State of California
The Resources Agency
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Report to the State Water Resources Control Board
in Accordance with Water Right Decision 1641

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Executive Summary 2007

This report summarizes the results of water quality monitoring and special studies conducted by the Environmental Monitoring Program (EMP) in the Sacramento-San Joaquin Delta and Suisun and San Pablo bays (the upper San Francisco Estuary) during calendar year 2007. This monitoring is mandated by Water Right Decision 1641 (D-1641) of December 1999, and this report is being submitted to fulfill the reporting requirements of this decision.

EMP monitored water quality using a protocol implemented in 1996. Under this monitoring protocol, 13 sampling sites — 2 of which were added after 1996 — representing 8 regions of the upper San Francisco Estuary were monitored for 15 physical and chemical water quality parameters. The results gathered from the sampling of these 15 parameters are described in this report. Parameters such as water temperature, secchi disk depth, dissolved oxygen concentration, specific conductance, dissolved inorganic nitrogen, orthophosphate, and volatile suspended solids were within their historical range. Measured parameters exhibited seasonal variation, as well as changes in response to significant rainfall events, or changes in flow rates. In addition to monitoring physical and chemical water quality parameters, biological sampling was conducted to monitor the productivity and community composition of phytoplankton, zooplankton and benthic communities.

Chlorophyll *a* is the principal photosynthetic pigment and is common to all phytoplankton. Chlorophyll *a* is thus used as a measure of phytoplankton biomass. Samples for chlorophyll *a* and phytoplankton were taken at 13 sampling sites in the estuary. Chlorophyll *a* concentrations for 2007 showed typical seasonal patterns and were generally below 10 µg/L for most regions and concentrations ranged between 0.25 µg/L and 108.00 µg/L throughout the estuary. Phytoplankton samples were collected using a submersible pump from 1 meter below the water's surface. All organisms collected in 2007 fell into 11 categories: centric diatoms, cyanobacteria, unidentified flagellates, green algae, pennate diatoms, cryptomonads, euglenoids, haptophytes, chrysophytes, dinoflagellates and synurophytes. Of the 11 groups identified, centric diatoms, cyanobacteria, unidentified flagellates, green algae and pennate diatoms constituted 96.88% of the organisms collected.

Zooplankton were collected at 22 sampling sites in the estuary. The introduced *Hyperacanthomysis longirostris* (formerly *Acanthomysis bowmani*) and the *Neomysis kadiakensis/japonica* complex remained the 2 most abundant mysids, followed by the native *Neomysis mercedis* and *Alienacanthomysis macropsis*. The native *Acartia* spp. was the most common calanoid copepod followed by *Pseudodiaptomus forbesi*. The introduced *Eurytemora* spp. was third most abundant. The 3 most common cyclopoid copepods remained the introduced *Limnoithona tetraspina* and *Oithona davisae*, followed by the native *Acanthocyclops vernalis*. The 3 most abundant cladocerans were *Bosmina* spp., *Daphnia* spp. and *Diaphanosoma* spp. *Keratella* spp. was the most common rotifer, followed by *Polyarthra* spp. and *Synchaeta* spp.

Benthic monitoring was conducted at 10 representative stations throughout the estuary to document substrate composition and the distribution, diversity and abundance of benthic organisms in the estuary. The benthic community was determined to be a diverse assemblage of organisms including annelids (worms), crustaceans, aquatic insects and molluscs (clams and snails). All organisms collected during 2007 fell into 9 phyla: Annelida, Arthropoda, Chordata,

Cnidaria, Mollusca, Nemertea, Nematoda, Phoronida and Platyhelminthes. Of these 9 phyla, Annelida, Arthropoda and Mollusca constituted 99.5% of the organisms collected during the study period. Ten species in these phyla represent 84.6% of all organisms collected during this period.

EMP also conducted a series of special studies to monitor dissolved oxygen (DO) levels in the Stockton Ship Channel during the late summer and early fall of 2007. The studies were conducted to determine if DO levels dropped below Central Valley Regional Water Quality Control Board and State Water Resources Control Board water quality objectives (5.0 mg/L and 6.0 mg/L, respectively) established for the channel. Monitoring was conducted biweekly from June 15 to December 12 from Prisoner's Point in the central Delta to the Stockton Turning Basin at the eastern terminus of the channel. Monitoring results showed DO concentrations did not vary much between regions in the channel (not including the turning basin), with an overall range of 4.2 to 10.2 mg/L at the surface and 3.5 to 10.2 mg/L at the bottom.

Karen Gehrts, Acting Chief
Bay-Delta Monitoring and Analysis Section
Division of Environmental Services

Table of Contents 2007

State of California
Arnold Schwarzenegger, Governor

The Resources Agency
Mike Chrisman, Secretary for Resources

Department of Water Resources
Lester A. Snow, Director

Susan Sims
Chief Deputy Director

Kasey Schimke
Asst. Director Legislative Affairs

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Deputy Director

Ralph Torres
Deputy Director

Division of Environmental Services
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Acronyms and Abbreviations

BDAT	Bay Delta and Tributaries Database
CB	Clarke-Bumpus
CDEC	California Data Exchange Center
cfs	cubic feet per second
cm	centimeter
CPUE	catch per unit of effort
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
DFG	California Department of Fish and Game
DIN	dissolved inorganic nitrogen
DO	dissolved oxygen
DON	dissolved organic nitrogen
DWR	California Department of Water Resources
EC	electrical conductance
EMP	Environmental Monitoring Program
EPA	US Environmental Protection Agency
FLIMS	Field and Laboratory Information Management System
IEP	Interagency Ecological Program
L	liter
m	meter
mg/L	milligrams per liter
mL	milliliters
NH_3	total ammonia
NO_3	nitrate
NO_2	nitrite
NTU	nephelometric turbidity units
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TSS	total suspended solids
µm	micrometer
µS	micro Siemens
USBR	US Bureau of Reclamation
USGS	US Geological Survey
VSS	volatile suspended solids

Metric Conversion Table

Quantity	*To Convert from Metric Unit*	*To Customary Unit*	*Multiply Metric Unit By*	*To Convert to Metric Unit Multiply Customary Unit By*
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

Chapter 1 Introduction

The State Water Resources Control Board (SWRCB) establishes water quality objectives and monitoring plans to protect the variety of beneficial uses of the water within the upper San Francisco Estuary. The SWRCB ensures that these objectives are met, in part, by inclusion of water quality monitoring requirements into water right decisions issued to the Department of Water Resources (DWR) and the United States Bureau of Reclamation (USBR) as conditions for operating the State Water Project (SWP) and Central Valley Project (CVP), respectively. These requirements include minimum outflows, limits to water exportation by the SWP and CVP, and maximum allowable salinity levels. In addition, DWR and USBR are required to conduct a comprehensive monitoring program to determine compliance with the water quality objectives and report the findings to the SWRCB. Water quality objectives were issued in December 1999 by Water Right Decision 1641 (D-1641) (SWRCB 1999).

[SWRCB] State Water Resources Control Board. 1999. Water Rights Decision 1641 for the Sacramento-San Joaquin Delta and Suisun Marsh. Sacramento.

Data collected since 1975 by the Environmental Monitoring Program (EMP) are stored and managed by DWR and the Department of Fish and Game (DFG). DWR manages phytoplankton and macrobenthic organism data as well as environmental water quality data from both discrete and continuous monitoring stations. DFG manages all zooplankton data. Internet access and download of the EMP data are available through the Bay Delta and Tributaries Database (BDAT) at www.baydelta.ca.gov/.[1]

This report, titled *Water Quality Conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays during 2007,* summarizes the findings of the EMP for calendar year 2007. Separate chapters are devoted to the water quality, benthic, phytoplankton, zooplankton and special study components of the EMP. Within each chapter, the major patterns and trends demonstrated by the water quality and biological data within and between years are described in the text and displayed in summary plots and tables. This report is submitted to the SWRCB to fulfill the reporting requirements of D-1641.

References

[SWRCB] State Water Resources Control Board. 1999. Water Rights Decision 1641 for the Sacramento-San Joaquin Delta and Suisun Marsh. Sacramento.

[1] For specific questions regarding availability of EMP data on BDAT, contact Mr. Karl Jacobs, Chief, Interagency Information System Services Section, Department of Water Resources, Division of Environmental Studies, 901 P Street, Sacramento, CA 95814; telephone: (916) 651-9581; or e-mail: kjacobs@water.ca.gov.

Chapter 2 Hydrologic Conditions

Content

Figures

Tables

Chapter 2 Hydrologic Conditions

Introduction

Hydrologic conditions are typically discussed using water years and provide a brief overview for historical and today's conditions in Sacramento River and San Joaquin River watersheds. Water year 2007 covered by this report comprises the period October 1, 2006, to September 30, 2007.

Methods

Water years are classified using the Sacramento Valley 40-30-30 Water Year Hydrological Classification Index[1],[2] (the Sacramento Valley Index) and the San Joaquin Valley 60-20-20 Water Year Hydrological Classification Index[3],[4] (the San Joaquin Valley Index) (SWRCB 1999). The Sacramento Valley Index is used to characterize water years statewide because most of California's precipitation falls in the northern half of the state and flows down the Sacramento River through the upper San Francisco Estuary (referred to as estuary; includes San Pablo Bay, Suisun Bay, and the Sacramento-San Joaquin River Delta). This index is also used because the Sacramento River watershed provides most of the water to the State Water Project and Central Valley Project (SWRCB 1999). The San Joaquin Valley Index is used to characterize water conditions in the San Joaquin Valley. The Net Delta Outflow Index[5] (Figure 2-1) is used to determine the freshwater outflow from the estuary. Much of this outflow is during late winter and early spring.

[SWRCB] State Water Resources Control Board. 1999. Water Rights Decision 1641. Sacramento: State Water Resources Control Board.

Figure 2-1 Net Delta Outflow Indices for 2007

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

[2] Sacramento River unimpaired runoff is the sum of Sacramento River flow at Bend Bridge, Feather River flow to Lake Oroville, Yuba River flow at Smartville, and American River flow to Folsom Lake (SWRCB 1999).

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

[4] 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.

[5] The Net Delta Outflow Index (NDOI) is a calculation of freshwater outflow from the Delta past Chipps Island. The NDOI includes a factor dependent upon inflows of the Yolo Bypass System, the eastside stream system (the Mokelumne, Cosumnes, 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 Morrison Creek).

Summary

Water year 2007 was considered a dry year for the Sacramento Valley and a critical year for the San Joaquin Valley in precipitation, seasonal runoff, reservoir storage, and snow water content.

The 8 major rivers of California provided 65% of the normal runoff and the statewide Water Year-to-date reported nearly 55% of the normal runoff (DWR 2007). Using the Sacramento Valley Index[6], water year 2007 was classified as dry. Under the San Joaquin Valley Index[7], water year 2007 was classified as critical. Figures 2-3 and 2-4 summarize these findings and include the previous 11 years for reference. Statewide water conditions for May 1 are summarized in Table 2-1 and include the previous 5 years for reference.

Figure 2-3 Sacramento River Hydrologic Region 40-30-30 Indices, 1996–2007

Figure 2-4 San Joaquin River Hydrologic Region 60-20-20 Indices, 1996–2007

Table 2-1 Summary of statewide major hydrologic characteristics of water years 2002–2007

Accounting for precipitation, runoff, reservoir storage, and snowpack water content, the unimpaired (full natural) runoff for the Sacramento River was classified as a dry water year and the San Joaquin River was classified as critical for the 2007 year. Table 2-2 summarizes these conditions and includes the previous 5 years for reference. Figure 2-2 demonstrates these flow periods and includes the previous 10 years for reference.

Table 2-2 Average unimpaired runoff for water years 2002–2007

Figure 2-2 Unimpaired runoff for the Sacramento and San Joaquin rivers, 1996–2007

Water year 2007 had maximum Delta outflow indices exceeding 1,173,000 acre-feet in February and minimum outflow indices approaching 252,000 acre-feet in August.

References

[CDEC] California Data Exchange Center. Homepage. 2007. Accessed April 2008 <http://cdec.water.ca.gov>.

[DWR] California Department of Water Resources. 2006-2007. *Water Conditions California. California Cooperative Snow Surveys Bulletin 120*. Report 1-4. Sacramento: California Department of Water Resources.

Hinojosa, Tracy, DWR, Chief of Compliance and Modeling Section, Division of Operations and Maintenance. 2008. WY 2007 totals. Personal communication to Luke Jones, Scientific Aide, DWR.

[SWRCB] State Water Resources Control Board. 1999. Water Rights Decision 1641. Sacramento: State Water Resources Control Board.

[6] Using the Sacramento Valley Index, water years are defined as follows: (1) a "Wet" year occurs when the index is equal to or greater than 9.2; (2) an "Above Normal" year occurs when the index is greater than 7.8 but less than 9.2; (3) a "Below Normal" year occurs when the index is greater than 6.5 but equal to or less than 7.8; (4) a "Dry" year occurs when the index is greater than 5.4 but equal to or less than 6.5; and, (5) a "Critical" year occurs when the index is equal to or less than 5.0 (SWRCB 1999).

[7] Using the San Joaquin Valley Index, water years are defined as follows: (1) a "Wet" year occurs when the index is equal to or greater than 3.8; (2) an "Above Normal" year occurs when the index is greater than 3.1 but less than 3.8; (3) a "Below Normal" year occurs when the index is greater than 2.5 but equal to or less than 3.1; (4) a "Dry" year occurs when the index is greater than 2.1 but equal to or less than 2.5; and , (5) a "Critical" year occurs when the index is equal to or less than 2.1 (SWRCB 1999).

Figure 2-1 Net Delta Outflow Indices for 2007

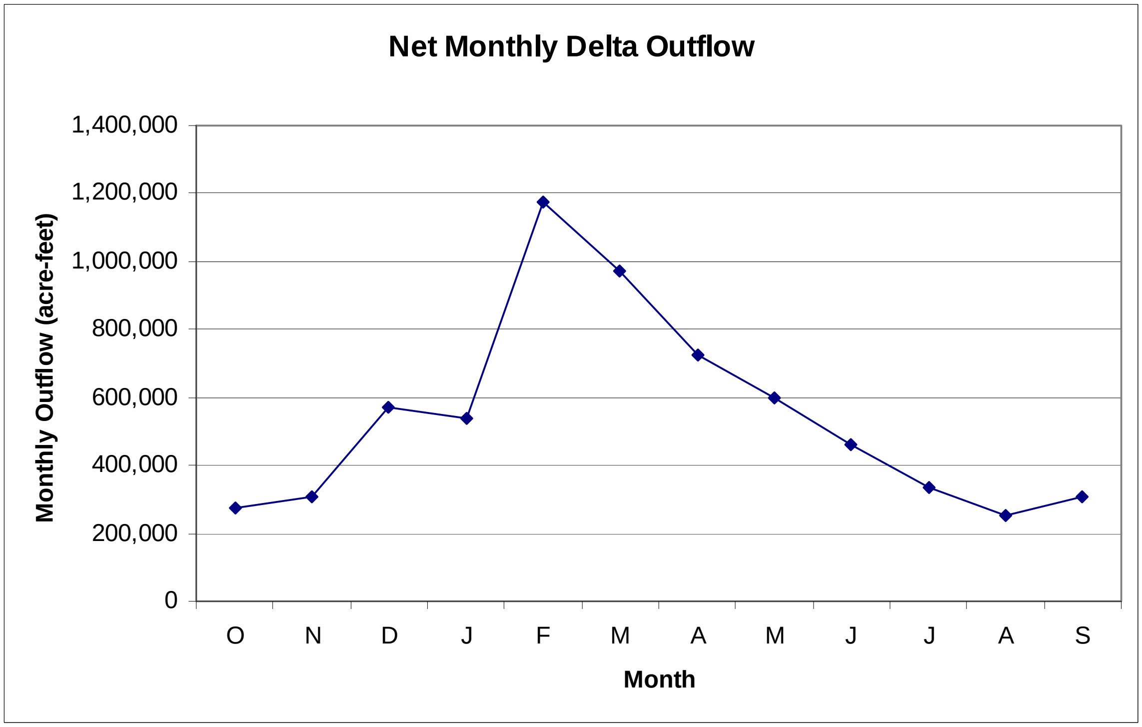


Figure 2-2 Unimpaired runoff for the Sacramento and San Joaquin rivers, 1996–2007

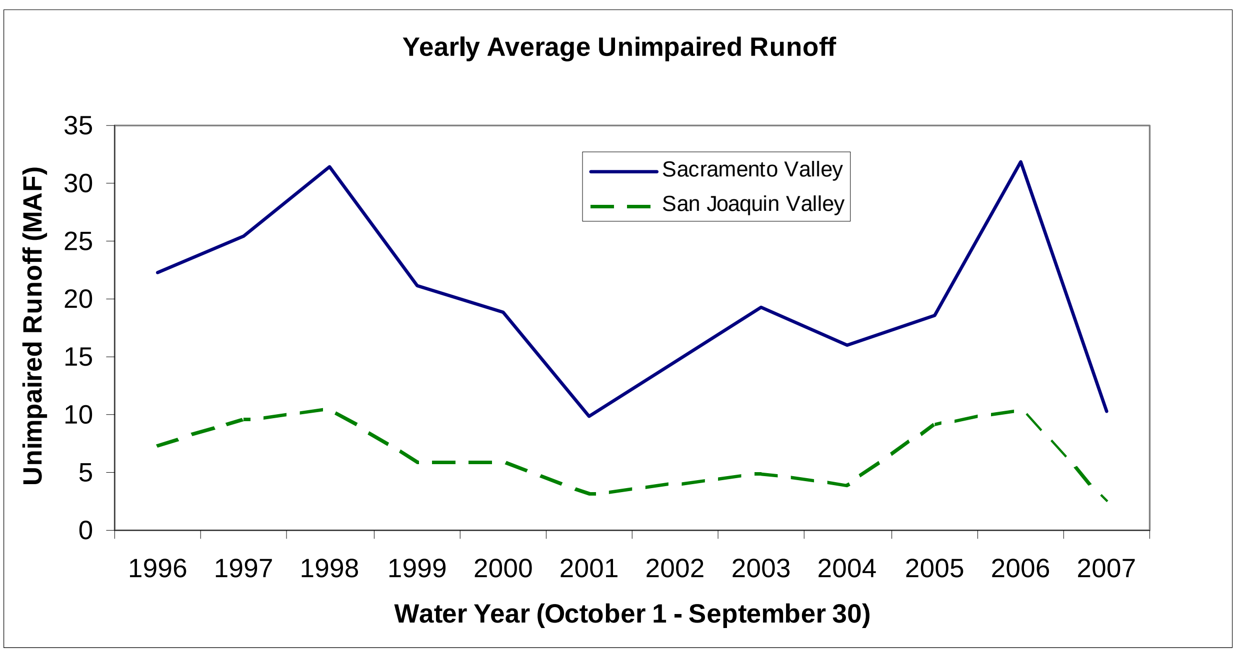


Figure 2-3 Sacramento River Hydrologic Region 40-30-30 Indices, 1996–2007

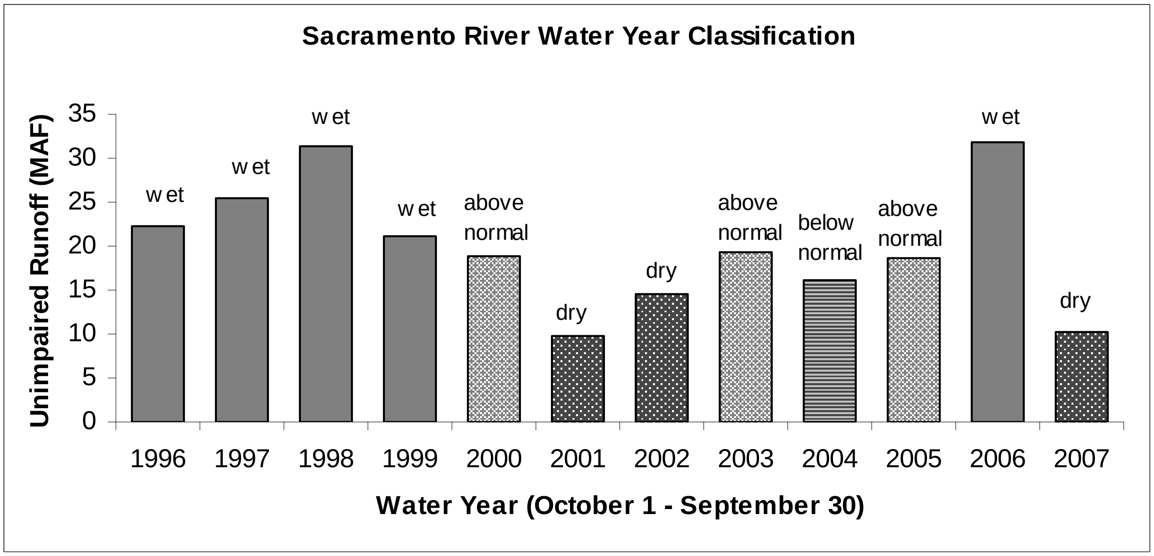


Figure 2-4 San Joaquin River Hydrologic Region 60-20-20 Indices, 1996–2007

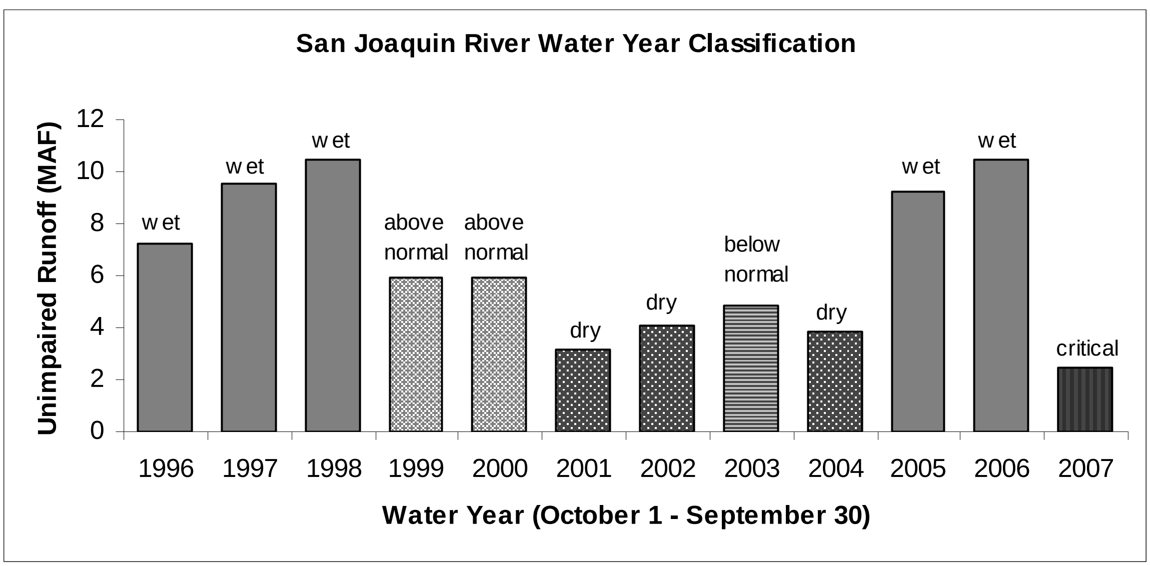


Table 2-1 Summary of statewide major hydrologic characteristics for water years 2002–2007

Water year	Precipitation (% of normal)	Seasonal runoff (% of normal)	Reservoir storage (% of normal)	Snow water content (% of normal)
2002	80	80	100	60
2003	110	100	105	105
2004	90	90	100	50
2005	135	80	105	150
2006	140	170	115	185
2007	65	55	105	25

Table 2-2 Unimpaired runoff for water years 2002–2007

Sacramento River				San Joaquin River			
Year	Oct 1- Mar 30 (MAF)	Apr1- Jul 30 (MAF)	Whole year (MAF)	Year	Oct 1- Mar 30 (MAF)	Apr1- Jul 30 (MAF)	Whole year (MAF)
2002	9.32	4.57	14.6	2002	1.27	2.75	4.06
2003	10.71	7.74	19.31	2003	1.25	3.49	4.87
2004	10.95	4.4	16.04	2004	1.51	2.25	3.81
2005	8.4	9.28	18.55	2005	2.73	6.28	9.21
2006	18.04	12.93	31.88	2006	2.87	7.37	10.45
2007	6.56	3.02	10.25	2007	0.98	1.44	2.46

Chapter 3 Water Quality Monitoring

Content

Figures

Tables

Chapter 3 Water Quality Monitoring

Introduction

Water quality monitoring in 2007 continued according to the amended protocol implemented by the Department of Water Resources (DWR) in 1996, with the incorporation of several changes recommended by the 2001-2002 Environmental Monitor Program review. Discrete water quality sampling sites included the 11 representative sites as described in the 1996 Water Quality Report (Lehman et al 2001), with the addition of 2 more sampling sites in May 2004, a move from station C3 to C3A in November 2004, and a move from station C10 to C10A in 2005.

Find 2001-2002 Environmental Monitor Program Review at http://www.baydelta.water.ca.gov/emp/EMP_Review_Final.html

Discrete samples were taken monthly at each station (Figure 3-1). Data were recorded within 1 hour of high slack tide and the time of each sample was recorded to the nearest 5 minutes of Pacific Standard Time. A qualitative statement of weather conditions (i.e., wind conditions and cloud cover) was recorded for each cruise. Samples were analyzed in terms of 15 physical and chemical parameters shown in Table 3-1. The complete database is available online at http://baydelta.water.ca.gov.

Figure 3-1 Environmental Monitor Program's Discrete water quality sampling stations

Table 3-1 Water quality parameters measured

As shown in Table 3-2, thirteen sampling stations were used in this study to represent 8 regions of the Bay-Delta system. Data results in this report are shown for each sample station.

Table 3-2 Water quality sampling sites and regions

Parameters Measured

Except as noted, all discrete water quality samples were obtained with shipboard sampling equipment using the US Bureau of Reclamation's research vessel *Endeavor* or the DWR research vessel *San Carlos*. Supplemental discrete samples were taken with mobile laboratory equipment at stations in the north and south Delta (C3A and C10A) that are inaccessible to the research vessels. Secchi disk depth is not measured at station C10A because of restrictions of the sample site, which requires sampling equipment to be deployed from 50 feet above the water's surface.

Water Temperature

Water temperature was measured in degrees Celsius (°C) with a YSI thermistor. For all stations except for C3A and C10A, temperatures were measured from water collected from a through-hull pump at a depth of 1 meter. At C3A and C10A, temperatures were measured from water collected at the continuous monitoring station through a float-mounted pump that draws water at 1 meter in depth.

A water temperature minimum of 7.1 °C was recorded in January 2007 at station D8 in the Suisun Bay (Figures 3-2 and 3-3). This minimum temperature represents a decrease of 2.2 °C from the previously recorded minimum in 2006 (Riordan et al. 2007).

Figure 3-2 Water temperature comparisons, 2007

Figure 3-3 Water temperature (°C) by station, 2007

Temperature minima at all sites during 2007 occurred during the month of January. The timing of these temperature minima is similar to the 2006 study period, where temperature minima occurred during January and December. (Riordan et al. 2007).

A water temperature maximum of 25.3 °C was recorded in July at station MD10A, in the east Delta. This maximum is a 1.4 °C decrease over the temperature maximum reported for 2006 (Riordan et al. 2007). Recorded temperatures exhibited strong seasonal variability, with cooling during the winter and warming during the summer.

Dissolved Oxygen

Dissolved oxygen (DO) was measured using the modified Winkler iodometric method described in Standard Methods (APHA 1992). A sample aliquot was collected from a through-hull pump or from a float-mounted pump at a continuous monitoring station (stations C3A and C10A), at a depth of 1 meter. The samples were collected in 300-milliliter (mL) glass-stoppered bottles and immediately analyzed.

During 2007, dissolved oxygen concentrations ranged from 5.1 mg/L at station P8 in July, to 18.5 mg/L at station MD10A in February (Figures 3-4 and 3-5). Seasonal trends were evident in most regions, with dissolved oxygen concentrations decreasing during the summer and rising in the winter. Reduced summer DO levels coincided with warmer water temperatures. This suggests that DO levels at many sites may be influenced primarily by physical processes (temperature, saturation capacity) rather than biological processes such as respiration and primary production.

Figure 3-4 Dissolved oxygen comparisons, 2007

Figure 3-5 Dissolved oxygen (mg/L) by station, 2007

Specific Conductance

Specific conductance, an estimate of salinity, was determined from samples collected from a through-hull pump or from a float-mounted pump at a continuous monitoring station (stations C3A and C10A) at a 1-meter depth. The samples were analyzed for specific conductance using a Seabird model CTD 911+ data logger, or a YSI 85 (sites C3A and C10A) with temperature compensation to 25 °C.

Specific conductance varied greatly between sites monitored, ranging from 136 µS/cm at site C3A in July to 44,357 µS/cm at site D41 in December (Figures 3-6 and 3-7). This range of specific conductance was similar to the range of 100.4 - 42,233 µS/cm reported for 2006 (Riordan et al 2007).

Figure 3-6 Specific conductance comparisons, 2007

Figure 3-7 Specific conductance (uS/cm) by station, 2007

Specific conductance generally increased from east to west and was well correlated to inflows and tidal action. Maximum values occurred in the winter when flows through the Delta were lower and marine intrusion was more pronounced.

Sites with high average specific conductivity such as D4, D6, D7, D8, D41 and D41A tended to show stronger seasonal variations, with specific conductance varying from lows in February through April, to highs in December. At sites with lower specific conductance, this seasonal trend was less apparent.

Secchi Disk Depth

Water transparency was measured to the nearest centimeter using a 20-cm diameter Secchi disk attached to a 2.5-m rod marked in cm. Secchi disk transparency was recorded as the average depth in which visual determination of the disk was lost as it was lowered into the water column, and the depth of its visual perception as it was raised. All measurements were made from the shaded side of the vessel.

A Secchi depth minimum of 22 cm was recorded at site D7 in Suisun Bay in June. (Figures 3-8 and 3-9). A Secchi depth maximum of 220 cm was recorded at sampling site MD10A (east Delta) in December. Secchi values during 2006 were similar, ranging from 20 to 196 cm (Riordan et al 2007).

Figure 3-8 Secchi disk depth comparison, 2007

Figure 3-9 Secchi disk depth (cm) by station, 2007

Secchi disk depth varied considerably at all sites, with little apparent seasonal correlation. Average Secchi depth was lowest at site D7, and was the highest at site D28A.

Turbidity

Turbidity is a measure of the optical properties of water and substances contained in the water that cause light to be scattered and absorbed rather than transmitted in straight lines (APHA 1992). Turbidity is caused by soluble organic compounds, plankton, and suspended matter, such as clay, silt, inorganic substances, and organic matter.

Turbidity was determined from samples collected from a through-hull pump at a 1-meter depth. The samples were pumped through a Turner Model 10 flow-through nephelometer calibrated with a reference sample of formazin suspension at 40 nephelometric turbidity units (NTU) according to Standard Reference protocol 214-A (APHA 1992). Turbidity was measured at sites C3A and C10A from samples collected via float-mounted pump at the continuous monitoring station using a Hawk 2100P Turbidimeter, due to their inaccessibility by vessel.

Turbidity varied greatly among sampled sites (Figures 3-10 and 3-11). Values ranged from 1.2 NTU at site MD10A (East Delta) in November and December, to 42.8 NTU at site D7 (Suisun Bay) in January. This range of turbidity was less than the 1.5 to 64.7 NTU range reported for 2006 (Riordan et al 2007).

Figure 3-10 Turbidity comparisons, 2007

Figure 3-11 Turbidity (NTU) by station, 2007

Turbidity levels at some sites exhibited a seasonal pattern of higher turbidity in the winter and early spring, followed by decreasing turbidity through the summer and fall; however, some sites showed no consistent seasonal pattern.

Orthophosphate

Orthophosphate is soluble inorganic phosphate, the phosphorus compound most immediately available for assimilation by phytoplankton. Orthophosphate concentrations were measured by first collecting sample aliquots from a 1-meter depth into new, rinsed polyethylene bottles. The water samples were then passed through a pre-washed membrane filter with a 0.45-micron pore size. The filtrate was immediately frozen and later transported to Bryte Laboratory[1] for analysis according to the US Environmental Protection Agency (EPA 1983) colorimetric automated ascorbic acid method 365.1. The minimum reporting limit for orthophosphate is 0.01 mg/L.

[1] Bryte Chemical Laboratory, Department of Water Resources, 1450 Riverbank Road, West Sacramento, CA 95605

Values for orthophosphate varied considerably between sites and across seasons (Figures 3-12 and 3-13). The lowest orthophosphate value was below the minimum reporting limit at station MD10A in February. The 2006 study period showed the lowest values (0.02 mg/L) of orthophosphate occurring at sites MD10A and C3A (Riordan et al 2007).

Figure 3-12 Orthophosphate comparisons, 2007

Figure 3-13 Orthophosphate (mg/L) by station, 2007

The highest value of orthophosphate, 0.25 mg/L, was recorded at site P8 in April. During 2006, site MD10A had the highest orthophosphate concentration (0.18 mg/L) in January (Riordan et al 2007).

Total Phosphorus

Total phosphorus is the sum of all phosphorus compounds in a sample. This parameter includes phosphorus compounds that are bioavailable, as well as those that are not. Phosphorus that is unavailable for bioassimilation includes phosphorus compounds incorporated into biological tissue and insoluble mineral particles.

Total phosphorus concentrations were measured by first collecting sample aliquots from a 1-meter depth into new, rinsed polyethylene bottles. The water samples were then passed through a pre-washed membrane filter with a 0.45-micron pore size. The filtrate was immediately frozen and later transported to Bryte Laboratory for analysis according to the EPA (1983) colorimetric semi-automated method 365.4. The minimum reporting limit for total phosphorus is 0.01 mg/L.

Values for total phosphorus varied considerably between sites and across seasons (Figures 3-14 and 3-15) and showed distributions similar to those reported for orthophosphate. The lowest value of 0.03 mg/L was recorded at site MD10A during October. This value is slightly higher than the minimum value of 0.02 mg/L recorded during 2006 at site C3A in February, March and April (Riordan et al 2007). A maximum value of 0.31 mg/L was recorded at site P8 in April. This value is slightly higher than the maximum value of 0.27 mg/L recorded during 2006 at site D7 in August (Riordan et al 2007).

Figure 3-14 Total phosphorus (mg/L) comparisons, 2007

Figure 3-15 Total phosphorus (mg/L) by station, 2007

Sites P8 and C10A had the highest average total phosphorus concentrations during 2007. Sites MD10A and D26 had the lowest average total phosphorus concentrations.

Kjeldahl Nitrogen

Kjeldahl nitrogen is nitrogen in the form of organic proteins or their decomposition product, ammonia, as measured by the Kjeldahl method (APHA 1992).

Kjeldahl nitrogen concentrations were measured by first collecting sample aliquots from a 1-meter depth into new, rinsed polyethylene bottles. The water samples were then passed through a pre-washed membrane filter with a 0.45-micron pore size. The filtrate was immediately frozen and later transported to Bryte Laboratory for analysis according to the EPA (1983) colorimetric semi-automated method 352.1. The minimum reporting limit for Kjeldahl nitrogen is 0.01 mg/L.

Kjeldahl nitrogen concentrations ranged from a low of 0.1 mg/L at sites D19 and D26 in April to 1.4 mg/L at sites D19 and P8 in December (Figures 3-16 and 3-17). During 2006, Kjeldahl nitrogen levels peaked at site P8 with a high of 1.0 mg/L (Riordan et al 2007).

Figure 3-16 Kjeldahl nitrogen comparisons, 2007

Figure 3-17 Kjeldahl nitrogen (mg/L) by station, 2007

Kjeldahl nitrogen concentrations were generally highest at sites C3A, C10A and P8. No strong seasonal or intra-annual trends were apparent among all the sites.

Dissolved Inorganic Nitrogen

Dissolved inorganic nitrogen (DIN) is a measure of total ammonia (NH_3), nitrate (NO_3), and nitrite (NO_2), the nitrogen forms immediately available for assimilation by phytoplankton. DIN was measured by first pumping water samples from a 1-meter depth into new, rinsed polyethylene bottles. The water samples were then passed through a pre-washed membrane filter with a 0.45-micron pore size. The filtrate was immediately frozen and later transported to Bryte Laboratory for analysis for total ammonia according to the EPA (1983) colorimetric, automated, phenate method 350.1; and for nitrate and nitrite according to the colorimetric automated cadmium reduction method 353.2 (EPA 1983). DIN was calculated as the sum of total ammonia plus nitrate and nitrite. The minimum reporting limit for inorganic nitrogen is 0.01 mg/L.

DIN concentrations ranged from a minimum of 0.11 mg/L at sites D28A and MD10A in September to a maximum of 2.94 mg/L at site P8 in December. (Figures 3-18 and 3-19). This range is slightly higher than the values observed during 2006, which recorded a minimum value of 0.02 mg/L at station MD10A and a maximum of 2.72 mg/L at station P8 (Riordan et al 2007) .

Figure 3-18 Dissolved inorganic nitrogen comparisons, 2007

Figure 3-19 Dissolved inorganic nitrogen (mg/L) by station, 2007

DIN values were consistently high at south Delta stations C10A and P8. In contrast, all other stations had most DIN values below 1.0 mg/L. The high values observed in the south Delta may be due to runoff and drainage from agricultural operations on the San Joaquin River.

Concentrations in the south Delta also showed the greatest degree of seasonal variability. The other sites did not show any apparent seasonal trends.

Dissolved Organic Nitrogen

Organic nitrogen is defined functionally as nitrogen that is bound to carbon containing compounds in the tri-negative oxidation state (APHA 1992). This form of nitrogen must be mineralized or decomposed before it can be used by the plant communities in aquatic and terrestrial environments. It does not include all organic nitrogen compounds, but does include proteins, peptides, nucleic acids, urea, and numerous synthetic organic compounds (APHA 1992).

Dissolved organic nitrogen (DON) was measured by first pumping water samples from a 1-meter depth into new, rinsed polyethylene bottles. The water samples were then passed through a pre-washed membrane filter with a 0.45-micron pore size. The filtrate was immediately frozen and later transported to Bryte Laboratory for analysis according to the EPA (1983) colorimetric, semi-automated method 351.2. The minimum reporting limit for DON is 0.1 mg/L.

DON concentrations were below the minimum reporting limit at station C3A in July, August and October, station D19 in April, station D26 in April, July and September, D28A in June and MD10A in July. A maximum concentration of 0.7 mg/L was recorded at station P8 in February. (Figures 3-20 and 3-21). Peak DON during 2006 was similar, reaching 0.6 mg/L at station MD10A in January. (Riordan et al 2007).

Figure 3-20 Dissolved organic nitrogen comparisons, 2007

Figure 3-21 Dissolved organic nitrogen (mg/L) by station, 2007

DON concentrations at all sites showed no clear seasonal or intra-annual pattern of variation.

Total Dissolved Solids

Total dissolved solids (TDS) are a measure of the solid fraction of a sample able to pass through a filter. The value of dissolved solids gives a general indication of the suitability of the water as a drinking source and for certain agricultural and industrial uses. Waters with high dissolved solids are of inferior palatability and may induce an unfavorable physiological reaction in consumers (APHA 1992).

Total dissolved solids were measured by first pumping water samples from a 1-meter depth into new, rinsed polyethylene bottles. The samples were then filtered through a pre-washed membrane filter with a 0.45-micron pore size. The filtrate was immediately refrigerated at 4 °C and later transported to Bryte Laboratory for analysis, using EPA (1983) method 160.1.

TDS in the Bay-Delta varied over a wide range, from 76 mg/L at site C3A in July to 27,900 mg/L at site D41 in December (Figures 3-22 and 3-23). The values were similar during 2006, which had a range of 57 mg/L to 27,420 mg/L (Riordan et al 2007). The high values seen in San Pablo Bay are likely due to tidal influences of seawater with high TDS entering the Delta. The lower TDS values seen at site C3A are likely due to spring flows of low TDS freshwater entering the Delta from the Sacramento Valley basin.

Figure 3-22 Total dissolved solids comparisons, 2007

Figure 3-23 Total dissolved solids (mg/L) by station, 2007

All sites subject to significant tidal exchange (sites D41, D41A, D6, D7, D8, and D4) show TDS concentrations in proportion to their proximity to the coast. These sites also showed seasonal variability in TDS concentrations. For these sites, low TDS values occurred in the spring and the highest values occurred in the winter.

Total Suspended Solids

Suspended solids are the solids present in a water sample that are retained on a filter after the sample is filtered. Suspended solids include a wide variety of material such as silt, living or decaying organic matter, and anthropogenic matter. High amounts of suspended solids block light penetration into the water column and increase heat absorption.

Total suspended solids (TSS) may increase in surface waters due to increases in flow rate, as higher velocities increase water's capacity to suspend solids. Runoff from heavy rains can simultaneously introduce large amounts of solids into surface waters and provide the capacity for their suspension. Therefore, suspended solids concentrations can vary significantly over relatively short time periods.

Water samples for TSS analysis were taken from aliquots collected from a depth of 1 meter, stored in polyethylene bottles, and refrigerated at 4 °C until analyzed at Bryte Laboratory using EPA (1983) method 160.2.

TSS in the Delta varied over a wide range, from below the minimum reporting limit (<1.0 mg/L) at site MD10A in November to 114 mg/L at site D7 in March (Figures 3-24 and 3-25). These results are in contrast to the 2006 study period, where the highest TSS value was recorded at site D7 (228 mg/L) and the lowest TSS value was below the minimum reporting limit at site D28A (Riordan et al 2007).

Figure 3-24 Total suspended solids comparisons, 2007

Figure 3-25 Total suspended solids (mg/L) by station, 2007

TSS values at most sites showed "pulse" increases at various times during the year. These increases did not show any discernable seasonal pattern. Although winter pulse variations may be due to rain or hydrological events, variations in TSS at other times may reflect changing levels of organic matter.

Volatile Suspended Solids

The measurement of volatile suspended solids (VSS) provides a relative indicator of the amount of organic matter present in the water sample. Water samples for VSS analysis were taken from aliquots collected from a depth of 1 meter, stored in polyethylene bottles and refrigerated at 4 °C until analyzed at Bryte Laboratory. Samples were analyzed for VSS according to EPA Method 160.4 (EPA 1983). The minimum reporting level for VSS in these analyses was 1.0 mg/L.

VSS levels occasionally fell below minimum reporting levels (<1 mg/L) in most regions, and reached a high of 35.0 mg/L at site C10A in July (Figures 3-26 and 3-27). These results were different from those observed in 2006, which had a maximum value of 26.0 mg/L at site D7 in August (Riordan et al 2007). Most sites showed a high degree of variability, with no apparent seasonal trends.

Figure 3-26 Volatile suspended solids comparisons, 2007

Figure 3-27 Volatile suspended solids (mg/L) by station, 2007

Silica

Water samples for silica analysis were taken from aliquots collected from a depth of 1 meter into new, rinsed polyethylene bottles. The water samples were then passed through a pre-washed membrane filter with a 0.45-micron pore size and refrigerated at 4 °C until analyzed at Bryte Laboratory. Samples were analyzed for silica according to EPA Method 200.7 (EPA 1983). The minimum reporting level for silica in these analyses was 0.1 mg/L.

Silica concentrations ranged from below the minimum reporting limit at site D41 in August to a high of 22.7 mg/L at site C3A in December (Figures 3-28 and 3-29). By comparison, values during 2006 ranged from 5.4 mg/L at site D41 in November to 19.5 mg/L at site D4 in January (Riordan et al 2007). A slight seasonal trend of declining silica levels in spring months followed by increased silica concentrations in late summer and fall was observed at the majority of sites, excluding those in the Suisun and San Pablo Bays. The sites in Suisun Bay and San Pablo Bay showed a slight trend of increasing silica concentrations in the early spring, with concentrations decreasing at the beginning of summer.

Figure 3-28 Silica comparisons, 2007

Figure 3-29 Silica (mg/L) by station, 2007

Chloride

Water samples for chloride analysis were taken from aliquots collected from a depth of 1 meter into new, rinsed polyethylene bottles. The water samples were then passed through a pre-washed membrane filter with a 0.45-micron pore size and refrigerated at 4 °C until analyzed at Bryte Laboratory. Samples were analyzed for chloride according to EPA Method 300.0 (EPA 1983).

Chloride concentrations in the Bay-Delta varied over a wide range from 5 mg/L at site C3A in April and July to 15,600 mg/L at site D41 in December (Figures 3-30 and 3-31). These results are very similar to those observed during 2006, which recorded a low of 2 mg/L at site C3A in April and a high of 14,800 mg/L at site D41 in November (Riordan et al 2007). The high values seen in San Pablo Bay are likely due to tidal influences of seawater entering the Delta, while the low values seen at site C3A are likely due to spring flows of fresh water down the Sacramento River. Values of chloride concentrations are closely correlated to values reported for specific conductance and total dissolved solids (TDS) reported earlier in this chapter.

Figure 3-30 Chloride comparisons, 2007

Figure 3-31 Chloride (mg/L) by station, 2007

Summary

The Department's monitoring and reporting of water quality data shown here is mandated in order to ensure compliance with water quality objectives; identify meaningful changes potentially related to the operation of the State Water Project and the Central Valley Project; and to reveal trends in ecological changes potentially related to project operations. Flow rates, influenced by project operations and natural forces, are a primary determinant of water quality dynamics at each site described. However, flow rates are not measured as part of this sampling protocol, and therefore a more analytical treatment of these data in relation to flow rates is not included. These data are presented as a snapshot of the system. They allow a historic comparison of a wide range of water quality parameters and show an overall consistency with recent years.

References

[APHA] American Public Health Association. 1992. Standard Methods for the Examination of Water and Wastewater. 18th Edition, Washington DC.

Lehman, P., S. Hayes, G. Marsh, C. Messer, C. Ralston, K. Gehrts, and J. Lee. 2001. Water Quality Conditions in the Sacramento-San Joaquin Delta during 1996. California Department of Water Resources, Sacramento, California.

Riordan, D., R. Barnett, S. Bell, T. Brown, M. Dempsey, A. Hennessy, B. Noble, and M. Vayssieres. 2007. Water Quality Conditions in the Sacramento-San Joaquin Delta during 2006. California Department of Water Resources, Sacramento, California.

[EPA] U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. Technical Report EPA-600/4-79-020.

