State of California
The Resources Agency
Department of Water Resources
Environmental Services Office

WATER QUALITY CONDITIONS IN THE SACRAMENTO-SAN JOAQUIN DELTA DURING 1995

Report to the State Water Resources Control Board
In Accordance with Water Right Decision 1485, Order 4(f)

August 1999

Gray Davis
Governor
State of California

Mary D. Nichols
Secretary for Resources
The Resources Agency

Thomas M. Hannigan
Director
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FOREWORD

The California State Water Project is a multipurpose project. In addition to its primary role of providing a statewide water supply, it provides flood control, power, and recreation. Operating this extensive system must include consideration of water quality needs and an understanding of the relationships between project operations and potential impacts on the aquatic environment.

The Department of Water Resources has operated the State Water Project in accordance with State Water Resources Control Board Decision 1485 (August 1978) and its predecessor, Decision 1379 (July 1971). Decision 1485 was amended in 1995 by the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (the Bay-Delta Plan) adopted by the Board on May 22, 1995. The previous Decisions and the Bay-Delta Plan have established water quality standards to protect beneficial uses of water supplies in the Delta and Suisun Marsh. Monitoring required by the Bay-Delta Plan is conducted by the Department of Water Resources, the U.S. Bureau of Reclamation, and the Department of Fish and Game to ensure compliance with these standards, identify changes potentially related to State Water Project and Central Valley Project operations, and assess the effectiveness of the Bay-Delta Plan in preserving Delta and Suisun Marsh water quality.

This program and associated special studies have helped water project operators gain a better understanding of the effects of State Water Project operation on the Delta's ecology. It has also provided information that will be used to help determine future operating criteria to protect waters of the Delta and San Francisco Bay.

Decision 1485 requires that a detailed report on monitoring results be prepared annually and submitted to the State Water Resources Control Board. Water quality data are being stored electronically so they can be accessed by interested parties. The database also serves as an important information source for agencies, organizations, and individuals involved in Delta study programs.

Randall L. Brown, Chief
Environmental Services Office

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EXECUTIVE SUMMARY

Water year 1995[1] was a wet year, ending an eight-year period of predominantly dry and critically dry water years. After a relatively dry fall, January and March precipitation was heavy and produced flooding in the Central Valley. By May 1, precipitation was 165% of average, snowpack water content was 215% of average, seasonal runoff was 170% of average, and reservoir storage was 110% of average.

In 1995, the Net Delta Outflow Index (NDOI) was used to estimate Delta outflow, and the Sacramento and San Joaquin River Unimpaired Runoff indices were used to determine water year type for 1995. Using these indices, water year 1995 was officially classified as wet on May 1, 1995. All standards including those in Water Right Decision 1485, as amended by the 1995 Water Quality Control Plan, were met in 1995. The entire 1995 calendar year was characterized by excess conditions[2], and both State Water Project and Central Valley Project water requirements were met as well as in-Delta consumptive uses. Delta outflows were high throughout the year, and the calculated average monthly flows exceeded 80,000 cubic feet per second (cfs) during the peak outflow period (January through May), and 3,000 cfs during the minimum outflow period (July through November).

Water quality for all Delta regions was within the historical range of values throughout the 1995 calendar year. Salinity and nutrient concentrations were lower than levels measured during the dry water years preceding the wet 1995 water year. Salinity intrusion was minor in the Suisun and San Pablo bays from October through December 1995, when Delta outflow had decreased. Finally, dissolved oxygen concentrations were stable throughout the year at relatively high concentrations.

Average daily flows in the San Joaquin River past Vernalis remained high (greater than 4,000 cfs) from August through October. These relatively high flow conditions contributed to the maintenance of dissolved oxygen levels in the eastern Stockton Ship Channel near Rough and Ready Island above the 5.0 mg/L standard from September through November. August dissolved oxygen levels dropped below 5.0 mg/L due, in part, to relatively warm water temperatures (24 to 26 °C) during this period. Because of the relatively high fall flows in the San Joaquin River, the rock barrier across the mouth of Old River was not constructed in 1995.

The high inflows into the Delta did not increase the potential toxicity of measured constituents in Delta water to humans and aquatic biota. Of the nine trace metals measured, seven were above minimum reporting limits, were within the range of previous years, and did not exceed the Primary Drinking Water Standards established for human health concerns or the Secondary Drinking Water Standards for taste and odor concerns. On one occasion in 1995, dissolved lead exceeded and dissolved copper levels equaled the aquatic biota toxicity levels for these trace metals established by the Environmental Protection Agency. None of the organic pesticides measured exceeded any of the minimum reporting limits in 1995.

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[1] This report covers the calendar year. However, hydrologic conditions are based on a water year, which begins October 1 and ends September 30. A water year is numbered using the year in which it ends.

[2] Excess conditions are defined in the Coordinated Operating Agreement (November 24, 1986) as periods where releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley inbasin uses, plus exports. These uses include Central Valley Project and State Water Project requirements plus Delta requirements.

The high spring inflows in 1995 brought high flows through the Delta. The scouring from the high flows increased the proportion of sand and reduced the proportion of fines slightly in the deeper channel sites of the Delta. However, sediment composition in the non-channel sites was relatively stable and similar in composition to that seen in the recent series of drier years. In San Pablo Bay and the western Delta, salinity was more variable and lower than in recent years. Benthic organism abundances were lower throughout the Bay-Delta system in 1995, especially in San Pablo Bay. *Potamocorbula amurensis* abundances were low, especially in the easternmost range of the habitat of this species. However, *P. amurensis*, as well as *Corbicula fluminea* and *Corphium stimpsoni* continued to dominate the benthos of the Bay-Delta system.

Chapter 1
INTRODUCTION

The State Water Resources Control Board (SWRCB) sets water quality objectives to protect beneficial uses of water in the Sacramento-San Joaquin Delta and Suisun Bay. These objectives are met by establishing standards mandated in water right permits issued by the SWRCB (SWRCB 1978). The standards include minimum Delta outflows, limits to Delta water export by the State Water Project (SWP) and the Central Valley Project (CVP), and maximum allowable salinity levels. Water quality standards in place since August of 1978 were issued by Water Right Decision 1485 (Decision 1485). These standards were amended in 1995 to conform to the *Principles for Agreement on Bay-Delta Standards*, issued in December 1994 and the *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Estuary*, adopted by the SWRCB on May 22, 1995. With these agreements, new Delta outflow standards were set and a variety of new indices were established to determine water year type and estimate Delta outflow.

Prior to 1995, Delta outflow was estimated using the Delta Outflow Index (DOI)[3]. The calculation of freshwater outflow past Chipps Island is important to ensure adequate water quality for fish and estuarine species. In 1995, the DOI was modified to include flows from the Consumnes, Mokelumne, and Calaveras rivers (eastside stream flows), and the Yolo Bypass flood control channel, and renamed the Net Delta Outflow Index (NDOI)[4]. The inclusion of Yolo Bypass and eastside stream flows can contribute significant inflow to the Delta during the winter and spring when flow conditions can be high.

The adopted 1995 Water Quality Control Plan also replaced the Sacramento River Index[5] with new indices to forecast unimpaired runoff[6] and water year type. The Sacramento Valley 40-30-30 Water Year Hydrological Classification and San Joaquin Valley 60-20-20 Water Year Hydrological Classification include indices[7,8] that give greater weight to April to July runoff and less weight to October to March runoff, and include carry-over storage from the previous water year. Both the Sacramento Valley 40-30-30 Water Year Hydrological Classification and the San Joaquin Valley 60-20-20 Water Year Hydrological Classification are used to determine water year type for each basin.

The SWP is operated to comply with water quality standards identified in the 1995 Water Quality Control Plan. SWP operations are adjusted based on their influences on flow and water quality variables to ensure and to meet contractual water quality objectives at all points of delivery. During dry or critically dry (critical) water years, SWP has reduced deliveries, more closely coordinated upstream releases, and altered exports to meet water quality and flow standards.

Decision 1485 requires the Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) to conduct a comprehensive monitoring program to determine compliance with the water quality

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[3] The Delta Outflow Index is a calculation of freshwater outflow from the Delta past Chipps Island. DOI is calculated daily from the sum of Sacramento River inflow, San Joaquin River inflow, and the Sacramento Wastewater Treatment Plant discharge minus the Delta consumptive use estimates and the water exported by the SWP, CVP, and Contra Costa Canal. DOI does not include inflows from the eastside streams (Consumnes, Mokelumne, Calaveras rivers, and the Yolo Bypass flood control channel) or miscellaneous Delta inflows (Bear Creek, Stockton Diverting Canal, French Camp Slough, Marsh Creek, and Morrison Creek.)

[4] The Net Delta Outflow Index is a calculation of freshwater outflow from the Delta past Chipps Island that includes a factor dependent upon inflows of the Yolo Bypass system, the eastside stream system (the Mokelumne, Consumnes, and Calaveras rivers), the San Joaquin River at Vernalis, the Sacramento Regional Treatment Plant and miscellaneous Delta inflows (Bear Creek, Dry Creek, Stockton Diverting Canal, French Camp Slough, Marsh Creek, and Morrision Creek).

[5] The Sacramento River Index is the sum of unimpaired runoff in the Sacramento River, Feather River inflow to Oroville, Yuba River at Smartville, and American River inflow to Folsom.

[6] Unimpaired runoff is the natural water production of a river basin, unaltered by upstream diversions, storage, and export of water to or import of water from other basins.

standards and to report results annually to the State Water Resources Control Board. This report summarizes water quality monitoring results for calendar year 1995, presents water quality patterns, and meets the reporting requirement of Term 4(f) of Decision 1485. A chapter describing the DWR-USBR continuous monitoring program is also included in the report. The continuous monitoring program was established in 1983 to provide water quality data to DWR operations managers on a real-time basis.

Monitoring and Data Storage

The Bay-Delta Compliance Monitoring Program provides regular surveillance of the upper estuary and enables rapid detection of short-term water quality changes. Discrete sampling is done at 26 sites (Figure 1), with field help and financial assistance from the USBR. Discrete monitoring sites are sampled once or twice each month for a variety of physical, chemical, and biological variables, including specific conductance, nutrient concentrations, air and water temperature, wind velocity, pH, dissolved oxygen concentration, chlorophyll concentration, phytoplankton and benthic community composition and density, and substrate composition. In addition, six multiparameter shoreline installations continuously monitor specific conductance, dissolved oxygen concentration, pH, air and water temperature, chlorophyll concentration, solar radiation, and wind velocity and direction at strategic locations.

Changes in water quality and in the phytoplankton and benthic communities of the upper estuary are detected by discrete sampling and continuous monitoring in the main channels using DWR and USBR monitoring vessels. The multi-parameter continuous monitoring instrumentation onboard DWR and USBR monitoring vessels measures specific conductance, water temperature, dissolved oxygen, pH, turbidity, and chlorophyll fluorescence. A mobile laboratory van is used to sample sites inaccessible to the monitoring vessels. Both the vessels and the van are equipped for onsite analyses of selected variables. Remaining samples are processed and stored for extensive laboratory analyses.

Compliance monitoring data collected during 1995 are stored electronically on the Interagency Ecological Program server and at the National Computer Center in Raleigh, North Carolina. Physical and chemical data are stored on the Environmental Protection Agency's STORET system, and the biological data are stored as Statistical Analysis System data sets. All data are available to the public on the internet from the Interagency Ecological Program Home Page at the following URL address: www.iep.water.ca.gov/d1485.

Hydrologic Conditions

Hydrologic information in this section is based on data from the following DWR reports. Bulletin 120, Water Conditions in California (Reports 1 to 4) for 1995; California Water Supply Outlook for 1994 and 1995 (various dates); California Cooperative Snow Survey Historical Water Year Classification Indices; and Bulletin 132-96, Management of the State Water Project.

Water year 1995 (October 1, 1994 to September 30, 1995) was the wettest year since water year 1983. Water year 1995 is classified as a wet year according to both the Sacramento Valley 40-30-30 Water Year Hydrological Classification (Figure 2) and San Joaquin Valley 60-20-20 Water Year Hydrological Classification (Figure 3). Using the Sacramento Valley 40-30-30 Index, water year 1995 follows an eight-year period with seven critically dry or dry water years and one above normal water year. For the 1995 water year, Sacramento River Unimpaired Runoff[9] was 33.9 million acre-feet (maf) (Figure 4) and San Joaquin River Unimpaired Runoff[10] was 12.4 maf (Figure 5).

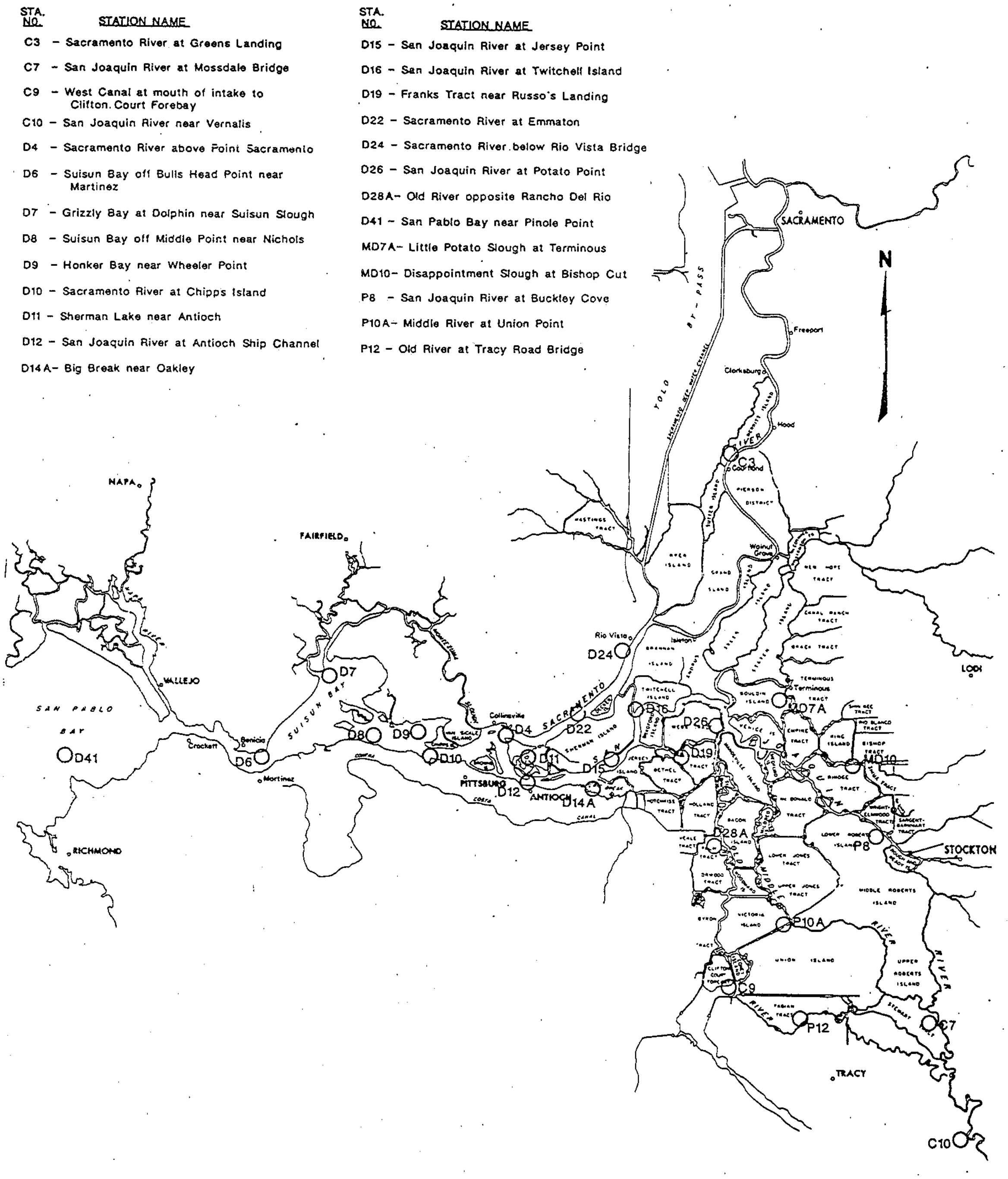
---

[7] The Sacramento Valley 40-30-30 Water Year Hydrological Classification Index = 0.4 × current April to July unimpaired runoff + 0.3 × current October to March unimpaired runoff + 0.3 × previous year's index (if the previous year's index exceeds 10.0, then 10.0 is used).

[8] San Joaquin Valley 60-20-20 Water Year Hydrological Classification Index = 0.6 × current April to July unimpaired runoff + 0.2 × current October to March unimpaired runoff + 0.2 × previous year's index (if the previous year's index exceeds 4.5, then 4.5 is used).

[9] Sacramento River Unimpaired Runoff is the sum of Sacramento River flow at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River flow at Smartville, and American River inflow to Folsom Lake.

[10] San Joaquin River Unimpaired Runoff is the sum of Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake.



STA. NO.	STATION NAME
C3	Sacramento River at Greens Landing
C7	San Joaquin River at Mossdale Bridge
C9	West Canal at mouth of intake to Clifton Court Forebay
C10	San Joaquin River near Vernalis
D4	Sacramento River above Point Sacramento
D6	Suisun Bay off Bulls Head Point near Martinez
D7	Grizzly Bay at Dolphin near Suisun Slough
D8	Suisun Bay off Middle Point near Nichols
D9	Honker Bay near Wheeler Point
D10	Sacramento River at Chipps Island
D11	Sherman Lake near Antioch
D12	San Joaquin River at Antioch Ship Channel
D14A	Big Break near Oakley
D15	San Joaquin River at Jersey Point
D16	San Joaquin River at Twitchell Island
D19	Franks Tract near Russo's Landing
D22	Sacramento River at Emmaton
D24	Sacramento River below Rio Vista Bridge
D26	San Joaquin River at Potato Point
D28A	Old River opposite Rancho Del Rio
D41	San Pablo Bay near Pinole Point
MD7A	Little Potato Slough at Terminous
MD10	Disappointment Slough at Bishop Cut
P8	San Joaquin River at Buckley Cove
P10A	Middle River at Union Point
P12	Old River at Tracy Road Bridge

Figure 1 Map of 1995 monitoring sites

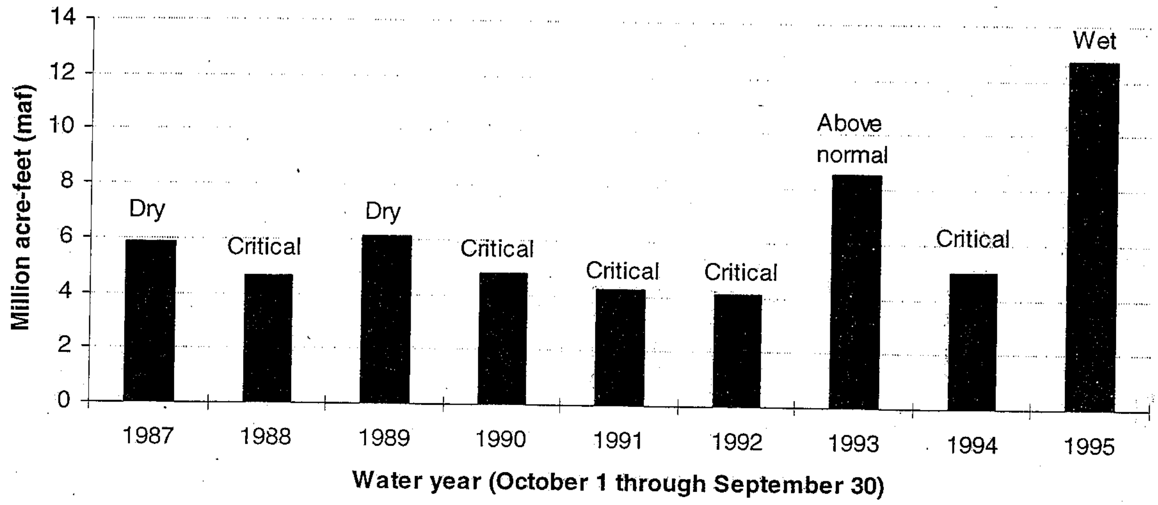


Figure 2 Sacramento River Hydrologic Region 40-30-30 Index from 1987 to 1995

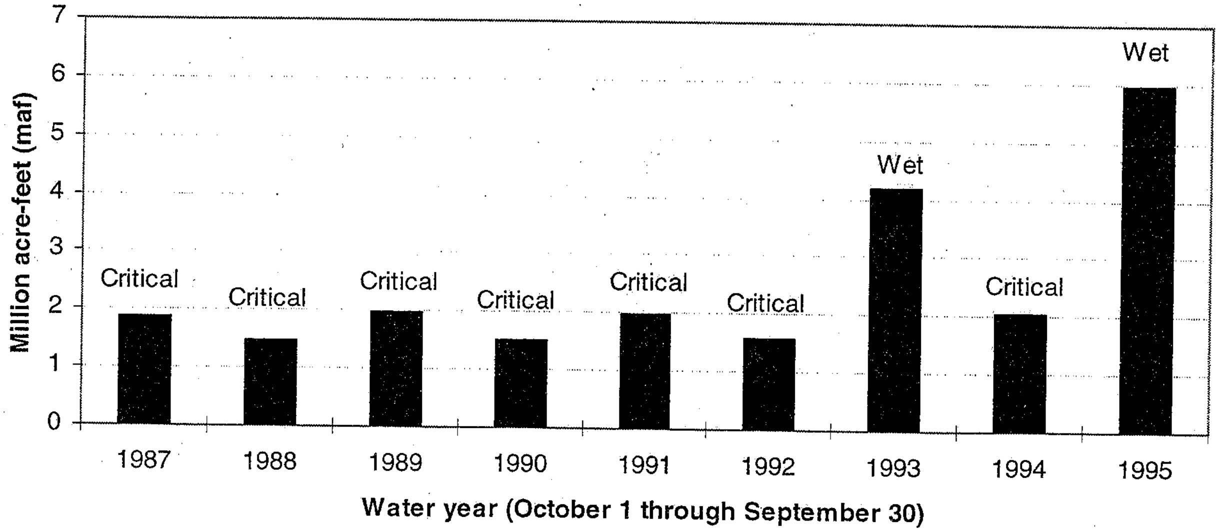


Figure 3 San Joaquin River Hydrologic Region 60-20-20 Index from 1987 to 1995

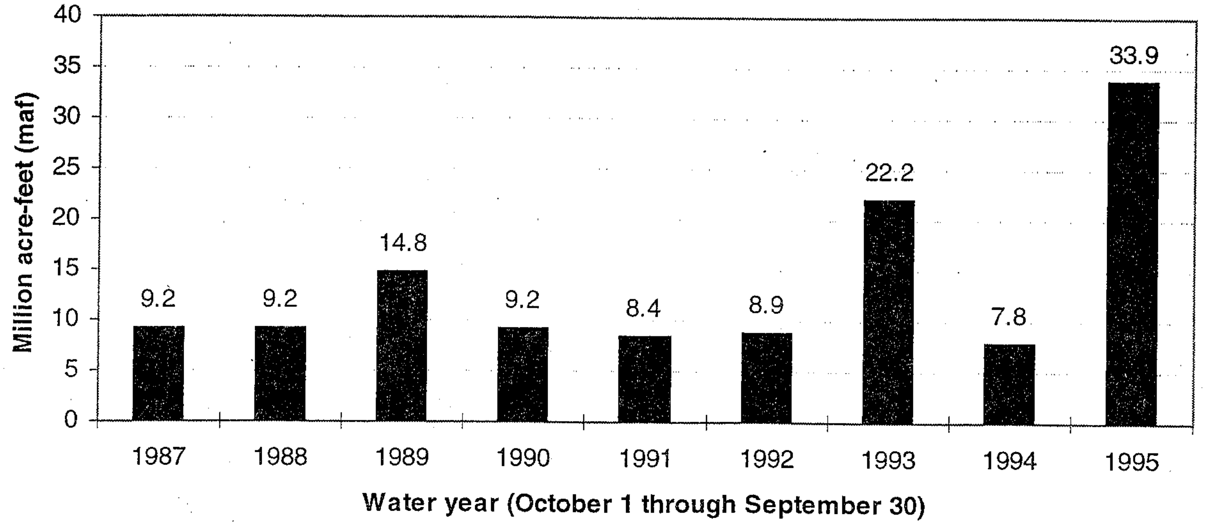


Figure 4 Sacramento River Unimpaired Runoff from 1987 to 1995

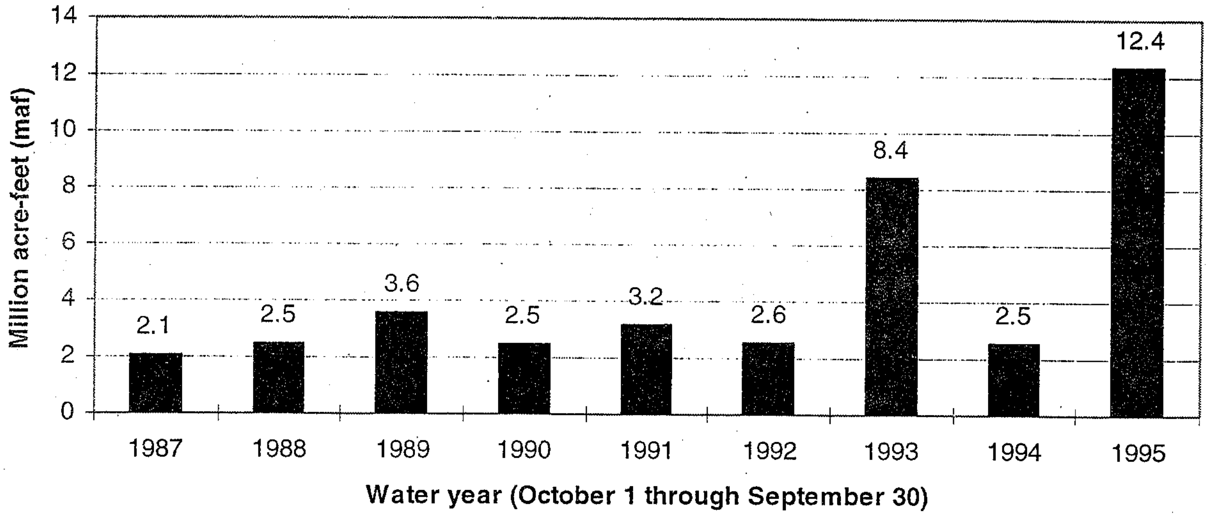


Figure 5 San Joaquin River Unimpaired Runoff from 1987 to 1995

Precipitation, snowpack, runoff, and reservoir storage were all above average for the 1995 water year. After a dry fall, heavy storms in January and March 1995 produced precipitation that was three times normal. Flooding occurred in northern California in January and in central California in March. Later, peak spring and summer runoff caused the lower San Joaquin River and some of its tributaries to rise to near or above flood warning stage during the second week of July.

