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April 6, 2001

Via e-mail and US Postal Service.

R30-A

Joe Karkoski
303(d) List Update Coordinator
California Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, CA 95827

Putah Creek

01 APR 10 AM 11:18

RECEIVED SACRAMENTO CVRWQCB

Dear Mr. Karkoski,

The Davis South Campus Superfund Oversight Committee (DSCSOC) is submitting the enclosed information in response to the CVRWQCB's request for "Public Solicitation of Water Quality Information."

DSCSOC is a US EPA Technical Advisor Grant (TAG) group for the UCD/DOE LEHR Superfund Site on the UC Davis campus in Davis, CA. DSCSOC is the citizens oversight group, which received its first TAG in 1995 when the site was placed on the National Priority List.

DSCSOC hired G. Fred Lee, PhD, DEE, as its technical advisor in 1995 and Dr. Lee has served in that capacity since that time. As part of Dr. Lee's responsibility he has reviewed the water quality of Putah Creek. Based on his review he recommended that the US EPA, CVRWQCB, DTSC and other RPMs for the LEHR Superfund site conduct a study to see if the fish in Putah Creek contain excessive concentrations of constituents that would cause them to be considered hazardous to use a food.

The Agency for Toxic Substance and Disease Registry (ATSDR), Division of Health Assessment and Consultation, Federal Facilities Assessment Branch, Energy Section, is conducting the Health Risk Assessment for the UCD/DOE LEHR site. As part of its assessment, ATSDR in cooperation with the US EPA conducted two fish sampling studies of Putah Creek. It was found that the mercury concentrations in some Putah Creek fish contain hazardous levels of mercury. DSCSOC is submitting ATSDR's studies and related comments for consideration for placing Putah Creek on the revised list of waters considered by the State to be impaired.

As a follow up studies the University of California Davis had Dr. Darell Slotton of UCD conduct a fish survey to determine the levels of mercury of Putah Creek fish. He found that not only did the fish near the LEHR site contain hazardous concentrations of mercury but also some fish through Putah Creek has excessive levels of mercury compared to US EPA guidelines for protection of human health.

The ATSDR and Slotton results clearly show that some fish in Putah Creek contain excessive levels of mercury. These results should cause Putah Creek to be listed as 303 (d) listed as impaired. We request that the CVRWQCB list Putah Creek as impaired because of excessive mercury concentrations in some of the fish that are used as food.

Enclosed documents:

1. "To individuals interested in hazardous chemical bioaccumulation in Putah Creek fish." By G. Fred Lee, PhD. DEE, dated April 16, 1999.

2. "*Health Consultation, Fish Sampling in Putah Creek 1996, Laboratory for Energy-Related Health Research, Davis, California dated April 4, 1997.*" Prepared by Agency for Toxic Substance and Disease Registry, Division of Health Assessment and Consultation, Federal Facilities Assessment Branch, Energy Section.

3. "Comments on, *Follow up Sampling and Analysis Guidelines for* Fish, *Sediment, and Water Sampling from the Putah Creek Adjacent to the Former Laboratory for Energy-Related Health Research, Davis, CA. Draft 2.2 dated September 17, 1997. Prepared by B. Lloyd and S. Telofski, US EPA-NAREL, Montgomery, AL.*" Submitted by G. Fred Lee, PhD. DEE, Technical Advisor to DSCSOC dated October 10, 1997.

4. "*Health Consultation, Survey of Fish in Putah Creek (Phase II) Laboratory for Energy-Related Health Research Davis California dated September 16, 1998.*" Prepared by the Agency For Toxic Substance and Disease Registry, Division of Health Assessment and Consultation, Federal Facilities Assessment Branch, Energy Section.

5. Letter to Gary Carlton, Executive Director, Central Valley Regional Water Quality Control Board from Julie Roth, Executive Director, Davis South Campus Superfund Oversight Committee dated October 12, 1997.

6. "Comments on the *US Department of Health and Human Services Public Health Service, Agency for Toxic Substance and Disease Registry, Draft Health Consultation, Fish Sampling of Putah Creek (Phase II) for the LEHR National Superfund Site* dated September 16, 1998." Comments submitted by G. Fred Lee, PhD. DEE, DSCSOC LEHR Superfund Site Technical Assistance Grant Advisor, dated October 24, 1998.

7. Letter to Gary M. Carlton, Executive Officer, Central Valley Regional Water Quality Control Board, from G. Fred Lee, PhD. DEE, dated October 26, 1998.

8. Letter to William Taylor, PhD, Agency for Toxic Substance and Disease Registry from Julie Roth, Executive Director, Davis South Campus Superfund Oversight Committee, dated September 30, 1998.

9. *"Lower Putah Creek 1997-1998 Mercury Biological Distribution Study."* Conducted For: The Department of Environmental Health and Safety, University of California, Davis. Study and Report by Darell G. Slotten, Shaun M. Ayers, John E. Reuter and Charles R. Goldman, dated February 1999.

See Libr. Hg0018

The attachment can be read with an Acrobat Reader. Please advise me if you need additional information. Thank you for consideration of this request.

Sincerely,

Julie Roth

Julie Roth, Executive Director

G. Fred Lee & Associates

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2-30-10

April 16, 1999

To individuals interested in hazardous chemical bioaccumulation in Putah Creek fish:

Attached are the two ATSDR reports covering the analysis of Putah Creek fish for mercury and chlorinated hydrocarbon pesticides and PCBs. The first report was finalized by ATSDR. The second report is only available thus far in draft form. I have also enclosed my comments on both reports.

As indicated, while there are significant problems with how the studies were conducted and, to some extent, the reporting of the results, the data that shows that some fish in Putah Creek contain excessive mercury compared to values that are typically used to issue fish consumption advisories are valid. If anything, the magnitude of the mercury bioaccumulation problem for the large game fish is greater than that indicated in the initial study due to the study including small fish in the composite sample.

Dr. Daryl Slotton has indicated that his data on Putah Creek fish also shows elevated concentrations of mercury. I understand that he will be making his report available in the near future.

Based on the existing data, there is need for Putah Creek to be included in the waterbodies being studied in the Central Valley because of the elevated mercury in edible fish tissue. These studies should include a comprehensive multi-year assessment of the bioaccumulation of mercury in edible fish and other organisms, the sources of the mercury, the discharges such as UCD's wastewater treatment plant, that under low flow conditions create an environment in Putah Creek that stimulates methylation of mercury, and investigation of possible control programs. Further, the public, who fish Putah Creek, should be warned that some of the fish in this creek have been found to contain excessive mercury.

As discussed in my comments on the two ATSDR studies, at this time there is inadequate data on the bioaccumulation of chlorinated hydrocarbon pesticides, PCBs and dioxins in Putah Creek fish. The first ATSDR study used inadequate analytical detection methods to detect potential problems due to the chlorinated hydrocarbons. In the second study there was a refrigerator malfunction which caused many of the samples for chlorinated hydrocarbon analyses to be lost. The San Francisco Estuary Institute has been collecting freshwater clams from Putah Creek for several years for use as part of their bioaccumulation monitoring of other waterbodies. As reported in their annual reports for the past three years, SFEI has found that clams taken from Putah Creek contain significantly elevated concentrations of chlorinated hydrocarbon pesticides. Based on these results it is highly likely that the Putah Creek fish with higher fat content will also contain elevated, and likely excessive, concentrations of several chlorinated hydrocarbons that are regulated as carcinogens. Future studies on bioaccumulation of hazardous chemicals in Putah Creek fish should include measurements of the chlorinated hydrocarbon pesticides, PCBs and dioxins, using appropriate analytical procedures.

Thus far, Mr. G. Carlton, executive officer for the CVRWQCB, has not responded to the October, 1998 letter that I developed at the request of members of the public who are concerned about the excessive bioaccumulation of hazardous chemicals in Putah Creek fish.

While I was not responsible for the planning, implementation and reporting of these studies, I can possibly answer questions about some aspects of them.

G. Fred Lee

HEALTH CONSULTATION

R30-C

FISH SAMPLING IN PUTAH CREEK, 1996

Laboratory for Energy-Related Health Research
Davis, California

CERCLIS NO. CA2890190000

April 4, 1997

Prepared by

Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Federal Facilities Assessment Branch
Energy Section

BACKGROUND

The Agency for Toxic Substances and Disease Registry (ATSDR) is mandated by Congress under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to conduct public health assessments at all sites listed or proposed for listing on the National Priorities List (NPL, or Superfund list). The Laboratory for Energy-Related Health Research (LEHR) in Davis, California, was listed on the NPL in May 1994.

ATSDR staff first visited the LEHR site in July 1995. As a result of that visit and after reviewing documents pertaining to the site, we issued a site summary report in December 1995. In that report, we recommended that the fish in Putah Creek, adjacent to the LEHR site, be sampled to ensure that people who eat the fish from the creek are not being exposed to unsafe levels of contamination. As a followup to this recommendation, ATSDR asked the Environmental Protection Agency's (EPA's) National Air and Radiation Environmental Laboratory (NAREL) to assist us by collecting and analyzing fish from Putah Creek near the LEHR site. NAREL completed the fish screening survey in September 1996, and this report contains a summary of the results of that study.

EPA NAREL staff asked EPA Region IX scientists to help with this fish survey. EPA Region IX scientists collected a total of 141 fish and crayfish from four locations along Putah Creek in a two week period during August and September 1996. They also collected water and sediment samples from the creek at the same four locations. They packaged the samples and sent them to the NAREL in Montgomery, Alabama, for analysis. NAREL scientists filleted the fish and removed the crayfish tails and, in some cases, combined them to have enough sample for analysis [1].

We have attached the data from the laboratory analyses of fish, water, and sediment collected from Putah Creek to the end of this report. ATSDR scientists and NAREL scientists reviewed the NAREL data [2]. ATSDR offers the following conclusions and recommendations:

CONCLUSIONS

1. Mercury and lead concentrations in some fish collected from Putah Creek pose a public health hazard.

2. Based on the samples that EPA Region IX collected in August and September 1996, neither the water nor the sediment in Putah Creek directly poses a public health hazard.

3. Radionuclides, organic pesticides, polychlorinated biphenyls (PCBs), and metals other than mercury and lead were not present in the fish, water, or sediment collected from Putah Creek in concentrations that pose a public health hazard.

RECOMMENDATIONS

1. Conduct an additional fish study to define the concentration of mercury and lead in different fish species within selected length ranges.

2. Until further data are available, post a general fish advisory for areas of Putah Creek near the former LEHR site; elevated concentrations of mercury and lead in the collected fish justify the advisory.

DISCUSSION

Mercury and lead in fish and crayfish collected from Putah Creek were present at levels that pose a public health hazard. The fish and crayfish that contain elevated levels of mercury or lead were collected at the location (Site #1) nearest the LEHR site. The high concentrations of mercury (0.69 milligrams of mercury per kilogram of wet fish [mg Hg/kg-wet fish]) and lead (1.06 milligrams lead per kilogram of wet fish [mg Pb/kg-wet fish]) were measured in two separate composites of fish fillets (or fish fillets and crayfish tails); each composite was made up of three different species of fish (six species in all). Composite 1 at Site #1 had approximately four times the mercury concentration of Composite 2, and Composite 2 had approximately four times the lead concentration of Composite 1. These data suggest that the bioconcentration of mercury and lead may vary by species of fish. In addition, because these samples are composites, these data reflect *average* concentrations. This means that one or two fish species may have much higher levels of mercury or lead than the maximum levels reported, and other species may have little or no mercury or lead.

ATSDR scientists note that the highest concentrations of mercury and lead reported by NAREL in these samples are higher than concentrations that may be considered toxic to people who would eat these fish frequently. The actual hazard to people depends on how often the people eat the contaminated fish and how much of the fish they eat. Because we do not know how much fish people actually eat from Putah Creek, we based our evaluation on estimated average fish consumption rates for the general U.S. population [3, 4].

Our conclusions and recommendations are based on a limited amount of data because we combined many fish into composite samples to have sufficient sample sizes to perform all the analyses we had planned.

We found that contamination is not at levels that pose a health hazard in the water or sediment. However, lead was in all the sediment samples, and mercury was in those sediment samples from Site #1--the same location where the fish with the highest concentration of mercury were collected.

Mercury and lead are especially toxic to fetuses, infants, and children. Both mercury and lead affect the central nervous system; both methylmercury (the most prevalent form of mercury found in fish) and lead are able to cross the placental and blood-brain barriers in children and cause permanent brain damage. Early signs of mercury poisoning are often nonspecific, e.g., malaise, blurred vision, or hearing loss; higher blood levels of mercury will cause kidney damage. Effects of lead poisoning in children are similar to those of mercury poisoning: impaired neurological development, lower IQ scores, and hearing loss. At significantly elevated blood levels, lead can interfere with normal cell metabolism and induce anemia [5, 6].

We recommend additional fish sampling to differentiate mercury and lead contamination across different species and sizes of fish in Putah Creek. Fish size or length is a surrogate for fish age. Since the fish can bioconcentrate the contaminants (mercury and lead), we expect the older fish will have the highest concentrations of contaminants. Additional fish sampling can clarify whether people who catch fish in Putah Creek should limit their consumption of those fish to certain species and size. Unlike the initial screening survey, which investigated many different contaminants and required large sample weights for the large number of different analytes, the next fishing survey should have to address mercury and lead contamination only. The laboratory analyses for mercury and lead require only small amounts (50 grams wet weight, total) of fish.

For questions or comments, please contact Dr. William H. Taylor, Health Assessor, Agency for Toxic Substances and Disease Registry, Mailstop E-56, Atlanta, Georgia 30333, 404-639-6035.

ATSDR is performing a public health assessment on the LEHR Site. The ATSDR public health assessment is scheduled for release in 1998.

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REFERENCES

1. Environmental Protection Agency, National Air and Radiation Environmental Laboratory. Sampling and analysis guidelines for fish, sediment, and water samples from the Putah Creek adjacent to the former Laboratory for Energy-Related Health Research, Davis, CA. 1997 Aug 24.

2. Environmental Protection Agency, National Air and Radiation Environmental Laboratory. Concentrations of selected radionuclides and chemicals in fish, sediment, and water collected from the Putah Creek near the former Laboratory for Energy-Related Health Research, Davis, CA. 1997 Mar 31.

3. Environmental Protection Agency. Guidance for assessing chemical contamination data for use in fish advisories, volume 1, fish sampling and analysis, second edition; 1995 Sep. Report No.:EPA 823-R-95-007,

4. U.S. Department of Agriculture. Food and nutrient intakes by individuals in the United States, 1 day, 1987-1988, nationwide food consumption survey; 1993 Sep. Report No.: 87-I-1.

5. Agency for Toxic Substances and Disease Registry. Toxicological profile for mercury (update). Atlanta: US Department of Health and Human Services, Public Health Service, 1994.

6. Agency for Toxic Substances and Disease Registry. Toxicological profile for lead (update). Atlanta: US Department of Health and Human Services, Public Health Service, 1993.

DATA TABLES FROM ATSDR / EPA NAREL FISH SAMPLING SURVEY, PUTAH CREEK, DAVIS CALIFORNIA, AUGUST-SEPTEMBER 1996

Table 1. Sampling Locations in Putah Creek Adjacent to the LEHR Site, Aug 27-Sep 12, 1996

Sampling Locations for Fish, Sediment, and Water		
Sampling Location	Latitude	Longitude
1	N 38° 31' 2.0"	W 121° 45' 22.1"
2	N 38° 31' 1.6"	W 121° 43' 58.0"
3	N 38° 31' 0.7"	W 121° 42' 46.8"
4 (background)	N 38° 31' 34.4"	W 121° 48' 42.9"

Figure 1.