Figure 3-1 EMP's discrete water quality sampling stations

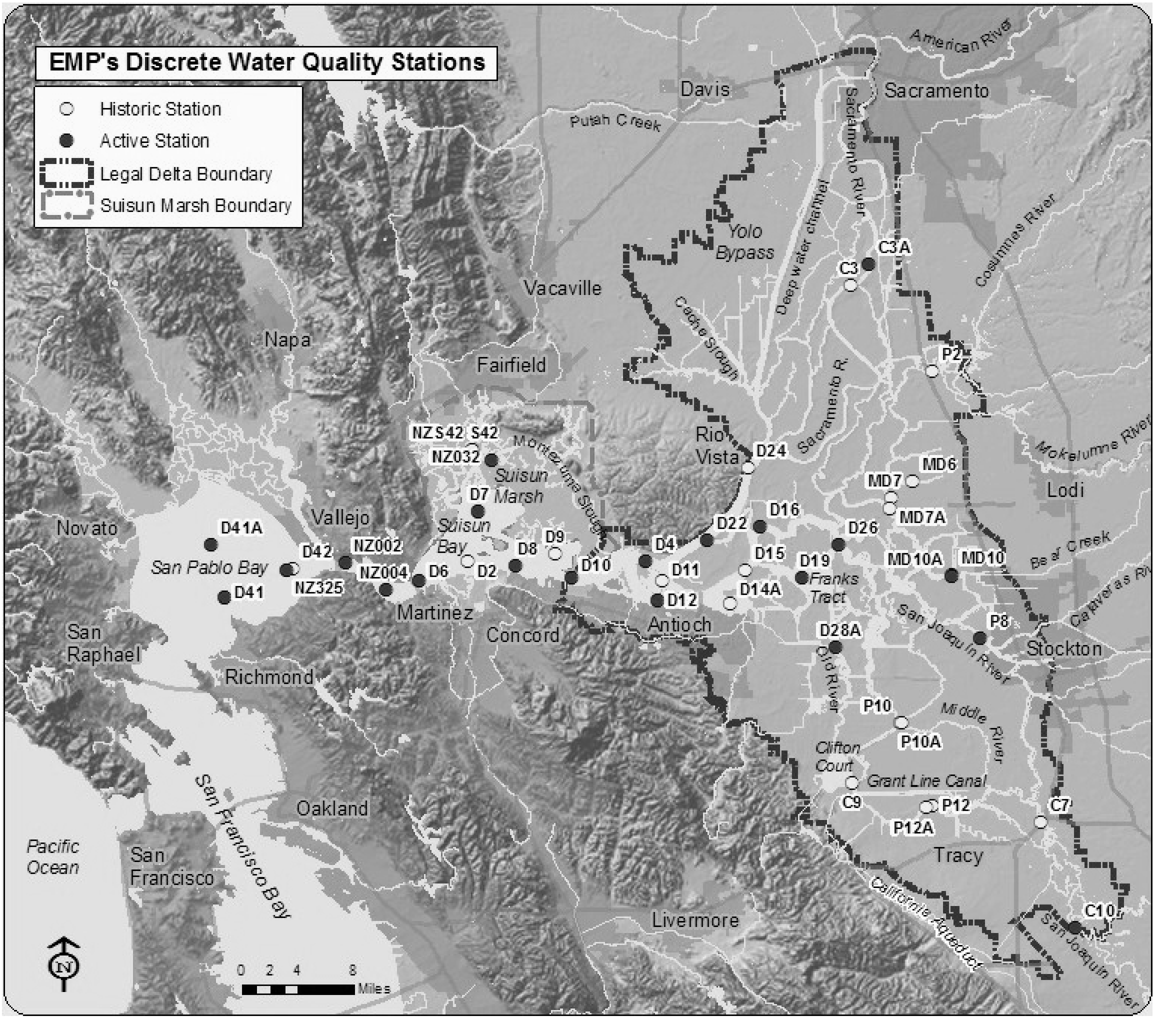


Figure 3-2 Water temperature comparisons, 2007

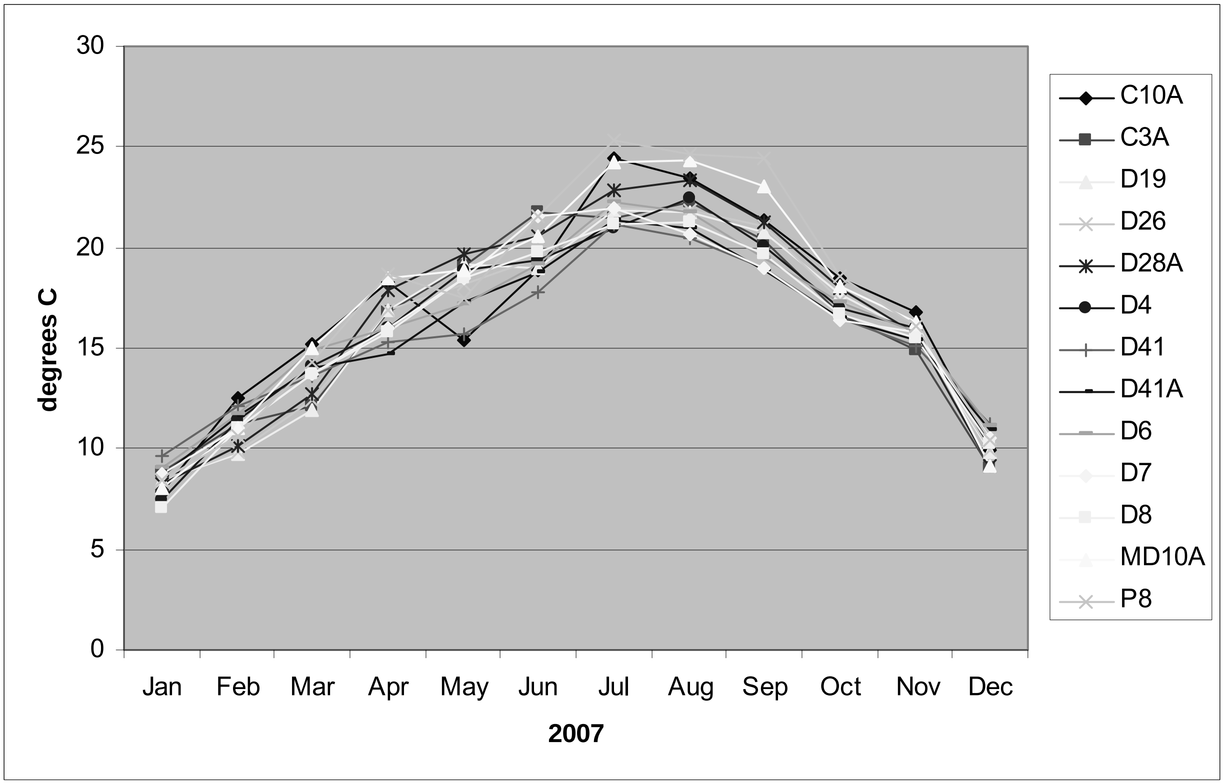


Figure 3-3 Water temperature (^{o}C) by station, 2007

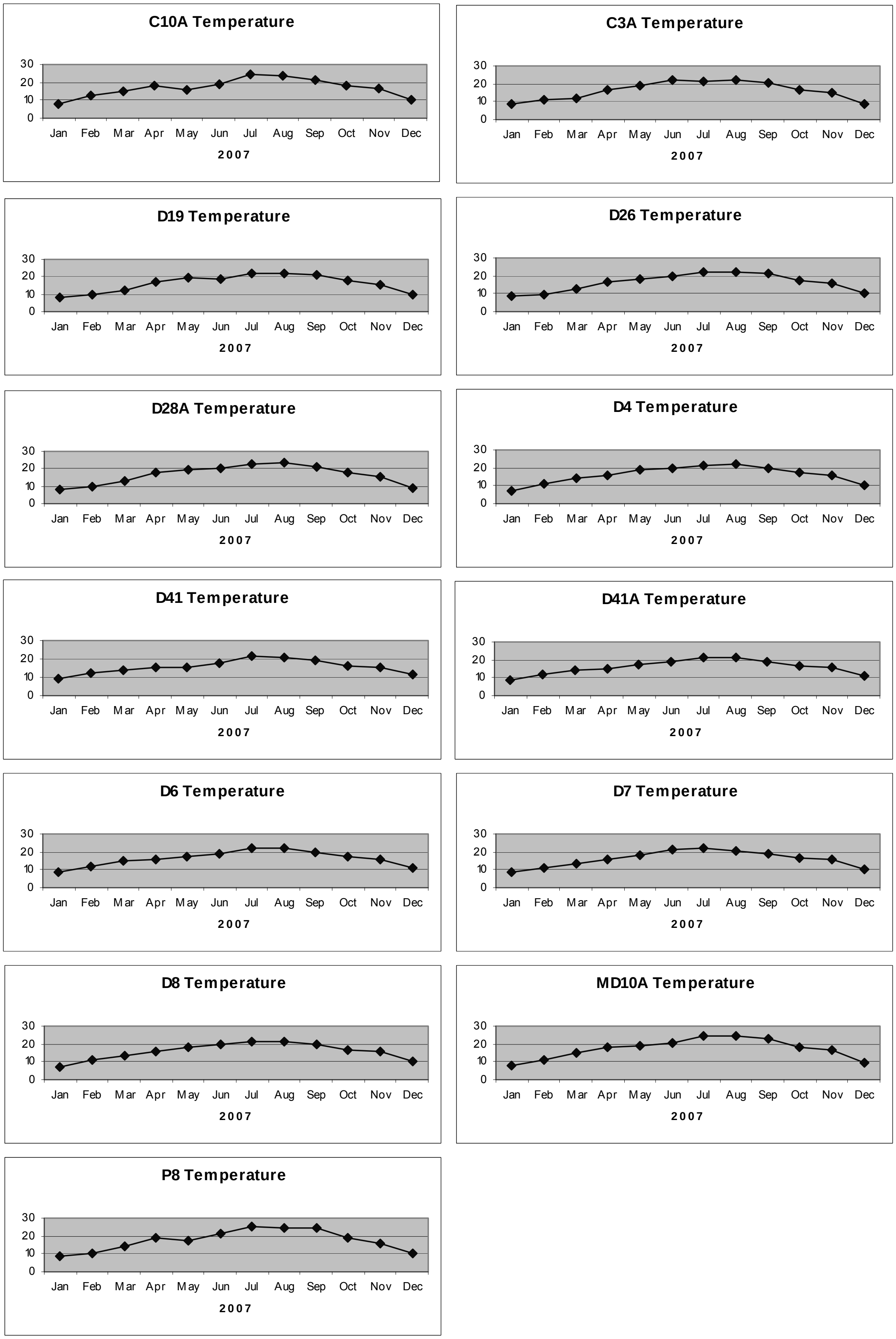


Figure 3-4 Dissolved oxygen comparisons, 2007

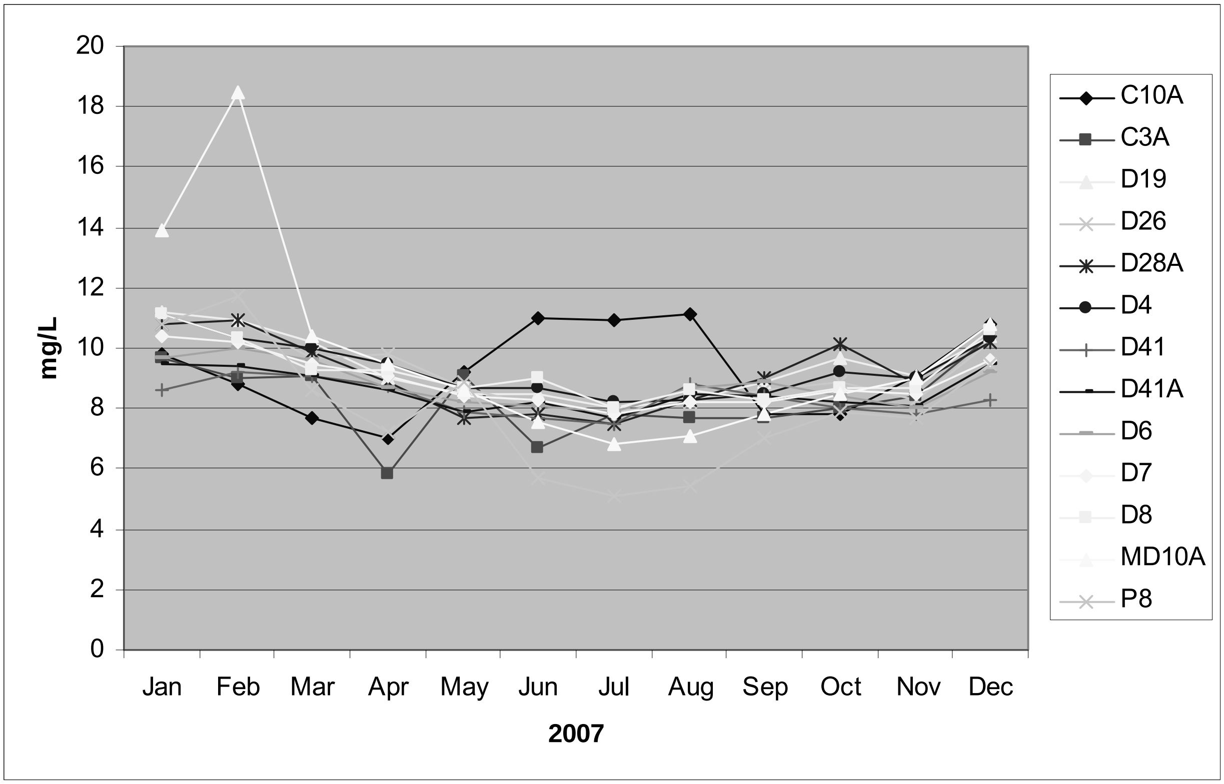


Figure 3-5 Dissolved oxygen (mg/L) by station, 2007

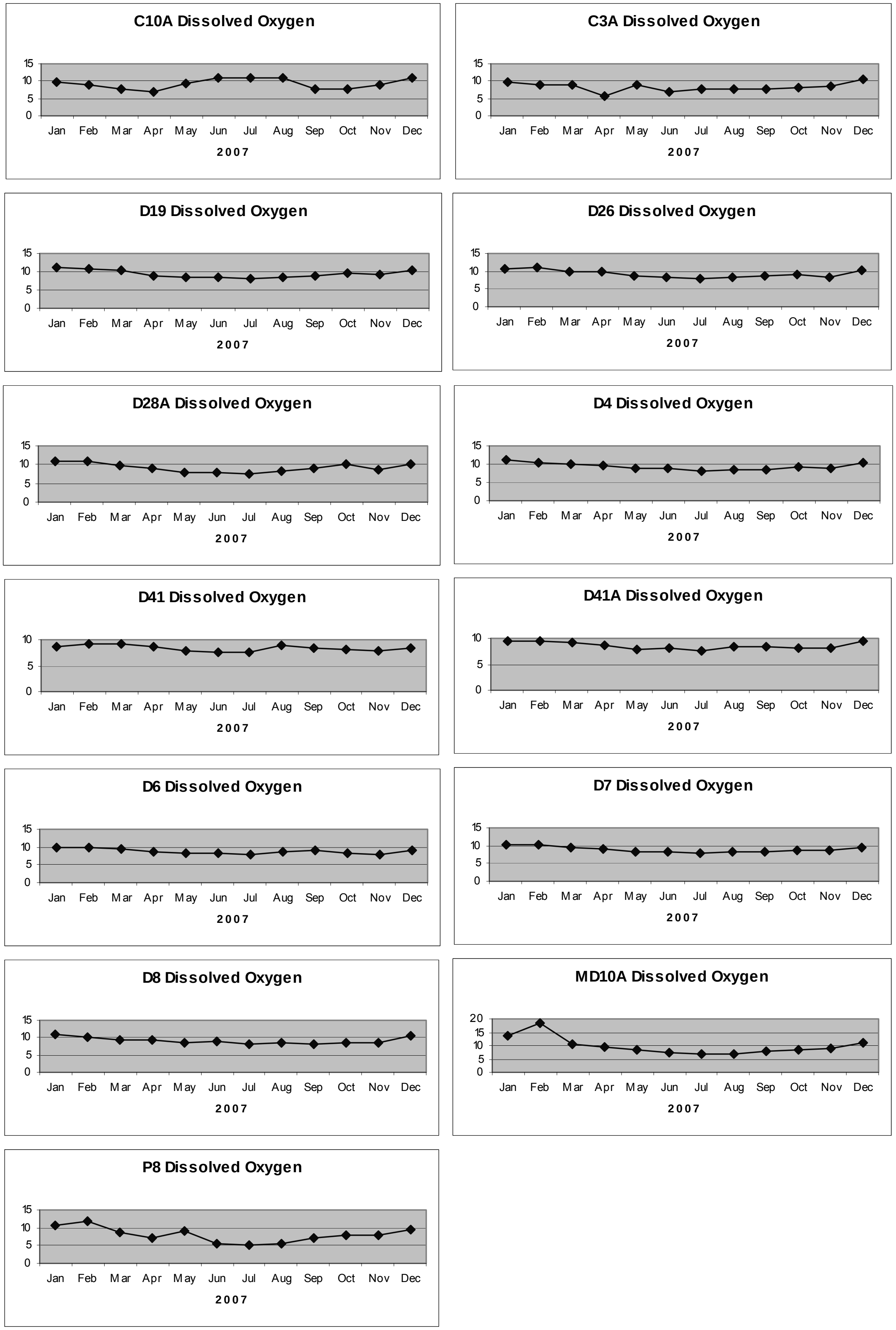


Figure 3-6 Specific conductance comparisons, 2007

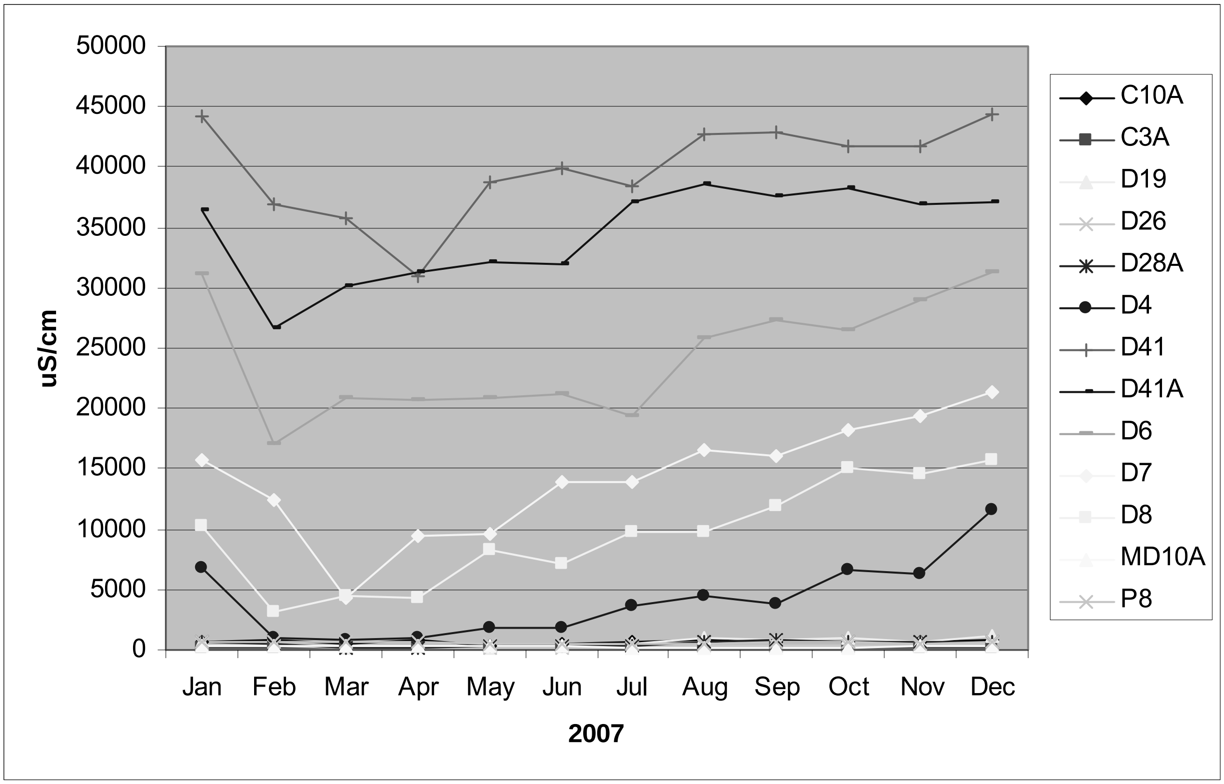


Figure 3-7 Specific conductance (uS/cm) by station, 2007

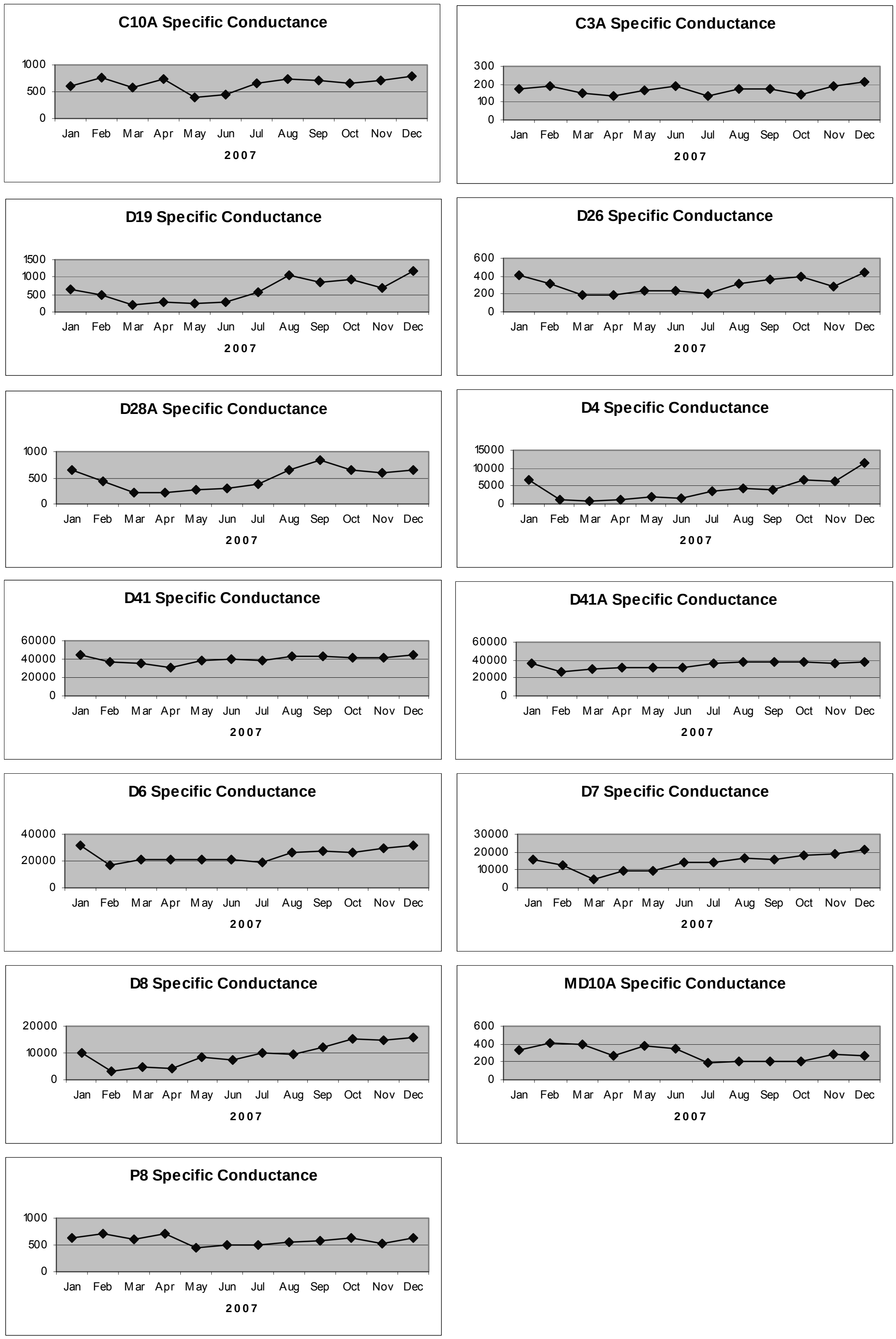


Figure 3-8 Secchi disk depth comparison, 2007

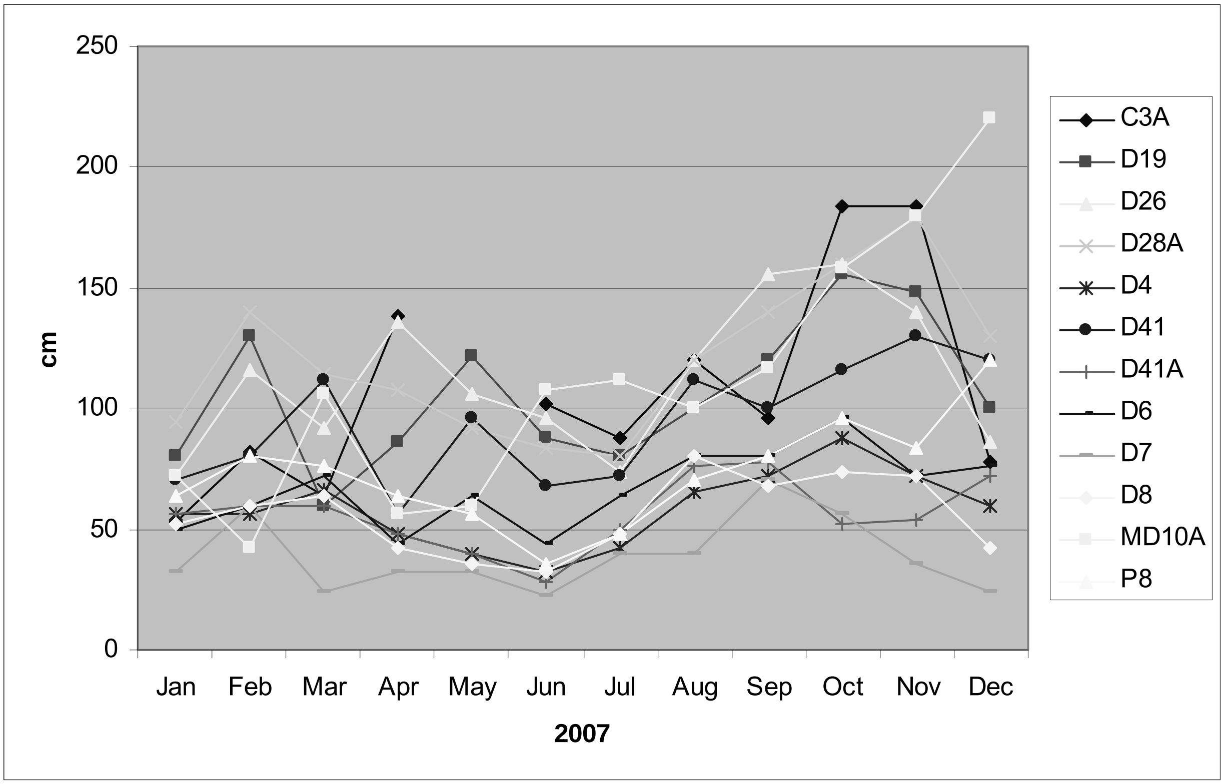


Figure 3-9 Secchi disk depth (cm) by station, 2007

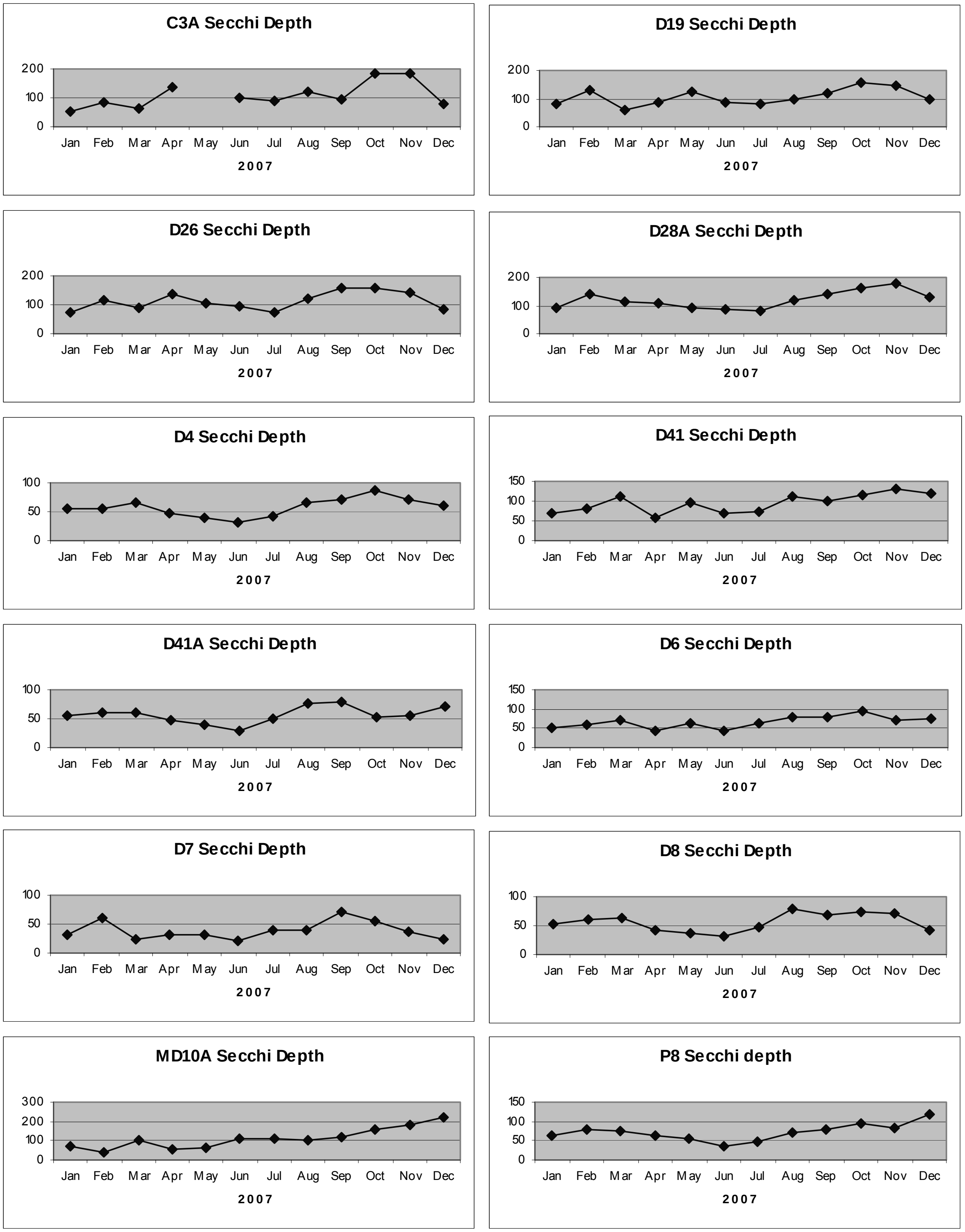


Figure 3-10 Turbidity comparisons, 2007

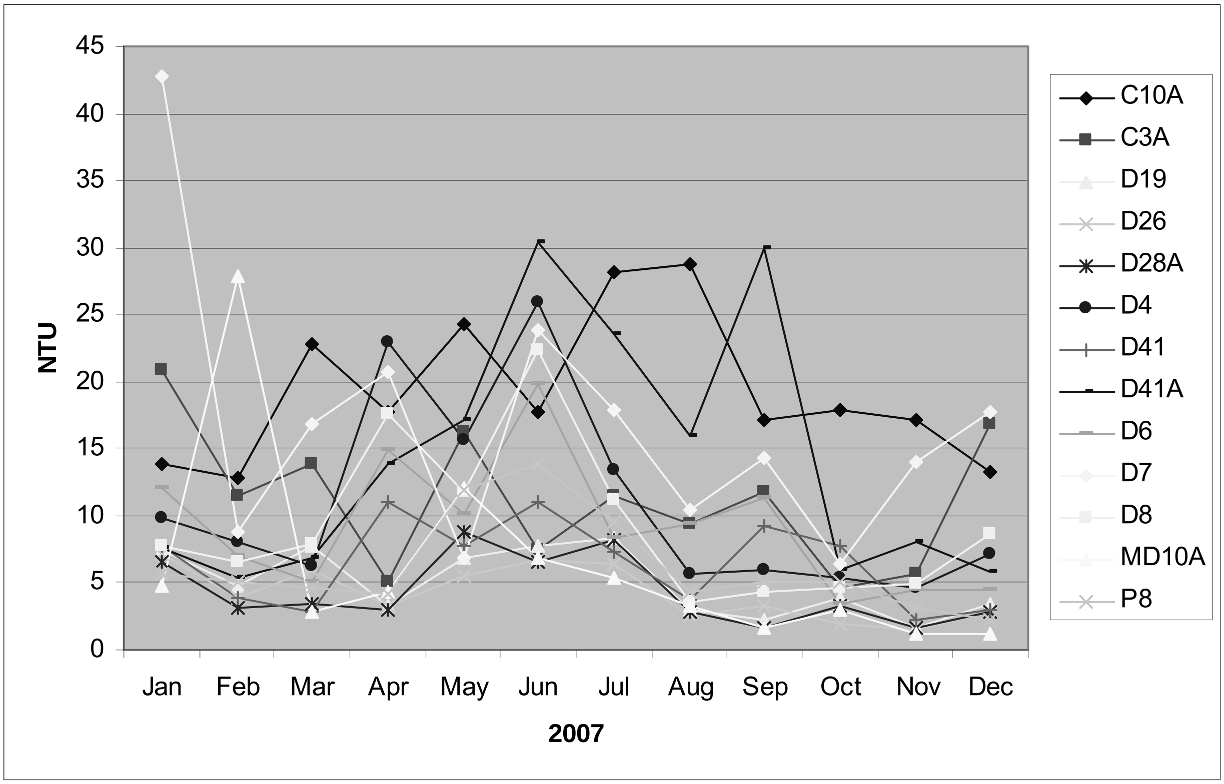


Figure 3-11 Turbidity (NTU) by station, 2007

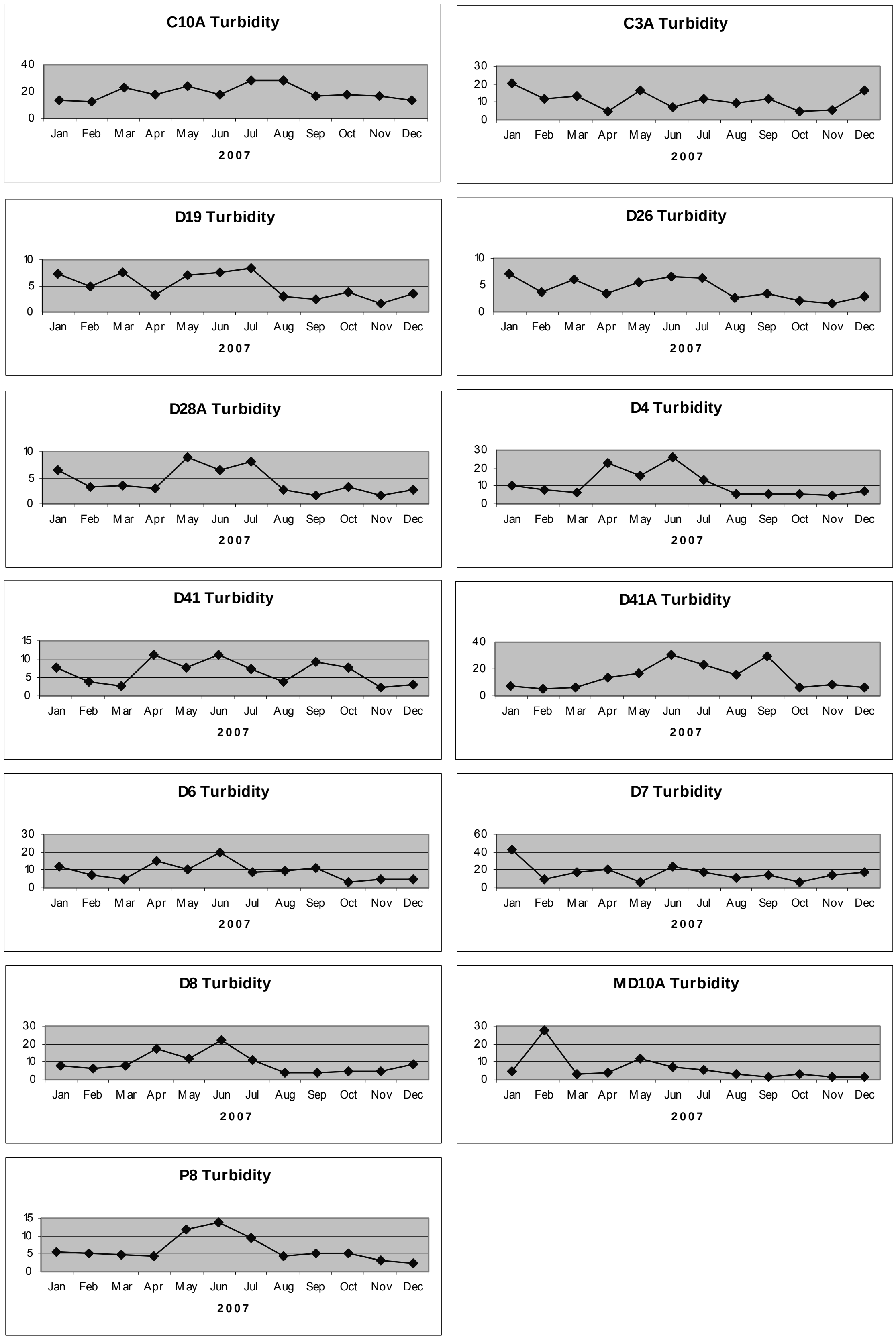


Figure 3-12 Orthophosphate comparisons, 2007

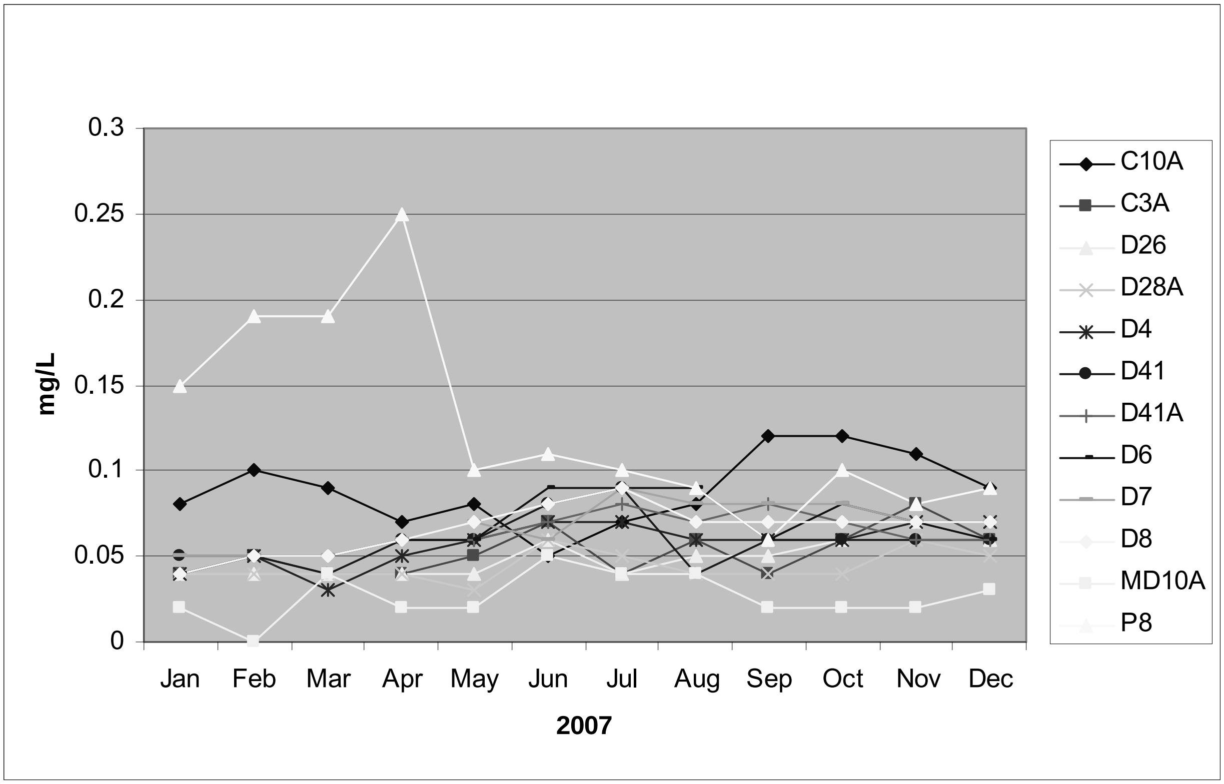


Figure 3-13 Orthophosphate (mg/L) by station, 2007

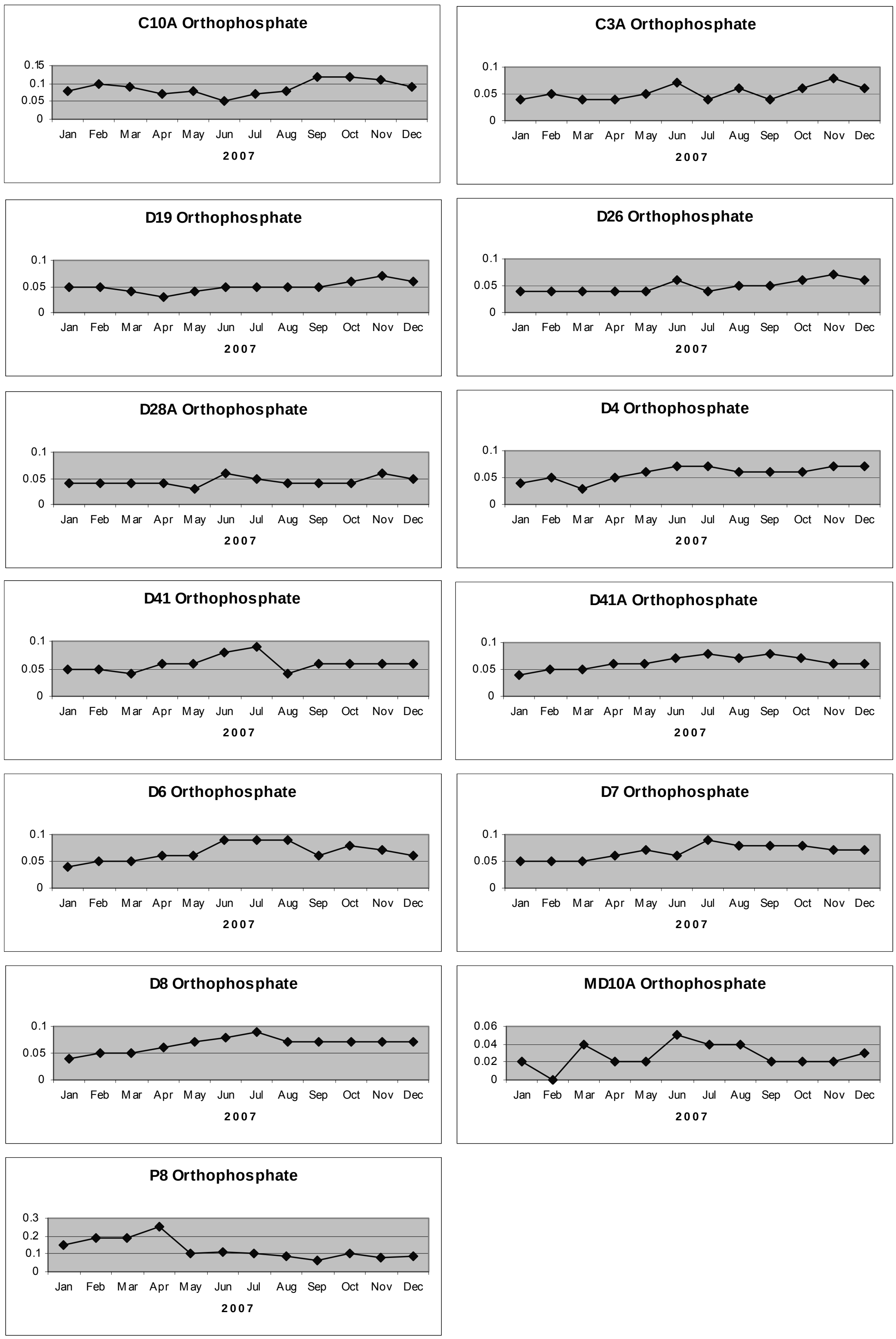


Figure 3-14 Total phosphorus (mg/L) comparisons, 2007

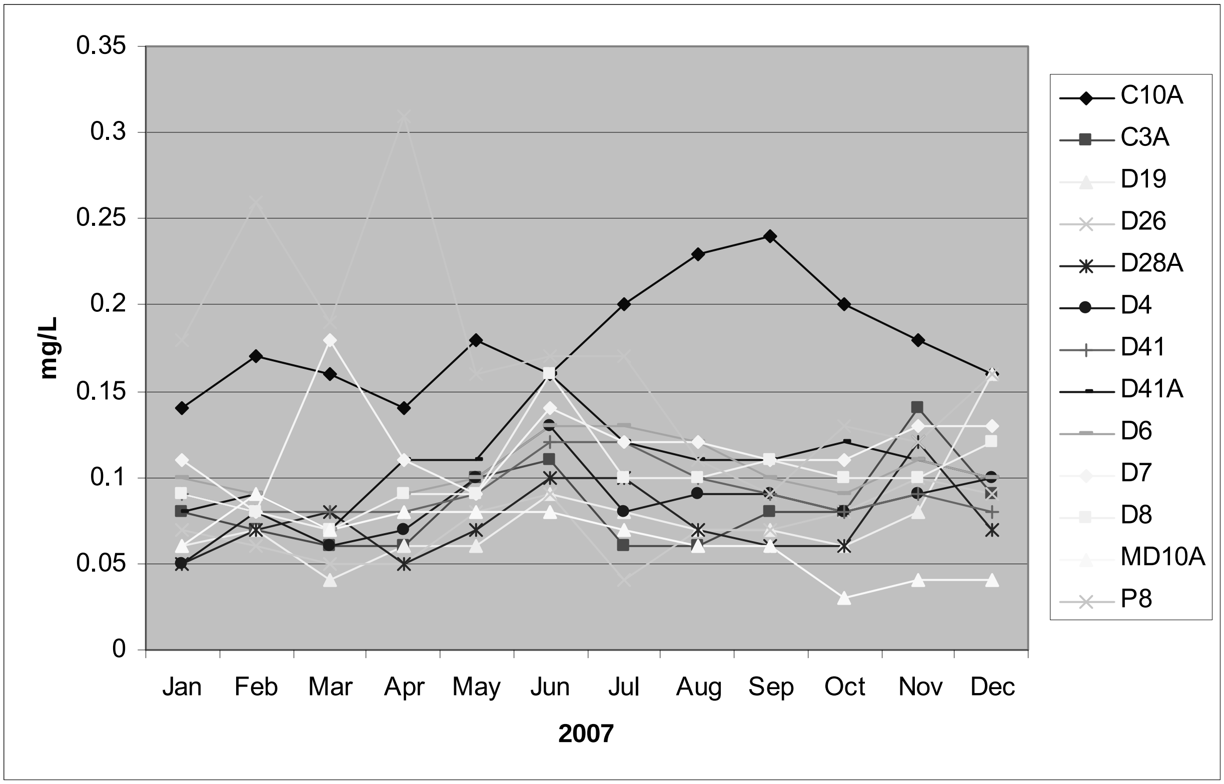


Figure 3-15 Total phosphorus (mg/L) by station, 2007

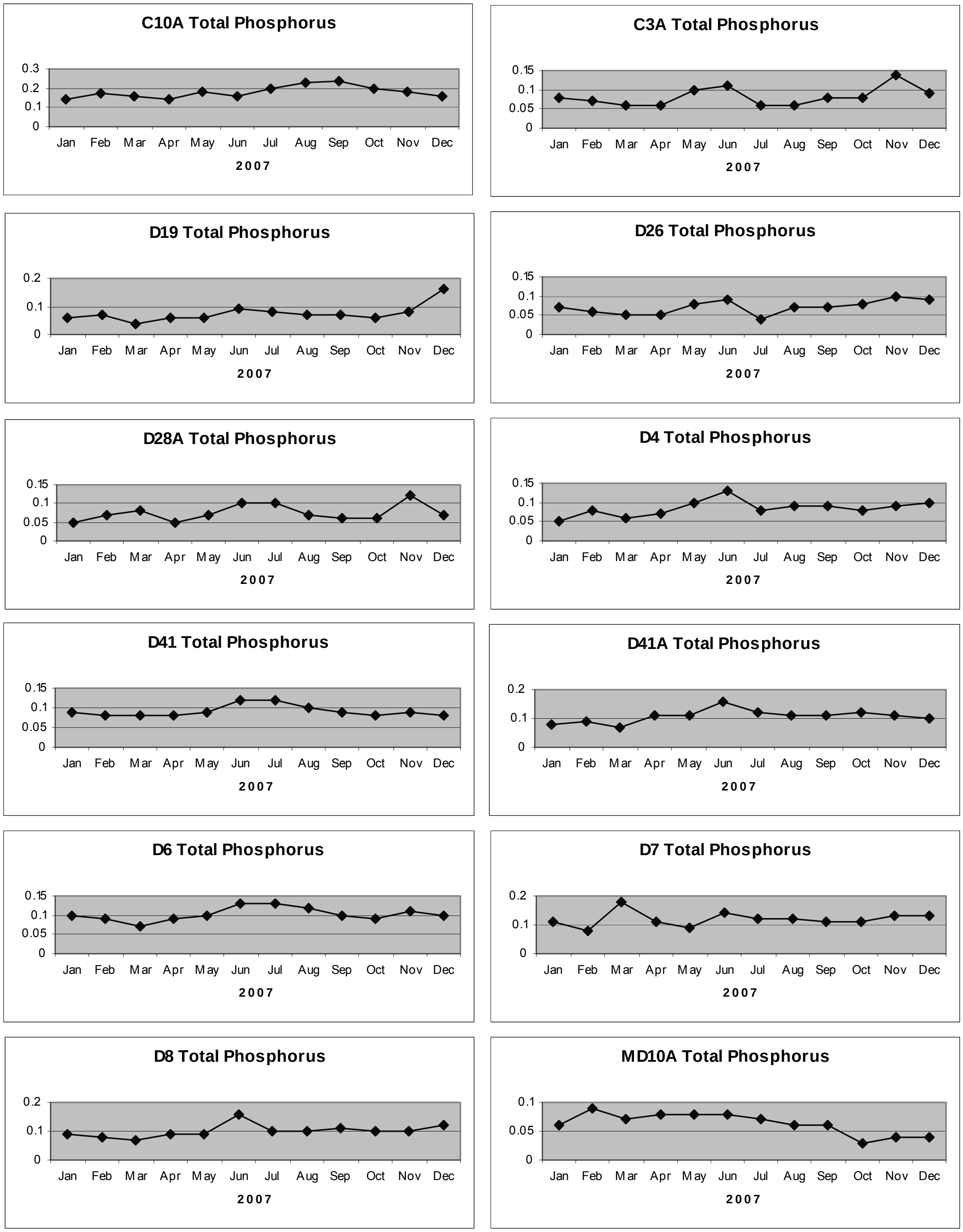


Figure 3-16 Kjeldahl nitrogen comparisons, 2007

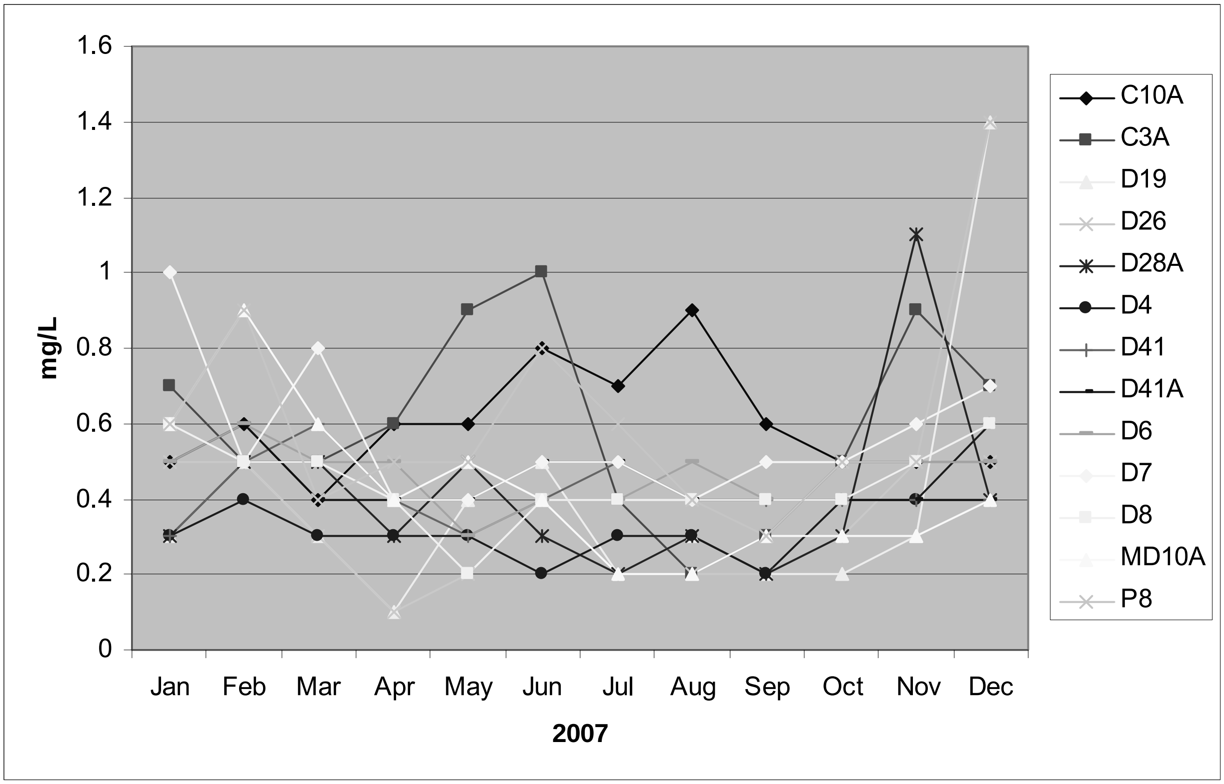


Figure 3-17 Kjeldahl nitrogen (mg/L) by station, 2007

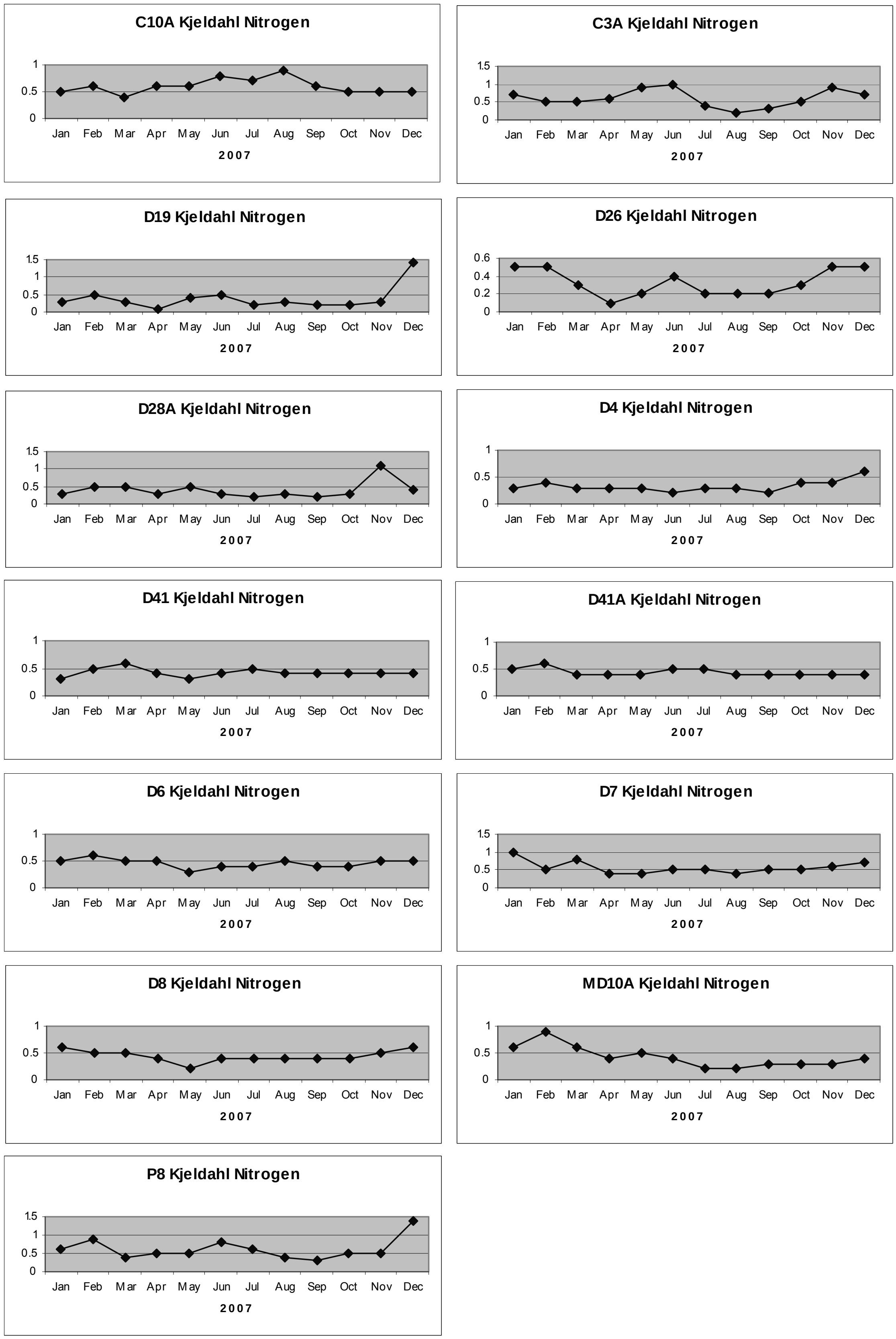


Figure 3-18 Dissolved inorganic nitrogen comparisons, 2007

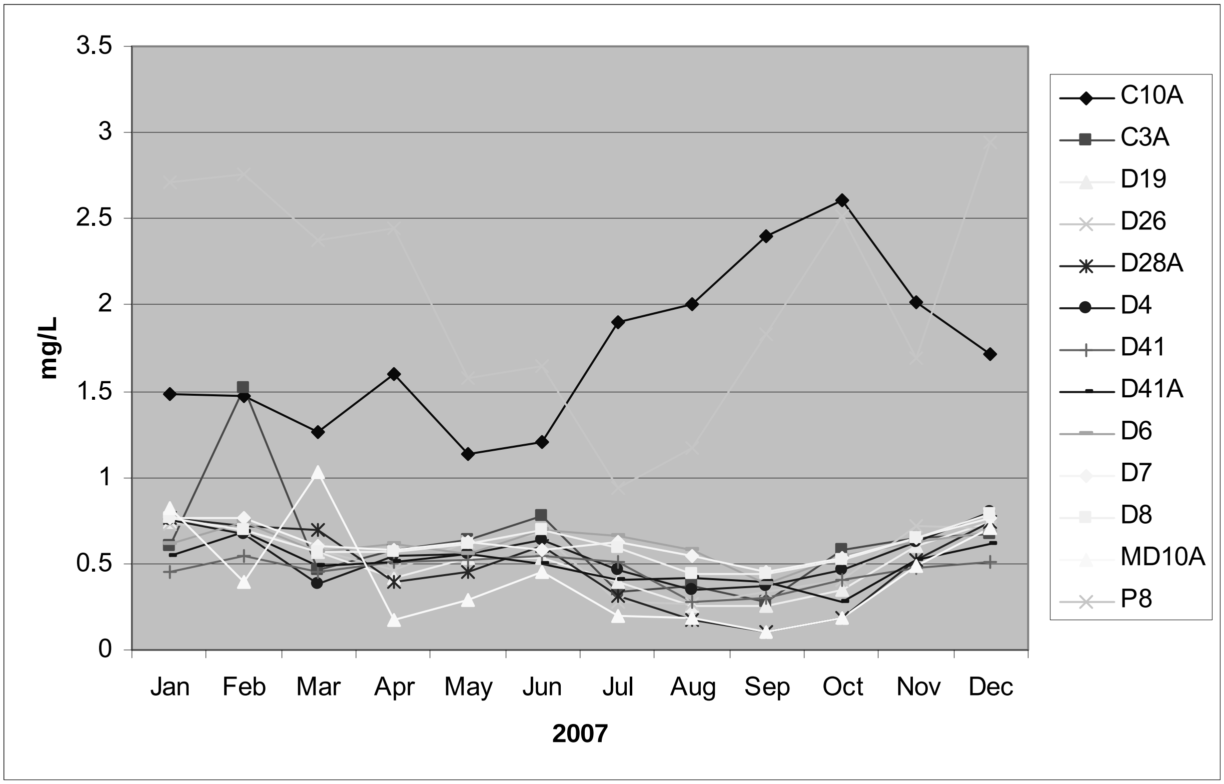


Figure 3-19 Dissolved inorganic nitrogen (mg/L) by station, 2007

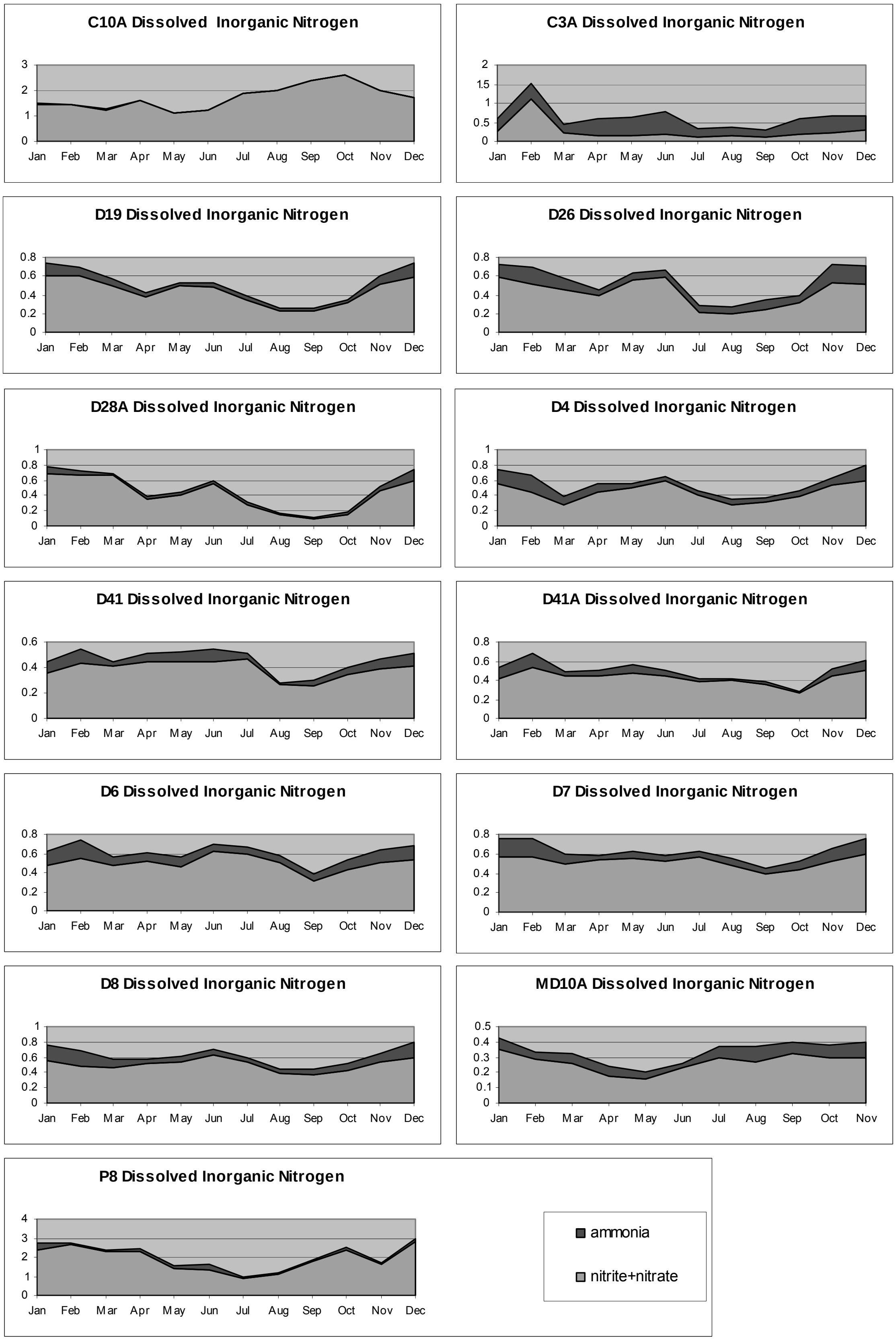


Figure 3-20 Dissolved organic nitrogen comparisons, 2007

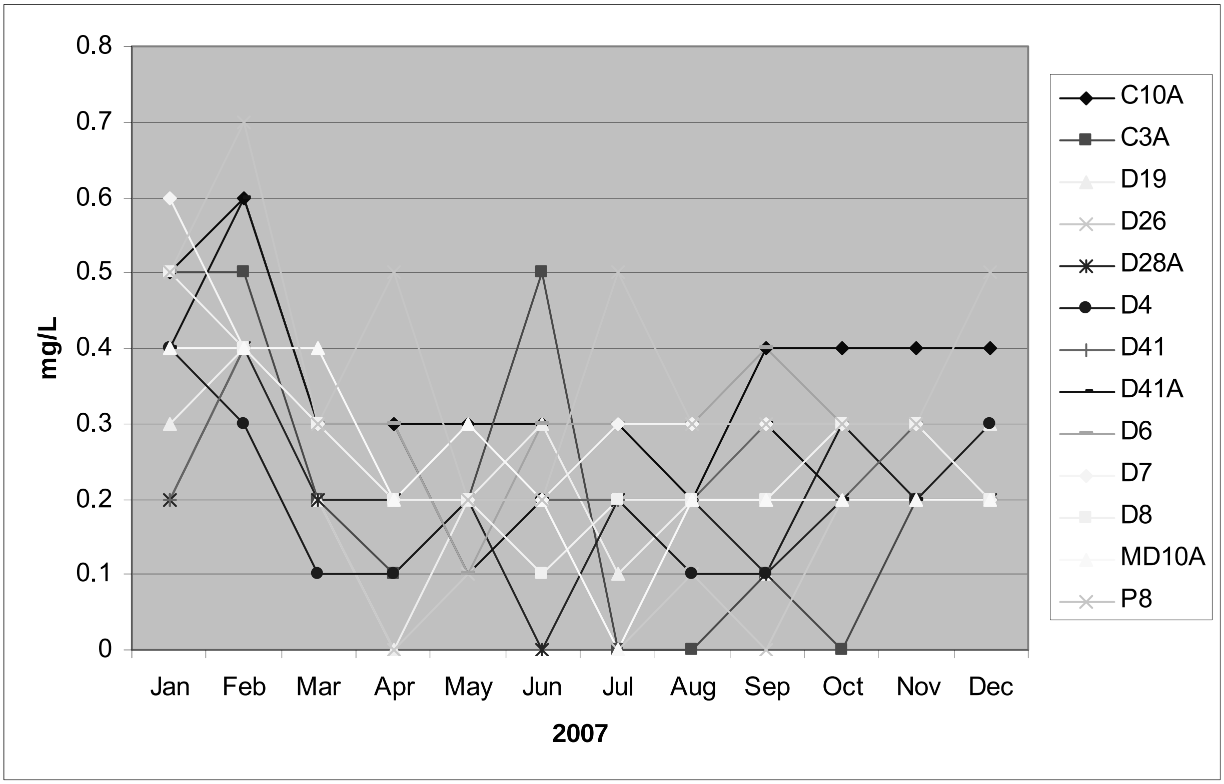


Figure 3-21 Dissolved organic nitrogen (mg/L) by station, 2007

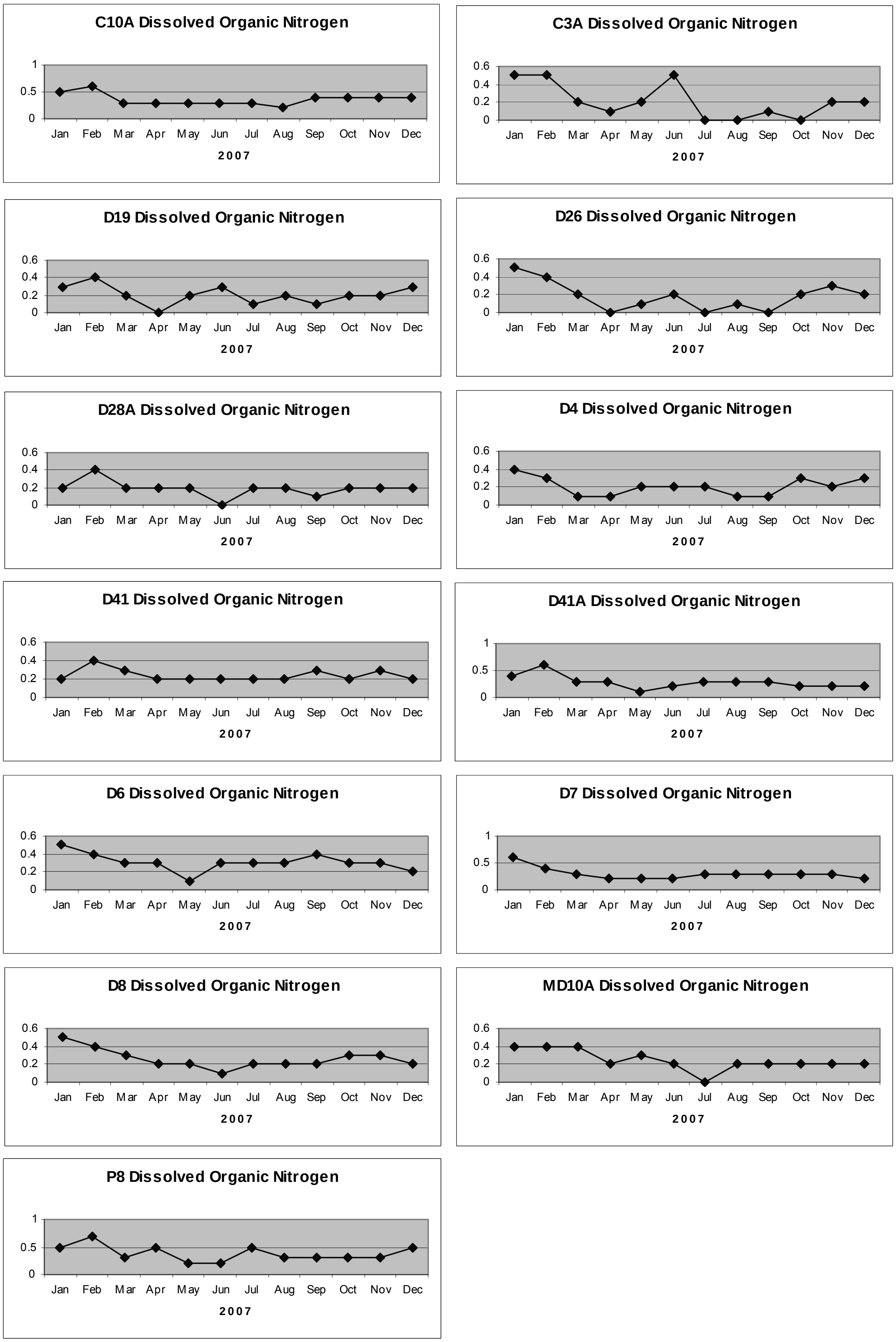


Figure 3-22 Total dissolved solids comparisons, 2007

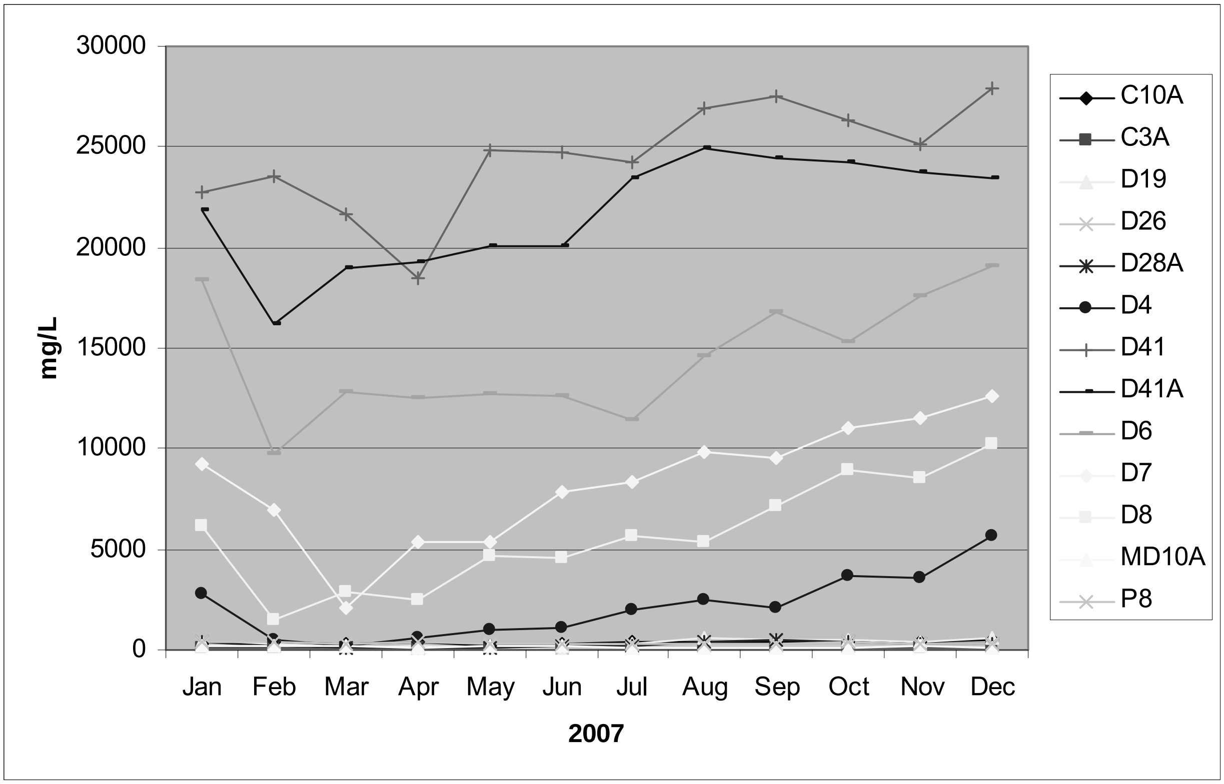


Figure 3-23 Total dissolved solids (mg/L) by station, 2007

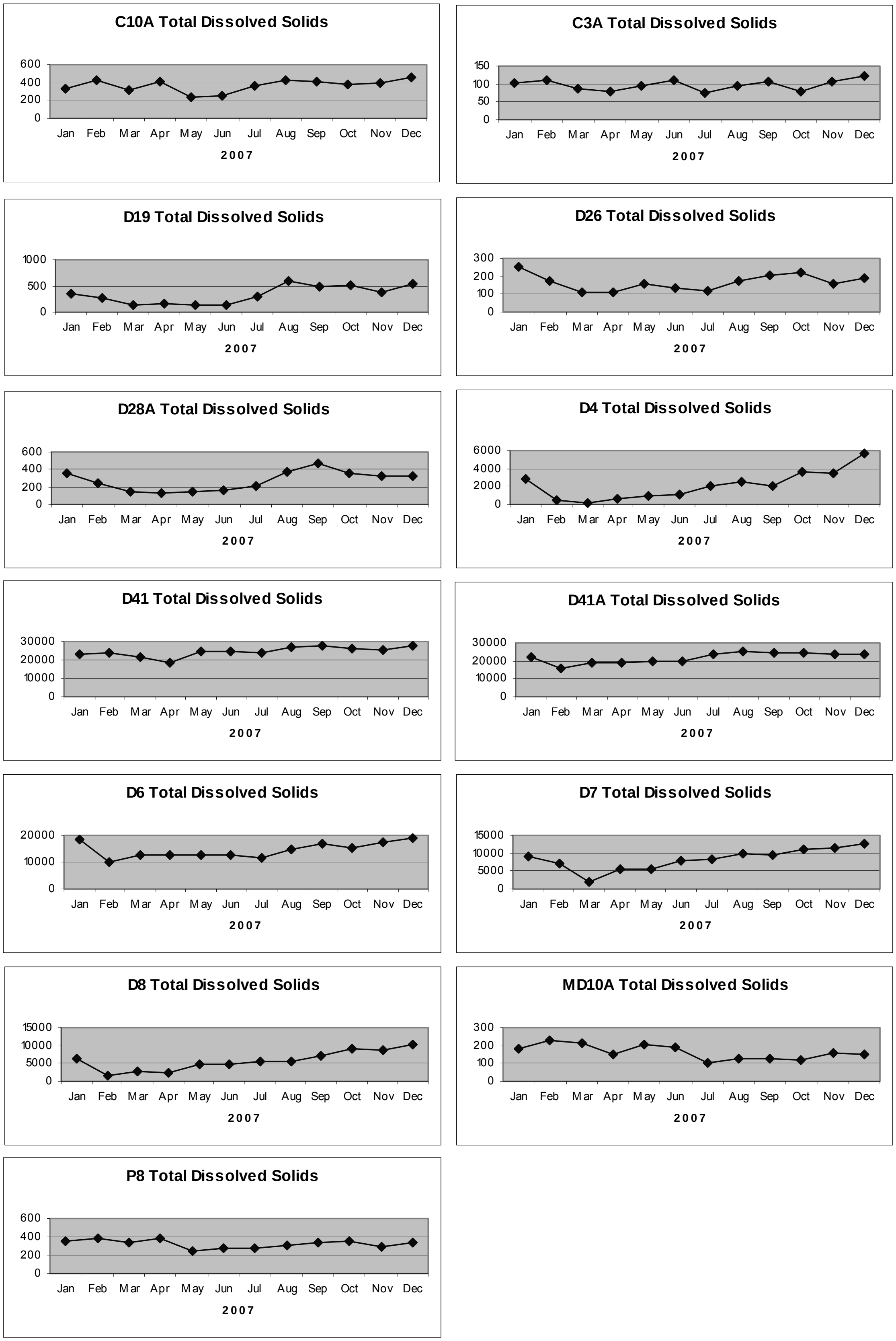


Figure 3-24 Total suspended solids comparisons, 2007

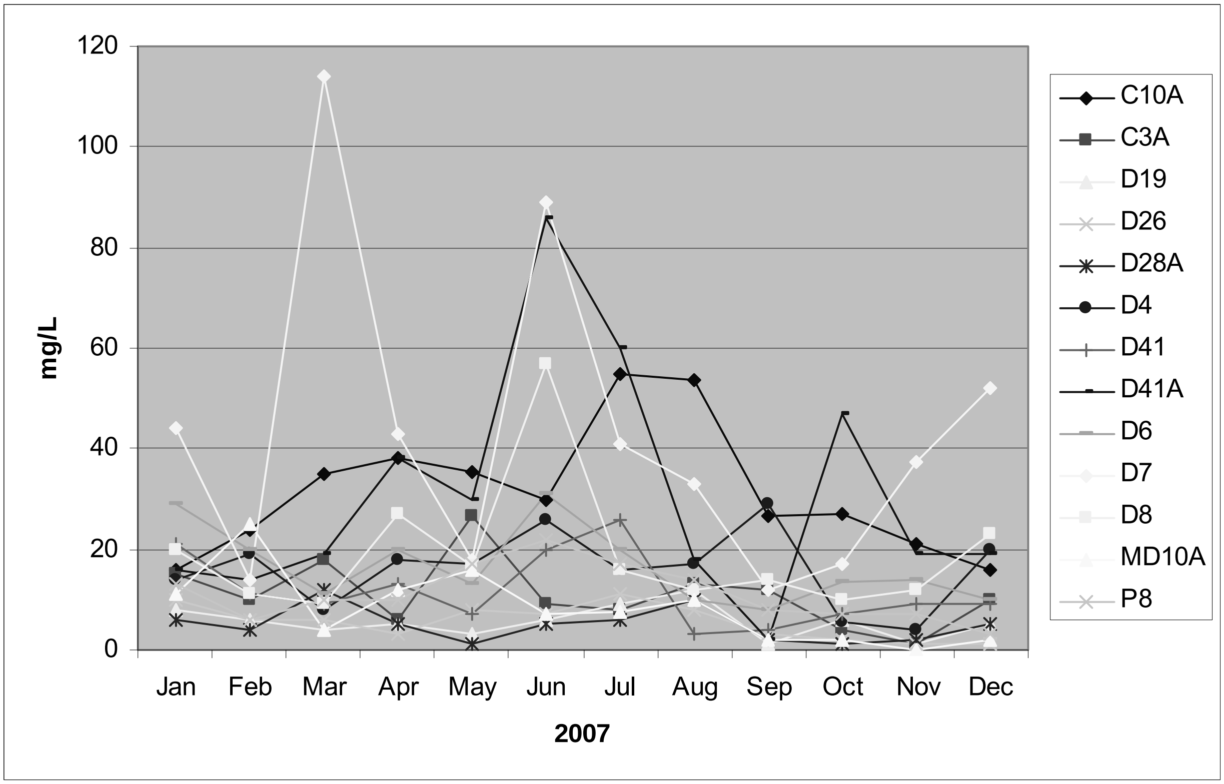


Figure 3-25 Total suspended solids (mg/L) by station, 2007

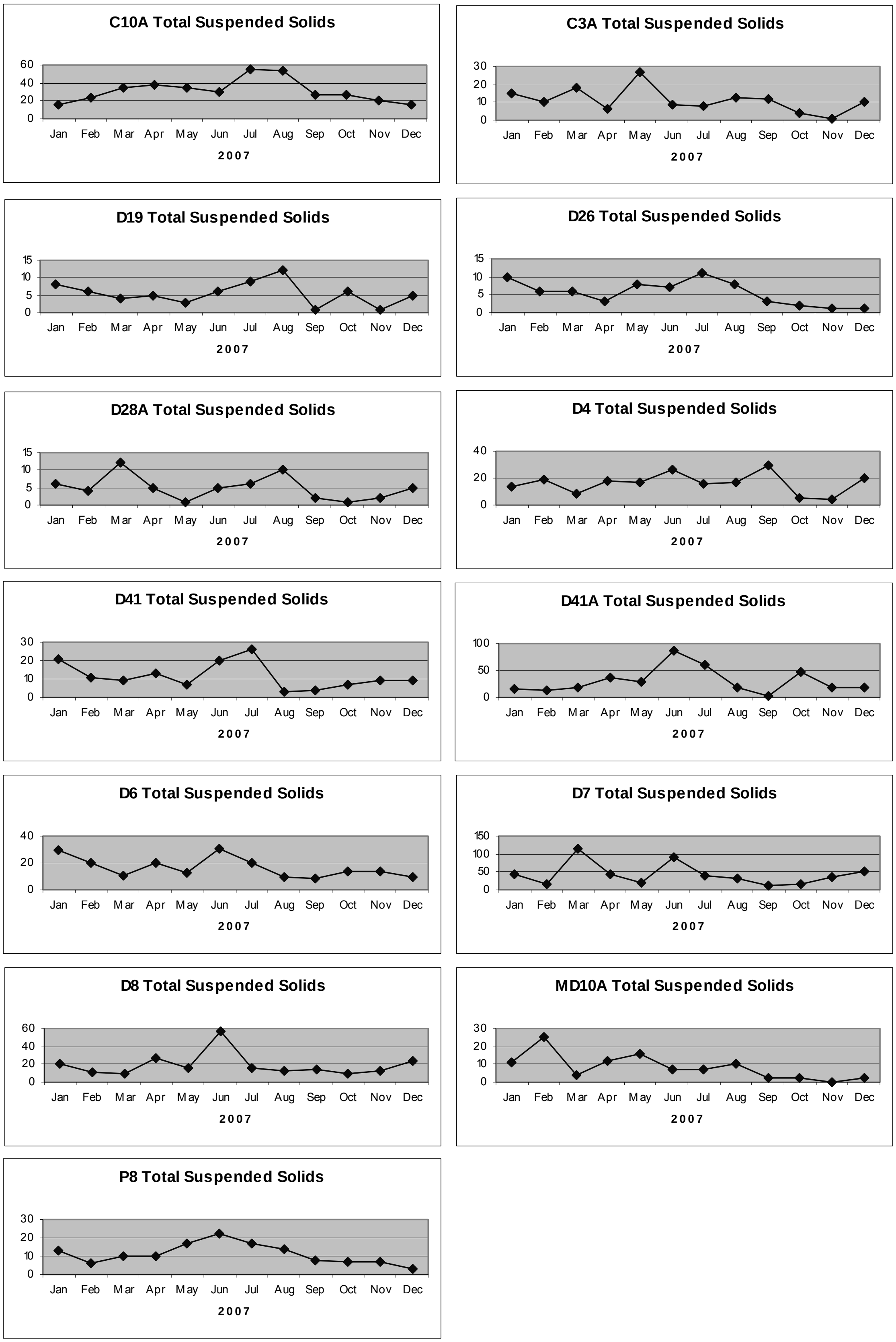


Figure 3-26 Volatile suspended solids comparisons, 2007

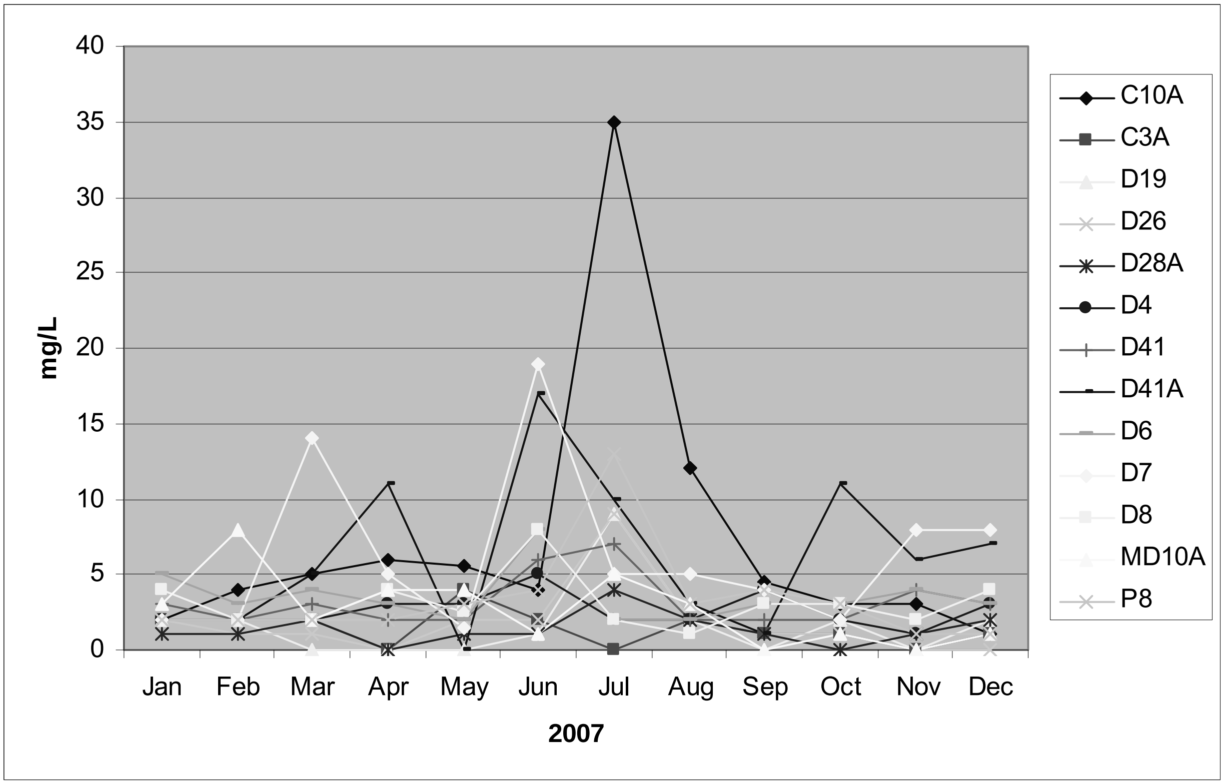


Figure 3-27 Volatile suspended solids (mg/L) by station, 2007

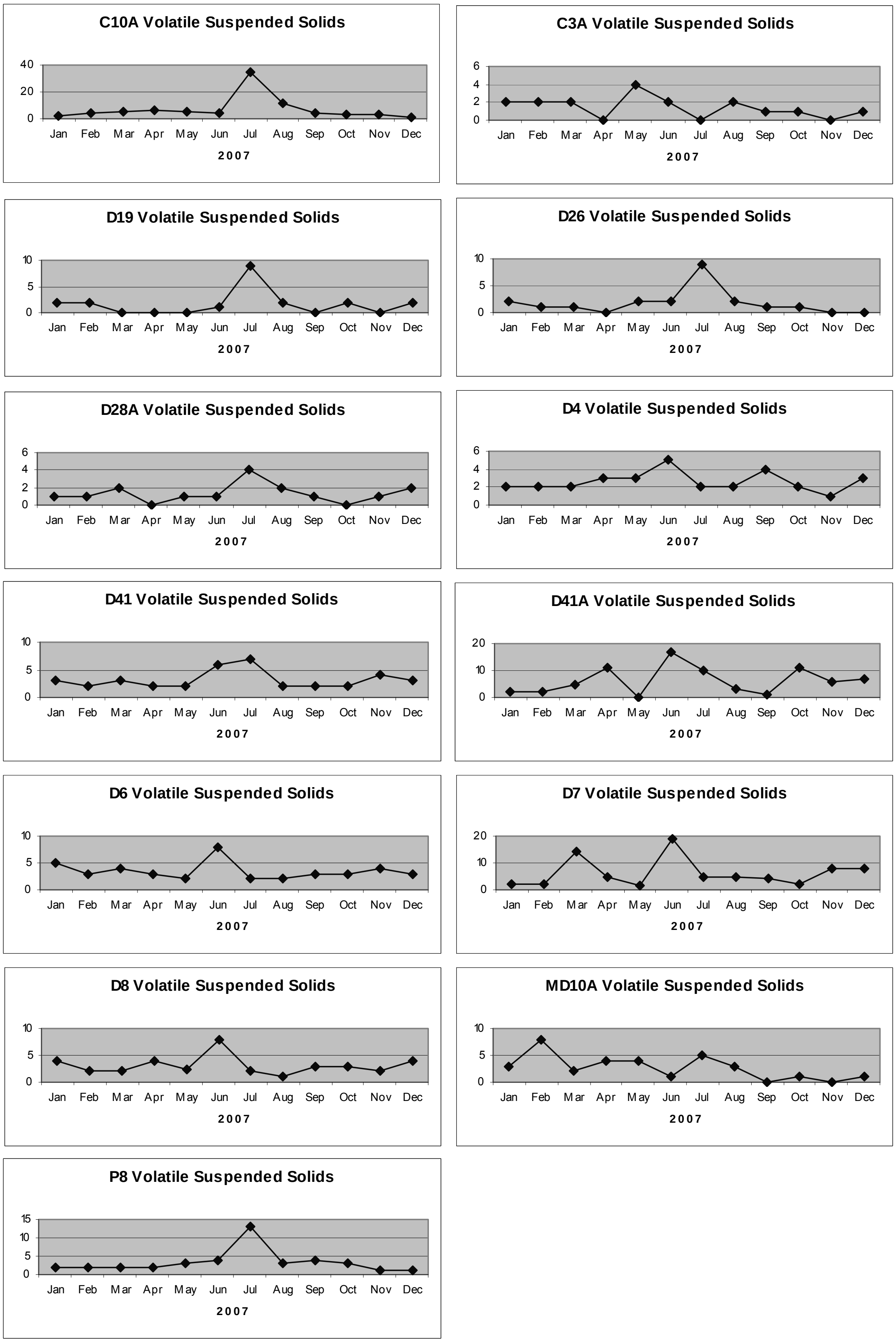


Figure 3-28 Silica comparisons, 2007

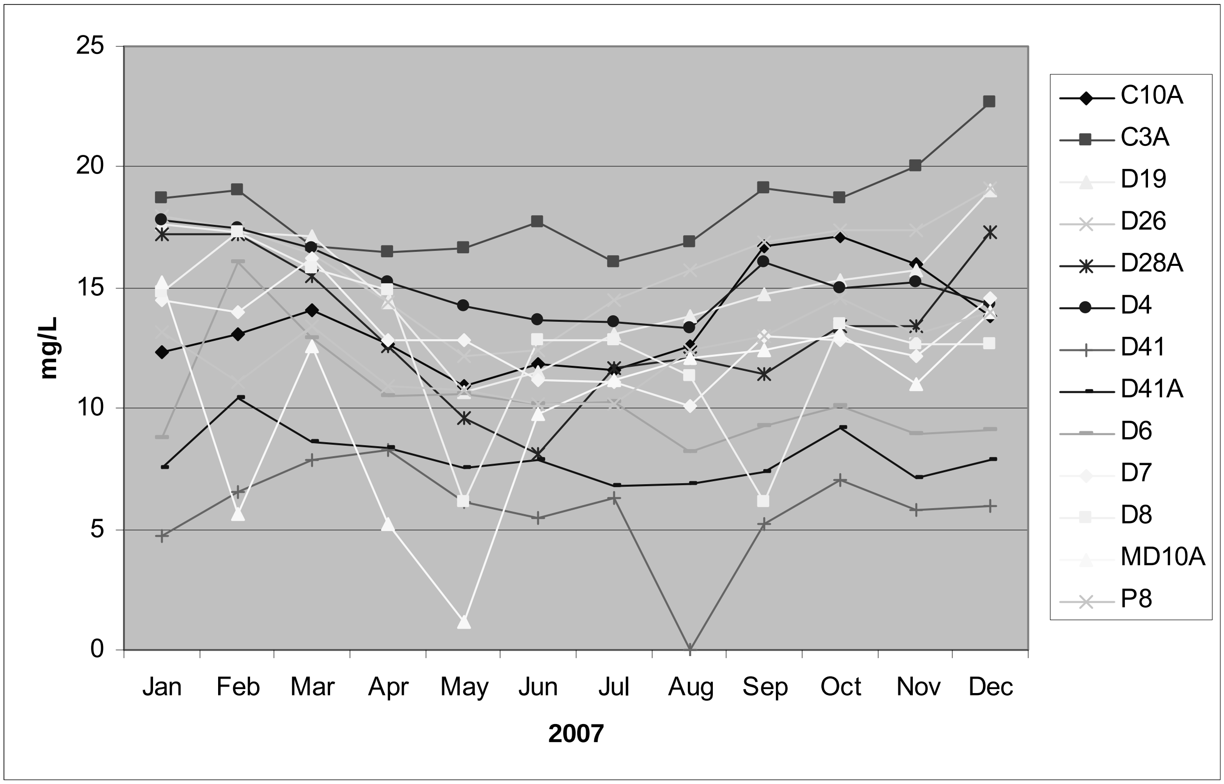


Figure 3-29 Silica (mg/L) by station, 2007

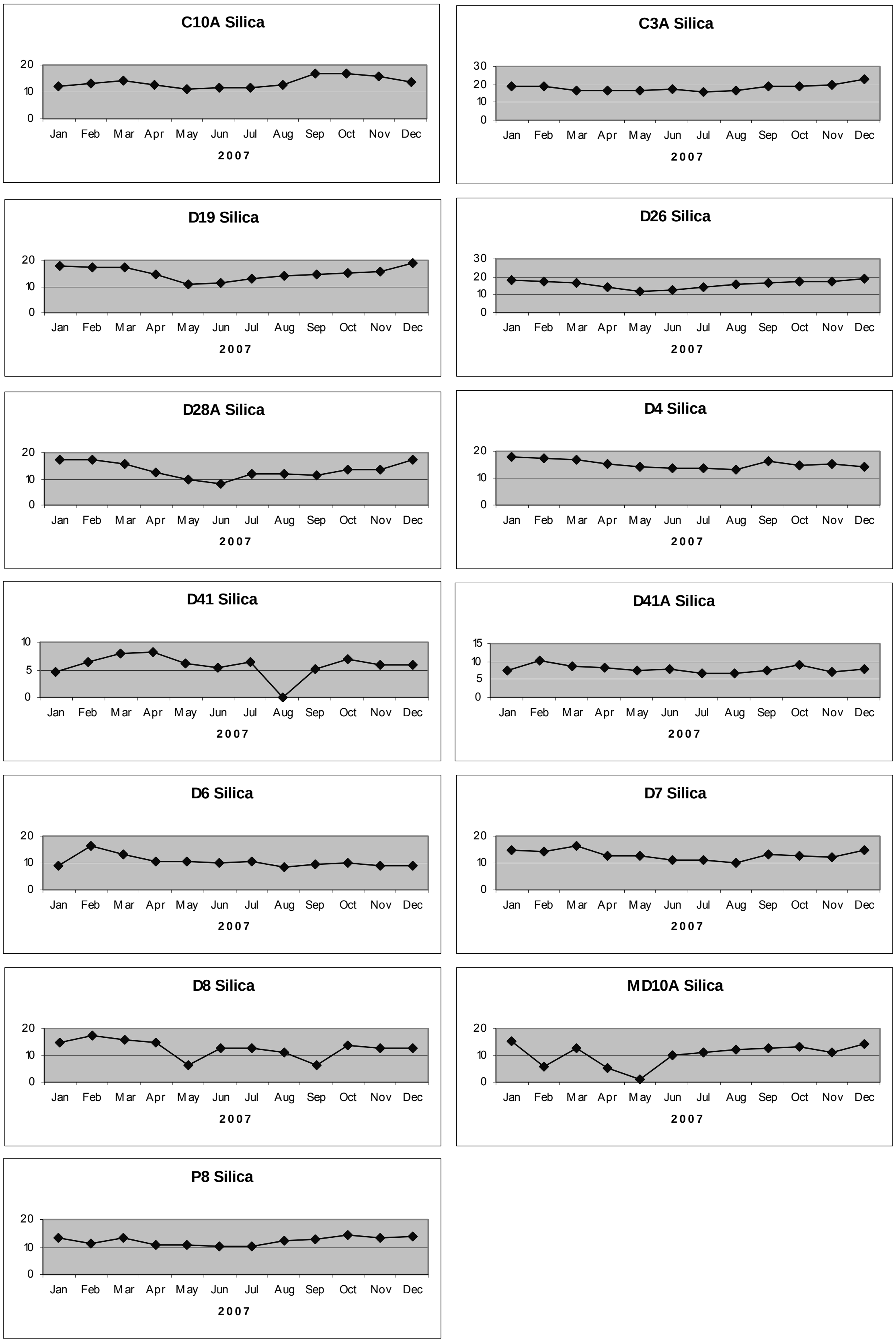


Figure 3-30 Chloride comparisons, 2007

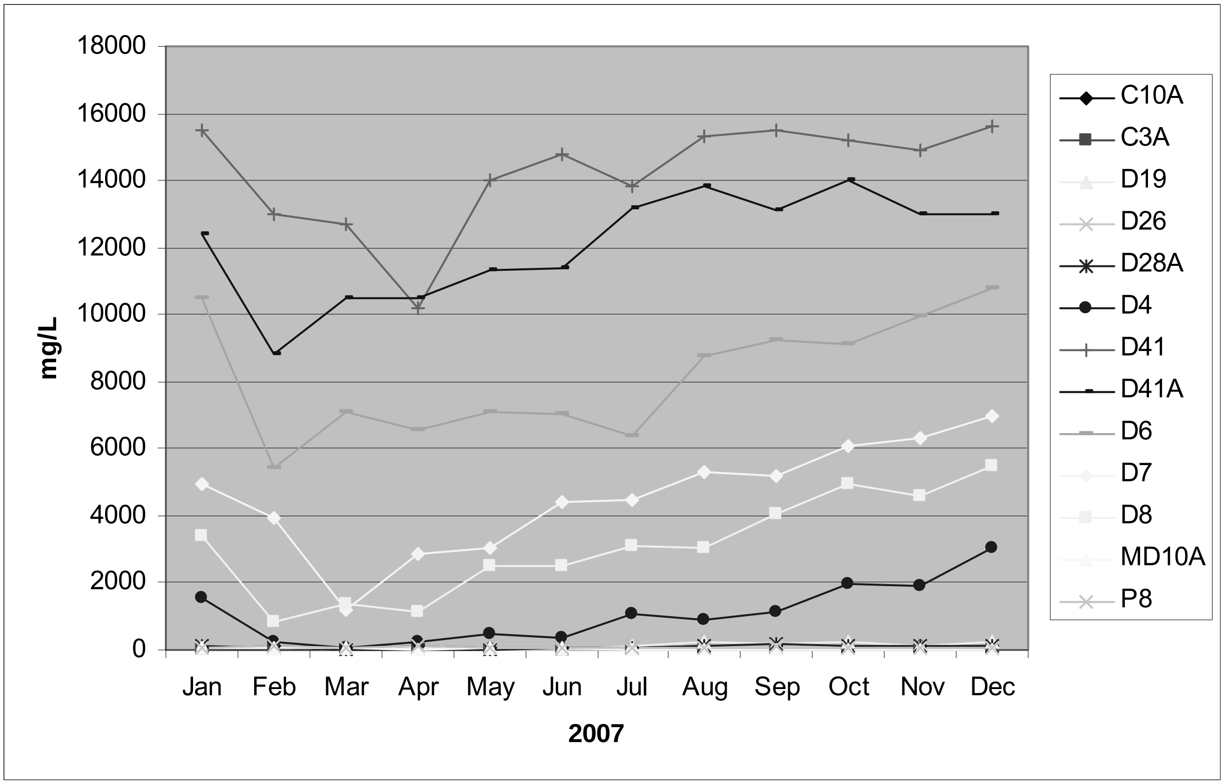


Figure 3-31 Chloride (mg/L) by station, 2007

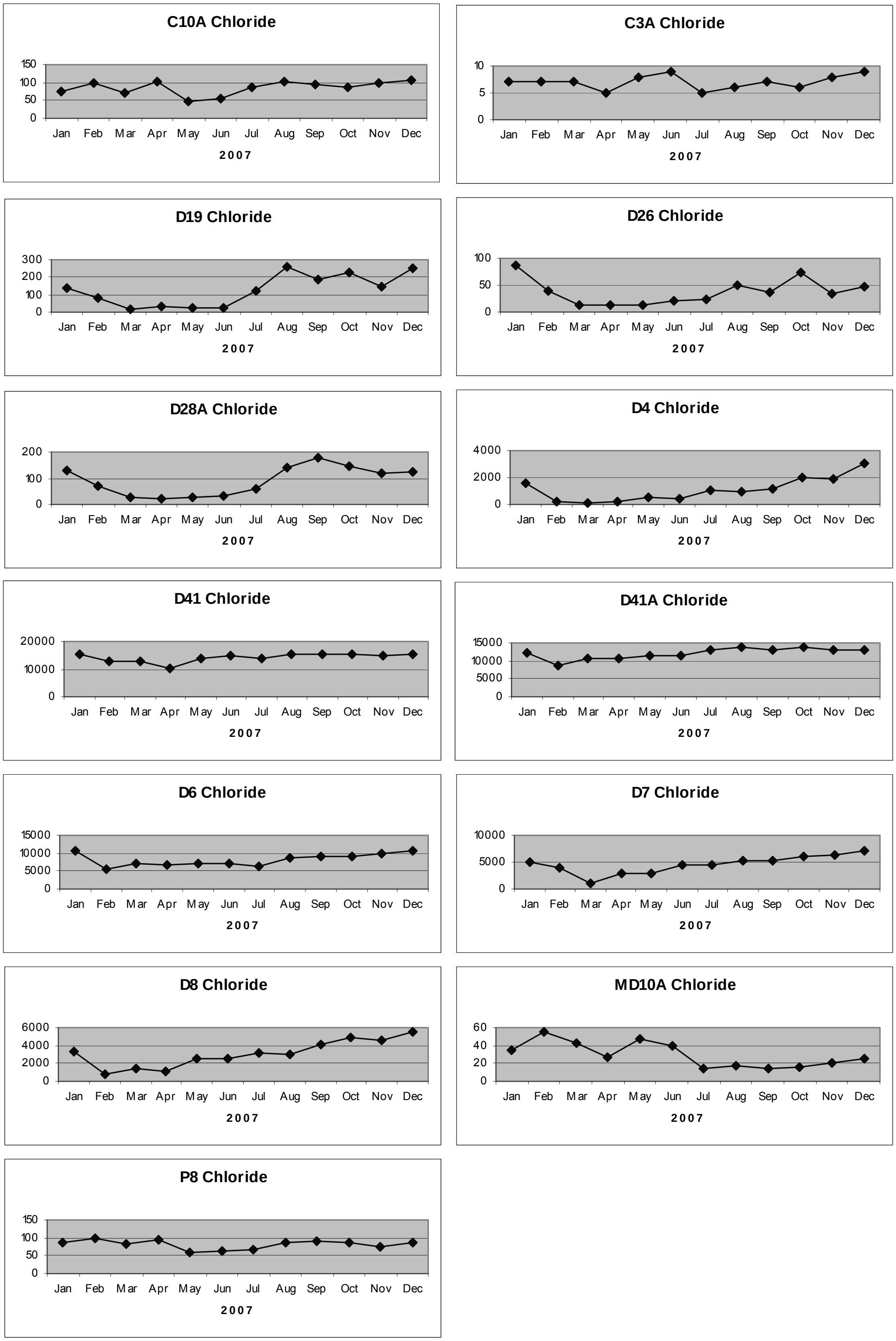


Table 3-1 Water quality parameters measured

Parameter	Units
Water temperature	°C
Dissolved oxygen	mg/L
Specific conductance	µS/cm
Secchi disk depth	cm
Turbidity	NTU
Orthophosphate	mg/L
Total phosphorus	mg/L
Kjeldahl nitrogen	mg/L
Dissolved inorganic nitrogen	mg/L
Dissolved organic nitrogen	mg/L
Total dissolved solids	mg/L
Total suspended solids	mg/L
Volatile suspended solids	mg/L
Silica	mg/L
Chloride	mg/L

Table 3-2 Water quality sampling sites and regions

Region	Sampling Sites
Lower Sacramento River	D4
Lower San Joaquin River	D19 and D26
North Delta	C3A
Central Delta	D28A
East Delta	MD10A
South Delta	C10A and P8
Suisun Bay	D6, D7 and D8
San Pablo Bay	D41 and D41A

Chapter 4 Phytoplankton and Chlorophyll

Content

Figures

Tables

Chapter 4 Phytoplankton and Chlorophyll

Introduction

Water Right Decision 1641 (D-1641) requires the Department of Water Resources (DWR) and the U.S. Bureau of Reclamation to collect phytoplankton and chlorophyll *a* samples to monitor algal community composition and biomass at selected sites in the upper San Francisco Estuary. There are 13 sampling sites from San Pablo Bay east to the mouths of the Sacramento, Mokelumne and San Joaquin rivers. These sites represent a variety of aquatic habitats, from narrow, freshwater channels in the Delta to broad, estuarine bays. This chapter describes the results of monitoring for calendar year 2007.

Primary production (carbon fixation through photosynthesis) by phytoplankton is 1 of the key processes that influence water quality in the estuary. Phytoplankton are small, free-floating organisms that occur as unicellular, colonial or filamentous forms (Horne and Goldman 1994). Phytoplankton can affect pH, dissolved oxygen, color, taste and odor, and under certain conditions, some species can develop noxious blooms resulting in animal deaths and human illness (Carmichael 1981). In freshwater, the cyanobacteria, or blue-green algae (class Cyanophyceae), are responsible for producing toxic blooms, particularly in waters that are polluted with phosphates (van den Hoek et al. 1995).

Carmichael, W., ed. 1981. The Water Environment, Algal Toxins and Health. NY: Plenum Press.

van den Hoek, C., DG Mann and HM Jahns. 1995. *Algae: an introduction to Phycology*. UK: Cambridge University Press.

In addition to being an important food source for zooplankton, invertebrates and some species of fish, phytoplankton species assemblages can be useful in assessing water quality (Gannon and Stemberger 1978). Due to their short life cycles, phytoplankton respond quickly to environmental changes; hence their standing crop and species composition are indicative of the quality of the water mass in which they are found (APHA 1998). However, because of their transient nature, patchiness and free movement in a lotic environment, the utility of phytoplankton as water quality indicators is limited and should be interpreted in conjunction with physiochemical and other biological data (APHA 1998).

Chlorophylls are complex phytopigment molecules found in all photosynthetic organisms, including phytoplankton. There are several types of chlorophyll identified by slight differences in their molecular structure and constituents. These include chlorophyll *a*, *b*, *c*, and *d*. Chlorophyll *a* is the principal photosynthetic pigment and is common to all phytoplankton. Chlorophyll *a* is thus used as a measure of phytoplankton biomass.

In addition to chlorophyll *a*, water samples were analyzed for pheophytin *a*. Pheophytin *a* is a primary degradation product of chlorophyll *a*, and its concentration, relative to chlorophyll *a*, is useful for estimating the general physiological state of phytoplankton populations. When phytoplankton are actively growing, the concentrations of pheophytin *a* are normally expected to be low in relation to chlorophyll *a*. Conversely, when the phytoplankton have died and are decaying, levels of pheophytin *a* are expected to be high in relation to chlorophyll *a*.

Phytoplankton biomass and the resulting chlorophyll *a* concentrations in some areas of the estuary may be influenced by extensive filtration of the water column by the introduced Asian clam, *Corbula amurensis* (Alpine and Cloern 1992). Well-established benthic populations of *C. amurensis* in Suisun and San Pablo bays are thought to have contributed to the low chlorophyll *a* concentrations (and increased water clarity) measured in these westerly bays since the mid-1980s (Alpine and Cloern 1992).

Methods

Phytoplankton

Phytoplankton samples were collected monthly at 13 monitoring sites throughout the upper estuary (Figure 4-1). Samples were collected using a submersible pump from 1 meter below the water surface. The samples were stored in 50-milliliter glass bottles. Lugol's solution was added to each sample as a stain and preservative. All samples were kept at room temperature and away from direct sunlight until they were analyzed. For samples collected from January through September, phytoplankton identification and enumeration were performed at DWR's Bryte Laboratory. EcoAnalyst Inc. identified and enumerated phytoplankton in samples collected from October through December. All samples were analyzed according to the Utermöhl microscopic method (Utermöhl 1958) and modified Standard Methods (APHA 1998). An aliquot was placed into a counting chamber and allowed to settle for a minimum of 15 hours. The aliquot volume, normally 10 mL, was adjusted according to the algal population density and turbidity of the sample. Phytoplankton were enumerated in 20 randomly chosen fields of a Whipple ocular micrometer grid for each settled aliquot. Sample analysis was conducted at a magnification of 700X using a Wilde M-40 inverted microscope.

Figure 4-1 Chlorophyll and phytoplankton monitoring stations

Organism counts for each sample can be converted to organisms/mL using the following formula:

Organisms = *(C x Ac) / (V x Af x F)*

where:

Organisms = Number of organisms (#/mL)
C = Count obtained
Ac = Area of cell bottom (mm^2)
Af = Area of each grid field (mm^2)

F = Number of fields examined (#)
V = Volume settled (mL)

This simplifies to:

Organisms = C / cV

where:

cV = Counted volume (mL)

(Note: cV = Ac / (V x Af x F))

The 10 most common genera were determined by summing the number of organisms per milliliter across all stations and months for each genus.

Chlorophyll *a*

Chlorophyll *a* samples were collected monthly at 13 monitoring sites throughout the upper estuary (Figure 4-1) using a submersible pump from 1 meter below the water's surface. Approximately 500 mL of water was passed through a 47-mm diameter glass-fiber filter with a 1.0 µm pore size at a pressure of 10 inches of mercury. The filters were immediately frozen and transported to Bryte Laboratory for analysis according to the Standard Methods (APHA 1998) spectrophotometric procedure. Samples were processed by mechanically grinding the glass-fiber filters and extracting the phytopigments with acetone. Chlorophyll *a* and pheophytin *a* pigment absorptions were measured with a spectrophotometer before and after acidification of the sample. Concentrations were calculated according to Standard Method's formula (APHA 1998).

Results

Phytoplankton Identification

Of the 11 groups identified, centric diatoms, cyanobacteria, unidentified flagellates, green algae and pennate diatoms constituted 96.88% of the organisms collected (Figure 4-2).

Figure 4-2 Percent phytoplankton composition by group, 2007

All organisms collected in 2007 fell into these 11 categories:

- Centric diatoms (class Coscinodiscophyceae)
- Cyanobacteria (class Cyanophyceae)
- Unidentified flagellates
- Green algae (classes Chlorophyceae, Ulvophyceae and Zygnematophyceae)
- Pennate diatoms (classes Bacillariophyceae and Fragilariophyceae)
- Cryptomonads (class Cryptophyceae)
- Euglenoids (class Euglenophyceae)
- Haptophytes (class Prymnesiophyceae)

- Chrysophytes (class Chrysophyceae)
- Dinoflagellates (class Dinophyceae)
- Synurophytes (class Synurophyceae)

Table 4-1 lists the genera found in each group in the upper estuary.

Table 4-1 Phytoplankton genera by group, 2007

The 10 most common genera collected in 2007 were:

- *Cyclotella* (centric diatom; class Coscinodiscophyceae)
- Unidentified flagellates
- *Chroococcus* (cyanobacteria; class Cyanophyceae)
- *Aulacoseira* (centric diatom; class Coscinodiscophyceae)
- Unidentified centric diatoms (centric diatom; class Coscinodiscophyceae)
- *Microcystis* (cyanobacteria; class Cyanophyceae)
- *Skeletonema* (centric diatom; class Coscinodiscophyceae)
- *Monoraphidium* (green alga; class Chlorophyceae)
- *Planktosphaeria* (green alga; class Chlorophyceae)
- *Achnanthes* (pennate diatom; class Bacillariophyceae)

A list of all phytoplankton genera identified, their shape codes, and the total number counted can be found in the Phytoplankton Dictionary available online at: http://www.baydelta.water.ca.gov/emp/Metadata/Phytoplankton/phytoplankton_dictionary.html

Pigment Concentrations

Chlorophyll *a* concentrations generally showed some seasonal patterns. Most maximums occurred in spring and summer, while minimums usually occurred in fall or winter. For some stations, however, peaks occurred in multiple seasons. Several stations had 1 or more high peaks in chlorophyll *a* that skewed the mean values higher than the median values (Table 4-2 and Figures 4-3 through 4-15; note the different scales for each graph).

Table 4-2 Chlorophyll *a* and pheophytin *a* concentrations

Monthly chlorophyll *a* concentrations throughout much of the estuary were low. Of the 156 samples taken in 2007, 91.0% (142 samples) had chlorophyll *a* levels below 10 µg/L. Chlorophyll levels below 10 µg/L are considered limiting for zooplankton growth (Müller-Solger et. al. 2002). Those samples with chlorophyll *a* levels above 10 µg/L were all taken from the east Delta, (MD10A) and south Delta (P8, C10A) in winter, spring and summer.

The mean chlorophyll *a* concentration for all samples in 2007 was 5.48 µg/L, and the median value was 1.79 µg/L. The maximum chlorophyll *a* concentration in 2007 was 108.00 µg/L, recorded in August in the south Delta (C10A). Chlorophyll *a* maximums were recorded in spring and summer for all stations, except D28A (Central Delta) and MD10A (east Delta); these stations both had their chlorophyll *a* maximums in February. The minimum chlorophyll *a* concentration was 0.25 µg/L, recorded in November in the lower Sacramento River (D4).

Chlorophyll *a* minimums were recorded in fall and winter at all stations, except D6 and D8 (both Suisun Bay stations), where the minimums were recorded in May.

Pheophytin *a* concentrations varied among stations, with some stations remaining relatively constant, while others had peaks during 1 or more months (Table 4-2 and Figures 4-3 through 4-15). The mean pheophytin *a* concentration for all samples in 2007 was 3.04 µg/L, and the median value was 1.37 µg/L. The maximum pheophytin *a* concentration was 39.90 µg/L, recorded at MD10A (east Delta) in February. Pheophytin *a* maximums were recorded in spring and summer at all stations except P8 (south Delta) and MD10A (east Delta), where maximums were recorded in winter. At D19 (central Delta), the maximum was recorded in fall. The minimum pheophytin *a* concentration was 0.27 µg/L, recorded at D26 (lower San Joaquin River) in November. Pheophytin *a* minimums were recorded in fall and winter at all stations except C3A (minimum recorded in August) and D41 (minimum recorded in June).