By May 1, statewide seasonal precipitation was 165% of average, snowpack water content was 215% of average, seasonal runoff was 170% of average, and reservoir storage was 110% of average. Total storage in major SWP reservoirs on September 30 was 4.63 maf, considerably above the average end of the water year total storage of 3.34 maf.

Net Delta Outflow Index

The average monthly NDOI values were over 80,000 cfs from January through May of 1995 (Figure 6). These high indices reflect the high rainfall, snowpack, and runoff of the 1995 water year. DOI values are plotted in addition to NDOI values in Figure 6 to allow comparison of the 1995 water year with previous years. The DOI values in 1994 were approximately ten percent of the values in 1995 for the January through May period. The highest average monthly NDOI of 178,656 cfs for water year 1995 occurred in March.

Figure 7 shows average monthly streamflow in the Sacramento and San Joaquin rivers for calendar year 1995. From January through May, Sacramento River streamflow was about twice the normal average for these months at about 60,000 cfs. From March through May, San Joaquin River streamflow was about three times the normal average for these months. Average monthly San Joaquin River streamflow peaked at 22,000 cfs in May of 1995.

Compliance with Delta Water Quality Standards

During calendar year 1995, all existing and amended Decision 1485 water quality standards for a wet water year were met. New or amended water quality standards included the following: (1) the habitat protection EC standard; (2) a San Joaquin River salinity standard at Jersey Point; (3) a narrative objective for salmon protection; and, (4) a narrative objective for brackish tidal marshes of Suisun Bay[11]. Excess conditions began in December of 1994, and continued through April of 1996. This was the longest period of excess conditions since the 1982-1983 water year. Export limits were modified in 1995 to include a maximum export rate of 35% of inflow from February through June and a maximum export rate of 65% of inflow from November through January, and were met.

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[11] Narrative Standard—Water quality conditions sufficient to support a natural gradient in species composition and wildlife habitat characteristic of a brackish marsh throughout all elevations of the tidal marshes bordering Suisun Bay shall be maintained. Water quality conditions shall be maintained so that none of the following occurs: (a) loss of diversity; (b) conversion of brackish marsh to salt marsh; (c) for animals, decreased population abundance of those species vulnerable to increased mortality and loss of habitat from increased water salinity; or (d) for plants, significant reduction in stature or percent cover from increased water or soil salinity of other water quality parameters.

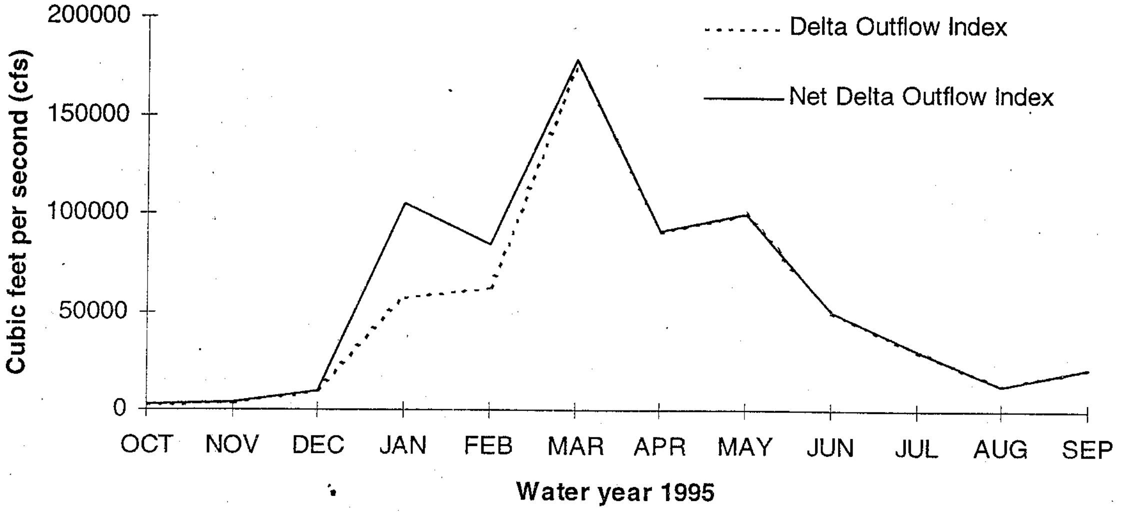

Figure 6 Average monthly Delta Outflow for Water Year 1995

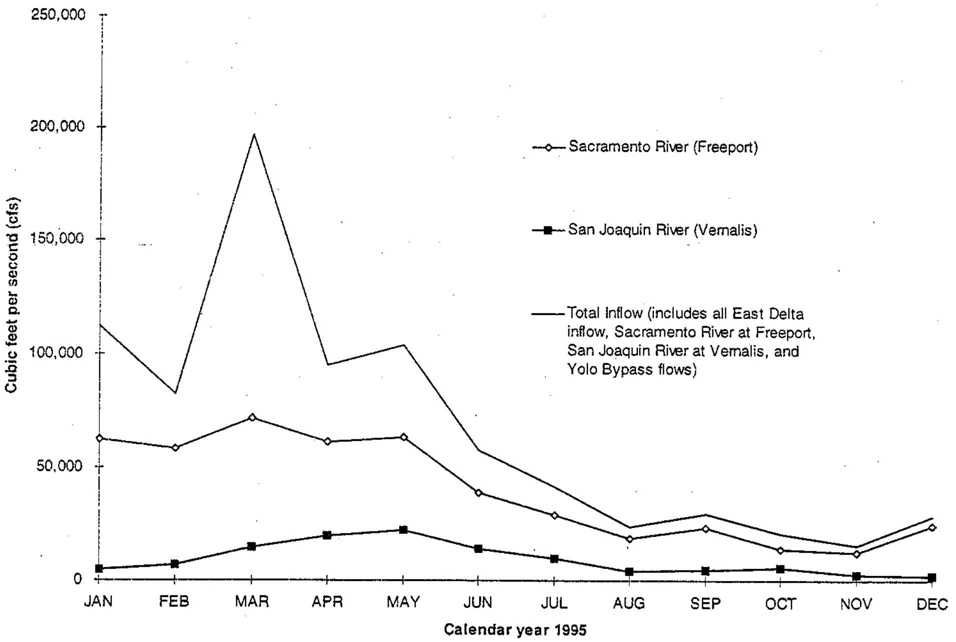

Figure 7 Average monthly streamflow in the Sacramento and San Joaquin rivers for calendar year 1995

Chapter 2
WATER QUALITY

As a requirement of Decision 1485, water quality samples are taken semimonthly to monthly from 26 locations throughout the Delta, Suisun Bay, and San Pablo Bay (see Figure 1). Changes in water quality are used to help assess the impact of State Water Project and Central Valley Project operations on estuarine biota, and to determine compliance with water quality standards. The regions of the estuary and their representative sampling sites are shown in the following table.

Region	*Representative Stations*
Northern Delta	C03
Lower Sacramento River	D04, D22, D24
Lower San Joaquin River	D16, D19, D26
Western Delta	D11, D12, D14, D15
Central Delta	C09, D28A, P10A
Eastern Delta	MD7, MD10
Southern Delta	C07, C10, P08, P12
Suisun Bay	D06, D07, D08, D09, D10
San Pablo Bay	D41

Regions were determined from hierarchical cluster analysis of stations using average monthly discrete water quality data. The analyses grouped stations for which 14 water quality variables demonstrated similar patterns over time (DWR 1997). The variables were: specific conductance, water and air temperature, dissolved oxygen, nitrate, orthophosphate, silica, chlorophyll and pheophytin concentration, water transparency (Secchi disk depth), pH, wind velocity, suspended solids, and turbidity.

General Patterns

Differences can occur in water temperature between regions because of differences in the geomorphology of each region and because of differing degrees of wind-induced mixing of the water column, tidal mixing, and seasonal inflows. Water temperatures increased during the summer for all Delta regions, but were highest (maximum of 25 °C) for the eastern and central regions where there was low inflow, little tidal influence and longer water residence times. Lower summer water temperatures (maximum of 21 °C) were seen in the northern Delta where there was greater inflow and shorter water residence times and the bay regions where there was greater tidal influence.

Specific conductance varied between regions due to volume of inflow and tidal influence. In general, inflow was high and salinities were low in all regions relative to other water years. There was only minor salinity intrusion into Suisun and San Pablo bays in November and December when Delta outflow was low. Specific conductance in Suisun and San Pablo bays was low when compared to 1994, a critically dry year.

A pattern of increasing water transparency compared to historical values continued in 1995. The annual average Secchi disk depth, a measure of water transparency, was 0.57 m in 1995. Although this value is similar to the average Secchi disk depth of 0.58 m measured for all sites for 1970 to 1993, wet water years had 7% to 30% lower water transparency than the average (DWR 1996). The high annual average water transparency compared to other wet years continues the trend of increased water transparency measured since the late 1970s (DWR 1996). In general, maximum water transparency was seen in late fall due to decreased inflows and decreased phytoplankton populations.

Dissolved oxygen concentrations were high compared to previous dry water years. Although dissolved oxygen concentrations in all regions decreased slightly during the summer, none of the regions experienced great fluctuations in dissolved oxygen concentration. The lowest monthly average dissolved oxygen values (6.4 to 6.6 mg/L) occurred in the central and southern Delta regions in July and August 1995.

Nutrient concentrations[12] (nitrate, ammonia, and orthophosphate) in the Delta and Suisun and San Pablo bays were generally low during the 1995 year. Nutrient

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[12] Nutrient concentrations in the text and Figures 8 through 16 are represented as nitrate for nitrate-nitrogen, ammonia for ammonia-nitrogen, orthophosphate for orthophosphate-phosphorus, and silica for silicon dioxide.

concentrations increased slightly for all stations during the winter periods of January through March and November through December 1995. These increased concentrations could have resulted from reduced utilization of nutrients by plankton during the cold weather periods and increased nutrient concentrations from surface runoff.

Northern Delta

The Sacramento River and the Yolo Bypass system during times of high flow provide most of the inflow to the northern Delta region. The water quality of this region is characterized by lower water temperatures, lower salinity (as measured by specific conductance), higher dissolved oxygen and lower pH (range of 6.2 to 7.5) than other regions of the Delta (DWR 1996) (Figure 8)[13]. In 1995, Sacramento River flows were high, averaging 40,000 cfs (see Figure 7). The annual average water temperature of 14.2 °C was significantly lower than the historical annual average water temperature of 16.6 °C in the upper estuary (DWR 1996). Compared to the critically dry 1994 water year, water year 1995 had lower water temperatures, water transparency, specific conductance, and pH values. Dissolved oxygen levels were higher in 1995, ranging from 8.1 to 10.9 mg/L as compared to 7.1 to 10.6 mg/L in 1994. Nutrient levels (nitrate, ammonia, and orthophosphate) were generally lower in 1995 than 1994, due in part to high inflows.

Seasonal trends seen in the northern Delta data include an increase in water temperatures (up to 21 °C) and a corresponding decrease in dissolved oxygen levels (down to 8.1 mg/L) during the summer. Salinity, nutrient concentrations, and wind velocities peaked within the period from October through December 1995. The elevated ammonia and silica concentrations could be the result of wind-induced mixing and resuspension of settled sediment, as well as reduced uptake by plankton.

Lower Sacramento River

Both tides and inflow from the Sacramento River affect the water quality of the lower Sacramento River region. When compared to the northern Delta region, the lower Sacramento River water temperatures were significantly warmer (2 °C), salinity was slightly higher, and the water was more basic (Figure 9). The range of dissolved oxygen levels in the lower Sacramento River was similar to the range of values in the northern Delta region. Nitrate, ammonia, and orthophosphate levels were low throughout the year and silica levels were highly variable.

Salinity, as measured by specific conductance, was less than 200 µS/cm from January through July, when outflows were relatively high. In August and November, salinity peaked at 700 and 900 µS/cm, respectively, when Sacramento River flows had decreased. Water transparency also increased in the late summer and fall. Because of the high outflows, the annual average specific conductance in 1995 (265 µS/cm) was significantly lower than in 1994 (2,327 µS/cm).

Lower San Joaquin River

Water quality in the lower San Joaquin River is affected by the tides and inflows from the San Joaquin River. Flows in the San Joaquin River were high throughout 1995 and peaked in March 1995. Water temperatures were similar to those in the lower Sacramento River and followed the same seasonal trend (Figure 10). Specific conductance ranged from 100 to 300 µS/cm in 1995, much lower than in 1994 when specific conductance ranged from about 500 to 2,000 µS/cm. The maximum salinity occurred in March and corresponded with flood events and increased surface runoff. Elevated nutrient concentrations were also measured from January through March 1995 due to large amounts of runoff into the San Joaquin River. However, nutrient concentrations were somewhat lower than in 1994, a critically dry year.

Dissolved oxygen levels in 1995 (7.8 to 10.0 mg/L) were similar to levels in 1994 (7.2 to 10.5 mg/L) and to historical levels (DWR 1996). Mid-range pH levels in 1995 (7.2) were slightly lower than in 1994 (7.5).

Overall, the average Secchi disk depth in the lower San Joaquin River was among the greatest of all regions within the Delta, with maximum values of 0.9 to 1.2 m measured from September through November when inflows were relatively low and water transparency was high. Water transparency was apparently slightly reduced in the winter due to increased sediment transport associated with higher flows, and also in the summer due to elevated standing crops of phytoplankton.

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[13] Figures 8 through 16 represent the average of the monthly discrete water quality data obtained at the representative stations included in each region.

