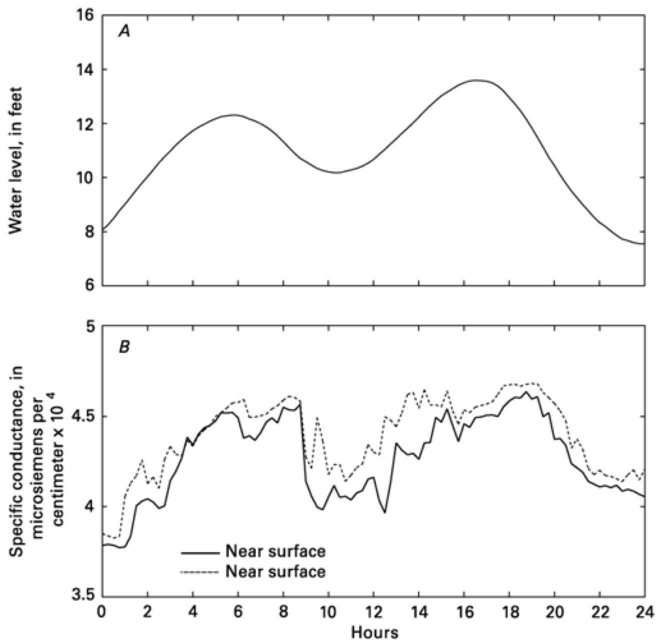


**Figure 7 Near-surface and near-bottom measurements of (A) water levels and (B) specific conductance at Point San Pablo, San Francisco Bay, October 1, 1999.** Vertical datum is 10 feet below mean sea level. For reference, seawater has a specific conductance of 53,000 microSiemens per centimeter ($5.3 \times 10^4$)

Other data, including maximum and minimum values of specific-conductance, water-temperature, and water-level data for the seven sites, are published annually in volume 2 of the USGS California water data report series available on the USGS website (http://ca.water.usgs.gov).

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# Fall Dissolved Oxygen Conditions in the Stockton Ship Channel for 2000

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## Introduction

Dissolved oxygen concentrations in the Stockton Ship Channel typically drop below 5.0 mg/L during the late summer and early fall of each year, especially in the eastern portion of the channel. Low San Joaquin River inflows, warm water temperatures, high biochemical oxygen demand, reduced tidal circulation, and intermittent reverse flow conditions in the San Joaquin River past Stockton are all likely to contribute to the dissolved oxygen decrease in this area. Low dissolved oxygen concentrations can cause physiological stress to fish and hinder upstream migration of salmon.

To protect fish and the aquatic ecosystem, water quality objectives for dissolved oxygen have changed over the years in the Stockton Ship Channel. The Central Valley Regional Water Quality Control Board in the Basin Plan originally set a baseline standard of 5.0 mg/L for the entire Delta region (including the Stockton Ship Channel) throughout the year (CVRWQCB 1998). This objective was modified to 6.0 mg/L within the channel from Turner Cut to Stockton from September through November when the Bay-Delta Plan (SWRCB 1995) was adopted by the SWRCB on May 22, 1995. The 6.0 mg/L objective within the channel has now been included in Water Right Decision 1641 (D-1641), which superseded the Bay-Delta Plan when it was adopted by the SWRCB on December 29, 1999 (SWRCB 1999). Because the majority of the channel study area is within the designated 6.0 mg/L objective area (Figure 1) and the majority of the study occurs from September through November, we compared the data to the 6.0 mg/L objective.