Table 4-2 shows the maximum and minimum values for chlorophyll *a* and pheophytin *a* for each station, as well as the median, mean, and standard deviation. Figures 4-3 through 4-15 show the results of chlorophyll *a* and pheophytin *a* analysis, and phytoplankton composition at each station. All chlorophyll *a* and pheophytin *a* data can be found at: http://www.iep.ca.gov/emp/data_index.html

Site C3A: North Delta

The highest chlorophyll *a* concentration was recorded in May (6.09 µg/L), and the lowest was recorded in October (0.49 µg/L) (Figure 4-3a, Table 4-2). The mean was 2.49 µg/L, and the median was 1.92 µg/L. There was some seasonality, with higher values recorded in spring and summer, and lower values recorded in fall and winter.

Figure 4-3a Pigment concentrations at C3A, 2007

Pheophytin *a* showed a somewhat seasonal pattern, with higher values occurring in spring and summer (Figure 4-3a). The maximum (9.61 µg/L) was recorded in May, and the minimum (0.71 µg/L) was recorded in August (Table 4-2). The mean was 2.72 µg/L, and the median was 1.79 µg/L.

Phytoplankton density was relatively low most of the year; there were peaks of centric and pennate diatoms in April, and another peak of centric diatoms in May (Figure 4-3b).

Figure 4-3b Phytoplankton composition at C3A, 2007

Site C10A: South Delta

The maximum chlorophyll *a* concentration was recorded in August (108.00 µg/L), and the minimum was in December (4.29 µg/L) (Figure 4-4a, Table 4-2). The large peak in chlorophyll *a* in August skewed the mean (31.38 µg/L) much higher than the median (14.50 µg/L). Chlorophyll *a* still showed a seasonal pattern despite this large peak (Figure 4-4a).

Figure 4-4a Pigment concentrations at C10A, 2007

The second largest pheophytin *a* value for the year was recorded at this station in July (33.40 µg/L) (Figure 4-4a; Table 4-2). The minimum occurred in December (2.35 µg/L). As with chlorophyll, the large peak in July skewed the mean (14.32 µg/L) higher than the median (9.76 µg/L) (Table 4-2). There was no seasonal pattern; it was higher in summer, and then stable the rest of the year (Figure 4-4a).

Centric diatoms in very high densities dominated this station (above 5,000 organisms per mL) for most of the year (Figure 4-4b). Densities were low in winter and May.

Figure 4-4b Phytoplankton compositions at C10A, 2007

Site P8: South Delta

Chlorophyll *a* did not show a strong seasonal pattern, as the highest values were recorded in winter and early spring before stabilizing for the rest of the year (Figure 4-5a). The maximum was recorded in May (14.60 µg/L), and the minimum in December (0.64 µg/L) (Table 4-2). The mean (5.13 µg/L) was higher than the median (3.17 µg/L).

Figure 4-5a Pigment concentrations at P8, 2007

Pheophytin *a* had large peaks in February, May, and June, but was relatively stable the rest of the year (Figure 4-5a). As a result, the mean (4.62 µg/L) was skewed slightly higher than the median (3.48 µg/L) (Table 4-2). The maximum was 12.50 µg/L in February, and the minimum was 0.79 µg/L in December.

Phytoplankton alternated between periods of high centric diatom density and high unidentified flagellate density, with very low densities of all phytoplankton in April and late summer (Figure 4-5b).

Figure 4-5b phytoplankton composition at P8, 2007

Site MD10A: East Delta

Chlorophyll *a* did not show a seasonal pattern; the highest values were recorded in winter and spring, and were low the rest of the year (Figure 4-6a). The maximum (80.30 µg/L) occurred in February, and skewed the mean (14.04 µg/L) much higher than the median (3.10 µg/L) (Table 4-2). The minimum was recorded in December (0.84 µg/L).

Figure 4-6a Pigment concentrations at MD10A, 2007

Pheophytin *a* showed a pattern similar to chlorophyll *a*, with peaks early in the year and low values after May (Figure 4-6a). This skewed the mean higher than the median (5.94 µg/L and 1.76 µg/L, respectively) (Table 4-2). The maximum was recorded in February (39.90 µg/L), and was the highest value at any station for the year. The minimum was recorded in December (0.59 µg/L).

Figure 4-6bPhytoplankton composition at MD10A, 2007

Centric diatoms dominated during the first half of the year; densities of all phytoplankton were low after May (Figure 4-6b).

Site D26: Lower San Joaquin River

Chlorophyll *a* mostly showed a seasonal pattern, but values were very low (< 5 µg/L) all year (Figure 4-7a). The maximum was 2.20 µg/L in August, and the minimum was 0.47 µg/L in November (Table 4-2). The mean and median were nearly identical (1.20 µg/L and 1.23 µg/L, respectively).

Figure 4-7a Pigment concentrations at D26, 2007

Pheophytin *a* showed a pattern similar to chlorophyll *a* (Figure 4-7a). The maximum was 1.56 µg/L in May, and the minimum was 0.27 µg/L in November (Table 4-2). The mean and median were nearly the same (0.89 µg/L and 0.85 µg/L, respectively).

Unidentified flagellates dominated for most of the year, except for peaks of cyanobacteria in June and August (Figure 4-7b). No phytoplankton were observed in May.

Figure 4-7b Phytoplankton composition at D26. 2007

Site D19: Central Delta

Chlorophyll *a* concentrations showed a clear seasonal pattern, with the maximum (2.82 µg/L) recorded in August, and the minimum (0.66 µg/L) recorded in November (Figure 4-8a, Table 4-2). The mean and median were very close (1.41 µg/L and 1.31 µg/L, respectively).

Figure 4-8a Pigment concentrations at D19, 2007

Pheophytin *a* was similar to chlorophyll *a*, showing a seasonal pattern (Figure 4-8a). The maximum was recorded in September (1.52 µg/L), and the minimum was recorded in November (0.35 µg/L) (Table 4-2). As with chlorophyll *a*, the mean and median were very close (1.07 µg/L and 1.05 µg/L, respectively).

Again, unidentified flagellates dominated at this station except for peaks in cyanobacteria in August and September (Figure 4-8b).

Figure 4-8b Phytoplankton composition at D19, 2007

Site D28A: Central Delta

Chlorophyll *a* showed a seasonal pattern except for a peak in February, which was the maximum for the year (4.36 µg/L) (Figure 4-9a, Table 4-2). The minimum of 0.67 µg/L was recorded in November. The large spikes in February, July, and August skewed the mean (2.02 µg/L) higher than the median (1.53 µg/L) (Table 4-2).

Figure 4-9a Pigment concentrations at D28A, 2007

Pheophytin *a* values tracked chlorophyll *a* closely, except for February and August, when values were much lower than chlorophyll *a* (Figure 4-9a). The mean and median were close (1.63 µg/L and 1.33 µg/L, respectively) (Table 4-2). The maximum of 3.95 µg/L was recorded in July; the minimum of 0.40 µg/L was recorded in November.

There was a large peak of cyanobacteria in August; otherwise, unidentified flagellates dominated the rest of the year (Figure 4-9b).

Figure 4-9b Phytoplankton composition at D28A, 2007

Site D4: Lower Sacramento River

Chlorophyll *a* showed a seasonal pattern, with peaks in spring and summer, and declines in winter (Figure 4-10a). The maximum was 3.64 µg/L in April; the minimum was 0.25 µg/L in November (Table 4-2). Despite the peak in April, the mean and median were very close (1.57 µg/L and 1.61 µg/L, respectively).

Figure 4-10a Pigment concentrations at D4, 2007

Pheophytin *a* also did not show a pattern; values were stable most of the year (Figure 4-10a). The maximum 1.89 µg/L) was recorded in February; the minimum (0.38 µg/L) was recorded in October (Table 4-2). The mean was 1.27 µg/L; the median was 1.22 µg/L.

Phytoplankton densities were low (less than 1,000 organisms per mL) for most of the year, and were dominated by unidentified flagellates (Figure 4-10b). There was a peak of cyanobacteria in October.

Figure 4-10b Phytoplankton composition at D4, 2007

Site D6: Suisun Bay

Chlorophyll *a* did not show a seasonal pattern, with peaks occurring throughout the year (Figure 4-11a). The maximum was 3.75 µg/L in March; the minimum was 0.73 µg/L in May (Table 4-2). The mean was 1.84 µg/L, and the median was 1.61 µg/L.

Figure 4-11a Pigment concentrations at D6, 2007

Pheophytin *a* also did not show a seasonal pattern; a peak in March was followed by low levels the rest of the year (Figure 4-11a). The maximum was recorded in March (2.37 µg/L) and the minimum was recorded in November (0.39 µg/) (Table 4-2). The mean and median were 0.86 µg/L and 0.68 µg/L, respectively.

Except for a peak of cyanobacteria in March, phytoplankton densities were low all year, and dominated by unidentified flagellates (Figure 4-11b). No phytoplankton were observed in January or April.

Figure 4-11b Phytoplankton composition at D6, 2007

Site D7: Suisun Bay

Chlorophyll *a* did not show a seasonal pattern; values were low for most of the year. The maximum was 4.91 µg/L in April, and the minimum was 0.42 µg/L in October (Figure 4-12a, Table 4-2). The mean was 1.58 µg/L, and the median was 1.42 µg/L.

Pheophytin *a* also did not show a clear pattern; there were large peaks in spring and fall, but otherwise values were low (Figure 4-12a). The maximum (4.13 µg/L) was recorded in April; the minimum (0.87 µg/L) was recorded in September (Table 4-2). The mean was 1.90 µg/L; the median was 1.76 µg/L.

Figure 4-12a Pigment concentrations at D7, 2007

Phytoplankton densities were low all year; cyanobacteria and unidentified flagellates dominated most of the year (Figure 4-12b). There was a small peak of pennate diatoms in April. No phytoplankton were observed in July or August.

Figure 4-12b Phytoplankton composition at D7, 2007

Site D8: Suisun Bay

Chlorophyll *a* showed a seasonal pattern, but it was slightly obscured by large peaks in April and August. The maximum was 3.37 µg/L in April, and the minimum was 0.85 µg/L in May (Figure 4-13a, Table 4-2). The mean was 1.54 µg/L, and the median was 1.27 µg/L.

Pheophytin *a* showed no clear pattern; values were low for most of the year (Figure 4-13a). The maximum (2.49 µg/L) was recorded in April; the minimum (0.38 µg/L) was recorded in October (Table 4-2). The mean was slightly higher than the median (0.97 µg/L and 0.85 µg/L, respectively).

Figure 4-13a Pigment concentrations at D8, 2007

Phytoplankton densities were extremely low all year (below 500 organisms per mL), and were dominated by unidentified flagellates (Figure 4-13b). No phytoplankton were observed in June.

Figure 4-13b Phytoplankton composition at D8, 2007

Site D41: San Pablo Bay

Chlorophyll *a* did show a seasonal pattern, although it was slightly obscured due to large peaks in March and August (Figure 4-14a). The peak in March was also the maximum for the year at this station (7.37 µg/L) (Table 4-2). The minimum of 1.48 µg/L was recorded in January. The mean (3.44 µg/L) and median (3.06 µg/L) were similar (Table 4-2).

Figure 4-14a Pigment concentrations at D41, 2007

Pheophytin *a* showed a slight seasonal pattern; values were higher in spring but then declined except for a second peak in July (Figure 4-14a). The maximum of 2.37 µg/L was recorded in April; the minimum of 0.54 µg/L was recorded in June (Table 4-2). The mean and median were somewhat close (1.32 µg/L and 1.18 µg/L, respectively).

There was a large peak of cyanobacteria in March; otherwise, phytoplankton densities were somewhat low, and dominated by unidentified flagellates (Figure 4-14b).

Figure 4-14b Phytoplankton composition at D41, 2007

Site D41A: San Pablo Bay

Chlorophyll *a* showed a slight seasonal pattern; there were large peaks in March, July and October. The maximum (7.80 µg/L) occurred in July (Figure 4-15a, Table 4-2). The minimum of 1.20 µg/L was recorded in January. Despite the 3 peaks, the mean and median were similar (3.66 µg/L and 3.12 µg/L, respectively) (Table 4-2).

Pheophytin *a* did not show a pattern; the maximum of 4.99 µg/L was recorded in July, and the minimum of 0.75 µg/L was recorded in September (Figure 4-15a, Table 4-2). The mean was 1.98 µg/L; the median was 1.77 µg/L.

Figure 4-15a Pigment concentrations at D41A, 2007

There were large peaks of cyanobacteria in February and March, with much smaller peaks of unidentified flagellates in July and August (Figure 4-15b). No phytoplankton were observed in January.

Figure 4-15b Phytoplankton composition at D41A, 2007

Summary

Phytoplankton and chlorophyll *a* samples were collected monthly at 13 sites in 2007. Chlorophyll *a* samples were also analyzed for pheophytin *a*, the primary degradation product of chlorophyll *a*. All phytoplankton identified fell into the following 11 categories: centric diatoms, cyanobacteria, unidentified flagellates, green algae, pennate diatoms, cryptomonads, euglenoids, haptophytes, chrysophytes, dinoflagellates and synurophytes. The 10 most common genera were *Cyclotella,* unidentified flagellates, *Chroococcus, Aulacoseira,* unidentified centric diatoms, *Microcystis, Skeletonema, Monoraphidium, Planktosphaeria* and *Achnanthes.* Chlorophyll *a* concentrations mostly showed a seasonal pattern; values ranged from

0.25 µg/L to 108.00 µg/L. Pheophytin *a* concentrations mainly did not show a seasonal pattern; values ranged from 0.27 µg/L to 39.90 µg/L. Despite sporadic peaks at some stations, chlorophyll *a* concentrations overall were relatively low when compared with the historical data.

References

Alpine, A. E., and Cloern, J. E. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnol. Oceanogr. 37: 946-955

[APHA] American Public Health Association, American Waterworks and Water Environmental Federation. 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th ed. Washington, D.C.: American Public Health Association.

Carmichael, W., ed. 1981. *The Water Environment, Algal Toxins and Health*. NY: Plenum Press.

Gannon, J. E. and R. S. Stemberger. 1978. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Trans. Amer. Microsc*. 97:16.

