Fathead Minnow Mortality in the Sacramento River

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Routine NPDES (National Pollution Discharge Elimination System) permit monitoring by the Sacramento Regional Wastewater Treatment Plant has found that the Sacramento River below Sacramento is toxic to larval fathead minnows about 50 percent of the time. SRWTP has monitored toxicity of the Sacramento River at either Garcia Bend (river mile 52) or Freeport Marina (river mile 46) since September 1988. These sampling sites are upstream of the treatment plant discharge but downstream of the combined wastewater and most stormwater discharge points for the Sacramento urban area.

The USEPA 3-species freshwater bioassay (USEPA 1994) is used for the monitoring. In the fish portion of this test, ten larval fathead minnows are placed in each of three tanks and exposed to undiluted river water for up to 7 days. The number of dead fish in each tank is counted daily, and the dead fish are removed. The percent mortality is calculated at the end of the 7-day period by dividing the number of dead fish by the total number of fish exposed. A control, which uses uncontaminated laboratory water, is run at the same time and treated in the same manner as the sample. The sample and the control are then compared using Dunnett's multiple comparison test to determine whether a statistically significant increase in mortality has occurred in the sample compared to the control.

The SRWTP testing has occurred in three distinct phases delineated by sampling frequency, period of record, and station. Each phase is discussed below. Mortality data for Phases II and III are summarized in Table 1. Phase I is not included because no significant mortality was found. The "day" columns on the table summarize the cumulative number of dead fish on each day of the test. Most of the mortality was between days 3 and 7. The 7-day mortality in the next to the last column is an indication of chronic toxicity calculated by dividing the number of dead fish on day 7 by the total number of fish exposed. Bold indicates that 7-day mortality is statistically significant compared to the control mortality, which is recorded in the last column.

In Phase I, 16 samples were collected about monthly from the Sacramento River at Garcia Bend from September 1988 through September 1989. The samples were collected from the dock adjacent to the boat launch ramp. No significant mortality to larval fathead minnows was found in any of these samples (Aqua Terra Technologies 1989). The Central Valley Regional Water Quality Control Board also monitored fathead minnow toxicity at a nearby site, Freeport (river mile 46.5), both before (Foe 1988) and throughout this period (Connor *et al* 1993). They found significant mortality in 1 of 20 samples in May 1988, or 5% of the total.

Table 1
TOXICITY OF SACRAMENTO RIVER WATER TO LARVAL FATHEAD MINNOWS
Sacramento Regional Water Treatment Plant
Phase II and Phase III Mortality Data

Test Start Date*	Cumulative Number Dead Out of 30 Animals							7-Day Mortality** (%)	Control Mortality (%)
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7		
12/12/90	0	0	1	1	1	1	9	30	10
02/05/91	0	0	0	2	3	5	6	**20**	0
05/09/91	1	1	1	1	1	8	21	**70**	7
06/14/91	0	0	0	10	17	20	21	**70**	3
08/29/91	0	0	19	20	22	24	25	**83**	3
09/25/91	0	0	0	10	22	24	25	**86**	17
10/16/91	0	0	0	0	1	4	9	**30**	0
10/28/91							1	3	0
11/19/91	0	0	0	0	0	0	1	3	3
02/11/92	0	0	5	5	7	7	7	**24**	0
05/12/92	0	0	0	0	0	0	0	0	0
06/17/92	0	0	0	1	4	4	4	13	7
08/11/92	0	0	0	0	0	0	0	0	10
08/28/92	1	1	1	2	2	2	2	7	40
10/14/92	1	1	2	2	4	4	5	17	3
11/17/92	0	0	2	2	2	2	2	7	3
11/16/93	0	0	0	0	1	2	2	7	7
02/16/94	2	2	3	9	18	29	29	**97**	7
03/25/94	0	0	7	13	14	14	14	**47**	7
05/25/94	0	0	2	9	14	15	18	**60**	10
08/17/94	0	1	1	3	3	3	3	10	0
10/19/94	0	0	0	0	0	0	0	0	30
02/15/95	0	0	4	9	13	14	14	**47**	3
05/23/95	0	0	2	5	5	6	6	**20**	0
08/15/95	0	0	0	0	0	0	0	0	20
11/14/95	0	0	0	0	0	1	1	3	7
11/28/95	0	0	2	3	3	7	9	30	17
01/16/96	0	1	4	7	11	17	17	**57**	0
02/21/96	0	0	4	11	15	17	17	**57**	0

* Sample collection date is typically the day before the test start date.
** 7-day mortality is calculated by dividing the number of dead fish on day 7 by the number of exposed fish. 30 fish were exposed except for 9/25/92 and 2/11/92 samples, for which 29 fish were exposed. **BOLD** indicates that the 7-day mortality is significantly greater than the control ($p<0.05$).