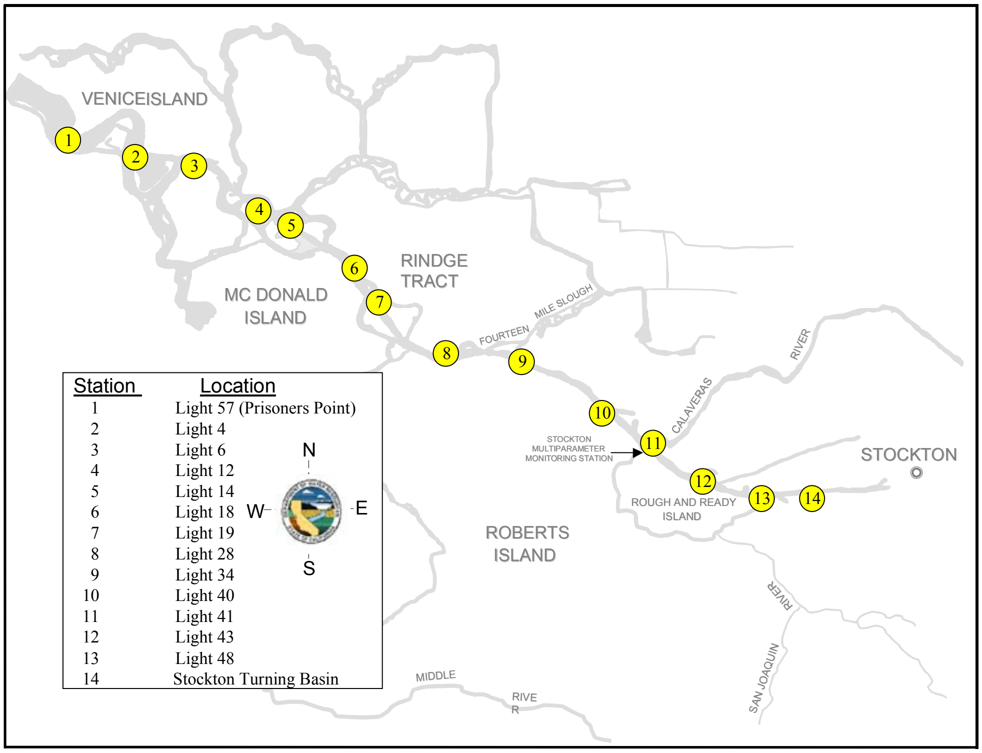


**Figure 1 Monitoring sites in the Stockton Ship Channel**

Since 1968, the Bay-Delta Monitoring Section and supporting Interagency Ecological Program (IEP) staff have measured dissolved oxygen concentrations in the channel during the late summer and early fall of each year. Dissolved oxygen is monitored to determine if placement of a temporary rock barrier across the head of Old River is necessary. This monitoring also documents dissolved oxygen levels during and after the placement of the barrier, if the barrier is affecting dissolved oxygen levels.

As part of a 1969 Memorandum of Understanding between the Department of Water Resources (DWR), the U.S. Fish and Wildlife Service, the U.S. Bureau of Reclamation, and the Department of Fish and Game, the Department of Water Resources usually installs the barrier during periods of projected low fall San Joaquin River outflow. The barrier increases net flows down the San Joaquin River past Stockton, which may contribute to the improvement of low dissolved oxygen concentrations in the eastern Stockton Ship Channel.

DWR installed the barrier at the head of Old River on October 7, 2000, because late summer San Joaquin River flows past Vernalis were relatively low (average daily San Joaquin River flows past Vernalis were approximately 2,300 cfs [64.1 $m^3/s$] in September), and fall flows were not projected to be sufficient to alleviate low dissolved oxygen conditions in the eastern channel. The barrier was removed on December 8, 2000, due to a sustained improvement in dissolved oxygen conditions throughout the channel, and in response to potential bank erosion and overtopping concerns resulting from an anticipated increase in late fall flows. These flows were projected to be sufficient to maintain acceptable dissolved oxygen levels throughout the channel. This report summarizes monitoring results for a year when the portion of San Joaquin River flow that normally enters Old River was diverted downriver toward the channel.