Putah Creek
Sampling Locations

Table 2. Fish Collected from Putah Creek near the Former LEHR Facility, Aug 27-Sep 12, 1996

Location	Fish Species (#)	Whole Wet Weight (g)	Fillet Wet Weight (g)
1	Black Crappie (2)	489	168
	Bluegill (1)	136	37
	Large Mouth Bass (2)	1122	421
	Composite 1 (5)	1747	626
	Crayfish (10)	413	38
	Black Bullhead (4)	1115	209
	White Catfish (2)	1492	262
	Composite 2 (16)	3020	509
2	Carp (1)	1564	367
	Black Bullhead (1)	212	46
	Composite (2)	1776	413
	Large Month Bass (1)	650	188
3	Black Crappie (2)	364	92
	Large Mouth Bass (1)	1234	362
	Composite 1 (3)	1598	454
	Crayfish (9)	289	26
	Carp (1)	1696	495
	Composite 2 (10)	1985	521
	White Catfish (1)	2624	670
4(background)	Bluegill (78)	1906	394
	Green Sunfish (13)	627	127
	Large Month Bass (3)	192	45
	Crayfish (8)	221	42
	White Catfish (1)	89	12
	Composite (103)	3035	620

Table 3. Radiological Results for Water Collected from Putah Creek near the Former LEHR Facility

Analyte	Site #1 LEHR96.05001/X (pCi/L)		Site #2 LEHR96.05000/X (pCi/L)		Site #3 LEHR96.05005 (pCi/L)	Site #4 LEHR96.04998 (pCi/L)
Gross Alpha	2.57±1.93	3.18±2.19	5.71±2.75	NA	4.57±2.54	1.76±1.73
Gross Beta	3.63±2.20	5.29±2.46	4.41±2.39	NA	6.87±2.67	2.76±2.22
U-238	0.2709±0.0699	NA	0.3430±0.0798	0.3819±0.0813	0.3737±0.0698	0.2737±0.0678
U-234	0.6306±0.1101	NA	0.5139±0.0984	0.6414±0.1075	0.6465±0.0937	0.6238±0.1055
Th-230	0.0414±0.0289	NA	0.0624±0.0340	0.0456±0.0326	0.0480±0.0267	0.0411±0.0282
Ra-226 (γ)	≤77.5	≤74.3	≤78.0	NA	≤79.2	≤85.6
Ra-226	0.26±0.03	0.22±0.05	0.07±0.01	NA	0.09±0.02	0.11±0.02
U-235	0.0463±0.0310	ND	0.0423±0.0309	0.0209±0.0221	0.0835±0.0350	0.0599±0.0361
Th-227	0.0095±0.0291	NA	0.0090±0.0275	0.0639±0.0635	0.0123±0.0214	0.0364±0.0364
Th-232	0.0238±0.0238	NA	0.0101±0.0156	0.0118±0.0182	0.0455±0.0268	0.0103±0.0158
Ra-228 (γ)	≤17.0	≤17.1	≤16.8	NA	≤16.2	≤24.0
Ra-228	2.9±1.0	1.0±1.0	0.35±0.75	NA	-0.12±0.78	0.88±0.73
Th-228	0.0202±0.0680	NA	0.0240±0.0651	0.0284±0.0718	0.0231±0.0555	-0.0330±0.0518
Tl-208	ND	ND	1.67±3.06	NA	ND	ND
Pu-238	0.0072±0.0131	NA	0.0286±0.0317	-0.0077±0.0292	0.0640±0.0564	0.0263±0.0358
Pu-239/240	-0.0012±0.0024	NA	0.00136±0.0090	0.0124±0.0164	0.0021±0.0137	0.0000±0.0101
K-40	≤51.6	≤54.9	≤51.6	NA	≤51.9	33.2±62.8
C-14	-80±82	-72±82	-96±81	NA	-77±82	NA
Ba-140	≤99.9	≤101	≤96.2	NA	≤99.0	≤161
Co-60	≤5.84	≤5.28	≤6.43	NA	≤5.62	≤8.44
Cs-137	≤4.52	≤4.31	≤4.16	NA	≤4.48	≤6.58
I-131	≤79.7	≤79.0	≤79.4	NA	≤80.2	≤101
Sr-89	-3.01±4.76	NA	3.78±4.80	NA	2.08±4.80	1.90±4.41*
Sr-90	0.571±0.717	NA	-0.400±0.755	NA	0.0112±0.757	-0.134±0.667*

(γ) -- measured by gamma spectrometry with a corresponding radiochemical analysis. ND -- not detected.
NA -- not analyzed. X -- designates a replicate analysis.
* Replicate analysis: Sr-89, 7.47±4.96 pCi/L; Sr-90, -0.750±0.740 pCi/L.
"Less than value" is equal to the Minimum Detectable Concentration (MDC).

Table 4. Inorganic Results For Water Collected From Putah Creek Near The Former LEHR Facility

Analyte	CAS Number	Site #1 LEHR96.05001[X] (μg/L or ppb)		Site #2 LEHR96.05000 (μg/L or ppb)	Site #3 LEHR96.05005 (μg/L or ppb)	Site #4 LEHR96.04998 (μg/L or ppb)
Antimony	7440-36-0	2.48[B]	4.43[B]	2.24[B]	2.52[B]	1.94[B]
Arsenic	7440-38-2	3.08[B]	2.03[B]	2.29[B]	3.08[B]	1.31[B]
Barium	7440-39-3	190.0[B]	260.0[B]	530.0[B]	570.0[B]	400.0[B]
Cadmium	7440-43-9	≤0.36	≤0.36	≤0.36	≤0.36	≤0.36
Chromium	7440-47-3	60.0[B]	60.0[B]	30.0[B]	50.0[B]	30.0[B]
Cobalt	7440-48-4	≤2.5	≤2.5	≤2.5	2.6[B]	≤2.5
Lead	7439-92-1	3.02	1.57[B]	≤1.26	1.52[B]	≤1.26
Mercury	7439-97-6	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05
Nickel	7440-02-0	7.1[B]	8.07[B]	≤5.5	17.8[B]	≤5.5
Selenium	7782-49-2	≤1.07	≤1.07	≤1.07	≤1.07	≤1.07
Silver	7440-22-4	≤0.18	≤0.18	≤0.18	≤0.18	0.21[B]
Thallium	7440-28-0	≤0.80	≤0.80	2.01[B]	≤0.80	≤0.80
Vanadium	7440-62-2	7.8[B]	7.5[B]	7.2[B]	12.5[B]	6.1[B]
Zinc	7440-66-6	70.0	80.0	60.0	70.0	60.0

[B] The value is less than the Reporting Limit but greater than or equal to the Instrument Detection Limit (IDL).

[X] The values in the second column are from a replicate analysis.

Table 5. Organic Results For Water Collected From Putah Creek Near The Former LEHR Facility

Analyte	CAS Number	Site #1 LEHR96.05001 (μg/L or ppb)	Site #2 LEHR96.05000 (μg/L or ppb)	Site #3 LEHR96.05005 (μg/L or ppb)	Site #4 LEHR96.04997 (μg/L or ppb)
Chlordane (Total)	57-74-9	≤0.05	≤0.05	≤0.05	≤0.05
4,4"-DDT	50-29-3	≤0.10	≤0.10	≤0.10	≤0.10
Dicofol	115-32-2	≤0.20	≤0.20	≤0.20	≤0.20
Dieldrin	60-57-1	≤0.10	≤0.10	≤0.10	≤0.10
Endosulfan I	959-98-8	≤0.05	≤0.05	≤0.05	≤0.05
Endosulfan II	33213-65-9	≤0.10	≤0.10	≤0.10	≤0.10
Endrin	72-20-8	≤0.10	≤0.10	≤0.10	≤0.10
Heptachlor Epoxide	1024-57-3	≤0.05	≤0.05	≤0.05	≤0.05
Hexachlorobenzene	118-74-1	≤0.05	≤0.05	≤0.05	≤0.05
Lindane	58-89-9	≤0.05	≤0.05	≤0.05	≤0.05
Toxaphene	8001-35-2	≤5.0	≤5.0	≤5.0	≤5.0
Aroclor 1016	12674-11-2	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1221	11104-28-2	≤2.0	≤2.0	≤2.0	≤2.0
Aroclor 1232	11141-16-5	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1242	53469-21-9	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1248	12672-29-6	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1254	11097-69-1	≤1.0	≤1.0	≤1.0	≤1.0
Aroclor 1260	11096-82-5	≤1.0	≤1.0	≤1.0	≤1.0

Note: The "less than value" is the Reporting Limit, i.e., analyte was analyzed for but not detected.

Table 6. Radiological Results for Sediment Collected from Putah Creek near the Former LEHR Facility

Analyte	Site #1 LEHR96.05002/X (pCi/g-dry)		Site #2 LEHR96.05003 (pCi/g-dry)	Site #3 LEHR96.05004 (pCi/g-dry)	Site #4 LEHR96.04999/X (pCi/g-dry)	
Gross Alpha	7.17±5.25	5.91±5.01	8.00±5.21	10.2±5.70	7.42±5.53	NA
Gross Beta	14.8±3.31	13.4±3.16	17.1±3.38	12.6±3.06	12.4±3.19	NA
U-238	0.343±0.0779	0.435±0.0904	0.631±0.102	0.459±0.0727	0.523±0.0971	NA
Th-234	ND	NA	0.399±0.150	ND	ND	ND
U-234	0.555±0.101	0.544±0.101	0.627±0.100	0.565±0.0810	0.431±0.088	NA
Th-230	0.369±0.0707	0.387±0.0682	0.576±0.0843	0.488±0.0753	0.549±0.0863	NA
Ra-226 (γ)	0.698±0.145	NA	1.30±0.223	0.860±0.207	1.06±0.216	1.24±0.201
Ra-226	0.43±0.04	0.41±0.03	0.92±0.04	0.59±0.03	0.71±0.04	NA
Pb-214	0.314±0.0158	NA	0.481±0.0214	0.385±0.0198	0.484±0.0219	0.561±0.0209
Bi-214	0.286±0.0169	NA	0.458±0.0230	0.369±0.0212	0.445±0.0238	0.518±0.0219
U-235	0.0285±0.0275	0.0684±0.0400	0.0806±0.0400	0.0483±0.0250	0.0698±0.0392	0.0755±0.0122
U-235 (γ)	ND	NA	0.0799±0.0134	ND	ND	ND
Th-227	0.0183±0.0254	0.0414±0.0308	0.0256±0.0248	0.0207±0.0207	0.0502±0.0366	NA
Ra-223	ND	NA	0.0681±0.0448	ND	ND	ND
Th-232	0.290±0.0624	0.326±0.0624	0.587±0.0851	0.545±0.0795	0.477±0.0802	NA
Ra-228 (γ)	0.296±0.0210	NA	0.594±0.0316	0.420±0.0296	0.483±0.0313	0.532±0.0295
Ra-228	1.1±0.56	0.99±0.52	1.7±0.54	0.94±0.56	0.99±0.65	NA
Th-228	0.314±0.0654	0.332±0.0638	0.676±0.0919	0.414±0.0699	0.510±0.0831	NA
Ra-224	0.223±0.155	NA	0.470±0.218	0.276±0.219	0.477±0.230	0.578±0.207
Pb-212	0.304±0.0165	NA	0.675±0.0236	0.432±0.0202	0.562±0.0230	0.574±0.0217
Bi-212	0.349±0.0901	NA	0.627±0.126	0.488±0.105	0.591±0.121	0.501±0.117
Tl-208	0.113±0.00936	NA	0.216±0.0127	0.154±0.0117	0.173±0.0128	0.199±0.0127
Pu-238	-0.00486±0.0335	-0.00272±0.0265	0.00475±0.0369	0.0000±0.0075	0.0224±0.0416	NA
Pu-239/240	0.0227±0.0215	0.00818±0.0147	0.00317±0.0098	0.00606±0.0084	0.00203±0.0132	NA
K-40	8.35±0.193	NA	13.7±0.271	9.83±0.253	9.87±0.266	9.92±0.239
Cs-137	0.0140±0.0057	NA	≤0.0167	0.0245±0.0079	≤0.0186	≤0.0179
Ba-140	≤0.308	NA	≤0.360	≤0.337	≤0.405	≤3.64
Co-60	≤0.0171	NA	≤0.0211	≤0.0194	≤0.0224	≤0.0201

Analyte	Site #1 LEHR96.05002/X (pCi/g-dry)		Site #2 LEHR96.0500 3 (pCi/g-dry)	Site #3 LEHR96.0500 4 (pCi/g-dry)	Site #4 LEHR96.04999/X (pCi/g-dry)	
1-131	≤0.250	NA	≤0.292	≤0.246	≤0.330	≤11.6
Sr-89	6.38±4.78'	NA	1.29±3.76	1.70±4.14	0.673±4.01	2.35±3.84
Sr-90	-0.662±0.659	NA	-0.128±0.561	-0.329±0.656	0.0351±0.612	0.187±0.561

"Less than value" is equal to the Minimum Detectable Concentration (MDC). γ – measured by gamma spectrometry. ND - not detected.

NA - not analyzed. + – less than MDC. X - designates replicate analysis.

Table 7. Inorganic Results for Sediment Collected from Putah Creek near the Former LEHR Facility

Analyte	CAS Number	Site #1 LEHR96.05002[X] (mg/kg or ppm)		Site #2 LEHR96.05003 (mg/kg or ppm)	Site #3 LEHR96.05004 (mg/kg or ppm)	Site #4 LEHR96.04999[X] (mg/kg or ppm)	
Antimony	7440-36-0	0.64[B]	0.54[B]	1.11[B]	0.92[B]	1.36	NA
Arsenic	7440-38-2	6.19	NA	10.12	5.92	12.09	12.35
Barium	7440-39-3	≤49.36	57.22[B]	98.05[B]	82.77[B]	127.01[B]	NA
Cadmium	7440-43-9	≤0.09	NA	≤0.09	≤0.10	0.48	0.19[B]
Chromium	7440-47-3	239.94	292.32	89.79	220.18	173.32	NA
Cobalt	7440-48-4	20.9	20.91	15.0	16.2	21.3	NA
Lead	7439-92-1	7.22	NA	9.93	9.06	9.27	9.52
Mercury	7439-97-6	0.15	0.18	≤0.03	≤0.03	≤0.03	NA
Nickel	7440-02-0	248	247.69	65.1	175	177	NA
Selenium	7782-49-2	0.29[B]	NA	0.31[B]	0.37[B]	0.40[B]	0.33[B]
Silver	7440-22-4	0.42	NA	0.07[B]	0.25[B]	0.11[B]	0.05[B]
Thallium	7440-28-0	≤0.21	NA	0.23[B]	≤0.22	0.22[B]	0.22[B]
Vanadium	7440-62-2	42.00	42.02	56.9	43.1	59.3	NA
Zinc	7440-66-6	102.45	150.32	162.04	116.99	105.32	NA

[B] The value is less than the Reporting Limit but greater than or equal to the Instrument Detection Limit (IDL).
[X] The values in the second column are from a replicate analysis. NA -- not analyzed.

Table 8. Organic Results for Sediment Collected from Putah Creek near the Former LEHR Facility

Analyte	CAS Number	Site #1 LEHR96.05002 (μg/kg or ppb)	Site #2 LEHR96.05003 (μg/kg or ppb)	Site #3 LEHR96.05004 (μg/kg or ppb)	Site #4 LEHR96.04999 (μg/kg or ppb)
Chlordane (Total)	57-74-9	≤2.2	≤2.2	≤2.3	≤2.2
4,4"-DDT	50-29-3	≤4.3	≤4.2	≤4.5	≤4.4
Dicofol	115-32-2	≤8.6	≤8.4	≤9.0	≤8.7
Dieldrin	60-57-1	≤4.3	≤4.2	≤4.5	≤2.2
Endosulfan I	959-98-8	≤2.2	≤2.2	≤2.3	≤2.2
Endosulfan II	33213-65-9	≤4.3	≤4.2	≤4.5	≤4.4
Endrin	72-20-8	≤4.3	≤4.2	≤4.5	≤4.4
Heptachlor Epoxide	1024-57-3	≤2.2	≤2.2	≤2.3	≤2.2
Hexachlorobenzene	118-74-1	≤2.2	≤2.2	≤2.3	≤2.2
Lindane	58-89-9	≤2.2	≤2.2	≤2.3	≤2.2
Toxaphene	8001-35-2	≤220	≤220	≤230	≤220
Aroclor 1016	12674-11-2	≤43	≤42	≤45	≤43
Aroclor 1221	11104-28-2	≤86	≤84	≤92	≤88
Aroclor 1232	11141-16-5	≤43	≤42	≤45	≤43
Aroclor 1242	53469-21-9	≤43	≤42	≤45	≤43
Aroclor 1248	12672-29-6	≤43	≤42	≤45	≤43
Aroclor 1254	11097-69-1	≤43	≤42	≤45	≤43
Aroclor 1260	11096-82-5	≤43	≤42	≤45	≤43

Note: The "less than value" is the Reporting Limit, i.e., analyte was analyzed for but not detected.