Connor *et al* (1993) also monitored fathead minnow toxicity from March 1988 to May 1990 at 24 other sites in the Sacramento watershed. Significant mortality to larval fathead minnows was found in 12% of samples collected in April, 32% collected in May, and 12% collected in June. Some of these samples were also assayed for toxicity to larval striped bass in 96-hour static nonrenewal bioassays. Many of these samples resulted in significant mortality to larval striped bass, including two out of four samples collected from the Sacramento River at Colusa (88% mortality), two out of three samples collected from Walnut Grove (95-100%), and one sample from Rio Vista (31%) (Bailey 1988; Bailey *et al* 1989).

In Phase II, 16 samples were collected roughly bimonthly from December 1990 through November 1992. The samples were collected at Garcia Bend until February 1992, when the sampling point was moved to Freeport Marina. The Freeport Marina samples were collected from a dock upstream of the marina. Significant mortality to larval fathead minnows was found in seven of the 16 samples, or 44% of the total in February, May, June, and August-October. Statistically significant 7-day mortality ranged from 20 to 86% (AQUA-Science 1991a-1993a). These data are plotted in Figure 1.

In Phase III, which is continuing, 13 samples have been collected from the Sacramento River at Freeport Marina from November 1993 through February 1996. The samples are collected mid-channel from a boat just upstream of the marina. Samples are collected quarterly during four seasons — wet weather (December-February), low streamflow (October-December), agricultural runoff (April- June), and tomato processing (July-September). In addition to the control and 100% river water samples, river samples are diluted with laboratory water to concentrations of 6.2, 12.5, 25, and 50% ambient water and also tested for toxicity. Significant mortality to larval fathead minnows in undiluted river water was found in 7 of 13 samples, or 54% of the total in January, February, March, and May. Statistically significant 7-day mortality ranged from 20 to 97%. In the past year, since February 1995, significant mortality was found in over 70% of the samples (AQUA-Science 1993b-1996). These data are plotted in Figure 2.

Although Garcia Bend and Freeport Marina are downstream of the combined wastewater and most of the stormwater discharge from the Sacramento urban area, these are probably not the source of the toxicity. Central Valley Regional Water Quality Control Board has monitored fathead minnow mortality in undiluted urban stormwater sumps that drain residential, commercial, and industrial areas in Sacramento (Foe 1987; Connor 1995). In more than 3 years of monitoring, significant fathead minnow mortality was found only in samples from an industrial area (Connor 1996). This toxicity would be substantially diluted when combined with flows from other areas and discharged to the Sacramento River. Sacramento's Combined Wastewater Treatment Plant has also monitored fathead minnow mortality in its discharge and two retention basins since December 1991. Significant fathead minnow mortality was found in 5 of 17 samples collected through March 1995, or 29% of the total (Tomko and Bumgardner 1995). However, "no-observed-effect concentrations" suggest that these samples would not be toxic on discharge to the Sacramento River.

A toxicity identification evaluation (TIE) was conducted on the February 1996 sample in an attempt to identify the toxicant. In a TIE, which is chemical detective work, the sample is subjected to various chemical and physical treatments, and toxicity is assayed after each treatment to determine if it has been removed. Results of the TIE were inconclusive, and additional testing is required to identify the toxicant. However, results are consistent with the presence of multiple toxicants, each at or below its toxic threshold, or a cationic nonpolar organic. Suspects include surfactants, a lipophilic fungicide, and pyrethoids.