Horne, A. and Goldman, C. 1994. *Limnology*. 2nd ed. New York, New York, McGraw-Hill, Inc.

Müller-Solger, A. B., A. D. Jassby and D.C. Müller-Navarra. 2002. Nutritional quality of food resources for zooplankton (*Daphnia*) in a tidal-freshwater system (Sacramento-San Joaquin River Delta). Limnol. Oceanogr. 47: 1468-1476.

Utermöhl, H. 1958. Zur Vervollkommnung der quantitativen Phytoplankton Methodik. *Mitt. Int. Verh. Limnol.* 9: 38.

van den Hoek, C., D.G. Mann and H.M. Jahns. 1995. *Algae: an introduction to Phycology*. UK: Cambridge University Press.

Figure 4-1 Chlorophyll and phytoplankton monitoring stations

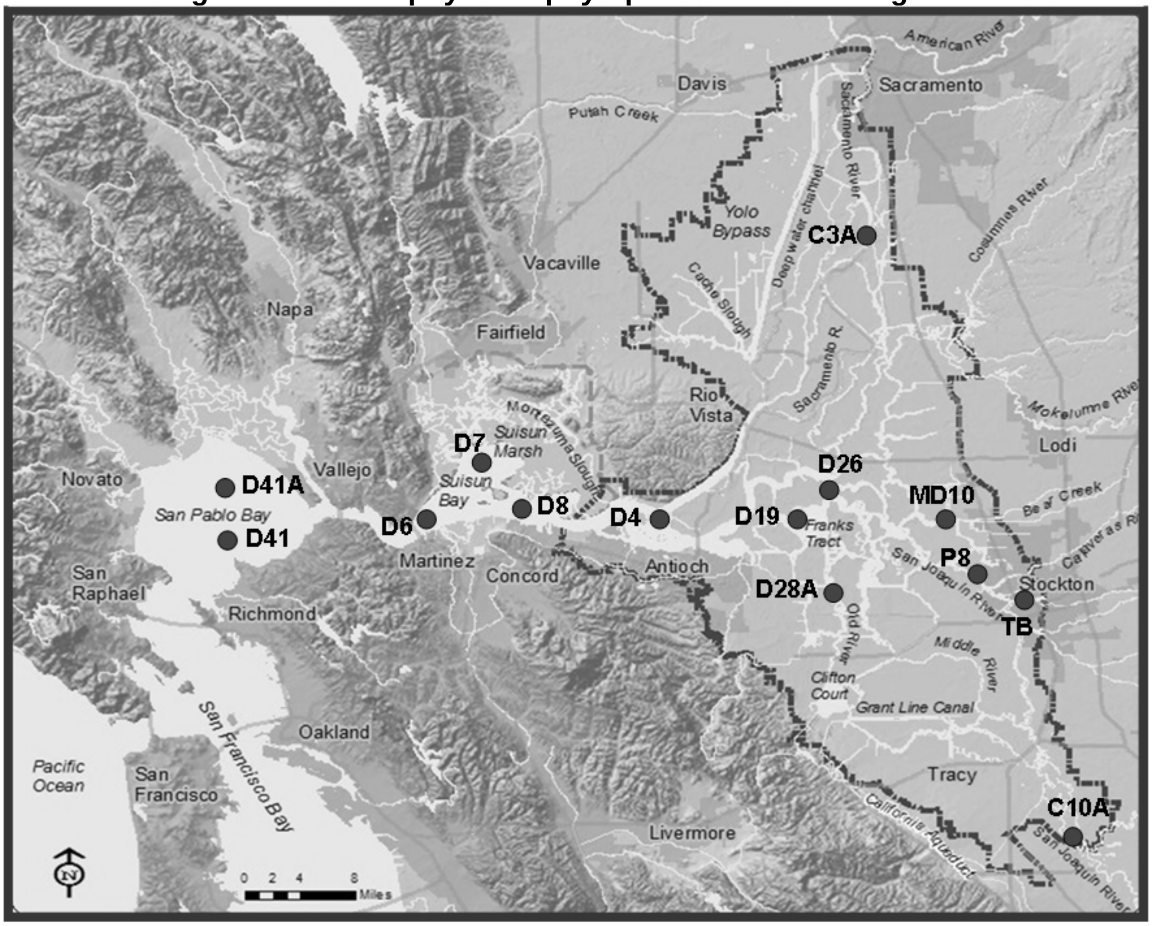


Figure 4-2 Percent phytoplankton composition by group, 2007

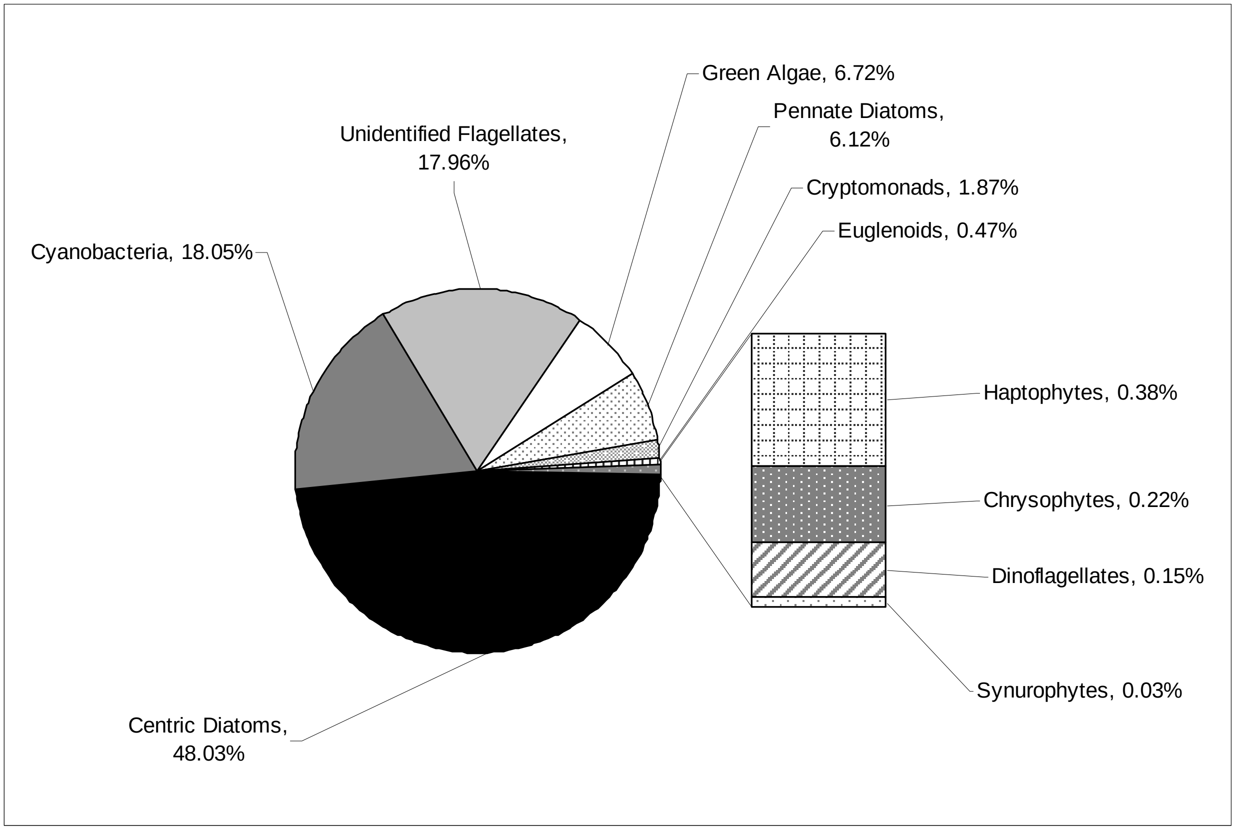


Figure 4-3a Pigment concentrations at C3A, 2007

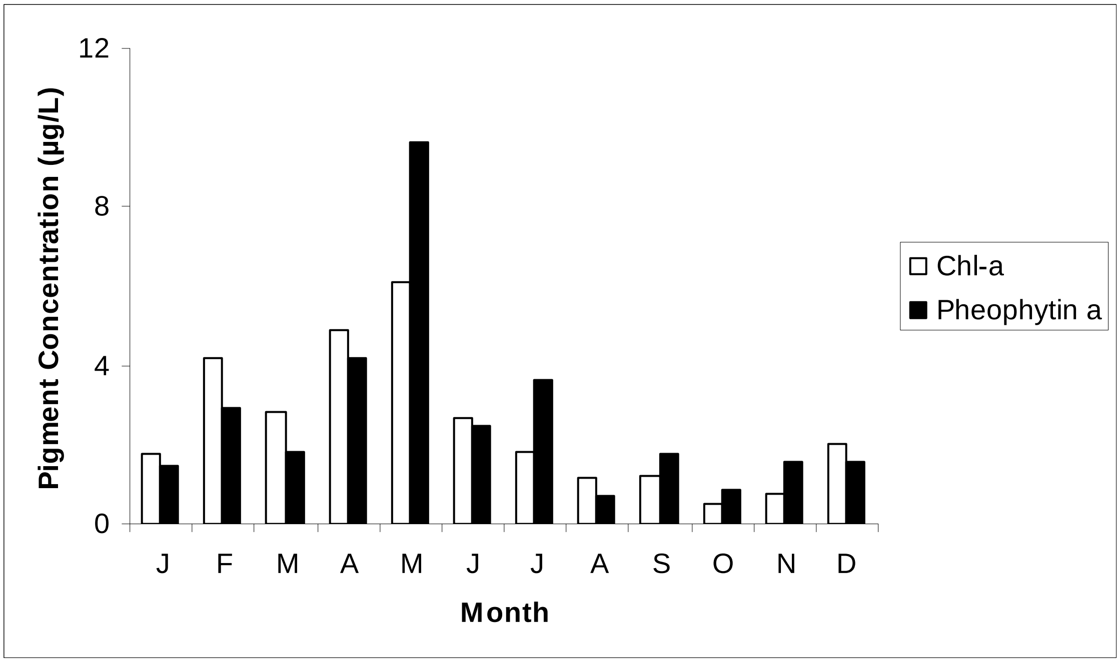


Figure 4-3b Phytoplankton composition at C3A, 2007

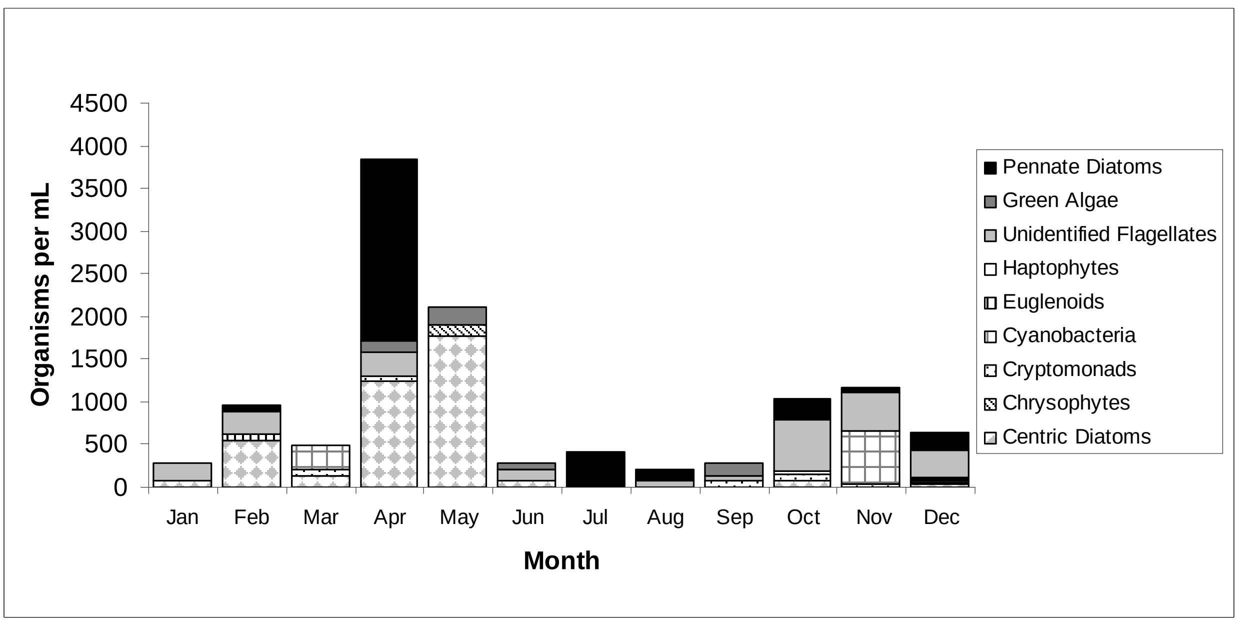


Figure 4-4a Pigment concentrations at C10A, 2007

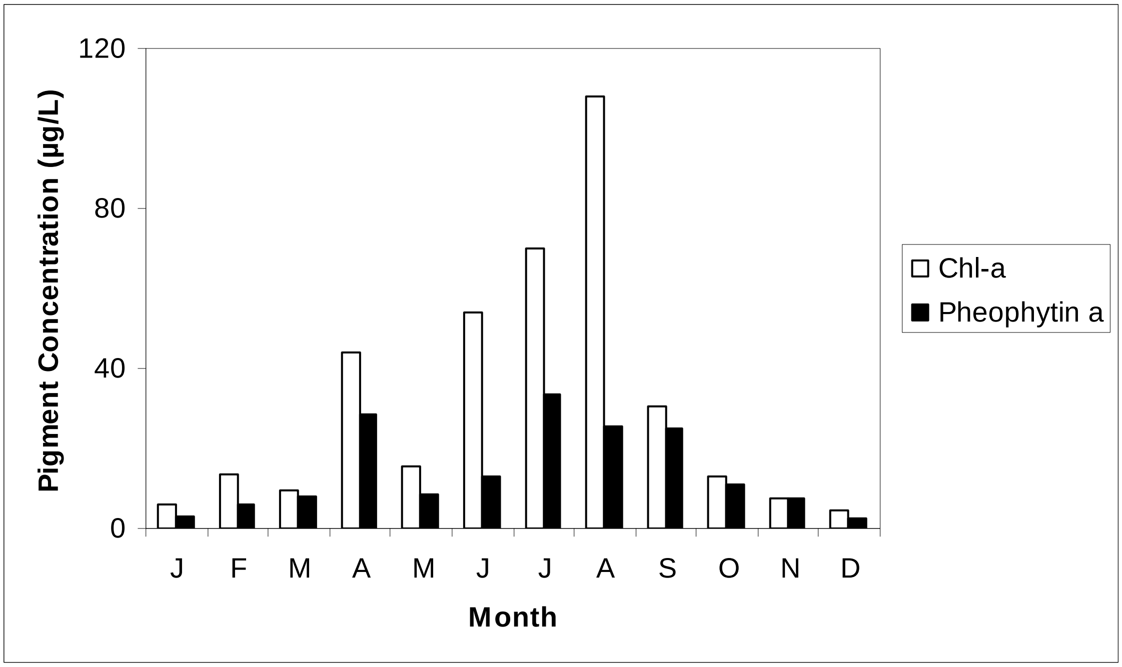


Figure 4-4b Phytoplankton compositions at C10A, 2007

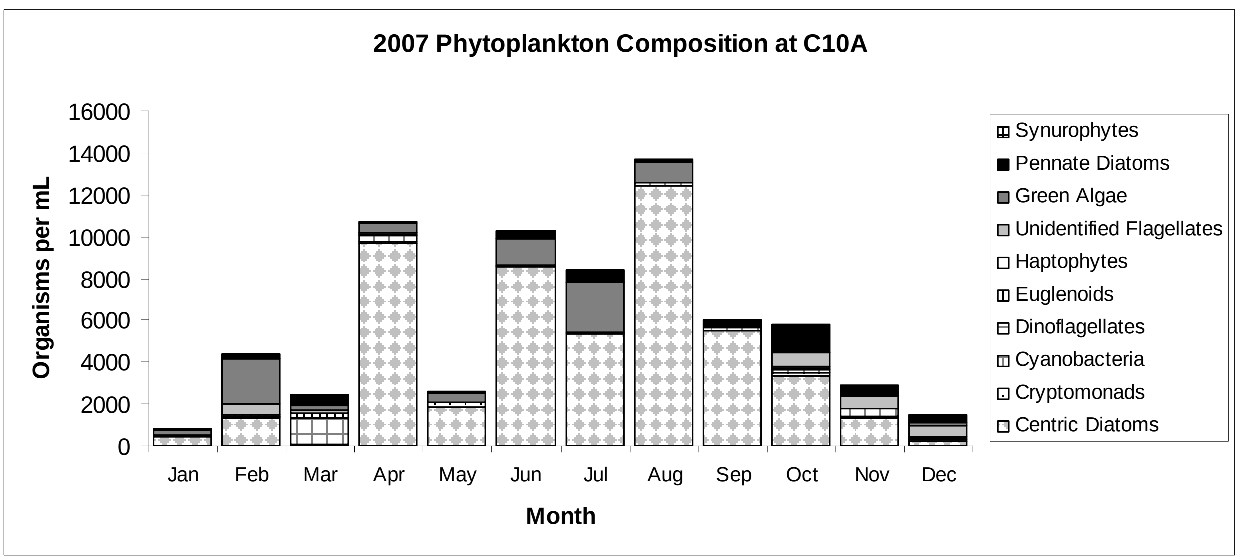


Figure 4-5a Pigment concentrations at P8, 2007

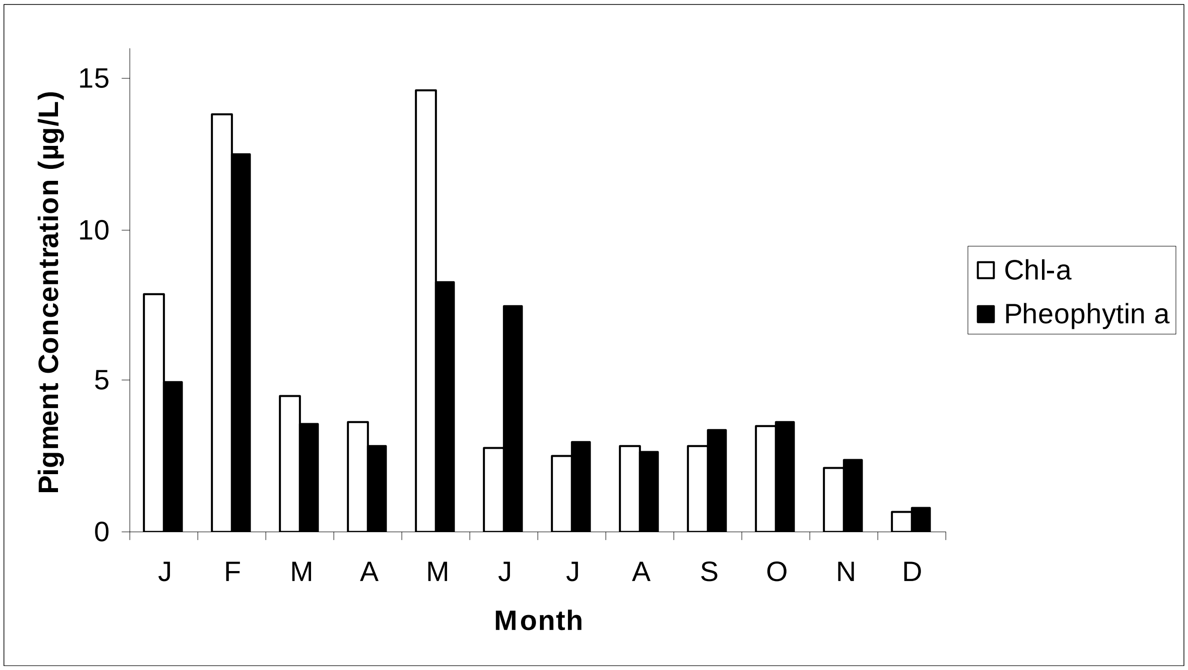


Figure 4-5b phytoplankton composition at P8, 2007

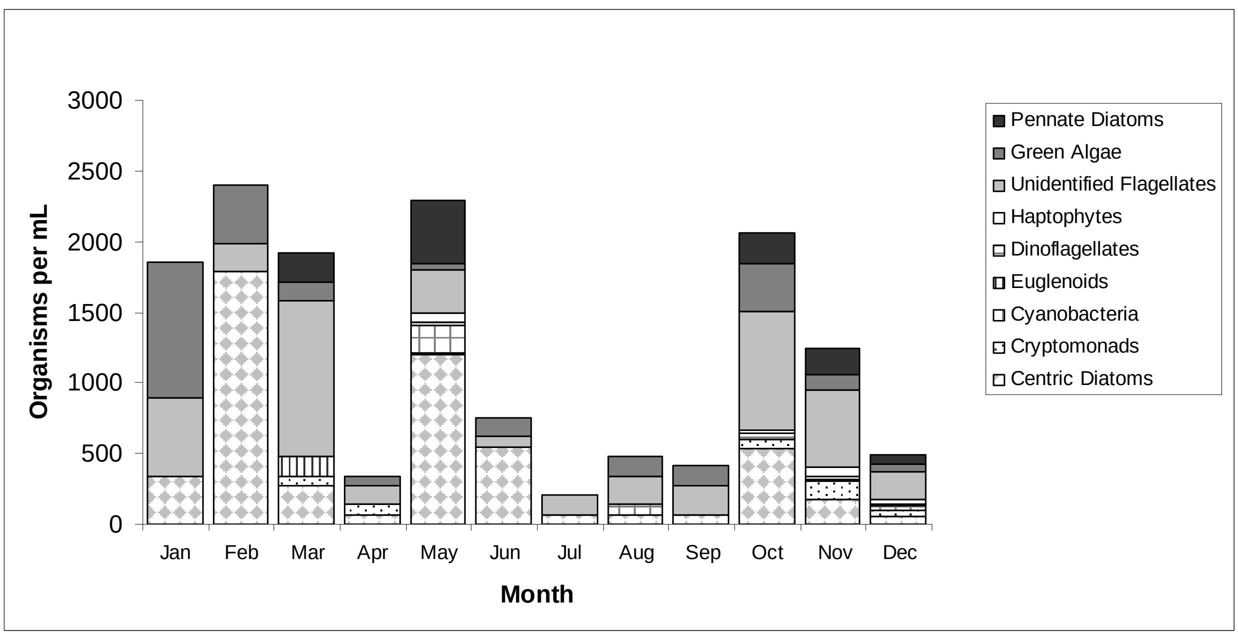


Figure 4-6a Pigment concentrations at MD10A, 2007

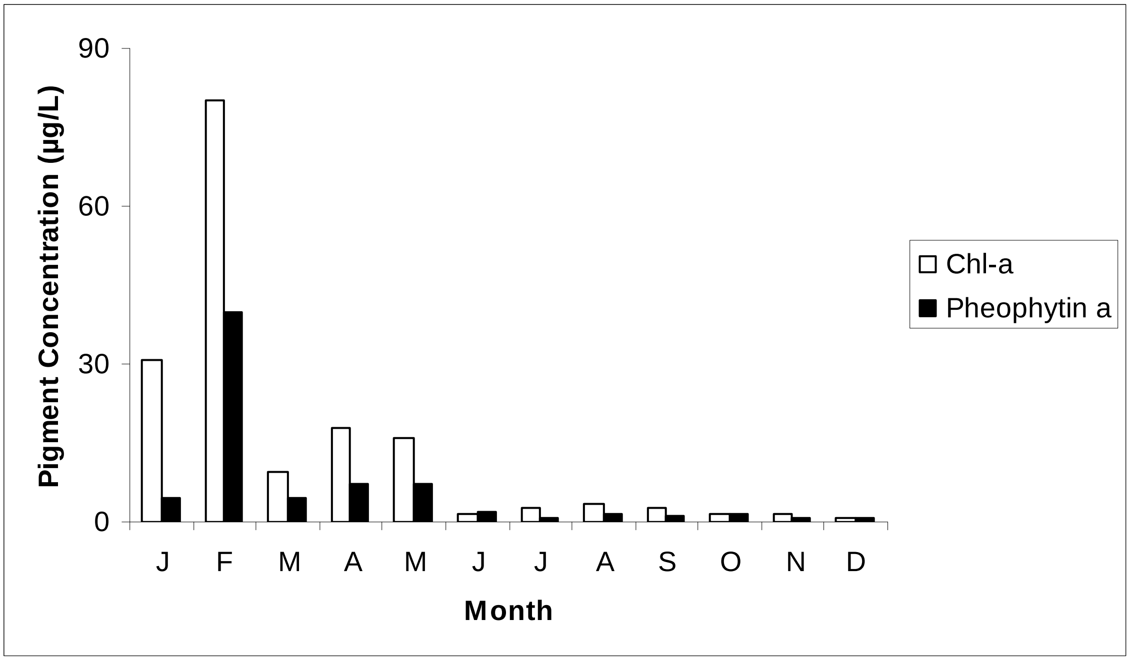


Figure 4-6bPhytoplankton composition at MD10A, 2007

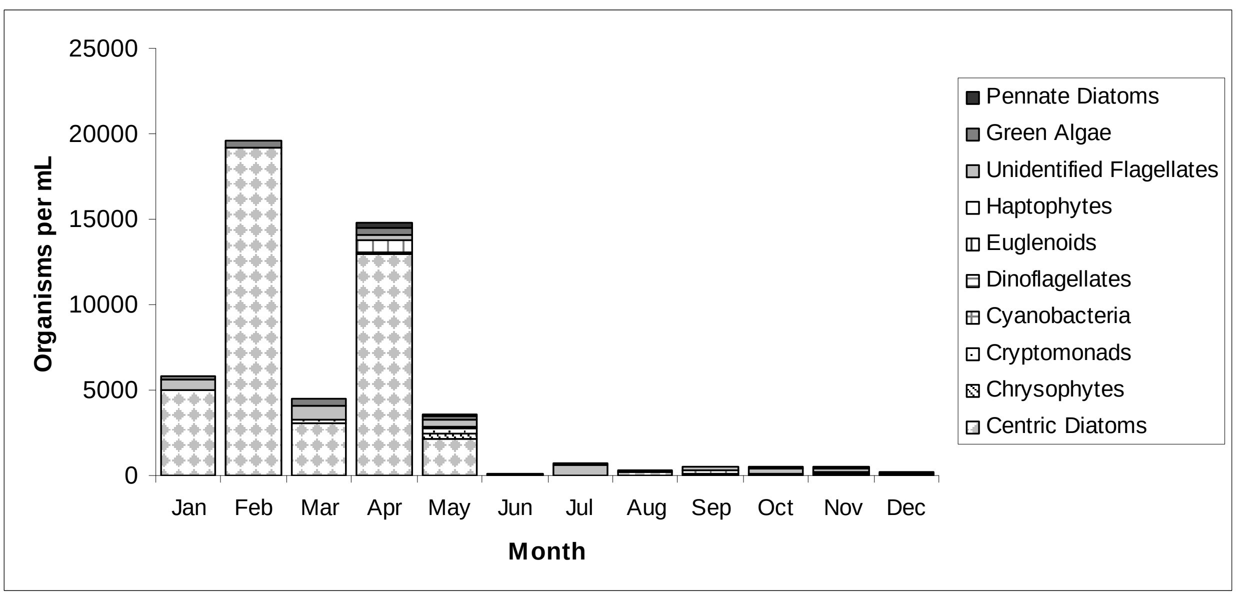


Figure 4-7a Pigment concentrations at D26, 2007

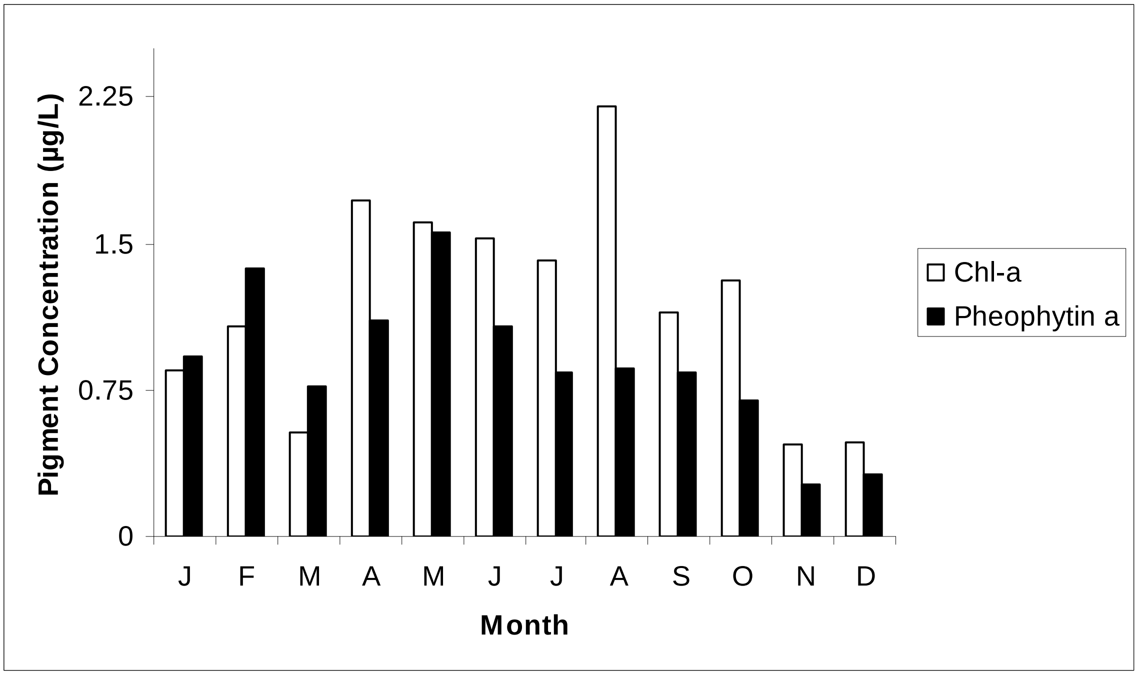


Figure 4-7b Phytoplankton composition at D26. 2007

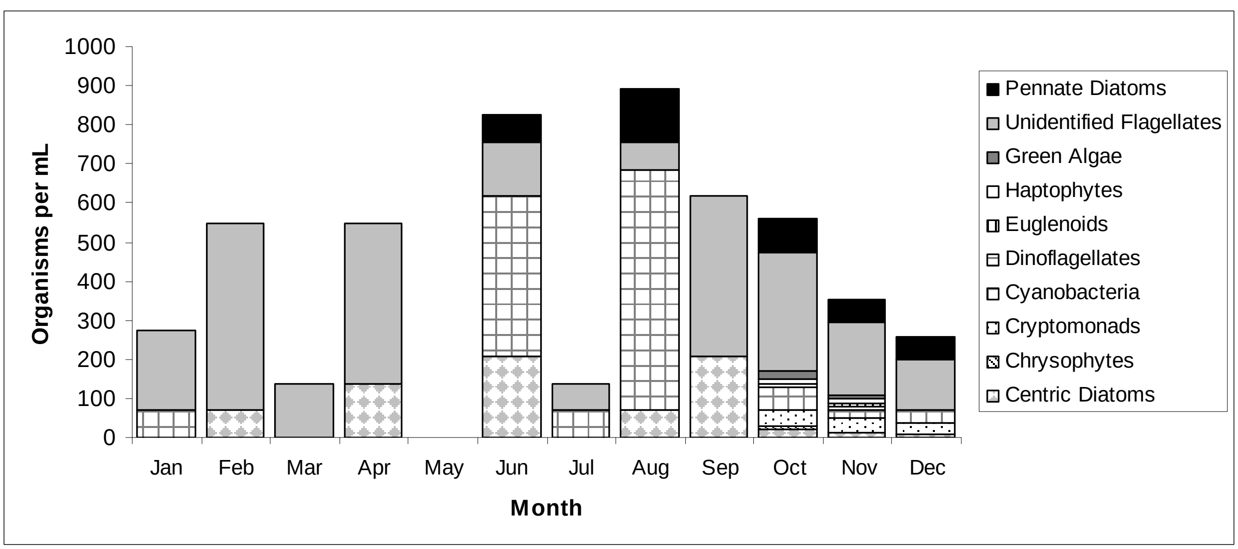


Figure 4-8a Pigment concentrations at D19, 2007

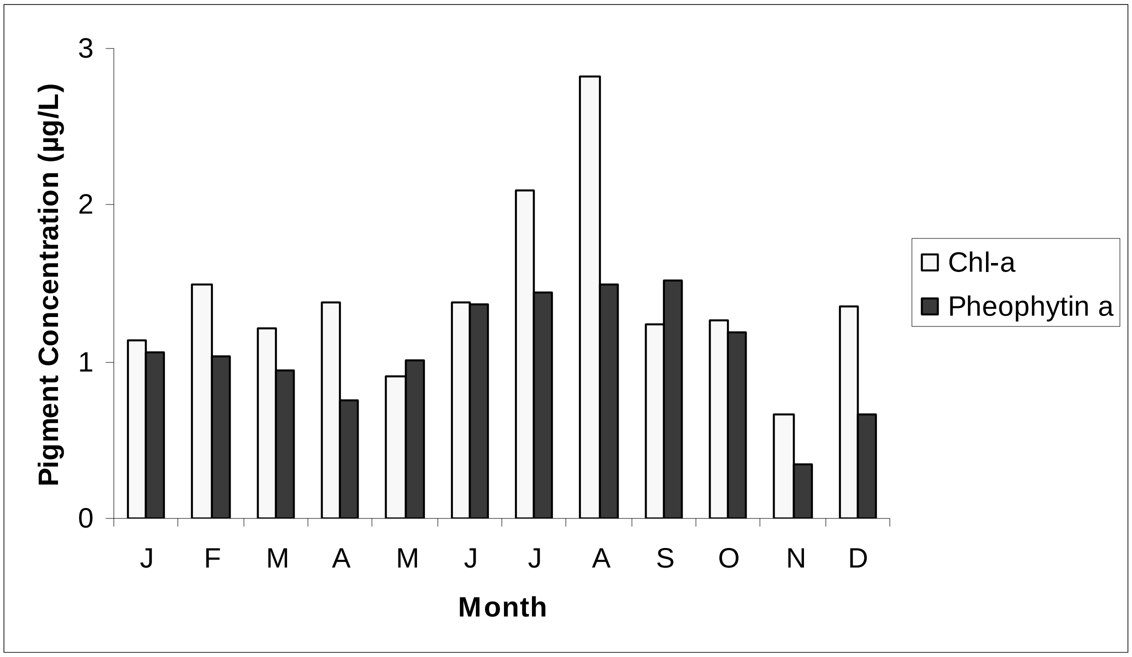


Figure 4-8b Phytoplankton composition at D19, 2007

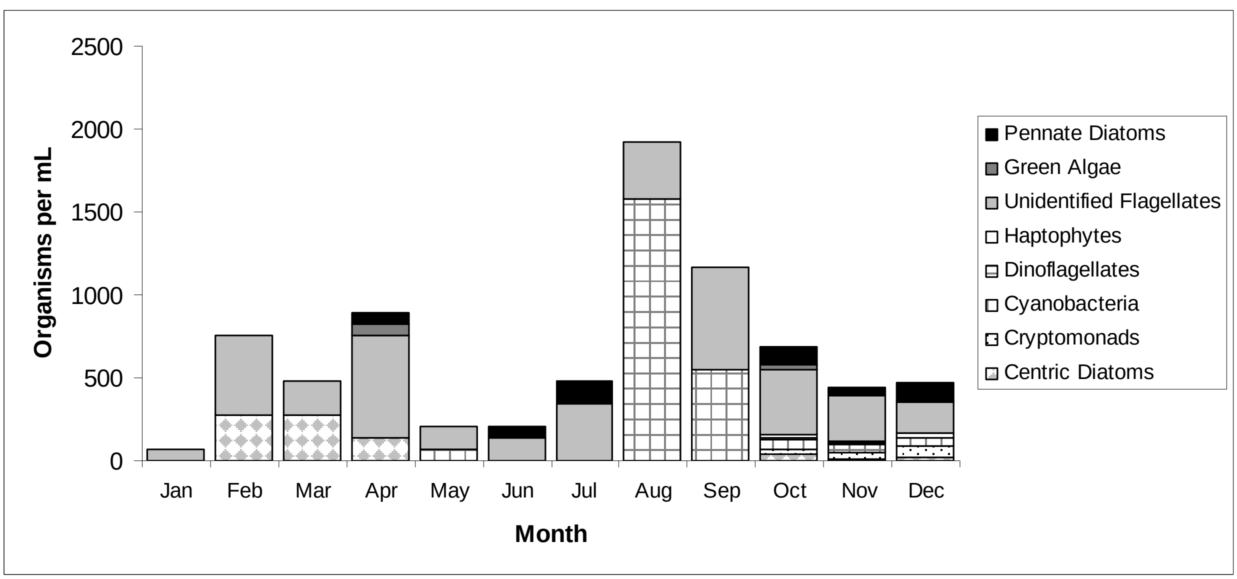


Figure 4-9a Pigment concentrations at D28A, 2007

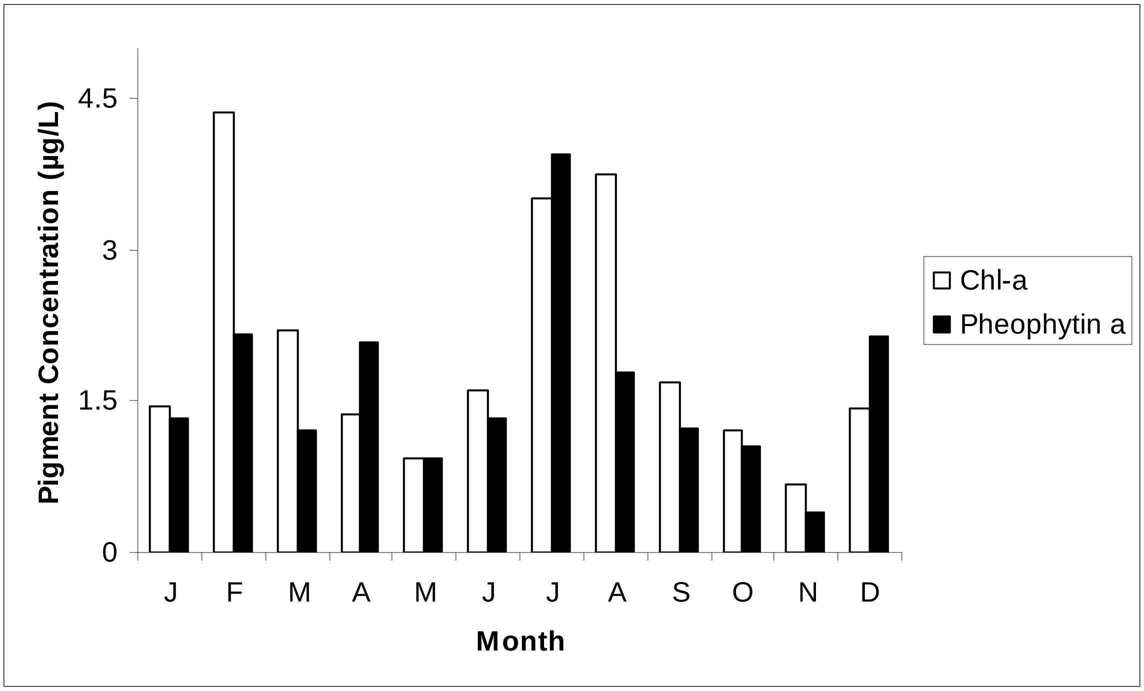


Figure 4-9b Phytoplankton composition at D28A, 2007

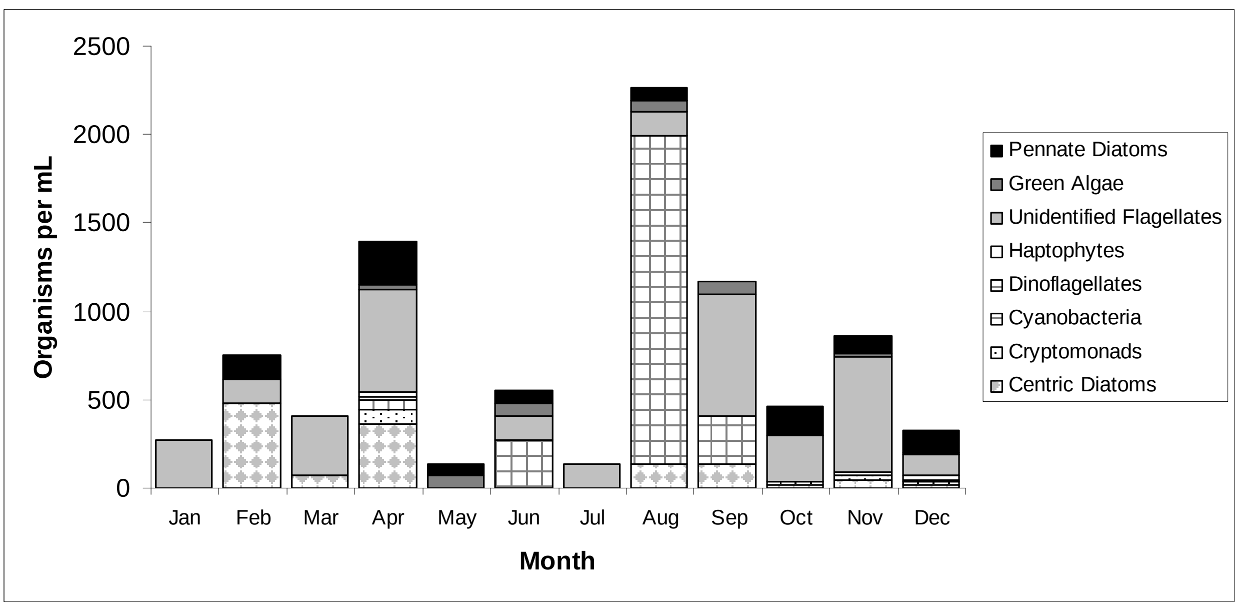


Figure 4-10a Pigment concentrations at D4, 2007

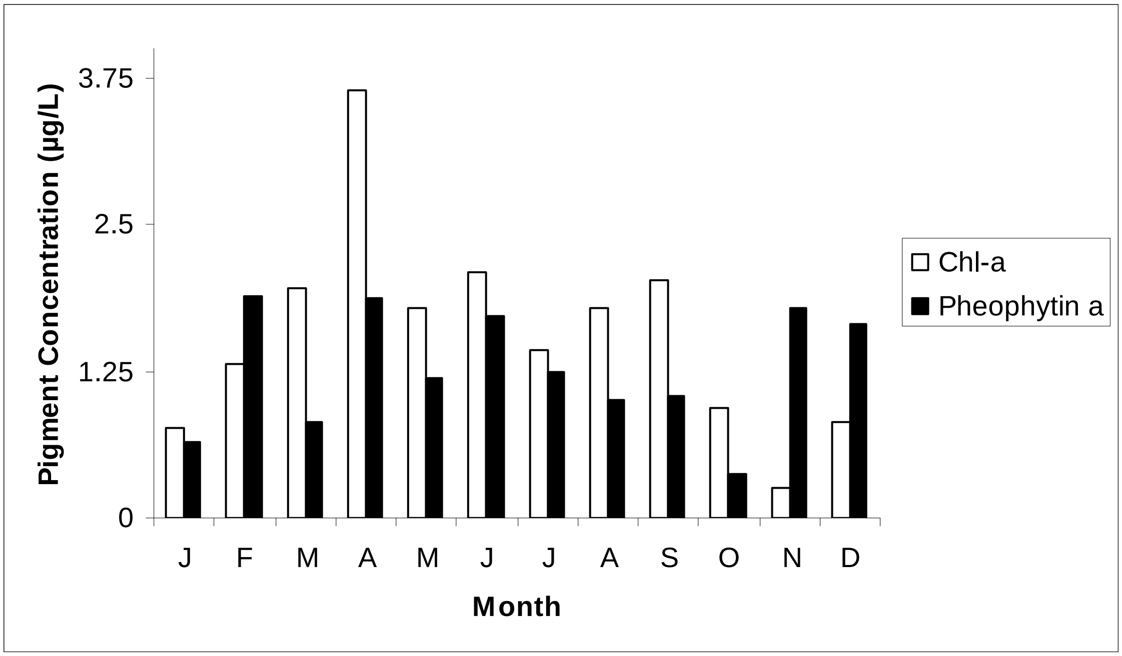


Figure 4-10b Phytoplankton composition at D4, 2007

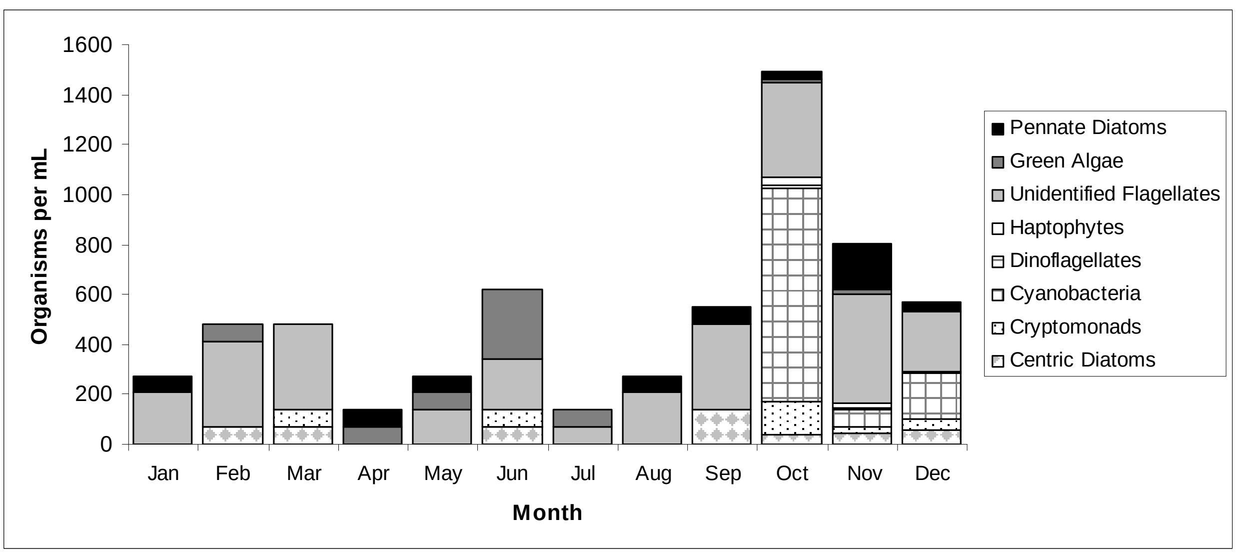


Figure 4-11a Pigment concentrations at D6, 2007

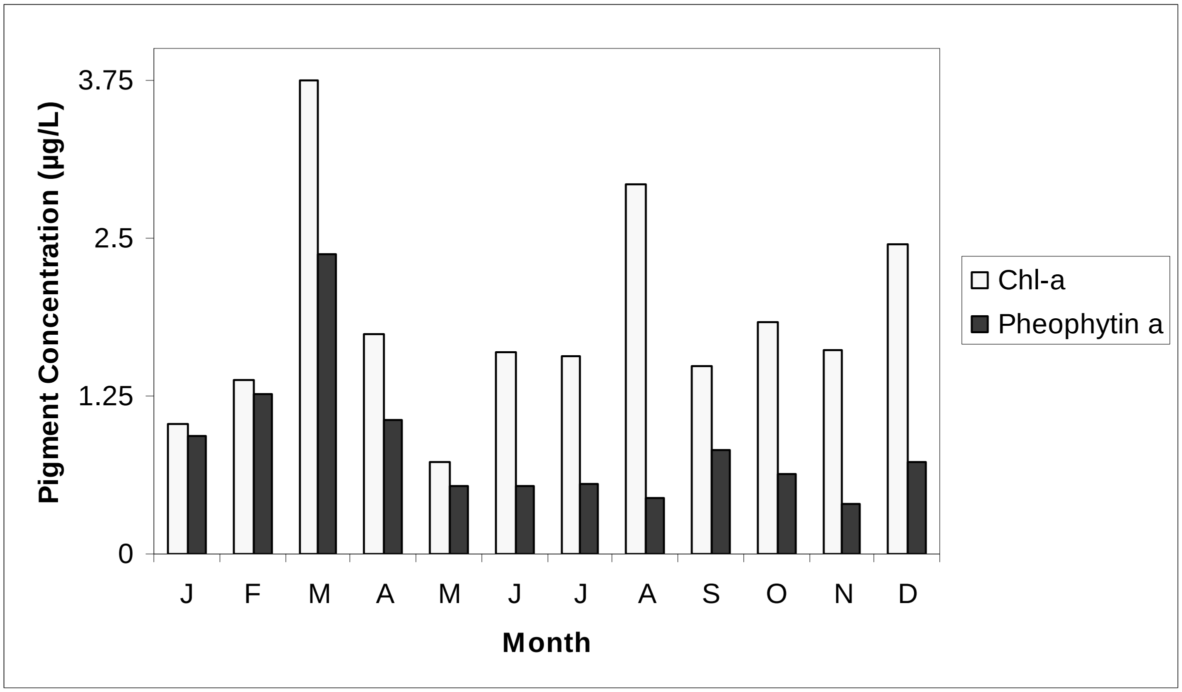


Figure 4-11b Phytoplankton composition at D6, 2007

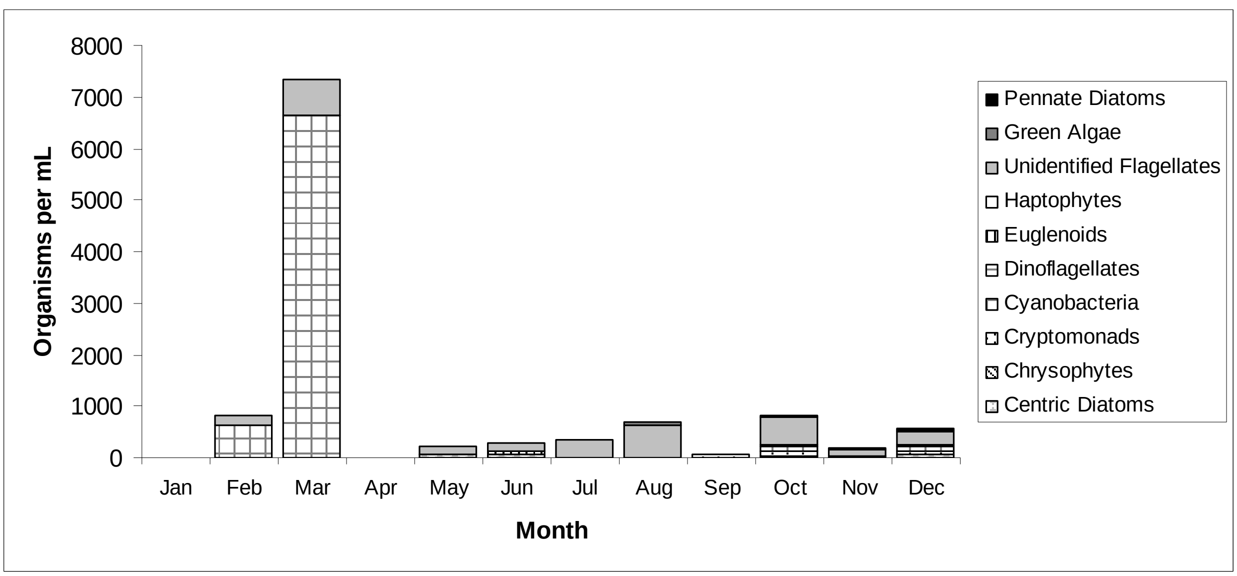


Figure 4-12a Pigment concentrations at D7, 2007

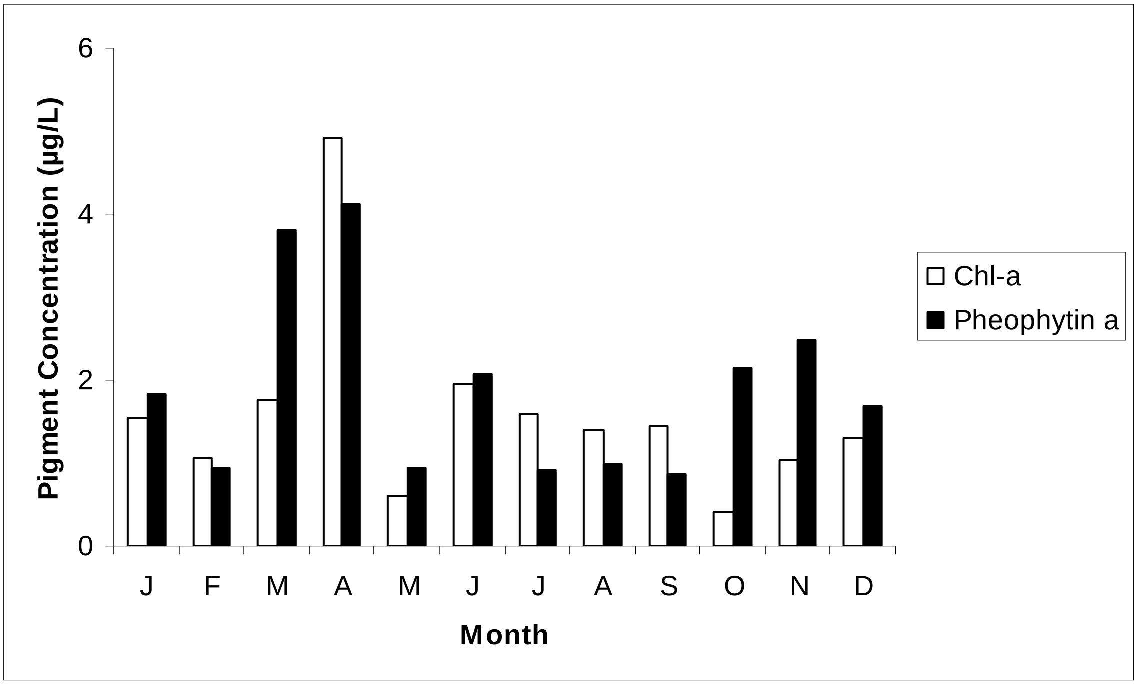


Figure 4-12b Phytoplankton composition at D7, 2007

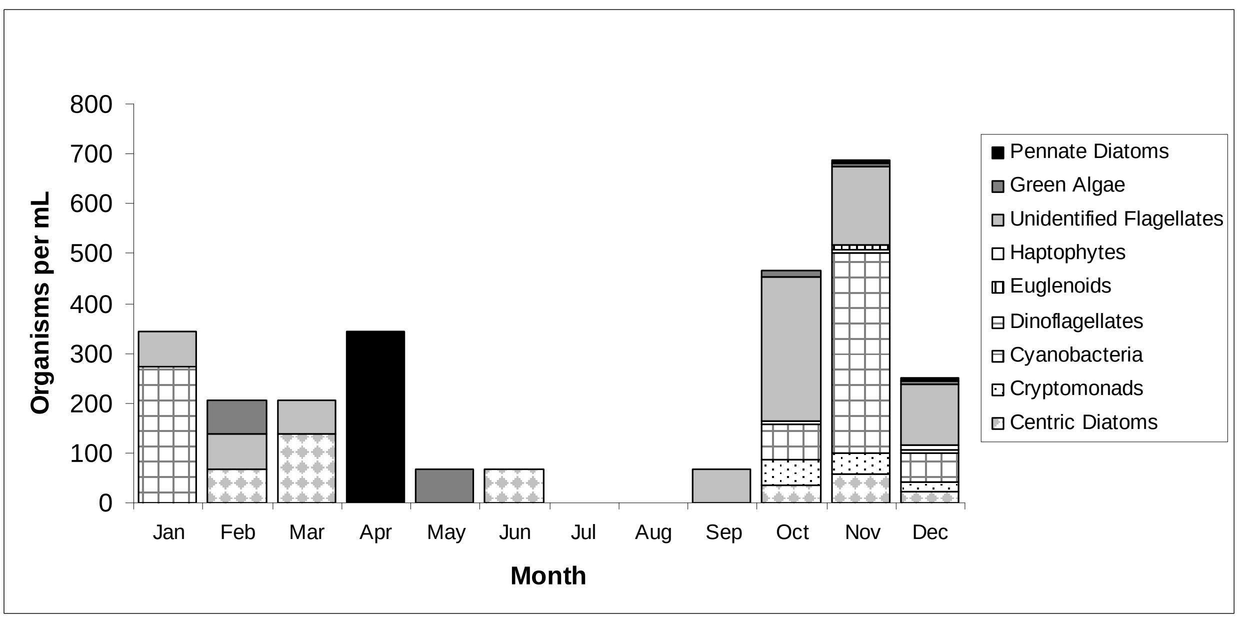


Figure 4-13a Pigment concentrations at D8, 2007

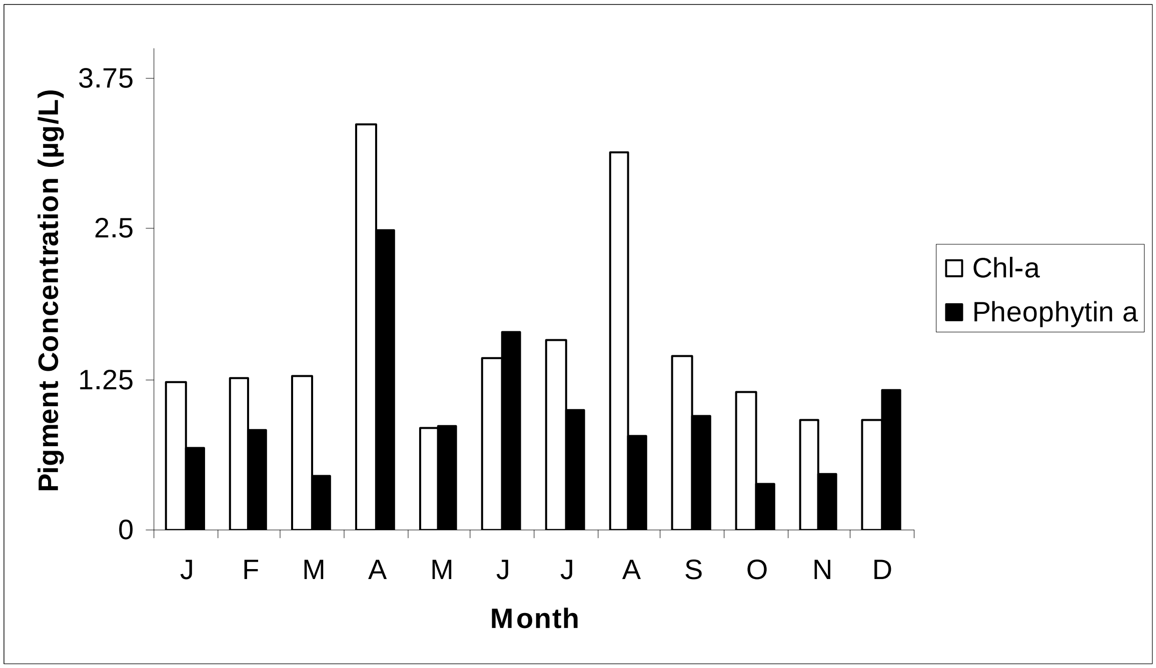


Figure 4-13b Phytoplankton composition at D8, 2007

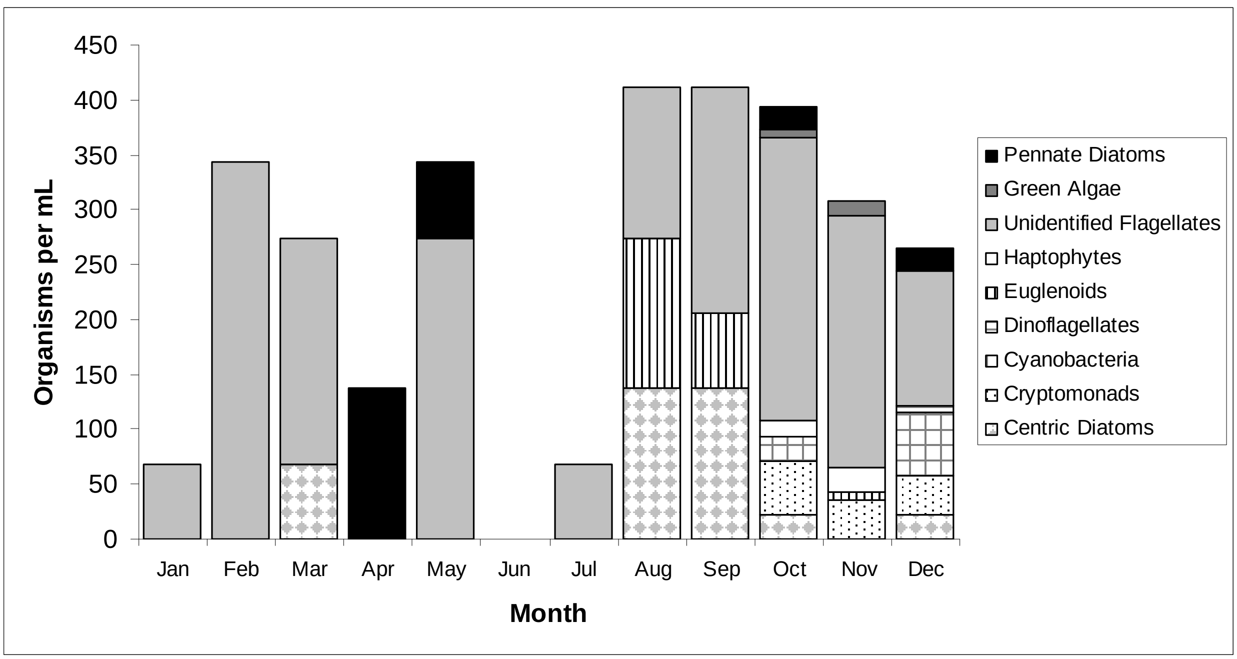


Figure 4-14a Pigment concentrations at D41, 2007

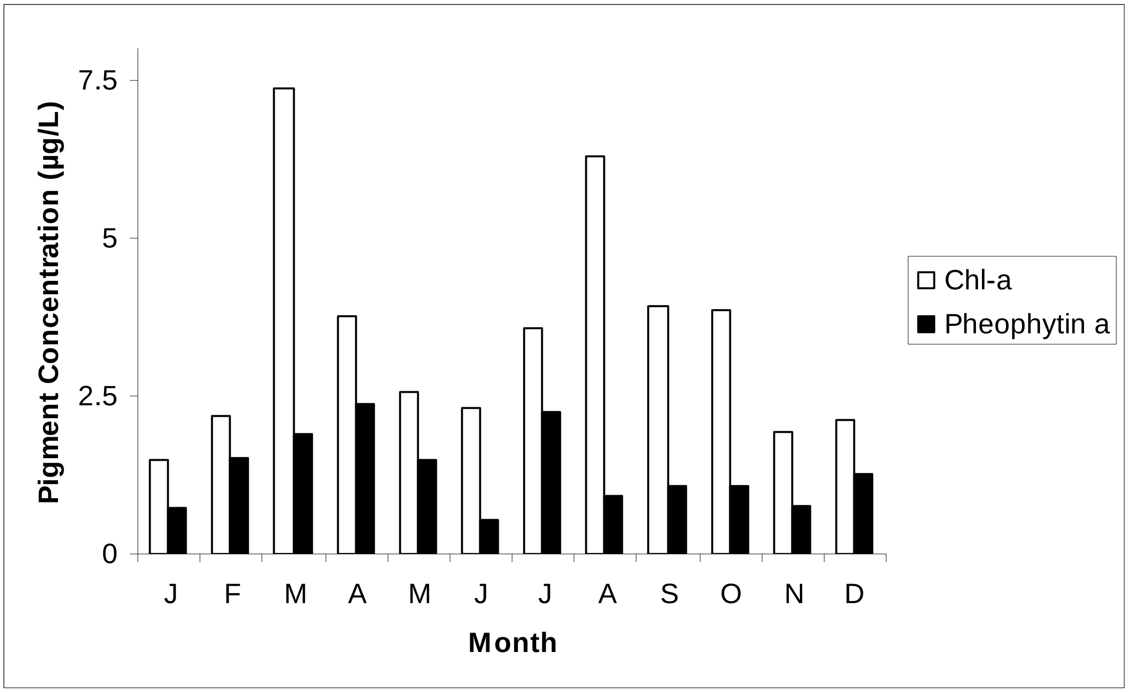


Figure 4-14b Phytoplankton composition at D41, 2007

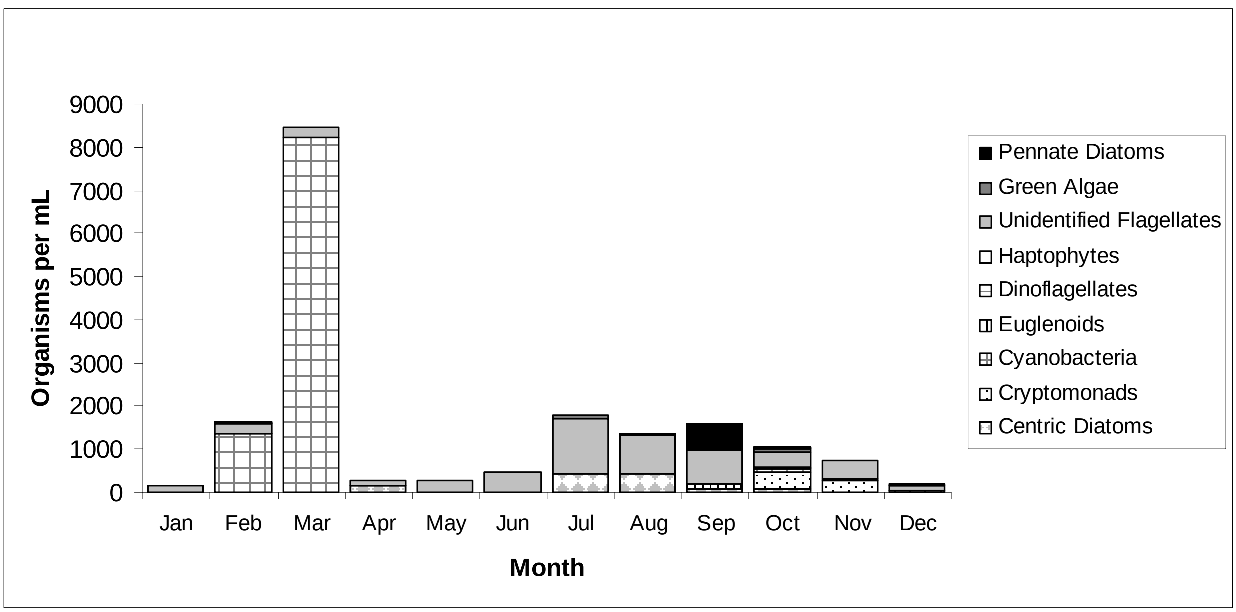


Figure 4-15a Pigment concentrations at D41A, 2007

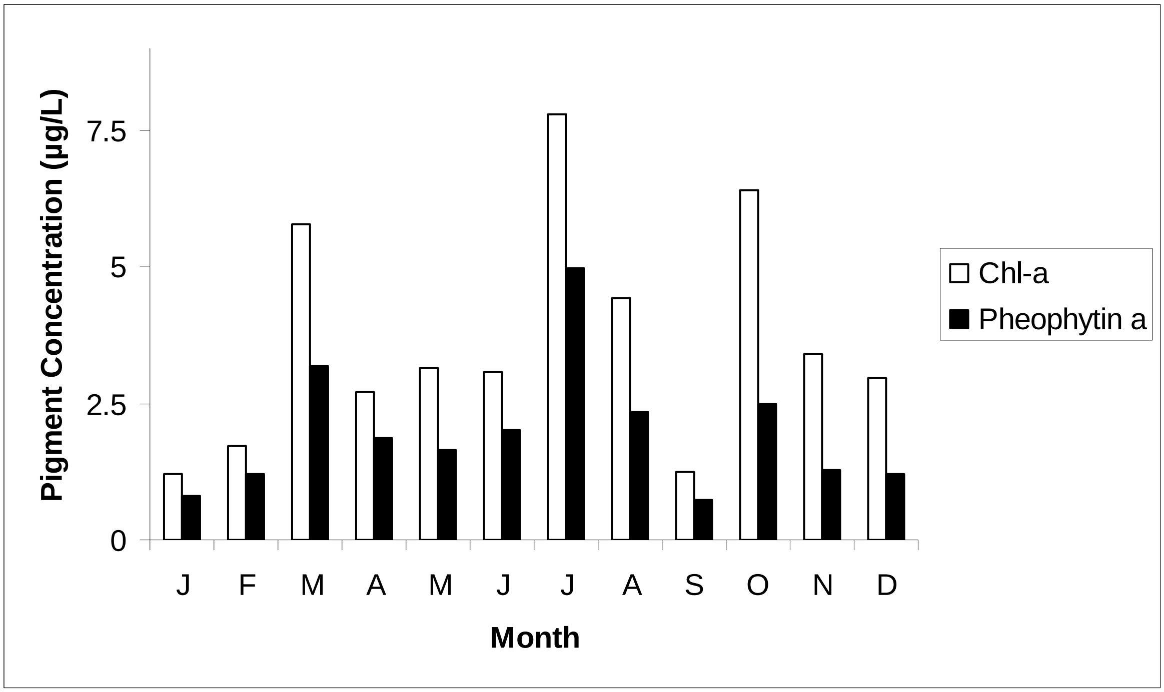


Figure 4-15b Phytoplankton composition at D41A, 2007

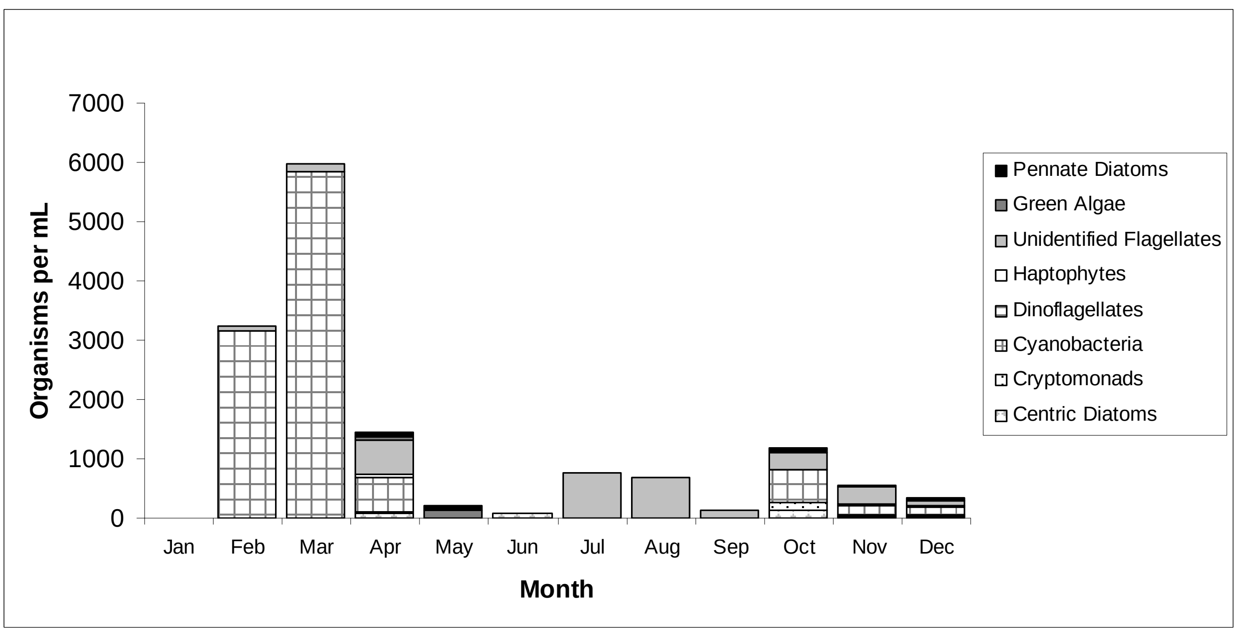


Table 4-1 Phytoplankton genera by group, 2007

Pennate Diatoms	Centric Diatoms	Green Algae	Cyanobacteria
Achnanthes	*Aulacoseira*	*Actinastrum*	*Anabaena*
Amphiprora	Centric Diatom	*Ankistrodesmus*	*Anabaenopsis*
Asterionella	*Cerataulina*	*Chlamydomonas*	*Aphanizomenon*
Cocconeis	*Chaetoceros*	*Chlorella*	*Chroococcus*
Cymatopleura	*Coscinodiscus*	*Chodatella*	*Lyngbya*
Cymbella	*Cyclotella*	*Closterium*	*Merismopedia*
Diatoma	*Rhizosolenia*	*Cosmarium*	*Microcystis*
Epithemia	*Skeletonema*	*Crucigenia*	*Oscillatoria*
Eunotia	*Stephanodiscus*	*Elakatothrix*	*Pseudanabaena*
Fragilaria	**Chrysophytes**	*Keratococcus*	*Raphidiopsis*
Frustulia	*Chromulina*	*Monoraphidium*	*Synechocystis*
Gomphonema	*Dinobryon*	*Oocystis*	**Euglenoids**
Gyrosigma	*Kephyrion*	*Pediastrum*	*Euglena*
Licmophora	Unid Chrysophyte	*Planktosphaeria*	*Phacus*
Mastogloia	**Cryptomonads**	*Scenedesmus*	*Trachelomonas*
Meridion	*Chroomonas*	*Schroederia*	**Unknown**
Navicula	*Cryptomonas*	*Tetraedron*	Unidentified Flagellates
Nitzschia	*Pyrenomonas*	Unid Greens	
Pennate Diatom	*Rhodomonas*	**Haptophytes**	
Pleurosigma	**Dinoflagellates**	*Chrysochromulina*	
Rhoicosphenia	*Gymnodinium*	**Synurophytes**	
Surirella	*Peridinium*	*Mallomonas*	
Synedra			
Tabellaria			

Table 4-2 Chlorophyll *a* and pheophytin *a* concentrations

Chlorophyll *a*(µg/L)

Station	Maximum	Minimum	Median	Mean	Standard Deviation
C3A	6.09	0.49	1.92	2.49	1.74
C10A	108.00	4.29	14.50	31.38	32.17
P8	14.60	0.64	3.17	5.13	4.58
MD10A	80.30	0.84	3.10	14.04	22.82
D26	2.20	0.47	1.23	1.20	0.54
D19	2.82	0.66	1.31	1.41	0.56
D28A	4.36	0.67	1.53	2.02	1.20
D4	3.64	0.25	1.61	1.57	0.88
D6	3.75	0.73	1.61	1.84	0.83
D7	4.91	0.42	1.42	1.58	1.14
D8	3.37	0.85	1.27	1.54	0.83
D41	7.37	1.48	3.06	3.44	1.80
D41A	7.80	1.20	3.12	3.66	2.08

Pheophytin *a* (µg/L)

Station	Maximum	Minimum	Median	Mean	Standard Deviation
C3A	9.61	0.71	1.79	2.72	2.41
C10A	33.40	2.35	9.76	14.32	10.73
P8	12.50	0.79	3.48	4.62	3.25
MD10A	39.90	0.59	1.76	5.94	10.96
D26	1.56	0.27	0.85	0.89	0.37
D19	1.52	0.35	1.05	1.07	0.36
D28A	3.95	0.40	1.33	1.63	0.90
D4	1.89	0.38	1.22	1.27	0.51
D6	2.37	0.39	0.68	0.86	0.54
D7	4.13	0.87	1.76	1.90	1.12
D8	2.49	0.38	0.85	0.97	0.59
D41	2.37	0.54	1.18	1.32	0.60
D41A	4.99	0.75	1.77	1.98	1.19

Chapter 5 Zooplankton

Contents

Figures

Tables

Chapter 5 Zooplankton

Introduction

Zooplankton are important food organisms for larval and juvenile salmon, striped bass, and splittail, and for planktivorous fishes, such as delta smelt, longfin smelt, and threadfin shad, throughout their lives. The Department of Fish and Game's Zooplankton Study monitors the annual and seasonal abundance and distribution of the major zooplankton taxa to assess fish food resources in the San Francisco Estuary. The study also seeks to detect the presence of newly introduced species, monitor their distribution and abundance, and determine their effects on native species. The study began monitoring the native mysid *Neomysis mercedis* in June 1968 and was expanded in January 1972 to monitor copepods, cladocerans, and rotifers. Other mysid species were consistently identified and enumerated as of 1998, while newly introduced copepods, cladocerans, and rotifers were identified and enumerated as they were detected.

Methods

Zooplankton were sampled monthly at 17 to 22 stations in the Delta and Suisun Bay (Figure 5-1). Twenty of these stations were at fixed locations and two were "floating" entrapment zone (EZ) stations located where bottom electrical conductance (EC) was 2 mS/cm and 6 mS/cm, +/-10%. One station in San Pablo Bay and two stations in Carquinez Strait were sampled only when their surface EC was less than 20 mS/cm. Monthly sampling was scheduled so that each station was sampled at approximately high slack tide.

Figure 5-1 Zooplankton monitoring stations

At each station, three types of gears were deployed: 1) a mysid net for macrozooplankton; 2) a modified Clarke-Bumpus (CB) net for mesozooplankton; and 3) a pump sampler for microzooplankton. The mysid net was 1.48 m long with a 28 cm interior mouth diameter and a mesh size of 505 µm. A General Oceanics model 2030 flowmeter was mounted at the center of the net mouth. The net was attached to a ski-mounted towing frame made of steel tubing. The CB net was 75 cm long with an interior mouth diameter of 12.4 cm and a mesh size of 154 µm. The CB frame was a 19.1 cm long, clear acrylic pipe with an inside diameter of 12.0 cm with a General Oceanics model 2030 flowmeter suspended in the center of the pipe. The CB net and frame were mounted on top of the mysid frame, and the nets were deployed together. The pump sampler consisted of a 15-liter/minute-capacity pump connected to a 15 m intake hose that discharged into a 19-L carboy.

At each station, a towing frame holding the mysid and CB nets was lowered to the bottom and retrieved obliquely in several steps for 10 minutes, while the vessel was under way. Flowmeter readings from both nets were recorded before and after each tow to calculate the volume of water filtered through each net. At the end of this tow, after forward momentum had ceased, the pump was turned on and the intake was lowered to the bottom and then raised slowly to the surface twice, while pumped water was discharged into the carboy. After sampling was completed, the carboy was shaken and a 1.5 to 1.9 liter sample decanted into a jar. All samples were fixed in 10% formalin and returned to the laboratory for identification (usually to genus or species level) and enumeration.

Before and after each mysid-CB tow, water temperature (± 0.1 ^{o}C) and electrical conductance (EC, in µS/cm) were measured at the top (1 meter below the surface) and bottom (1 meter above the substrate) of the water column using a Seabird 911+ CTD.

In this report, abundance is reported only for the gear that collects the taxon most efficiently: 1) the CB net for all calanoid copepods, the cyclopoid copepod *Acanthocyclops vernalis*, and all cladocerans; 2) the pump for all rotifers; and 3) both the CB and pump for the cyclopoid copepods *Limnoithona tetraspina* and *Oithona davisae*. Abundance for both gears is presented for the latter two species because larger adults are retained by the CB mesh and smaller adults are more effectively sampled by the pump.

Zooplankton distribution within the estuary is determined more by salinity than geography. Therefore, stations were categorized into three EC zones: 1) upstream of the entrapment zone (where bottom EC < 1.8 mS/cm); 2) the entrapment zone (where bottom EC ranged from 1.8 mS/cm to 6.6 mS/cm); and 3) downstream of the entrapment zone (where bottom EC > 6.6 mS/cm). All floating entrapment zone stations were included in the entrapment zone EC zone, as well as all stations within the EC range noted above.

Monthly and annual abundance indices for each taxon were calculated as the mean number per cubic meter for each gear type and EC zone. The number of stations in each zone varied monthly due to upstream and downstream shifts in salinity. Averaging the abundance for each zone provided a common basis for comparisons.

To depict seasonal changes in abundance, data were log transformed ($\log_{10}$ (abundance+1)) before plotting. Log transformation smoothed trend lines and allowed low abundance to be discerned when abundance ranged across several orders of magnitude.

For brevity, trends from only a subset of the taxa collected are discussed. Taxa were ranked based on mean 2007 abundance for all stations sampled. Monthly abundance trends are presented for the top three to five ranked mysids, calanoid copepods, cyclopoid copepods, cladocerans, and rotifers.

Results

Mysids

Hyperacanthomysis longirostris (formerly *Acanthomysis bowmani*) is an introduced mysid that was first collected in the upper estuary in 1993. In 2007, *H. longirostris* was again the most abundant mysid in all zones (Table 5-1). Abundance was highest in the entrapment zone, and abundance downstream of the entrapment zone was similar, at 94% of the entrapment zone abundance (Figure 5-2). Upstream abundance was much lower at only 7% of the entrapment zone abundance. Seasonality was similar among zones, with abundance peaking in July upstream of and within the entrapment zone, while abundance peaked in June downstream of the entrapment zone. Abundance declined in fall in all of the zones, after which abundance increased again within and downstream of the entrapment zone. Although abundance typically peaks during summer, late summer and early fall abundance was lower than usual.

Figure 5-2 Monthly *Hyperacanthomysis longirostris* (*Acanthomysis bowmani*) abundance upstream, within, and downstream of the entrapment zone, 2007

The native brackish-water mysid *Neomysis kadiakensis* is very similar to *Neomysis japonica,* a freshwater mysid that may be present in the estuary. Until we are able to distinguish between the two species, they will be grouped together as *Neomysis kadiakensis/japonica*. *N. kadiakensis/japonica* was the second most abundant mysid overall in 2007, although numbers were very low, and was found mostly in and downstream of the entrapment zone (Table 5-1). Abundance of *N. kadiakensis/japonica* was very low upstream of the entrapment zone in 2007, indicating that if *N. japonica* is present in the estuary, abundance was very low in 2007, and was only collected from January through March and in July and in very low numbers (Figure 5-3). Abundance peaked in early spring and summer within and downstream of the entrapment zone.

Figure 5-3 Monthly *Neomysis kadiakensis/japonica* abundance upstream, within, and downstream of the entrapment zone, 2007

Alienacanthomysis macropsis is a native brackish-water mysid that was the third most abundant mysid in 2007 (Table 5-1). *A. macropsis* was collected only once upstream of the entrapment zone and once in the entrapment zone in 2007 (Figure 5-4). Downstream of the entrapment zone, *A. macropsis* was collected during every month of 2007, although in very low numbers. *A. macropsis* abundance peaked downstream of the entrapment zone in December 2007.

Table 5-1 Mysid abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-4 Monthly *Alienacanthomysis macropsis* abundance upstream, within, and downstream of the entrapment zone, 2007

Neomysis mercedis was the fourth most abundant mysid in 2007, and was collected mainly within and upstream of the entrapment zone (Table 5-1, Figure 5-5). Until the mid-1990s, this native species had been the most common mysid in the estuary. Only one *N. mercedis* was collected downstream of the entrapment zone in 2007. Since 1993 however, *N. mercedis* abundance has been very low. In 2007, abundance peaked in June upstream of the entrapment zone, but was very low in all zones in every month.

Figure 5-5 Monthly *Neomysis mercedis* abundance upstream, within, and downstream of the entrapment zone, 2007

Calanoid Copepods

The genus *Acartia* consists of three native brackish water species and was the most abundant calanoid copepod in 2007 (Table 5-2), switching ranks with *Pseudodiaptomus forbesi*, which was the most abundant in 2006. *Acartia* spp. was the most common calanoid copepod collected downstream of the entrapment zone (Figure 5-6). Upstream of the entrapment zone *Acartia* spp. was collected in very low numbers from January through March and again in December. Within the entrapment zone, it was collected in 6 different months, also in very low numbers. Downstream, abundance was highest from February through June and lowest in August.

Table 5-2 Calanoid copepod abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-6 Monthly *Acartia* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

The introduced *Pseudodiaptomus forbesi* was the second most abundant calanoid copepod in 2007 (Table 5-2). *P. forbesi* was most abundant within and upstream of the entrapment zone (Figure 5-7). In all zones, abundance was highest from early summer through fall, with a peak in June.

Figure 5-7 Monthly *Pseudodiaptomus forbesi* abundance upstream, within, and downstream of the entrapment zone, 2007

The introduced *Acartiella sinensis* was the third most abundant calanoid copepod (Table 5-2), switching ranks with *Eurytemora affinis*, which ranked third in 2006. *A. sinensis* abundance was highest within the entrapment zone (Figure 5-8). Abundance upstream peaked from July through October, while abundance downstream and in the entrapment zone peaked from July through November.

Figure 5-8 Monthly *Acartiella sinensis* abundance upstream, within, and downstream of the entrapment zone, 2007

Eurytemora affinis was the fourth most abundant calanoid copepod in 2007 (Table 5-2). *E. affinis* was most common in the entrapment zone, where abundance peaked from February through May and declined sharply thereafter (Figure 5-9). Upstream of the entrapment zone abundance peaked from April through June and then again in November and December. Downstream of the entrapment zone, abundance peaked in November and December.

Figure 5-9 Monthly *Eurytemora affinis* abundance upstream, within, and downstream of the entrapment zone, 2007

Sinocalanus doerrii was the fifth most abundant calanoid copepod in 2007 (Table 5-2), as it was in 2005 and 2006. It was most common upstream of the entrapment zone, where abundance peaked in May and June before declining sharply (Figure 5-10). A similar seasonal trend was seen in the entrapment zone and downstream of the entrapment zone.

Figure 5-10 Monthly *Sinocalanus doerrii* abundance upstream, within, and downstream of the entrapment zone, 2007

Cyclopoid Copepods

Since it was first detected in 1993, *Limnoithona tetraspina* has become the most abundant cyclopoid copepod in the study area. It was abundant in all three EC zones, with the highest CPUE (catch per unit effort) in and downstream of the entrapment zone (Table 5-3). Abundance was highest throughout the year in the pump samples, except in March and June upstream of the entrapment zone where there was no catch in the pump samples and very low numbers in the CB samples (Figure 5-11). Upstream of the entrapment zone,

Table 5-3 Cyclopoid copepod abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-11 Monthly *Limnoithona tetraspina* abundance upstream, within, and downstream of the entrapment zone, 2007

abundance peaked in both the CB and pump samples in August and September, with lows occurring in March and June. Within and downstream of the entrapment zone, the pump sample abundance was highest in summer and fall, whereas the CB sample abundance was stable throughout the year with mild fluctuations.

Another introduced species, *Oithona davisae*, was the most abundant cyclopoid copepod in the CB samples in 2007 and was the second most abundant cyclopoid copepod in the pump samples (Table 5-3). It was most common downstream of the entrapment zone in both the CB and pump samples from late summer through fall (Figure 5-12). Within and upstream of the entrapment zone, abundance was low for both gears all year, with a small peak in January.

Figure 5-12 Monthly *Oithona davisae* abundance upstream, within, and downstream of the entrapment zone, 2007

The native *Acanthocyclops vernalis* was the third most common cyclopoid copepod in 2007, as it was in 2006, and was most abundant in and upstream of the entrapment zone (Table 5-3). In all zones abundance was highest during the first half of the year and then declined in late summer and early fall, followed by a slight increase in November and December (Figure 5-13).

Figure 5-13 Monthly *Acanthocyclops vernalis* abundance upstream, within, and downstream of the entrapment zone, 2007

Cladocerans

The most common cladocerans collected by this study are freshwater, and therefore are found upstream of the entrapment zone. Rankings for the three most abundant genera remained unchanged from 2006 to 2007.