Table 9. Radiological Results for Fish Collected from Putah Creek near the Former LEHR Facility

Analyte	Site #1, Comp 1/Comp 1/Comp 2 LBHR96.05987/7X/8 (pCi/g-wet)			Site #2, Comp/LMB LEHR96.05989/73 (pCi/g-wet)		Site #3, Comp 1, Comp 2, WCF LBHR96.05990/91/81 (pCi/g-wet)			Site #4, Comp LEHR96.05992 (pCi/g-wet)
Gross Alpha	0.0933±0.0792	NA	0.0917±0.0859	0.00825±0.0547	NA	0.000±0.0580	-0.00285±0.0403	0.0207±0.0408	0.0476±0.0732
Gross Beta	3.36±0.142	NA	3.13±0.143	3.12±0.135	NA	3.44±0.149	3.13±0.135	3.29±0.128	3.14±0.165
U-238	0.000524±0.000349	NA	0.00122±0.000521	0.000646±0.000421	0.000540±0.000473	0.000863±0.000490	0.000876±0.000471	0.000102±0.000187	0.00131±0.000528
Th-234	ND	ND	ND	ND	ND	ND	ND	ND	ND
U-234	0.000475±0.000353	NA	0.00110±0.000500	0.000855±0.000475	0.000731±0.000546	0.00177±0.000639	0.00170±0.000636	0.000408±.0.000314	0.00150±0.000570
Th-230	0.000099±0.000114	NA	0.00177±0.000554	0.000812±0.000334	0.000222±0.000216	0.000711±0.000379	0.000562±0.000308	0.000546±0.000368	0.00113±0.000674
Ra-226 (γ)	≤0.0907	≤0.0891	≤0.198	≤0.181	≤0.279	≤0.354	≤0.108	≤0.0799	≤0.0910
Ra-226	0.03±0.01	NA	0.03±0.01	0.07±0.01	0.03±0.01	-0.01±0.01	0.01±0.01	0.04±0.01*	0.02±0.01
Pb-214	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bi-214	ND	ND	ND	ND	ND	ND	ND	ND	ND
U-235	ND	ND	ND	ND	ND	ND	ND	ND	ND
U-235 (γ)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Th-227	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ra-223	ND	ND	ND	ND	ND	ND	ND	ND	ND
Th-232	0.000154±0.000149	NA	0.00475±0.000907	0.00410±0.000753	0.000±0.000110	0.000152±0.000211	0.000288±0.000217	-0.0000494±0.000262	0.000354±0.000391
Ra-228 (γ)	≤0.0203	≤0.0317	≤0.0506	≤0.0469	≤0.0619	≤0.0685	≤0.0340	≤0.0289	≤0.0223
Ra-228	0.18±0.15	NA	0.07±0.15	0.06±0.13	0.10±0.18	0.19±0.18	0.16±0.17	0.40±0.20	0.20±0.19
Th-228	-0.00195±0.000263	NA	0.00348±0.00102	0.00351±0.000902	-0.00290±0.000538	-0.000510±0.000633	0.000679±0.000414	-0.000368±0.000639	0.000607±0.00121
Ra-224	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pb-212	ND	ND	ND	ND	ND	0.0209±0.0216	ND	ND	ND
Bi-212	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tl-208	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pu-238	-0.000387±0.000415	0.0000362±0.000114	-0.000169±0.000313	0.0000107±0.000126	NA	0.0000516±0.000103	0.000387±0.000485	0.000192±0.000339	0.000215±0.000625
Pu-239/240	0.000±0.000141	0.0000362±0.000114	0.0000563±0.000172	0.0000321±0.0000641	NA	0.0000861±0.000150	0.0000738±0.000165	0.000±0.000	-0.0000537±0.0000760
K-40	3.11±0.101	3.04±0.147	2.54±0.224	2.84±0.174	3.41±0.229	2.94±0.211	2.99±0.166	3.01±0.137	2.62±0.0948
C-14	4.9±1.8	NA	5.4±1.7	3.9±1.9	2.4±2.1	3.6±2.8	4.8±1.6	3.8±1.6*	20±14
Cs-137	≤0.00538	≤0.00739	≤0.0157	≤0.0132	≤0.0175	≤0.0192	≤0.00929	≤0.00657	≤0.00571
Ba-140	≤0.251	≤0.594	≤0.565	≤1.13	≤0.268	≤0.861	≤0.356	≤0.0907	≤0.398
Co-60	≤0.00665	≤0.0100	≤0.0129	≤0.0151	≤0.0221	≤0.0248	≤0.0131	≤0.0106	≤0.00802
Hg-203	0.0137±0.00431	0.0109±0.0054	ND	ND	ND	ND	ND	ND	ND
I-131	≤0.298	≤0.989	≤0.711	≤2.45	≤0.188	≤1.08	≤0.387	≤0.0550	≤0.575
Sr-89	0.0824±0.0691	0.0561±0.0954	-0.00365±0.0625	-0.0208±0.0477	NA	0.0369±0.0664	-0.0123±0.0634	0.000216±0.0537	-0.0537±0.113
Sr-90	-0.00903±0.00954	-0.00366±0.0133	0.00217±0.0103	0.00618±0.00686	NA	-0.00717±0.0111	0.00417±0.0107	0.00300±0.00882	0.0139±0.0163

γ -- measured by gamma spectrometry with a corresponding radiochemical analysis. ND -- not detected. NA -- not analyzed. + -- less than Minimum Detectable Concentration (MDC). X -- designates a replicate analysis.
*-- Replicate analysis, C-14, 15±1.8; Ra-226, 0.03±0.01; Ra-228, 0.64±0.28. "Less than value" is equal to the MDC.

Table 10. Inorganic Results for Fish Collected from Putah Creek near the Former LEHR Facility

Analyte	CAS Number	Site #1, Comp 1/2 LEHR96.05987/8 (mg/kg-wet or ppm-wet)		Site #2, LMB/Comp LEHR96.05973/89 (mg/kg-wet or ppm-wet)		Site #3, WCF/WCF/Comp 1/Comp 2 LEHR96.05981/81[X]/90/91 (mg/kg-wet or ppm-wet)				Site #4, Comp LEHR96.05992 (mg/kg-wet or ppm-wet)
Antimony	7440-36-0	0.38[B]	0.49[B]	0.70	0.44[B]	0.75	0.52	0.53	0.41[B]	0.84
Arsenic	7440-38-2	≤0.06	≤0.06	≤0.06	≤0.06	≤0.06	≤0.06	≤0.06	0.11[B]	≤0.06
Barium	7440-39-3	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0	≤12.0
Cadmium	7440-43-9	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02	≤0.02
Chromium	7440-47-3	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10	≤9.10
Cobalt	7440-48-4	≤0.25	≤0.25	≤0.45	≤0.25	≤0.25	≤0.25	≤0.25	0.29[B]	≤0.25
Lead	7439-92-1	0.28[B]	1.06	0.20[B]	0.17[B]	0.17[B]	≤0.08	0.24[B]	0.19[B]	≤0.08
Mercury	7439-97-6	0.69	0.15	0.25	0.16	0.48	0.46	0.24	0.13	0.13
Nickel	7440-02-0	≤0.55	0.90[B]	≤0.55	≤0.55	≤0.55	≤0.55	≤0.55	≤0.55	≤0.55
Selenium	7782-49-2	0.27[B]	≤0.08	0.25[B]	0.25[B]	≤0.08	≤0.08	0.23[B]	0.36[B]	0.33[B]
Silver	7440-22-4	0.04[B]	0.03[B]	0.65	0.02[B]	0.03[B]	0.03[B]	0.01[B]	0.01[B]	0.01[B]
Thallium	7440-28-0	≤0.06	≤0.06	≤0.06	≤0.06	0.12[B]	0.10[B]	≤0.06	≤0.06	≤0.06
Vanadium	7440-62-2	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17	≤0.17
Zinc	7440-66-6	9.80	8.70	12.0	13.4	6.10	11.6	8.70	15.3	17.60

[B] The value is less than the Reporting Limit but greater than or equal to the Instrument Detection Limit (IDL).

[x] The values in the second column are from a replicate analysis.

Table 11. Organic Results for Fish Collected from Putah Creek near the Former LEHR Facility

Analyte	CAS Number	Site #1, Comp 1/2 LEHR96.05987/8 (µg/kg-wet or ppb-wet)		Site #2, LMB/Comp LEHR96.05973/89 (µg/kg-wet or ppb-wet)		Site #3, WCF/ Comp 1/Comp 2 LEHR96.05981/90/91 (µg/kg-wet or ppb-wet)			Site #4, Comp LEHR96.05992 (µg/kg-wet or ppb-wet)
Chlordane (Total)	57-74-9	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1
4,4"-DDT	50-29-3	≤10.0	≤10.0	≤10.0	≤10.0	≤20.0	≤10.0	≤10.0	≤10.0
Dicofol	115-32-2	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0
Dieldrin	60-57-1	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0
Endosulfan I	959-98-8	≤5.0	≤5.0	≤5.0	≤5.0	≤5.1	≤5.0	≤5.0	≤5.0
Endosulfan II	33213-65-9	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0
Endrin	72-20-8	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0	≤10.0
Heptachlor Epoxide	1024-57-3	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1
Hexachlorobenzene	118-74-1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1
Lindane	58-89-9	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1	≤5.1
Toxaphene	8001-35-2	≤510	≤510	≤510	≤510	≤510	≤510	≤510	≤510
Aroclor 1016	12674-11-2	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1221	11104-28-2	≤200	≤200	≤200	≤200	≤200	≤200	≤200	≤200
Aroclor 1232	11141-16-5	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1242	53469-21-9	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1248	12672-29-6	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1254	11097-69-1	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100
Aroclor 1260	11096-82-5	≤100	≤100	≤100	≤100	≤100	≤100	≤100	≤100

Note: The "less than value" is the Reporting Limit, i.e., analyte was analyzed for but not detected.

Comments on
"Follow-Up Sampling and Analysis Guidelines for Fish, Sediment, and Water Samples from the Putah Creek Adjacent to the Former Laboratory for Energy-Related Health Research, Davis, CA"
Draft 2.2, dated September 17, 1997
Prepared by
B. Lloyd and S. Telofski, US EPA-NAREL, Montgomery, AL

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October 10, 1997

Background

On September 19, 1997 via e-mail I received a request to review on short notice a US EPA proposed follow-up sampling for fish, sediment and water from Putah Creek near the University of California, Davis - Department of Energy LEHR national Superfund site. This request came at a time when I am participating in an American Chemical Society sponsored lecture tour through Kentucky and Indiana. Following review of the draft re-sampling plan, since there was concern about being able to sample in the near future, I called W. Taylor to indicate that I had no problems with the proposed sampling components of the plan with respect to fish sampling locations and overall approach for sample handling. I informed Dr. Taylor that I had significant problems with some of the proposed analytical procedures and proposed approaches for analysis of data, as well as the overall scope of analysis for the proposed re-sampling. I also informed Dr. Taylor that I would be submitting detailed written comments on these issues. My comments on the draft re-sampling plan are presented below.

As a preface to these comments, in the spring of 1997 I sent letters to Julie Roth dated April 15, 1997 and to Dr. William Taylor dated May 9, 1997 discussing the inadequacies of the initial US EPA/ATSDR sampling program for excessive bioaccumulation of hazardous chemicals in Putah Creek fish, sediments and water taken from the Creek near the LEHR site. In that correspondence I pointed out that the analytical methods used for a number of key parameters did not have sufficient sensitivity to detect several of the constituents of concern at potentially hazardous levels based on values that the US EPA Region 9 had provided to the San Francisco Regional Water Quality Control Board in connection with their bioaccumulation studies of potentially hazardous constituents in San Francisco Bay fish.

I also pointed out that a number of the statements regarding a potential lack of problems based on measured concentrations in water and fish made in the US EPA National Air and Radiation Environmental Laboratory (NAREL)/ATSDR report were not necessarily valid based on the study program used. There could readily be problems with the parameters mentioned as not causing public health or environmental problems which were not detected by the study program used. Subsequent to submitting my letters on the deficiencies in the original study program and the interpretation of data, the University of California, Davis. L. Vanderhoef administration issued several statements as part of its propaganda efforts to try to prove that its campus domestic wastewater treatment plant was not causing water quality problems in Putah Creek in which the UCD L. Vanderhoef administration used statements from the US EPA NAREL and ATSDR report to claim that no problems were being encountered associated with certain constituents.

The UCD L. Vanderhoef administration has also, in propaganda statements, attempted to discredit the US EPA/ATSDR findings with respect to mercury and lead bioaccumulation in fish to excessive levels based on the fact that the original study used a composite of various types and sizes of fish in their initial screening for potential excessive bioaccumulation. The UCD L. Vanderhoef administration in these statements, however, ignored the comments that I had submitted to J. Roth on April 15, 1997 and Dr. William Taylor on May 9, 1997 on the deficiencies in the original US EPA/ATSDR studies in their propaganda statements about how the UCD campus wastewater treatment plant's discharges of partially treated campus wastewaters to Putah Creek near the LEHR site were not having an adverse impact on the beneficial uses of Putah Creek. This situation is typical of the distorted, unreliable information that is released by the L. Vanderhoef administration as factual, but is, in fact, propaganda that is not supported by the facts concerning the impacts of UCD's management of its campus wastes on public health and the environment.

On September 10, 1997, I received a letter from Dr. William Taylor which acknowledged that my assessments as set forth in my April 15, 1997 and May 9, 1997 letters concerning the deficiencies in the US EPA/ATSDR studies on bioaccumulation of potentially hazardous chemicals in Putah Creek were appropriate. As a result, Dr. Taylor states,

> *"While we did not detect these substances in the fish, the data were not sufficiently sensitive to conclude that these substances were not present at levels that might pose an increased cancer risk to people who would eat the fish over a period of years. We currently believe that levels of the pesticides dicofol, dieldrin, toxaphene, and DDT (and its metabolites) are an indeterminate public health hazard, and PCBs in fish are also an indeterminate public health hazard, based on our data."*

This situation provides important background to any future studies of excessive bioaccumulation in Putah Creek fish where it is important to use analytical methods with sufficient sensitivity to be certain to detect the constituents of concern at potentially hazardous levels based on current US EPA Region 9 guidance that has been provided over the past few years for similar situations of protecting public health and the environment.

Dr. Taylor further states:

> *"Our reevaluation does not change our conclusions regarding elevated mercury and lead in fish. These substances were elevated in some of the fish we collected and we still maintain they pose a public health hazard."*

He also states,

> *"Lead and mercury in fish in Putah Creek will be the focus of our follow up investigation."*

Dr. Taylor's comments concerning lead and mercury are appropriate in that, as I have pointed out, the concentrations found based in a mixed population of fish taken from Putah Creek are of significant concern since almost certainly the concentrations in the higher trophic level fish that would be the most likely used as food by those who fish the Creek would be higher than the average concentrations found in the US EPA/ATSDR studies.

I am concerned, however, about Dr. Taylor's statement that the follow up studies would focus on lead and mercury only. The US EPA/ATSDR has not yet conducted a credible study of excessive bioaccumulation for a variety of potential carcinogens that could readily be present in Putah Creek fish which in the previous studies were measured with analytical methods with inadequate sensitivity. Dr. Taylor in his letter states that the analytical methods used by the US EPA were based on *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition, Method 8081*, and states,

> *"These methodologies are recommended for use in conducting evaluations and measurements needed to comply with the Resource Conservation and Recovery Act (RCRA), and appeared to be appropriate for the screening study we planned."*

Unfortunately, the screening study planned did not consider the fact that US EPA Region 9/Central Valley Regional Water Quality Control Board/San Francisco Estuary Institute, in connection with studies on bioaccumulation of these hazardous chemicals in San Francisco Bay fish, had previously evaluated the adequacy of these analytical methods and concluded that they were inadequate to detect the constituents at concentrations that are potentially hazardous to public health through the consumption of organisms as food. As a result, through the San Francisco Estuary Institute contractors, more appropriate analytical methods were used in the San Francisco Bay bioaccumulation studies which did have sufficient sensitivity to measure the constituents of concern at potentially hazardous levels. The situation, therefore, is not one where there is a lack of reliable analytical methods to conduct such analyses at sufficient sensitivity, it is that the US EPA laboratory that is doing this work did not use methods with sufficient sensitivity and evidently does not normally use such methods in bioaccumulation studies. This is not justification, however, for future studies not using appropriate methods.