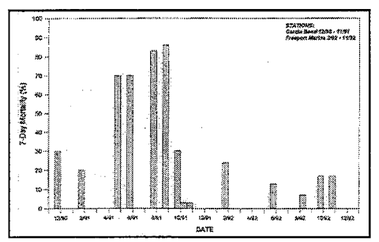

Figure 1
TOXICITY OF SACRAMENTO RIVER WATER TO LARVAL FATHEAD MINNOWS, PHASE II

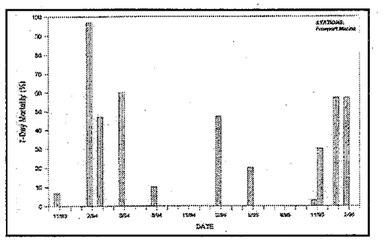

Figure 2
TOXICITY OF SACRAMENTO RIVER WATER TO LARVAL FATHEAD MINNOWS, PHASE III

The fathead minnow mortality data in Table 1 were analyzed to determine whether there is any correlation between streamflow and toxicity. The 7-day mortality data were correlated with Sacramento River flow at Freeport (from DAYFLOW). The analysis indicates that there is no relationship ($r_2=0.02$, $p=0.49$) between streamflow and toxicity. Although most of the samples are clustered around a flow of about 10,000 cfs, significant mortality was also present in two samples collected at flows over 40,000 cfs, suggesting that high flows do not dilute the toxicity.

The fathead minnow mortality data were also analyzed to determine whether there is any correlation between average larval fathead minnow mortality in May and June and striped bass abundance (fall midwater trawl index) and survival (38mm index). Striped bass was selected for this analysis because previous toxicity testing had demonstrated that the Sacramento River is periodically toxic to striped bass and it is the only species of concern that failed to respond to increased flows in 1995. This analysis indicates that there is no statistically significant relationship between either the midwater trawl index ($r_2=0.13$; $p=0.55$) or the 38mm index ($r_2=0.04$; $p=0.76$) and the SRWTP May/June larval fathead minnow mortality. This is not surprising because these are periodic grab samples and do not represent average mortality over the May-June period. Much more intensive sampling would have to be conducted to estimate average monthly toxicity.

In summary, since 1990, the Sacramento River below Sacramento has been toxic to fathead minnows about half the time. Of the 29 samples collected between December 1990 and February 1996, 14 caused significant larval fathead minnow mortality, killing 20-97 percent of exposed fish. Significant fathead minnow mortality has also been reported elsewhere in the Sacramento watershed and occurs up to 32 percent of the time in May. Based on tabulations of LC50s, most other fish appear to be more sensitive to chemicals than fathead minnows. Limited testing with larval striped bass indicates that the Sacramento River is also periodically toxic to this species. Therefore, surface water in the Sacramento River watershed may cause direct mortality to other larval fish a significant fraction of the time. This level of toxicity may have contributed to the decline of a number of species, and it may explain why striped bass failed to rally at the end of the drought in 1995.

The Central Valley Regional Water Quality Control Board and other agencies are developing a coordinated research program to expand the sampling program to define the temporal and spatial occurrence of fathead minnow toxicity, to extend the work to other fish species, and to identify the toxicant.

References

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AQUA-Science. 1991b. *Phase II Effluent Variability Study, Report 2 (May-91 and June-91,* July 7.

AQUA-Science. 1991c. *Phase II Effluent Variability Study, Report 3 (Aug-91 to Oct-91),* November 26.

AQUA-Science. 1992a. *Phase II Effluent Variability Study, Report 4 (Nov-91 and Feb-92),* March 18.

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Tomko, J., and J. Bumgardner. 1995. *Effluent and Receiving Water Quality and Toxicity Summary Report for 1991-1995 and Proposed Sampling Program for 1995/1996.* City of Sacramento Report Submitted to CVRWQCB.

USEPA. 1994. *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms.* Report EPA-600-4-91-002.

Research Enhancement Program

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For several years the Interagency Ecological Program sponsored a relatively modest Research Enhancement Program designed to stimulate research in the bay/delta ecosystem. The U.S. Environmental Protection Agency, through the San Francisco Estuary Project, contributed significant funding. The other funding came from Department of Water Resources, Department of Fish and Game, U.S. Bureau of Reclamation, and the State Water Resources Control Board.

The basic process was to solicit research proposals, obtain peer review, and award contracts based on peer review, management interests and available funding. Fifteen research contracts were awarded, with a total funding of about $802,000, of which $455,000 came from the Environmental Protection Agency.

All but three of the contracts are completed, and we received final reports from nine of the eleven completed projects. I have listed the nine final reports below, as well as some of the peer-reviewed papers that resulted either directly from the funding or from collaborative research that the funding helped make available. Contact Lisa (916/227-7541) to obtain copies of the final reports. Allow a few weeks for delivery so that Lisa can assess the overall demand for the reports before making copies.