Table 5-4 Cladoceran abundance upstream, within, and downstream of the entrapment zone, 2007

Bosmina spp. was the most abundant cladoceran in 2007 (Table 5-4). Upstream numbers were relatively high all year, with the highest abundance in late spring and early summer (Figure 5-14). Within and downstream of the entrapment zone, abundance was much lower and had a similar seasonal pattern most of the year.

Figure 5-14 Monthly *Bosmina* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

The second most abundant cladoceran in 2007 was *Daphnia* spp. (Table 5-4). It was most common upstream, where abundance was relatively high most of the year, with a peak in late spring and early summer followed by a sharp decline in July that lead to a crash in August (Figure 5-15). Within and downstream of the entrapment zone, abundance was much lower and followed a similar pattern most of the year, with highest abundance in early spring and a peak in June.

Figure 5-15 Monthly *Daphnia* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

Diaphanosoma spp. was the third most abundant cladoceran in 2007 (Table 5-4). As with *Bosmina* and *Daphnia*, it was most common upstream where abundance peaked in summer and early fall, then declined thereafter (Figure 5-16). Within and downstream of the entrapment zone, abundance was very low all year with small peaks in the entrapment zone in June, July, and September.

Figure 5-16 Monthly *Diaphanosoma* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

Rotifers

Rotifers are primarily freshwater organisms, except the brackish-water species *Synchaeta bicornis.* Therefore, rotifer abundance is highest upstream of the entrapment zone, except during high-flow events when they are washed downstream into the entrapment zone and beyond. Although the same taxa were most common in both 2007 and 2006, their relative rankings changed.

The most common rotifer in 2007 was *Keratella* spp. (Table 5-5). It was most abundant upstream of the entrapment zone, but was relatively abundant in the other zones most of the year as well (Figure 5-17). Upstream of the entrapment zone, abundance was stable throughout the year with a low in December. In the entrapment zone, abundance peaked in February and declined thereafter with lows in August and November. Downstream of the entrapment zone, abundance remained stable throughout most of the year, except in December when none were caught.

Table 5-5 Rotifer abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-17 Monthly *Keratella* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

Polyarthra spp. was the second most abundant rotifer in 2007 (Table 5-5). It was most abundant upstream of the entrapment zone, but was relatively abundant in the other zones as well (Figure 5-18). Upstream of the entrapment zone, abundance was stable throughout the year with a peak in April and lows in January and December. In the entrapment zone, abundance was stable through spring then dropped sharply in June and again August through November. Downstream of the entrapment zone, abundance fluctuated widely with lows in May, July, and December.

Figure 5-18 Monthly *Polyarthra* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

Synchaeta spp. was the third most common rotifer in 2007, and includes the brackish-water species *Synchaeta bicornis* (Table 5-5). Like the other two taxa, abundance was relatively stable upstream of the entrapment zone (Figure 5-19). Within the entrapment zone, abundance fluctuated widely with lows occurring in January and February, and again in June and September. Downstream of the entrapment zone, abundance was highly variable with a low in February and a peak in July.

Figure 5-19 Monthly *Synchaeta* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

Summary

In 2007, the most common zooplankton taxa were the same as 2006, although their relative rankings changed. Monthly abundance patterns in 2006 and 2007 were similar, although in most cases abundance was much lower in 2007 than 2006. The introduced *H. longirsotris* and the *N. kadiakensis/japonica* complex remained the two most abundant mysids, followed by the native *A. macropsis* and *N. mercedis*, which switched ranks from 2006. The native *Acartia* spp. replaced *P. forbesi* as the most abundant calanoid copepod in 2007. *P. forbesi*, ranked first in 2006, was second, followed by *A. sinensis*, *E. affinis*, and *S. doerrii*. *A. sinensis* and *E. affinis* also switched ranks from 2006 to 2007. The three most common cyclopoid copepods remained the introduced *O. davisae*, *L .tetraspina*, and *A. vernalis*. In 2007, *O. davisae* was most abundant in CB samples, while *L. tetraspina* was more abundant in pump samples. The top three cladocerans remain unchanged from 2006 to 2007 with *Bosmina* spp. being the most common, *Daphnia* spp. was second and *Diaphanosoma* spp. third. The rotifers switched ranks from 2006 to 2007; with *Keratella* spp. moving from second most abundant in 2006 to most abundant in 2007, *Polyarthra* spp. moving from third most abundant in 2006 to second most abundant in 2007, and *Synchaeta* spp. moving from the most abundant in 2006 to third most abundant in 2007.

Figure 5-1 Zooplankton monitoring stations

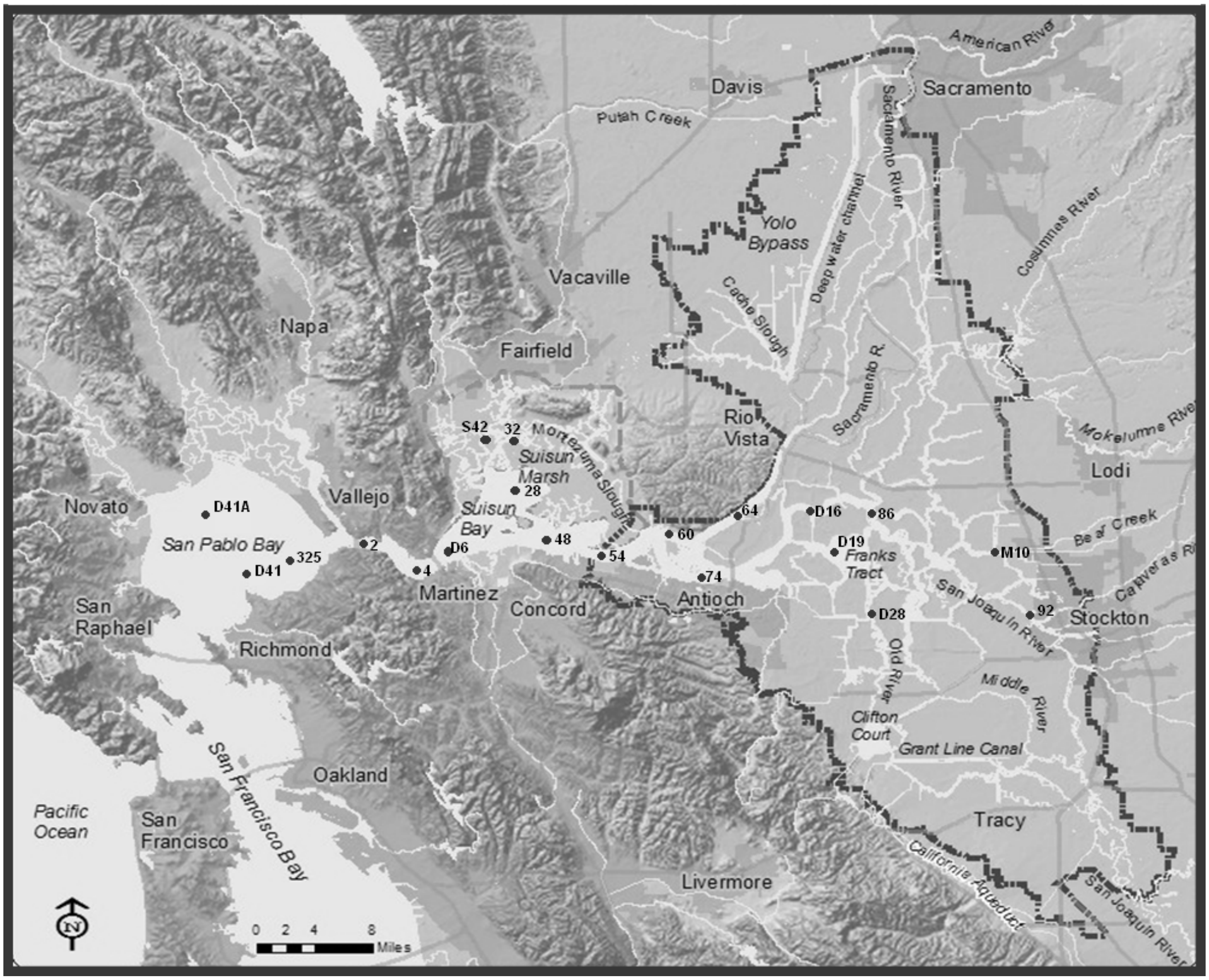


Figure 5-2 Monthly *Hyperacanthomysis longirostris* (*Acanthomysis bowmani*) abundance upstream, within, and downstream of the entrapment zone, 2007

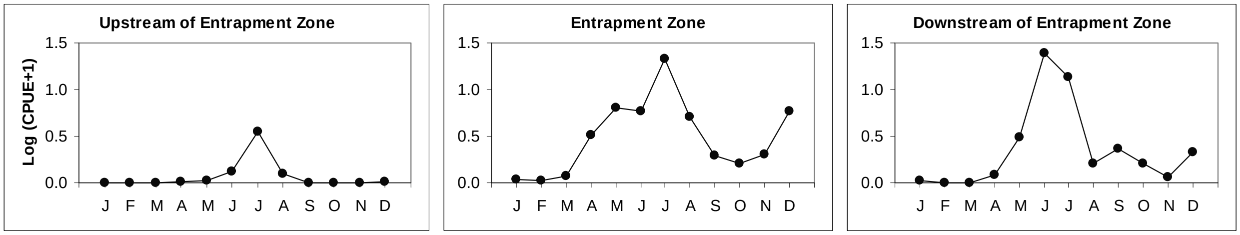


Figure 5-3 Monthly *Neomysis kadiakensis/japonica* abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-4 Monthly *Alienacanthomysis macropsis* abundance upstream, within, and downstream of the entrapment zone, 2007

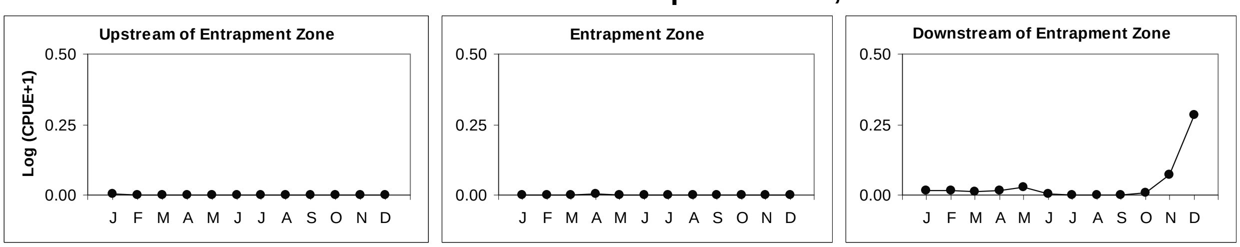


Figure 5-5 Monthly *Neomysis mercedis* abundance upstream, within, and downstream of the entrapment zone, 2007

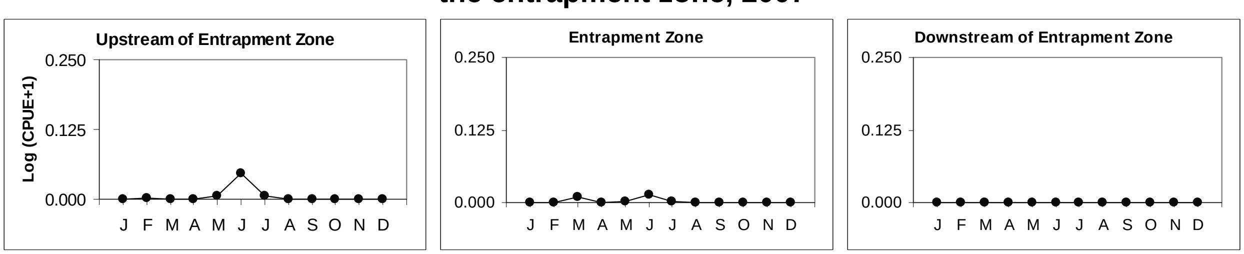


Figure 5-6 Monthly *Acartia* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-7 Monthly *Pseudodiaptomus forbesi* abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-8 Monthly *Acartiella sinensis* abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-9 Monthly *Eurytemora affinis* abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-10 Monthly *Sinocalanus doerrii* abundance upstream, within, and downstream of the entrapment zone, 2007

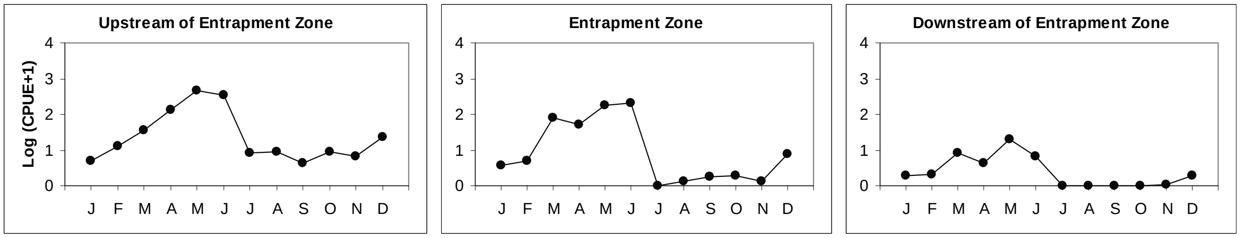


Figure 5-11 Monthly *Limnoithona tetraspina* abundance upstream, within, and downstream of the entrapment zone, 2007.

Figure 5-12 Monthly *Oithona davisae* abundance upstream, within, and downstream of the entrapment zone, 2007.

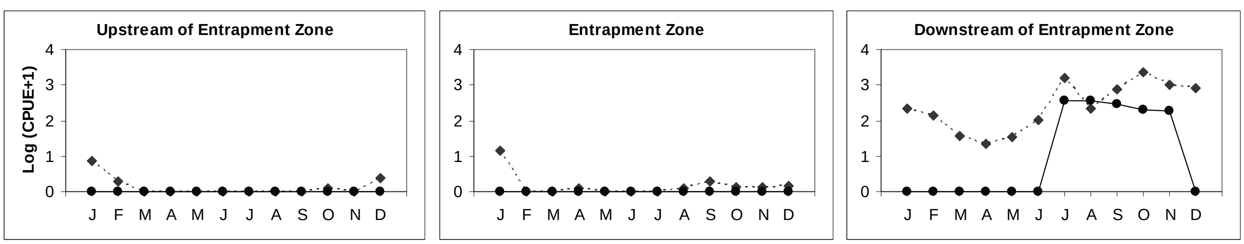


Figure 5-13 Monthly *Acanthocyclops vernalis* abundance upstream, within, and downstream of the entrapment zone, 2007

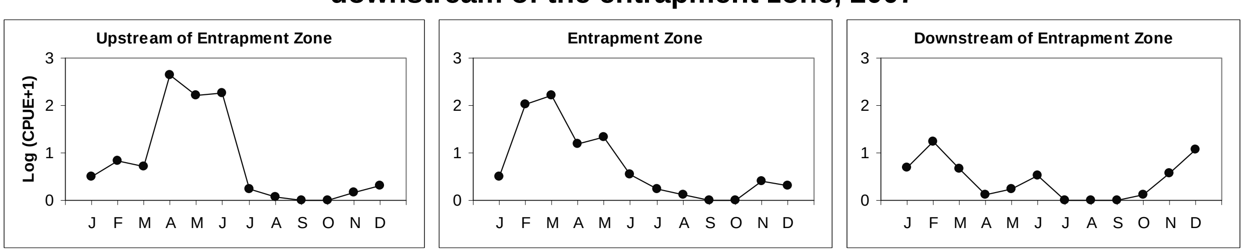


Figure 5-14 Monthly *Bosmina* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-15 Monthly *Daphnia* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

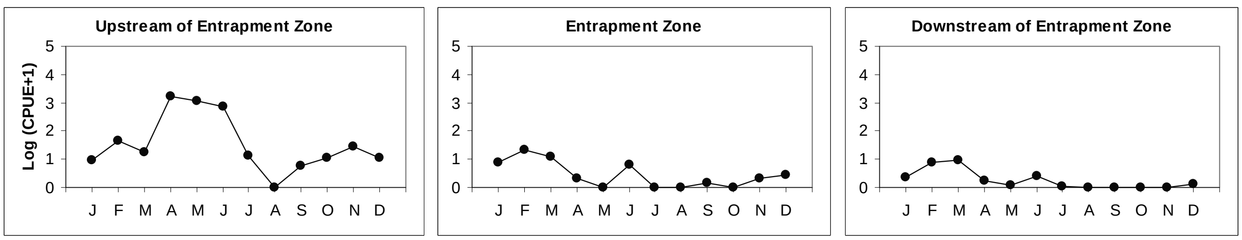


Figure 5-16 Monthly *Diaphanosoma* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

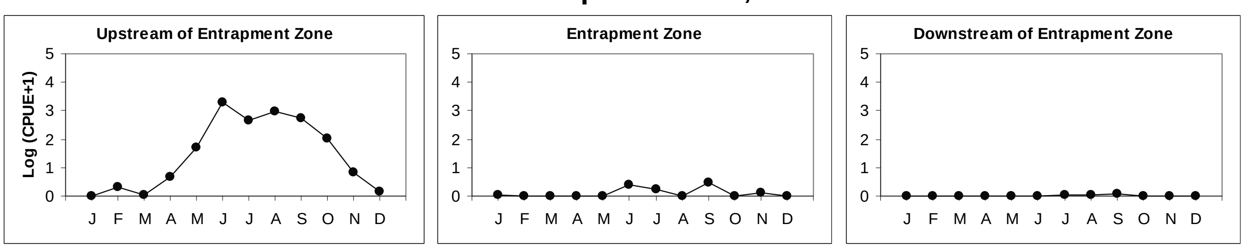


Figure 5-17 Monthly *Keratella* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

Figure 5-18 Monthly *Polyarthra* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

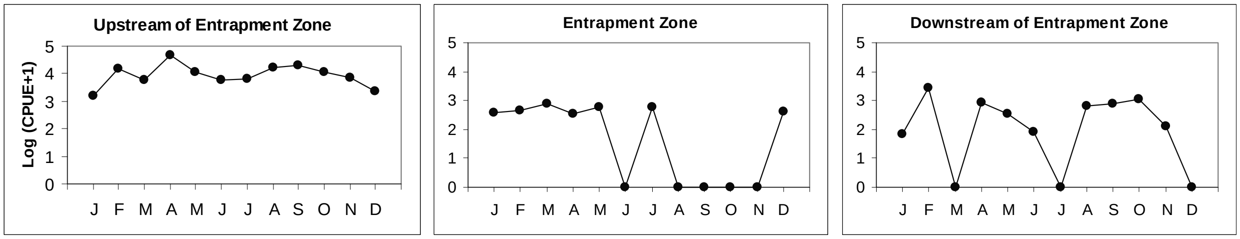


Figure 5-19 Monthly *Synchaeta* spp. abundance upstream, within, and downstream of the entrapment zone, 2007

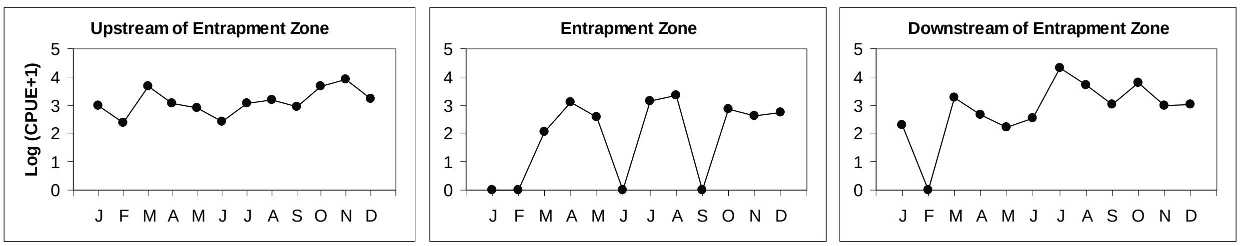


Table 5-1 Mysid abundance upstream, within, and downstream of the entrapment zone, 2007

	Upstream	Entrapment Zone	Downstream	All Zones
Hyperacanthomysis longirostris	0.27	3.70	3.49	2.28
Neomysis kadiakensis/japonica	0.00	0.12	0.31	0.15
Alienacanthomysis macropsis	0.00	0.00	0.13	0.05
Neomysis mercedis	0.01	0.00	0.00	0.01

Table 5-2 Calanoid copepod abundance upstream, within, and downstream of the entrapment zone, 2007

Calanoid Copepods	Upstream	Entrapment Zone	Downstream	All Zones
Acartia spp.	0.5	3.0	1055.5	431.5
Pseudodiaptomus forbesi	695.6	360.7	43.0	360.2
Acartiella sinensis	27.8	390.7	127.2	143.2
Eurytemora affinis	63.4	73.4	33.1	53.1
Sinocalanus doerrii	94.1	40.3	2.8	45.8

Table 5-3 Cyclopoid copepod abundance upstream, within, and downstream of the entrapment zone, 2007

	Upstream	Entrapment Zone	Downstream	All Zones
CB net:				
Oithona davisae	0.6	1.1	683.7	279.5
Limnoithona tetraspina	5.0	98.1	49.9	42.5
Acanthocyclops vernalis	76.7	30.4	3.4	37.2
Pump:				
Limnoithona tetraspina	604	10489	13018	7806
Oithona davisae	0	0	126	52

Table 5-4 Cladoceran abundance upstream, within, and downstream of the entrapment zone, 2007

Cladocerans	Upstream	Entrapment Zone	Downstream	All Zones
Bosmina spp.	3175.5	8.9	4.6	1228.3
Daphnia spp.	368.1	4.2	1.3	143.3
Diaphanosoma spp.	325.0	0.3	0.0	125.4

Table 5-5 Rotifer abundance upstream, within, and downstream of the entrapment zone, 2007

Rotifers	Upstream	Entrapment Zone	Downstream	All Zones
Keratella spp.	13957	3262	771	6267
Polyarthra spp.	13982	314	544	5566
Synchaeta spp.	2071	641	3313	2286

Chapter 6 Benthic Monitoring

Content

Figures

Table

Chapter 6 Benthic Monitoring

Introduction

The benthic monitoring program is designed to document the distribution, diversity, and abundance of benthic (bottom dwelling) organisms in the estuary. Geographic coverage of the sampling sites ranges from San Pablo Bay east through the Sacramento-San Joaquin Delta to the mouths of the Sacramento, Mokelumne, and San Joaquin rivers. The benthic community of the upper estuary is a diverse assemblage of organisms, which includes worms, crustaceans, insects and molluscs. This program monitors both benthic macrofauna (organisms larger than 0.5 mm) (DWR 2001) and sediment composition. General trends in sediment composition are documented at the same sites where benthic samples are collected.

[DWR] California Department of Water Resources, 2001. *Water Quality Conditions in the Sacramento-San Joaquin Delta During 1996*. A report to the State Water Resources Control Board in Accordance with Water Right Decision 1485, Order 4(f).

The benthic monitoring program began in 1975. From 1975 through 1979, the program collected samples biannually from 11 to 16 sites. In 1980, DWR revised the benthic monitoring program and began monthly sampling at 5 sites. In 1995, major programmatic revisions were implemented to form the current program. Since 1996, monitoring has usually been conducted at 10 sites sampled monthly. Between October 2003 and September 2004, quarterly sampling was conducted to allow special studies to be carried out to assess potential changes to the program.

Table 6-1 Macrobenthic monitoring station characteristics, 2007

The current sites represent a wide variety of habitats that vary in size and physical characteristics. Table 6-1 contains site-specific information. More detailed information about the location, number and physical characteristics of the historical sites can be found in Interagency Ecological Program (IEP) Technical Report 12 (Markmann 1986) and IEP Technical Report 38 (Hymanson et al. 1994).

Markmann, C. 1986. *Benthic Monitoring in the Sacramento-San Joaquin Delta. Results from 1975 through 1981.* Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Technical Report 12. DWR

Hymanson, Z., D. Mayer, J. Steinbeck. 1994. *Long-Term Trends in Benthos Abundance and Persistence in the Upper Sacramento-San Joaquin Estuary. Summary Report: 1980-1990.* Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 38. DWR

Methods

Benthic Organisms

In 2007, field sampling was conducted monthly at 10 sites throughout the estuary. Figure 6-1 shows the location of each site, and Table 6-1 summarizes latitude, longitude, salinity substrate composition for each site. The research vessels *San Carlos*, *Endeavor* and 2 Boston Whalers, all equipped with a hydraulic winch or davit and a Ponar dredge, were used to conduct this sampling. The Ponar dredge samples a bottom area of 0.052 square meters. The contents of the dredge were washed over a Standard No. 30 stainless steel mesh screen (0.595 mm openings) to remove as much of the substrate as possible. All material remaining on the screen was preserved in approximately 20% buffered formalin containing Rose Bengal dye and was transported to the

Figure 6-1 Location of macrobenthic monitoring stations

laboratory for analysis. The benthic macroinvertebrate sampling methodology used in this program is described in *Standard Methods for the Examination of Water and Wastewater* (APHA 1998).

In the laboratory, the field preservative was decanted and the sample was washed with deionized water over a Standard No. 30 stainless steel mesh screen. Organisms were then placed in 70% ethyl alcohol for identification and enumeration. Hydrozoology[1], a private laboratory under contract with DWR, identified and enumerated organisms in the macrofaunal samples. A stereoscopic dissecting microscope (70X-120X) was used to identify most organisms. When taxonomic features were too small for identification under the dissecting scope, the organism was mounted on a slide and examined under a compound microscope. If more than 3 hours of picking were required and a sample contained many organisms but few species, a one-fourth volume sub sample was chosen at random from the sample. The sub sample was picked, and the results were multiplied by 4 to represent the total sample. The remainder of the sample was inspected to make sure no taxa were overlooked. Individual species counts were multiplied by 19 to convert the number of organisms per grab sample to organisms per square meter (where $19 = 1.0\ m^2 / 0.052\ m^2$ and $0.052\ m^2$ = sample area of the Ponar).

All organisms identified and enumerated were recorded onto datasheets by Hydrozoology staff. These datasheets were returned to DWR staff for entry into the benthic monitoring program database.

Sediment

Sediment composition samples were collected monthly in the field from the *Endeavor* and the *Whaler* using the same Ponar dredge used in the benthic sampling. A random sub sample of the sediment was placed into a 1-liter plastic jar for storage and transported to the DWR's Soils and Concrete Laboratory for analysis.

Particle size analysis and dry weight measurements were performed for each sediment sample. Sediment was analyzed for particle size according to the American Society of Testing and Materials Protocol D422 (ASTMa 2000). Particles were sorted into the following categories: sand (>75 µm) and fine (<75 µm). The organic content of the sediment was determined using the American Society of Testing and Materials Protocol D2974, Method C (ASTMb 2000). For this method, the ash-free dry weight of the sample was used to determine the organic content of the sediment.

[1] Hydrozoology. P.O. Box 682, Newcastle, CA 95658

[APHA] American Public Health Association, American Waterworks and Water Environmental Federation. 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th ed. Washington, D.C.: American Public Health Association, 10.60-10.74.

[ASTMa] American Society of Testing and Materials, 2000. Soil and Rock (I): D420 - D5779, Vol. 04.08: protocol D422

[ASTMb] American Society of Testing and Materials. 2000. Soil and Rock (I): D420 - D5779, Vol. 04.08: ASTM protocol D2974 method C.

Results

Benthic Composition and Abundance

The benthic monitoring program collects a large number of organisms, but a relatively small number of species. Of the 174 species collected, 10 represented 84.6% of all organisms collected. These species are listed below.

Numerically Dominant Species

Amphipods

- *Ampelisca abdita*
- *Americorophium spinicorne*
- *Corophium alienense*
- *Gammarus daiberi*
- *Americorophium stimpsoni*

Sabellidae Polychaete

- *Manayunkia speciosa*

Tubificidae Worms

- *Varichaetadrilus angustipenis*
- *Limnodrilus hoffmeisteri*

Asian Clams

- *Corbula amurensis*
- *Corbicula fluminea*

Of the 10 dominant species, *Corbula amurensis* and *Ampelisca abdita* represent macrofauna that inhabit a typically higher saline environment and were found in San Pablo Bay, Suisun Bay and Grizzly Bay. *Corophium alienense, Americorophium stimpsoni, Americorophium spinicorne, and Limnodrilus hoffmeisteri* tolerate a wider range of salinity. They were collected in both the higher saline western sites and the more brackish water to freshwater eastern sites, such as the San Joaquin River at Twitchell Island and the Sacramento River above Point Sacramento. The remaining 4 species; *Gammarus daiberi, Varichaetadrilus angustipenis, Manayunkia speciosa* and *Corbicula fluminea* are predominantly freshwater species and were collected at sites east of Suisun Bay.

Data Management and Summarization

The EMP maintains a database containing all information on benthic organisms identified in the upper estuary. This database continuously undergoes peer review and updating. When a new organism is found at any of the sampling sites, the organism is identified to the lowest possible taxonomic level and added to the database. All data are available at http://www.baydelta.ca.gov.

All organisms collected during 2007 fell into 9 phyla:

- Cnidaria (hydras, sea anemones)
- Chordata (tunicate)
- Phoronida (phoronids)
- Platyhelminthes (flatworms)
- Nemertea (ribbon worms)
- Nematoda (roundworms)
- Annelida (segmented worms)
- Arthropoda (aquatic insects, amphipods, isopods, shrimp, crabs, mites, etc.)
- Mollusca (clams, snails)

Of the 9 phyla identified, Annelida, Arthropoda and Mollusca constituted 99.5% of the organisms collected during the study. Figure 6-2 shows the total percent contribution by phylum for all sites. Figures 6-3 through 6-7 show the total contribution by phylum for each site and organism abundance for each site.

Figure 6-2 Total contribution by phyla for all stations during 2007

Organism abundance (organism per square meter or org/m^2) and dominant phyla varied between sites. Temporal changes in organism abundance (for example, intra- and interannual) also varied greatly between sites. These variations and trends (for example, maximum/minimum abundance and dominant species) are discussed for each individual site (Figures 6-3 through 6-7). Sediment composition is also discussed for each site (Figures 6-8 through 6-17).

Benthic Abundance

Maximum abundances in 2007 ranged from 41,791 organisms per square meter in July at D41 to 850 organisms per square meter in November at D16. Minimum abundances ranged from 6,484 organisms per square meter in April at D41A to 48 organisms per square meter in March at D16.

Site C9: South Delta

Maximum abundance in 2007 occurred in June with a total of17,661 organisms per square meter (Figure 6-3). *Ilyodrilus frantzi* (6,246 org/m^2) and *Limnoldrilus hoffmeisteri* (3,121 org/m^2) were the dominant species. The minimum abundance in 2007 occurred in January with a total of 627 organisms per square meter. *Limnodrilus hoffmeisteri* (333 org/m^2) and *Varichaetadrilus angustipenis* (181 org/m^2) were the dominant species.