## Methods

Monitoring of dissolved oxygen concentrations in the Stockton Ship Channel was conducted by vessel seven times between August 14, 2000, and November 14, 2000[1]. During each of the monitoring runs, 14 sites were sampled at low water slack tide from Prisoners Point in

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

the central Delta (Station 1) to the Stockton Turning Basin (Station 14) at the terminus of the channel (Figure 1). Dissolved oxygen and water temperature data were collected at each site near the surface and bottom of the water column during ebb slack tide using a Hydrolab Model DS-3 Multiparameter Surveyor, Seabird 9/11 multiparameter sensor or YSI 6600 Sonde[1].

## Results

A dissolved oxygen sag (levels ≤5.0 mg/L) was rarely present within the channel throughout the late summer and fall of 2000. However, a persistent dissolved oxygen depression (levels ≤6.0 mg/L) occurred within the central portion of the channel throughout much of August and September of 2000 due in part to warm water conditions and relatively low San Joaquin River inflows.

Dissolved oxygen levels differ by regions within the channel. Dissolved oxygen concentrations within the western portion of the channel from Station 1 to Station 4 were relatively high and stable throughout the study period. Dissolved oxygen values ranged from 6.7 to 11.2 mg/L from August 14 to November 14 (Figure 2). The robustness of dissolved oxygen concentrations in this portion of the channel is apparently due to the greater tidal mixing and the absence of conditions creating excessive biochemical oxygen demand.

In the central portion of the channel from Station 5 to Station 9, dissolved oxygen concentrations dropped from the consistently high concentrations in the western channel to concentrations approaching 5.0 mg/L throughout the monitoring period (Figure 2). In the eastern channel from Station 10 to Station 13, the dissolved oxygen concentrations were stratified and more variable than those of the central channel, and ranged from 5.0 mg/L in August to 9.25 mg/L in November (Figure 2). The inflow of the San Joaquin River into the eastern channel partially accounts for the variable dissolved oxygen levels in this region.

A persistent dissolved oxygen depression developed at the surface and at the bottom of the central channel throughout August. On August 14, a surface depression developed from Station 6 through Station 9 in the central channel, and a more extensive bottom depression developed from Station 6 in the central channel through Station 12 in the eastern channel. In the heart of this region (Stations 7 through 9), bottom dissolved oxygen levels dropped to 5.0 mg/L or less.

In the eastern portion of the channel a significant dissolved oxygen stratification developed, with bottom dissolved oxygen levels approximately 2 to 3 mg/L less than surface levels. Dissolved oxygen conditions within the channel improved slightly on August 29, as the bottom dissolved oxygen sag within the central channel and the stratification within the eastern channel disappeared. However, a surface and bottom depression persisted primarily within the central channel. Relatively warm, late-summer water temperatures (22 to 27 °C) and low San Joaquin River inflows into the channel east of Rough and Ready Island appear to have contributed to the low dissolved oxygen concentrations in the central and eastern channel. Average daily flows in the San Joaquin River past Vernalis in August ranged from 1,638 cfs to 2,802 cfs (46.4 to 79.3 $m^3/s$). Reverse flow conditions were consistently present in the San Joaquin River past Stockton, as average daily flows ranged from –401 to +89 cfs (–11.4 to +2.5 $m^3/s$) in August.

Dissolved oxygen levels continued to improve in early September, but returned to depressed levels by the end of the month. On September 12, surface and bottom dissolved oxygen levels at all stations were 6.8 mg/L or greater. However, stratified dissolved oxygen conditions returned to Stations 10 through 13 in the eastern channel. On September 26, a dissolved oxygen depression returned to the central channel, with surface values at Stations 6 and 7, and bottom values at Stations 6 through 9 ranging from 5.0 to 5.8 mg/L. The minimum surface and bottom dissolved oxygen values of 5.0 mg/L were measured at Station 7 in the heart of this region. Although September water temperatures (21 to 24 °C) were slightly cooler than August temperatures within the channel, September flows in the San Joaquin River were similar to those of August. Average daily flows past Vernalis ranged from 2,022 to 2,930 cfs (57.3 to 83.0 $m^3/s$). Intermittent reverse flow conditions past Stockton persisted in September as average daily flows ranged from –244 to +170 cfs (–6.9 to 4.8 $m^3/s$).