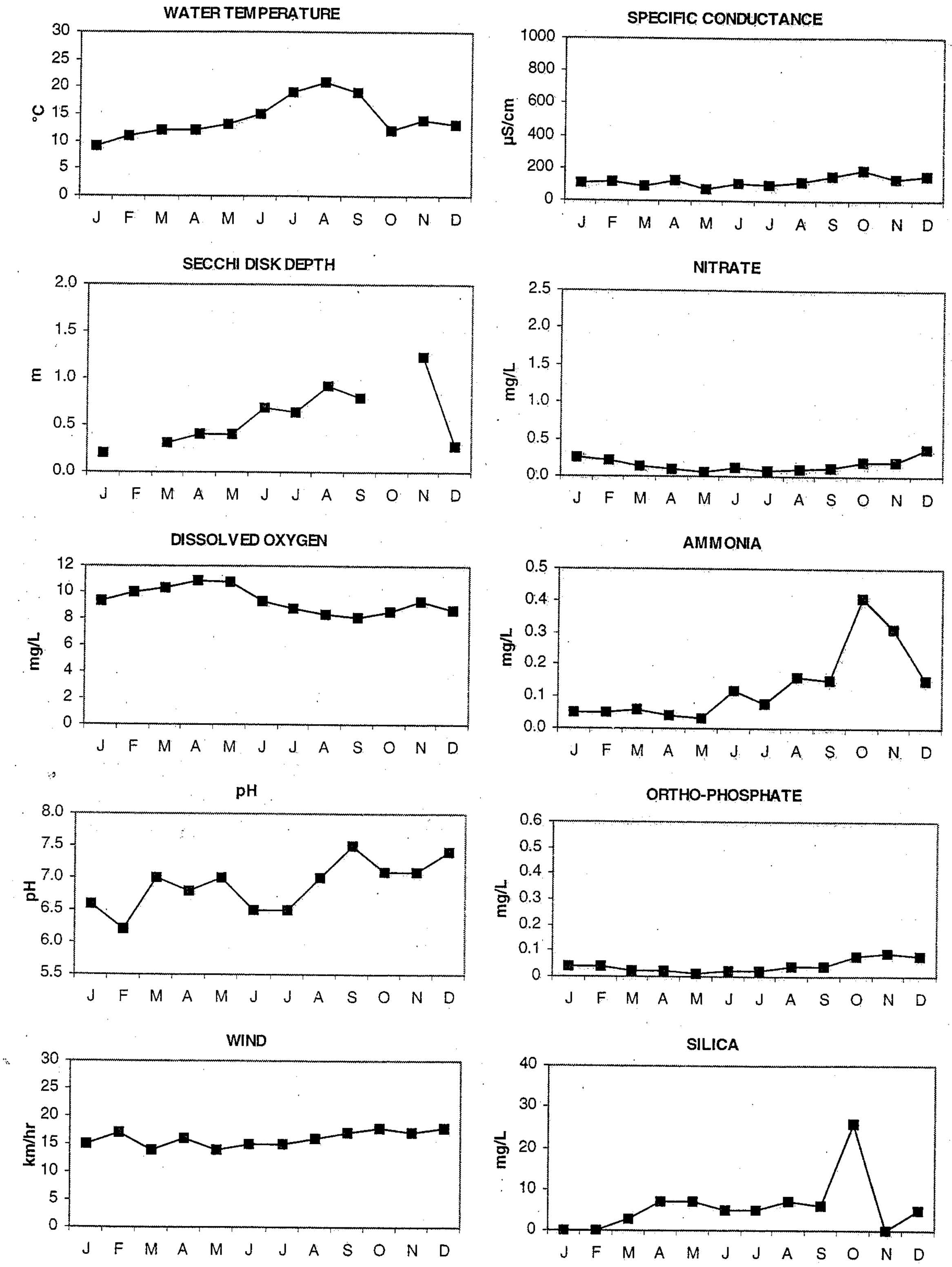


Figure 8 Water quality in the northern Delta during 1995

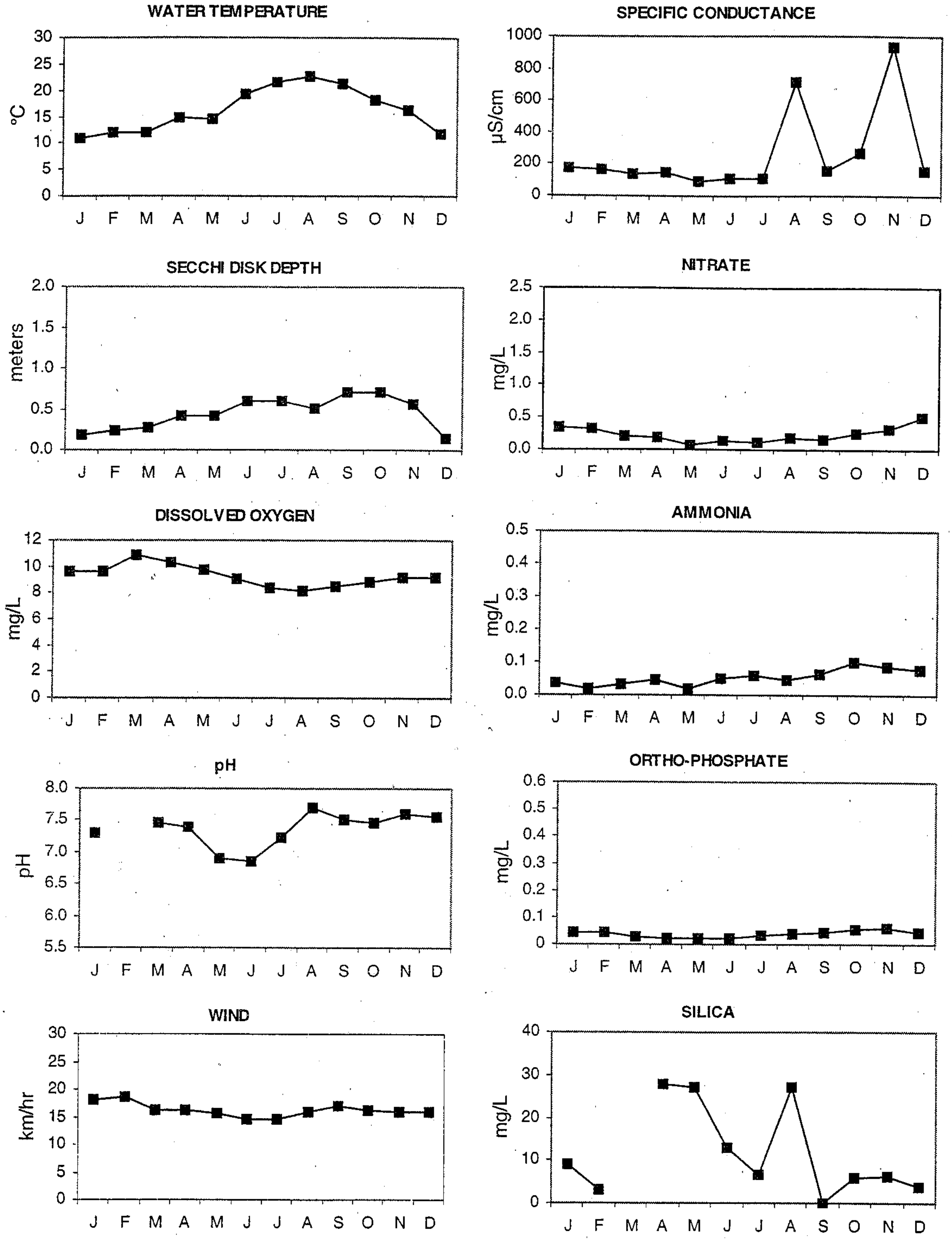


Figure 9 Water quality in the lower Sacramento River during 1995

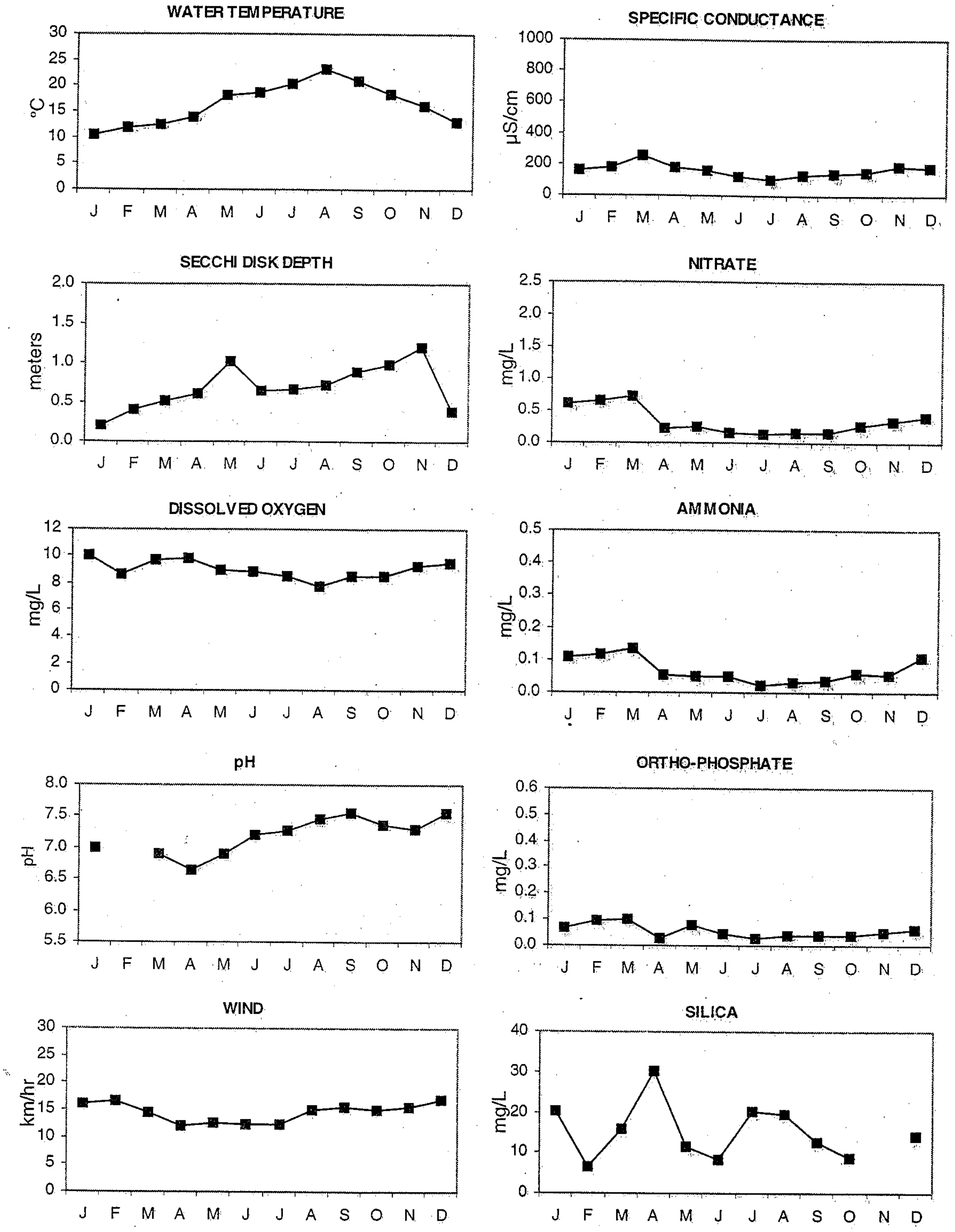


Figure 10 Water quality in the lower San Joaquin River during 1995

Western Delta

This region includes the confluence of the Sacramento and San Joaquin rivers. Water quality in this region is affected by flow in these rivers, tidal fluctuation, and salinity intrusion. Water temperatures were slightly higher (0.5 °C) than water temperatures in the lower Sacramento and lower San Joaquin regions (Figure 11). Salinities were generally intermediate between the salinities of the lower Sacramento River and the lower San Joaquin River regions. Specific conductance was relatively low from January through October (<240 µS/cm) and peaked at 819 µS/cm in November, when river inflows were at their lowest. Water transparency increased in the late summer and fall corresponding with decreased flows in the Sacramento and San Joaquin rivers.

As with the lower Sacramento and lower San Joaquin rivers, increased nitrate, ammonia, and orthophosphate concentrations were measured from January through March, coinciding with high winter runoff. Silica levels were variable throughout the year. As with the other regions in the Delta, pH levels decreased in the western Delta during the high winter runoff period and increased throughout the summer and fall due, in part, to increased algal productivity.

Central Delta

The central Delta region includes the Old and Middle rivers. Water quality in this region is influenced by low summer and fall stream inflow, longer water residence times than regions in the Sacramento and San Joaquin rivers, and high phytoplankton biomass. Water temperatures were higher in the central Delta (August maximum of 25 °C) than in most other regions (Figure 12). Dissolved oxygen levels in the central Delta averaged 7.9 mg/L. The July dissolved oxygen level of 6.5 mg/L measured in the central Delta was among the lowest measured at all regions in 1995.

Salinity in the central Delta region was relatively low (<400 µS/cm), but was elevated during the high outflow winter period and peaked in March 1995 as it did in the lower San Joaquin River region. Although this peak is not normally seen during high flow periods, it is apparently the result of high concentrations of dissolved solids in surface runoff occurring during the flooding of the San Joaquin River watershed. Winter nutrient concentrations (nitrate, ammonia, and orthophosphate) also were elevated due to high inflows into the central Delta during this period.

Eastern Delta

The eastern Delta region is north of the San Joaquin River and east of the Mokelumne River. The Sacramento and San Joaquin rivers, as well as smaller rivers and creeks such as the Mokelumne River and Bear Creek, influence water quality in this region. Sacramento River water enters this region when the Delta Cross Channel between the Sacramento River and the Mokelumne River is open. Delta Cross Channel gates were closed from January 4 through mid-July due to sustained high Delta outflows. The gates were open for most of the period from August through December 1995 when Delta outflows had decreased.

During 1995, water temperatures slowly increased to a July maximum of 25 °C (Figure 13). When the Delta Cross Channel gates were opened in late July, the eastern Delta stations received cooler Sacramento River water and water temperatures in this region decreased. Water transparency also increased after July, due, in part, to the presence of the less turbid Sacramento River water. The average annual water temperature in the central Delta during 1995 was 16.8 °C, and was slightly lower than the 1994 annual average temperature of 17.2 °C. Salinity in the eastern Delta was among the lowest of all Delta regions, and was lower than what would have been expected during a normal or dry year due to the wet year conditions. For example, the annual average salinity was 163 µS/cm in 1995, compared to 246 µS/cm in 1994, a critically dry year. Nutrient levels (nitrate, ammonia, and orthophosphate) were higher during the winter (January through March and December) due to transport from runoff during these high inflow months.

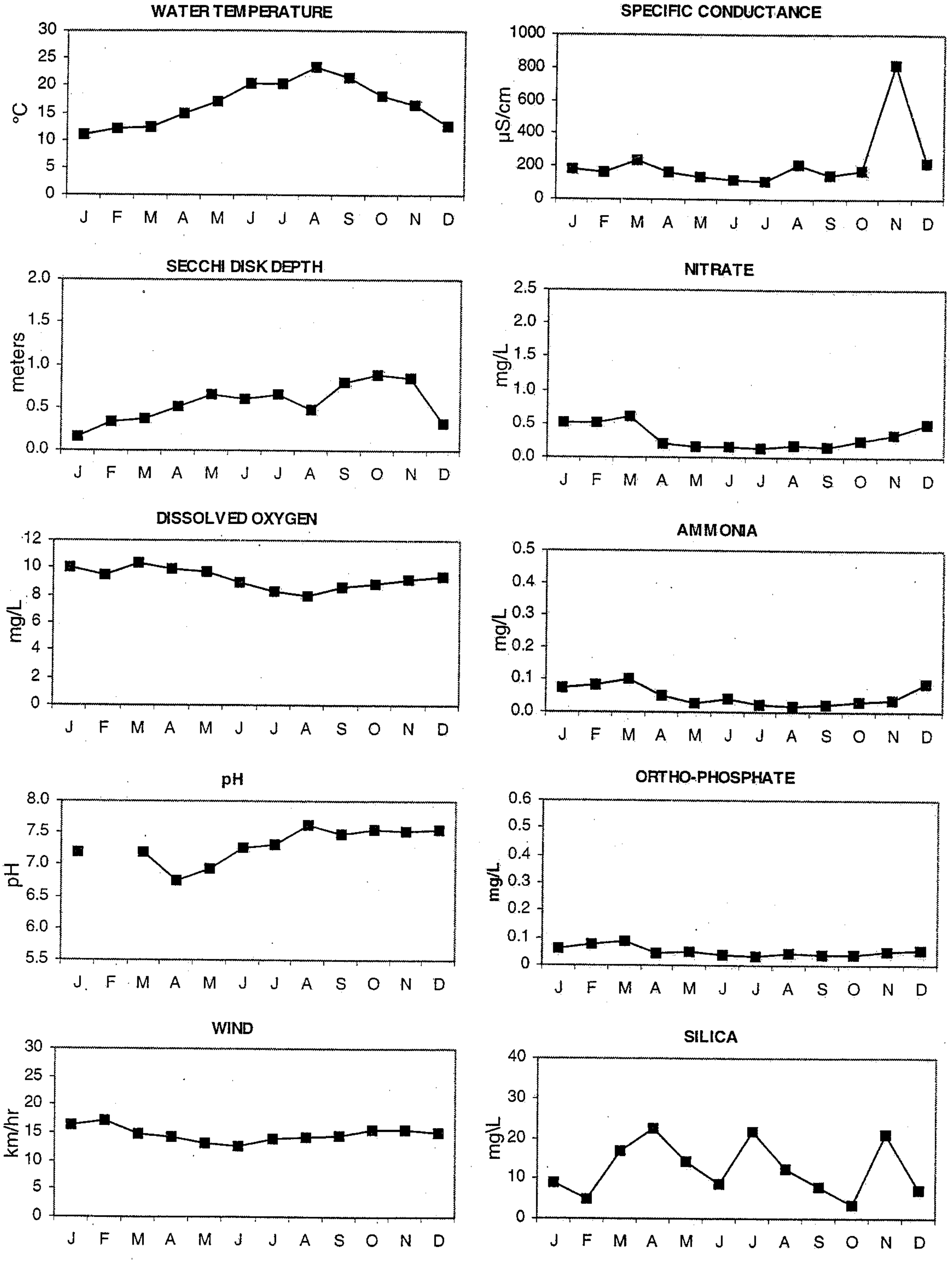


Figure 11 Water quality in the western Delta during 1995

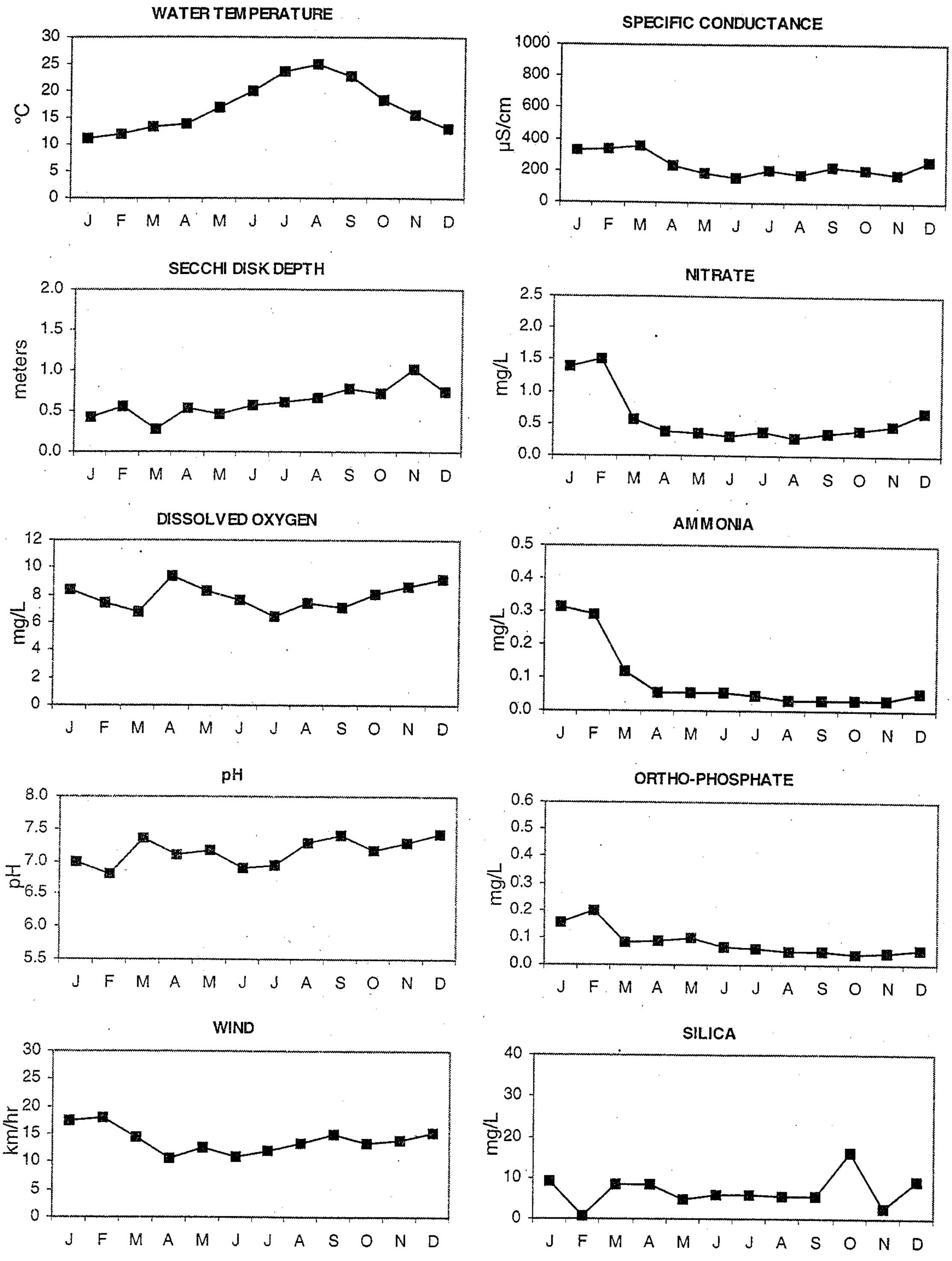


Figure 12 Water quality in the central Delta during 1995

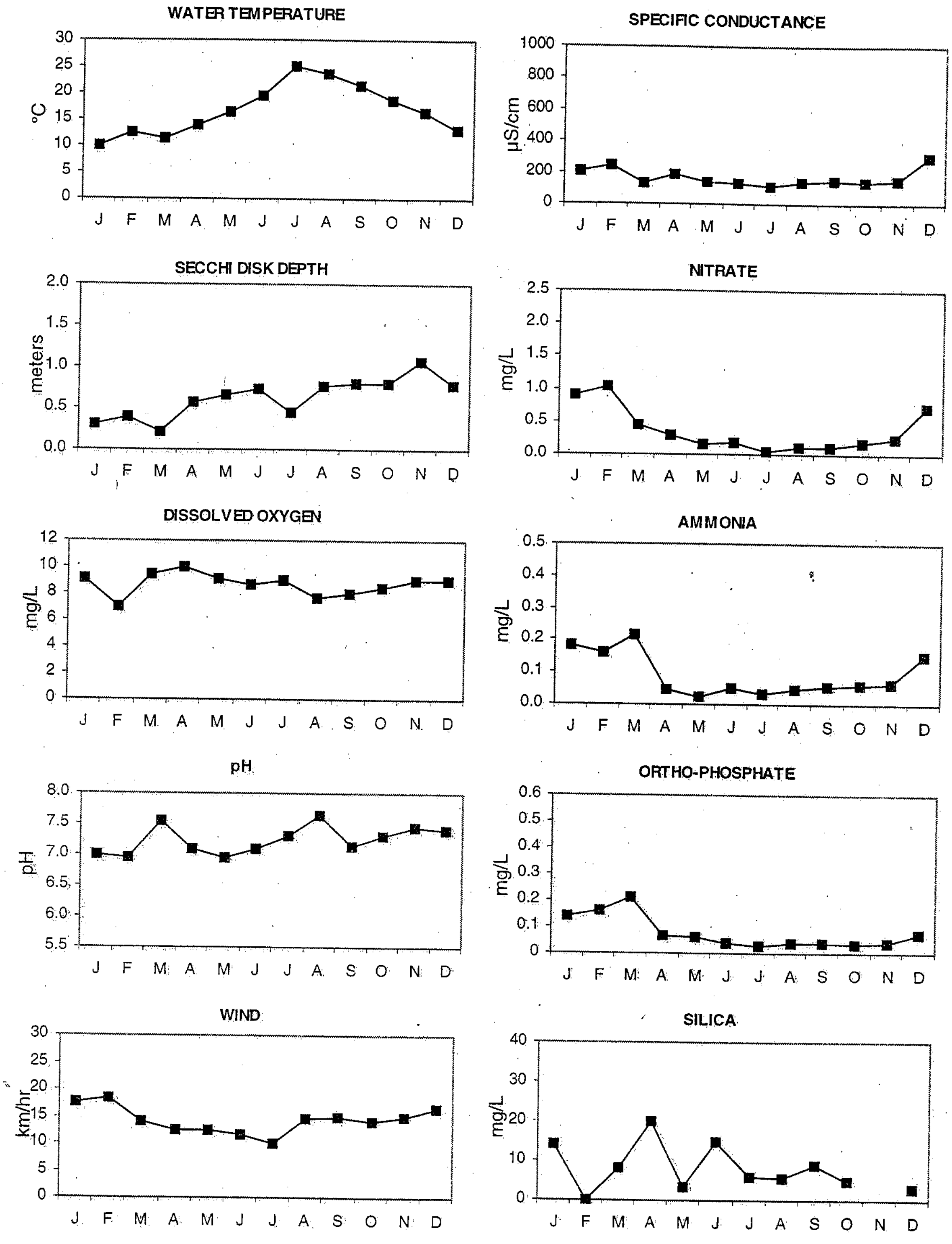


Figure 13 Water quality in the eastern Delta during 1995

Southern Delta

The southern Delta region includes the San Joaquin River from the Stockton area southward and the upper Old River, which branches off the San Joaquin River and flows westward towards Clifton Court Forebay. Water quality in this region is influenced by low summer and fall inflow, minimal tidal influence, high summer phytoplankton chlorophyll concentrations, and long water residence times. Water quality data for this region are summarized in Figure 14.

Water temperatures in this region were higher than those in the northern Delta and bay regions but lower than water temperatures in the eastern and central Delta. The maximum monthly water temperature of 24 °C occurred in August. Dissolved oxygen levels were relatively stable in this region and ranged from a low of 6.4 mg/L in August to a high of 9.2 mg/L in April. The low summer dissolved oxygen levels occurred when summer water temperatures were at their highest. Water transparency was 0.5 m or less from January through October due, in part, to a combination of high phytoplankton concentrations and turbid irrigation return waters.

Salinity levels in the southern Delta region were highly variable and were higher than all other Delta regions, except the bay regions where salinity intrusion is a factor. Salinity in this region is the result of San Joaquin River streamflow and summer agricultural irrigation runoff. As winter and spring flows in the San Joaquin River increased, salinity decreased with a minimum monthly average of 174 µS/cm measured in May of 1995. Salinity then gradually increased throughout the summer with a monthly average peak of 536 µS/cm measured in August. The peak was probably the result of agricultural drainage and low inflows. Salinity continued to increase in November and December when flows in the San Joaquin River were at a minimum and irrigation return flows continued.

A localized dissolved oxygen depression occurs annually in the South Delta region within the eastern Stockton Ship Channel. A special study of the depression is summarized in Chapter 6.

Suisun Bay

The Suisun Bay region includes Suisun Bay and the combined channels west of the confluence of the Sacramento and San Joaquin rivers. This region experiences tidal mixing, salinity intrusion during drought years, and high inflow during non-drought years. The introduced Asian clam, *Potamocorbula amurensis*, is abundant in this region. *P. amurensis* filters the water in this region reducing suspended materials (Alpine and Cloern 1992).

Water temperatures were relatively low, ranging from 11 °C in January 1995 to 22 °C in August 1995, with an annual average of 16 °C (Figure 15). In 1995, the annual average salinity (3,200 µS/cm) was significantly lower than that of 1994 (14,600 µS/cm), and reflected the high outflow conditions throughout much of 1995. In fact, specific conductance in Suisun Bay was less than 1,500 µS/cm from January through July of 1995. Salinity intrusion occurred from August through December 1995, when inflows were low. The maximum salinity value of 13,150 µS/cm was measured in November. Dissolved oxygen concentrations in 1995 were stable, ranging from 8.0 mg/L in August 1995 to 10.7 mg/L in March 1995.

Transparency in Suisun Bay averaged 0.34 m in 1995, was the lowest of all regions, and was slightly lower than the 0.45 m average measured in 1994. Sediment transport from high inflows and wind-induced mixing of the water column and associated resuspension of sediment probably contributed to this low water transparency. Nitrate, ammonia, and orthophosphate concentrations were low throughout the year and increased slightly in December when phytoplankton productivity was relatively low. Silica concentrations were variable with peaks in March, May, July, and December. Minimum silica levels in June and September appear to be due to silica utilization by phytoplankton.