It also appears that these laboratories are using inappropriate, out-of-date CERCLA guidance values for assessing potential hazards of bioaccumulatable chemicals compared to those that are readily available and are being used by the US EPA Region 9 in non-CERCLA-related activities. Since CERCLA activities should use local ARARS values to judge potentially hazardous conditions associated with chemical constituents found in water and fish tissue, it should be concluded that the use of the CERCLA screening values for hazardous conditions associated with bioaccumulation of chemicals in fish for Putah Creek fish is technically invalid and inappropriate in accord with current CERCLA requirements for protecting public health and the environment based on criteria, standards and guidance values that are used in a particular region by regional or local public health and other regulatory agencies.

UCD has announced that it plans to conduct its own bioaccumulation studies for mercury. They have not, however, made the study plan available for review by the RPMs, DSCSOC and other interested parties. In order for these studies to have credibility, they must be conducted with full public peer review of the proposed sampling and analytical program presentation and interpretation of results, etc. The UCD L. Vanderhoef administration should not attempt to conduct another study like it has done in the past where it establishes study conditions and then controls the study plan and reporting of results in such a way as to bias the program to support the UCD L. Vanderhoef administration's previously adopted position on issues that its campus wastewater discharges and stormwater runoff is not adversely impacting beneficial uses of Putah Creek.

The public has justifiably concluded that the UCD L. Vanderhoef administration cannot be relied on to conduct a credible investigation of impacts relating to its campus waste management as they may impact Putah Creek. This justification stems from the so-called cumulative impact studies that the public called for in connection with the permitting of UCD's discharge of its fourth campus landfill leachate-polluted groundwaters to Putah Creek after only minimal treatment involving VOC air stripping. The UCD L. Vanderhoef administration refused to conduct an independent, third-party public peer reviewed evaluation of the cumulative impacts of UCD's campus wastewater discharges and stormwater runoff. Instead, it worked out a behind-the-scenes deal between the Central Valley Regional Water Quality Control Board chairman and executive officer in which a contract study group that must present results in accord with the client's wishes or not receive future support for studies of this type was chosen by UCD to conduct the cumulative impact studies. The results of these studies were first reported as a final report in the draft environmental impact report for the proposed campus wastewater treatment plant expansion. A review of these studies, as I have documented in previous correspondence, shows that they were grossly superficial and did not address cumulative impact issues of concern to the public such as bioaccumulation of lead and mercury or aquatic life toxicity. A few months later, the US EPA ATSDR studies which were initiated at the suggestion of DSCSOC showed that the campus wastewater treatment plant discharge area which is also the area for part of the LEHR site stormwater runoff was the area of Putah Creek which contained fish with excessive concentrations of lead and mercury. Any further studies conducted by the UCD L. Vanderhoef administration must be conducted in a full, public peer review arena in order to have credibility with the public. Behind-the-scenes, contrived studies of the type that have been done in the past will not be accepted in the future as being a reliable assessment of water quality issues pertinent to Putah Creek.

Comments on Proposed Follow Up Sampling and Analysis Guidelines

Page 1, 1.0 "Purpose," first paragraph, the statement is made, *"The screening analysis survey indicated levels of lead and mercury in fish tissue which exceeded relevant USEPA screening values for fish and could present a health hazard."* That paragraph should include an additional sentence, "A number of chlorinated hydrocarbon pesticides could also be present in fish tissue taken from Putah Creek at hazardous levels that were not detected in the previous NAREL studies based on NAREL using insufficiently sensitive analytical methods compared to US EPA Region 9 guidance values for determining potentially hazardous concentrations of bioaccumulated chemicals in fish tissue."

Page 1, "Purpose," first paragraph, it is stated, *"It was recommended that an additional study be performed to define the concentration of lead and mercury within species and size ranges."* While it would be appropriate to do additional studies to assess the magnitude of the potential lead and mercury hazards in Putah Creek fish, there is still need to properly conduct studies on the other chlorinated hydrocarbons that were measured in the previous studies with insufficiently sensitive analytical methods. If these methods cannot be done by NAREL, then they could be done through the San Francisco Estuary Institute contractors who have developed reliable procedures for measuring concentrations of these constituents at potentially hazardous levels based on US EPA Region 9 guidance.

DSCSOC should recommend that the follow-up studies include not only additional studies on lead and mercury, but also a proper screening for all of the chlorinated hydrocarbons of typical concern, including PCBs and dioxins, to ensure that those who consume fish from Putah Creek are not exposed to hazardous concentrations of these constituents. If these studies cannot be done through the US EPA Region 9 re-sampling studies, then the RPMs and the Central Valley Regional Water Quality Control Board should require that UCD and DOE conduct appropriate studies of the bioaccumulation issues on Putah Creek fish.

For further information on appropriate analytical methods for the constituents of concern, please contact Dr. J. Davis, San Francisco Estuary Institute, 180 Richmond Field Station, 1325 South 46th Street, Richmond, CA 94804; PH: 510-231-9539, ext 625; FX: 510-231-9414; em: jay@sfei.org.

Page 2, first full paragraph, states, *"The final report will then be forwarded to ATSDR, with copies sent to the EPA Region 9 laboratory, the EPA Region 9 Superfund Office, and internally at NAREL."* Because of the problems with inappropriate data interpretation in the previous NAREL report on Putah Creek fish bioaccumulation issues, it would be appropriate to issue a draft report for review by the RPMs, DSCSOC and the PRPs (DOE and UCD) to provide the opportunity for interested parties to comment on the technical appropriateness of the follow-up studies and thereby possibly minimize the production of yet another report with inaccurate and unreliable information that would be used by the UCD L. Vanderhoef administration as more propaganda on important public health and environmental issues.

Page 2, under "Sample Analysis and Potential Contamination of Concern," the studies on lead and mercury appear to be appropriate, but these studies must be expanded, either through this study or through additional studies funded by the PRPs using appropriate analytical methods to determine whether the constituents that were measured with inadequate analytical methods previously or were not measured at all, such as dioxins, are present at hazardous levels in the fish taken from Putah Creek.

The bottom of page 2, Table 1 presents the detection limits that are proposed for use in the studies. The detection limits for Fish/Crayfish and Soil appear to be adequate. The detection limits for mercury in water are inadequate to measure mercury at concentrations that would potentially bioaccumulate to hazardous levels. The US EPA "Gold Book" water quality criterion for mercury is 12 ng/L. Recently, the US EPA Region 9 has proposed a revised human health-based criterion for mercury of 50 ng/L. It is understood that this raising of the critical level of mercury in water to protect against bioaccumulation is an artifact of new interim procedures that are being used to calculate the hazards of mercury in water based on bioaccumulation in fish tissue and that, ultimately, a concentration in water on the order of 3 to 5 ng/L will be adopted after completion of the US EPA's current national efforts in reviewing the hazards of mercury in the environment. Therefore, in order to be able to state that there are no potential water-related problems due to mercury in water taken from Putah Creek, it is necessary to use an analytical method for mercury in water which has a reliable detection limit of about 2 ng/L. The currently proposed reporting limits in Table 1 on page 2 of 200 ng/L are inadequate for this purpose. While it may not be possible for the NAREL group to measure mercury in water at appropriate levels, it is important that the final report not make the same errors as was done previously of reporting no problems for a particular constituent based on concentrations that are less than the detection limits, when inadequate detection limits were used.

Page 3, section 2.1 "Comparison Values for Metals," the discussion in paragraph 2 of this section reflects a technically inadequate and invalid approach where it is stated, *"Mercury in water will be compared to the USEPA Drinking Water Standard level of 2 ppb..."* In a situation such as Putah Creek, the critical issue is not drinking the water but bioaccumulation. Concentrations of mercury above about 3 to 5 ng/L are now well-known to potentially bioaccumulate to excessive levels in aquatic life. This issue should be discussed in this report. If it is not, then it will be a technically deficient report and will provide unreliable information to the public on the issue.

Page 3, 2.2 "Comparison Values for Metals," third paragraph, states, *"Lead and mercury in sediment will not be compared to any standards."* That is an appropriate statement since there are no reliable standards for lead and mercury in sediments. It is important, however, that the error that was made in the previous report of claiming that there were no problems because of the concentrations found not be repeated. As discussed in my previous correspondence, it is impossible to judge whether lead and mercury in sediments in Putah Creek are a problem based on the kinds of studies that have been and are proposed to be conducted. A far more comprehensive, reliable study needs to be conducted to be able to make any interpretation of lead and mercury concentrations in sediment with reference to the potential for bioaccumulation. As I discussed in previous correspondence, finding the concentrations of lead and/or mercury or, for that matter, any other constituent in Putah Creek sediments near where UCD's campus wastewater discharges and LEHR site stormwater runoff occur does not mean that the constituents derived from these sources is not a cause of the excessive bioaccumulation that has been found previously and could be found in future studies. Such an approach assumes that the aqueous environmental chemistry in lead and mercury from these sources is identical to the background lead and mercury chemistry. Those familiar with aquatic chemistry know that such an assumption is technically invalid. There could readily be mercury discharged in the UCD campus wastewater treatment plant or LEHR site stormwater runoff which is in a form that while not contributing significantly to the overall concentrations of lead and mercury in the sediments could readily be an important source of bioaccumulatable lead and mercury. This is especially true for mercury since it is now well-known that there is no relationship between the total mercury content of sediments and the amount that bioaccumulates in fish tissue. The bioaccumulation depends on the specific forms of mercury that are present and a variety of other factors that need to be considered.

Page 3, third paragraph, under "Comparison Values for Metals," in red, my copy states, *"WITH THIS IN MIND, SHOULD WE COLLECT AND ANALYZE VEGETATION IN THE CREEK ALSO?"* It is my recommendation that rather than collecting vegetation for analysis which will not provide data that are interpretable with respect to lead, mercury or other constituent bioaccumulation issues, that the resources available be devoted to obtaining additional samples and analyses for the wide variety of constituents that have not yet been properly analyzed in fish tissue from Putah Creek near the LEHR site.

Page 3, section 2.1 "Comparison Values for Metals," fourth paragraph, states, *"Lead in fish will be compared to the calculated screening value of 0.3 ppm determined in the final report of the initial screening study..."* It should be understood that the 0.3 ppm value assumes that the 15 µg/L drinking water value is protective. A critical review of the US EPA's discussion of the reliability of the 15 µg/L drinking water value shows that the Agency believes that it may not be protective under some conditions. The report should discuss these issues, pointing out that the 15 µg/L drinking water value may not be protective and that children who consume large amounts of fish taken from Putah Creek that are at or below the 0.3 ppm screening level that is proposed to be used could be damaged by consumption of these fish.

With respect to the mercury screening value of 0.6 ppm stated in the fourth paragraph on page 3 under section 2.1 "Comparison Values for Metals," this value is inadequate. The value that should be used is the value that was developed by the US EPA Region 9 for consumption of fish in San Francisco Bay. This value is 0.14 ppm. It appears that the NAREL staff are still ignoring the US EPA Region 9 guidance on these issues. This is inappropriate. US EPA Region 9 guidance is, in my opinion, the best guidance available at this time on critical concentrations of mercury in fish tissue for consuming one meal per week.

I have previously provided Dr. William Taylor with a table of values from the San Francisco Regional Water Quality Control Board's bioaccumulation studies on San Francisco Bay "Contaminant Levels in Fish Tissue from San Francisco Bay, Final Report, June, 1995," that present the concentrations of various constituents in fish tissue that the US EPA Region 9 has adopted as guidance on what constitutes excessive concentrations of the constituent at two different fish consumption rates. These values or any updates from these values should be used as the basis for judging excessive concentrations of the analytes of concern.

In reporting the results of bioaccumulation studies, it is important for the analyst to indicate the presence of potentially significant unknown peaks that occur in the GCMS or other analytical procedures that are used. This should be added to this study program as part of the analyses that are done on the chlorinated hydrocarbons.

Page 3, 2.2 "Comparison Concentrations for Hg-203," DHS needs to evaluate whether the approach used herein is appropriate and provide their comments to the RPMs and DSCSOC.

Page 4, 3.1 "Fish Species and Length," states, *"Putah Creek contains an excellent collection of both native and introduced species."* I question the use of the word "excellent." The author of that statement should state the basis for categorizing the collection of native and introduced species as "excellent." Compared to what? Statements of this type could readily lead to the UCD L. Vanderhoef administration trying to use the word "excellent" before the Regional Board to prove that their wastewater treatment plant and other discharges from the campus are not adversely impacting Putah Creek. That wording should be deleted unless it can be properly documented.

Page 5, first full paragraph, states, *"Since the study is designed to determine if target analytes are present in different concentrations based on age (length) of fish, it is desired to collect different size ranges of fish."* The issue is not to determine whether the concentrations of mercury or lead change with age (length of fish). This is well-known. The purpose is to determine for various sizes of fish, the actual bioaccumulation that has occurred at the time of sampling.

With respect to the types of fish sampled, the fish sampling should be done on those species that are used as food from Putah Creek in that region. If necessary, appropriate studies should be conducted to determine what people are catching and eating.

It is important to understand that because of the seasonal and flow-related differences, it is possible that studies at this time, especially this year, since the flows in Putah Creek have been elevated compared to previous years and what will likely occur in future years, that tissue concentrations could be found to be non-hazardous this time, but have been hazardous in the past and be hazardous in the future. The bioaccumulation studies on Putah Creek associated with UCD's campus wastewater discharges and stormwater runoff from the LEHR site must be on-going studies done each year for at least half a dozen years to establish for the full suite of constituents of potential concern, including dioxins, whether there is a potential problem of excessive bioaccumulation in the Creek fish. Such studies should be part of the NPDES permits for the campus wastewater discharges to the Creek as well as the LEHR site stormwater runoff NPDES permit monitoring requirements.

Page 5, third paragraph, states that a minimum of four fish samples will be taken at each location. Four fish samples is low compared to the desired number. At least five should be taken.

With respect to the North Fork sampling mentioned on page 6, it is unknown at this time whether the North Fork of Putah Creek has fish that are used for consumption. If it does, then sampling should be done since UCD did dump and continues to discharge stormwater runoff to the North Fork of Putah Creek. Hazardous concentrations of constituents have been found in these waters. If the sampling is not done by the ATSDR/NAREL studies, then this should be done by UCD as part of its NPDES stormwater runoff permit.

Page 7, 3.3.2 "Water Sampling," mentions that particulates will be removed from the samples by filtration. That approach is inappropriate in surveying for potential problems associated with mercury in water as it may lead to bioaccumulation problems. The total mercury and lead as well as other constituents as well as the so-called filtered or dissolved should be analyzed in each sample since part of the particulate forms of these constituents could become available for bioaccumulation in downstream locations.

Page 7, 3.3.3 "Sediment Sampling," mentions that a type of dredge or core will be used. It is important to understand that it does not matter very much what is used for sampling sediments since the sediment data are uninterpretable. Even high concentrations of constituents in sediments does not mean that the sediments are a source of a constituent that bioaccumulates. It is well-known that there is no relationship between sediment concentrations as measured in a study of this type and water quality impacts. If there is interest in trying to understand the role of constituents in sediments as a source of constituents that leads to excessive bioaccumulation then a much more comprehensive, significantly different type of study will need to be conducted. I can provide guidance on those studies should this be of interest. I do not recommend them at this time. They could, however, be necessary at a later date if it is found that sediments may be a source of on-going bioaccumulation problems that could mean that UCD and/or DOE would have to remove the polluted sediments from Putah Creek in order to stop the excessive bioaccumulation problems that are occurring.

The issue of bioaccumulation of hazardous substances in fish is one that I have devoted considerable research and consulting activity over the past 37 years. I have published extensively on this topic. A number of my papers and reports on these and related issues are available from my web site (http://members.aol.com/gfredlee/gfl.htm). If anyone wishes additional information on the issues discussed herein, please contact me.

HEALTH CONSULTATION

R30-e

SURVEY OF FISH IN PUTAH CREEK
(PHASE II)

Laboratory for Energy-Related Health Research
Davis, California

CERCLIS NO. CA2890190000

September 16, 1998

Prepared by

Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Federal Facilities Assessment Branch
Energy Section

PURPOSE

The purpose of this health consultation is to report the results from an ATSDR fish survey of the fish in Putah Creek in 1997, and report our conclusions and public health recommendations from that survey. The survey was conducted to better define the concentrations of mercury and lead in different fish species in Putah Creek.