Figure 6-3 Total abundance at Station C9, 2007

Site P8: South Delta

The maximum abundance in 2007 was in May with a total of 6,265 organisms per square meter (Figure 6-4). *Manayunkia speciosa* (1,815 org/m^2) and *Limnodrilus hoffmeisteri* (1,192 org/m^2) were the dominant species. The minimum abundance in 2007 was in April with a total of 2,000 organisms per square meter. *Limnodrilus hoffmeisteri*

Figure 6-4 Total abundance at P8, 2007

(513 org/m2) and *Manayunkia speciosa* (409 org/m2) were the dominant species.

Site D28A: Central Delta

Maximum abundance in 2007 occurred in November with a total of 15,276 organisms per square meter (Figure 6-5). *Cyprideis sp.A* (5,980 org/m^2), and *Manayunkia speciosa* (4,674 org/m^2) were the dominant species. The minimum abundance in 2007 occurred in July with a total of 850 organisms per square meter. *Americorophium spinicorne* (290 org/m^2) and *Corbicula fluminea* (195 org/m^2) were the dominant species.

Figure 6-5 Total abundance at Station D28A, 2007

Site D16: Lower San Joaquin River

Maximum abundance in 2007 occurred in November with a total of 850 organisms per square meter (Figure 6-6). *Corbicula fluminea* (675 org/m^2) was the dominant species. The minimum abundance in 2007 occurred in March with a total of 48 organisms per square meter. *Corbicula fluminea* (29 org/m^2) was the dominant species.

Figure 6-6 Total abundance at Station D16, 2007

Site D24: Lower Sacramento River

Maximum abundance in 2007 occurred in May with a total of 8,422 organisms per square meter (Figure 6-7). *Americorophium stimpsoni* (6,873 org/m^2) was the dominant species. The minimum abundance in 2007 occurred in July with a total of 1045 organisms per square meter. *Corbicula fluminea* (803 org/m^2) was the dominant species.

Figure 6-7 Total abundance at Station D24, 2007

Site D4: Lower Sacramento River

Maximum abundance in 2007 occurred in May with a total of 28,310 organisms per square meter (Figure 6-8). *Americorophium spinicorne* (24,771 org/m^2) was the dominant species. The minimum abundance in 2007 occurred in September with a total of 4,555 organisms per square meter. *Americorophium spinicorne* (1,463 org/m^2) was the dominant species.

Figure 6-8 Total abundance at Station D4, 2007

Site D6: Suisun Bay

Maximum abundance in 2007 occurred in January with a total of 16,677 organisms per square meter (Figure 6-9). *Corbula amurensis* (16,459 org/m^2) was the dominant species. The minimum abundance in 2007 occurred in October with a total of 2,290 organisms per square meter. *Corbula amurensis* (2,180 org/m^2) was the dominant species.

Figure 6-9 Total abundance at Station D6, 2007

Site D7: Suisun Bay

Maximum abundance in 2007 occurred in September with a total of 13,675 organisms per square meter (Figure 6-10). *Corbula amurensis* (7,363 org/m^2) and *Corophium alienese* (5,729 org/m^2) were the dominant species. The minimum abundance in 2007 occurred in May with a total of 3,700 organisms per square meter. *Corbicula amurensis*

Figure 6-10 Total abundance at Station D7, 2007

(1,682 org/m^2) and *Corophium alienense* (1,648 org/m^2) were the dominant species.

Site D41: San Pablo Bay

Maximum abundance in 2007 occurred in July with a total of 41,791 organisms per square meter (Figure 6-11). *Ampelisca abdita* (39,135 org/m^2) was the dominant species. The minimum abundance in 2007 occurred in March with a total of 936 organisms per square meter. *Ampelisca abdita* (599 org/m^2) was the dominant species.

Figure 6-11 Total abundance at Station D41, 2007

Site D41A: San Pablo Bay

Maximum abundance in 2007 occurred in November with a total of 33,621 organisms per square meter (Figure 6-12). *Ampelisca abdita* (29,578 org/m^2) was the dominant species. The minimum abundance in 2007 occurred in April with a total of 6,484 organisms per square meter. *Ampelisca abdita* (4,494 org/m^2) was the dominant species.

Figure 6-12 Total abundance Station D41A, 2007

Sediment Analysis

Sediment organic content was determined using the ash-free dry weight and is given as a percent of the total sample mass. In 2007, organic content ranged from 0.2% at site D16 to 43.9% at site D4.

Site C9: South Delta

Sandy clay dominated the summer months while sand and a mixture of silty sand dominated the sediment at site C9 for 2007 (Figure 6-13). The percentage of organic content ranged from 0.5% to 4.0%. Higher measurements of organic matter coincided with higher amounts of finer sediments.

Figure 6-13 Sediment grain size and organic content at Station C9 during 2007

Site P8: South Delta

Fine sediment dominated site P8 during February through May in 2007 (Figure 6-14). Sand dominated in June, July and September while the rest of the months had even sediment distribution. The organic matter ranged from 1.3% to 4.5%, with the higher organic values typically coinciding with finer sediments.

Figure 6-14 Sediment grain size and organic content at Station P8 during 2007

Site D28A: Central Delta

Sandy sediment was dominant most months at site D28A for 2007 with the exception of February and May when fine sediment held the majority (Figure 6-15). The organic matter ranged from 1.5% to 13.1%. Larger quantities of organic matter coincided with an abundance of fine sediment.

Figure 6-15 Sediment grain size and organic content at Station D28A during 2007

Site D16: Lower San Joaquin River

Sand dominated the sediment type at site D16 for 2007 with the exception of May when clay dominated (Figure 6-16). The amount of organic matter at this site ranged from 0.2% to 4.5% with higher values coinciding with higher percentages of fine sediment.

Figure 6-16 Sediment grain size and organic content at Station D16 during 2007

Site D24: Lower Sacramento River

Sand dominated the sediment at site D24 during 2007 with the exception of May when sandy clay dominated (Figure 6-17). The amount of organic matter ranged from 0.4% to 6.2% with higher values coinciding with higher percentages of fine sediment.

Figure 6-17 Sediment grain size and organic content at Station D24 during 2007

Site D4: Lower Sacramento River

Sand dominated the sediment at site D4 during March through December. January and February were the exception with their sediment being described as silty sand (Figure 6-18). The percent of organic matter at this site was high for most of the year and ranged from 1% to 43.9%.

Figure 6-18 Sediment grain size and organic content at Station D4 during 2007

Site D6: Suisun Bay

Fine sediments dominated site D6 during January, February and August through December of 2007. The remaining months of 2007 had an even sediment distribution with the exception of sandy sediment in July (Figure 6-19). Organic matter at this site ranged from 1.5% to 8.1%.

Figure 6-19 Sediment grain size and organic content at Station D6 during 2007

Site D7: Suisun Bay

Fine sediments dominated site D7 for all of 2007 with the exception of May when sand made up 99% of the sample (Figure 6-20). The organic matter at this site was stable throughout the year ranging from 2.6% to 4.4% with the exception of May when the organic matter was only 0.5%.

Figure 6-20 Sediment grain size and organic content at Station D7 during 2007

Site D41: San Pablo Bay

The majority of the months at site D41 in 2007 contained higher percentages of fine sediment with the exception of May, which contained a higher percent of sand (Figure 6-21). The organic matter at this site ranged from 1% to 3.8%.

Figure 6-21 Sediment grain size and organic content at Station D41 during 2007

Site D41A: San Pablo Bay

Fine sediments dominated site D41A for all of 2007 with the exception of May, which contained high percentages of sand (Figure 6-22). The percent organic matter at this site ranged from 1.7% to 4.5%.

Figure 6-22 Sediment grain size and organic content at Station D41A during 2007

Summary

The benthic monitoring program is designed to document the distribution, diversity and abundance of benthic organisms in the upper San Francisco Estuary. The monitoring program collects a large number of organisms, but a relatively small number of species. All organisms collected during 2007 fell into 9 phyla: Annelida, Arthropoda, Chordata, Cnidaria, Mollusca, Nemertea, Nematoda, Phoronida and Platyhelminthes. Of these 9 phyla, Annelida, Arthropoda and Mollusca constituted 99.5% of the organisms collected during the study. Ten species represent 84.6% of all organisms collected. These species are: (1) the amphipods — *Americorophium stimpsoni*, *Americorophium spinicorne*, *Corophium alienense*, *Ampelisca abdita* and *Gammarus daiberi*; (2) the Sabellidae polychaete — *Manayunkia speciosa* ; (3) the Tubificidae worms, *Varichaetadrilus angustipenis,* and *Limnodrilus hoffmeisteri*; and (4) the Asian clams—*Corbula amurensis* and *Corbicula fluminea*.

References

[APHA] American Public Health Association, American Waterworks and Water Environmental Federation. 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th ed. Washington, D.C.: American Public Health Association, 10.60-10.74.

[ASTMa] American Society of Testing and Materials. 2000. Soil and Rock (I): D420 - D5779, Vol. 04.08: protocol D422.

[ASTMb] American Society of Testing and Materials. 2000. Soil and Rock (I): D420 - D5779, Vol. 04.08: ASTM protocol D2974 method C.

[DWR] California Department of Water Resources. 2001. *Water Quality Conditions in the Sacramento-San Joaquin Delta During 1996*. A report to the State Water Resources Control Board in Accordance with Water Right Decision 1485, Order 4(f).

Hymanson, Z., D. Mayer, and J. Steinbeck. 1994. *Long-Term Trends in Benthos Abundance and Persistence in the Upper Sacramento-San Joaquin Estuary. Summary Report: 1980—1990*. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 38. Department of Water Resources.

Markmann, C. 1986. *Benthic Monitoring in the Sacramento-San Joaquin Delta. Results from 1975 through 1981*. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Technical Report 12. California Department of Water Resources.

Thompson, J. 2005. "*Potamocorbula amurensis* is, for now, *Corbula amurensis*." Interagency Ecological Program Newsletter. Spring; 18(2). California Department of Water Resources.

Figure 6-1 Location of macrobenthic monitoring stations

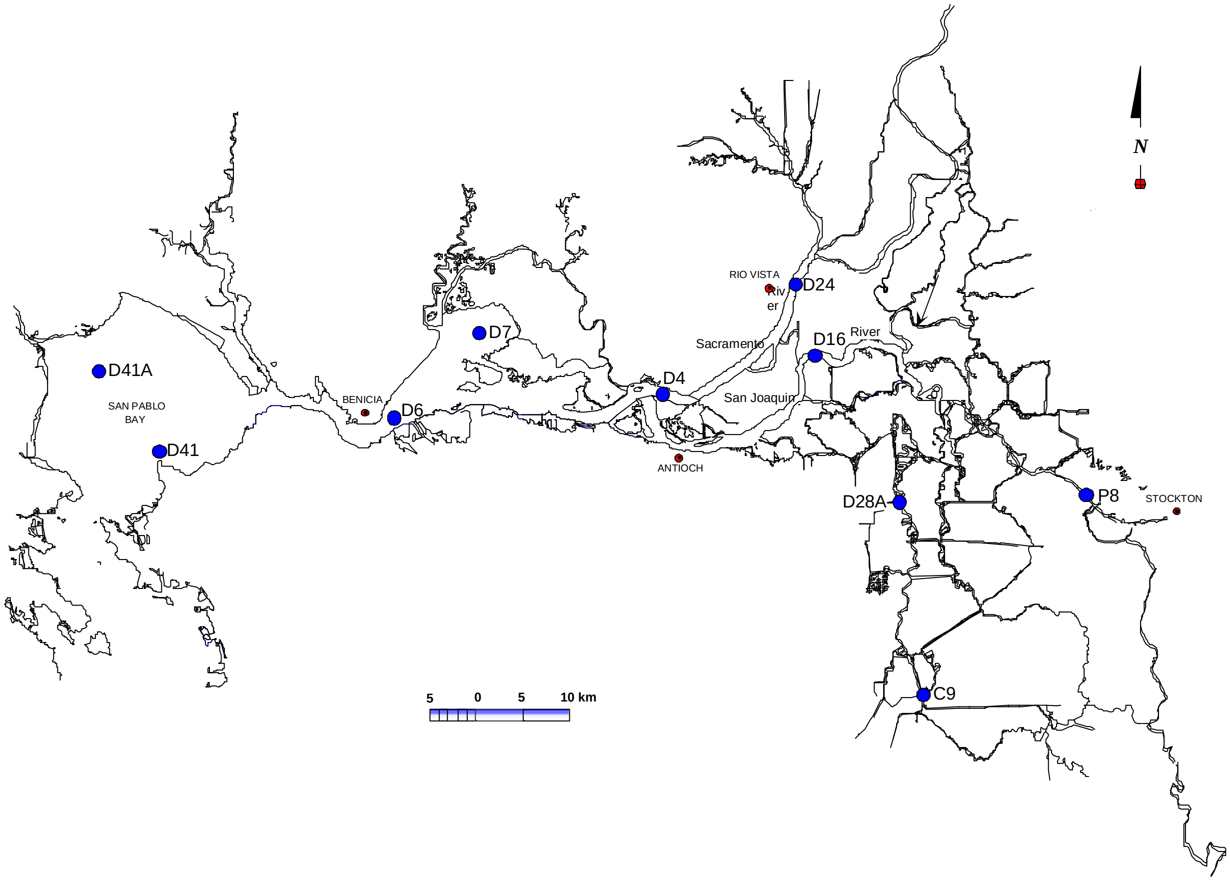


Figure 6-2 Total contribution by phyla for all stations during 2007

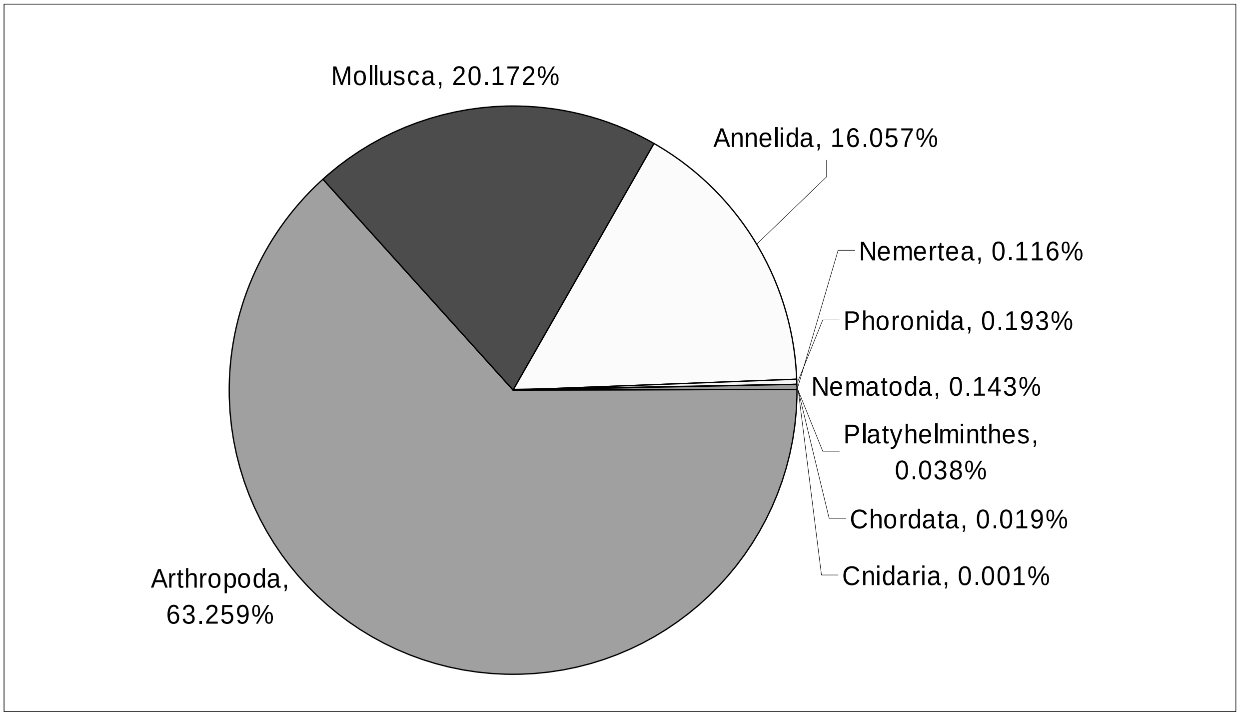


Figure 6-3 Total abundance at Station C9, 2007

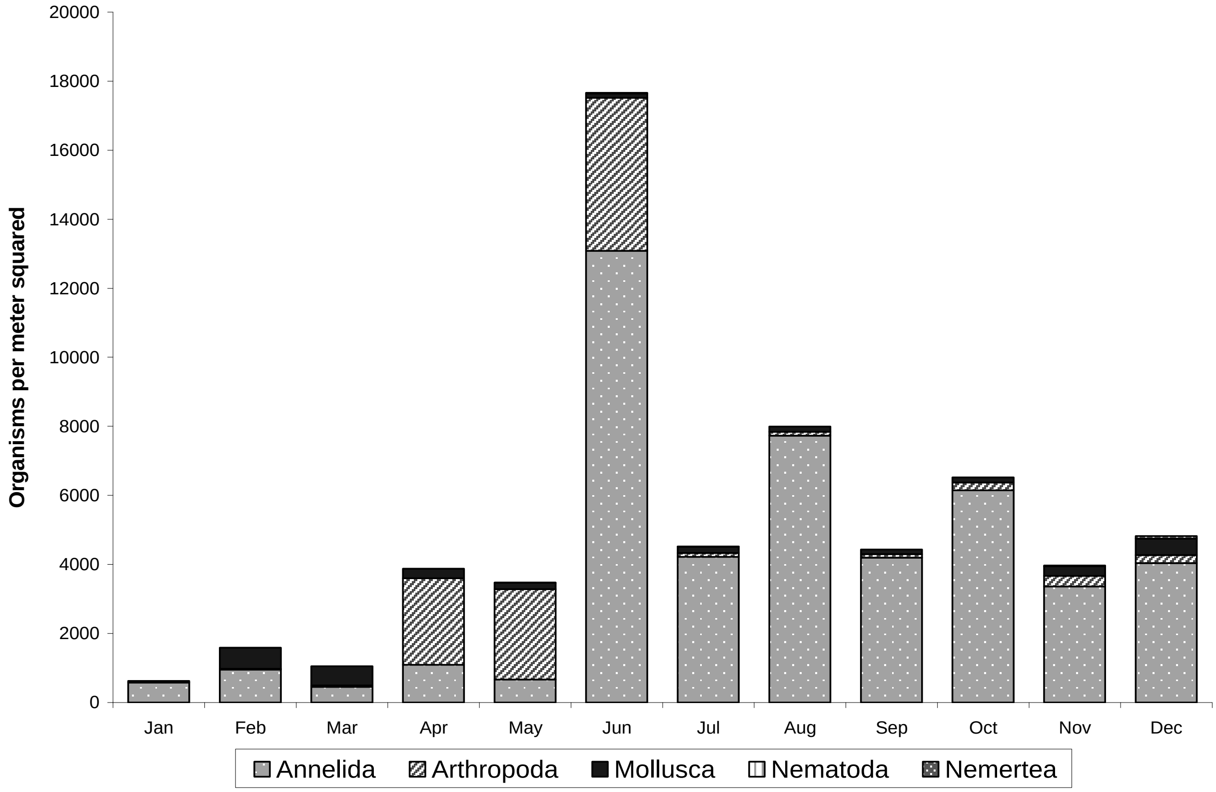


Figure 6-4 Total abundance at Station P8, 2007

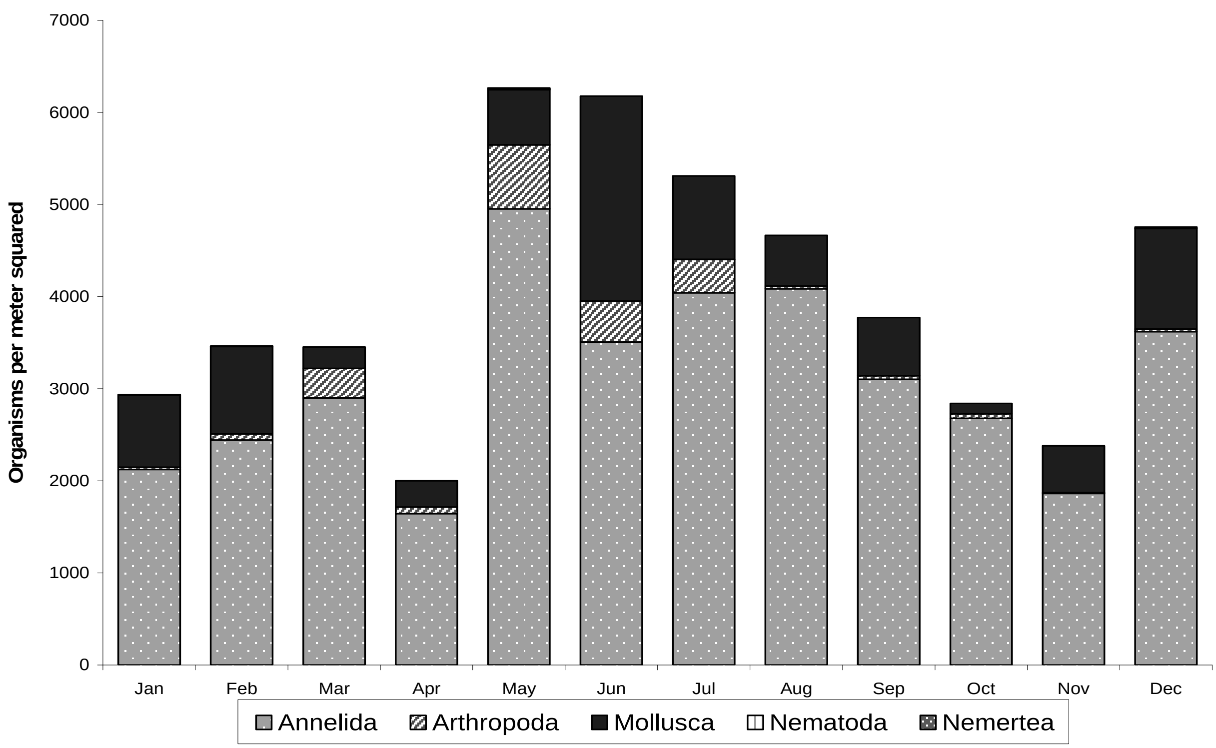


Figure 6-5 Total abundance at Station D28A, 2007

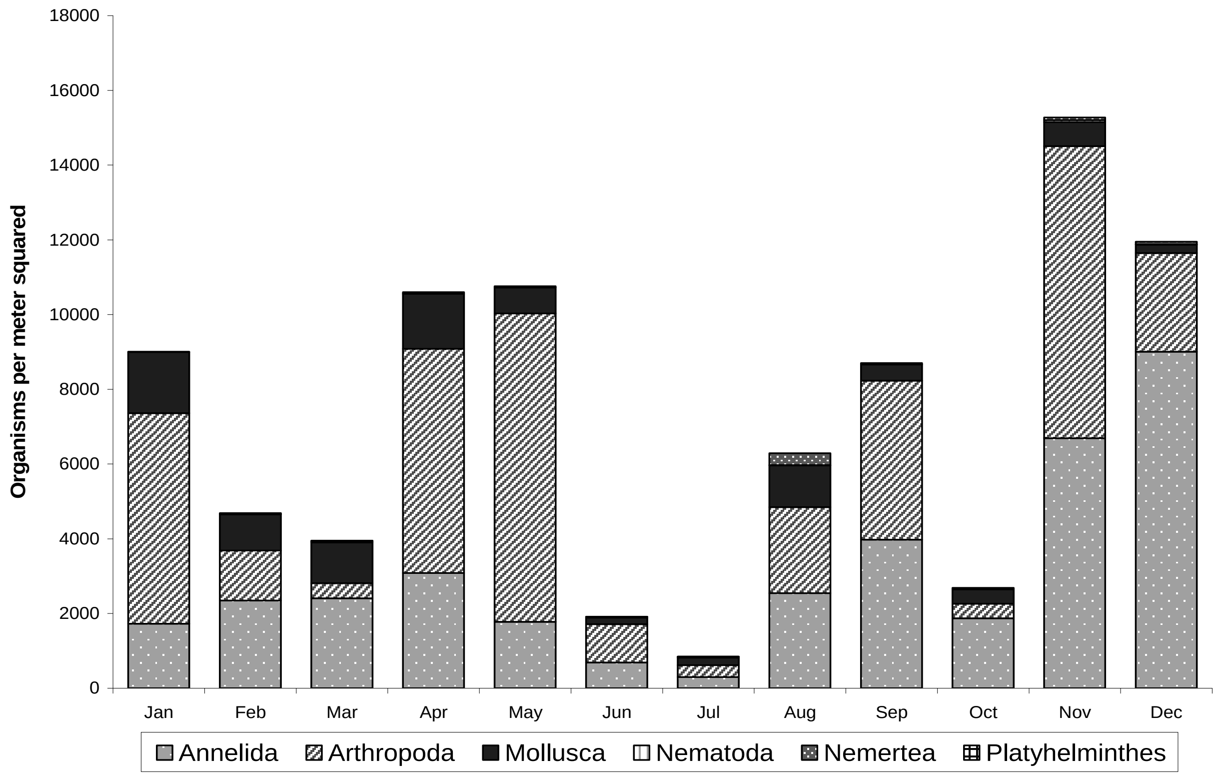


Figure 6-6 Total abundance at Station D16, 2007

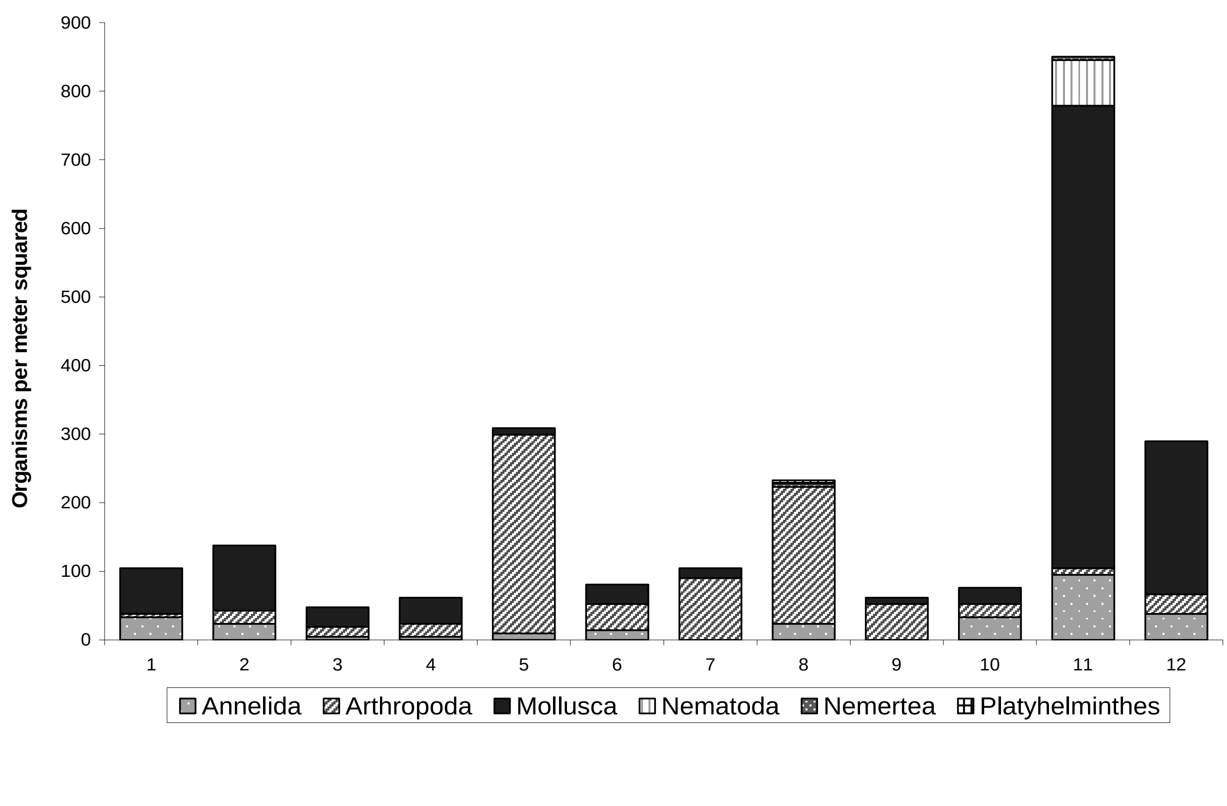


Figure 6-7 Total abundance at Station D24, 2007

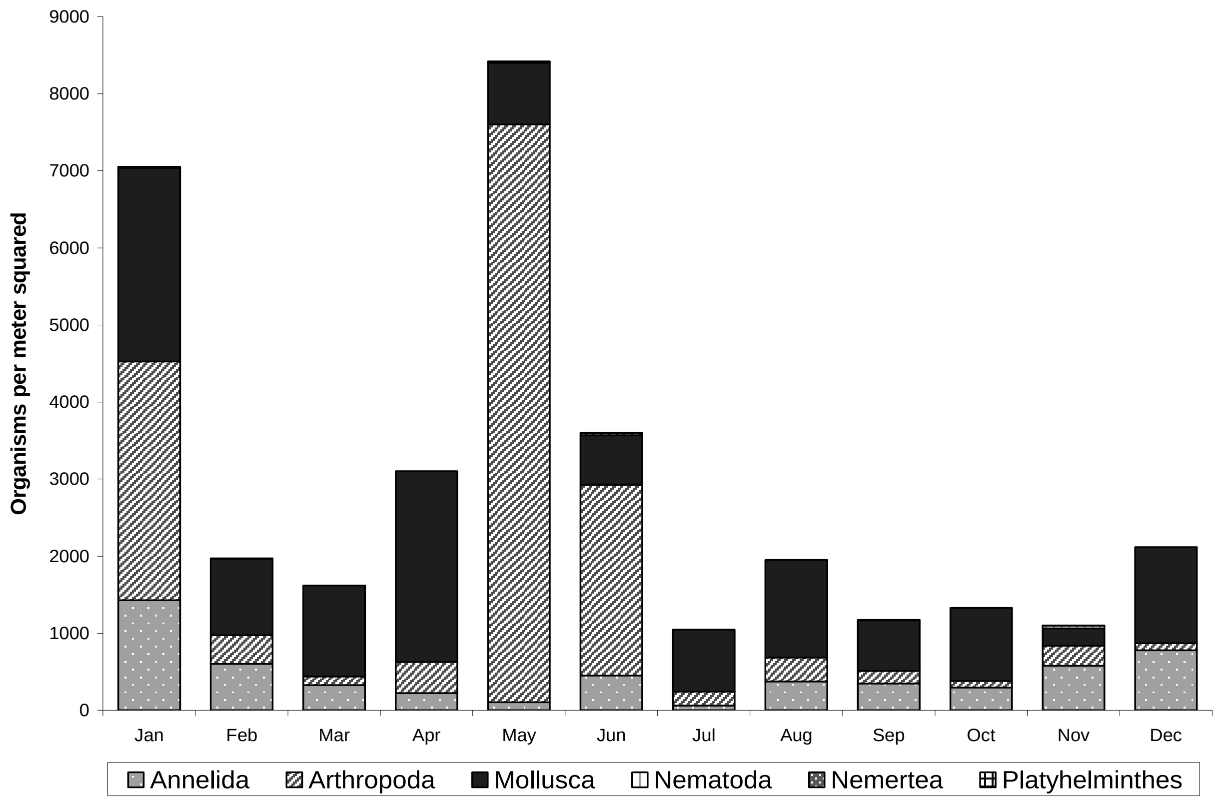


Figure 6-8 Total abundance at Station D4, 2007

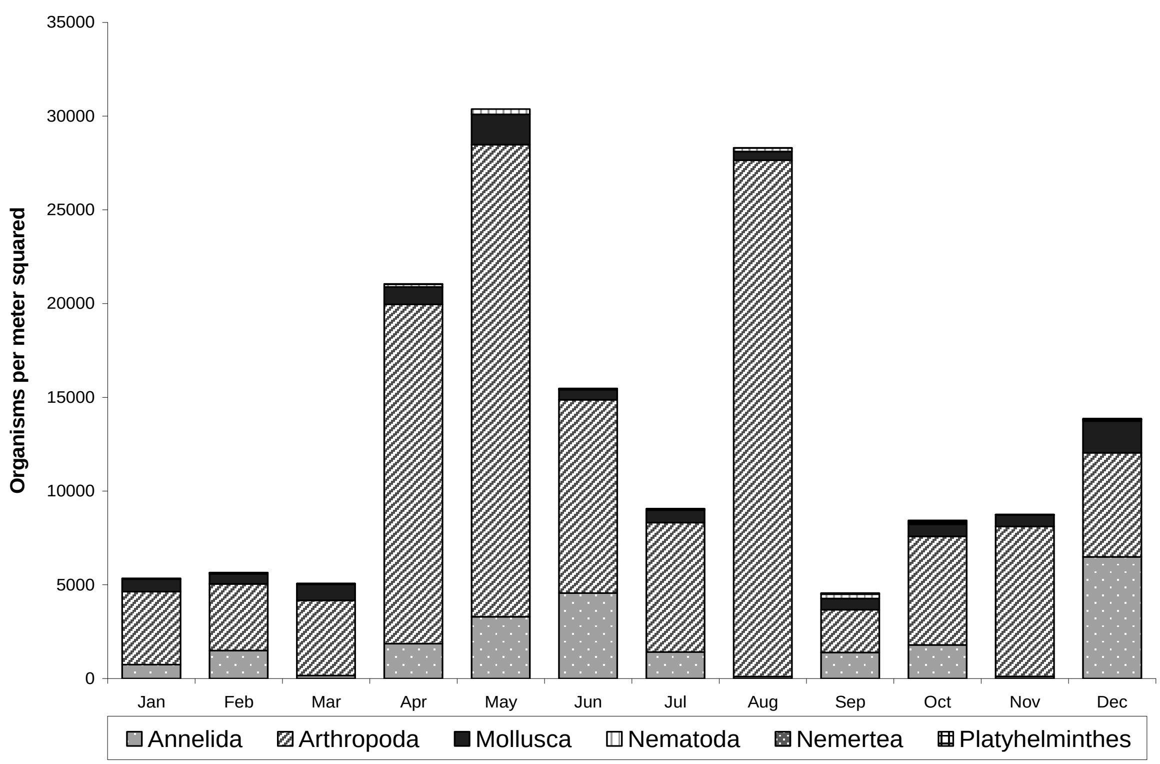


Figure 6-9 Total abundance at Station D6, 2007

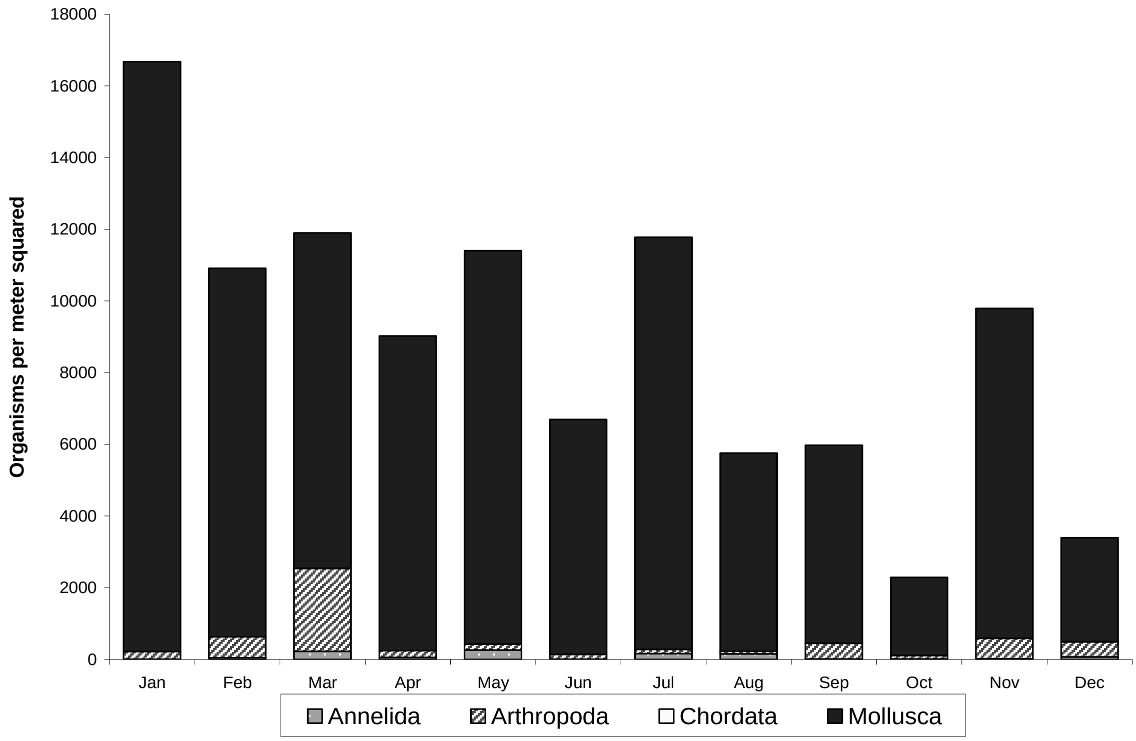


Figure 6-10 Total abundance at Station D7, 2007

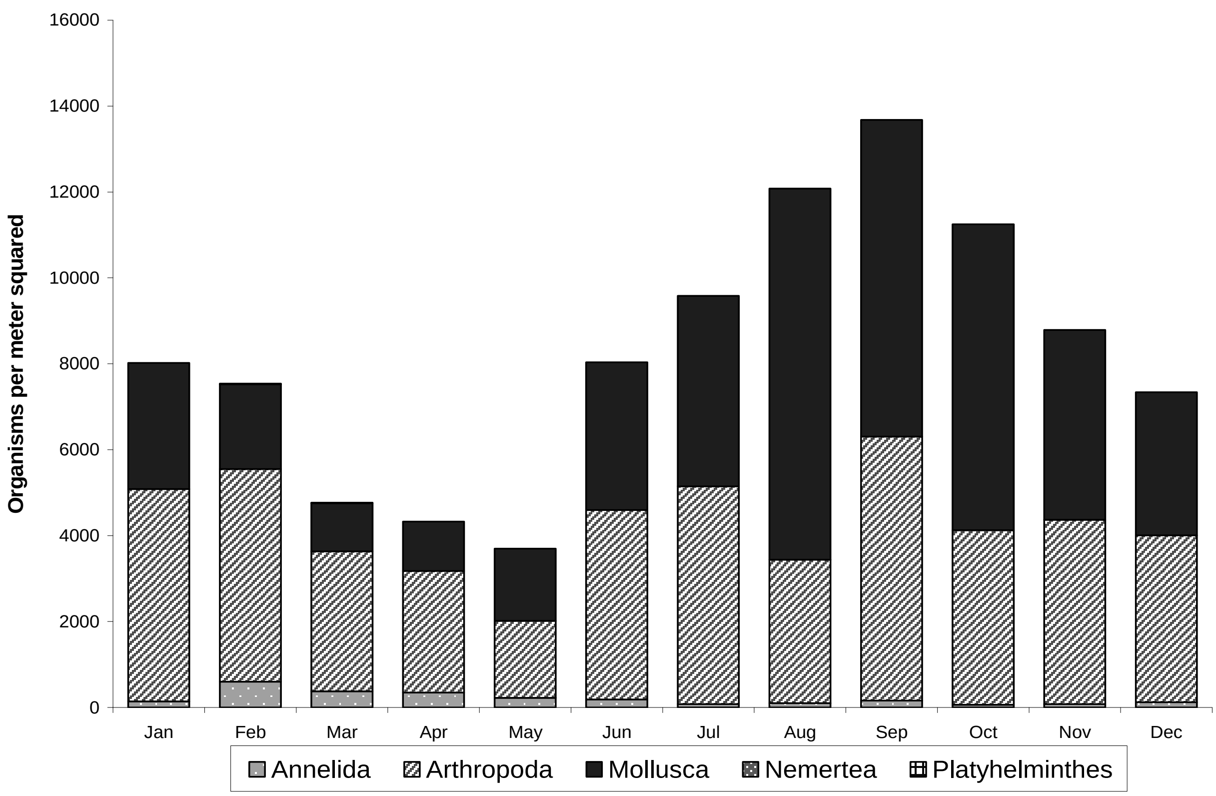


Figure 6-11 Total abundance at Station D41, 2007

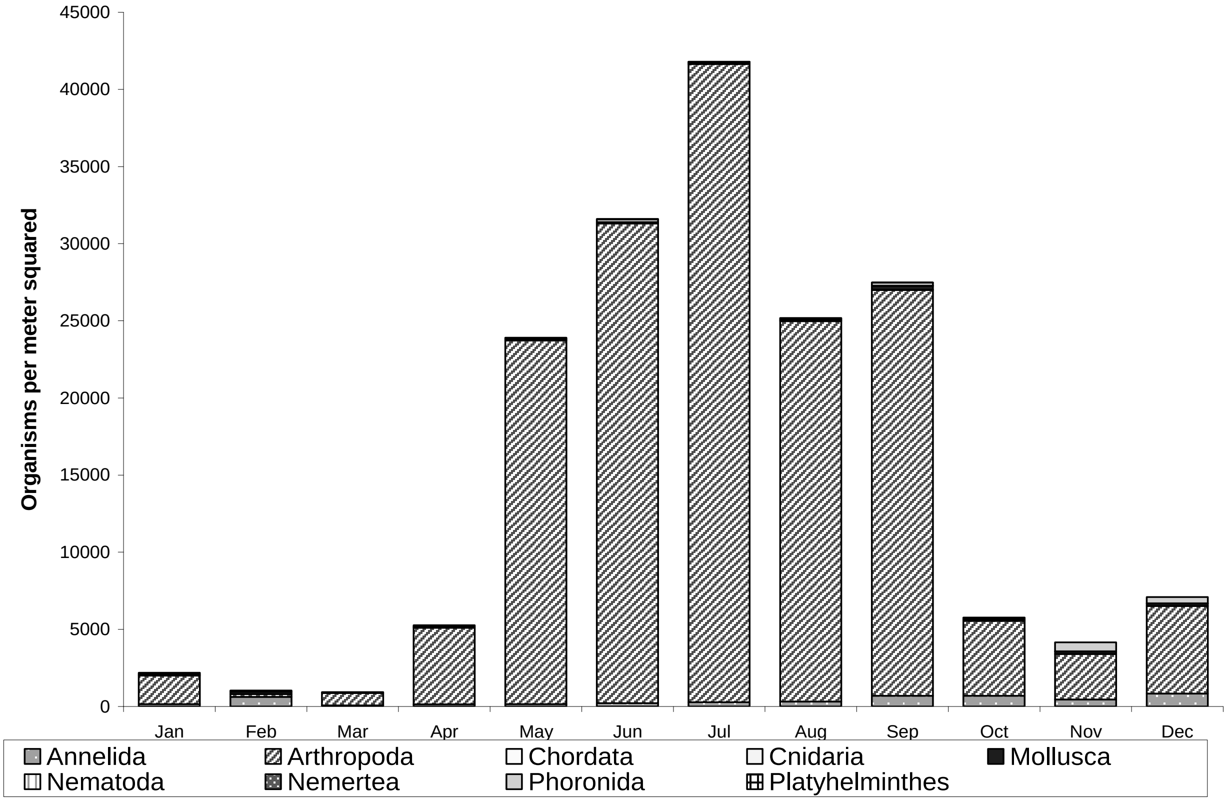


Figure 6-12 Total abundance at Station D41A, 2007

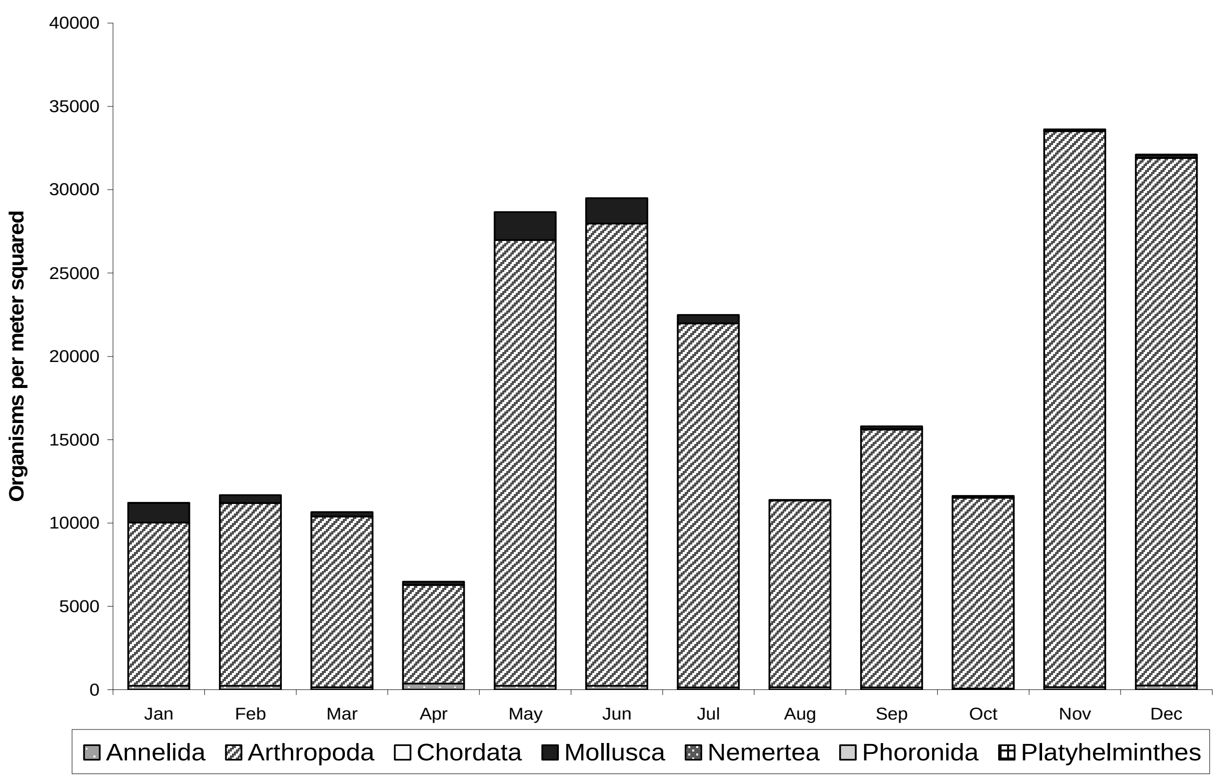
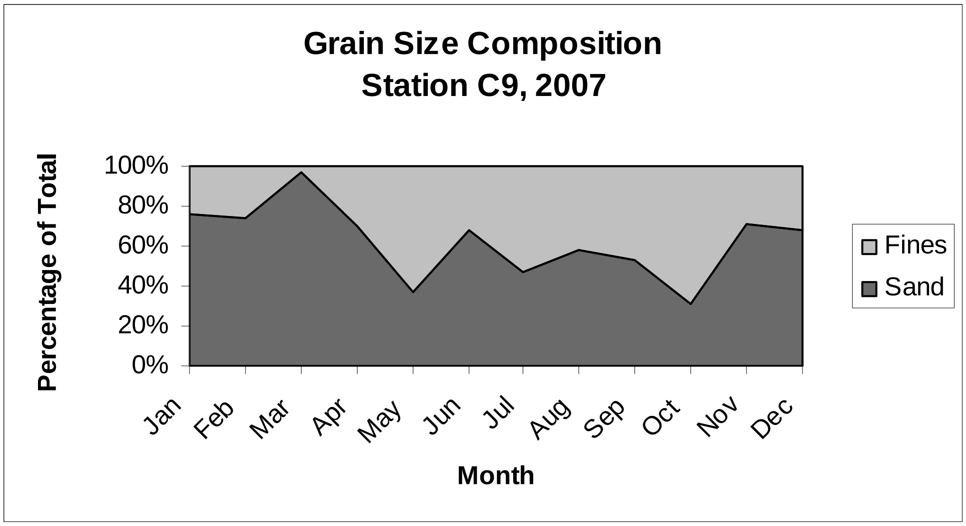


Figure 6-13 Sediment grain size and organic content at Station C9 during 2007



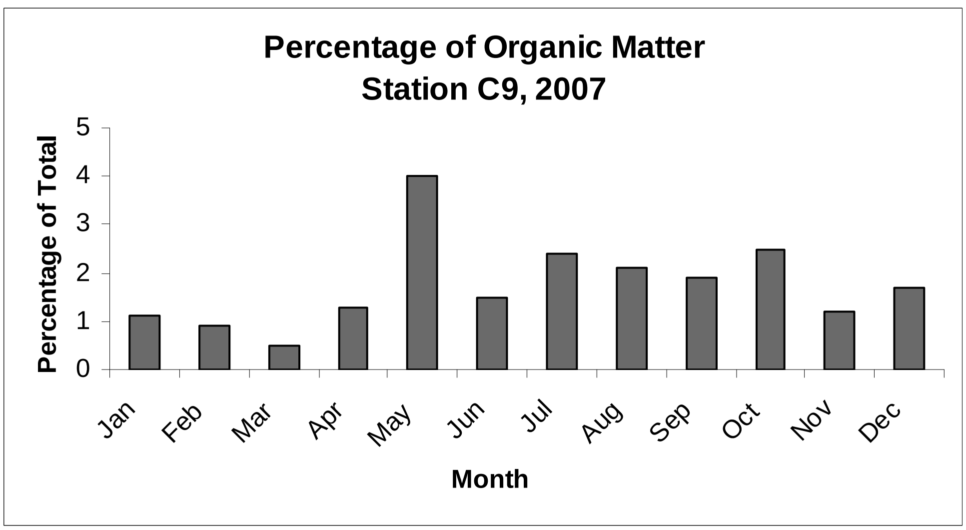
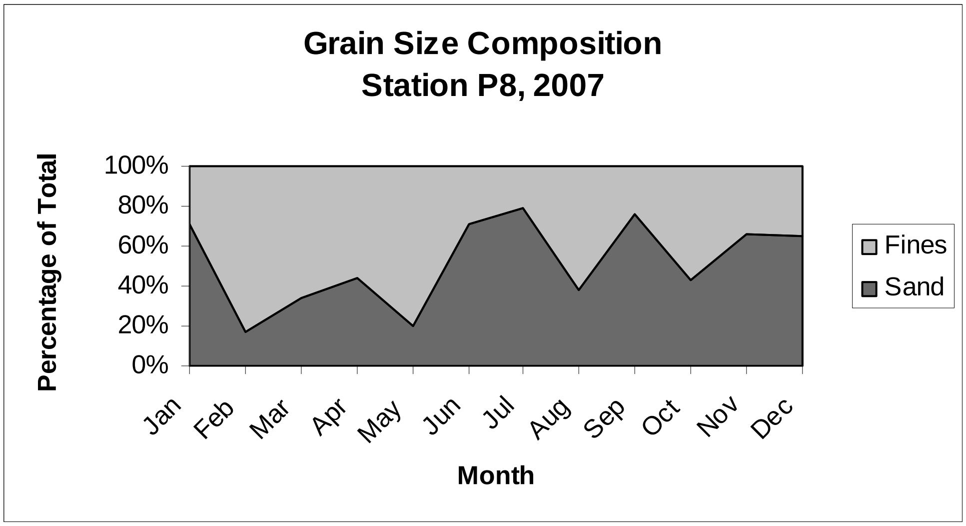


Figure 6-14 Sediment grain size and organic content at Station P8 during 2007



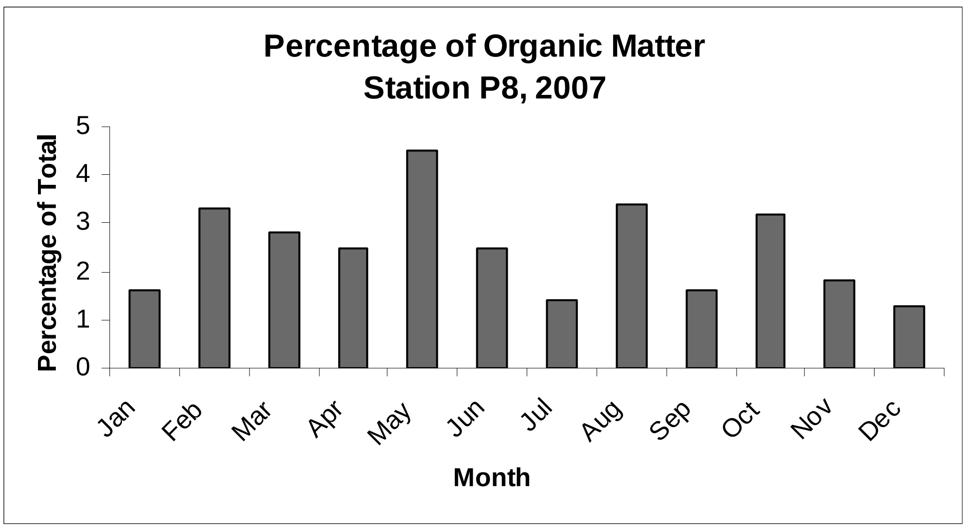
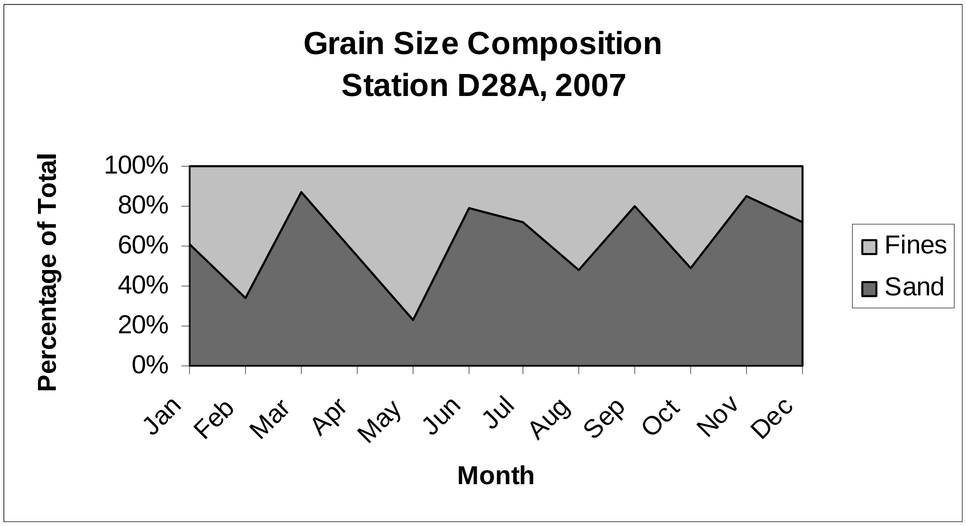


Figure 6-15 Sediment grain size and organic content at Station D28A during 2007



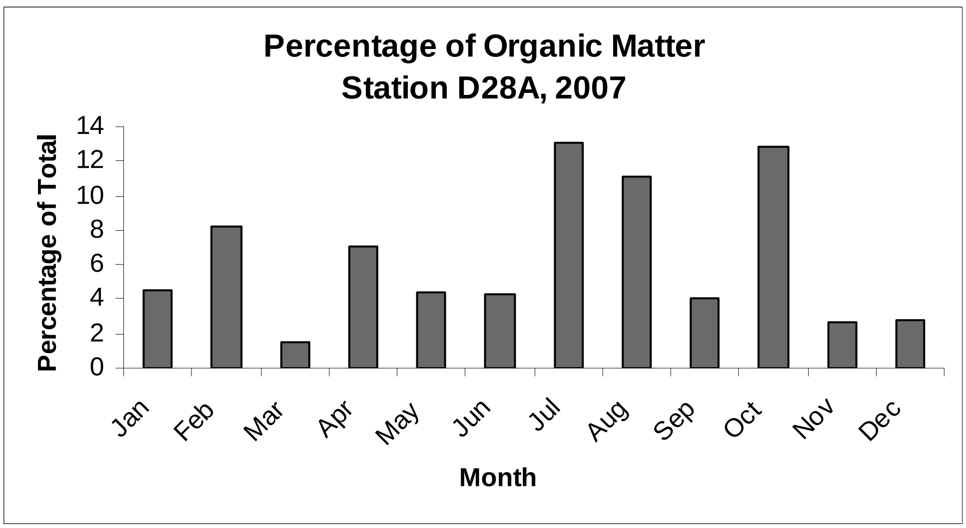
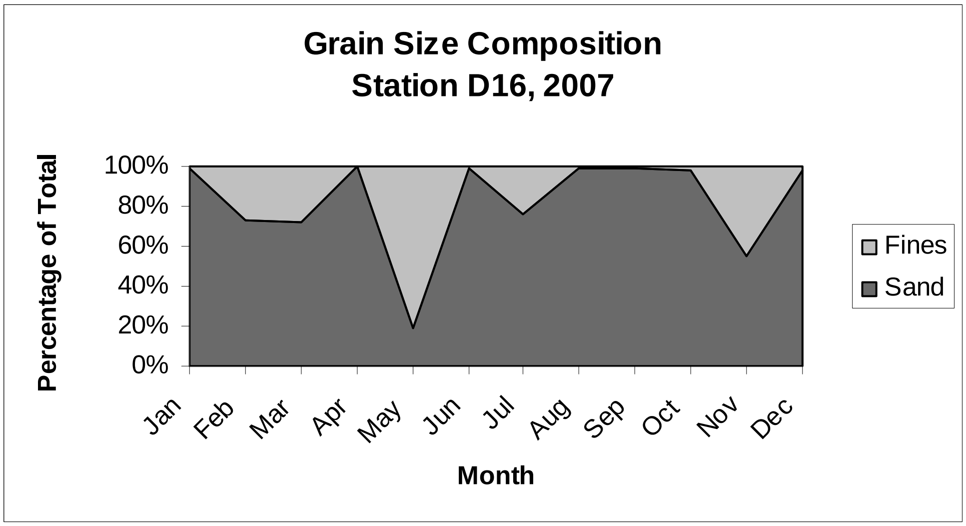