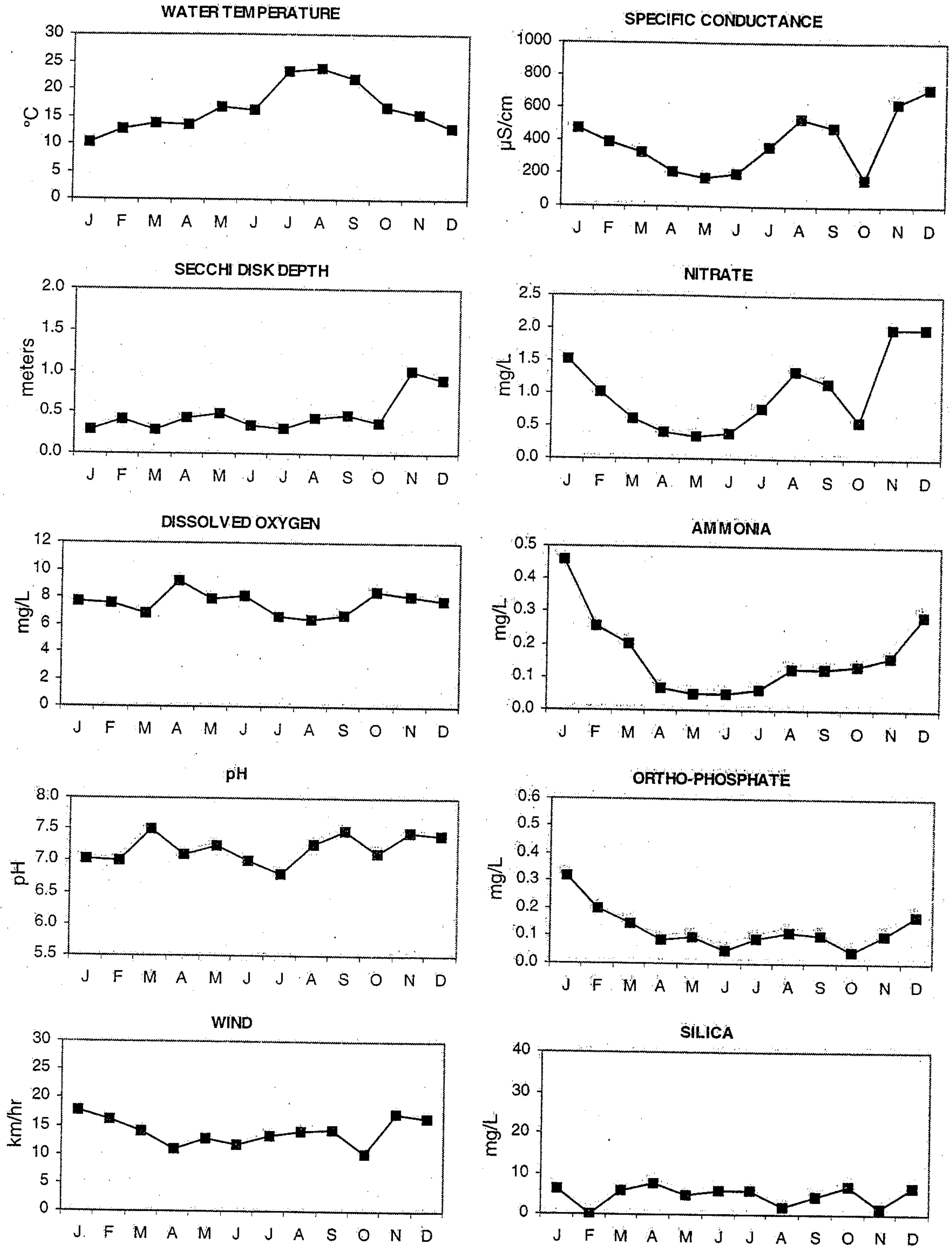


Figure 14 Water quality in the southern Delta during 1995

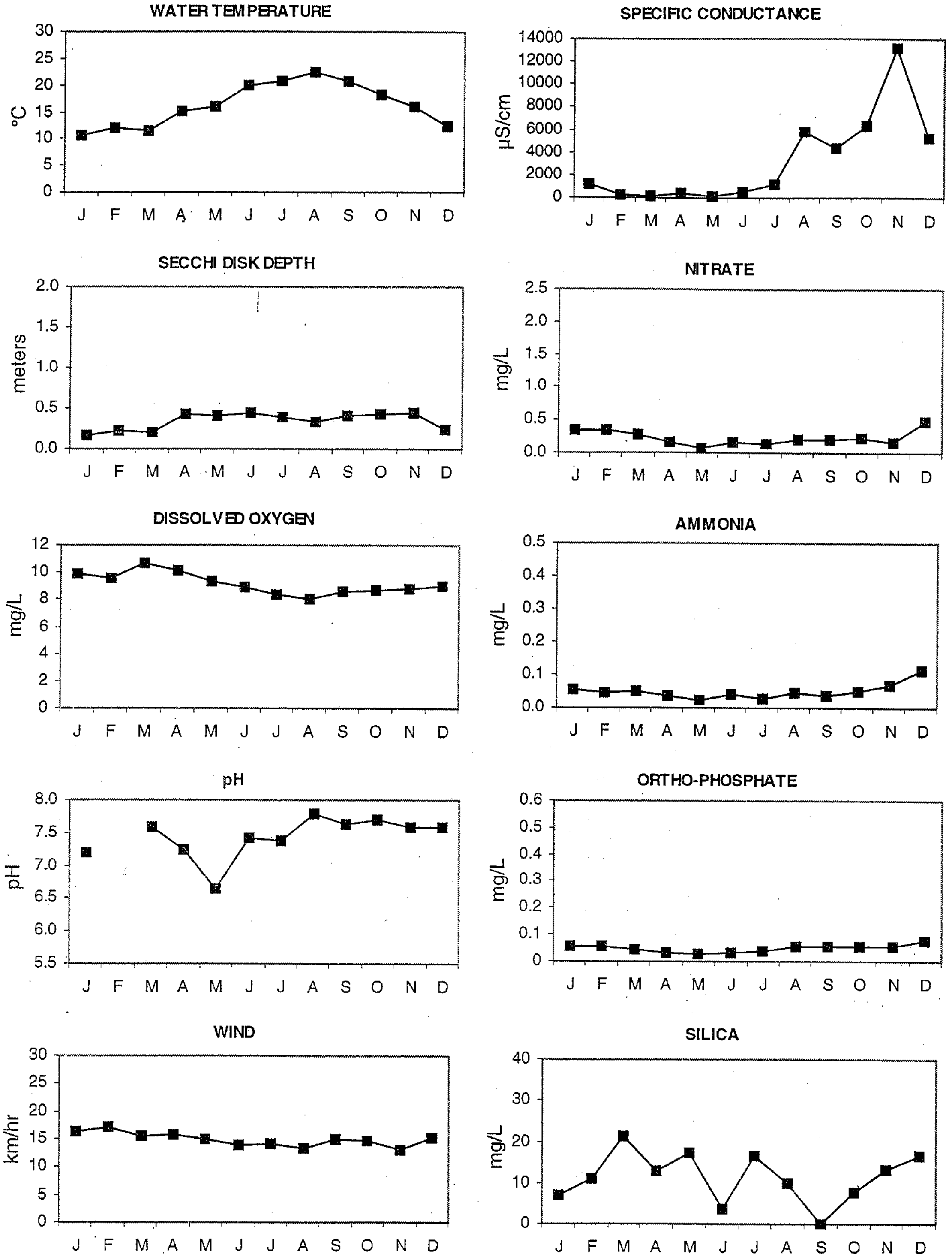


Figure 15 Water quality in Suisun Bay during 1995

San Pablo Bay

The San Pablo Bay region is the westernmost region, is represented by one station, and is subject to the strongest tidal influence and salinity intrusion of all of the regions described. *P. amurensis* is also abundant in this region. Water temperatures were relatively low in San Pablo Bay in 1995, and ranged from a minimum of 11 °C in January to a maximum of 21 °C in September (Figure 16). Salinity in San Pablo Bay was the highest of all regions, but the 1995 levels were significantly less than levels measured in dry years. Average specific conductance from January through June of 1995 approached 20,000 μS/cm, which was approximately half of the 40,000 μS/cm average for the same time period in 1994. Salinity intrusion produced specific conductance measurements greater than 25,000 μS/cm during the low inflow months of August through December in 1995.

Water transparency averaged 0.81 m in San Pablo Bay in 1995 and was the highest of all regions sampled. The high transparency levels may be due to filtration of the water column by well-established populations of *P. amurensis*. Peak transparencies approaching 2.0 m were measured in November and December and could be due to continued *P. amurensis* filtration as well as salinity intrusion and reduced algal productivity.

Dissolved oxygen concentrations were high, relatively stable, and ranged from a low of 7.9 mg/L in November to a high of 10.5 mg/L in March. As with the Suisun Bay region, nutrient concentrations were relatively low throughout the year. Nutrient levels were higher in the winter (January through March and in December) when runoff carrying increased nutrient levels was relatively high and phytoplankton productivity was relatively low.

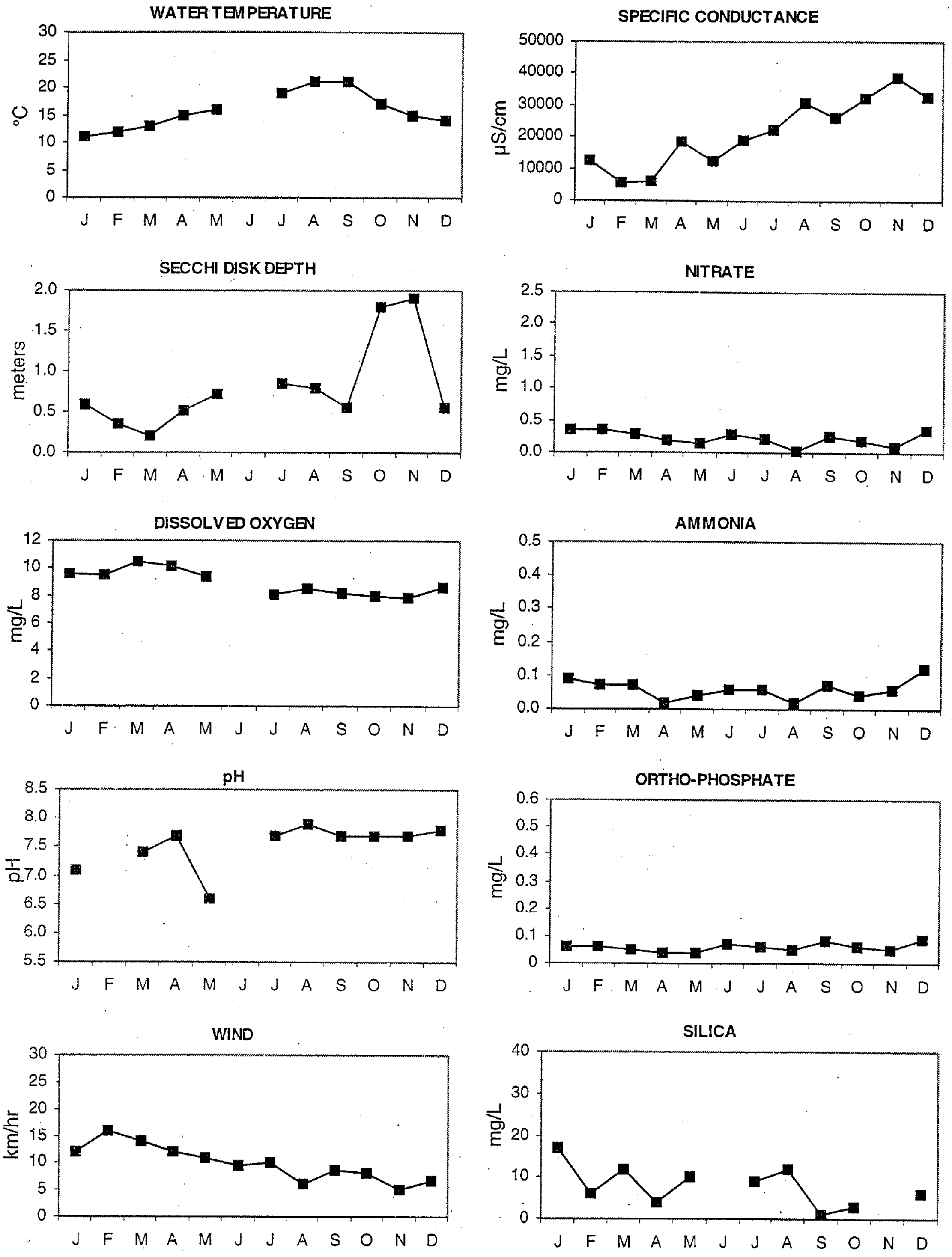


Figure 16 Water quality in San Pablo Bay during 1995

Chapter 3

CHLOROPHYLL *A* CONCENTRATION AND PHYTOPLANKTON COMMUNITY COMPOSITION

This chapter describes changes in chlorophyll *a* concentration (an estimate of phytoplankton biomass) and community composition for 1995 at various locations in the Delta and Suisun and San Pablo bays. As required by Decision 1485, the Department of Water Resources and U.S. Bureau of Reclamation collect phytoplankton samples at stations throughout the upper estuary. Samples are collected semimonthly or monthly for measurement of chlorophyll *a* concentration at 26 stations (see Figure 1) and for identification and enumeration of phytoplankton at 16 stations (Figure 17). For this summary, selected stations were grouped into regions based on a hierarchical cluster analysis as described in Chapter 2.

High percent chlorophyll *a* concentration is used as an indicator of actively growing phytoplankton cells. Percent chlorophyll *a* concentration is computed as the ratio of chlorophyll *a* concentration to chlorophyll *a* plus phaeophytin concentration multiplied by 100. Percent chlorophyll *a* concentration increases during the initial phase of a phytoplankton bloom, when cell division is exponential, and decreases during the decline phase of a bloom, when pigment breakdown products increase.

Figures 18 through 26 describe average monthly chlorophyll *a* concentration and percent chlorophyll *a* concentration at regions in the estuary during 1995.

Chlorophyll *a* concentrations were below 5 µg/L for six of the nine regions in the Delta during 1995. Concentrations below 5 µg/L persisted in the northern Delta, lower Sacramento River, lower San Joaquin River, western Delta, central Delta, and Suisun Bay. Peak chlorophyll *a* concentrations occurred in the spring for three of the regions: in May for the northern Delta and lower Sacramento River and in April for Suisun Bay. For the lower San Joaquin River, western Delta, and central Delta, summer chlorophyll *a* concentrations peaked in August. Peak chlorophyll *a* concentration commonly occurs in the spring for the Delta (DWR 1996), and the summer peak in 1995 may have been due to high streamflows caused by floods in January 1995. Flushing associated with flood flows may also have contributed to the unusually low chlorophyll *a* concentrations in 1995, which were lower than those measured in the wet years before the 1987 to 1992 drought (DWR 1996).

Phytoplankton growth in regions with low chlorophyll *a* concentrations was moderate. Percent chlorophyll *a* concentrations commonly ranged between 40% and 70% with the highest percentages occurring near months with peak chlorophyll *a* concentrations.

Phytoplankton species composition associated with the chlorophyll *a* maximum differed among regions. Diatoms comprised the chlorophyll *a* maximum in April and May for all regions. The chain-forming diatom, *Skeletonema potamos*, was abundant in the lower Sacramento River and Suisun Bay, and was accompanied by the diatoms *Asterionella formosa* and *Cyclotella* spp. in Suisun Bay. A mixed phytoplankton assemblage dominated by diatoms characterized the chlorophyll *a* maxima in the northern and central Delta. A mixed phytoplankton assemblage also characterized the chlorophyll *a* maximum in the lower San Joaquin River, but was replaced further downstream in the western Delta by the chain-forming diatom *Thalassiosira eccentrica*.

The highest chlorophyll *a* maxima were measured in the eastern (14 µg/L) and southern (10 µg/L) Delta in July, and in San Pablo Bay in August (15 µg/L). For all of these regions, background concentrations remained below 6 µg/L. These low background concentrations were unusual for the eastern and southern Delta, where concentrations commonly exceeded 20 µg/L in the early 1990s. In contrast, the maximum chlorophyll *a* concentration in San Pablo Bay was among the highest recorded.

Phytoplankton growth was relatively low in the eastern Delta where percent chlorophyll *a* concentrations were usually lower than 50%. Growth was somewhat higher in the southern Delta where percent chlorophyll *a* concentrations ranged from 40% to 60%, but the best growth was in San Pablo Bay where percentages were usually over 70%.

Chlorophyll *a* maxima in the eastern Delta were associated with the chain-forming diatom *Aulacoseira granulata. A. granulata* often forms blooms in the eastern Delta, but not upstream in the southern Delta where other diatoms and green algae are most abundant. The species composition in the chlorophyll *a* maximum for San Pablo Bay differed from the other regions and was comprised of the cryptophytes, *Rhodomonas lacustris* and *Cryptomonas ovata*, and the dinoflagellate, *Glenodinium* spp.

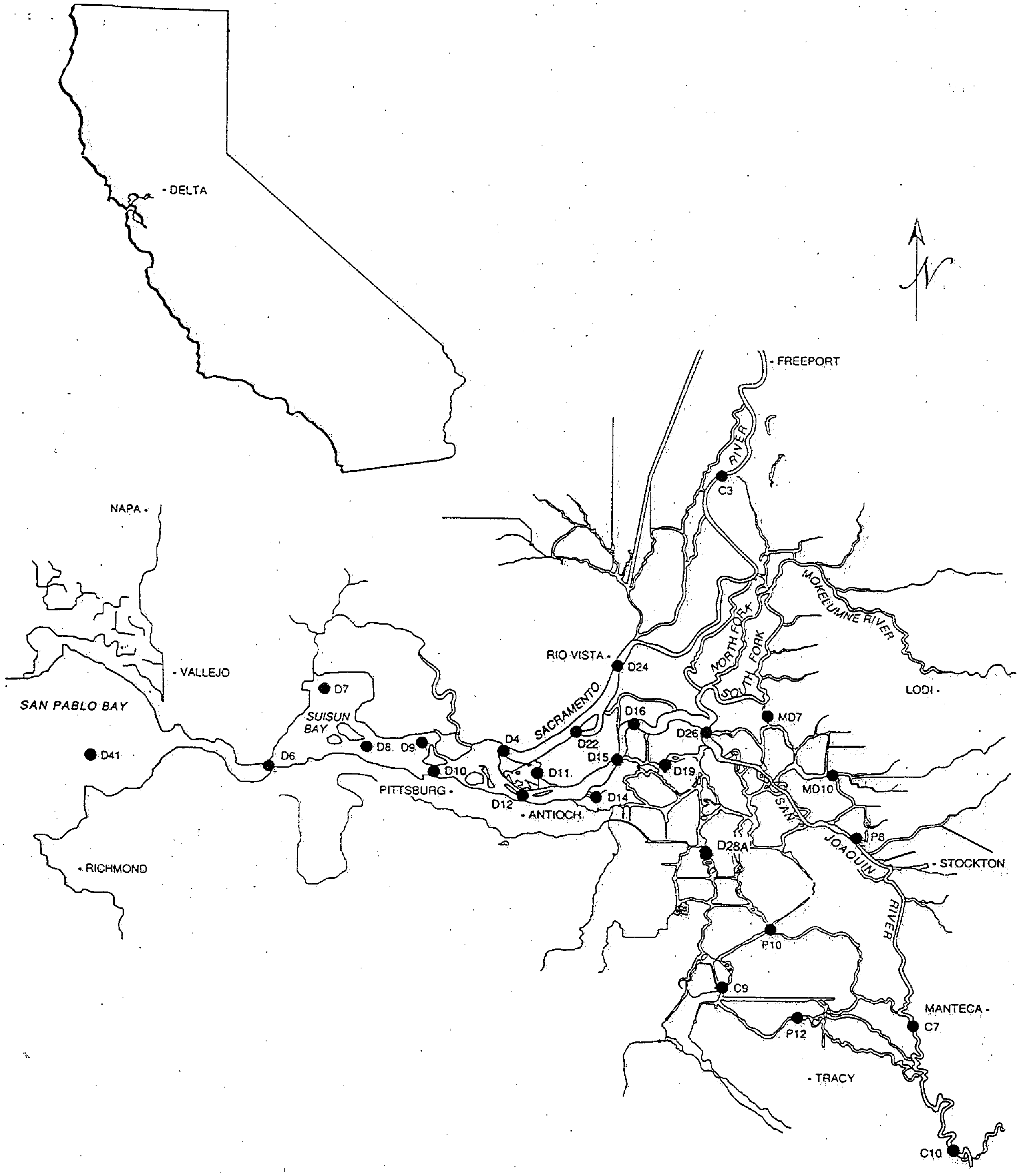


Figure 17 Sampling locations for chlorophyll *a* concentration and physical and chemical variables

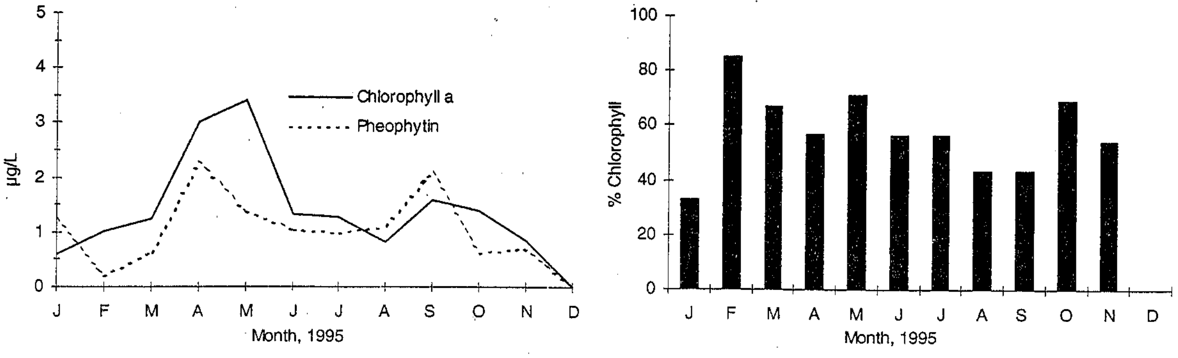


Figure 18 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in the northern Delta during 1995

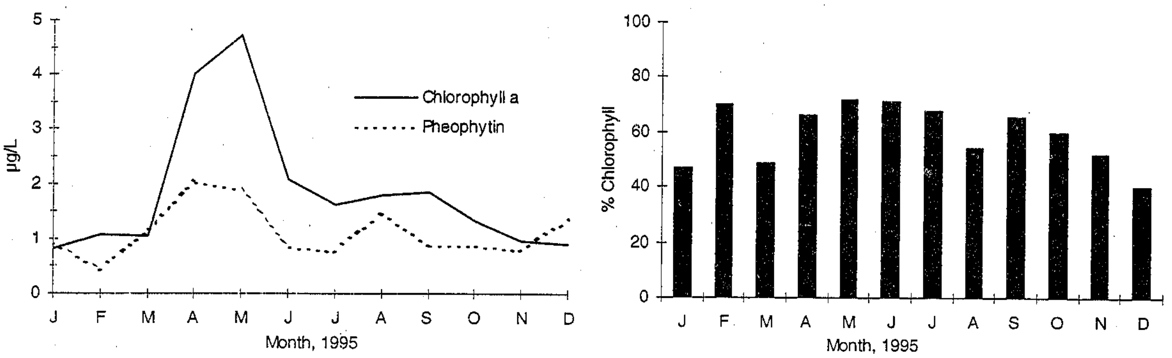


Figure 19 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in the lower Sacramento River during 1995

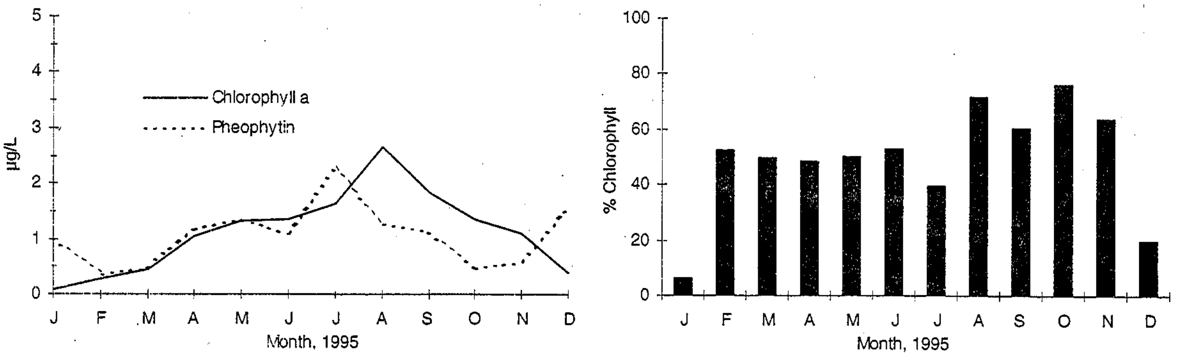


Figure 20 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in the lower San Joaquin River during 1995

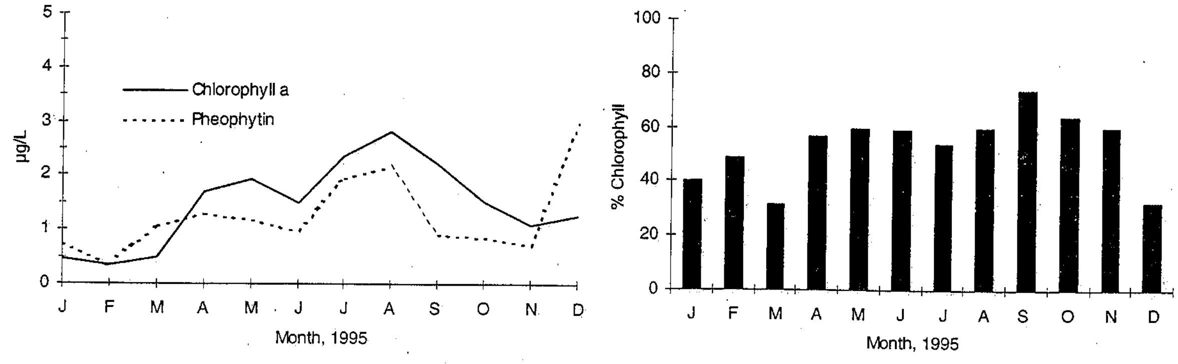


Figure 21 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in the western Delta during 1995