BACKGROUND

This report is the second health consultation issued by the Agency for Toxic Substances and Disease Registry (ATSDR) which addresses fish in Putah Creek near the Laboratory for Energy-Related Health Research (LEHR) Superfund site on the University of California at Davis (UCD) campus, in Davis, California.

ATSDR recommended in a Site Summary report in December 1995 that fish in Putah Creek should be sampled and analyzed for hazardous substances, because people were eating fish from Putah Creek and there had been no previous analyses of the fish [1]. The U.S. Environmental Protection Agency (EPA) Region IX collected fish and crayfish, water, and sediment samples from four locations along the creek, and the EPA National Air and Radiation Environmental Laboratory (NAREL) analyzed the samples for ATSDR. ATSDR released a health consultation in April 1997 describing the results of the first fish survey [2].

The most important conclusion in the first health consultation was that mercury and lead concentrations in some fish collected from Putah Creek pose a public health hazard to people who eat the fish. However, NAREL composited many of the fish and crayfish before analyzing them because the laboratory required certain sample volumes to do all the analyses planned (18 pesticides and other organic chemicals, 14 metals, gross alpha, gross beta, and gamma spectrometry). Compositing the fish was appropriate for an initial screening survey of this kind.

Because mercury and lead were elevated in composite fish samples, ATSDR recommended in the first health consultation that an additional fish study be conducted to better define the concentrations of mercury and lead in different fish species. EPA agreed to assist ATSDR again, to collect a second round of fish and crayfish from Putah Creek. This health consultation reports the results of those efforts.

EPA Region IX collected a total of 152 fish and crayfish, plus water and sediment samples, at five locations along Putah Creek in October and November 1997. EPA staff were assisted by staff from Thomas R. Payne & Associates, Inc. (TRPA). TRPA is an independent contractor conducting fisheries monitoring on lower Putah Creek for the Solano County Water Agency. TRPA has sampled fish in Putah Creek for six years. Their staff shared their fishing expertise and their knowledge of Putah Creek with EPA staff for this ATSDR program. EPA Region IX scientists packaged the samples and sent them to the NAREL in

Montgomery, Alabama, for analysis. NAREL scientists homogenized the whole fish or crayfish. Composite samples of two or more fish were prepared of some of the fish, of a single species and size range from a single location.

We have attached the data from the laboratory analyses of fish, water, and sediment collected from Putah Creek to the end of this report. ATSDR scientists and NAREL scientists reviewed the NAREL data. ATSDR offers the following results, conclusions, recommendations, and follow-up public health actions based on these data.

RESULTS

1. All largemouth bass samples contained mercury. The mercury concentrations in the samples ranged from 0.11 milligrams of mercury per kilogram of fish (mg/kg-fish) to 0.81 mg/kg-fish. The largemouth bass contained the highest levels of mercury that were found in this survey.

2. The highest levels of lead were found in crayfish. All crayfish samples contained lead. The lead concentrations in the samples ranged from 0.15 mg/kg-fish to 1.1 mg/kg-fish.

CONCLUSIONS

1. The concentrations of mercury in some largemouth bass in Putah Creek are at levels of health concern for fetuses and nursing children whose mothers eat these fish.

2. The concentrations of lead and other metals in crayfish in Putah Creek are *not* at levels of health concern for people who eat these fish.

3. The 101 bluegill, 4 carp, 1 channel catfish, and 1 black bullhead fish that we caught did not contain toxic metals at levels of public health concern.

4. None of the radiological analyses of any of the fish indicate that radionuclides in the fish pose a public health hazard.

5. None of the analyses indicate that metals or radionuclides in water pose a public health hazard.

6. None of the analyses indicate that metals or radionuclides in sediment pose a public health hazard.

RECOMMENDATIONS

Women of child bearing age, especially those who are pregnant or are nursing, should refrain from eating largemouth bass from Putah Creek.

FOLLOW-UP PUBLIC HEALTH ACTIONS

1. ATSDR representatives will meet with local health officials to develop and implement a plan for providing information about the fish survey to people who eat fish from Putah Creek. This information will include a brochure that outlines the results of the fish survey, provides suggestions to reduce exposure to mercury, and provides names of agency representatives who can answer questions about the study.

2. ATSDR will work with representatives from the local health departments to distribute information to local health care providers who provide care to pregnant or lactating women who may consume fish from Putah Creek. This information will include a summary of the fish survey and health implications of mercury exposure, and will be targeted to the interests of health care providers.

DISCUSSION

Although we were able to catch a substantial number of bluegill and we had enough fish of each species to adequately complete our laboratory analyses, we had important gaps in some fish species and fish sizes that limit what we can state about the hazards from eating these fish. The low numbers of channel catfish, carp, and black bullhead we collected mean that we have less certainty that the concentrations of metals and radionuclides we measured are typical of the concentrations we would find throughout these species in Putah Creek. In addition, the numbers of fish of different species that we caught may not be representative of what local fishers typically catch and eat. For example, we collected only one channel catfish. However, catfish are a species sought by fishers, and people who fish from Putah Creek likely catch and eat more of these fish than our data suggest.

Largemouth bass:

Mercury was detected in all the largemouth bass that we caught. The large-sized largemouth bass have more mercury and higher concentrations of mercury in them than the small-sized largemouth bass; thus, the largemouth bass are bioaccumulating mercury. As a first approximation, mercury concentration increases in largemouth bass by one unit (1 mg/kg-fish) for every two kilogram increase in body mass of the fish. See Figure 1. We have also plotted milligrams of mercury vs. fish mass for largemouth bass in Figure 2 to show how mercury content increases with (largemouth bass) fish size.

There is no indication that the location where we caught largemouth bass had any significant bearing on the accumulation of mercury. When we take into consideration the size of the fish, mercury accumulation in largemouth bass was consistent at all locations where we caught those fish. However, we only caught large-sized largemouth bass at locations 1 and 2, and no largemouth bass at location 4. We would have liked to have caught fish from each size range at each location to better determine whether location had any affect on mercury accumulation. We suspect, however, that these data gaps are not important because the fish do not stay at one location and mercury concentrations in sediment were similar at all locations (0.7

± 0.4 mg mercury per kilogram sediment dry weight). Therefore, until more or better data become available, we expect that other largemouth bass caught in this area of Putah Creek will contain mercury at concentrations similar to those we found in this survey.

ATSDR has proposed a minimum risk level (MRL) for chronic oral exposure to methylmercury of 0.0005 milligrams of methylmercury per kilogram body weight per day (0.0005 mg/kg/day) [3]. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse noncancerous health effects over a specified duration of exposure. ATSDR derived this proposed MRL primarily from a study designed to test the hypothesis that prenatal exposure to low concentrations of methylmercury through maternal ingestion of fish is related to child development outcomes [4]. The child development outcome that was noted in the study that apparently arose from the lowest exposure levels of mercury that were above the proposed MRL is decreased physical activity in male infants.

We have assumed that all the mercury in the fish we caught in Putah Creek is methylmercury. We considered, as we did in our previous health consultation, an average consumption rate of 54 grams of fish per day [5]. This amount (54 grams = 1.9 ounces) is an average daily rate derived from an equivalent of approximately two meals of fish per week (e.g., 1.9 ounces/day x 7 days = 13.3 ounces per week). For a 60 kilogram adult female eating 54 grams of fish per day, the proposed MRL equates to approximately 0.56 mg/kg-fish, or 0.56 ppm in fish. We used 0.56 mg/kg-fish as our screening value for mercury in fish. Mercury concentrations in the two largest largemouth bass exceeded this value.

The concentrations of mercury we observed in the two largest largemouth bass could have an effect on the development of the fetus or the nursing child whose mother eats these fish more than once a week. We acknowledge that a typical fish meal from Putah Creek will likely contain fish other than largemouth bass, and mercury levels in the majority of the largemouth bass caught in this survey are below the ATSDR proposed MRL. However, Putah Creek may also contain larger largemouth bass than the ones we caught, and we expect larger largemouth bass will have higher levels of mercury than those we measured[1]. Therefore, we recommend that pregnant and nursing women avoid eating largemouth bass from Putah Creek because of the possibility they will eat larger fish than those we caught, as well as the uncertainties in the consumption rates of women eating fish from Putah Creek.

Crayfish:

Crayfish contained the highest levels of lead we measured in this fish survey. Lead was detected in all the crayfish samples.

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[1] The state record for the largest largemouth bass caught in the State of California, i.e., 21.75 lbs., is more than five times larger than the largest one we caught, though we don't know whether Putah Creek could support larger fish than those we caught [6].

Lead is a toxic metal that affects virtually every system in the body. It is particularly toxic to developing fetuses and young children. Developmental neurobehavior effects have been observed in humans following prenatal exposure to low levels of lead [7]. In 1991, the Centers for Disease Control (CDC) recommended a threshold for intervention of 10 micrograms of lead per deciliter of blood (10 μg/dL) in children [8]. We evaluated lead in fish by considering whether the concentrations of lead in the crayfish could lead to blood lead levels of 10 μg/dL.

We used a consumption rate of 54 grams of crayfish per day and a diet slope factor of 0.034 μg/dL per μg of lead ingested per day to calculate the blood lead level of a pregnant woman eating crayfish at the highest concentration of lead in crayfish that we measured [5, 9].

We considered that people may eat more crayfish (total mass) per meal than they eat of finfish, but they eat fewer meals of crayfish per month (on average) than meals of finfish. There are few fish consumption surveys available that estimate shellfish consumption separate from total fish consumption. It appears that the consumption of shellfish among fishers and their families may be half, or less, than that of finfish [10]. For our calculations, and to be conservative, we used the same consumption rate (54 grams per day) as we used for finfish.

Our calculations indicate the blood lead level of a woman eating crayfish with the maximum levels of lead we measured would be approximately 2 μg/dL. Inhalation of dust and consumption of other food and beverages will contribute an additional 0.5 μg lead per dL blood [7]. The combined blood lead concentration (2.5 μg/dL) from crayfish and other environmental sources is well below the threshold for intervention (10 μg/dL) for blood lead levels in children. Therefore, the lead levels in the fish we collected from Putah Creek are not a public health hazard to fetuses or infants whose mothers eat those fish.

OTHER RESULTS AND ISSUES

In addition to the fish, EPA staff collected water and sediment samples at the five fishing locations along Putah Creek. None of the concentrations of metals or radionuclides detected in water or sediment samples were at levels of health concern. The only radionuclides detected in these samples that are not naturally occurring are cesium-134, cesium-137, and iodine-131. Iodine-131 was detected in water and the cesium isotopes were detected in sediment. Neither iodine nor cesium were detected in fish[2]. The concentrations of metals and radionuclides in sediment were similar at all five locations. We are providing those data at the end of this report along with the fish data.

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[2] Based on our results in the first fish survey, our highest analytical priority for these fish samples was mercury and lead concentrations. Therefore, NAREL analyzed the metals first to insure compliance with sample holding times specified by the analytical methodologies for mercury and lead. Because we did not expect to find short-lived radionuclides in the fish, gamma spectrometry was not performed early enough to have been able to detect iodine-131 in the fish.

This health consultation does not address whether some fish in Putah Creek may be safe to eat. We did not collect a sufficient quantity of some fish species (e.g., black bullhead, channel catfish) to know whether the contaminant levels we measured in these fish are representative of the concentrations in their respective populations in Putah Creek. In addition, we have only incomplete data describing concentrations of toxic organic substances, such as pesticides, in the fish in Putah Creek. (The NAREL laboratories did not analyze any of the fish collected in this survey for toxic organic substances.) None of the information we do have— except mercury in largemouth bass as described in this report— indicates the fish in Putah Creek pose a health hazard to people who eat them. However, the data we have do not fully address whether toxic organic substances are at levels of health concern in the fish.

We have found, after two surveys, that it is not a simple matter to collect sufficient numbers of fish of different species to perform all the laboratory analyses we need to reach conclusions and make public health recommendations. This suggests that we may not be able to catch enough fish to answer all the questions about the safety of the fish as a food source that we would like to have answered. An alternate approach, such as conducting a more thorough survey of creek sediment, or surveying an indicator species, such as freshwater clams (*Corbicula fluminea*) may provide more useful information. ATSDR is currently evaluating the information that is available. We welcome any comments and suggestions and will evaluate these fully before recommending further investigations of Putah Creek.

Figure 1.

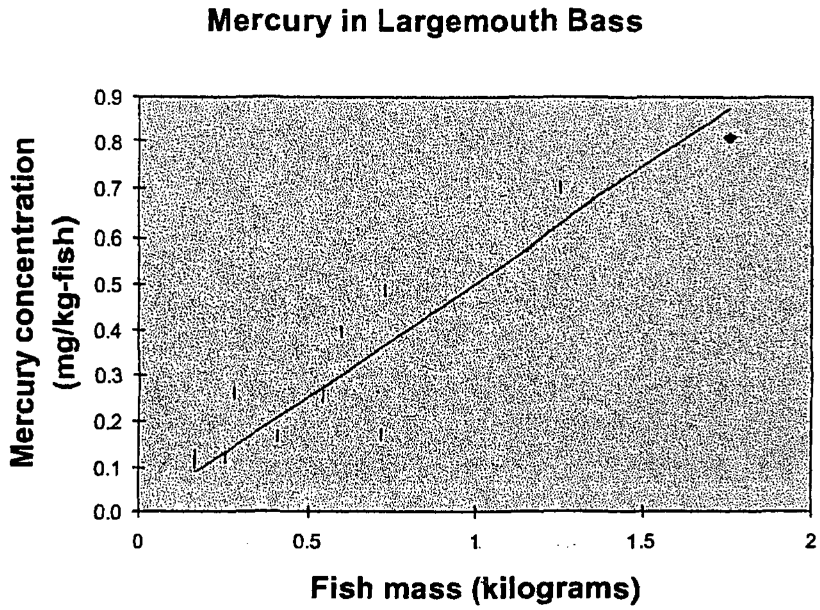
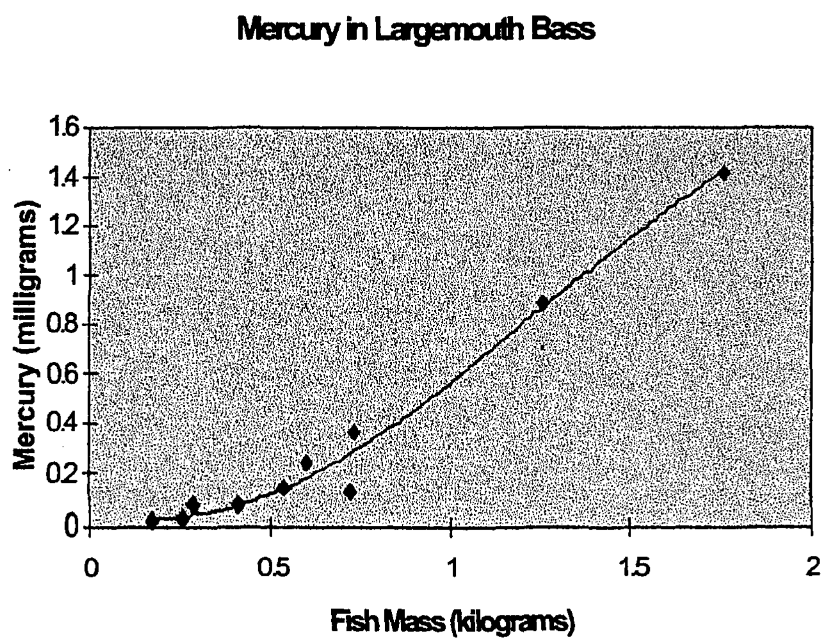


Figure 2.



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ATSDR

REVIEWERS OF REPORT

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ATSDR

ACKNOWLEDGMENTS

ATSDR acknowledges and thanks Thomas Payne and Associates, Inc., California Department of Health Services-Environmental Health Investigations Branch, EPA Region IX, and EPA NAREL for assistance with this project.

The preparer of this report also acknowledges and thanks the following ATSDR staff who provided their assistance and expertise: Henry Abadin, M.S.P.H.; Richard Canady, PhD; Gwendolyn Eng; Richard (Mike) Fay, PhD; Beverly Harris; Theresa NeSmith; John Risher, PhD; Allan Susten, PhD.

RESOURCES

For further information, or to request copies of our documents, including Toxicological Profiles and Case Studies in Environmental Medicine, contact ATSDR on our toll-free number: 1-800-447-1544, or visit our Internet Home Page at http://atsdr1.atsdr.cdc.gov:8080/.