1. Monitoring of the channel by vessel is supplemented by information from an automated multi-parameter water quality recording station near Stockton at the western end of Rough and Ready Island.

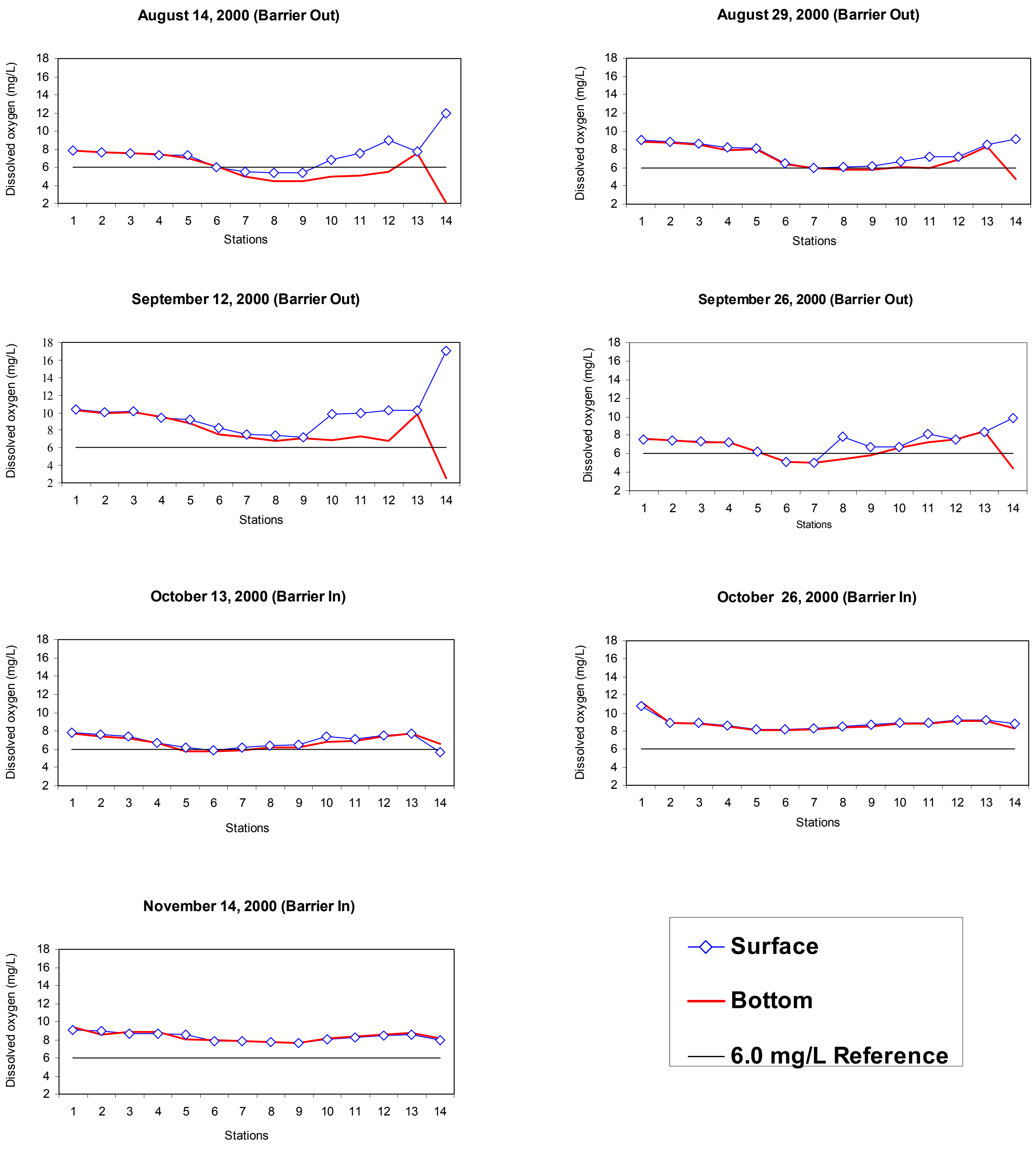


**Figure 2 Dissolved oxygen concentrations in the Stockton Ship Channel in 2000**

A gradual but sustained improvement of dissolved oxygen conditions within the channel occurred in October. Initial sampling on October 13 showed a minor depression within the center of the channel, with bottom levels between 5.8 to 5.9 mg/L at Stations 5 through 7, and a surface measurement of 5.9 mg/L at Station 5. By October 26, conditions throughout the channel had recovered substantially. Dissolved oxygen concentrations throughout the channel were greater than 8.0 mg/L. These higher values can be attributed to cooler water temperatures (14 to 19 °C) and locally improved inflow conditions. Average daily river flows past Vernalis ranged from 2,223 to 3,658 cfs (62.9 to 103.6 $m^3/s$) in October, and intermittent reverse flow conditions past Stockton were eliminated through much of October. Average daily flows in the San Joaquin River past Stockton in October ranged from –146 to +626 cfs (–4.1 to 17.7 $m^3/s$).

Monitoring on November 14 confirmed a sustained improvement of dissolved oxygen levels throughout the channel. Surface dissolved oxygen levels ranged from 7.6 to 9.1 mg/L and bottom levels ranged from 7.6 to 9.4 mg/L. Water temperatures, at 12 to 16 °C, were 2 to 3 °C cooler than temperatures recorded on October 26. The relatively high San Joaquin River flows past Vernalis were maintained in November, as average daily flows past Vernalis ranged from 2,227 to 2.932 cfs (63.1 to 83.0 $m^3/s$). In addition, average daily flows past Stockton ranged from –225 to 292 cfs (–6.4 to 8.3 $m^3/s$). Cooler water temperatures, increased San Joaquin River inflows, reservoir releases, and increased rainfall apparently contributed to and maintained the improved dissolved oxygen concentrations throughout the channel. Because of the sustained improvement, no further dissolved oxygen studies were conducted.