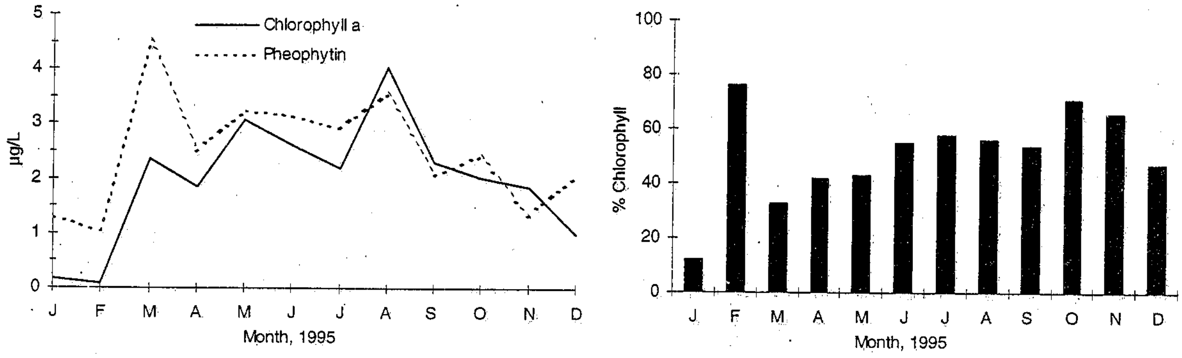


Figure 22 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in the central Delta during 1995

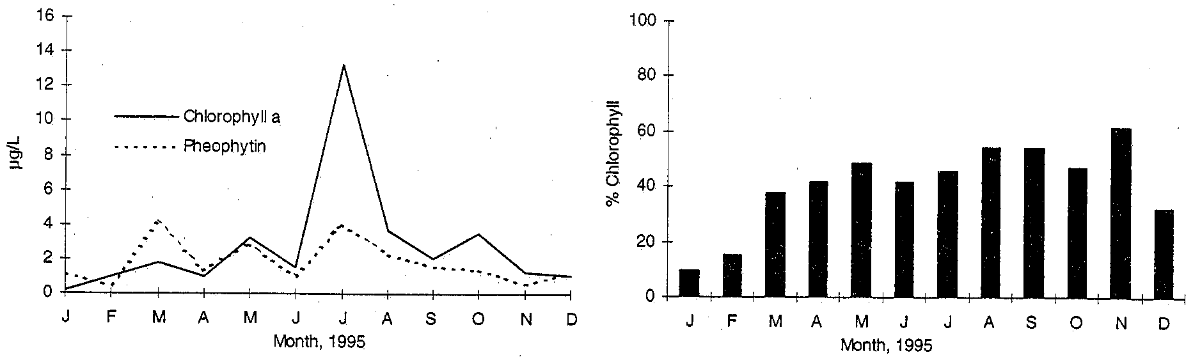


Figure 23 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in the eastern Delta during 1995

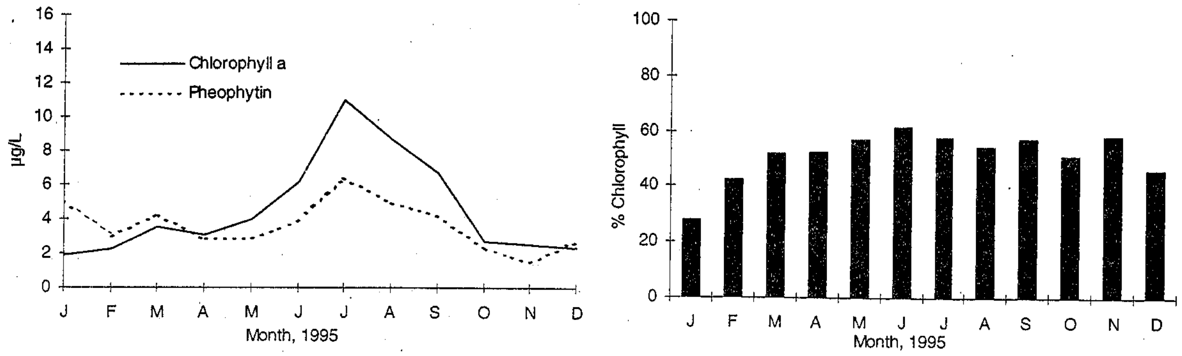


Figure 24 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in the southern Delta during 1995

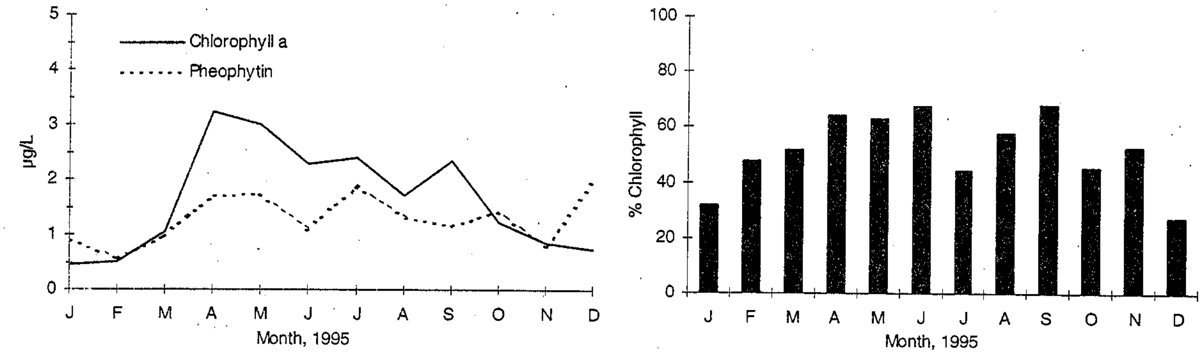


Figure 25 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in Suisun Bay during 1995

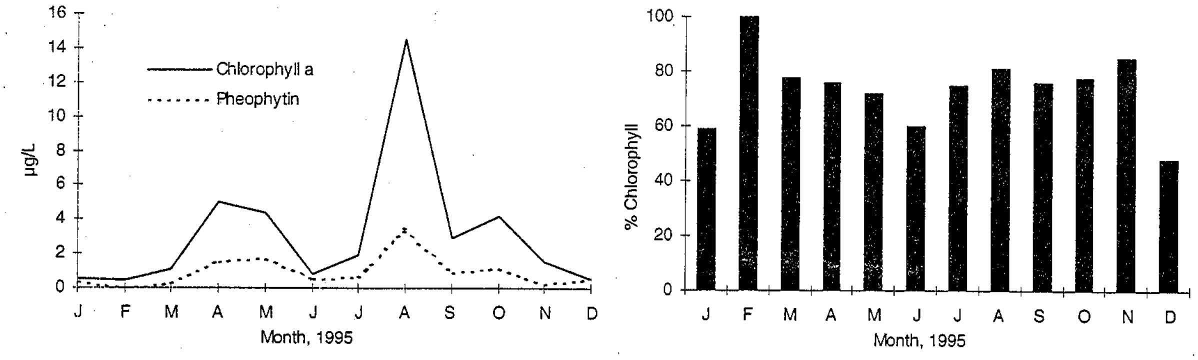


Figure 26 Concentrations of chlorophlyll *a* and pheophytin and percent chlorophyll in San Pablo Bay during 1995

Chapter 4
BENTHIC MONITORING

The benthic monitoring program is designed to document the distribution and abundance of benthic (bottom dwelling) organisms and substrate composition in the Sacramento-San Joaquin Delta and Suisun and San Pablo bays. The benthic community of the Delta and bays is a diverse assemblage of organisms; ranging from single-celled bacteria, fungi, and ciliates to large crabs and clams. The program monitors changes in the benthic macrofauna, which include organisms larger than 0.5 mm. Trends in substrate composition are used to establish associations between changes in benthic fauna and the surrounding habitat.

Since 1980, the benthic monitoring program has consisted of monthly bottom grab samples collected from five environmentally diverse sites (Figure 27). The sixth site, D41A, was added in 1991. Each site is divided into a maximum of three channel sectors: right bank (R), left bank (L), and center channel (C). Bottom grab samples for benthic macrofauna or substrate analysis are collected at the sites and sectors as indicated in Table 1.

A private laboratory identifies and counts the organisms in the macrofauna samples. Inorganic and organic content analyses, as well as particle size analyses of substrate samples are conducted by the DWR Soils and Concrete Laboratory. Inorganic and organic content are determined using ASTM test designation D2974-87 titled, "Moisture, Ash, and Organic Matter of Peat Materials Method C." Inorganic particle size is determined by ASTM designation D422-63 (Reapproved 1990), titled, "Particle Size Analysis of Soils." Particle size categories are fines (silt and clay, 1 to 100 µm), sand (0.1 to 1.5 mm), and gravel (1.5 to 50 mm).

This chapter reviews major changes in substrate composition and in benthic assemblage and abundance in calendar year 1995. Water year 1995 was classified as a wet year and included many extremely high runoff events from January through March of 1995. Channel scouring during highest runoff events resulted in many organisms being absent from their usual habitats during and immediately following the high flow period in the spring of 1995.

Table 1 Benthic and substrate sampling sites

Site	*Sector*[a]	*Type of Sample*[b]	*Habitat*
D4	R	Substrate/Benthos	River Channel
	C	Substrate/Benthos	
	L	Substrate/Benthos	
D7	R	Substrate	Shallow Bay
	C	Substrate/Benthos	
D11	R	Substrate	Flooded Tract
	C	Substrate/Benthos	
	L	Substrate	
D19	R	Substrate	Flooded Tract
	C	Substrate/Benthos	
	L	Substrate	
D28A	R	Substrate/Benthos	River Channel
	C	Substrate/Benthos	
D41A	R	Substrate/Benthos	Shallow Bay

[a] Sectors are determined while facing downstream (R = Right, C = Center, and L = Left).

[b] Substrate samples consist of one random grab. Benthic samples consist of three grabs.

Substrate Composition

Substrate composition in 1995 was similar to that measured during previous years, in spite of high outflow conditions in February, March, and April 1995. Water velocity and sediment carrying capacity were increased as a result of the extremely high outflows and flooding conditions in the Delta. Scouring from high flows left a slightly higher proportion of sand and reduced fines in deeper channel sites. However, relative substrate composition did not change as dramatically as would have been expected from the level of Delta outflow and the apparent displacement of benthic organisms. Substrate trends for 1995 are shown in Figure 28.

STA.
NO. **STATION NAME**

D4 – Sacramento River above Point Sacramento
D7 – Grizzly Bay at Dolphin near Suisun Slough
D11 – Sherman Island near Antioch
D19 – Franks Tract near Russo's Landing
D28A – Old River opposite Rancho Del Rio
D41A – San Pablo Bay

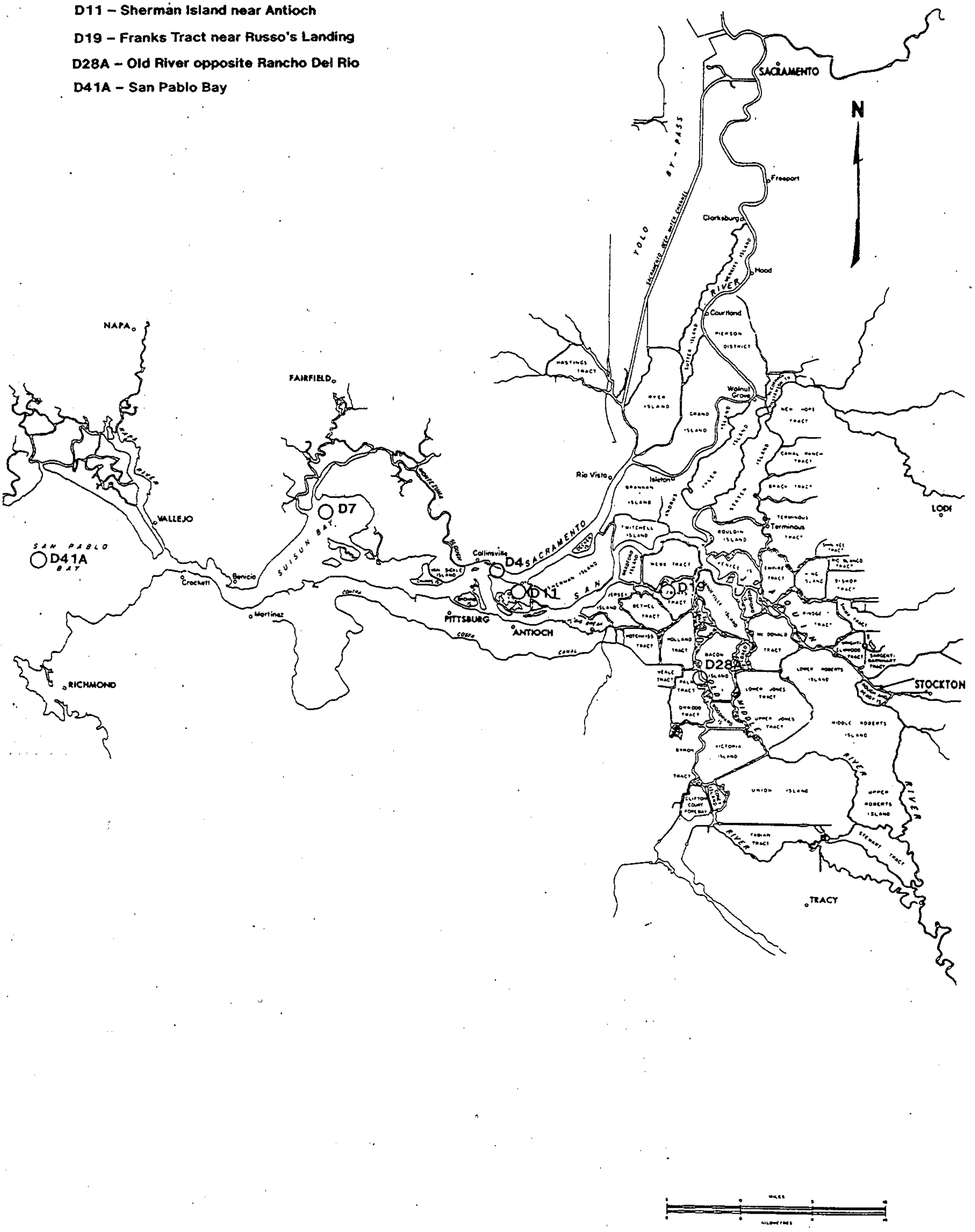


Figure 27 Benthic monitoring sites during 1995

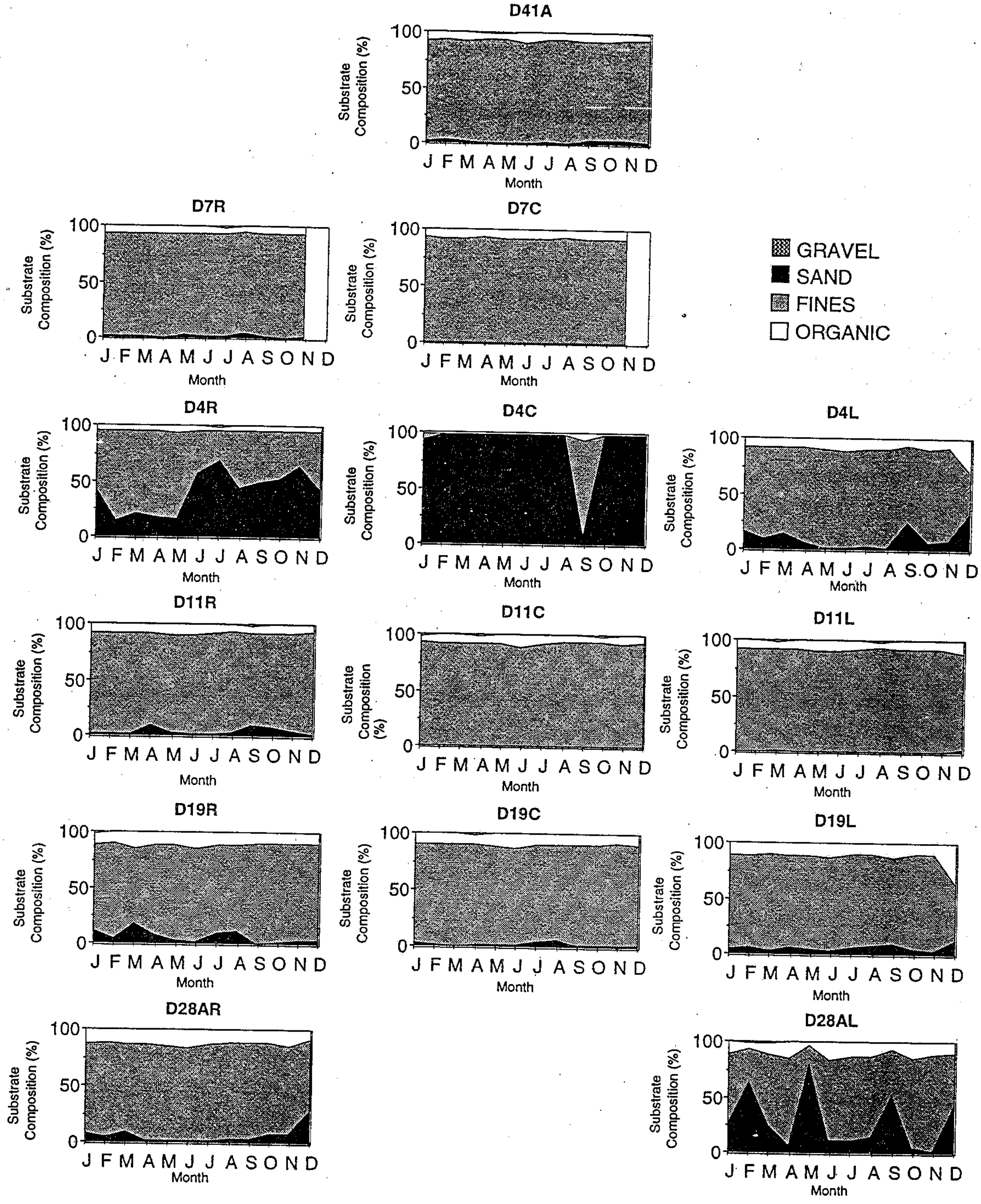


Figure 28 Percent substrate composition at benthic monitoring sites during 1995

Substrate composition at the channel sites (D4, D28A) was more variable than in the non-channel sites (D7, D11, D19, D41A). Sand was consistently present at both channel sites during 1995, dominated the substrate at D4C throughout most of the year, and comprised a significant portion of the substrate in the summer and fall at D4R. Sand was also a significant substrate component during the winter and spring at D28AL. The percentage of sand decreased and the percentage of fines increased during 1995 at D4L and D28AR when compared to previous years. At these two specific sites, fine sediments were dominant throughout the year.

Substrate composition at the non-channel sites was stable and consisted mostly of fine silt and clay sediments throughout the year. The organic content at all sites was consistently low and stable in 1995, and remained within the historical range of values for all sites.

Benthic Macrofauna Analysis

Fluctuations in total abundance and in the abundance of the four most abundant species in 1995 were used to investigate recent trends in the benthic community. Results for each site are discussed below. Data from all site sectors are averaged together to obtain total abundance and abundance of the four most abundant species.

Site D41A

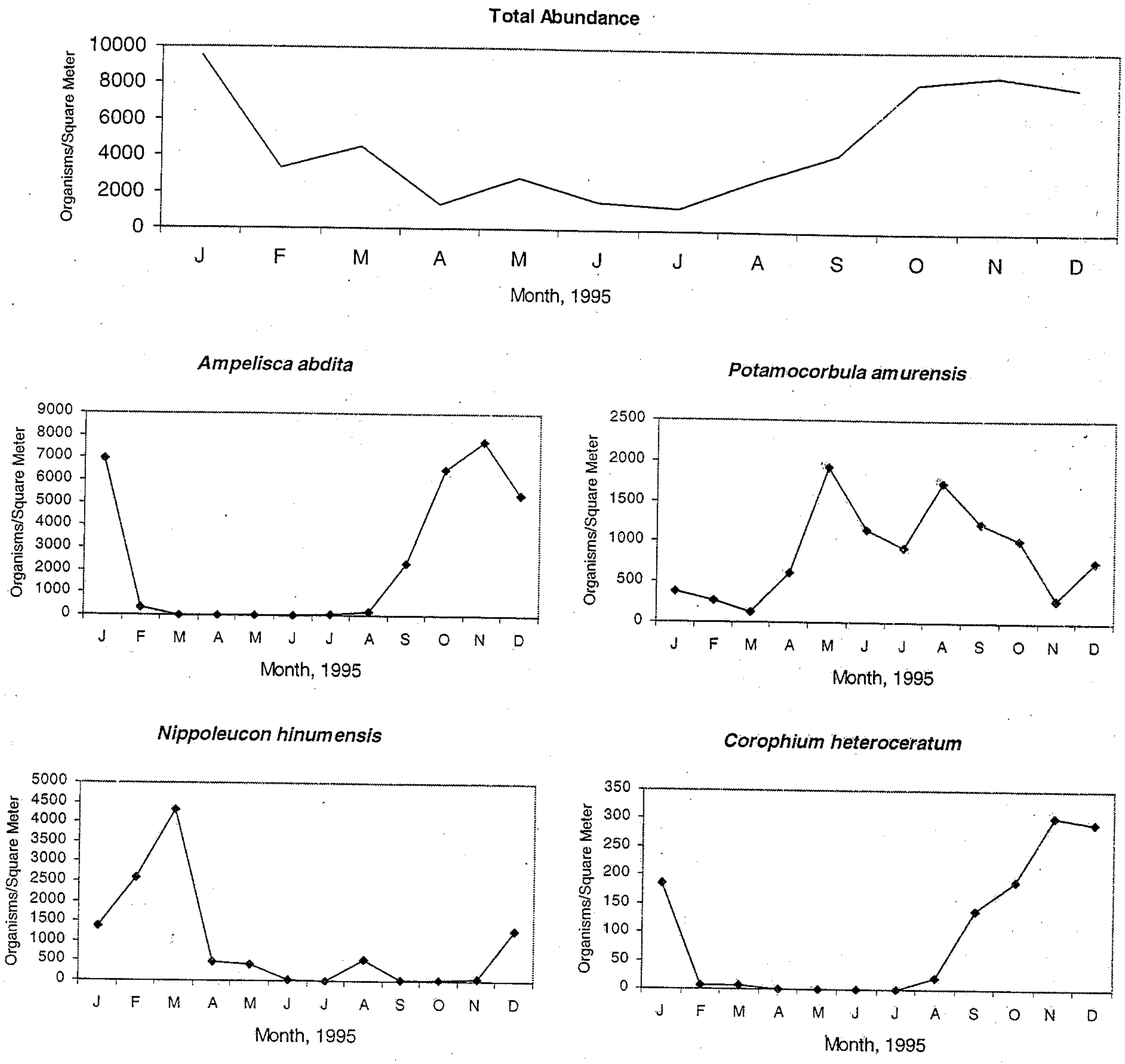
Site D41A is located in a shoal region of San Pablo Bay. Water depth varies with the tide, ranging from three to ten feet. D41A was added to the DWR-USBR Compliance Monitoring Benthic Sampling Program in 1991, and is the westernmost and most saline of the D-1485 benthic monitoring sites. Specific conductance in San Pablo Bay was more variable than in most years and ranged from 5,760 to 38,600 µS/cm. Total organism abundances at D41A were very low in 1995, showing only one tenth as many organisms/m^2 as were measured in 1994 (DWR 1997). The greatest densities occurred in the January (9,513 organisms/m^2) and November (8,669 organisms/m^2) sampling periods (Figure 29).

