite the fact that, among all the islands, San Miguel is the furthest from the most significant source of DDT contamination in the region: sediments near the White's Point outfall on the Palos Verde Shelf.