Highly stratified dissolved oxygen conditions were detected in the Stockton Turning Basin (Station 14) throughout much of the late summer of 2000. Sampling on August 14 and 29 and September 12 and 26 showed surface dissolved oxygen concentrations ranging from 9.1 to 17.0 mg/L, and bottom dissolved oxygen concentrations ranging from 2.1 to 4.8 mg/L. Sampling on October 13 and 26, and November 14, showed that the distinct dissolved oxygen stratification had subsided, with surface dissolved oxygen concentrations ranging from 5.7 to 8.9 mg/L and bottom dissolved oxygen concentrations ranging from 6.6 to 8.3 mg/L.

The periodic dissolved oxygen stratification appears to be the result of localized biological and water quality conditions occurring in the Turning Basin. The basin is at the eastern dead-end terminus of the channel and is subject to reduced tidal activity, restricted water circulation, and increased residence times when compared to the remainder of the channel. As a result, water quality and biological conditions within the basin have historically differed from those within the main downstream channel, and have led to extensive late summer and fall algal blooms and die-offs. The late summer and early fall of 2000 were no exception, as an intense algal bloom composed of cryptomonads, diatoms, flagellates, and blue-green and green algae was detected. Stratified dissolved oxygen conditions appear to be produced in the water column of the basin by blooms in the following manner: (1) high algal productivity at the surface of the basin produces elevated surface dissolved oxygen concentrations; and, (2) dead or dying bloom algae settle out of the water column and sink to the bottom to contribute to high biochemical oxygen demand (BOD). Bottom dissolved oxygen concentrations in the basin are further degraded by additional BOD loadings in the area, such as regulated discharges into the San Joaquin River and from recreational boating activities adjacent to the basin. When bloom activity subsides, the dissolved oxygen stratification is reduced, and basin surface and bottom dissolved oxygen concentrations become less diverse.