Corophium heteroceratum was among the four most dominant organisms at D41A in 1995. Populations of this introduced amphipod increased through the fall of 1995, to peak in November at 304 organisms/m^2. *C. heteroceratum* was not present from samples at this site from April through July 1995.

The introduced cumacean arthropod, *Nippoleucon hinumensis*, was the third most abundant species at D41A. In 1994, *N. hinumensis* was among the top four most abundant species at D7 in Grizzly Bay, which is nearly 30 miles east of the D41A site. *N. hinumensis* population density increased through the winter and peaked in March 1995 at 4,332 organisms/m^2. Summer and fall densities of this species were low and smallest densities were measured in June, July, and September at 25, 6, and 19 organisms/m^2 respectively.

The introduced clam *Potamocorbula amurensis* was moderately abundant at D41A in 1995, and was the second most abundant organism at this site. The maximum density of 1,919 organisms/m^2 in May was consistent with densities measured in 1994, but less than one-fifteenth of the maximum of 30,000 organisms/m^2 measured in 1993. Lowest densities of this clam were seen in March, after the period of highest spring outflows through the estuary. The highest densities occurred from late spring through early fall, when flows were low and stable.

The tube dwelling amphipod *Ampelisca abdita* was the most prolific organism at D41A in 1994 and remained so through 1995. Fall populations increased to a maximum abundance of 7,752 organisms/m^2 in November. This population peak was approximately half of the maximum of 13,000 organisms/m^2 seen in January of 1994. *A. abdita* populations were low through the spring and summer and demonstrated an inverse relationship in population density with the Asian clam, *P. amurensis*.



Total Abundance

Ampelisca abdita

Potamocorbula amurensis

Nippoleucon hinumensis

Corophium heteroceratum

Figure 29 Total abundance and abundance of the four most abundant organisms at site D41A

Site D7

Site D7 is in a shoal region of Suisun Bay. Water depth varies with the tide ranging from three to nine feet. Specific conductance at Site D7 ranged from 150 to 15,300 µS/cm in 1995, and was at or below 200 µS/cm from January through June 1995 due to high outflow through the spring. Total organism density generally declined throughout 1995. Maximum densities of 5,839 organisms/m^2 were recorded in January, peaking again in May at 4,294 organisms/m^2, and dropping to no organisms by December (Figure 30).

N. hinumensis was one of the four most abundant organisms at D7 in 1995. The greatest population density of this organism was measured in January at 2,679 organisms/m^2, which is similar to the maximum densities seen in 1994. Population densities were low throughout most of 1995, and this organism was absent from D7 samples in May, June, and July.

The arthropod *Corophium stimpsoni* was the third most abundant organism at D7 in 1995. Highest densities of this arthropod were seen in April (1,102 organisms/m^2) through July (823 organisms/m^2). Densities remained below 20 organisms/m^2 through the remainder of the year.

P. amurensis was the second most abundant species at D7 in 1995, as it was in 1994. A peak density of 1,621 organisms/m^2 was measured in January. Populations abruptly decreased to less than 200 organisms/m^2 in February and remained low through August. A secondary peak occurred in the fall with a maximum of 583 organisms/m^2 measured in September.

Corophium alienense was the most abundant organism at D7 in 1995, as it was in 1994. Population densities peaked at 1,248 organisms/m^2 in January, gradually fell to zero by August, and remained less than 100 organisms/m^2 through the end of the year.

Site D11

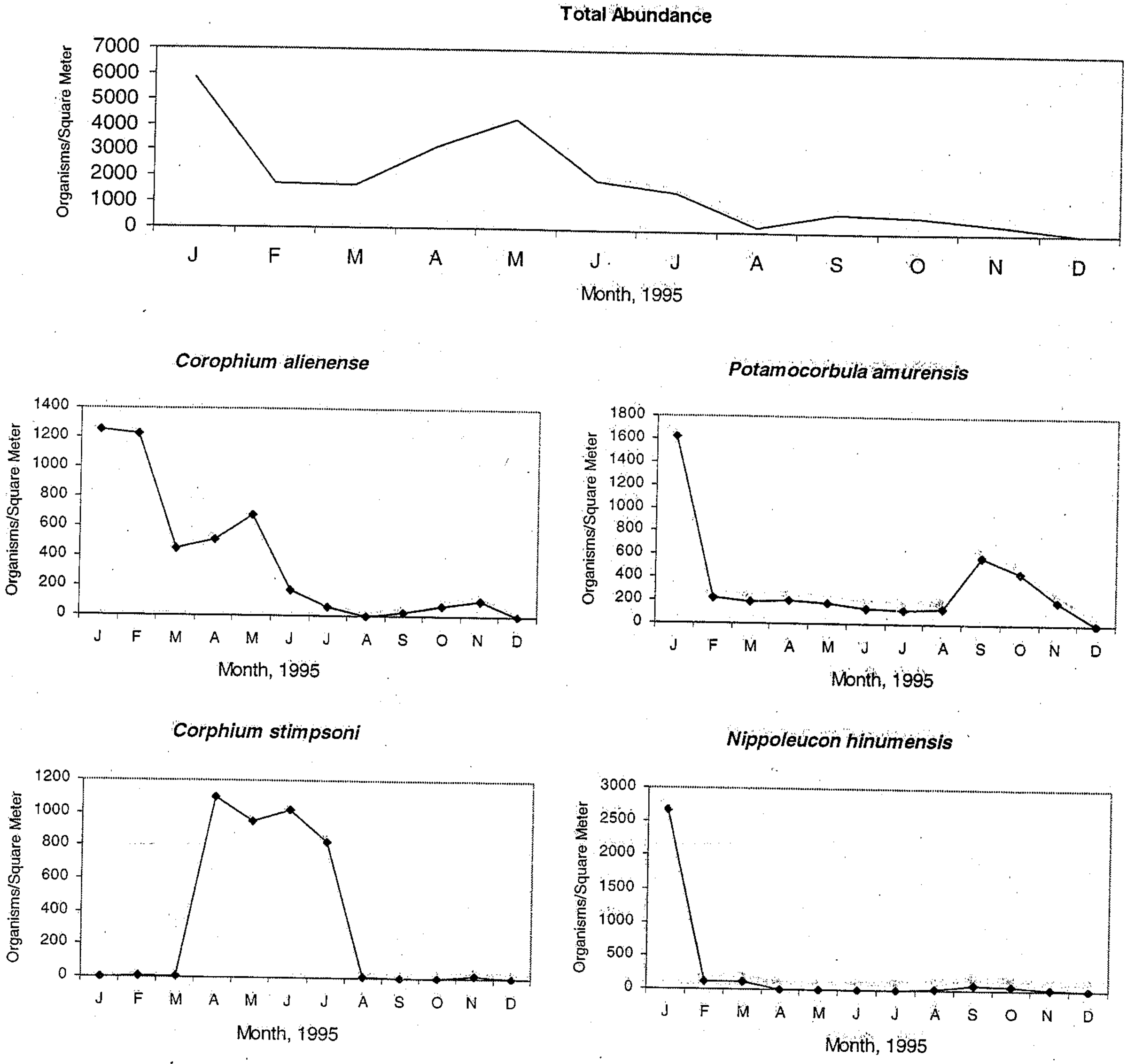
Site D11 is in the center of Sherman Lake, a flooded tract in the western Delta. Water depth is tidally influenced and ranges between 6 and 15 feet. In 1995, specific conductance at Site D11 ranged from 92 to 1,340 µS/cm, which is much lower than the conductivity values of 385 to 6,780 µS/cm seen in 1994. Total organism abundance increased throughout the spring, peaked in June at 10,883 organisms/m^2, and decreased in the fall to a minimum of 1,549 organisms/m^2 in December. The four most abundant species did not change between 1994 and 1995, though their rank did (Figure 31).

Gammarus daiberi, an introduced amphipod, moved from third to fourth most abundant species at D11 in 1995. Populations of *G. daiberi* increased in the spring to a June peak of 1,837 organisms/m^2. Populations decreased significantly in the summer and fall. By December, *G. daiberi* was absent from samples at this site.

Limnodrilus hoffmeisteri moved from fourth to third most abundant species at D7 in 1995. Populations of this tubificid worm rose during the summer to a peak in July of 1,507 organisms/m^2, more than double the maximum density of 700 organisms/m^2 measured in July of 1994. *L. hoffmeisteri* populations rose to a lesser fall peak of 659 organisms/m^2 in November of 1995.

Corbicula fluminea was again the second most abundant organism at D7 in 1995. Winter population densities peaked in February at 2,008 organisms/m^2, and gradually declined through the remainder of the year, reaching minimums of 785 and 887 organisms/m^2 in July and December, respectively. Densities of this Asian clam at D7 during 1995 were generally lower than those seen in 1994.

Corophium stimpsoni was again the most dominant organism found at D11. Population densities were low in the winter (less than 1,200 organisms/m^2), increased in the spring, and were high in the summer. A peak of 5,010 organisms/m^2 was measured in June. Densities fell in the fall and winter to 602 organisms/m^2 in November and 19 organisms/m^2 in December.


Total Abundance

Corophium alienense

Potamocorbula amurensis

Corphium stimpsoni

Nippoleucon hinumensis

Figure 30 Total abundance and abundance of the four most abundant organisms at site D7

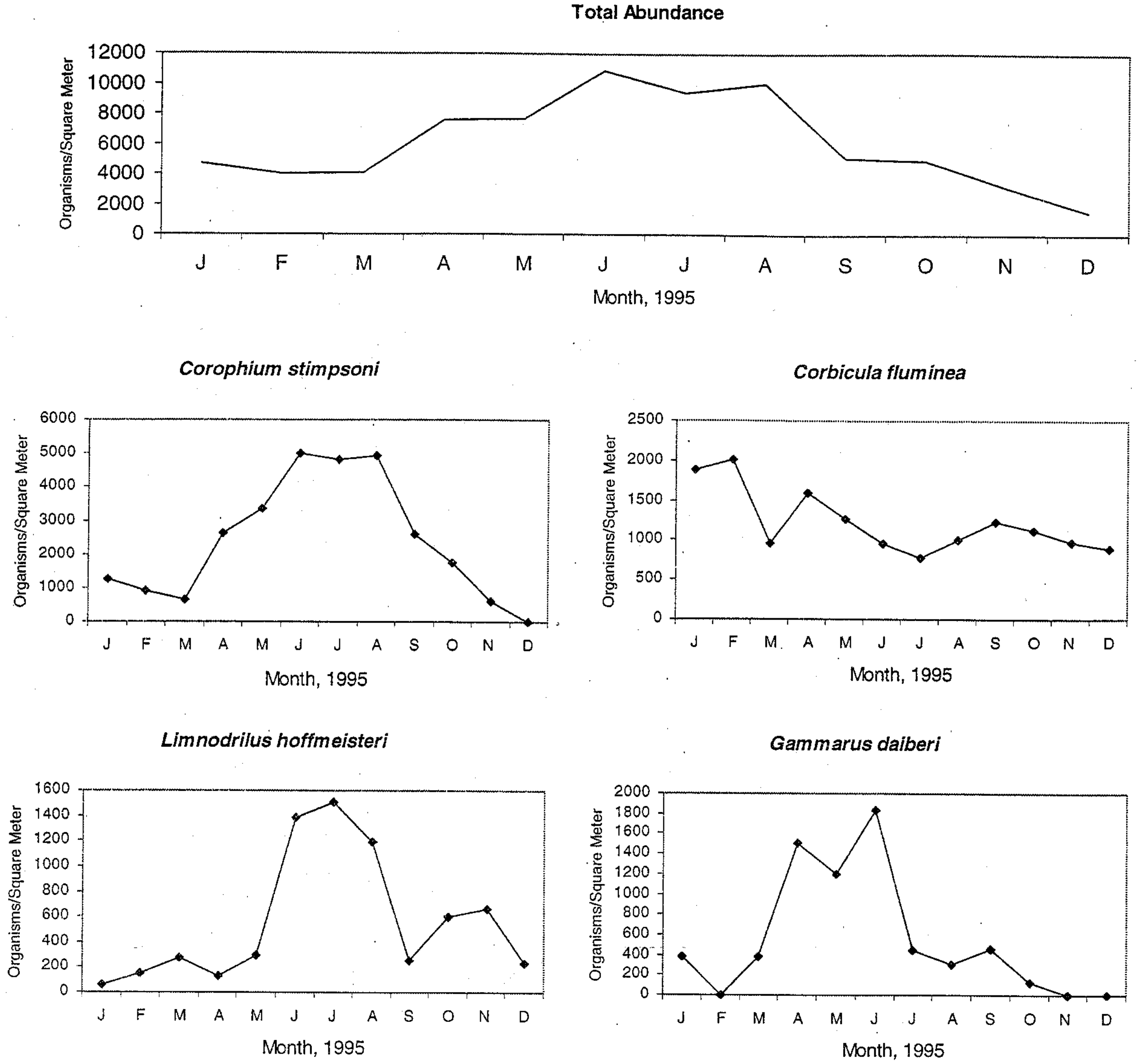


Figure 31 Total abundance and abundance of the four most abundant organisms at site D11

Site D4

Site D4 is located near Collinsville at the mouth of the Sacramento River. Samples are taken in the swift water channel (midstream) and at both banks, where the velocity is less. D4 is subject to a wide range of flows during all water year types. Water depth is variable among three sectors: 10 to 16 ft at D4-R; 30 to 39 ft at D4-C; and 21 to 32 ft at D4L. In 1995, specific conductance at Site D4 ranged from 110 to 2,350 µS/cm, and was below 500 µS/cm during most of the year. Total organism abundance, averaged between the three grab sites, peaked in May at 8,370 organisms/m^2, which is significantly less than the maximum of 44,500 organisms/m^2 seen at this site in 1994. Organism densities fell to under 1,000 organisms/m^2 by December 1995 (Figure 32).

Limnodrilus hoffmeisteri was again one of the top four most abundant organisms at D4. Population densities were variable throughout the year, peaking in August at 2,175 organisms/m^2, and were lowest in December at 42 organisms/m^2.

Corophium stimpsoni was the third most abundant organism at D4, although in 1994 it was by far the most abundant species found there. Populations were less than 100 organisms/m^2 in the fall and winter, and increased to a spring maximum density of 4,050 organisms/m^2 in May. Summer populations of *C. stimpsoni* gradually decreased from the May peak to the low fall levels.

Gammarus daiberi, a recently introduced amphipod, continued to be an abundant organism at D4 in 1995, but occurred at only one-tenth the density seen in 1994. Densities were generally low in the late fall and winter months, with minimum densities of approximately 80 organisms/m^2 measured in February and September. *G. daiberi* population densities increased in the spring to a peak of 2,248 organisms/m^2 in May. Summer populations of *G. diaberi* gradually decreased from the May peak to the low fall levels.

The tube dwelling polychaete *Varichaetadrilus angustipenis* was the most abundant species at D4 in 1995. Densities of *V. angustipenis* were sparse in the winter at approximately 300 organisms/m^2 during January and December, but gradually reached a maximum of 2,451 organisms/m^2 in August of 1995.

Site D19

Site D19 is located in the northwest corner of Frank's Tract, a shallow submerged area in the central Delta. Water depth varies with the tide and ranges from six to ten feet. Specific conductance at Site D19 ranged from 118 to 346 µS/cm throughout 1995. Low current velocities and a stable, silty substrate composition characterize Frank's Tract habitat. In the recent past, this station was the only sampling site that was not dominated by introduced species. In 1995, however, the introduced Asian clam *Corbicula fluminea* became one of the top four most abundant species at this site. Total organism abundance remained high throughout 1995. As a result, D19 had the highest total organism abundance of all sites sampled. Organism abundance was least in March, when densities fell to 36,492 organisms/m^2. Densities gradually increased throughout the spring and summer and peaked in September at 61,966 organisms/m^2 and in December at 61,314 organisms/m^2 (Figure 33).

Aulodrilus limnobius abundances remained below 200 organisms/m^2 through the winter and early spring. Population densities gradually increased in the late spring to a June peak of 3,103 organisms/m^2, followed an August peak of 5,003 organisms/m^2. *A. limnobius* declined through the fall to a minimum of 418 organisms/m^2 in November.

C. fluminea, seen at D19 since the mid 1970s, was the third most abundant species found at this site in 1995. Population densities in the winter and spring were low, less than 1,000 organisms/m^2 from January through April. The first population peak for 1995 was measured in May at 2,451 organisms/m^2, followed by a September peak of 5,656 organisms/m^2, and a December peak of 6,352 organisms/m^2.

Cyprideis species A was the second most abundant species at D19 in 1995. Populations of this ostracod were extremely abundant in January at 11,210 organisms/m^2. Organism densities dropped to less than 2,000 organisms/m^2 in the late winter and early spring, and rebounded in the late spring and early summer to densities of 4,000 to 5,000 organisms/m^2.

Densities of *Manayunkia speciosa*, a native freshwater polychaete worm, remained fairly low (less than the 2,000 organisms/m^2) from January through June. Fall and winter population peaks occurred in September and December reaching 8,208 and 10,735 organisms/m^2 respectively.

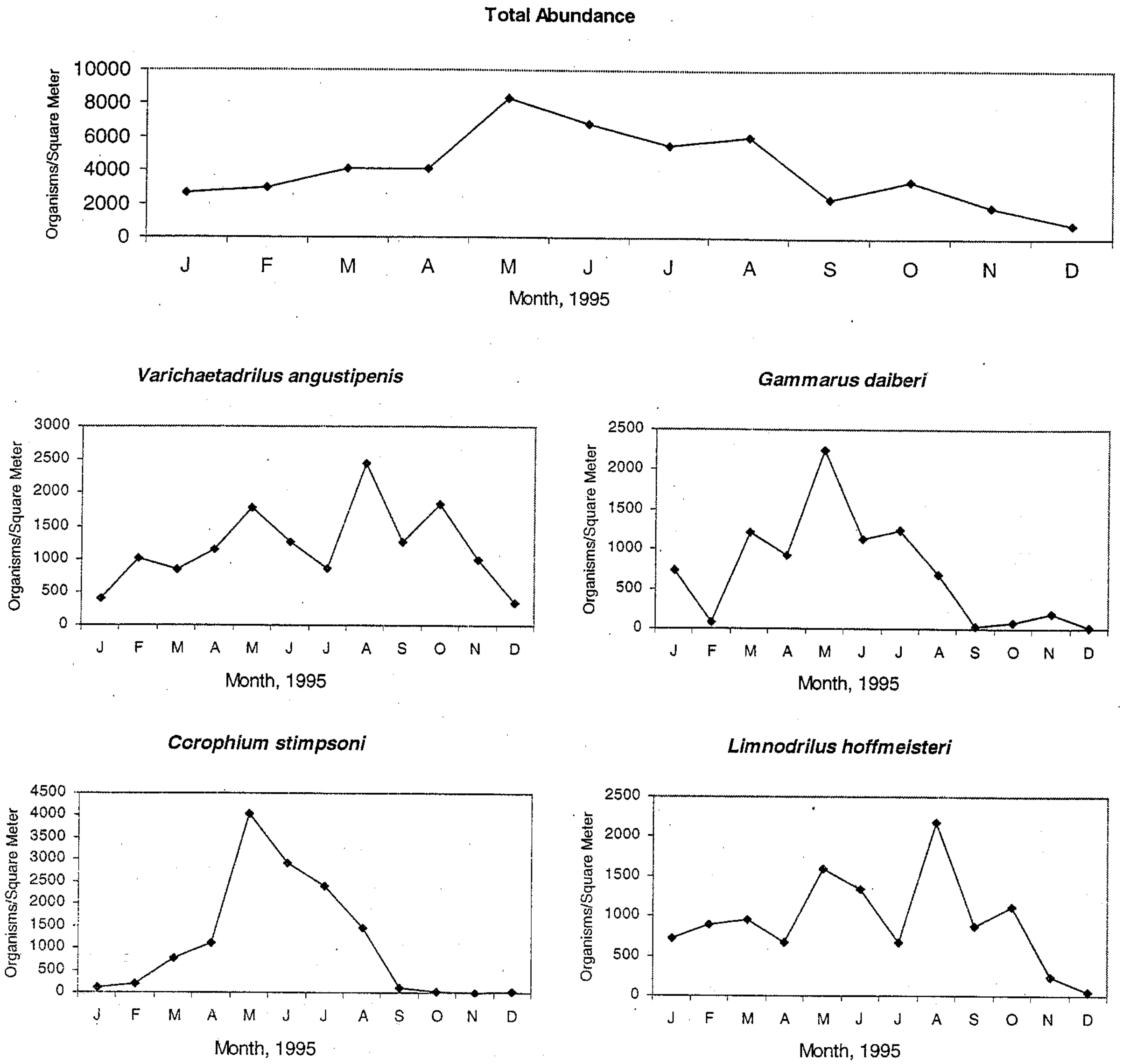
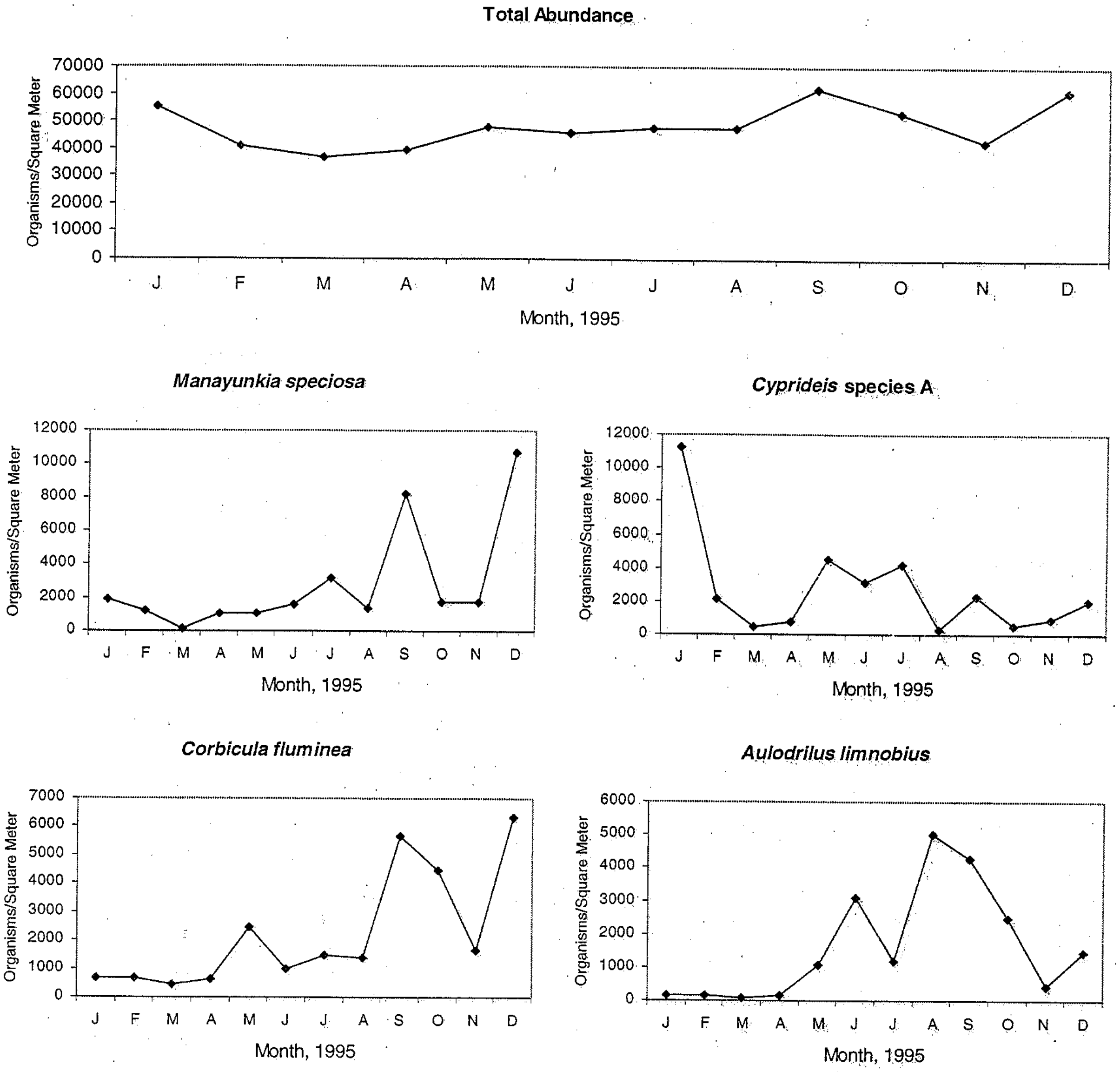