The Research Enhancement Program has served its purpose, and it did stimulate research activities in the bay/delta. Unfortunately, agency budgets are pretty tight these days, and there is no money available to continue the program.

1. Harvey, James T., and Michael L. Torok. *Movements, Dive Behaviors, and Food Habits of Harbor Seals (Phoca vitulina richardsi) in San Francisco Bay, CA.* March 1994
2. Largier, John L. *Hydrodynamic Exchange Between San Francisco Bay and the Ocean: The Role of Ocean Circulation and Stratification.* July 1994
3. Bennett, William A., Laura Rogers-Bennett, and Peter B. Moyle. *Interactive Influence of Starvation and Predation on Mortality of Striped Bass Larvae: A Field Experimental Approach.* July 1993
4. Tjeerdema, Ronald S. and Donald G. Crosby. *Bioconcentration and Metabolic Fate of a Petroleum-Based Hydrocarbon in Striped Bass.* March 1993
5. Mager, Randall C., Serge I. Doroshov, and Joel P. Van Eenennaam. *Gonadal Development and Gametogenesis of Delta Smelt, Hypomesus transpacificus.*
6. Sobey, Rodney. *Hydrodynamic Influences on the Survival of Wetlands in San Francisco Bay.*
7. Collins, Joshua N., and Theodore C. Foin. *Evaluation of the Impacts of Aqueous Salinity on the Shoreline Vegetation of Tidal Marshlands in the San Francisco Estuary.* October 1992
8. Werner, Ingeborg, Kurt F. Kline, and James T. Hollibaugh. *Stress Proteins in Amphipods as Biomarkers of Sediment Pollution in San Francisco Bay.* (Technical Report 48). In press (likely available in August).
9. Orr, Michelle, and James R. Hunt. *Aggregation of Petroleum Hydrocarbons with Particles in Urban Runoff and Estuarine Water.* July 1996

Although we have not received final reports for three additional projects, they have generated several journal and otherwise peer-reviewed publications, as listed below. (These are examples I had on hand, and I suspect that the nine projects above also had publications.)

10. Daehler, Curtis, and Donald R. Strong. *Status Ecology and Potential Control of the Invasive Alien Cordgrass in San Francisco Bay* (final report pending).
    - ➛Daehler, Curtis C., and Donald R. Strong. *Status, Prediction, and Prevention of Introduced Cordgrass (Spartina spp.),* (in press).
    - ➛*Reduced Herbivore Resistance in Introduced Smooth Cordgrass (Spartina alterniflora) after a Century of Herbivore-free Growth* (in press).
    - ➛*Spread and Control of Alien Smooth Cordgrass in San Francisco Bay. Impact of High Herbivore Densities on Introduced Smooth Cordgrass, Spartina alterniflora, Invading San Francisco Bay, CA* (in press)
11. Flegal, Russell. *Pore Water Geo-Chemistry of Trace Elements in South Bay.* (final report pending).
    - ➛Flegal, A.R., I. Rivera-Duarte, S.A. Sañudo-Wilhelmy. *Silver Contamination in Aquatic Environments. Reviews of Environmental Contamination and Toxicology* (in press).
    - ➛Rivera-Duarte, I. and A.R. Flegal. *Porewater Gradients and Diffusive Benthic Fluxes from Relatively Pristine and Contaminated Sites in San Francisco Bay: Co, Ni, Cu, Zn, and Cd. Croatica Chimica Acta* (in press).
    - ➛Rivera-Duarte, I. and A.R. Flegal. *Microtechniques for the Determination of Nanomolar Concentrations of Trace Elements in ≤10mL of Sediment Porewater. Analytica Chimica Acta.* (in press).
    - ➛Sañudo-Wilhelmy, S.A., I. Rivera-Duarte, and A.R. Flegal. *Cycling and Distribution of Colloidal Trace Metals in the San Francisco Bay Estuary. Geochimica et Cosmochimica Acta* (in press).
    - ➛Sañudo-Wilhelmy, S.A., I. Rivera-Duarte and A.R. Flegal. *Cycling and Distribution of Colloidal Trace Metals in the San Francisco Bay Estuary. Geochimica et Cosmochimica Aca* (in press).