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8. Agency for Toxic Substances and Disease Registry. Health Consultation, Fish Sampling in Putah Creek, 1996. April 4, 1997.

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Comments on
the US Department of Health and Human Services Public Health Service
Agency for Toxic Substances and Disease Registry
Draft Health Consultation "Fish Sampling of Putah Creek (Phase II)"
for the LEHR National Superfund Site
dated September 16, 1998

R 30-8

Comments Submitted by
G. Fred Lee, PhD, DEE
DSCSOC LEHR Superfund Site Technical Assistance Grant Advisor
October 24, 1998

In July 1995, with the US EPA's funding of the Technical Assistance Grant (TAG) to the Davis South Campus Superfund Oversight Committee (DSCSOC) and the appointment of Dr. G. Fred Lee as the TAG advisor, Dr. Lee pointed out, at a meeting with Dr. William Taylor of the Agency for Toxic Substance and Disease Registry (ATSDR), that the previously conducted studies over the past half a dozen years on the potential public health and environmental impacts of the UCD DOE LEHR national Superfund site were significantly deficient with respect to evaluating the potential for hazardous chemicals present in LEHR site stormwater runoff and wastewater discharges to cause public health and environmental problems associated with the use of Putah Creek. Of particular concern was the lack of information on the potential for LEHR site-derived wastes to bioaccumulate in Putah Creek fish to hazardous levels for those who use the fish as food, as well as other forms of aquatic and terrestrial wildlife. This situation led to ATSDR developing a cooperative working relationship with the US EPA Region 9, where a set of fish, water, and sediment samples were collected in 1996 from Putah Creek for analysis for chemicals that are of typical concern because of their potential to bioaccumulate to excessive levels in fish and other aquatic life, causing these organisms to be a threat to those who use them as food.

In the Winter of 1997 the first draft versions of the 1996 Putah Creek bioaccumulation studies were released. Since that time there have been a series of comments on that study relative to the important information gained from it and the deficiencies in the study. These comments have been prepared by J. Roth, Executive Director of DSCSOC and Dr. G. Fred Lee. The results of the 1996 fish bioaccumulation studies and the comments on these studies are available for review on the DSCSOC website, http://members.aol.com/dscsoc/dscsoc.htm. They include the following:

"Concentrations of Selected Radionuclides and Chemicals in Fish, Sediment, and Water Collected from the Putah Creek Near the Former Laboratory for Energy-Related Health Research," March 31, 1997.

"Health Consultation; Fish Sampling in Putah Creek, 1996," April 4, 1997.
"Agency for Toxic Substance and Disease Registry's (ATSDR) Fish Hazardous Chemical Study Report for Putah Creek," undated.

"Comments on UCD Bioaccumulation Studies," July 2, 1998.

"Follow-up Sampling of Putah Creek Fish for Hazardous Chemical Content," October 12, 1997.

"Unreliable Information on the Hazards of Consuming Putah Creek Fish Due to Excessive Bioaccumulation of Mercury and Lead," April 14, 1998.

"Additional Comments on Responses to 1996 ATSDR Bioaccumulation Studies," April 27, 1998.

In addition, several of the RPM meeting comments submitted by Dr. Lee to DSCSOC contain additional information on these issues.

The 1996 fish bioaccumlation study showed that Putah Creek fish taken from the vicinity of where some of the LEHR site stormwater and UCD campus wastewater, which includes waste from the LEHR site, as well as stormwater runoff from this site, contained excessive concentrations of mercury and lead. Fish taken upstream and downstream of this location did not contain excessive concentrations of these or other constituents that typically bioaccumulate in fish tissue to levels that represent a threat to human health.

However, as pointed out by Dr. Lee, there were significant problems with some of the analytical methods used for some other constituents of potential concern, especially certain chlorinated hydrocarbon pesticides, in that the analytical methods did not have sufficient sensitivity to measure the constituent of concern at the level that the US EPA Region 9 has established as a guideline value for potential human health impacts. Further, there were some problems with the ATSDR US EPA report with respect to interpretation of the sediment quality data. DSCSOC recommended that follow-on studies be conducted to better define the magnitude of the bioaccumulation problem, the year-to-year variability of the results, and to measure the other constituents with sufficient analytical method sensitivity to determine if these constituents were present in fish tissue above US EPA Region 9 guideline values. Also of concern was the initiation of studies to determine the source of the lead and mercury that was found in the fish taken from Putah Creek near Old Davis Road.

Overall Comments on 1997 Fish Bioaccumulation Studies

The 1997 bioaccumulation studies, which are the subject of this report, showed that some fish taken from Putah Creek in the vicinity of the University of California, Davis wastewater and stormwater discharges to Putah Creek contained excessive concentrations of mercury. Of particular concern were the higher trophic-level "game" fish, such as largemouth bass. However, again, there were significant problems with the analysis of the fish obtained in these studies with reference to certain chlorinated hydrocarbon chemicals that are of concern because of their tendency to bioaccumulate to excessive levels in fish tissue, causing the fish to be considered hazardous to those who consume them as food. These studies confirm that there is a potentially significant public health problem associated with consuming fish from Putah Creek because of excessive concentrations of mercury and possibly other constituents in the fish tissue.

There is need for the regulatory agencies and the responsible parties for the LEHR site, the University of California, Davis, and others to implement a comprehensive, ongoing monitoring program for excessive bioaccumulation of hazardous chemicals in Putah Creek fish in order to define the magnitude of the problem, factors influencing the degree of bioaccumulation, the sources of the bioaccumulatable chemicals, and/or other constituents that lead to excessive bioaccumulation, such as the discharge of inadequately treated campus wastewaters to Putah Creek by the University of California, Davis. Further, in accord with current regulatory requirements, Putah Creek should be listed as an impaired waterbody that will lead to the development of a comprehensive remediation program to control the excessive bioaccumulation of hazardous chemicals in Putah Creek fish. Presented below are specific comments on the September 16, 1998 draft 1997 fish bioaccumulation studies.

Specific Comments

The cover page for this report lists the LEHR site as Yolo County. The LEHR site is in Solano County.

On page 1, under "Background," third paragraph, no mention is made of the fact that inadequate analytical methods were used in the 1996 fish bioaccumlation studies for several of the constituents of concern to detect the presence of the constituent at potentially hazardous concentrations. This should be mentioned, since now the presentation of the results is misleading, in that there could have been other bioaccumulation problems other than lead and mercury, which would have been detected if appropriate analytical methods had been used. As pointed out by the DSCSOC in their comments on the 1996 fish bioaccumulation studies, the second set of samples should have included organics as well, where more appropriate analytical methods were used for certain of the organics than were used in the 1996 sampling.

On page 1, last paragraph, it is mentioned that Thomas R. Payne & Associates, Inc. has been conducting fisheries monitoring on the lower Putah Creek for the Solano County Water Agency for the past six years. Copies of that data should be obtained and reviewed.

On page 2, under "Conclusions," it is of interest to find that mercury is still being found to be at excessive concentrations in some Putah Creek fish taken near the LEHR site.

On page 2, Conclusion 6, the statement, *"None of the analyses indicate that metals or other radionuclides in sediments pose a public health hazard."* This statement cannot be made from the data that are available. As discussed in DSCSOC's comments on the 1996 study, it is not possible from the data available to rule out that mercury in sediments in Putah Creek are a source of the mercury that is bioaccumulating to excessive levels in Putah Creek fish.

Conclusion No. 6 needs to be modified to state that "None of the analyses indicate that the metals in the sediments pose a public health hazard through direct contact. The mercury in sediments could be a public health threat through conversion to methylmercury, which then bioaccumulates in some fish to excessive levels."

Page 3, under "Follow-Up Public Health Actions," focuses on preparing a brochure which could be distributed to pregnant and nursing women to warn them about eating largemouth bass from Putah Creek. This approach is not adequate for protection of public health; Putah Creek should be posted so that anyone fishing in the creek has the opportunity to readily observe signs that indicate that some fish taken from the creek contain excessive concentrations of mercury that are a threat to pregnant women and their fetuses, nursing women, and young children.

Page 4, first paragraph, makes an erroneous, or what could readily be an inappropriate conclusion with respect to the relationship between the total mercury concentration in sediments and the potential for the sediments to be a source of bioaccumulatable mercury. It is well known that the total concentration of mercury in sediments is not the primary determining factor in the development of methylmercury, which is the form of mercury that accumulates in fish tissue. Sediments with the same total mercury can readily have different rates of conversion to methylmercury, depending on other characteristics of the sediments. These issues were discussed in DSCSOC's previous comments on the 1996 sampling of Putah Creek fish and sediments. It is unfortunate that this same type of error has occurred again in this report since it provides unreliable information on key issues that need to be considered in evaluating the hazards that mercury in sediments in Putah Creek represent to people who use Putah Creek fish as food. As discussed in DSCSOC's previous comments, the reason that the 1996 sampling of fish may have shown excessive concentrations of mercury off the area where the campus wastewater treatment plant discharges to Putah Creek and some of the LEHR site stormwater that enters the Creek is that the treatment plant and stormwater runoff contribute substances to the Creek which promote methylmercury formation in the sediments.

On page 4, third paragraph, mention is made that ATSDR has used 0.56 mg/kg wet weight fish tissue concentration as the screening value for excessive mercury in fish. That value is about four times higher than what the US EPA Region 9 has recommended as a screening value for mercury in fish for individuals who eat one meal per week of fish containing this level of mercury. This situation reflects the difference of opinion between US EPA and ATSDR on the critical concentrations of mercury in fish.

Page 6, first paragraph, states that the data that have been collected on potentially hazardous organics are not adequate to determine whether toxic organic substances are at levels of health concern in fish. This issue was pointed out by DSCSOC in the comments on the 1996 study conducted by the US EPA and ATSDR. It is unfortunate that the 1997 study still did not address this issue adequately. This further substantiates DSCSOC's position that there is need to do credible, on-going bioaccumulation studies of fish and other aquatic life in Putah Creek to ensure protection of public health and the environment from the hazards associated with the presence of these constituents in Putah Creek water and sediments.

Page 15, Table 3B indicates that the information on the size of a channel catfish and black bullhead is not available. It is difficult to understand why such information is not available.

It should be noted, from the data presented, that many of the fish - bluegill, carp - contain concentrations of mercury at or just under the US EPA Region 9 guideline value.

Page 18, Table 5A for the chromium data which is assumed to be total chromium shows that the dissolved chromium, which could readily be chromium VI, is present in Putah Creek water at concentrations that are potentially toxic to zooplankton. This data and similar data taken in the past indicate that Putah Creek should be listed as an impaired waterbody due to the fact that the concentrations of chromium are repeatedly being found to be higher than well-established values for chromium VI toxicity to zooplankton. This, in turn, should cause the regulatory agencies to follow current regulatory practice of initiating a remediation program, including the development of TMDLs, to control the sources of chromium to Putah Creek so that they do not cause aquatic life toxicity within the Creek.

Page 19, Table 5B, indicates that the mercury concentrations in the Putah Creek water at the various locations were less than the detection limits used in the studies. Unfortunately, this is another example of inadequate detection limits used in these studies. The current US EPA "Gold Book" criterion for total recoverable mercury in water is 12 ng/L. This table indicates that the detection limit used in this study was 120 ng/L. The US EPA will, as part of its revised national mercury study, decrease the allowable mercury in water to approximately 5 ng/L. Based on how the Putah Creek studies were conducted, all that could be said about the water concentrations of mercury is that the concentrations are less than the detection limit. However, what should be said is that the analytical method detection limit used is inadequate to detect mercury at concentrations which represent worst-case-based assessments for bioaccumulation of mercury to excessive levels in fish. There are analytical methods that can detect mercury at the critical levels. Unfortunately, these were again not used in these studies, even though this problem was pointed out in the DSCSOC comments on the 1996 study.

One of the issues that should be mentioned in this report is that the Putah Creek flow regimes during the 1996 and 1997 studies are significantly different. Increased flow, such as occurred in 1997, would tend to lead to a more widespread distribution of fish and mercury problems than would occur under low-flow conditions associated with UCD wastewater and/or LEHR site stormwater runoff-derived mercury or constituents that promote mercury methylation.

G. Fred Lee & Associates

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October 26, 1998

Gary M. Carlton
Executive Officer
Central Valley Regional Water
Quality Control Board
3443 Routier Road
Sacramento, CA 95827-3098

K30- 9

Dear Gary:

Attached is a report that I have developed on mercury bioaccumulation issues in fish taken from Putah Creek. I am bringing this to your attention since the Central Valley Regional Water Quality Control Board needs to begin to develop and implement a mercury source evaluation and control program to protect those who consume fish from Putah Creek from mercury toxicity. There are sufficient data now with the recent release of the US EPA Region 9 - ATSDR data for samples of fish taken during 1997, coupled with the 1996 data to demonstrate that there is a human health hazard associated with consuming fish taken from Putah Creek. My report provides specific recommendations on issues that the CVRWQCB should address.

I have also enclosed a copy of my comments to the ATSDR on the September, 1998 draft report on Putah Creek hazardous chemical bioaccumulation issues.

This request for regulatory attention to address mercury bioaccumulation in fish is being submitted on behalf of the public and is supported by the Davis South Campus Superfund Oversight Committee. If there are questions about this issue, please contact me.

Sincerely yours,

G. Fred Lee

G. Fred Lee, PhD, DEE

Copy to: J. Bruns
C. Foe
V. Connor

S. Yee
Yolo County Dept. of Health
Solano County Dept. of Health
R. Woodard
B. Macler
B. Jennings-DeltaKeeper
Gail Louis, US EPA Region 9
J. Roth, DSCSOC
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Sacramento River Watershed Toxics and Monitoring Subcommittees
Putah Creek Council
LEHR National Superfund Site RPMs and PRPs

GFL:oh
Enclosure

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September 30, 1998

Dr. William Taylor
ATSDR
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Atlanta, GA 30333

R 30 -h

Re: ATSDR's Phase II Fish Study

Dear Bill,

I have reviewed ATSDR's Phase II Fish Study and wish to thank ATSDR for conducting the second fish study as part of the Public Health Risk Assessment for the DOE-UCD LEHR Superfund site on the UC Davis campus. I also wish to thank you for discussing the health hazard associated with mercury in Putah Creek fish to the Davis community's attention at DSCSOC's Town Meetings. The mercury hazard in the creek has been ignored prior to ATSDR's studies. It would be wonderful if this community looked upon ATSDR's studies as the catalyst to cleanup Putah Creek. I think the most effective way to protect the fish, the public's health and our environment is to eliminate the mercury source(s) and post the creek warning the public not to eat fish form the creek. Also an effort to try to inform pregnant-nursing women about the hazards of eating fish taken form the creek should be undertaken.

There may be several sources of excessive mercury in Putah Creek fish; it is time to investigate and control the source (s). Citizens should be able to enjoy their waterways without risk. A source investigation must include the UCD campus and LEHR site stormwater runoff and the UCD campus wastewater treatment plant discharge to Putah Creek. Mercury is one of the LEHR COC's which is present at the site and may be contributing to the bioaccumulation in Putah Creek's large mouth bass and other fish.

The University of California, Davis should conduct a study to see if any of UCD's numerous discharges to Putah Creek are impacting or contributing to the mercury problems. Some members of this community have asked that UCD conduct a reliable and independent cumulative impact study of all of its discharges to the creek without success. UCD is the only discharger to Putah Creek in this area. If UCD wants to use Putah Creek as its own private sewer than UCD must take whatever actions are necessary to protect the pubic who use the creek.

Members of the public, who are not of child bearing age, may not pay attention to warnings for pregnant or child bearing age women and may unknowing provide fish to women who are at risk. If members of the public saw a sign warning them of the hazard of eating fish at a location where they intended to fish, they would be more likely refrain eating the fish or passing the fish on to those at risk. The way to protect the public is to eliminate the source(s) and post the creek.

I appreciate the opportunity to comment on ATSDR's Phase II document.

Sincerely,

Julie Roth, Ex. Dir.

cc: DSCSOC's Ex. Board
Dr. G. Fred Lee
LEHR RPMs
LEHR PRPs
Jane Riggan, CDHS

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October 12, 1997

Via fax

Gary Carlton
Executive Officer
Central Valley Regional Water Quality Control Board
3443 Routier Road, Suite A
Sacramento, CA 95827

Dear Mr. Carlton,

Enclosed please find Dr. G. Fred Lee's comments on the ATSDR's planned "Follow-Up Sampling of Putah Creek Fish for Hazardous Chemical Content" submitted to DSCSOC and forwarded to William Taylor, ATSDR. Please forward Dr. Lee's comments to the CVRWQC Board members for their review prior to their consideration of the University of California, Davis Wastewater Treatment Plant Discharge Requirements, Cease and Desist Order and the proposed Replacement Wastewater Treatment Plant Facility issues now pending before the Board and scheduled for hearing on October 24th.