Figure 32 Total abundance and abundance of the four most abundant organisms at site D4


Total Abundance

Manayunkia speciosa

Cypridеis species A

Corbicula fluminea

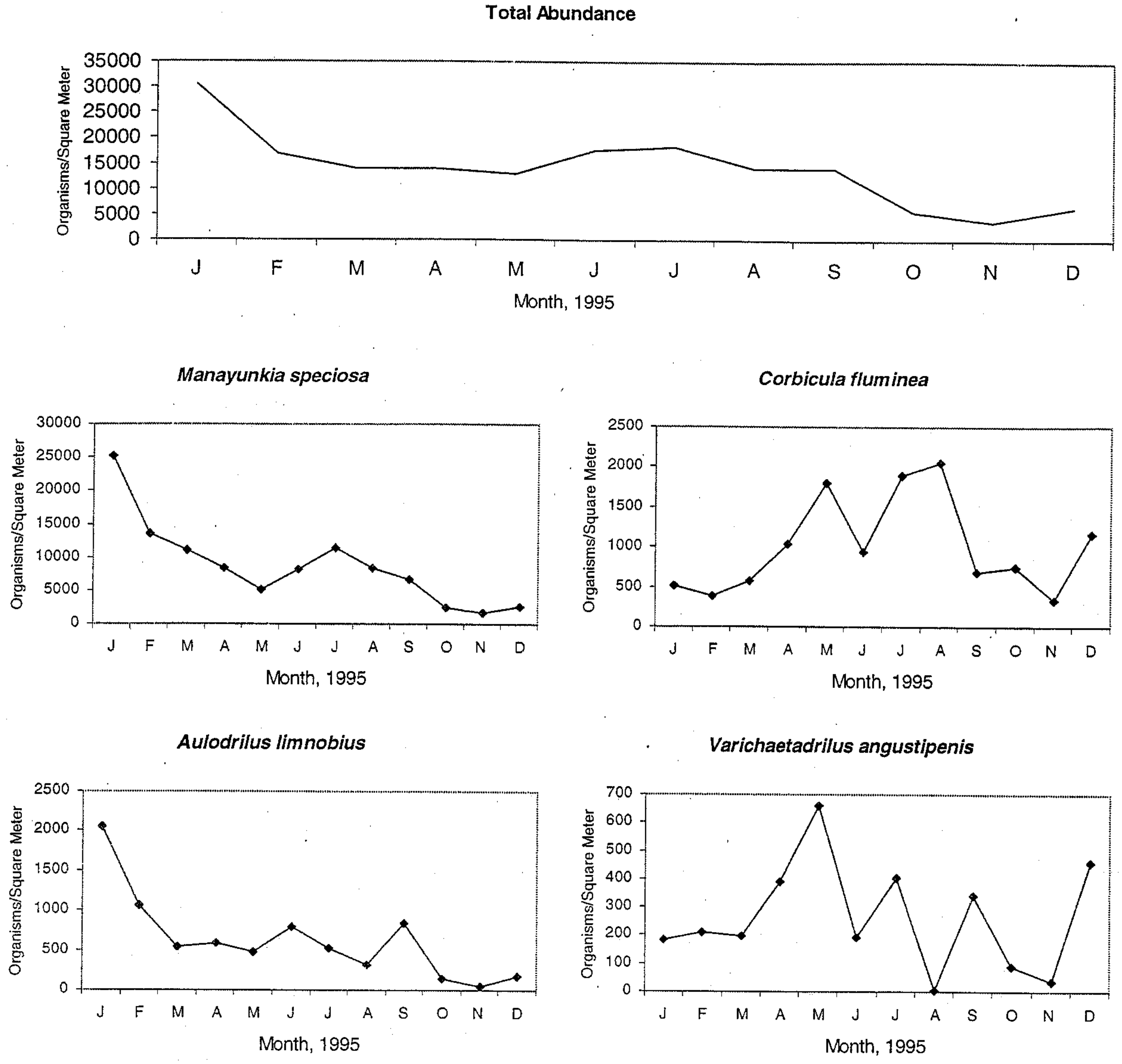
Aulodrilus limnobius

Figure 33 Total abundance and abundance of the four most abundant organisms at site D19

Site D28A

Site D28A is in Old River immediately upstream from its junction with Rock Slough. Old River is a natural approach channel to Clifton Court Forebay in the southern Delta. Water depth along both banks varies from 12 to 20 ft, depending on flows. In 1995, specific conductance at Site D28A ranged from 118 to 346 μS/cm. Total organism abundance at this site was relatively stable from February through September and ranged from 13,000 to 19,000 organisms/m^2 during this period. Maximum total organism density was measured in January at 30,411 organisms/m^2, and the minimum total population occurred in November at 3,700 organisms/m^2 (Figure 34).

Varichaetadrilus angustipenis was one of the four most abundant species at D28A in 1995. Population densities of this tubificid worm varied highly throughout the year. Maximum abundance occurred in May with densities of 661 organisms/m^2. Lowest abundance was in August when there were less than 10 organisms/m^2 at this site.



Total Abundance

Manayunkia speciosa

Corbicula fluminea

Aulodrilus limnobius

Varichaetadrilus angustipenis

Figure 34 Total abundance and abundance of the four most abundant organisms at site D28A

The tubificid worm *Aulodrilus limnobius* was also abundant at D28A in 1995. Maximum densities of 2,058 organisms/m^2 were seen in January, but populations gradually declined to 50 organisms/m^2 by November.

Corbicula fluminea populations flourished in the spring and summer with an initial peak of 1,802 organisms/m^2 in May and a second peak of 2,055 organisms/m^2 in August. This clam is generally less abundant in the winter with densities of less than 500 organisms/m^2 during January and February.

Manayunkia speciosa was, by far, the most abundant species at D28A. This sabellid worm was most abundant in January at 25,229 organisms/m^2. Populations declined in winter and spring to a minimum of 5,000 organisms/m^2 in May. *M. speciosa* populations then increased during the summer to produce a second, lesser peak of 11,500 organisms/m^2 in July. Populations declined throughout the remainder of 1995 to produce a minimum of 1,600 organisms/m^2 in November.

Chapter 5

DISSOLVED OXYGEN CONDITIONS IN THE STOCKTON SHIP CHANNEL

Dissolved oxygen concentrations in the Stockton Ship Channel are closely monitored during the late summer and early fall of each year because levels can drop below 5.0 mg/L in the eastern channel due to low San Joaquin River inflows, warm water temperatures, high biochemical oxygen demand, reduced tidal circulation, and intermittent reverse flow conditions in the San Joaquin River past Stockton. These low dissolved oxygen levels can cause physiological stress to fish and block upstream migration of salmon.

As a part of a 1969 Memorandum of Understanding between the Department of Water Resources, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, and the Department of Fish and Game, DWR usually closes the head of Old River by installing a temporary rock barrier (the Old River Closure) during periods of projected low fall outflow. The closure increases net flows down the San Joaquin River past Stockton, and helps alleviate dissolved oxygen concerns in the eastern channel. In 1995, however, the enclosure was not installed because late summer and early fall (August through October) flow conditions in the San Joaquin River were much higher than previous years. Average daily flows in the San Joaquin River past Vernalis were 4,000 cfs or greater from August through October. These flows far exceeded the late summer and early fall average daily flows of 1,000 cfs or less experienced during the past drought years, and were the result of residual effects (reduced irrigation demand and reservoir carryover) of the wet 1995 water year. Even after an exceptionally dry fall, average daily San Joaquin River flows past Vernalis still approached 3,000 cfs in November. In addition, net downstream flows past Stockton remained positive throughout fall 1995, in contrast to intermittent reverse flow conditions that existed in previous years.

Compliance monitoring of dissolved oxygen levels in the channel was conducted by vessel from August through November of 1995 to monitor dissolved oxygen patterns within the channel under high inflow conditions. During each of the monitoring runs, fourteen sites were sampled from Prisoner's Point in the central Delta to the Stockton Turning Basin at the terminus of the channel (Figure 35). Discrete samples were taken at each site for dissolved oxygen and water temperature at the top and bottom of the water column at ebb slack tide. The discrete samples were subsequently analyzed according to standard methods (APHA and others 1995) using the Winkler Method. The results are summarized in Figure 36. Monitoring of the channel by vessel is supplemented by an automated multiparameter water quality recording station near Stockton at the western end of Rough and Ready Island at Burn's Cutoff. The full monitoring effort in the area permits the planning of special studies and scheduling of the Old River Closure when necessary in response to deteriorating dissolved oxygen conditions in the channel.

In spite of the improved San Joaquin river flow conditions in 1995, a zone of depressed dissolved oxygen levels developed in the channel in and immediately west of the Rough and Ready Island area in August. The maximum dissolved oxygen depression historically occurs in the Rough and Ready Island area (the Light 41 through 48 area). In 1995, however, bottom dissolved oxygen levels were less than 5.0 mg/L from the western end of the island (Light 41) to Turner Cut (Light 28) on August 9. On August 23, the bottom depression area (levels < 5.0 mg/L) had expanded from the middle of the Island (Light 43) to west of Turner Cut (Light 19). Surface dissolved oxygen levels during August remained above 5.0 mg/L except in the heart of the sag area near Fourteen Mile Slough (Light 34) where levels dropped to 4.8 mg/L on August 9 and 4.5 mg/L on August 23. The westward shift of the surface and bottom depression from its historical location was apparently due to the higher 1995 flows.

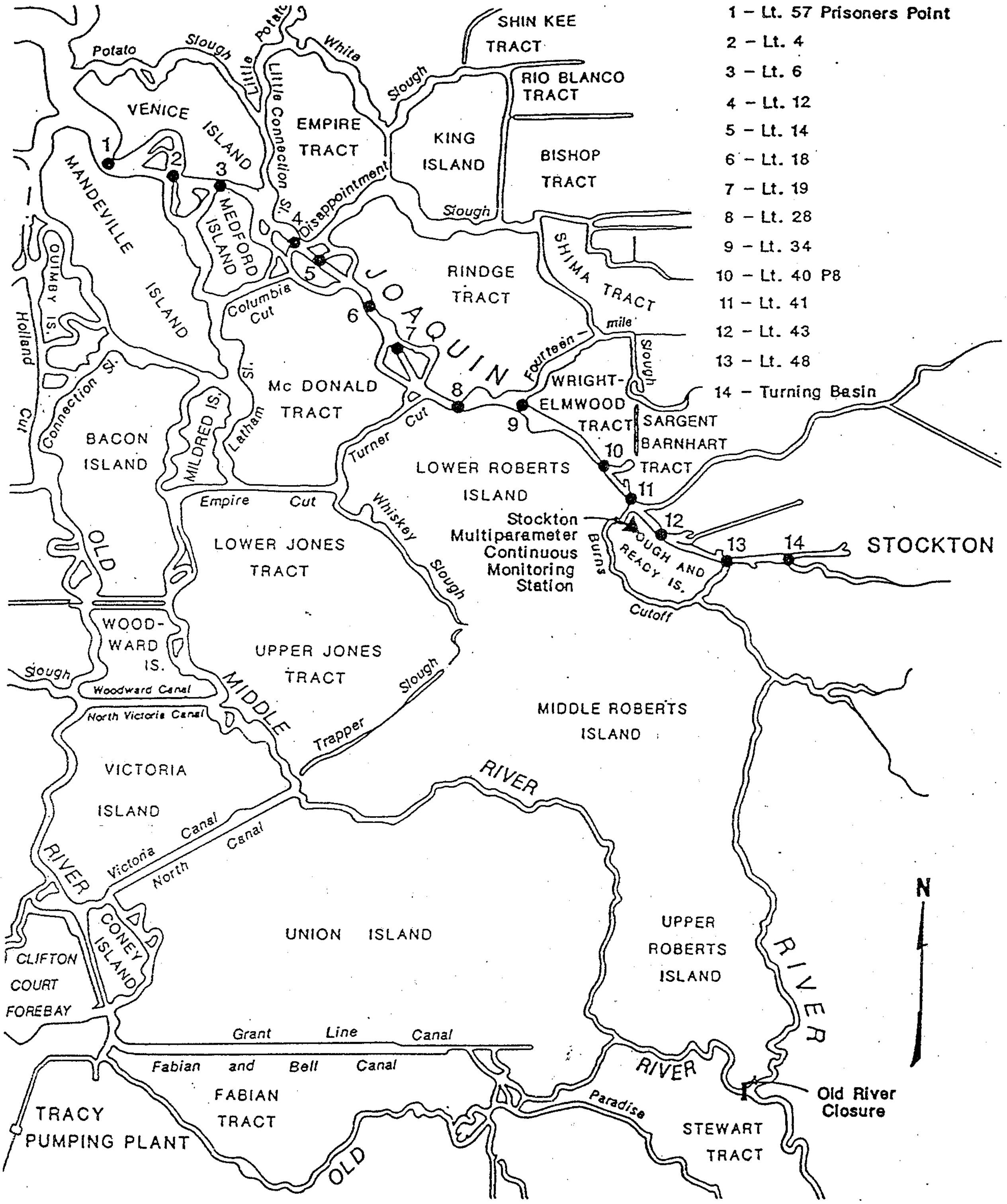


Figure 35 Dissolved oxygen sampling sites in the San Joaquin River

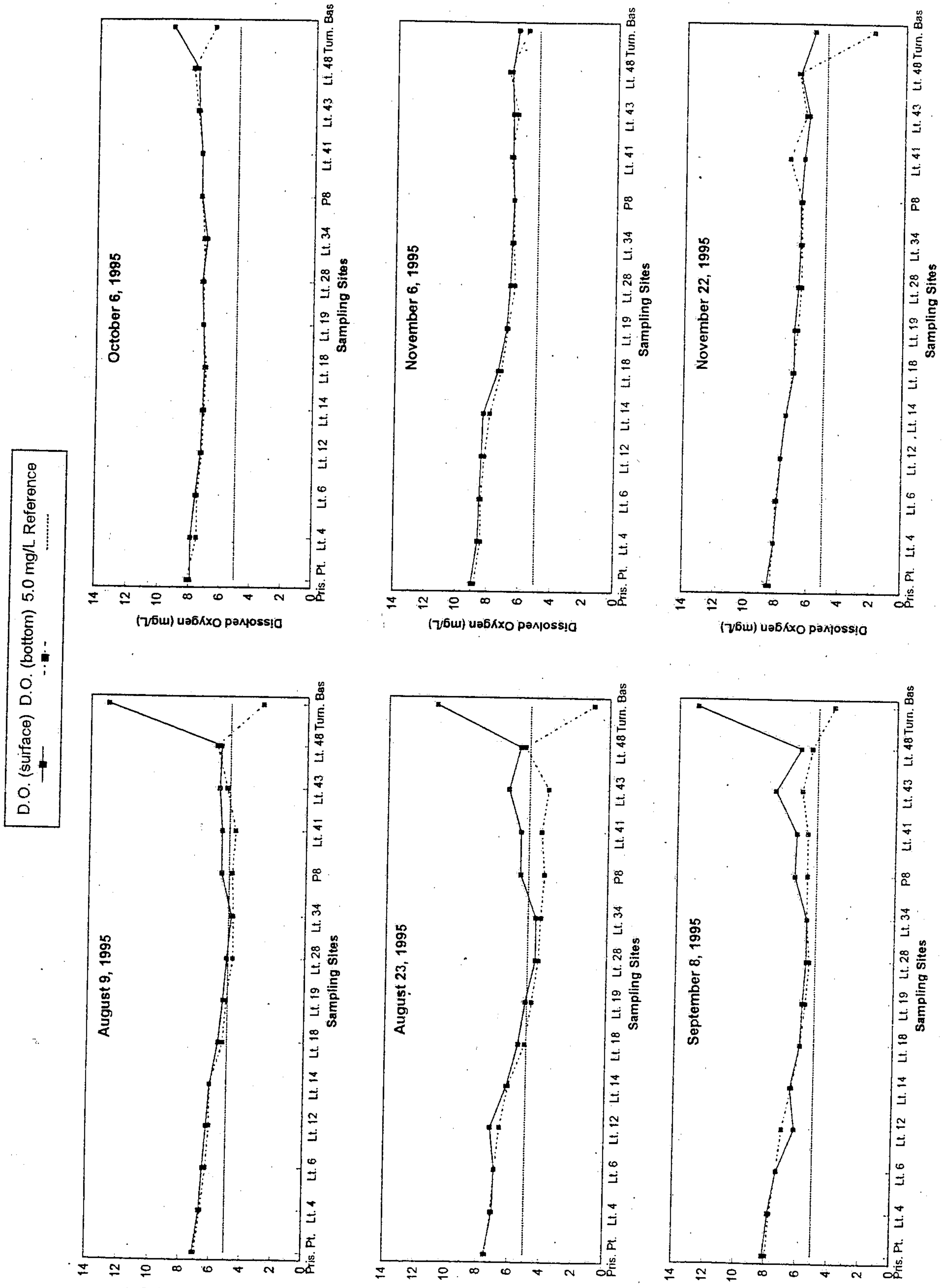


Figure 36 Dissolved oxygen concentrations in the Stockton Ship Channel in 1995

Monitoring conducted in September and October gradually improved surface and bottom dissolved oxygen conditions in all portions of the eastern channel. On September 8, 1995, all surface and bottom dissolved oxygen levels in the eastern channel exceeded 5.0 mg/L. Surface values ranged from 5.6 mg/L in the previously measured maximum sag area (Lights 28 and 34) to 7.7 mg/L at Light 43, and bottom values ranged from 5.4 to 6.0 mg/L. On October 6, 1995, all surface and bottom dissolved oxygen levels in the eastern channel were 7.0 mg/L or greater. Surface dissolved oxygen levels ranged from 7.0 to 7.3 mg/L in the maximum sag area to 7.7 at Light 48, and bottom values ranged from 7.0 to 8.0 mg/L throughout the eastern channel. The continued decrease in water temperatures (from 24 to 26 °C in August, to 23 to 24 °C in September, and 18 to 19 °C in October), sustained high outflow conditions, and the absence of reverse flow conditions past Stockton all appear to have contributed to the improved dissolved oxygen conditions in the channel.

In contrast to previous years, however, November surface and bottom dissolved oxygen levels in the eastern channel (6.0 to 7.0 mg/L) were slightly lower than the October values (7.0 to 8.0 mg/L). Because of the exceptionally dry fall conditions in the San Joaquin River drainage basin, November flows in the San Joaquin River dropped significantly from earlier levels and daily flows past Stockton declined to an average of 500 to 600 cfs. The absence of a reverse flow pattern and cooler water temperatures (15 to 16°C), however, appear to have maintained dissolved oxygen levels above 6.0 mg/L throughout the eastern channel during November.

The highly stratified dissolved oxygen conditions detected in the Stockton Turning Basin in August and September of 1995 appear to be the result of localized biological and water quality conditions occurring in the basin. The basin is at the eastern dead-end terminus of the channel, and is subject to reduced tidal activity, restricted water circulation, and extended water residence times when compared to the remainder of the channel. As a result of these unique conditions, a series of algal blooms and die-offs occur within the basin during the late summer and early fall of each year. Blooms appear to produce stratified dissolved oxygen conditions in the water column of the basin in the following way: high algal productivity at the surface of the basin produces elevated surface dissolved oxygen levels and dead or dying bloom algae settle out of the water column and sink to the bottom to contribute to high biochemical oxygen demand (BOD). Bottom dissolved oxygen levels in the basin are further degraded by additional BOD loadings in the area such as regulated discharges into the San Joaquin River and from recreational activities adjacent to the basin. When bloom activity subsides, the dissolved oxygen stratification is reduced, and basin surface and bottom dissolved oxygen levels become less diverse.

The bloom pattern was repeated in 1995, with cryptomonad and green flagellated algal blooms detected in the basin in August and September 1995. Monitoring conducted on August 9 and 23 and September 8 revealed exceptionally high dissolved oxygen levels at the surface (10.9 to 12.9 mg/L) and critically low levels at the bottom (1.0 to 4.0 mg/L) as a result of the blooms. The similar dissolved oxygen values measured at the surface and bottom of the basin on November 6, 1995, indicate that previous bloom conditions had subsided.

Chapter 6
TRACE METALS AND ORGANIC COMPOUNDS

Concentrations of nine trace metals and 41 chlorinated organic pesticides are measured biannually (spring and fall) at 11 sites in the Sacramento-San Joaquin Delta and Suisun Bay as part of the water quality monitoring program required by Decision 1485. Results are used to indicate long-term changes in levels of potentially toxic substances.

Although some of the compounds monitored occur naturally in Bay-Delta waters, many occur as a result of agricultural, urban, and industrial activities. Elevated concentrations of trace metals, organic pesticides, and other pollutants are of concern because they may adversely affect water quality and the biological resources of the San Francisco Bay and Sacramento-San Joaquin Delta (Phillips 1987; Bailey and others 1994).

This chapter compares trace metal and pesticide concentrations measured in 1995 to those measured in a series of drought years (1987 to 1992), a wet year (1993), and a dry year (1994).

Trace Metals

During 1995, seven of the nine trace metals monitored were found at concentrations above the minimum reporting limit[14] (Table 2). Total metal concentrations are derived from the concentrations of metals in both the dissolved and suspended fractions of the water sample. The 1995 concentrations of trace metals followed a pattern similar to those of the previous years. The pattern is as follows:

- Total iron and manganese were consistently detected.
- Dissolved and total arsenic, total zinc, and dissolved manganese and iron were frequently detected.
- Dissolved zinc was occasionally detected.
- Dissolved and total copper and lead, and total chromium were rarely detected.
- Dissolved and total cadmium, dissolved chromium, and total mercury were not detected.

Total and dissolved trace metal concentrations measured in 1995 were within the range of values measured in previous years. In addition, the frequency of detection of trace metals in 1995, such as dissolved and total arsenic, iron, manganese, and zinc, was similar to the frequency of detection in previous years.

Dissolved trace metals did not exceed any primary or secondary drinking water standards in 1995. The Department of Health Services has established primary drinking water standards for dissolved arsenic, cadmium, chromium, lead, and mercury and secondary standards for dissolved copper, iron, manganese, and zinc. Primary drinking water standards are based on State primary drinking water regulations and are the maximum permissible contaminant levels in water to protect human health when the water is used continuously for drinking or cooking. Secondary drinking water standards are based on State secondary drinking water regulations and are the maximum permissible contaminant levels to assure that taste, odor, or appearance of drinking water are not adversely affected. Secondary drinking water standards are not based on human health concerns.

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[14] The minimum reporting limit is the lowest level of detection at the 99% confidence level of the laboratory conducting the analyses. The U.S. Bureau of Reclamation Laboratory and Department of Water Resources Bryte Laboratory conducted the trace metal analyses.