## Conclusions

Dissolved oxygen concentrations in the central and eastern Stockton Ship Channel consistently fell below 6.0 mg/L in the late summer and early fall of 2000 due in part to relatively low flows in the San Joaquin River past Vernalis and warm water temperatures in August and September. As a result of low dissolved oxygen levels, a temporary barrier was installed at the head of Old River to increase flows down the main channel of the San Joaquin River. On October 7, 2000, dissolved oxygen levels improved to greater than 7.0 mg/L throughout the channel. Dissolved oxygen conditions improved at least partly in response to cooler water temperatures, increased San Joaquin River inflows, and the reduction of reverse flow conditions past Stockton due to the placement of the barrier, reservoir releases, and increasing rainfall. The barrier was removed on December 8, 2000.

## References

[CVRWCB] 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, Sacramento River Basin and San Joaquin River Basin. 4th ed. Sacramento, CA. 80 p.

[SWRCB] State Water Resources Control Board. 1995. Water Quality Control Plan for the San Francisco Bay/ Sacramento-San Joaquin Estuary. Sacramento, CA. 45 p.

[SWRCB] State Water Resources Control Board. 1999. Water Right Decision 1641 to implement flow objectives for the Bay-Delta Estuary, approve a petition to change points of diversion of the CVP and SWP in the southern Delta, and approve a petition to change places of use and purposes of use of the CVP. Sacramento, CA. 211 p.

# On the Horizon

## An Update on the Early Life History of Fishes in the San Francisco Estuary and Watershed Symposium and Proceedings

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This exciting project is going full steam ahead and will be funded primarily by IEP, with some additional support from the CALFED Science Program. The symposium will take place in early 2003 and will be held in California at a conference associated with the American Fisheries Society. In an effort to inform others of the content being developed for this symposium and proceedings volume (and to put the force of peer pressure on our esteemed colleagues to complete their manuscripts on time), below is the most recent list of contributed papers and topics. Additional papers from anyone interested in publishing work on the science or management of fish early life history in the estuary, adjacent coastal ocean, or watershed are highly encouraged. Participation at the symposium for all presenters will be paid for by IEP. Contact Fred Feyrer (ffeyrer@water.ca.gov) if you are interested in participating.

- Larval fish assemblages of San Francisco Bay
  *M. McGowan (SFSU)*
- Ecology of larval herring (*Clupea harengus*) in San Francisco Bay
  *S. Bollens and A. Sanders (RTC/SFSU)*
- The importance of salinity to larval Pacific herring in San Francisco Bay
  *F. Griffin (UCD/BML)*
- Larval anchovy ecology in San Francisco Bay
  *M. McGowan (SFSU)*
- Characteristics of atherinid spawning and rearing habitat in east-central San Francisco Bay
  *A. Jahn, J. Amdur, and J. Zaitlin (Port of Oakland)*
- Larval fish ecology in Suisun Marsh
  *R. Schroeter and P. Moyle (UCD)*
- Fish abundance and distribution trends from DFG's 20-mm Survey
  *M. Dege and K. Fleming (DFG)*
- Spatial and temporal trends in larval fish abundance in the Sacramento-San Joaquin Delta
  *L. Grimaldo (DWR)*
- Ecological segregation of native and non-native larval fish communities in the southern Sacramento-San Joaquin Delta
  *F. Feyrer (DWR)*
- Cohort mortality of larval striped bass in the San Francisco Estuary, California
  *S. Foss and L. Miller (DFG)*
- Vertical distribution of delta smelt in the San Francisco Estuary, California
  *A. Rockriver and K. Fleming (DFG)*
- Egg and larval dispersion in a tidal channel with diversions using a particle tracking model
  *C. Harrison and C. Enright (DWR)*
- Tidal and diel variability in fish entrainment through screened and unscreened agricultural diversion siphons in the lower Sacramento River
  *M. Nobriga and Z. Matica (DWR)*
- Feeding ecology of larval fishes in the entrapment zone of the San Francisco Estuary, California
  *B. Bennett and J. Hobbs (UCD/BML)*