It is important that the Board members understand that contrary to UCD's David Phillips' testimony at the Board's meeting on managing toxicity held on September 19, 1997 that Putah Creek is in "excellent condition" and not adversely affected by its campus wastewater treatment plant's discharges, the weight of evidence currently available is that UCD is responsible for the mercury and hazardous chemical bioaccumulation problems in Putah Creek that have been found in the previous ATSDR/NARPEL studies. Fish taken from Putah Creek near the Wastewater Treatment Plant discharge have bioaccumulated hazardous levels of mercury and lead and represent a public health hazard to those who use the fish as food. Further, contrary to Mr. Phillips' propaganda statement, there can be little doubt that the chronic toxicity that has been present in UCD's wastewater discharges to Putah Creek at least over the past few years has caused toxic conditions in Putah Creek which are in violation of the Basin Plan requirements of no toxics in toxic amounts. Mr. Phillips' "excellent condition" statement is based on a superficial review of the characteristics of the fish population in Putah Creek which ignores the bioaccumulation issues and the measured toxicity in the wastewater discharges.

There were some problems with the sensitivity of the analytical procedures used in the ATSDR/NARPEL studies. Several chlorinated hydrocarbons were not measured with sufficiently sensitive analytical procedures to determine whether there is an excessive bioaccumulation problem. Further, no measure was made of dioxins where are frequently the cause bioaccumulation problems. It would be premature for this Board to accept UCD's statements regarding its impacts on Putah Creek until a more comprehensive study is completed which includes sufficient sensitivity to detect hazardous constituents of concern that have bioaccumulated in fish tissue at potentially hazardous levels based on values that the US EPA Region 9 has provided to the San Francisco Regional Water Quality Control Board has been conducted.

As discussed in Dr. Lee's comments on the proposed ATSDR/NARPEL additional studies on bioaccumulation in Putah Creek fish, the ATSDR/NARPEL cannot do the follow-up studies on the chlorinated hydrocarbon chemicals of concern. Since the excessive bioaccumulation problems that have been found in fish taken from the Creek near the UCD campus wastewater discharge are almost certainly associated with UCD's wastewater discharges or stormwater runoff to Putah Creek, the public requests that as part of issuing a revised Wastewater Treatment Plant permit the CVRWQCB require that UCD develop an on-going bioaccumulation study program which would not only address the deficiencies in the previously conducted studies, but also would provide continuing information on bioaccumulation issues associated with UCD's discharges of wastewaters and stormwaters to Putah Creek.

While there have been problems in the past with the approach that has been followed by the CVRWQCB staff in enforcing UCD's compliance with Basin Plan objectives, the public requests that this Board require full compliance with Basin Plan objectives for protection of public health and the environment where compliance is properly monitored by UCD.

Dr. Lee invites those who have questions or comments about his information to contact him. On behalf of Dr. Lee, I invite you, CVRWQC Board members and staff or others who have questions regarding this information to contact Dr. Lee.

I thank you for your attention to this matter.

Sincerely,

Julie Roth, Ex. Dir.

cc: Dr. G. Fred Lee
DSCSOC's Board Members
William H. Taylor
LEHR RPMs

LEHR PRPs
Jane Riggan
Brian Shafer

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February 11, 2000

County of Yolo
Department of Public Health
Tom Y. To, R.E.H.S., MPH, Director
Environmental Health Services
10 Cottonwood Street
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R30-1

County of Solano
Department of Public Health
Birgetta Corsella
Environmental Health Services
601 Texas Street
Fairfield, CA 94533

Dear Mr. To and Ms. Corsella,

As part of the UC Davis/Department of Energy (UCD/DOE) LEHR Superfund site investigation on the UCD campus near Putah Creek, the Agency for Toxic Substance and Disease Registry (ATSDR) conducted two fish studies. Both studies found that mercury had bioaccumulated in some fish at hazardous levels and poses a public health hazard to those who consume the fish. ATSDR's first study recommended Putah Creek be posted to warn people about the hazard of consuming fish in the vicinity of the UCD campus wastewater and stormwater discharges to Putah Creek near the LEHR site. Although both Yolo and Solano County Environmental Health Agencies and other public agencies were notified of ATSDR's recommendation, no action was taken and Putah Creek was never posted to warn the public about consuming fish taken from Putah Creek.

ATSDR's second study (Phase II) confirmed the hazardous levels of mercury in edible (primarily largemouth bass) fish in Putah Creek near the UCD campus. ATSDR recommended that as a follow-up Public Health Action, the public be contacted on this issue. In a follow-up study, Dr. Darrell Slotton of UC Davis found that not only is there a problem of excessive mercury in fish taken near the University of California, Davis wastewater discharges to Putah Creek and its LEHR site stormwater discharges to Putah Creek, but also there were problems with excessive mercury accumulation in some fish throughout the length of Putah Creek.

ATSDR representatives proposed to work with local health officials to develop and implement a plan for providing survey information to persons who eat fish from Putah Creek. ATSDR also indicated that it would work with health department representatives to distribute information, including a summary of the fish survey and health implications of mercury exposure to local health care providers who provide care to pregnant or lactating women. To my knowledge, ATSDR and/or local public health agencies have not implemented ATSDR's proposed follow-up Public Health Action. Further, the public has not been informed by the local health agencies, or, for that matter, anyone else, about the hazard of consuming fish taken from Putah Creek.

DSCSOC, the citizens oversight group at the LEHR site, has repeatedly requested that Putah Creek be posted and ATSDR's follow-up actions be implemented. The first priority must be to protect the public's health. The health risk to the public who use Putah Creek fish as a food source is not disputed. The reason DSCSOC has been given that ATSDR's recommendations have not been implemented is that no local agency is willing to accept authority/responsibility for posting the creek or conducting the recommended follow-up actions.

In the Friday, February 11, 2000 *San Francisco Chronicle* is an article on page A21 titled "**San Pablo Reservoir Fish Tainted.**" (Copy enclosed.) This article states "**High levels of mercury found in largemouth bass in San Pablo Reservoir prompted Contra Costa County officials this week to issue an advisory warning against eating the fish.**" The Contra Costa County Department of Health Services' advisory warns of the same health hazard to the public who eat mercury-contaminated fish from the San Pablo Reservoir as ATSDR recommended for the pubic who eat Putah Creek mercury-contaminated fish.

The article goes on to state that "[Greg] **Karras,** [senior scientist at Communities for a Better Environment] **and other activists said state and local government should move quickly to determine how great a threat dioxin, PCBs and mercury pose to various species of fish and to take action against known sources of pollution.**" These same recommendations with respect to mercury in Putah Creek fish were issued by DSCSOC's technical advisor, Dr. G. Fred Lee, in his comments regarding the ATSDR studies and his comments on UCD/LEHR wastewater and stormwater discharges to Putah Creek. (I have enclosed a copy of Dr. Lee's "**Unreliable Information on Hazards of Consuming Putah Creek Fish Due to Excessive Bioaccumulation of Mercury and Lead**" dated April 13, 1998. Other comments provided by Dr. Lee on these subjects can be found on DSCSOC's document web site http://members.aol.com/dscsoc/doc.htm.)

It is unfortunate that, after two ATSDR studies found high levels of mercury contamination in Putah Creek fish and stated that these fish pose a public health hazard, Yolo and Solano County Departments of Health Services failed to implement ATSDR's recommended actions and failed to warn the citizens who eat Putah Creek fish. On the other hand, Contra Costa County Department of Health Services issued an advisory to warn its citizens of the public health hazard posed by eating mercury-contaminated fish from the San Pablo Reservoir, based on the same mercury contamination in its fish. Contra Costa County's action confirms that County Departments of Health Services have the authority/responsibility to issue advisory warnings to citizens against eating mercury-contaminated fish.

DSCSOC requests that Yolo and Solano County Departments of Public Health Services issue an immediate advisory warning for Putah Creek fish; move quickly to determine how great a threat dioxin, PCBs and mercury pose to various species of fish; and take action against known sources of pollution. The advisory warning, the posting of Putah Creek, implementing ATSDR's follow-up Public Health Actions, and a study of other possible hazardous chemicals in Putah Creek fish are actions that Yolo and Solano County Departments of Health Services should take immediately to protect the public's health. These actions should be given a priority by your agencies.

Sincerely,

Julie Roth
Executive Director

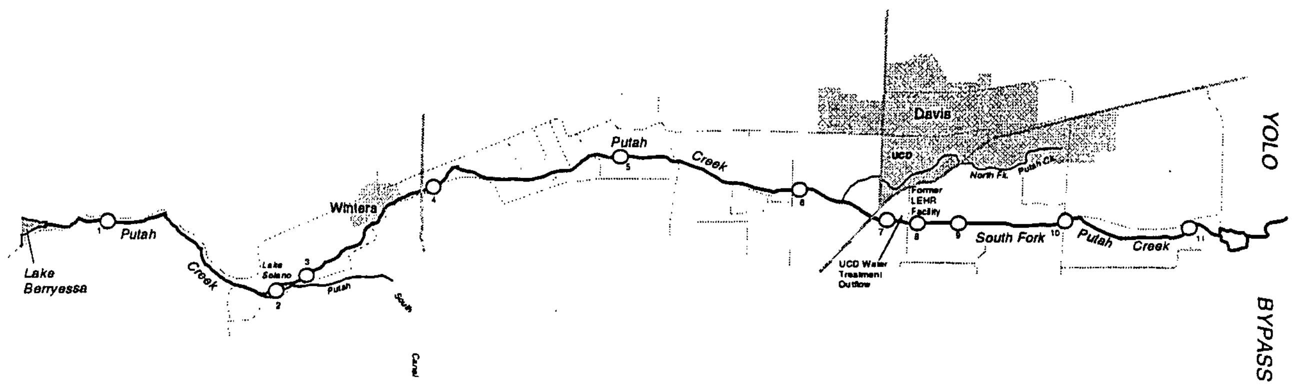
cc: Wayne Henry, ATSDR
LEHR RPMs & PRPs
Gary Carlton, CVRWQCB
Dr. Val Connor, CVRWQCB
Dr. C. Foe, CVRWQCB
Bill Jennings, DeltaKeeper
Dr. G. Fred Lee, DSCSOC Advisor

LOWER PUTAH CREEK 1997-1998 MERCURY BIOLOGICAL DISTRIBUTION STUDY

February 1999

CONDUCTED FOR:

The Department of Environmental Health and Safety,
University of California, Davis



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EXECUTIVE SUMMARY

- In the fall seasons of 1997 and 1998, an extensive study of mercury in biota was conducted in lower Putah Creek. This study was initiated (1) to accurately determine potential spatial variability in mercury contamination in the creek and (2) to provide a large new data base of mercury concentrations in Putah Creek organisms.

- Limited prior sampling by federal agencies in 1996, together with associated public and expert comments, had suggested that the University of California, Davis might in some way exacerbate mercury contamination problems in Putah Creek. It was hypothesized that potential drainage from the University's former Laboratory for Energy-Related Health Research (LEHR, adjacent to the creek) and outflow from the campus wastewater treatment plant could be important. Limited follow-up collections by the same federal agencies in 1997 indicated that, while mercury was indeed elevated in certain Putah Creek organisms, the problem was apparently widespread in the creek and unrelated to the University. Public and expert comment found significant fault with both federal studies and continued to hypothesize that the University might adversely impact mercury dynamics in Putah Creek.

- The current research work utilized eleven sampling sites. In order to place potential mercury-related loadings from the LEHR site and other UC Davis property into geographic context, sites were sampled throughout the length of lower Putah Creek, between the Monticello Dam at Lake Berryessa and the outlet of the creek at the Yolo Bypass. Sites were generally distributed every 3-4 creek miles and chosen so as to sample important potential sources of both inorganic or methylated mercury.

- An extensive array of biological samples was collected and analyzed for mercury, including adult fish edible muscle samples from 16 different species in a range of sizes (127 individual adult fish samples). A wide variety of small and juvenile fish were sampled and analyzed in consistent, multi-individual, whole body composites (48 total), as were 25 composite samples of aquatic insects. Muscle mercury was additionally analyzed in 80 individual samples of adult crayfish, also distributed across the entire length of lower Putah Creek. A primary objective of this work was to provide readily comparable, equivalent samples at different sites to facilitate the meaningful comparison of relative mercury exposure, uptake, and accumulation.

- The study confirmed that many of the Putah Creek fish species contained mercury concentrations in edible muscle at levels of potential concern, depending on the exposure criterion used, with larger individuals of the top predatory species most highly contaminated. The data further indicate that certain Putah Creek crayfish may represent a hazard for both human and wildlife consumption and that certain small or juvenile fish may represent a chronic hazard to fish-eating wildlife.

- Neither the town of Winters, the agricultural fields, nor the UC Davis region of the creek were found to significantly alter biological mercury trends in any of the organisms sampled, including those which exhibit high levels of site fidelity. Where closely comparable data could be collected, the stretch of Putah Creek adjacent to the University and downstream to a distance of at least 3 miles frequently contained among the lowest relative levels. Highest relative levels occurred in selected biota from just below Lake Berryessa, in and downstream of Lake Solano, and near the Yolo Bypass. The results of this study are consistent with remnant, mining-derived mercury (together with some level of ongoing transfer through Lake Berryessa) constituting the primary source of ongoing mercury contamination in lower Putah Creek.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Largely as a legacy of historic mining activities, water bodies throughout much of Northern and Central California are currently impacted by mercury contamination problems, particularly in relation to the consumption of fish. Mercury is a heavy metal that occurs in a number of different molecular forms. One of these, methyl mercury, has the unfortunate property of bioconcentrating through food webs. This means that the majority of ingested methyl mercury is retained at each trophic (feeding) level, to be passed on to higher level consumers. The result of this is that increasing concentrations of methyl mercury can accumulate at succeeding rungs of the "trophic ladder" and dangerously high levels of methyl mercury can accumulate in the upper level predatory species present in impacted aquatic systems. When these species are utilized as food by humans or wildlife, the concern arises that exposure to neurological toxicity may occur. Methyl mercury is a potent neuro-toxin that has been shown to exhibit effects primarily on rapidly growing nervous system tissue. This places fetuses and young children at greatest risk and is the reason that current fish consumption guidelines are most protective of pregnant women and children under age 6.

Mercury contamination is a serious problem throughout much of the Northern Hemisphere. Across the Midwest and Eastern regions of the United States and Canada, as well as the majority of Europe, trace deposition of global, atmospherically spread mercury (derived from general industrial power production, etc.) has been sufficient to contaminate numerous water bodies to above health guideline levels. In California, we are fortunate to have water quality (typically alkaline and containing higher levels of suspended matter) that is relatively less compatible with the production, solubility, and biological uptake of methyl mercury. However, California water bodies are additionally exposed to massive, bulk mercury contamination from historic mining activities on both sides of the state. The California Coast Ranges contain one of the world's great geologic mercury–enriched belts. When the California Gold Rush occurred in the mid 1800s, relatively inexpensive mercury was used extensively to amalgamate gold, greatly increasing yields. Mercury was used to bind and retain the smaller, otherwise easily lost particles of gold. Upon distilling with heat, the mercury could be vaporized, leaving behind the accumulated gold. This generated a corresponding "Mercury Rush" in California, with dozens of medium to large-scale mercury mining operations in the Coast Ranges supplying refined, elemental mercury ("quicksilver") for use in the Sierra Nevada gold fields. Today, California is the site of numerous abandoned, leaking mercury mines throughout the Coast Ranges and, also, significant tonnage of misplaced elemental mercury throughout the Sierra Nevada gold and silver mining regions. Because of the relatively favorable water quality typical in California, with regard to methyl mercury formation, solubility and biological uptake, mercury accumulations of concern here are typically associated only with instances of bulk mercury contamination. However, bulk mercury contamination is present in numerous water bodies throughout the region (Reuter *et al.* 1989, 1998, Gill and Bruland 1990, TSMP 1990-1997, Slotton *et al.* 1991, 1995a,b, 1996, 1997a,b,c, Suchanek *et al.* 1993, 1995, 1997, 1999).