Figure 6-16 Sediment grain size and organic content at Station D16 during 2007



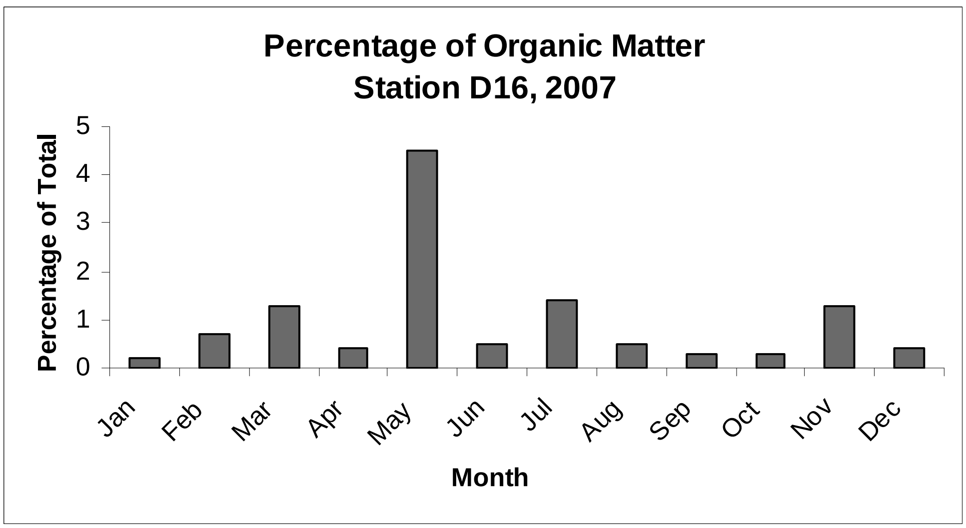
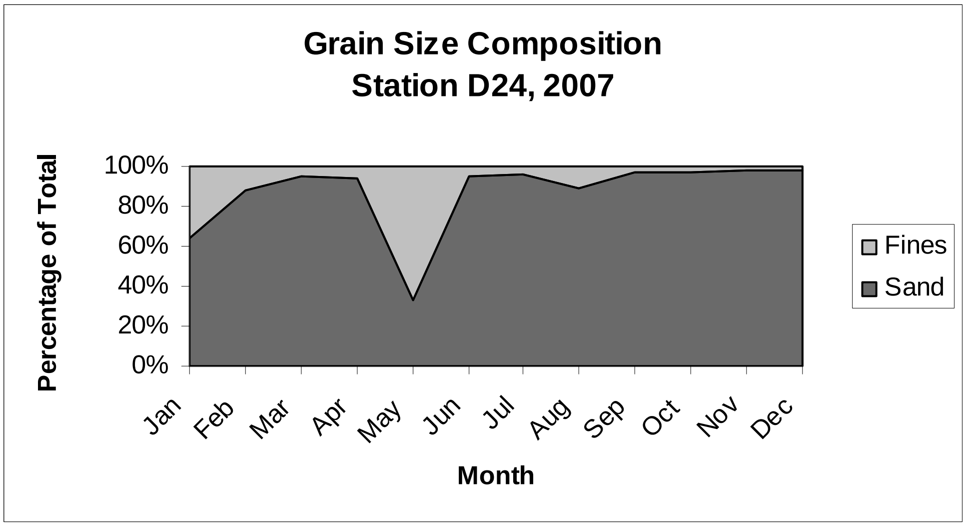


Figure 6-17 Sediment grain size and organic content at Station D24 during 2007



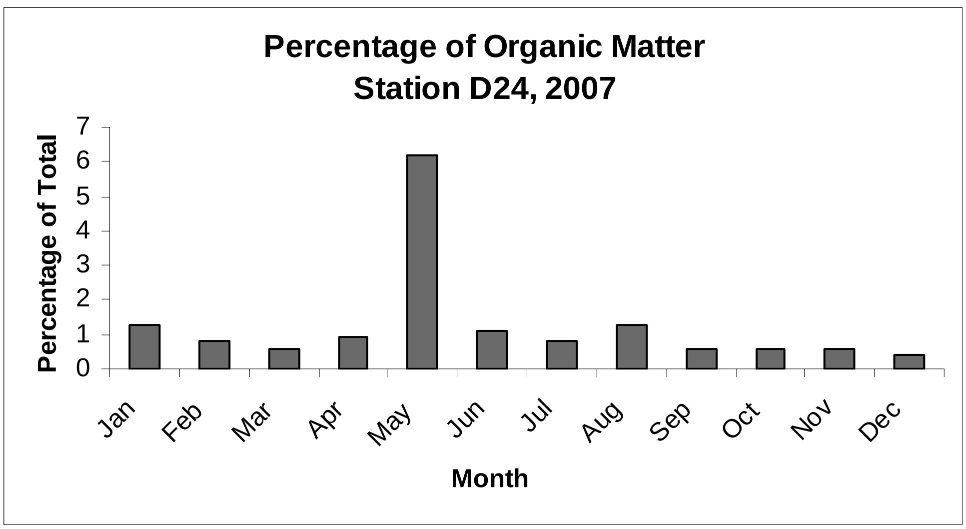


Figure 6-18 Sediment grain size and organic content at Station D4 during 2007

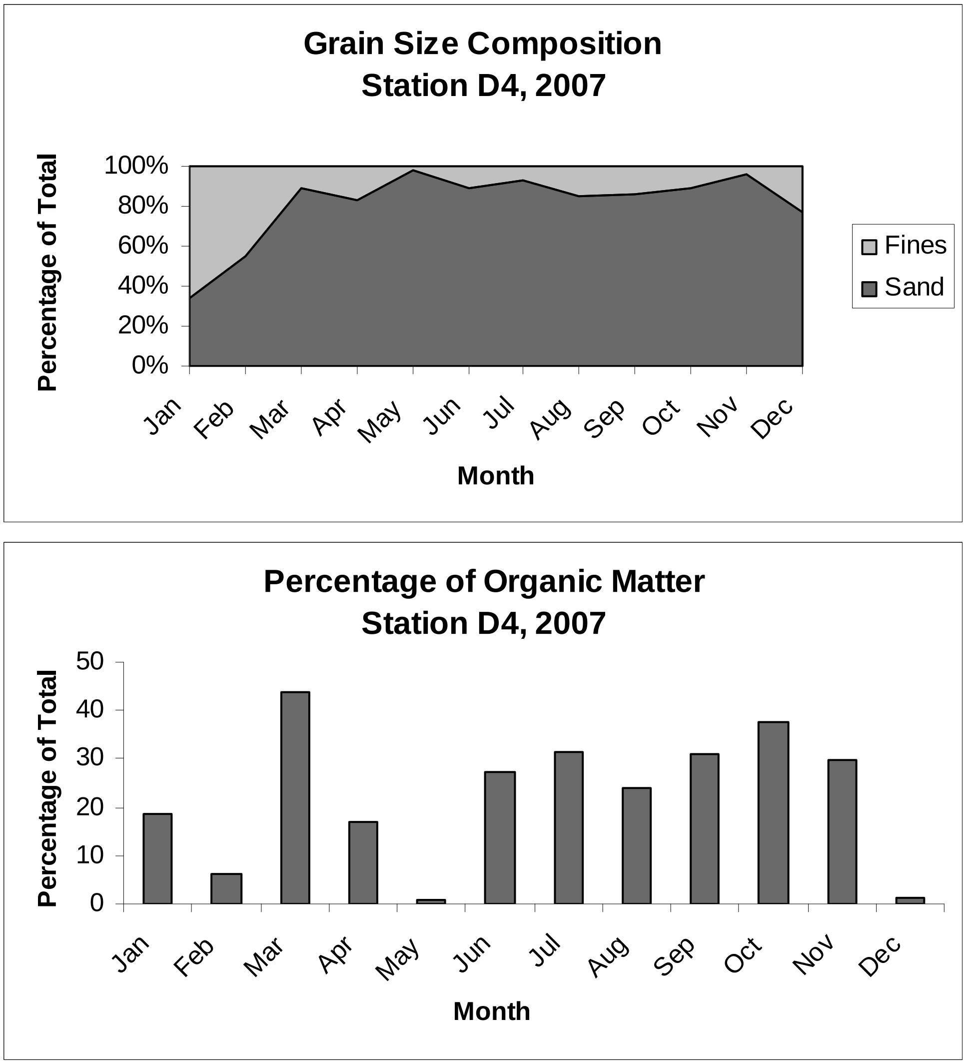
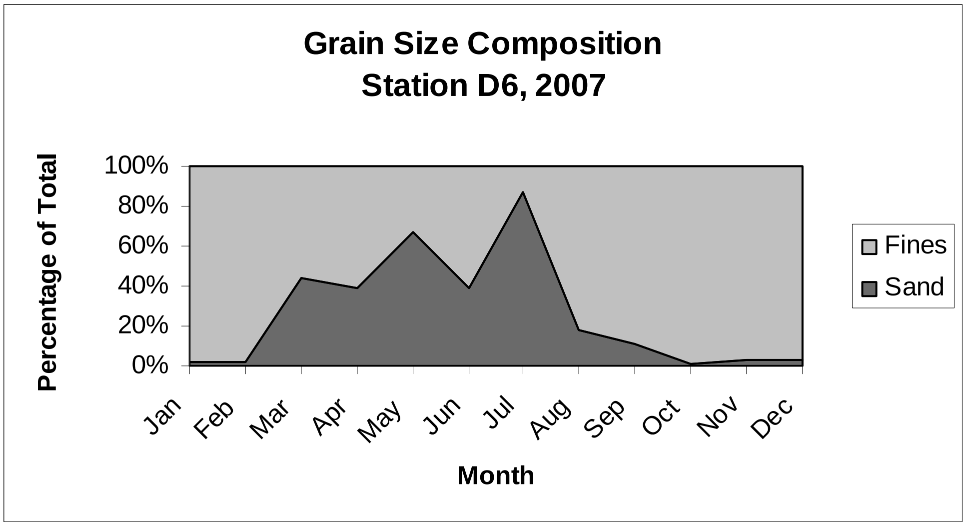


Figure 6-19 Sediment grain size and organic content at Station D6 during 2007



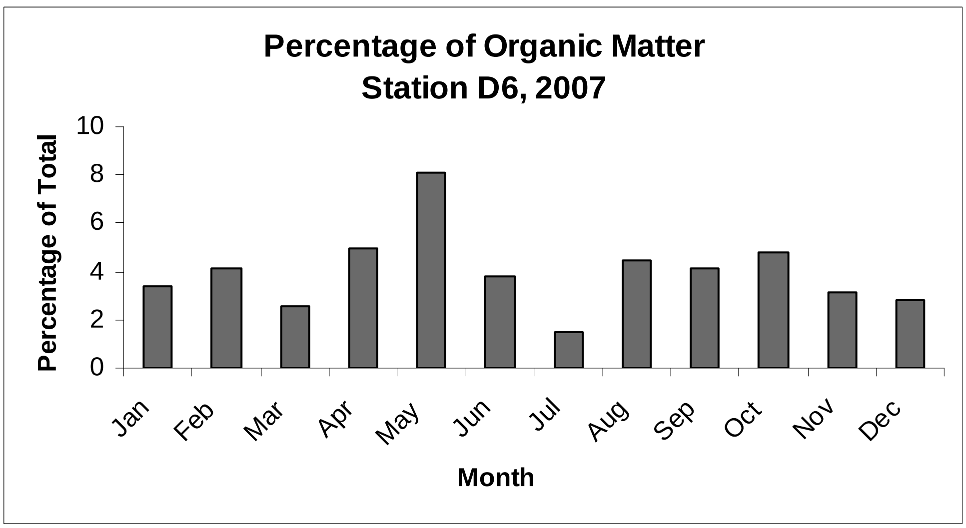
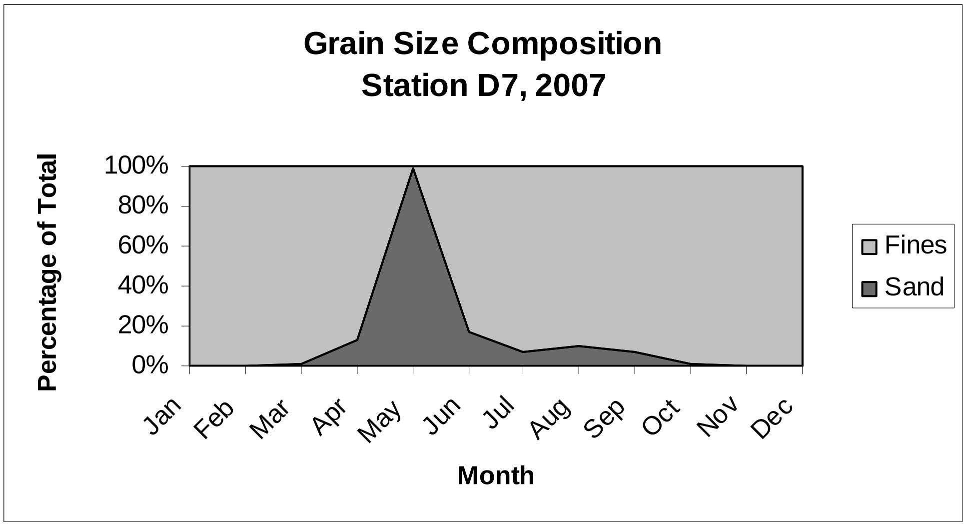


Figure 6-20 Sediment grain size and organic content at Station D7 during 2007



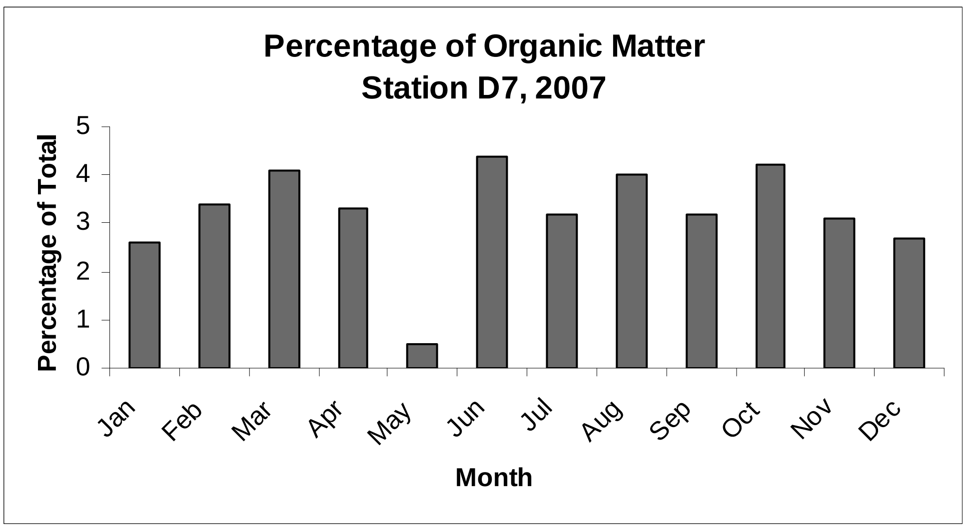
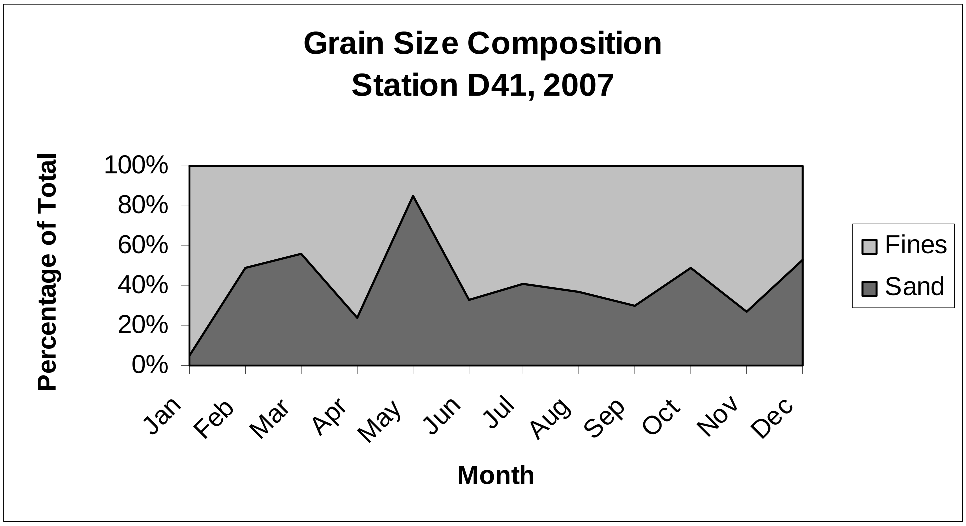


Figure 6-21 Sediment grain size and organic content at Station D41 during 2007



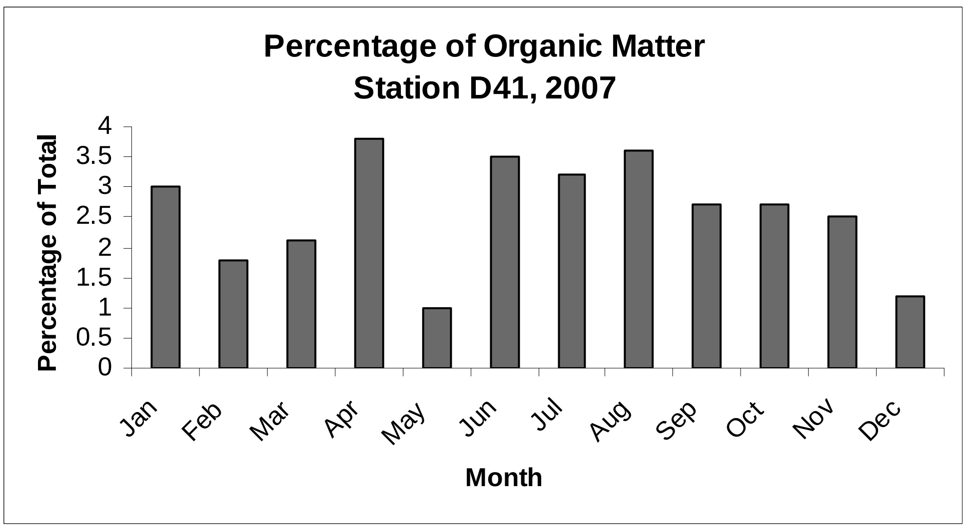
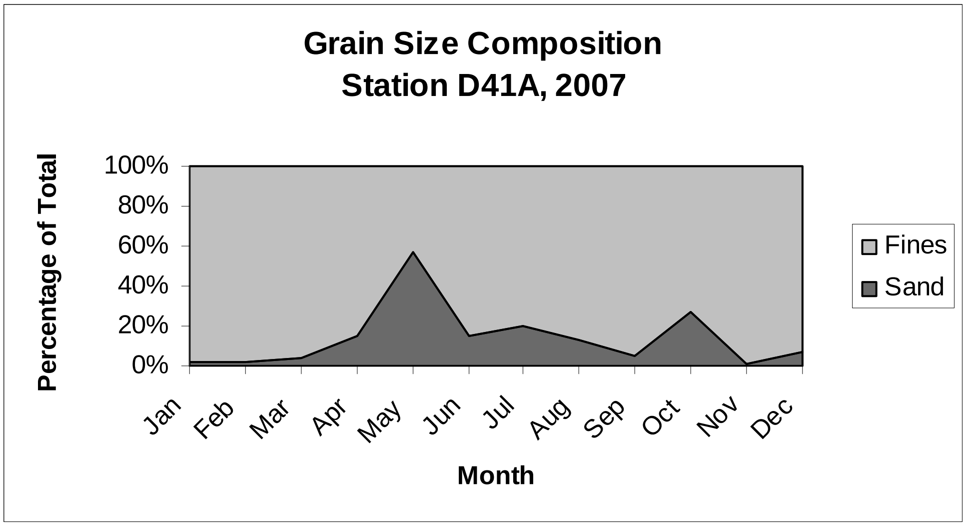


Figure 6-22 Sediment grain size and organic content at Station D41A during 2007



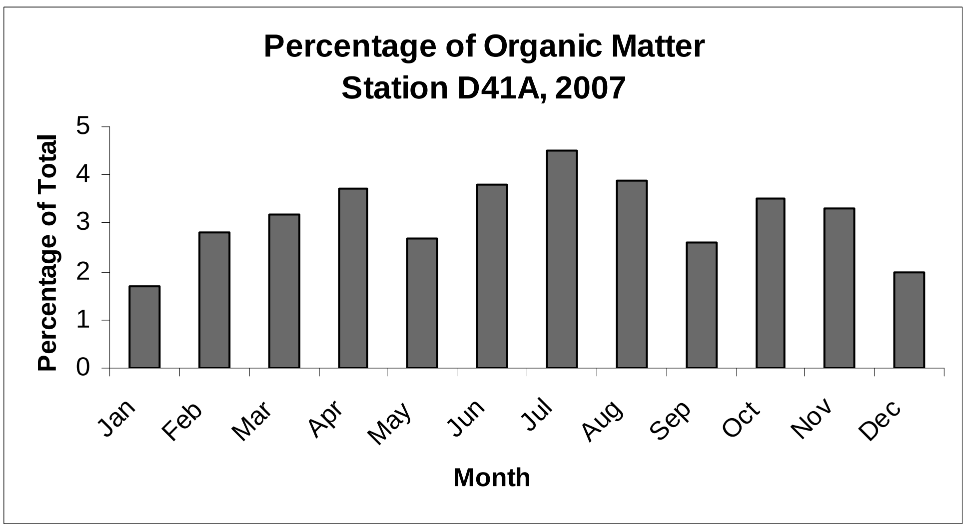


Table 6-1 Macrobenthic monitoring station characteristics, 2007

Station Region	Latitude Longitude	Substrate composition	Approx. salinity range (uS/cm)
C9 Delta-Old River	37° 49' 50" 121° 33' 09"	Consistent. More than 90% sand.	200-800
P8 Delta San Joaquin River	37° 58' 42" 121° 22' 55"	Consistent. High sand content (60%).	175-750
D28A Delta Old River	37° 58' 14" 121° 34' 19"	Mixed composition of sand and fines.	200-350
D16 Delta San Joaquin River	38° 05' 50" 121° 40' 05"	Consistent. Mostly fines with some organic materials.	130-500
D24 Delta Sacramento River	38° 09' 27" 121° 41' 01"	Consistent. High sand content (80%).	200-1200
D4 Delta Sacramento River	38° 03' 45" 121° 49' 10"	Mixed composition of sand, fines, and organic materials.	130-8,000
D6 Suisun Bay	38° 02' 40" 122° 07' 00"	Fairly equal mixture of sand and fines.	135-30,000
D7 Grizzly Bay	38° 07' 02" 122° 02' 19"	Consistent. Mostly fines with some organic materials.	200-20,000
D41 San Pablo Bay	38° 01' 50" 122° 22' 15"	Consistent. High content of fine material (87%).	20,000-45,000
D41A San Pablo Bay	38° 03' 75" 122° 24' 40"	Consistent. High content of fine material (90%).	30,000-44,000

Chapter 7 Dissolved Oxygen Monitoring in the Stockton Ship Channel

Content

Figures

Chapter 7 Dissolved Oxygen Monitoring in the Stockton Ship Channel

Dissolved oxygen (DO) levels in the Stockton Ship Channel have been monitored by staff of the Bay-Delta Monitoring and Analysis Section during the late summer and fall since 1968. Due to a variety of factors, DO levels have historically fallen in the central and eastern portions of the channel during this period. Some of the factors responsible include low San Joaquin River inflows, warm water temperatures, high biochemical oxygen demand (BOD), reduced tidal circulation, and intermittent reverse flow in the San Joaquin River at Stockton.

Because low DO levels can have adverse impacts on fisheries and other beneficial uses of the waters within the Bay-Delta, the State Water Resources Control Board (SWRCB) has established specific water quality objectives to protect these uses. Within the channel, 2 separate DO objectives have been established. The most recent Basin Plan (1998) of the Central Valley Regional Water Quality Control Board establishes a baseline objective of 5.0 milligrams per liter for the entire Delta region (including the Stockton Ship Channel) throughout the year. However, an objective of 6.0 mg/L was adopted for September through November by the SWRCB in its latest Bay-Delta Plan (1995). This objective is established to protect fall-run Chinook salmon and applies to the lower San Joaquin River between Stockton and Turner Cut, which includes the eastern channel.

[CVRWQCB] Central Valley Regional Water Quality Control Board. 1998. *Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region, the Sacramento River Basin, and San Joaquin River Basin*. 4th ed.

[SWRCB] State Water Resources Control Board. 1995. *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Estuary*. Adopted May 22, 1995, pursuant to Water Right Order 95-1. Sacramento. 44pp.

As part of a 1969 Memorandum of Understanding between the Department of Water Resources, the U.S. Fish and Wildlife Service, the U.S. Bureau of Reclamation, and the state Department of Fish and Game, DWR has installed a rock barrier across the mouth of Old River during periods of projected low San Joaquin River outflow. The head of Old River barrier (barrier) increases net flows down the San Joaquin River past Stockton. The higher flows can contribute to improving DO levels. The barrier is usually installed in the fall and spring when average daily San Joaquin River flows past Vernalis are projected to be approximately 2,000 cubic feet per second (cfs) or less.

Barrier construction began on October 8 and was completed on October 18. Barrier removal began on November 9 and was completed on November 29.

Methods

Monitoring of DO concentrations in the Stockton Ship Channel was conducted by vessel on 13 monitoring runs from June 15 to December 12, 2007[1]. During each of the monitoring runs, 14 sites were sampled at low water slack, beginning at Prisoners Point (station 1) in the central Delta and ending at the Stockton turning basin at the terminus of the Stockton Ship Channel (station 14). For geographic reference and simplicity of reporting, the sampling stations are keyed to channel light markers[2] as shown in Figure 7-1.

Figure 7-1 Monitoring sites in the Stockton Ship Channel

[1] Funding for these special studies was provided by the DWR Division of Operations and Maintenance.

[2] Channel Light Markers are ship navigational aides placed in navigable waters. Although they are not spaced at fixed intervals, they provide convenient landmarks for identifying sample locations.

Because monitoring results differ along the channel[3], sampling stations are grouped into western, central and eastern regions. These regions are highlighted in Figure 7-1. The western channel begins at Prisoners Point (station 1) and ends at light 14 (station 5). The central channel begins at light 18 (station 6) and ends at light 34 (station 9). Finally, the eastern channel begins at light 40 (station 10) and ends at light 48 (station 13). The Stockton turning basin (station 14) is unique within the channel because it is east of the entry point of the San Joaquin River into the channel and isolated from down-channel flow. Because of the unique hydro-morphology of station 14, the findings for this station are discussed separately from those of the other channel stations.

Discrete samples were taken from the top (1 meter from the surface) and bottom (1 meter from the bottom) of the water column at each station at low water slack, and analyzed for DO concentrations and temperature. Top DO samples were collected using a through-hull pump and were analyzed with the modified Winkler titration method (APHA 1998). Bottom DO samples were obtained using a Seabird submersible sampler and measured using a YSI polarographic electrode (model no. 5739) with a Seabird CTD 911+ data logger. Surface and bottom water temperatures were measured using a Seabird SBE3 temperature probe or a YSI 6600 sonde equipped with a Model No. 6560 thermistor temperature probe.

[APHA] American Public Health Association, American Waterworks, and Water Environmental Federation. 1998. *Standard Methods for the Examination of Water and Wastewater.* 20th ed. Washington, D.C.: American Public Health Association

Flow data for the San Joaquin River at Vernalis were obtained from station data recorded at the Vernalis monitoring station, operated jointly by the U.S. Geological Survey (USGS) and DWR[4]. Average daily flows past Vernalis were obtained by averaging 15-minute data for a daily average flow rate. Tidal cycles of ebb and flood are not seen in flows at Vernalis, and flow proceeds downstream (positive flow) throughout the year.

Flows of the San Joaquin River past Stockton used in this report were obtained from data recorded by the USGS flow monitoring station southeast of Rough and Ready Island[5]. Flow rates in the San Joaquin River at Stockton are heavily influenced by tidal action, with daily ebb and flood tidal flows of 3,000 cfs or greater in either direction. To calculate net daily flows, the tidal pulse is removed from the USGS 15-minute flow data with a Butterworth filter[6]. Due to low inflows, upstream agricultural diversions, and export pumping, net daily flows at Stockton can frequently approach zero and can sometimes reverse direction. During June through December 2007, net flow at Stockton reached a minimum of -264 cfs.

[3] The findings of previous fall studies have shown that fall DO levels are typically: high and stable (7.0-9.0 mg/L) in the western channel; transitional, variable (4.0-7.0 mg/L), and stratified in the central channel; and low (3.0-5.0 mg/L) and stratified in the eastern channel.

[4] Station information: DWR Station SJR at Vernalis, RSAN112

[5] Station information: USGS 304810 SJR at Stockton, RSAN063.

[6] The USGS uses a Butterworth bandpass filter to remove frequencies (tidal cycles) from 15-minute flow data that occur on less than a 30-hour period. The resulting 15-minute time-series is then averaged to provide a single daily value which represents net river flow exclusive of tidal cycles.

Results

During the period of this study (June 15 to December 12, 2007), DO levels varied significantly throughout the season and between regions within the channel (excluding the turning basin). Overall, seasonal range was 4.2 to 10.2 mg/L at the surface and 3.5 to 10.2 mg/L at the bottom. In the western channel, DO concentrations were relatively high and stable, ranging from 6.9 to 10.1 mg/L at the surface and 6.8 to 10.2 mg/L at the bottom. In the central portion of the channel, DO concentrations were variable, ranging from 4.5 to 10.2 mg/L at the surface and 3.5 to 10.2 mg/L at the bottom. In the eastern channel, DO levels were the lowest and tended to be more stratified than the other stations, ranging from 4.2 to 10.2 mg/L at the surface and 3.5 to 9.9 mg/L at the bottom.

During the study, flows on the San Joaquin River near Vernalis ranged from a high of 2,537 cfs in June to a low of 768 cfs in July. Net daily flow on the San Joaquin River past Stockton, exclusive of tidal pulses, ranged from a high of 1,780 cfs in October to a low of -264 cfs in August.

The findings for the summer and fall of 2007 are briefly summarized by month as follows.

June

Sampling was conducted on June 15 and June 28. Surface DO levels ranged from 4.2 mg/L (station 10) to 8.6 mg/L (station 1). Bottom DO levels ranged from 3.5 mg/L (stations 9 and 10) to 8.2 mg/L (station 1). A DO sag (below 5 mg/L) was observed at stations 8 – 12 at the surface and bottom. (Figure 7-2)

Water temperatures ranged from 22.8 °C (station 1) to 24.9 °C (station 12) at the surface and 22.6 °C (station 13) to 24.6 °C (station 9) at the bottom. (Figure 7-3)

Flows on the San Joaquin River near Vernalis ranged from 1,225 to 2,537 cfs. Net flow in the San Joaquin River near Stockton ranged from 173 to 1,070 cfs (Figure 7-4).

July

Monitoring during 2 sampling runs on July 12 and July 26 showed surface DO levels ranging from 4.6 mg/L (station 11) to 7.9 mg/L (station 1). Bottom DO levels ranged from 4.3 mg/L (stations 9, 10 and 11) to 7.8 mg/L (station 1). A DO sag[7] (below 5 mg/L) was observed at the surface at stations 9 – 11 and at the bottom at stations 8 – 12. (Figure 7-2)

Water temperatures during the July sampling run ranged from 21.8 °C (station 1) to 26.0 °C (station 11) at the surface and 21.8 °C (station 1) to 25.5 ˚C (station 13) at the bottom. (Figure 7-3)

Flows on the San Joaquin River near Vernalis ranged from 768 to 1,297 cfs during July. Net flow in the San Joaquin River past Stockton ranged from -115 to 231 cfs (Figure 7-4).

[7] In this report, we define a DO “sag” as a region within the channel where DO levels do not meet the SWRCB objective.

August

Monitoring during 2 sampling runs, August 10 and 23, showed surface DO levels ranging from 5.1 mg/L at station 9 to 8.0 mg/L at stations 1 and 3. Bottom DO levels ranged from 4.3 mg/L at station 13 to 8.6 mg/L at station 1. A DO sag (<5.0 mg/L) was observed at stations 9 – 12 at the bottom. (Figure 7-2)

Figure 7-2 DO concentrations at 14 stations in the Stockton Ship Channel, summer/fall 2007

August water temperature values ranged from 22.4 °C (station 1) to 25.8 °C (station 12) at the surface, and from 22.3 °C (station 1) to 25.3 °C (station 13) at the bottom (Figure 7-3).

Figure 7-3 Water temperatures (°C) at 14 stations in the Stockton Ship Channel, summer/fall 2007

Average daily flows on the San Joaquin River past Vernalis in August ranged from 878 to 1,117 cfs. Net flow in the San Joaquin River past Stockton ranged from -264 to 362 cfs (Figure 7-4).

Figure 7-4 San Joaquin River mean daily flow, summer/fall 2007

September

Monitoring during 2 sampling runs on September 10 and 25 showed surface DO levels ranging from 5.3 mg/L at station 9 to 8.2 mg/L at station 1. Bottom DO levels ranged from 5.1 mg/L at station 10 to 8.3 mg/L at station 1(Figure 7-2). A DO sag (<6.0 mg/L) was observed at stations 8 – 11 and station 13.

September surface water temperatures ranged from 19.4 °C at station 1 to 25.1 °C at station 12. Bottom temperatures ranged from 19.4 °C at station 1 to 24.8 °C at stations 10 – 12 (Figure 7-3).

Flow rates past Vernalis during September ranged from 920 to 1,166 cfs. Flows at Stockton during September ranged from a low of 21 cfs to a high of 436 cfs (Figure 7-4).

October

Sampling runs were conducted on October 11 and 25. Surface DO levels ranged from 6.8 mg/L at station 9 to 10.2 mg/L at station l2. Bottom DO levels ranged from 6.8 mg/L at station 9 to 9.9 mg/L at station 13 (Figure 7-2). All DO levels measured during the month were above the SWRCB objective.

Surface water temperatures in October ranged from 16.6 °C at station 1 to 18.8 °C at stations 8 and 9 (Figure 7-3). Bottom water temperatures were similar, ranging from 16.6 °C at station 1 to 18.6 °C at station 8.

Average daily flows of the San Joaquin River at Vernalis ranged from 1,073 to 2,337 cfs during the month of October (Figure 7-4). Net daily flows at Stockton ranged from 226 to 1,780 cfs.

November

DWR conducted monitoring runs on November 9 and 26. Surface DO levels ranged from 7.6 mg/L at stations 11 and 12 to 9.0 mg/L at stations 4 – 7. Bottom DO levels ranged from 7.1 mg/L at station 12 to 8.9 mg/L at stations 1 and 6. All DO levels measured during the month were well above the SWRCB objective.

Surface water temperatures ranged from 12.8 °C at station 1 to 16.3 °C at station 6. Bottom water temperatures ranged from 12.8 °C at stations 1 – 5 to 16.2 °C at stations 6 and 7 (Figure 7-3).

San Joaquin River flows at Vernalis ranged from 1,397 to 2,283 cfs. Net daily flows past Stockton ranged from -14 cfs to 1,750 cfs (Figure 7-4).

December

DWR conducted the final monitoring run of the season on December 12. Surface DO levels ranged from 8.8 mg/L at station 11 to 10.2 mg/L at stations 6 and 7. Bottom DO levels ranged from 8.8 mg/L at station 12 to 10.2 mg/L at stations 1 – 3, 5 and 6. All DO levels measured during the month were well above the SWRCB objective.

Surface water temperatures ranged from 9.6 °C at stations 4 – 6 to 10.7 °C at stations 10 – 12. Bottom water temperatures ranged from 9.6 °C at stations 3 – 6 to 10.6 °C at stations 10 and 11 (Figure 7-3).

San Joaquin River flows at Vernalis ranged from 1,346 to 1,564 cfs. Net daily flows past Stockton ranged from -87 cfs to 298 cfs (Figure 7-4).

Stockton Turning Basin

DO levels in the Stockton turning basin were above SWRCB objectives at the surface during the entire study. However, bottom DO levels dropped below the SWRCB standard from June through October. DO levels in June ranged from 6.9 mg/L at the surface to 1.7 mg/L at the bottom (Figure 7-2). DO levels in July ranged from 10.1 mg/L at the surface to 2.6 mg/L at the bottom. DO levels in August ranged from 9.9 mg/L at the surface to 2.1 mg/L at the bottom. September DO levels at the surface and bottom ranged from 7.2 to 4.9 mg/L, respectively. DO levels in October ranged from 11.9 mg/L at the surface to 5.7 mg/L at the bottom. November DO readings ranged from 8.8 mg/L at the surface to 7.7 mg/L at the bottom. December DO readings ranged from 8.7 mg/L at the surface to 8.4 mg/L at the bottom.

Summary

DO concentrations in the Stockton Ship Channel fell below the SWRCB's 5.0 mg/L and 6.0 mg/L objectives June, July, August and September. All sites were above the SWRCB DO objective on subsequent sampling runs.

Flows on the San Joaquin River near Vernalis ranged from a low of 768 cfs in July to a high of 2,537 cfs in June. Net daily flow on the San Joaquin River past Stockton ranged from a low of -264 cfs in August to a high of 1,780 cfs in October. The head of Old River barrier was installed by October 18th and completely removed by November 29.

Further monitoring operations for the summer and fall 2007 special study were suspended after December 12, 2007.

References

[APHA] American Public Health Association, American Waterworks, and Water Environmental Federation. 1998. *Standard Methods for the Examination of Water and Wastewater.* 20th ed. Washington, D.C.: American Public Health Association.

[CVRWQCB] Central Valley Regional Water Quality Control Board. 1998. *Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region, the Sacramento River Basin, and San Joaquin River Basin*. 4th ed.

[SWRCB] State Water Resources Control Board. 1995. *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Estuary*. Adopted May 22, 1995, pursuant to Water Right Order 95-1. Sacramento. 44pp.

Figure 7-1 Monitoring sites in the Stockton Ship Channel

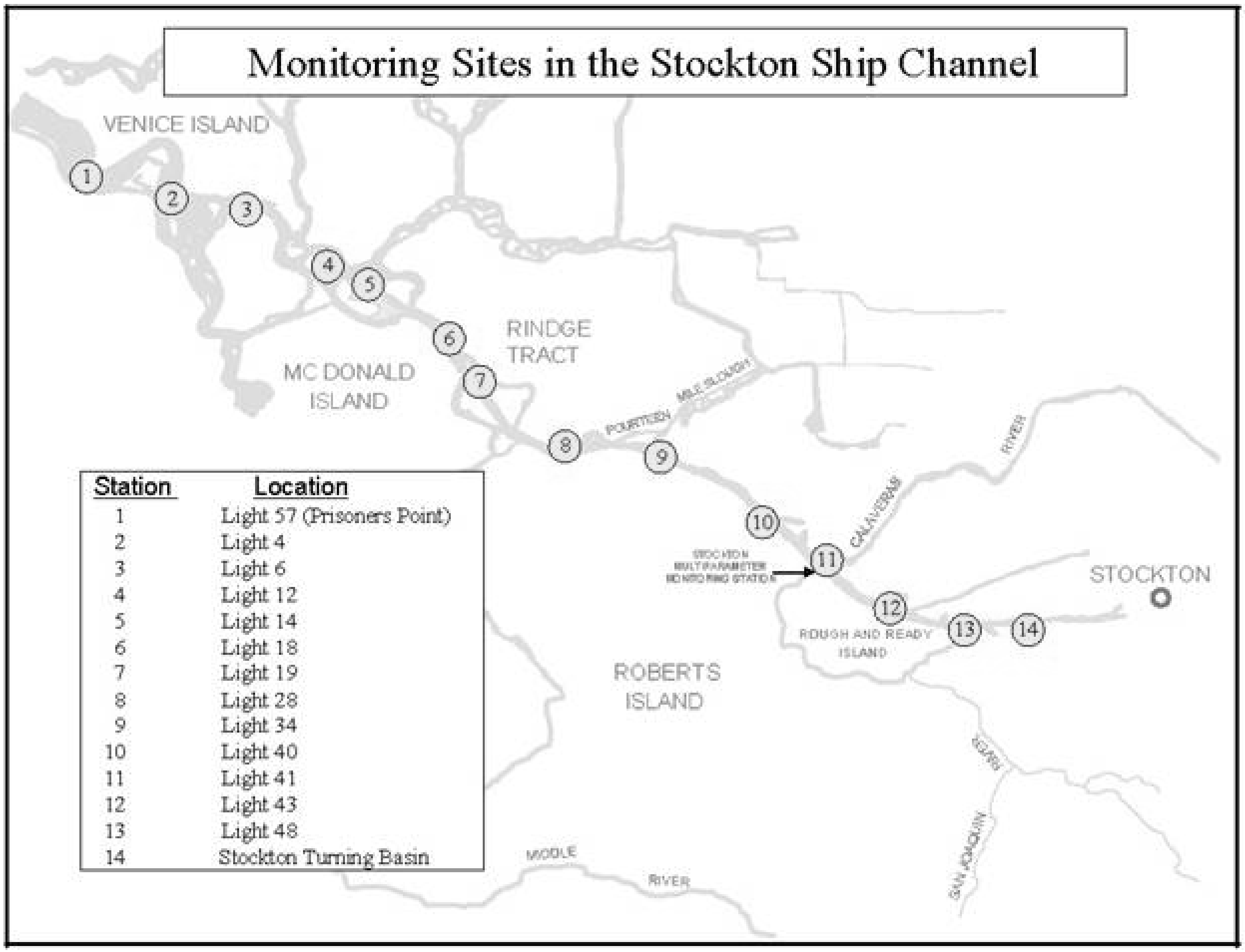


Figure 7-2a Dissolved oxygen concentrations at 14 stations in the Stockton Ship Channel, summer/fall 2007

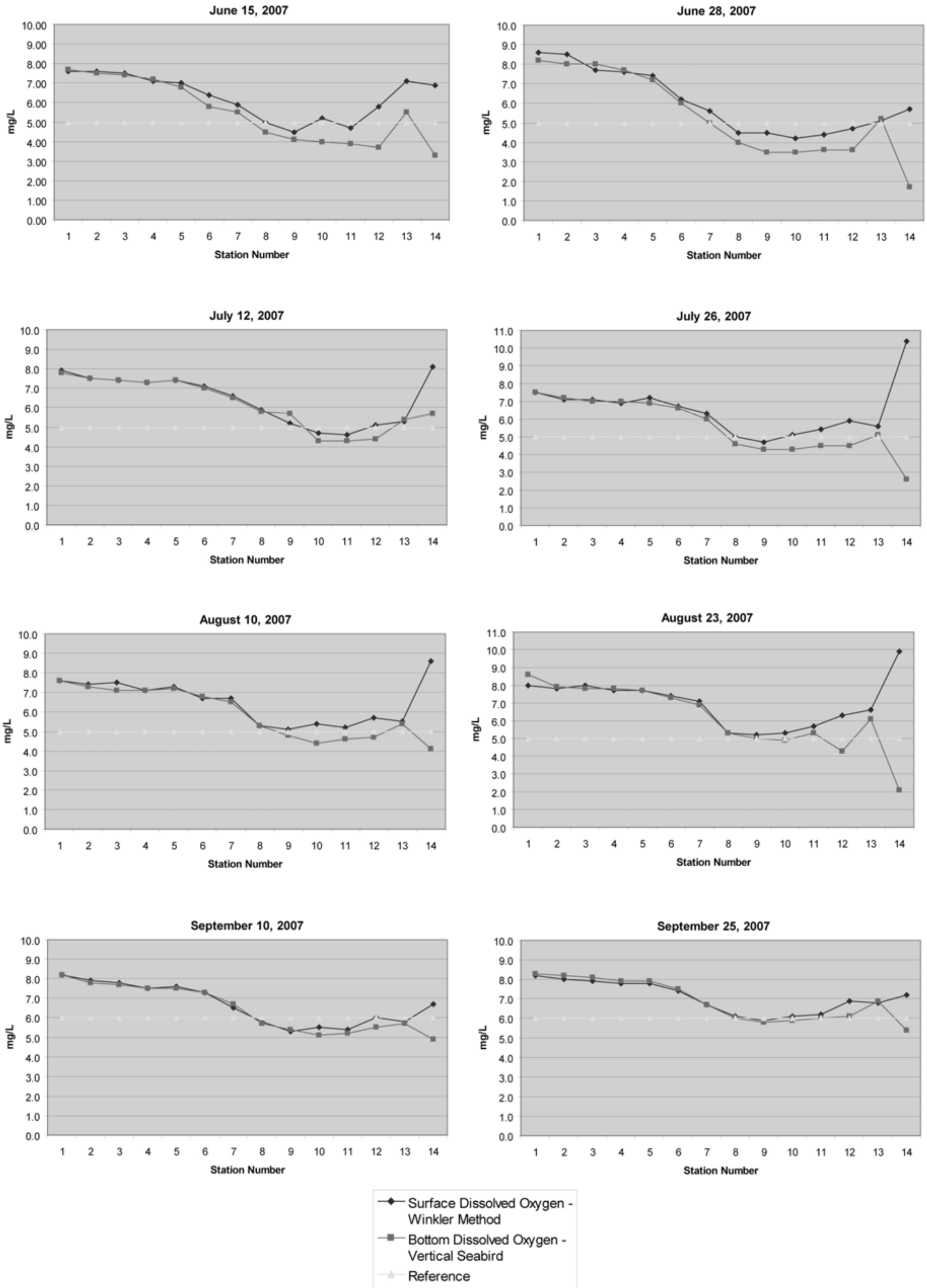


Figure 7-2b Dissolved oxygen concentrations at 14 stations in the Stockton Ship Channel, summer/fall 2007 Continued

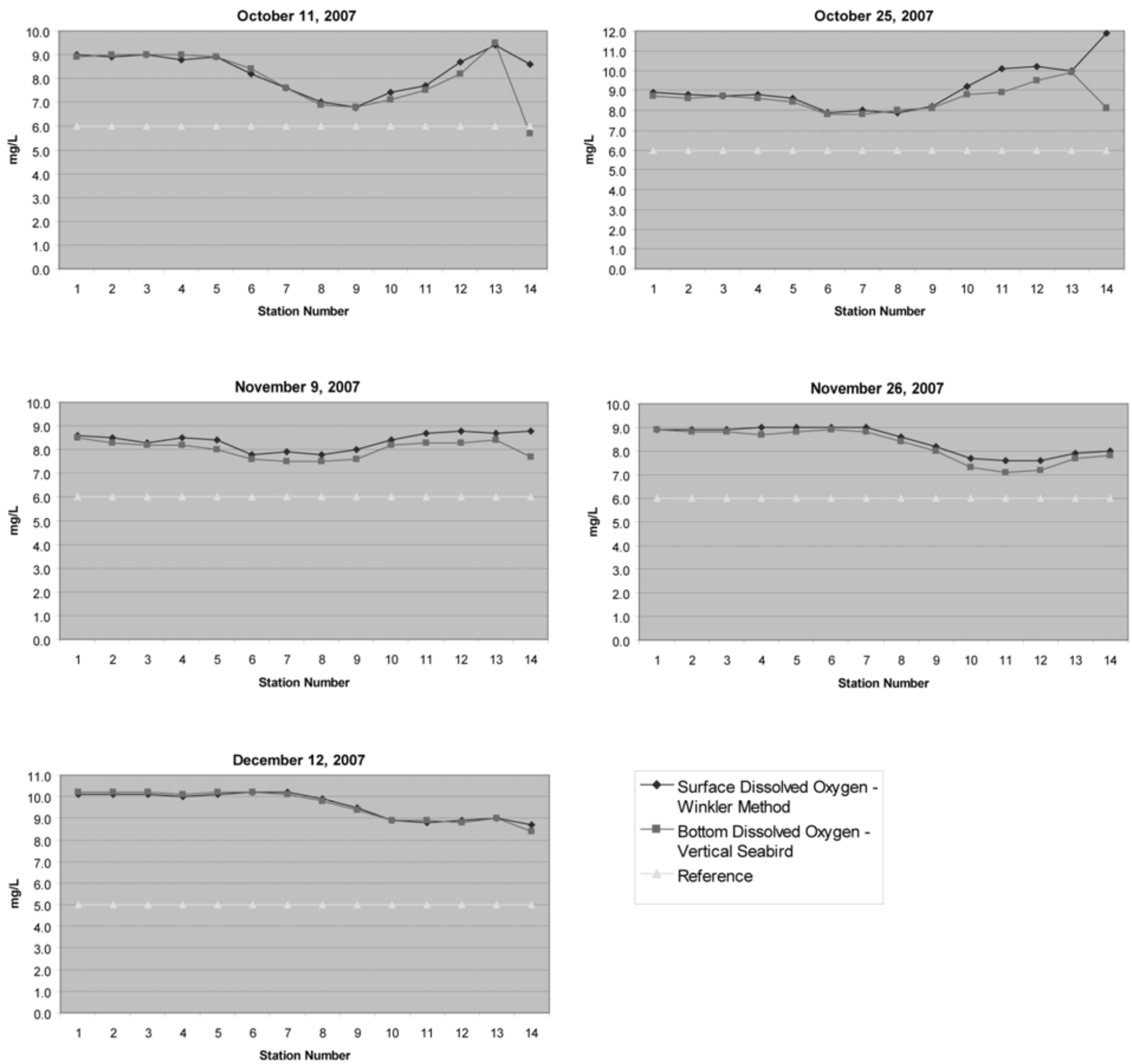


Figure 7-3a Water temperatures (°C) at 14 stations in the Stockton Ship Channel, summer/fall 2007

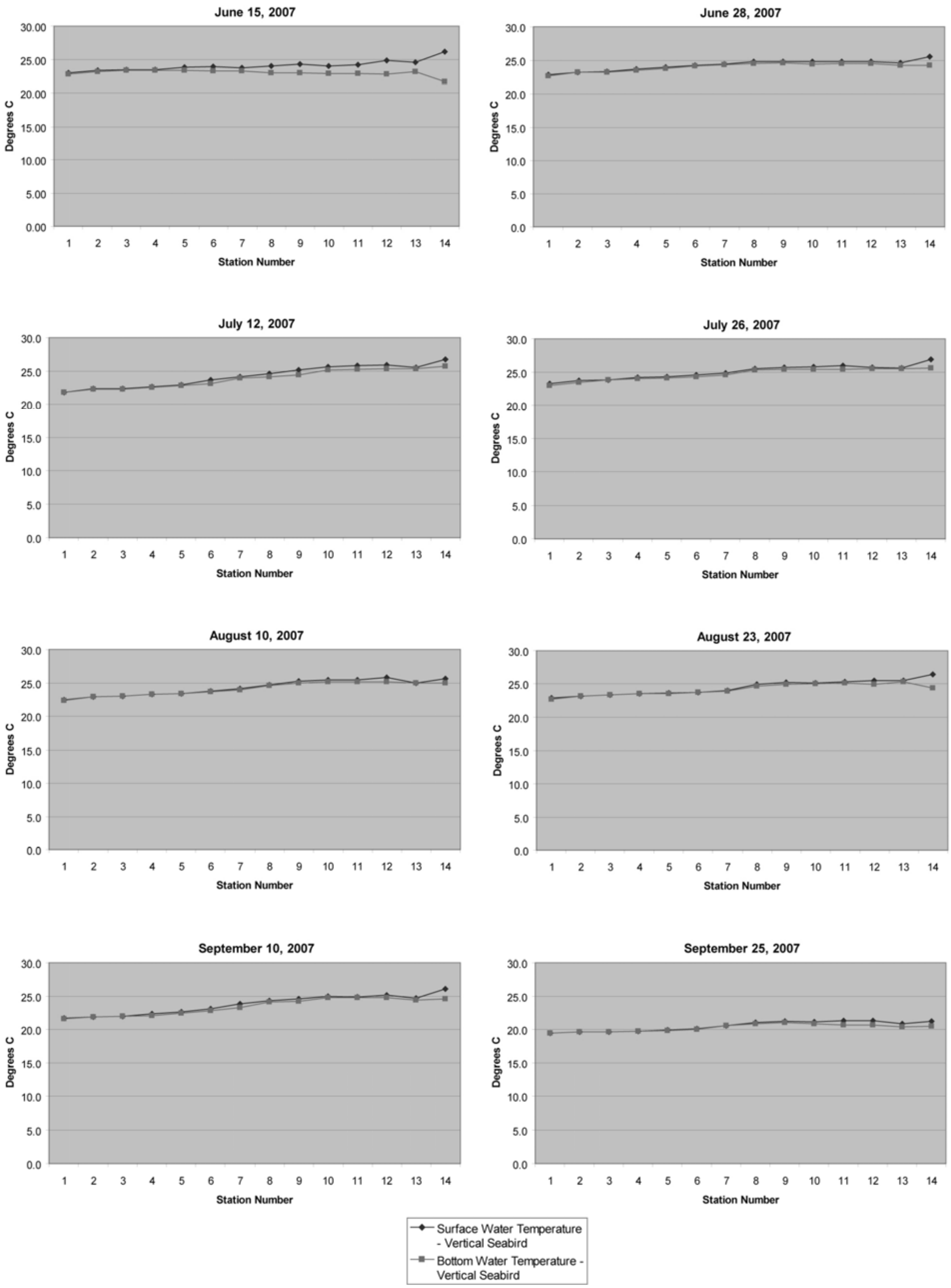


Figure 7-3b Water temperatures (°C) at 14 stations in the Stockton Ship Channel, summer/fall 2007 Continued

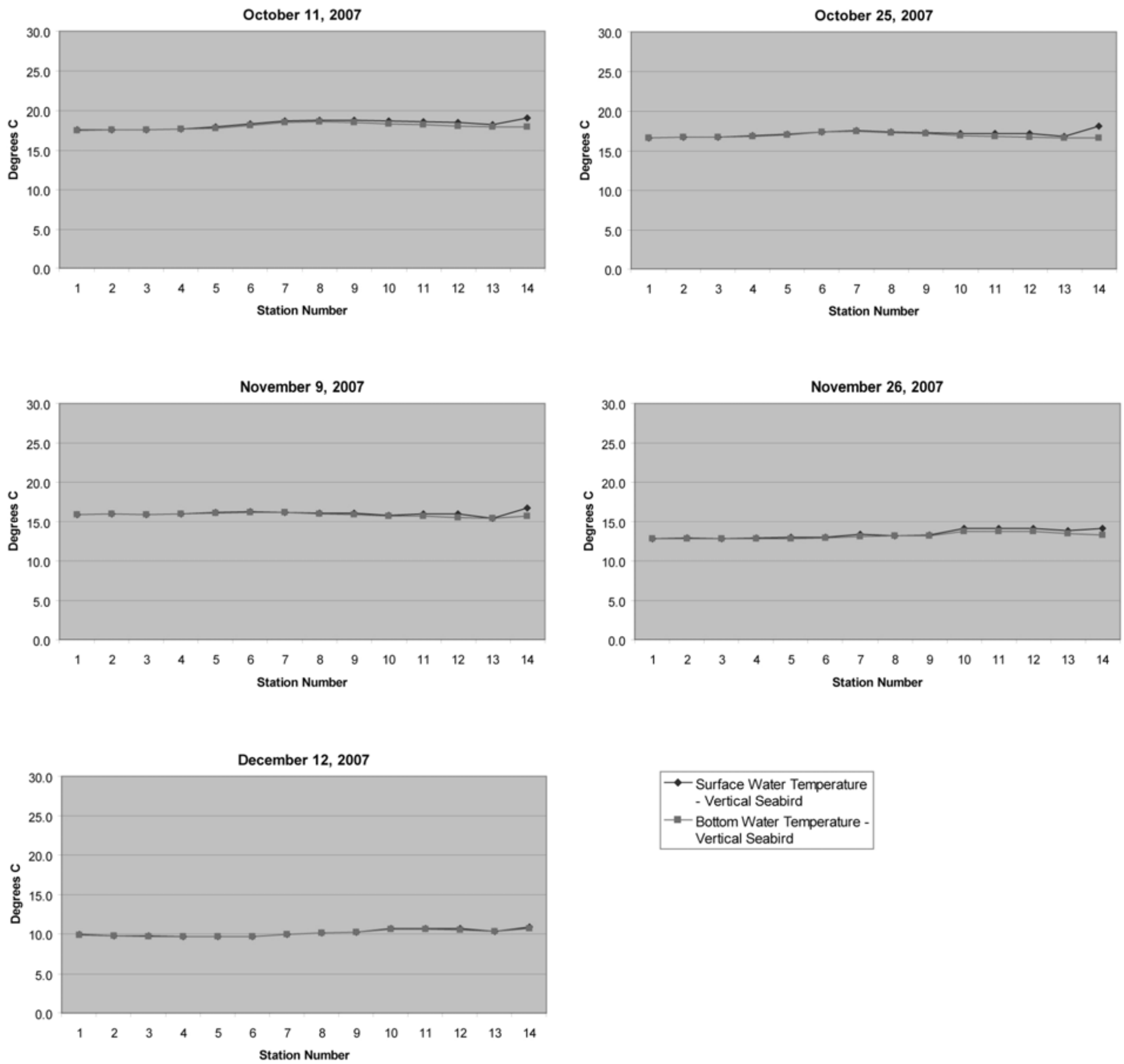
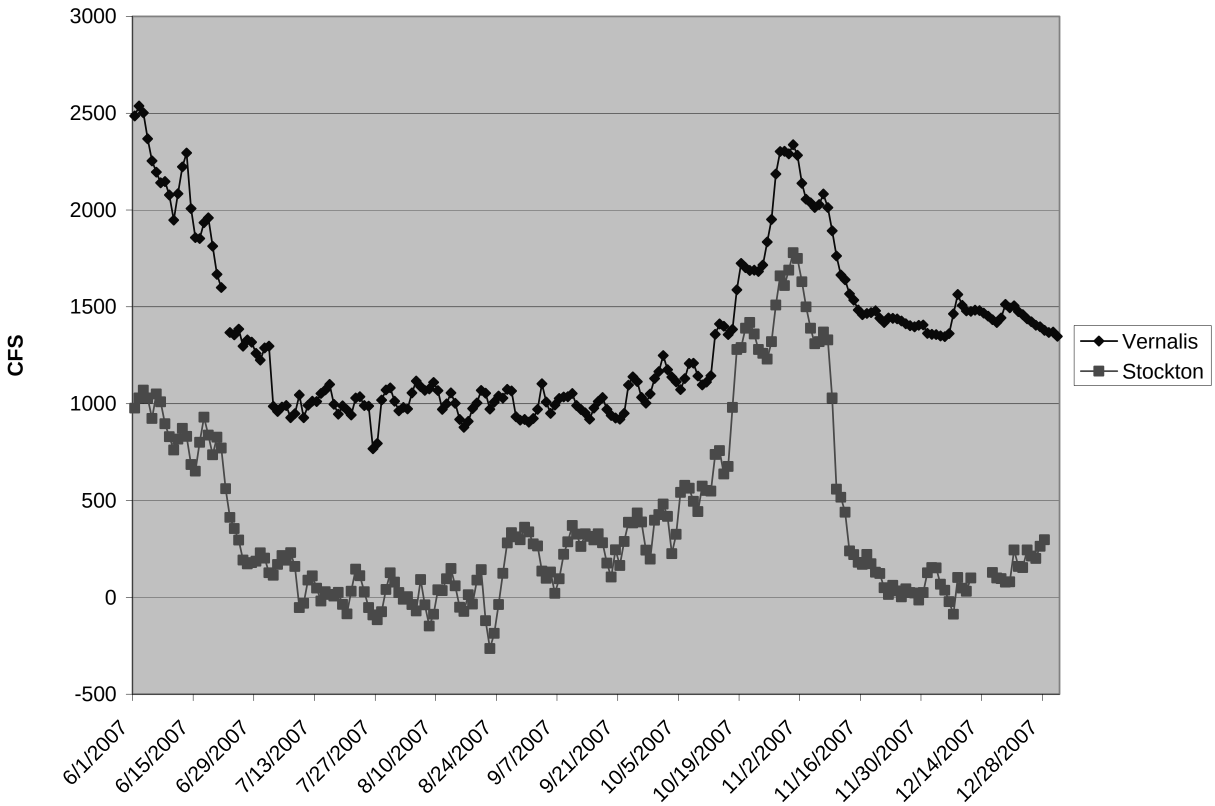


Figure 7-4 San Joaquin River mean daily flow, summer/fall 2007



Chapter 8 Data Management

Content

Chapter 8 Data Management

Introduction

All data collected by the EMP are stored in digital format for data management and dissemination. Each monitoring element (discrete and continuous water quality, benthic, phytoplankton and zooplankton) has a particular process for data entry, quality control, management and dissemination. All data, except zooplankton and sediment composition, can be downloaded via the Internet from BDAT. At present, the EMP continuous water quality data are available on BDAT under the category <BDAT Links> and then <Time Series>.