Table 2 Dissolved and total trace metal concentrations measured during 1995[a] (µg/L)

		As		*Cd*		*Cr*		*Cu*		*Fe*		*Pb*		*Mn*		*Zn*		*Hg*
Site	*Date*	*D*[b]	*T*[c]	*D*	*T*	*D*	*T*	*D*	*T*	*D*	*T*	*D*	*T*	*D*	*T*	*D*	*T*	*T*
C3	05/03/95	*[d]	1	*	*	*	10	*	6	56	3100	*	*	*	56	*	22	*
	10/12/95	1	1	*	*	*	*	*	*	40	410	*	*	8	20	7	*	*
C7	05/03/95	1	2	*	*	*	*	*	*	123	1940	*	*	32	61	*	7	*
	10/12/95	*	1	*	*	*	*	*	72	80	1420	*	*	12	78	*	6	*
D4	05/03/95	*	1	*	*	*	*	*	*	56	1460	*	*	5	33	*	13	*
	10/12/95	1	2	*	*	*	*	*	6	50	820	*	*	*	19	*	*	*
D6	05/03/95	1	2	*	*	*	6	*	*	62	2220	*	*	*	36	*	9	*
	10/12/95	2	2	*	*	*	*	11	17	*	4400	7	7	*	13	*	*	*
D9	05/03/95	1	2	*	*	*	6	*	*	57	2120	*	*	*	36	*	13	*
	10/12/95	2	2	*	*	*	*	7	10	40	1740	*	*	14	39	7	7	*
D11	05/03/95	*	2	*	*	*	*	*	*	48	1300	*	8	*	25	*	9	*
	10/12/95	1	2	*	*	*	*	*	*	50	490	*	*	*	11	*	*	*
D12	05/03/95	1	2	*	*	*	*	*	*	91	770	*	*	11	22	*	8	*
	10/12/95	2	2	*	*	*	*	*	*	50	590	*	*	*	16	*	*	*
D19	05/03/95	2	2	*	*	*	*	*	*	137	4770	*	*	22	26	8	11	*
	10/12/95	*	*	*	*	*	*	*	*	60	300	*	*	6	13	*	*	*
D14A	05/03/95	2	2	*	*	*	*	*	*	121	582	*	*	16	23	18	20	*
	10/12/95	1	2	*	*	*	*	*	*	50	530	*	*	6	18	6	7	*
D28A	05/03/95	2	2	*	*	*	*	*	*	147	1300	*	*	25	50	7	23	*
	10/12/95	2	2	*	*	*	*	*	*	60	330	*	*	5	15	*	*	*
P8	05/03/95	2	2	*	*	*	*	*	*	115	1220	*	*	32	52	6	15	*
	10/12/95	1	2	*	*	*	*	*	8	30	1100	*	*	44	70	*	5	*

[a] The minimum reporting limit was 1 µg/L for mercury and arsenic, and 5 µg/L for all others.

[b] D = Dissolved

[c] T = Total

[d] Below reporting limit.

Table 3 Dissolved and total concentrations of trace metals measured and corresponding dissolved toxicity levels and drinking water standards[a,b,c]

	Range of Values, Trace Metals (μg/L)								
	As	*Cd*	*Cr*	*Cu*	*Fe*	*Pb*	*Mn*	*Zn*	*Hg*
Dissolved Concentrations									
1987-1994	2-5	*[d]	* --11	* --149	* --608	* -- 12	* --126	* --163	--
1995	*--2	*	*	* --11	* --147	* --7	* --44	* --18	--
Total Concentrations									
1987-1994	2-6	*	* --18	* -478	300-6500	* --85	10-388	* --590	*
1995	*--2	*	* --10	* --72	300-4700	* --8	11--78	* --23	*

	Levels and Standards, Trace Metals (μg/L)								
	As	*Cd*	*Cr*	*Cu*	*Fe*	*Pb*	*Mn*	*Zn*	*Hg*
Freshwater									
Acute Toxicity	360	3.7	15	17	1000	65	----	110	2.1
Chronic Toxicity	190	1	10	11	----	2.5	----	100	0.012
Marine									
Acute Toxicity	69	42	1100	2.4	----	210	----	90	1.8
Chronic Toxicity	36	9.3	50	2.4	----	8.1	----	81	0.025
Drinking Water Standards									
Primary	50	5	50			15			2
Secondary				1000	300		50	5000	

[a] (Source: EPA 1986)
[b] (Source: EPA 1995)
[c] (Source: DHS 1998)
[d] Below minimum reporting limit.

The most recent ambient water quality criteria were established by the Environmental Protection Agency in 1995. These criteria contain chronic and acute toxicity levels for freshwater and marine aquatic biota for dissolved trace metals (Table 3). These criteria, which are to protect freshwater and marine organisms from adverse effects, are often lower than drinking water standards and usually do not have regulatory impact.

Since 1987, levels of dissolved trace metals in the Bay-Delta system have occasionally equaled or exceeded the toxicity levels for marine and freshwater organisms. In May of 1995, dissolved lead levels of 7.0 μg/L at Suisun Bay off Bulls Head Point near Martinez (Site D6) exceeded the freshwater chronic toxicity levels of 2.5 μg/L for this trace metal. In October of 1995, dissolved copper levels of 11.0 μg/L at Bulls Head equaled the freshwater chronic toxicity level for this trace metal. The salts of copper and lead are widely used in the metal finishing, fabrication, dye, textile, and paint industries (McKee and Wolf 1963). The salts of lead and copper have also been used for other unique purposes. Tetraethyl lead has been used as an anti-knock additive in motor fuels and lead arsenate has been used for insect control on croplands. Copper sulfate is used extensively for the reduction and control of undesirable plankton growth in water supply reservoirs, tanks, conveyance channels, and natural water bodies (McKee and Wolf 1963). Use of the salts of these metals for any of these purposes within the drainages to the Delta or in the nearby industrial areas of Pittsburg, Antioch, or Martinez could account for the increased levels of these trace metals at D6.

Table 4 Toxicity levels, drinking water standards, and minimum reporting limits for synthetic organic compounds tested in the compliance monitoring program

	Toxicity Levels[a,b] *(µg/L)*				*Drinking Water Standards*[c] *(µg/L)*		*Minimum Reporting Limit (µg/L)*
	Freshwater		*Marine*				
Compound	*Acute*	*Chronic*	*Acute*	*Chronic*	*Primary*	*Secondary*	
Alachlor							0.05
Aldrin	3		1.3				0.01
Atrazine					0.003		
BHC, Alpha							0.01
BHC, Delta							0.01
BHC, Gamma	2	0.08	0.16		0.004		0.01
Captan							0.02
Chlordane	2.4	0.0043	0.09	0.004	0.0001		0.05
Chlorothalonil							0.01
Chlorpropham							0.02
Chlorpyrifos							0.01
DCPA							0.01
DDD							0.01
DDE	1.050		14				0.01
DDT	1.1	0.001	0.13	0.001			0.01
Dichloran							0.01
Dicofol							0.01
Dieldrin	2.5	0.0019	0.71	0.0019			0.01
Diuron							0.25
Endosulfan Sulfate	0.22	0.056	0.034	0.0087			0.02
Endosulfan	0.22	0.056	0.034	0.0087			0.01
Endosulfan I	0.22	0.056	0.034	0.0087			0.01
Endosulfan II	0.22	0.056	0.034	0.0087			0.01
Endrin	0.18	0.0023	0.037	0.0023	0.0002		0.01
Endrin Aldehyde							0.01
Heptachlor	0.52	0.0038	0.053	0.0036	0.00001		0.01
Heptachlor Epoxide	0.52	0.0038	0.053	0.0036	0.00001		0.01
Methoxychlor	0.012	0.03		0.03	0.1		0.05
PCB	2	0.014	10	0.03			0.10
PCB-1016	2	0.014	10	0.03			0.10
PCB-1221	2	0.014	10	0.03			0.10
PCB-1232	2	0.014	10	0.03			0.10
PCB-1242	2	0.014	10	0.03			0.10
PCB-1248	2	0.014	10	0.03			0.10
PCB-1254	2	0.014	10	0.03			0.10
PCB-1260	2	0.014	10	0.03			0.10
PCNB							0.01
Simazine					0.010		0.02
Thiobencarb					0.07	0.001	0.02
Toxaphene	0.73	0.0002	0.21	0.0002	0.005		0.10

[a] (Source: EPA 1986)

[b] (Source: EPA 1985)

[c] (Source: DHS 1990)

Organic Compounds

The list of synthetic organic compounds in the water quality monitoring program has expanded over the years as a result of increased analytical capabilities. The number of compounds monitored increased from 4 to 25 in 1987, and from 25 to 39 in 1988 (Table 4).

Concentrations of chlorinated organic pesticides above the minimum reporting limit were rarely detected between 1987 and 1995 (Table 5). No organic pesticides were detected in 1987, 1990, 1991, 1992, 1993, and 1995. In 1989, diuron was detected at Mossdale (C7) and Buckley Cove (P8) on the San Joaquin River. Diuron was also detected at Buckley Cove in 1988. In addition, endosulfan sulfate was also detected at Mossdale in 1989. The insecticide carbophenothion, a chemical not routinely monitored, was also detected at Buckley Cove in September 1989. Unidentified compounds with concentrations between 0.02 and 0.05 µg/L were detected during 1989. Two of the unidentified compounds were detected in the San Joaquin River at Buckley Cove, one compound each was detected at Franks Tract (D19), the Antioch Ship Channel (D12), and at Sherman Lake (D11). Finally, the compound simazine was detected at levels exceeding the minimum reporting limit at all monitoring sites in May of 1994. Simazine concentrations ranged from 0.07 µg/L at Mossdale to 7.47 µg/L at Old River (D28A).

All of the pesticides detected in the Delta from 1987 through 1995 appear to be consistent with historical patterns of pesticide use within the system. Diuron and endosulfan sulfate are pesticides that have been applied to many crops grown in the Delta or drainages to the Delta. Diuron is an herbicide applied to crops such as alfalfa, cotton, grapes, barley, and wheat to kill broadleaf weeds. Concentrations measured in the Delta (0.09 to 0.50 µg/L) were far below those known to affect fish. Chronic toxicity tests in flowthrough systems indicated rainbow and cutthroat trout can survive indefinitely at concentrations of 140 and 500 µg/L, respectively (Johnson and Finley 1980). Endosulfan sulfate is an insecticide applied to various vegetable, fruit, nut, and grain crops. The concentration of endosulfan sulfate measured (0.04 mg/L) was below the reported freshwater acute (0.22 µg/L) and chronic (0.056 µg/L) toxicity levels, but exceeded the marine acute (0.034 µg/L) and chronic (0.0087 µg/L) toxicity levels (USEPA 1986). Carbophenothion is an organo-phosphate class insecticide and acaricide. This chemical is used to control insects and mites in fruit, cotton, nuts, vegetables, maize, and other row crops. Carbophenothion is highly toxic to fish, crustaceans, marine organisms, and amphibians. However, the measured concentration at Buckley Cove in 1989 (0.01 µg/L) was below the acute toxicity level for water shrimp (5.2 µg/L) (Johnson and Finley 1980), bluegill (13 µg/L) (USEPA 1986), and rainbow trout (56 µg/L) (Verschueren 1983).

Simazine is a selective triazine herbicide used to control broadleaf weeds and annual grasses in berry fruit, vegetable, and ornamental crops and in orchards and vineyards. This chemical is usually applied in the spring as a pre-emergence herbicide. Apparently this was the case in the Delta, for monitoring in fall 1994 revealed that simazine concentrations at all sites had dropped to below the minimum reporting limit of 0.02 µg/L. Simazine has been reported to have a low toxicity to most aquatic species. The 48-hour LC50 for simazine in rainbow trout is 56 mg/L (Sine 1993), a concentration dramatically higher than the highest concentration of 7.47 µg/L (0.00747 mg/L) detected at Old River in May 1994. The Environmental Protection Agency has set a Lifetime Health Advisory for simazine in drinking water at 0.004 µg/L. EPA believes that water containing simazine at or below this level is acceptable for drinking every day over one's lifetime and does not impose any health concerns (DHS 1997).

The Bryte Laboratory's minimum reporting limits for chlordane, DDT, dieldrin, endosulfan sulfate, endosulfan, endosulfan I, endosulfan II, endrin, heptachlor, heptachlor expoxide, methoxychlor, PCB, and toxaphene exceeded the chronic freshwater and marine organism toxicity levels adopted in November 1991 by the Environmental Protection Agency (Table 5). Although the Compliance Monitoring Program has not detected these pesticides, we cannot conclude at this time that the pesticide levels are below the EPA toxicity levels.

Table 5 Chlorinated organic compounds with levels exceeding the minimum reporting limit from 1987 to 1995

		Organic Pesticide (µg/L)			
Site	*Date*	*Diuron*	*Edosulfan Sulfate*	*Carbophenothion*	*Simazine*
C3	05-11-94	---	---	---	0.150
C7	05-11-89	0.090	---	---	---
	09-05-89	---	0.040	---	---
	05-02-94	---	---	---	0.070
D4	05-05-94	---	---	---	0.120
D6	05-06-94	---	---	---	0.100
D9	05-05-94	---	---	---	0.170
D11	05-06-94	---	---	---	0.100
D12	05-06-94	---	---	---	0.130
D14A	05-06-94	---	---	---	0.140
D19	05-05-94	---	---	---	0.160
D28A	05-04-94	---	---	---	7.470
P8	09-02-88	0.100	---	---	---
	05-10-89	0.500	---	---	---
	09-06-89	---	---	0.010	---
	05-04-94	---	---	---	0.100

Chapter 7

CONTINUOUS MONITORING PROGRAM

Introduction

The continuous monitoring program supplements the monthly and semi-monthly D-1485 monitoring program by providing frequent real-time water quality data. The continuous data provide rapid detection of short-term water quality changes that can be used to assess impacts of State Water Project and the Central Valley Project operations and to adjust operations to comply with water quality standards. Continuous data have been collected since 1983.

Station Locations and Parameters Measured

Six sampling stations are located in the Bay-Delta system and the locations extend from the south on the San Joaquin River to Mossdale Crossing, north on the Sacramento River to the Rio Vista Bridge, and west to the Carquinez Strait (Figure 37). Sample water is collected from one meter below the surface and distributed to a manifold of water quality sensors. Water temperature, pH, dissolved oxygen, specific conductance, air temperature, wind speed, wind direction, solar radiation intensity and chlorophyll are measured at each site. The values on the sensors are scanned three times per second and hourly averages are stored by the data recorder. In the early 1990s, additional sensors were installed five feet from the channel bottom at the Antioch, Mallard Island, and Martinez stations to measure bottom specific conductance and tidal stage in order to determine compliance with the 2 ppt bottom salinity standard (also known as X2) proposed by EPA and mandated in the Delta smelt opinion of 1995. Table 6 summarizes the measurements for each continuous monitoring site.

Availability of Data

Water quality data are available on the Interagency Ecological Program (IEP) Home Page at http://www.iep.water.ca.gov. Complete hourly or quarter hourly data for water year 1995 are available for Stockton, Rio Vista, Martinez and Mallard Island stations. Incomplete data are available for the Mossdale and Antioch stations[15]. These data are stored on the IEP Home Page as text files, organized by water year. Figure 38 shows the monthly averages of the available data[16].

Future Directions

To supplement the continuous water quality data from the six stationary sampling stations, water quality sensors have been installed on the research vessel San Carlos. These sensors continuously analyze and store water temperature, electrical conductivity, dissolved oxygen and geographical location data. The sensors can be lowered in the water column to obtain information on the vertical stratification of these water quality parameters. The Environmental Service Office's Monitoring and Analysis Branch staff are refining procedures to make this continuous monitoring data available to water operations managers and other users on a near real-time basis and in a readily usable format.

Table 6 Station characteristics for the Continuous Monitoring Program

Station Location	*Parameters Measured*	*Frequency of Measurement*
Mossdale	All[a]	Hourly
Stockton	All	Hourly
Rio Vista	All	Hourly
Antioch	All	Hourly
	Bottom EC, Stage	Quarter Hourly
Mallard Island	All	Hourly
	Bottom EC, Stage	Quarter Hourly
Martinez	All	Hourly
	Bottom EC, Stage	Quarter Hourly

[a] All includes EC, DO, pH, water temperature, wind speed, wind direction, solar radiation intensity, and chlorophyll.

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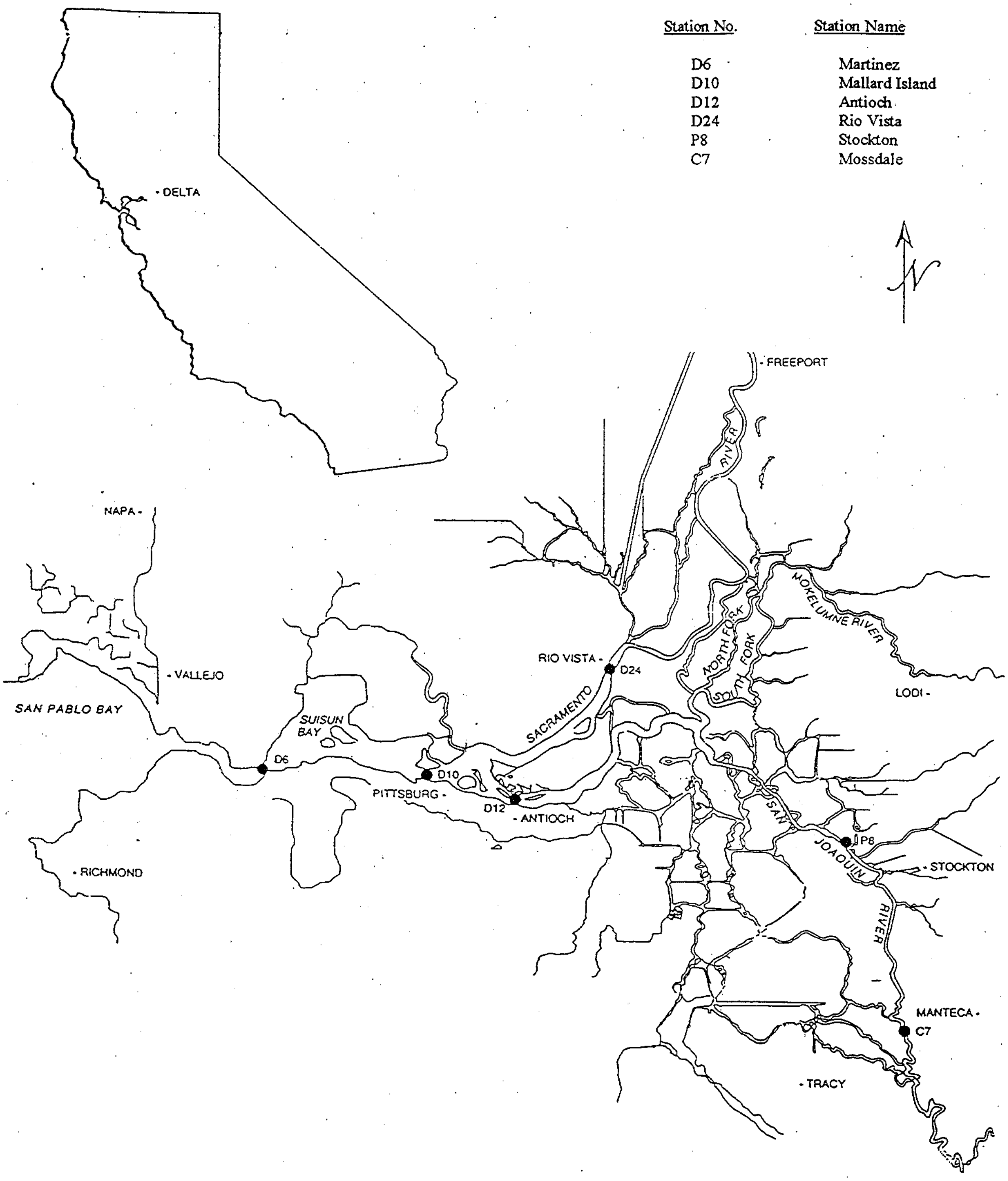
15. A fire from a nearby structure spread to the Antioch continuous monitoring station in October 1994 and caused extensive damage, which was not fully repaired until February 1995. As a result, continuous monitoring data at this site was not available from October 1994 through January 1995. During the winter floods of January 1995, the Mossdale station also suffered extensive damage. Continuous monitoring data at this station was not available from February through September 1995.
16. Plotted values are estimates because the data recorders carry over the highest high and the lowest low for each hour to the next hour.



Station No.	Station Name
D6	Martinez
D10	Mallard Island
D12	Antioch
D24	Rio Vista
P8	Stockton
C7	Mossdale

Figure 37 1995 sampling stations for the Continuous Monitoring Network in the Sacramento-San Joaquin Delta

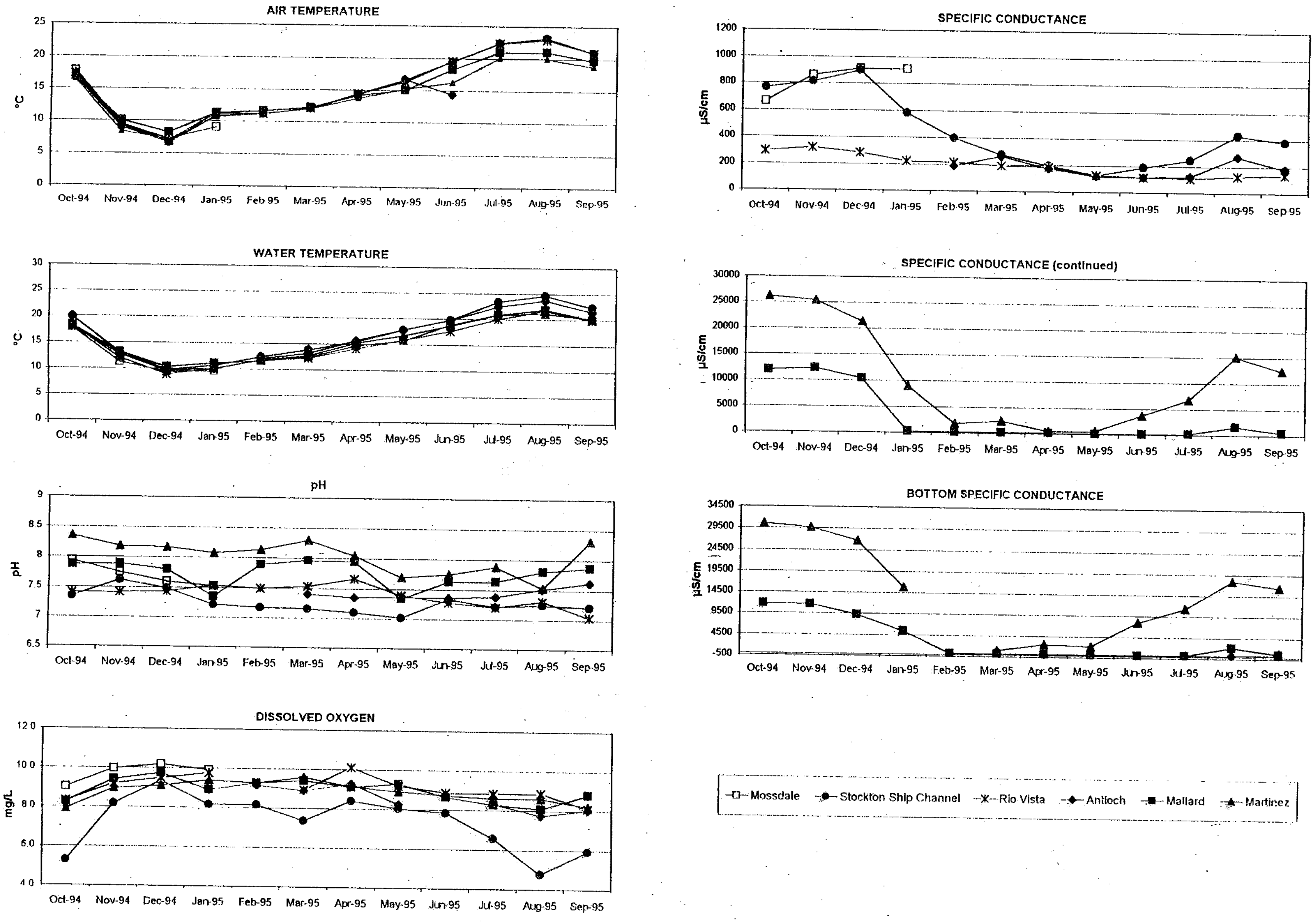


Figure 38 Monthly averages of water quality parameters measured at the Continuous Monitoring Stations for Water Year 1995

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