BDAT consolidates and provides public access to environmental data contributed by more than 50 organizations. The database includes water quality, biological and meteorological data from throughout the estuary. The EMP water quality, benthic and phytoplankton data stored in this database are available at baydelta.water.ca.gov.

Information about the various EMP monitoring elements and detailed information about the EMP can be found at www.iep.water.ca.gov/emp/.

Metadata information describes sampling site locations, sampling methodology, and field and laboratory processing for all the data variables and is available on the IEP website at http://www.baydelta.water.ca.gov/emp/metadata_index.html.

Complete metadata files are available for the benthic, phytoplankton and discrete water quality monitoring elements of this program. Metadata files are being developed for the continuous water quality monitoring elements and zooplankton. These files also provide contact information for the staff member responsible for each monitoring element.

Data Management Procedures

The procedures for handling each type of EMP data are described below. The description includes where data are stored, how data are checked for quality, what data are available, how to obtain these data and who is responsible for data management of each monitoring element. Water quality is monitored with both discrete and continuous sampling. The discrete monitoring sites are surveyed monthly, primarily by vessel. The continuous monitoring stations are equipped with automated probes and data recorders that log data every 10 minutes to 1 hour depending on the water quality variable.

Discrete Water Quality Data

During monthly sampling runs, field measurements are recorded on datasheets and entered into the field module of the DWR Field and Laboratory Information Management System (FLIMS). Laboratory analyses are performed at DWR's Bryte Laboratory and the results are entered by laboratory staff into the lab module of the FLIMS database. Data are then loaded electronically into EMP's Discrete Water Quality database, which is a Microsoft Access database. This database is the reference database for this program element. EMP staff periodically review the data against datasheet records for accuracy, completeness and consistency. Data are then exported electronically to BDAT.

Discrete water quality data from 1975 to present are available for download through the BDAT web interface at baydelta.water.ca.gov/index.html.

For more information regarding management and access to discrete water quality data, contact Brianne Noble at bnoble@water.ca.gov.

Continuous Water Quality Data

Data from automated continuous water quality monitoring stations are retrieved by downloading each station's data recorders onto a handheld "pocket PC." Data are then loaded into the EMP's Continuous Water Quality database, which is an IBM/Informix database. This database is the reference database for this program element. EMP staff review these data for accuracy, completeness, and consistency using probe verification and calibration records. Data that are the result of a measuring instrument that was operating out of proper calibration are "flagged" and are retained in the database. The "flagged" data are not available on the BDAT website, but may be obtained from EMP staff upon request.

Continuous water quality data from 1983 to present are available for download through the BDAT interface at baydelta.water.ca.gov/index.html.

A subset of the data from automated continuous water quality monitoring stations is sent by telemetry in near real-time to DWR's California Data Exchange Center (CDEC). **These real time data are unchecked and may include data that are the result of malfunctioning instruments.** They are available for viewing and download at cdec.water.ca.gov/

For more information regarding management and access to continuous water quality data, contact Mike Dempsey at mdempsey@water.ca.gov.

Benthic Data

Laboratory identification and enumeration of macrobenthic organisms in each sample is performed by Hydrozoology, a private laboratory under contract with DWR. The results are reported to DWR on standard datasheets. Laboratory analysis of sediment samples is performed by DWR's Soils and Concrete Laboratory. The results of the sediment analyses are provided to EMP staff in a written report.

Both sediment and benthic organism data are entered into the EMP's Benthic Database, which is a Microsoft Access database. This is the reference database for the benthic program element. EMP staff periodically review the data for accuracy, completeness and consistency. Data are exported electronically to BDAT each quarter.

Benthic data from 1975 to present are available for download through the BDAT web interface at baydelta.water.ca.gov/index.html.

Sediment composition data gathered by the benthic monitoring element are exported to BDAT, but are not yet available for download via the Internet.

For more information regarding benthic or sediment data, contact Karen Gehrts at kagehrts@water.ca.gov.

Phytoplankton Data

Phytoplankton sampling sites are surveyed monthly, primarily by vessel. DWR's Bryte Laboratory identified, enumerated and measured the size of phytoplankton for the samples collected from January through September. EcoAnalyst, a private contractor, analyzed those from October through December. These data are entered into the EMP phytoplankton database using Microsoft Access software. This is the reference database for the phytoplankton monitoring element. EMP staff periodically review the data for accuracy, completeness and consistency. Data are then exported electronically to BDAT.

Phytoplankton data from 1975 to present are available for download through the BDAT web interface at baydelta.water.ca.gov/index.html.

For more information regarding phytoplankton data, contact Tiffany Brown at tbrown@water.ca.gov.

Zooplankton Data

Zooplankton sampling sites are surveyed monthly by vessel. Laboratory identification and enumeration of zooplankton and mysid organisms is performed by the DFG's Bay-Delta Branch Laboratory. Data are entered directly into a computer during processing and stored electronically in a Microsoft Access database. Data are periodically reviewed for accuracy and completeness by DFG staff. Currently, zooplankton data are only available through DFG; however, construction is under way of a zooplankton database able to export data to BDAT.

Data are available upon request from April Hennessy at ahennessy@dfg.ca.gov.

Chapter 9 Continuous Monitoring

Content

Figures

Table

Chapter 9 Continuous Monitoring

Introduction

The Department of Water Resource's Continuous Monitoring Program supplements DWR's monthly discrete Compliance Monitoring Program by providing real-time hourly and quarter-hourly water quality and environmental data from nine shore-based automated sampling stations in the upper San Francisco Estuary (Figure 9-1). These stations provide continuous measurements of seven water quality parameters and four environmental parameters. These measurements are used by operators of the State Water Project and the Central Valley Project to assess the impacts of the project operations and to adjust project operations to comply with mandated water quality standards. The Continuous Monitoring Program has been in operation since 1983. This chapter summarizes the results of continuous water quality monitoring at nine sites for calendar year 2007. The stations were divided into three regions to allow for detail in the plots:

Figure 9-1 Station locations

Sacramento River stations:	Hood and Rio Vista
San Joaquin River stations:	Mossdale, Prisoner's Point, Vernalis and Stockton
Tidally influenced stations:	Antioch, Mallard Island, and Martinez

Methods

Continuous data are collected for the water quality and environmental parameters shown in Table 9-1. Each of the nine monitoring stations collects continuous data for water temperature, pH, dissolved oxygen, surface specific conductance, chlorophyll fluorescence, and turbidity. Additional sensors are installed at the Antioch, Mallard Island, and Martinez stations to monitor bottom specific conductance, 1.5 meters above the channel bottom. These measurements, along with river stage data measured at the Mallard and Martinez stations, are needed to determine compliance with the salinity standard (also known as X2) mandated by the Bay-Delta Plan (SWRCB 1995). Environmental data — such as air temperature, solar radiation, wind speed, and direction — are measured at all stations except Mossdale (only air temperature), Prisoners Point, Vernalis, and Hood stations (none) as part of Water Right Decision 1641's Table 3 objectives (SWRCB 1999).

Table 9-1 Parameters measured by the Continuous Monitoring Program

Except for bottom specific conductivity, all water samples are collected at 1 meter below the water surface using a float-mounted multiparameter water quality sonde. Water quality data and environmental data are recorded continuously at 15-minute intervals.

Complete hourly or quarter-hourly data for air and water temperature, pH, dissolved oxygen, surface and bottom specific conductance, chlorophyll florescence, turbidity, wind velocity, wind direction, solar radiation intensity and river stage are available on the Bay Delta and Tributaries (BDAT) Project database http://bdat/index.html unless otherwise noted. All other inquiries are available by request to the Chief of the Real Time Monitoring and Support Section[1].

Results

The monthly averages of the water quality data measured continuously (air and water temperature, pH, dissolved oxygen, surface and bottom specific conductance, chlorophyll fluorescence and turbidity) for calendar year 2007 are shown in Figures 9-2 to 9-10.

Water Temperature

Water temperature was measured in degrees Centigrade (°C) using a YSI 6600 multiparameter water quality sonde.

Average monthly water temperatures in the San Francisco Estuary (Estuary) ranged from 7.3 °C in January 2007 at the Prisoners Point station on the San Joaquin River to 25.8 °C in July 2007 at the Stockton station on the San Joaquin River (Figure 9-2). Maximum water temperature values are similar to the same time period in 2006. Minimum water temperature was lower at all stations by greater than 1.5 °C over same time in 2006

Figure 9-2 Average monthly water temperature at nine stations, 2007

Average monthly water temperatures at the Sacramento River stations were lower in comparison to the San Joaquin River stations, with the greatest divergence occurring in the months of July through September at the San Joaquin River stations of Stockton, Mossdale and Vernalis.

Dissolved Oxygen

Dissolved oxygen was measured using a YSI 6600 multiparameter water quality sonde utilizing new technology optical DO sensor.

Average monthly dissolved oxygen values for the nine monitoring stations ranged from 4.2 mg/L to 13.5 mg/L (Figure 9-3). The greatest degree of variability was seen at the San Joaquin River stations of Stockton and Mossdale. A monthly average of 4.2 mg/L was calculated for the Stockton station in June 2007, and a value of 13.5 mg/L was calculated for the Mossdale station for July 2007. All other stations showed monthly averages between 8.0 mg/L and 10.9 mg/L with the Stockton station recording lower values starting in June 2007. All compliance monitoring stations, except the Stockton station, recorded values above the standard of 5.0 mg/L set by the Central Valley Water Resources Control Board in the Basin Plan. Monthly average dissolved-oxygen values at the Stockton station were highly variable and ranged from 4.2 mg/L to 11.3 mg/L. The Stockton station, located in the Stockton Deep Water Ship Channel, showed a significant DO sag to 4.2 mg/L in June 2007 in contrast to 2006 data where the drop did not occur until July. The San Joaquin River stations at Mossdale and Vernalis showed a significant rise in DO for the same period. The pattern of winter sag was first identified in 2000 was not evident in 2007.

Figure 9-3 Average monthly dissolved oxygen at eight stations, 2007

During summer and fall 2007, monthly average dissolved oxygen values at the Mossdale and Vernalis stations showed a familiar pattern of increase for July and August. Monthly average dissolved oxygen values in previous years

[1] Chief Real-Time Monitoring and Support Section, Division of Environmental Services, Office of Water Quality, Environmental Water Quality and Estuarine Studies Branch, 901 P Street, Sacramento CA 95814

showed a similar pattern from June to September. The July increase to 13.5 mg/L at the Mossdale station in 2007 showed a rise in summer DO levels from the high of 9.0 mg/L in 2006. The high average summer DO levels seen at the Mossdale and Vernalis stations coincided with high chlorophyll fluorescence during the same period (Figure 9-9).

Specific Conductance

Specific conductance was measured using a YSI 6600 multiparameter water quality sonde.

Monthly average surface specific conductance for the San Francisco Estuary ranged from 136 µS/cm to 26683 µS/cm, with the lower values in the Sacramento River at Hood and the higher values at the more tidally influenced Martinez station (Figure 9-4). The 2007 data is very similar to the 2006 data range. Data collected at the Mossdale and Stockton stations on the San Joaquin River upstream of the confluence of the Sacramento and San Joaquin rivers show a higher average specific conductance than the data collected from Hood and Rio Vista stations on the Sacramento River upstream of the confluence of the Sacramento and San Joaquin rivers (Figure 9-4a).

Figure 9-4 Average monthly specific conductance at nine stations, 2007

Bottom specific conductance measured at the Antioch, Mallard Island, and Martinez stations exhibited seasonal patterns and ranges similar to the surface specific conductance (Figure 9-5).

Figure 9-5 Average monthly surface and bottom specific conductance at three tidally influenced stations, 2007

pH

pH was measured using a YSI 6600 multiparameter water quality sonde.

Monthly average pH levels for the Estuary for all stations ranged from 7.3 to 9.3 pH units (Figure 9-6). Unlike 2006—where the stations on the San Joaquin River showed a decrease in pH from April thru June, the Mossdale and Vernalis stations showed a significant increase in pH values during the same period in 2007.

Figure 9-6 Average monthly pH at eight stations, 2007

Air Temperature

Air temperature was measured using a Schneider Instruments RM25C-036 system.

Monthly average air temperatures in the Estuary ranged from 6.2 °C in January 2007 at the Stockton station on the San Joaquin River to 24.9 °C July 2007 at the Mossdale station on the San Joaquin River. (Figure 9-7). Both the maximums and minimums monthly average air temperatures were lower than 2006 values.

Figure 9-7 Monthly average air temperature at six stations, 2007

Chlorophyll Fluorescence

Chlorophyll fluorescence was measured using a.YSI 6600 multiparameter water quality sonde .

Monthly average chlorophyll fluorescence recorded at the stations in the Estuary ranged from minimums of 0.95 fluorescence units (FU) in September 2007 at the Prisoners Point station on the San Joaquin River to maximums of 70.2 FU in July 2007 at the Mossdale station on the San Joaquin River (Figure 9-9, a-c).

Figure 9-9 Average monthly chlorophyll at eight stations, 2007

Turbidity

Turbidity was measured using a YSI 6600 multiparameter water quality sonde.

Monthly average turbidity was recorded at the stations in the Estuary ranged from minimums of 2 Nephelometric Turbidity Units (NTU) at the Prisoners Point station on the San Joaquin River in October 2007 to maximums of 54 NTU at the Martinez station in the Carquinez Strait in March 2007 (Figure 9-10, a-c).

Figure 9-10 Average monthly turbidity at two Sacramento River stations, 2007

Stockton Ship Channel Dissolved Oxygen

As part of DWR's mandate to monitor water quality in the Delta, a special monitoring study is focused on dissolved oxygen (DO) conditions in the Stockton Ship Channel from Prisoner's Point to the Stockton Turning Basin (see Chapter 7). Continuous data from a monitoring station in the ship channel (Stockton Station P8a) supplements monthly discrete sampling and alerts DWR personnel when DO levels become critical.

The Central Valley Regional Water Quality Control Board has established a baseline objective of 5.0 mg/L for the entire Delta (CVRWQCB 1998); however, due to the special concerns in the Stockton Ship Channel to protect fall-run Chinook salmon, a DO objective of 6.0 mg/L has been established for September through November by the State Water Resources Control Board (SWRCB 1995).

Monthly average DO values in 2007 ranged from 4.2 to 13.5 mg/L. The lowest DO value occurred in June 2007 at the Stockton station on the San Joaquin River while the highest value of 13.5 mg/L occurred in July 2007 at the Mossdale station on the San Joaquin River.

Monthly average DO values did drop below the state-mandated standards of 5.0mg/L for June (4.2 mg/L) and July 2007 (4.6 mg/L) at the Stockton station on the San Joaquin River in the Stockton Deep Water Ship Channel. The hourly values for the Stockton station ranged from 2.5 to 13.3 mg/L. The minimum value of 2.5 mg/L was recorded in June 2007 with the maximum value recorded in February 2007. As seen in previous years, the DO levels drop during the summer in July, August, and September. The pattern of falling DO levels in the winter, first observed in 2000, was not observed in 2007 and remained above the 5.0 mg/L standard.

For 2007, average monthly DO values at the Stockton station dropped below the standard 6.0 mg/L for September 2007 but recovered for October and November 2007 during the mandated months of September through November. (Figure 9-8).

Figure 9-8 Range of monthly dissolved oxygen values at San Joaquin River at Rough and Ready Island, 2007

The box plots (Figure 9-8) show the maximum and minimum range of average hourly DO values for the month, along with monthly medians and averages. Horizontal "whiskers" indicate the range of hourly DO values for each month. Boxes represent monthly medians and averages. Open boxes indicate that the monthly median is greater than the monthly average, with the top of the box indicating the median, and the bottom of the box indicating the average. Filled boxes indicate that the monthly average is greater than the median, with the top of the box indicating the average and the bottom of the box indicating the median. A horizontal dashed line indicates that the median and the average are equal.

Summary

Water quality conditions in the upper San Francisco Estuary for calendar year 2007 were in the expected range of values for water temperature, dissolved oxygen, specific conductance, pH, air temperature, and chlorophyll *a* fluorescence at the Sacramento River stations. The exceptions continue to be found on the San Joaquin River.

The upper San Joaquin River stations at Mossdale and Vernalis showed higher chlorophyll *a* fluorescence values in July, than any other station in the Estuary. the San Joaquin station at Mossdale showed higher dissolved oxygen values in July and August, than any other station in the Estuary with the Stockton station showing the lowest values for dissolved oxygen in July and August. Unlike 2006, the pH values at the Mossdale and Vernalis stations on the San Joaquin River increased during the months of June through September and returned near or lower than pH values measured at the other Estuary stations end of the year.

The San Joaquin River station at Stockton dropped below the 5.0 mg/L standard, which was set by the CVRWQCB (1998), for June and July 2007. The dissolved oxygen levels dropped below the 6.0 mg/L standard (SWRCB 1995) for the passage of fall-run Chinook salmon through the Stockton Deep Water Channel for September 2007 but recovered in October and November 2007 control period.

References

[CVRWQCB] Central Valley Regional Water Quality Control Board. 1998. *Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region, the Sacramento River Basin, and San Joaquin River Basin*. Fourth Edition.

[SWRCB] State Water Resources Control Board. 1995. *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Estuary*. Adopted May 22, 1995, pursuant to Water Right Order 95-1. Sacramento, CA. 44pp.

[SWRCB] State Water Resources Control Board. 1999. *Water Right Decision 1641*. Adopted December 29, 1999, Revised in Accordance with order WR2000-02 March 15, 2000, Sacramento, CA. 211pp.

Figure 9-1 Location of 9 shore-based automated sampling stations in the upper San Francisco Estuary

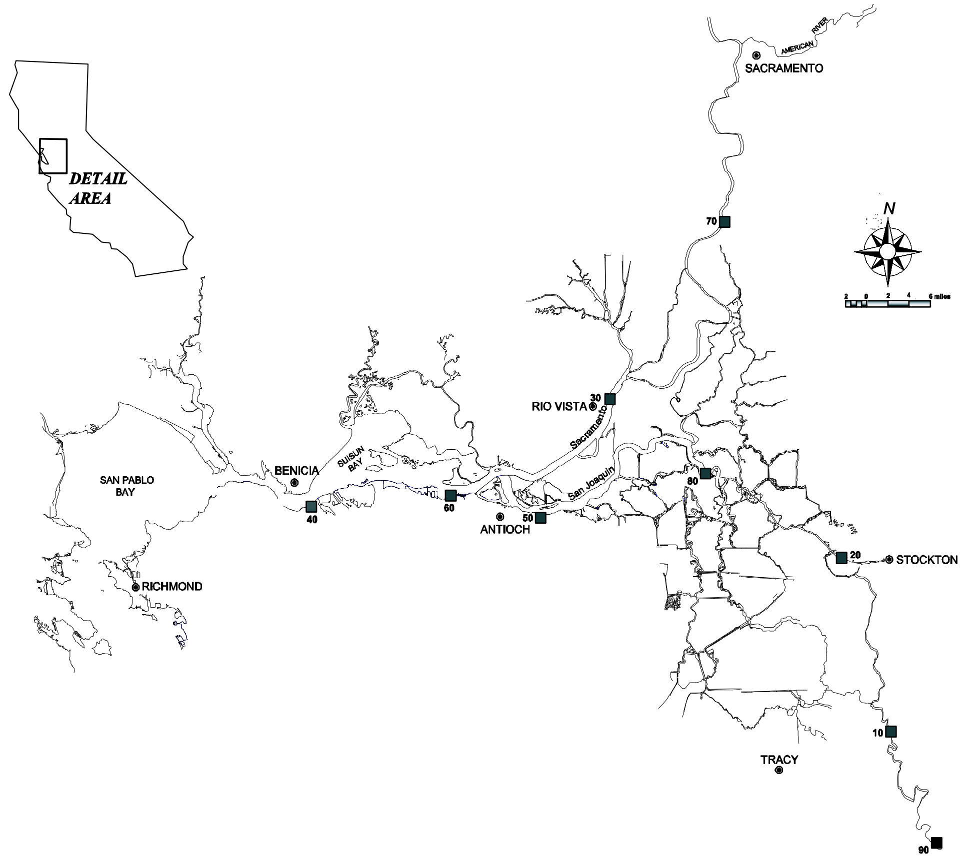


Figure 9-2 Average monthly water temperature at 9 stations, 2007

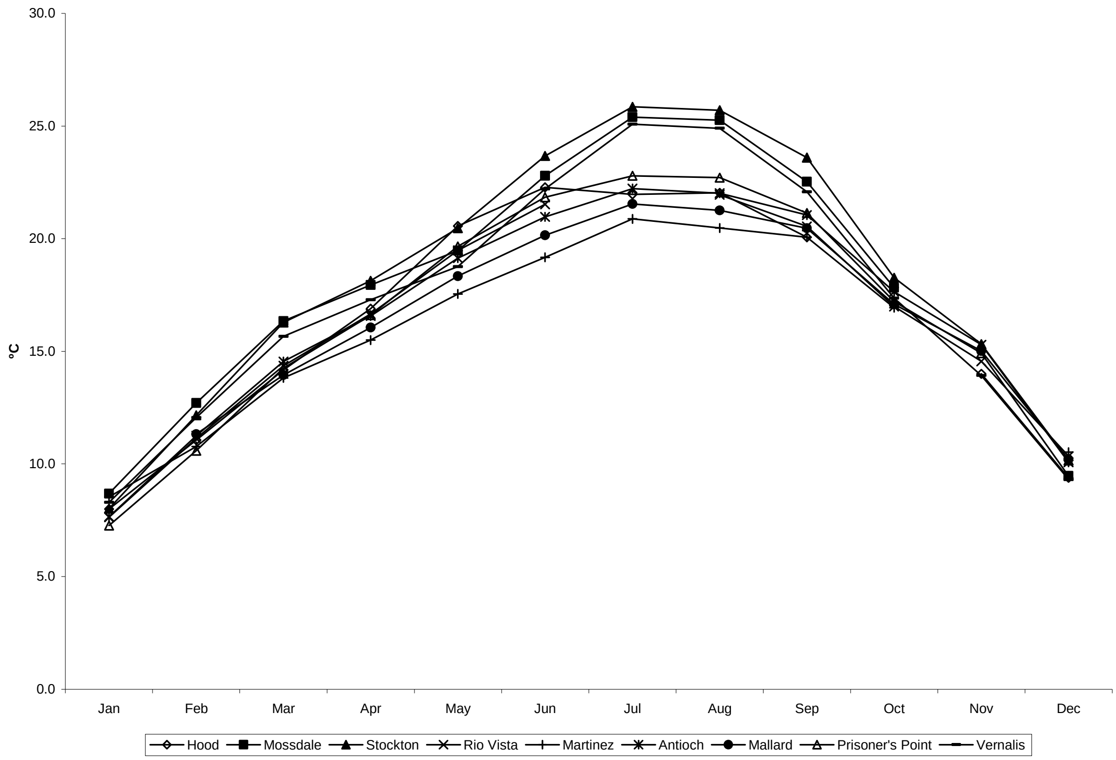


Figure 9-3 Average monthly dissolved oxygen at 9 stations, 2007

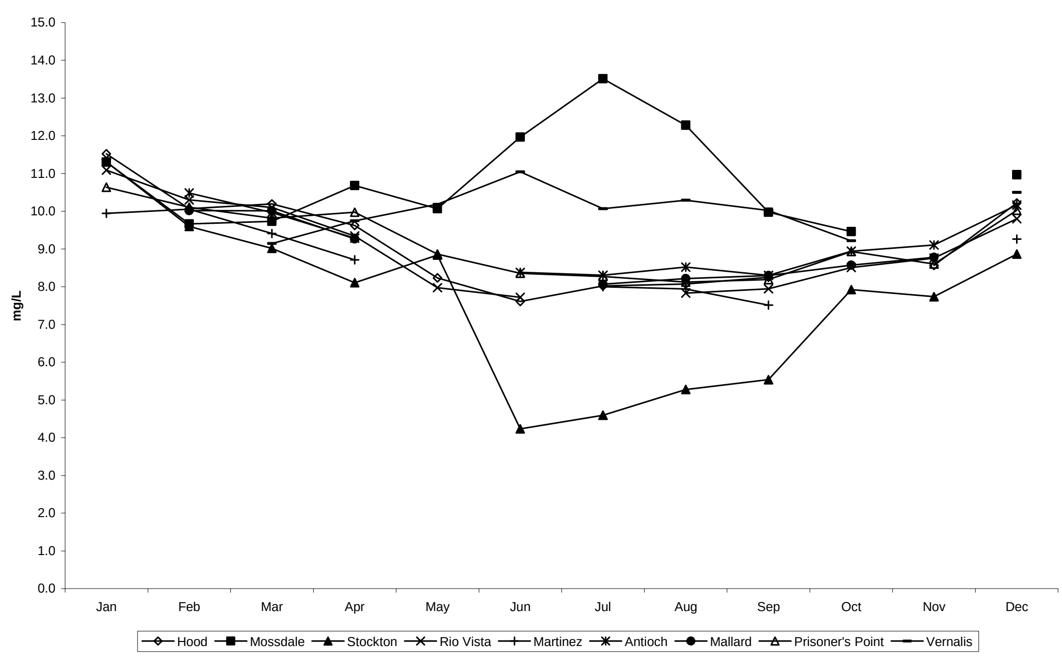


Figure 9-4 Average monthly specific conductance at 9 stations, 2007

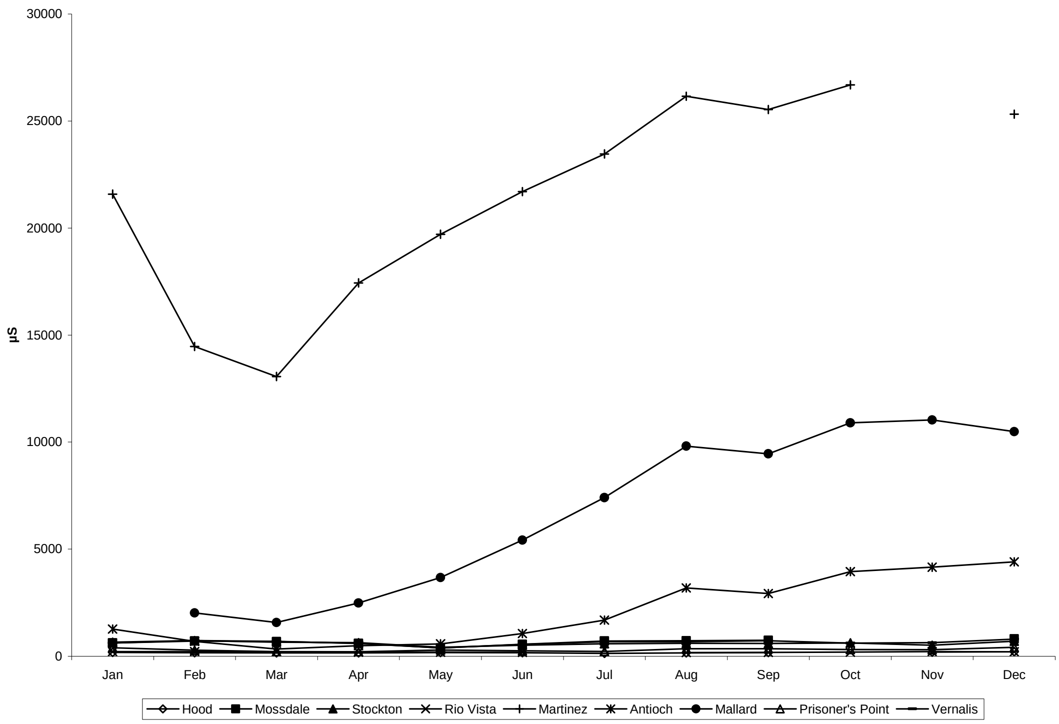


Figure 9-4A Average monthly specific conductance at 6 river stations

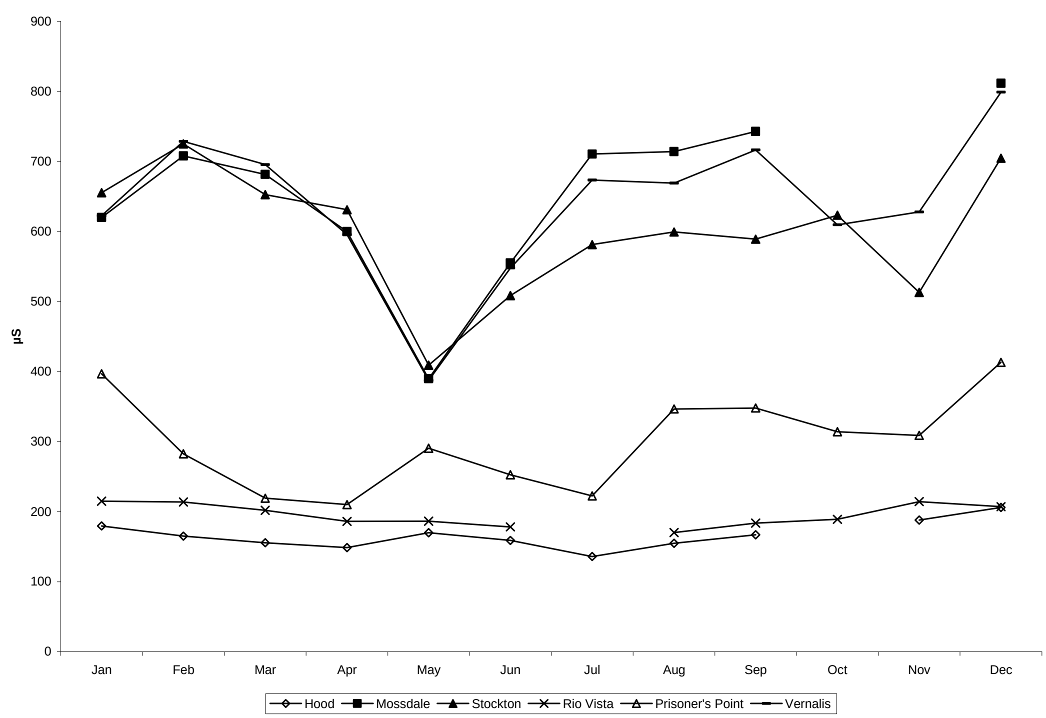


Figure 9-5 Average monthly surface and bottom specific conductance at 3 tidally influenced stations, 2007

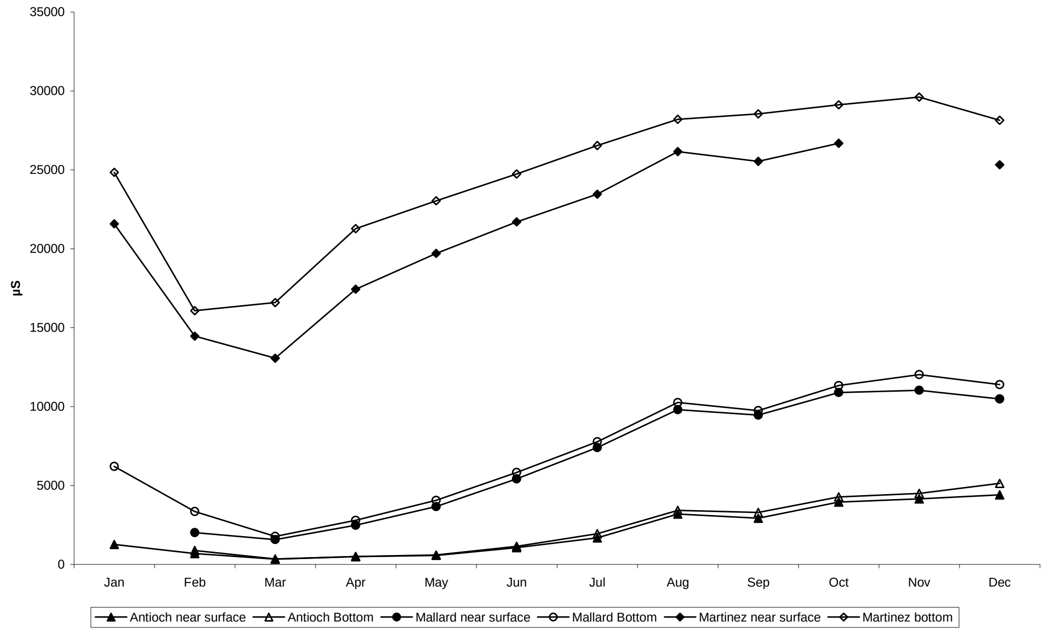


Figure 9-6 Average monthly pH at 9 stations, 2007

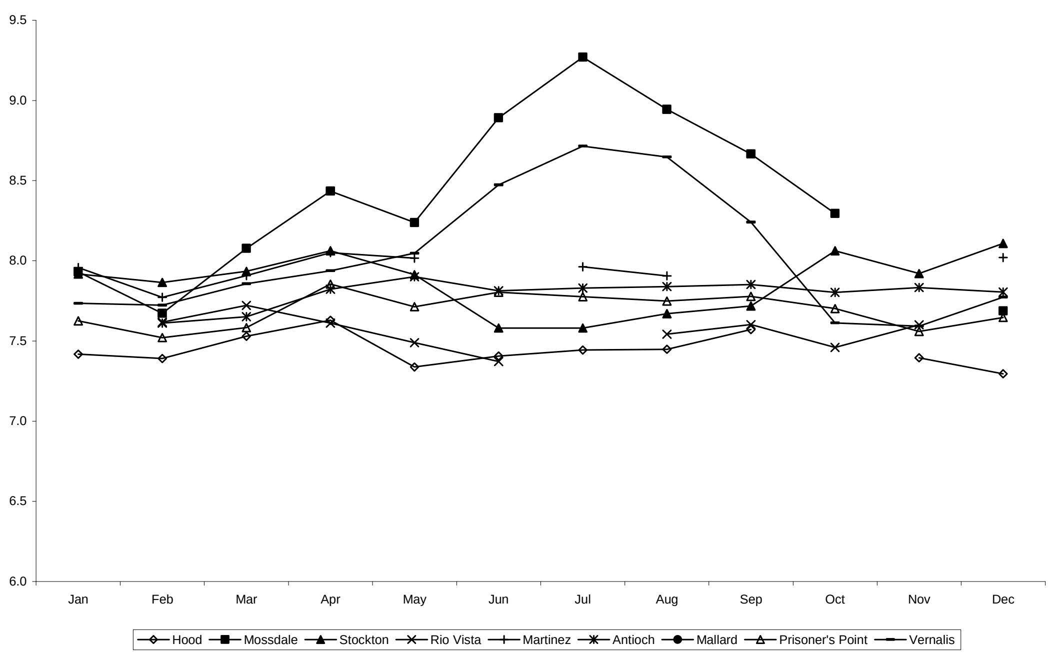


Figure 9-7 Monthly average air temperature at 6 stations, 2007

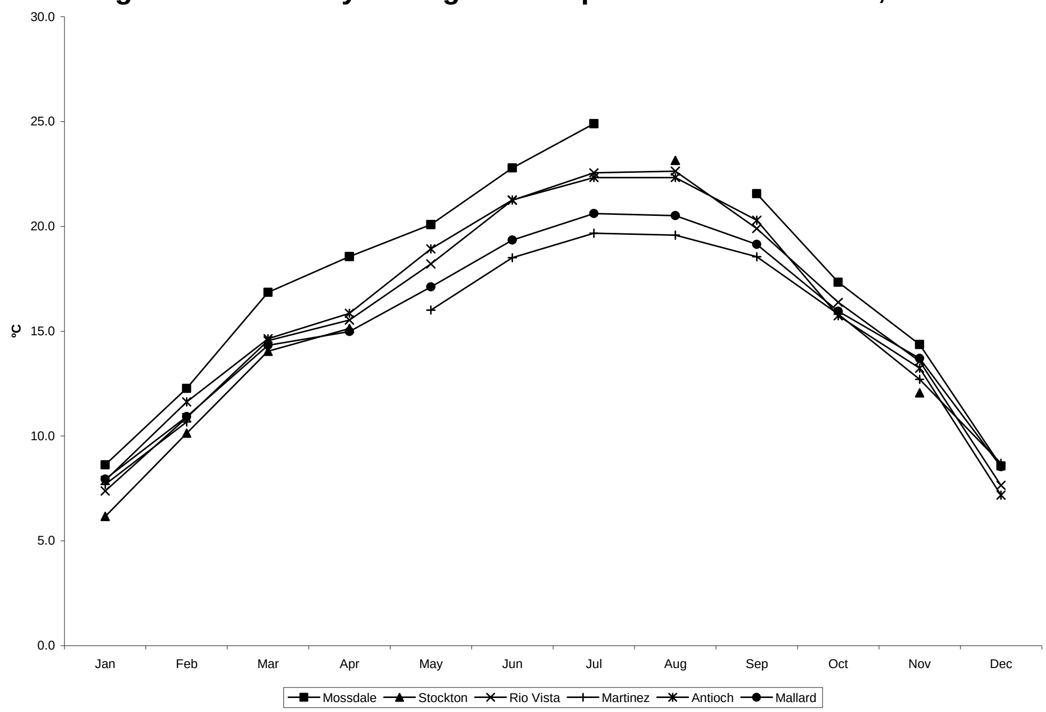
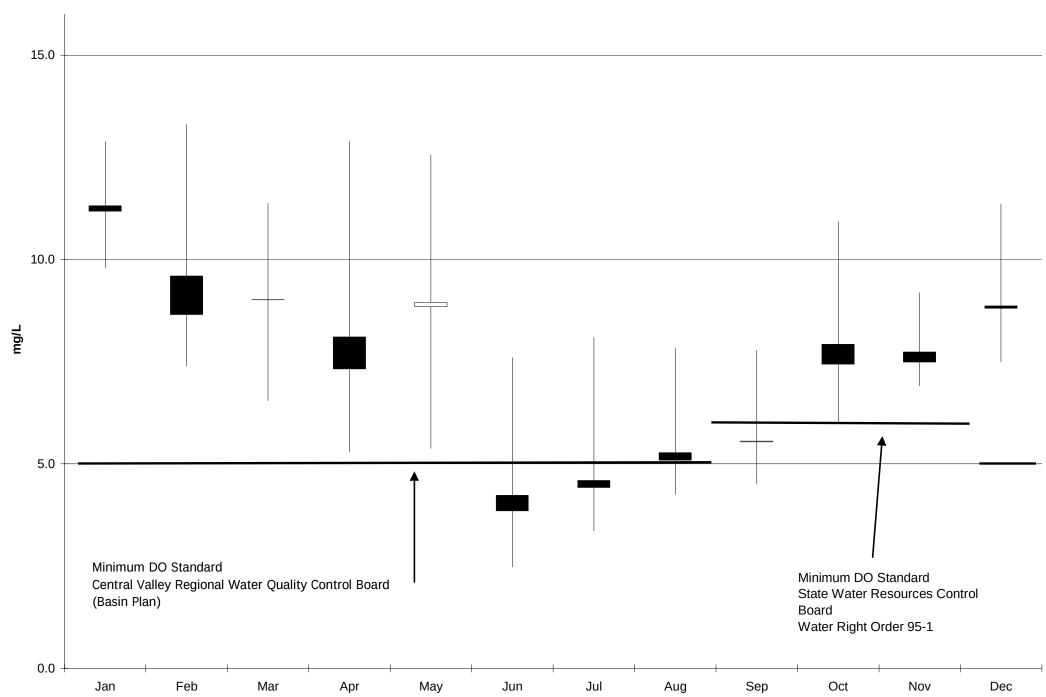


Figure 9-8 San Joaquin River at Rough and Ready Island Range of monthly dissolved oxygen values, 2007



* Solid boxes when monthly average higher than monthly median

Figure 9-9 Average monthly chlorophyll at 9 stations, 2007

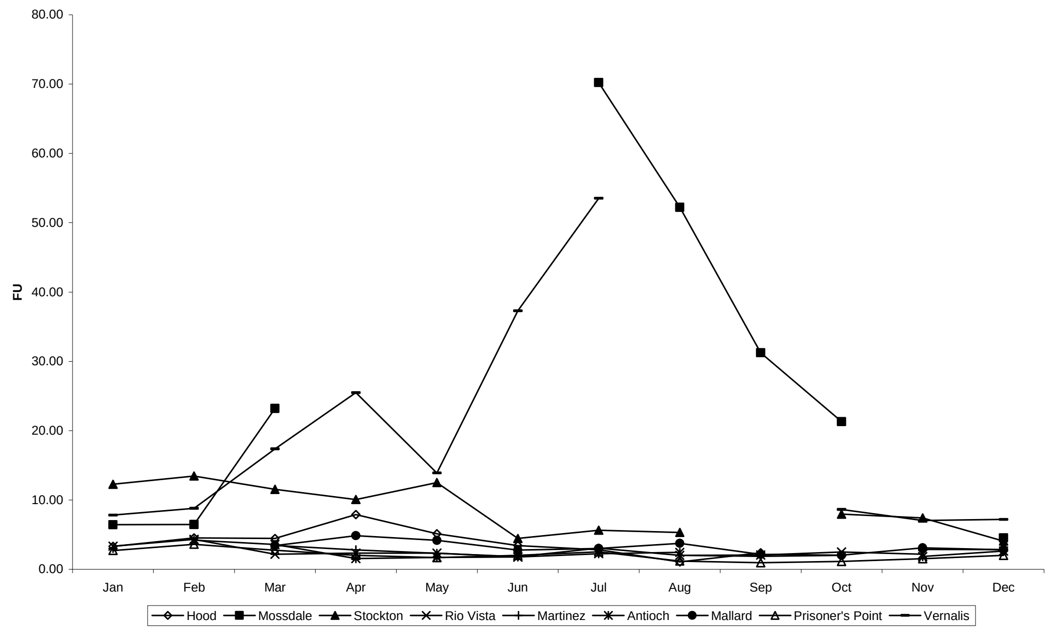


Figure 9-9a Average monthly chlorophyll at 2 Sacramento River stations, 2007

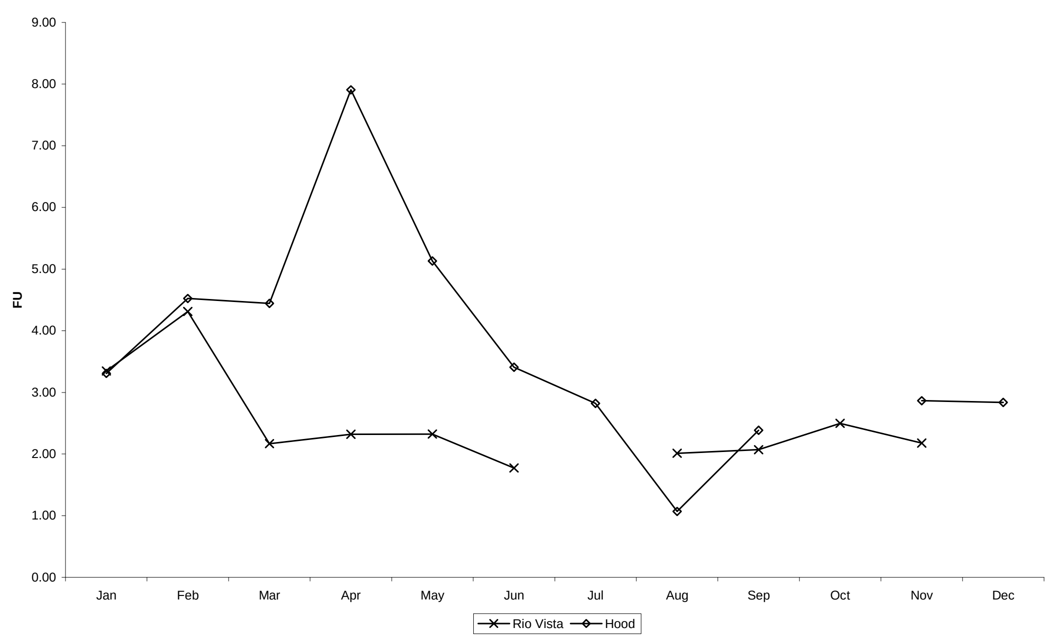


Figure 9-9b Average monthly chlorophyll at 4 San Joaquin River stations, 2007

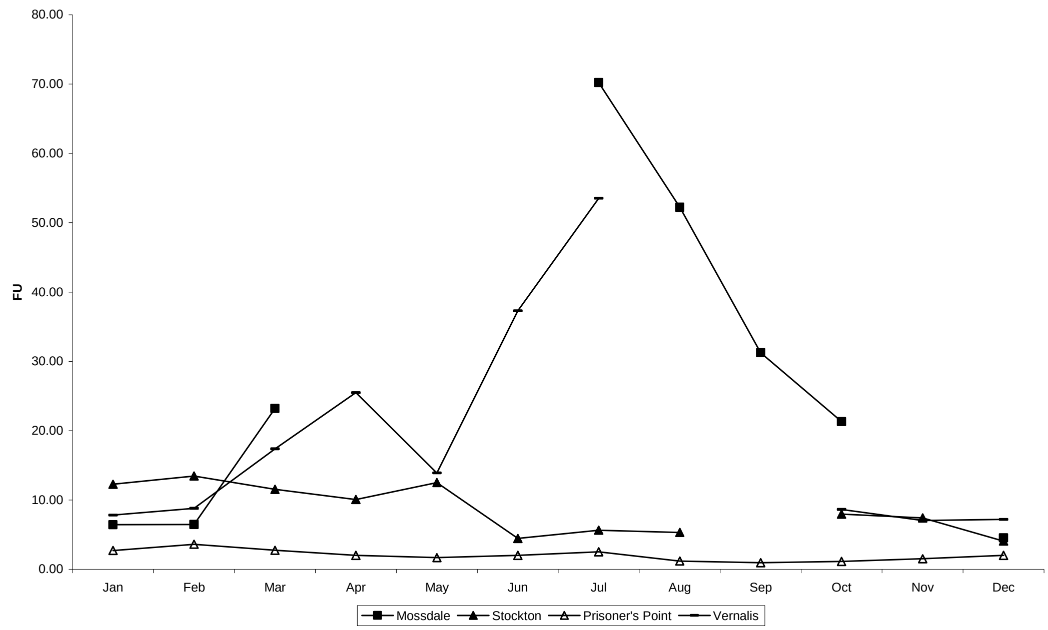


Figure 9-9c Average monthly chlorophyll at 3 tidally influenced stations, 2007

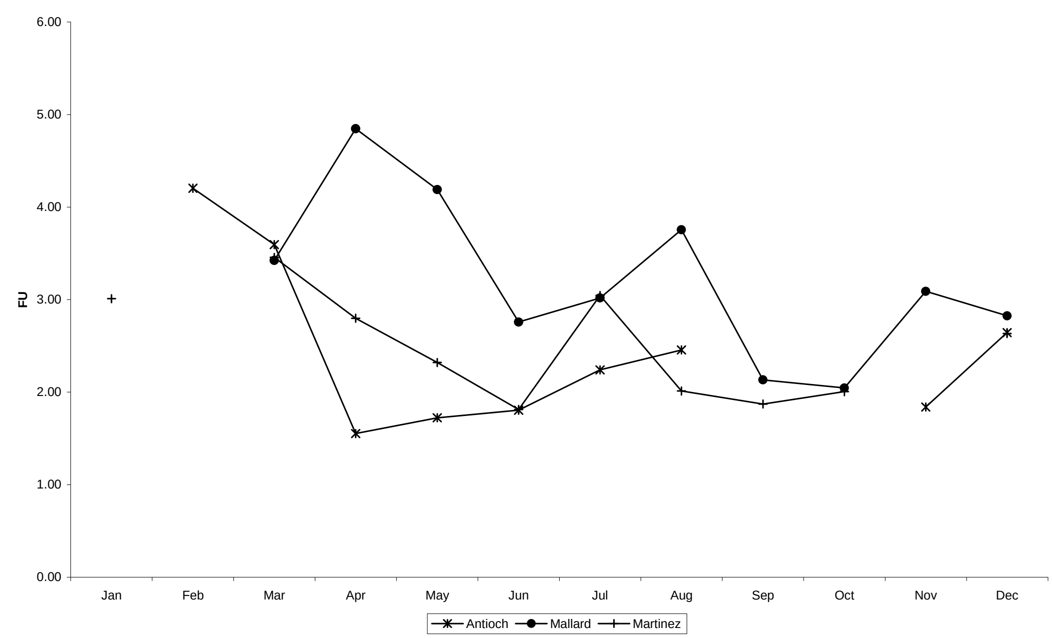


Figure 10 Average monthly turbidity at 9 stations, 2007

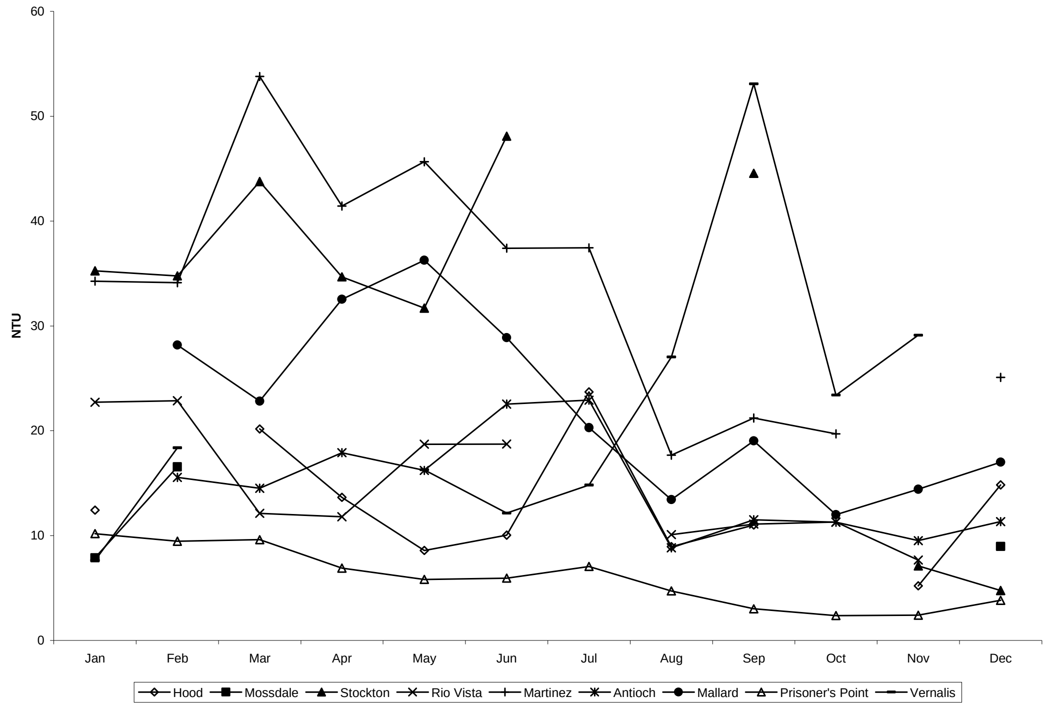


Figure 9-10a Average monthly turbidity at 2 Sacramento River stations, 2007

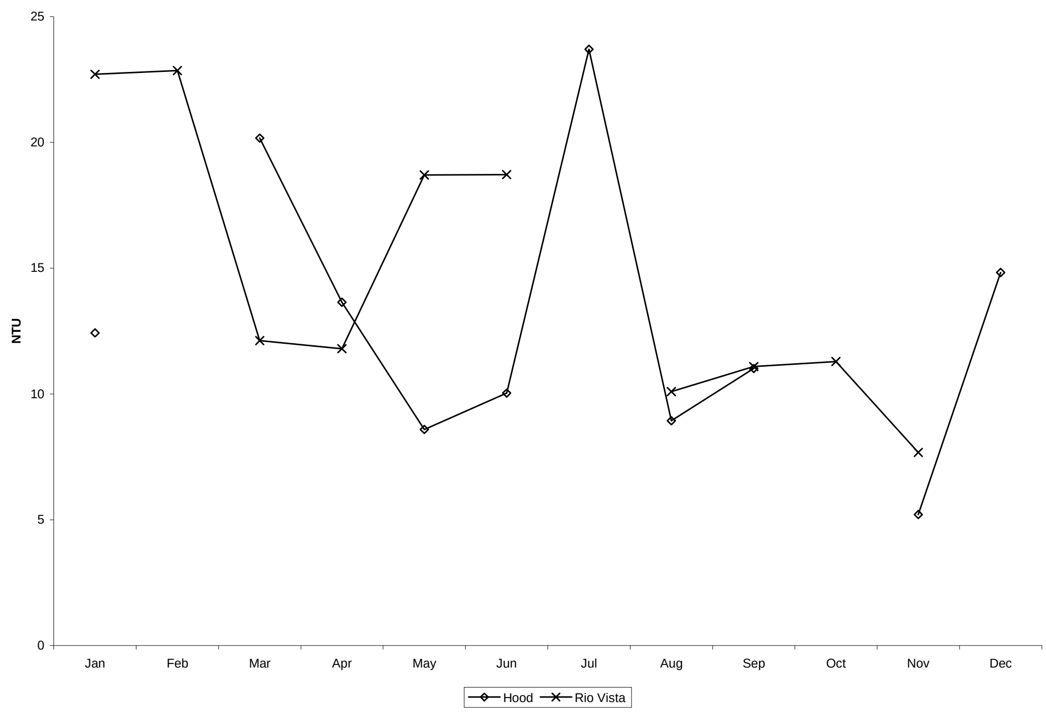


Figure 9-10b Average monthly turbidity at 4 San Joaquin river Stations, 2007

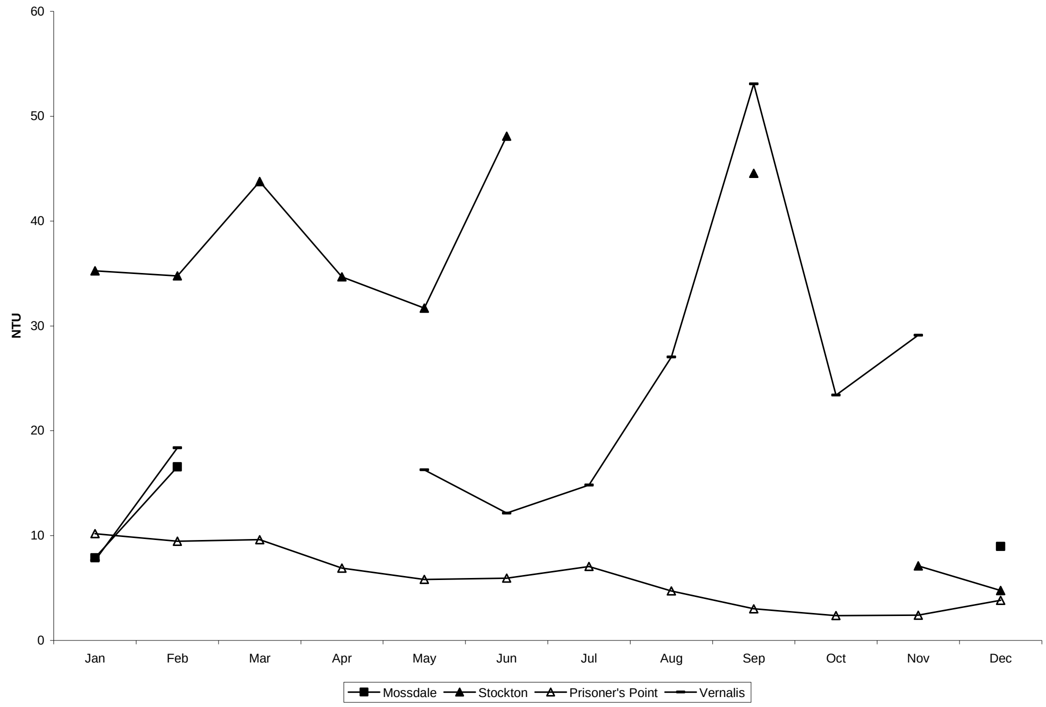


Figure 9-10c Average monthly turbidity at 3 tidally influenced stations, 2007

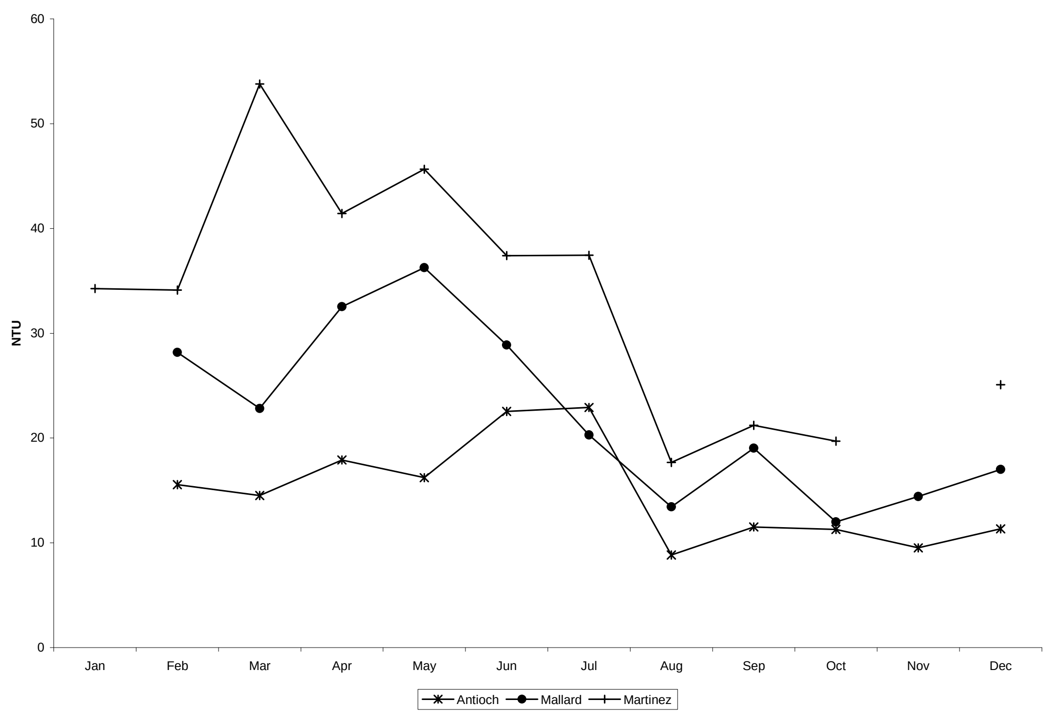


Table 9-1 Parameters

Parameter	Units	Frequency
Water temperature	°C	Hourly average
Air temperature	°C	Hourly average
Dissolved oxygen	mg/L	Hourly average
pH	unitless	Hourly average
Chlorophyll fluorescence	fluorescence units	10 minute instantaneous
Turbidity	NTU	10 minute instantaneous
Surface specific conductance	µS/cm	Hourly average
Bottom specific conductance	µS/cm	15 minute instantaneous
River stage	feet (from mean sea level)	15 minute instantaneous
Wind speed	knots/hr	15 minute instantaneous
Wind direction	degrees	15 minute instantaneous
Solar radiation	$cal/min/cm^2$	15 minute instantaneous