The research work documented in this report was conducted in response to a previous study conducted by a federal agency, the Agency for Toxic Substances and Disease Registry (ATSDR), together with US EPA Region 9 (ATSDR 1997, NAREL 1997). In 1996, these agencies investigated a large array of potential toxicants in biological samples collected from Putah Creek. The sampling was conducted in relation to the former UC Davis Laboratory for Energy-Related Health Research (LEHR), which had been designated a US EPA Superfund cleanup site. Primarily focusing on a wide range of radioactive isotopes which had been utilized decades earlier at the site, the ATSDR and EPA Region 9 collections from adjacent Putah Creek analyzed for an intensive suite of radionuclides, pesticides, other organic toxics, and heavy metals.

Of the large suite of investigated toxic substances, none of the organics or radionuclides were found at levels of concern (though some controversy continues as to the adequacy of the organic parameter list, Lee 1997, 1998). However, the heavy metals mercury and lead were found at relatively elevated levels in certain samples. Lead was elevated in one composite sample collected from Putah Creek immediately downstream of the UC Davis former LEHR site. Mercury was elevated relative to an upstream control in samples taken downstream near the University. It was suggested that UC Davis and the LEHR site were the source of the elevated levels.

Lead in the creek can probably be ruled out as a serious threat to human and wildlife health. Lead does not typically bioconcentrate in edible (fillet) fish tissue (Forstner and Wittman 1981, Hutchinson and Meema 1987), which is why it is routinely monitored in liver only, where it can concentrate (TSMP 1990-1997). Lead in fish flesh is not typically the subject of health advisories (TSMP 1990-1997, Cal. Fish and Game 1999). Lead could conceivably be detected in apparently elevated concentrations if the gut contents of bottom feeders were included in samples, due to sediment in the gut which contained lead. The concentrations of most metals (other than mercury) in bottom sediments are generally orders of magnitude greater than corresponding concentrations accumulated in the edible muscle tissue of aquatic organisms. Lead from the Putah Creek ATSDR sites followed this pattern, though absolute concentrations of sediment lead were not elevated relative to regional sediments. It is notable that the single case of apparently elevated lead in biological tissues came from a composite sample which included tail meat (presumably including intestinal tracts) of 10 large crayfish, which are bottom dwelling omnivore/detritivores. One conclusion that may be drawn is that crayfish may harbor sediment-associated metals in their digestive tracts. Elevated lead was not found in fish muscle in follow-up studies (ATSDR 1998).

Mercury, in comparison to lead, has been extensively documented to bioconcentrate through aquatic food webs, demonstrating incremental elevations in concentration with trophic level and size/age of fish, reaching highest concentrations in large/old individuals of top predator species (Huckabee *et al.* 1979, EPRI 1991, Wiener 1995). Because of the strong relationships typical between fish trophic level and mercury accumulation, and between fish size/age (for many predatory species) and mercury accumulation, it is imperative that exposure comparisons between different sites be made using similar samples. The sampling design of the ATSDR wide-spectrum screening project, however, required very large sample sizes (2 kg) to supply the myriad analyses undertaken. To provide sufficient sample at each site, it was necessary to pool multiple species of unrelated fishes and multiple individuals of widely varying sizes/ages. This resulted in significantly different samples from each of the sites. Where same species were taken, they were often of different life stage and feeding habit. The varied individuals were then mixed together, primarily into groups of surface and water column species (bass, bluegill, crappie) versus bottom dwellers (carp, catfish, bullhead, and crayfish). It is very notable that the background sample in the ATSDR study from above Pedrick Road was composed entirely of juvenile fish and crayfish. The sample was greatly dominated by low-trophic-level juvenile bluegill and green sunfish (521 g of the 620 g composite, or >84%). The remainder of the sample consisted of young largemouth bass (7% of the sample) much smaller than those near the LEHR site and UC Davis (mean size 64 g, as compared to 400-650 g individuals downstream), crayfish (7% of the sample), and a young white catfish (1% of the sample, 89 g, as compared to individual catfish of 700-2,600 g and bullhead in the 200-300 g range at the near-university site). Relative to the low trophic level background sample, the finding of elevated mercury in the samples taken near the university was not surprising. Those samples were dominated by muscle tissue from large individuals of predatory fish species such as catfish and bass.

While the initial ATSDR work did not provide readily comparable data between sites, it served its purpose as a screening study. The presence of elevated mercury in some of the downstream biological composites indicated that mercury levels of concern existed in some fraction of the creek biota. An eminent local biogeochemist, Dr. G. Fred Lee, advised that follow-up work be conducted (Lee 1997). Dr. Lee hypothesized that, despite the incomparability of the upstream/downstream ATSDR data, potential University discharges (both from the LEHR site and the campus wastewater treatment plant) might exacerbate mercury contamination in the creek. A follow-up set of fish collections was made by ATSDR and EPA Region 9 in 1997 (ATSDR 1998). These collections found relatively elevated, similar mercury levels in fishes taken upstream, adjacent to, and downstream of the University, confirming the presence of mercury at levels of concern in certain fish, and suggesting that the contamination was apparently a regional phenomenon, unrelated to potential University inputs. The ATSDR/EPA follow-up work, though based on samples of individual fish species, was again hampered somewhat by dissimilarity between samples taken at the different sites.

Dr. Lee raised the possibility that lower flow conditions in 1996 may have precluded upstream migration at barriers, isolating fish potentially exposed to University-related mercury effects in that year, and partially explaining the relatively higher mercury found adjacent to and downstream of the university in that year, as compared to upstream (Lee 1998). He suggested that the more uniform upstream/downstream results from 1997, a high water year, could have resulted from migration throughout the creek of fish which had obtained their mercury accumulations at or near the University property. He further hypothesized that while the university might not be a relatively important source of mercury to the system, it might contribute other water quality constituents (primarily dissolved and particulate organics from the wastewater outflow) which might exacerbate the production of methyl mercury, a bacterially mediated process that occurs primarily at the aerobic/anaerobic interface of aquatic systems.

The current study, reported here, utilized eleven sampling sites which were distributed along the entire length of lower Putah Creek, from Lake Berryessa to the Yolo Bypass (Figs. 1 and 2). The primary objective of the research was to compare relative levels of mercury exposure, uptake, and biological accumulation across the full length of the lower creek, testing the hypothesis that potential UC Davis inputs significantly influenced mercury levels in the creek biota. Figure 1 places the study area into regional context, while Figure 2 gives a close-up view of the sites. In addition to making extensive collections of adult fish of numerous species and across a range of sizes for muscle mercury analyses, we collected small and juvenile fish, crayfish, and aquatic insects at each of the sites, as available. These organisms supplemented the fish muscle data and were used as consistent bioindicators of more site-specific conditions.

In addition to the primary focus on possible spatial variation in relative mercury levels, a secondary objective of the study was to develop a substantial data base of absolute mercury concentrations for a wide range of aquatic organisms in Putah Creek. These supplement the preliminary work done by ATSDR and can be used by various agencies in determining potential human health and wildlife health exposures. Table 1 summarizes the numbers of mercury analytical samples collected for this project in 1997 and 1998. Total mercury was analyzed in 280 individual biological samples taken from sites along lower Putah Creek between Lake Berryessa and the Yolo Bypass. Additional analytical samples for the project included numerous field and laboratory duplicates, spike recovery samples, and standard reference materials.

Throughout this report, the data for each major sampling parameter are generally presented both in tabular and graphic form. Where appropriate, map figures of the spatial distribution of key data parameters are included for the entire study region. Tables and figures are placed at the ends of each section.

Table 1. Summary of Samples Analyzed for Mercury in This Project

Aquatic Insect Composites:	25
Small Fish/Tadpole Whole-body Composites:	48
Individual Crayfish Tail Muscle Samples:	80
Individual Adult Fish Fillet Muscle Samples:	127
TOTAL BIOTA SAMPLES:	**280**

Figure 1. Lower Putah Creek, Regional Map

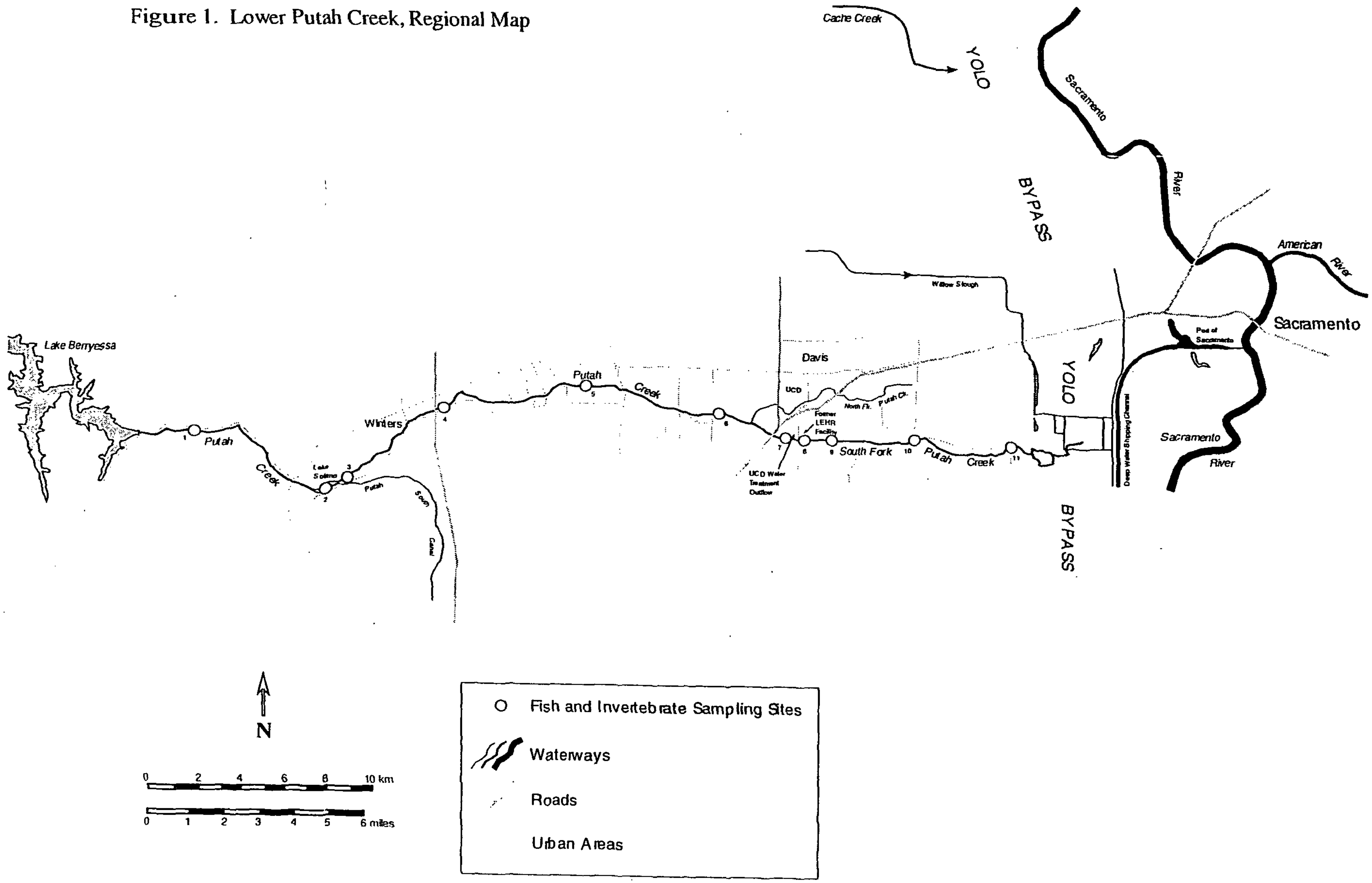
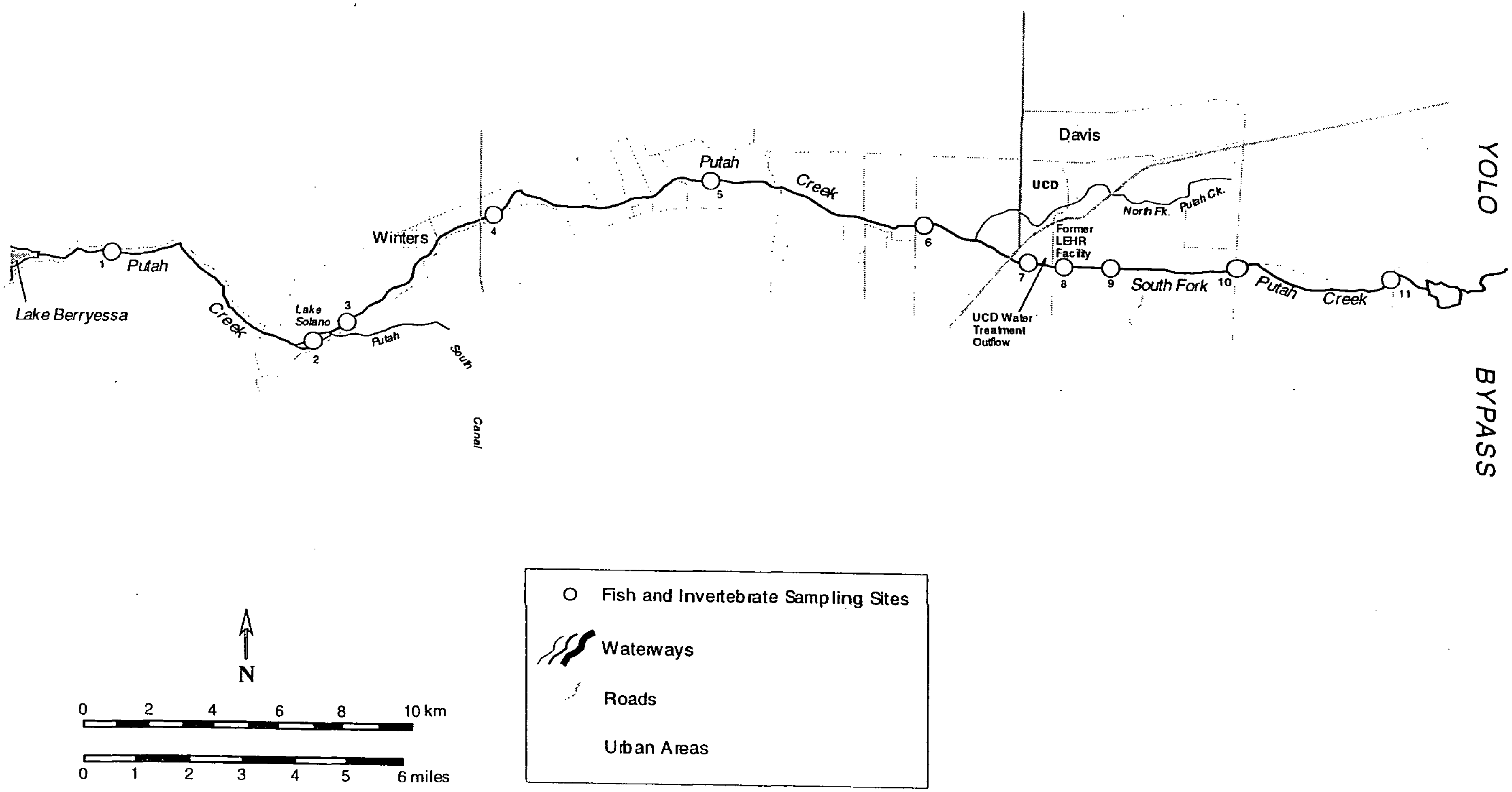


Figure 2. Lower Putah Creek, With Sampling Locations



2. METHODS

2.1 Site Selection

The sampling sites utilized for the project are shown in Figures 1 and 2. In order to place potential mercury loading from the LEHR site and other UC Davis property into geographic context, sites were sampled throughout the length of lower Putah Creek, between the Monticello Dam at Lake Berryessa and the outlet of the creek at the Yolo Bypass. Sites were generally distributed every 3-4 creek miles and chosen so as to sample important potential sources of both inorganic or methylated mercury. Eleven sites were utilized in the study. Site 1, representing Lake Berryessa releases, was located within the upper trout waters. Site 2, in Lake Solano, tested the possibility that this impoundment might result in increased mercury methylation and subsequent bioaccumulation by organisms. Site 3, located directly beneath Lake Solano, sampled the downstream release from the impoundment. Site 4, at Highway 505 below Winters, sampled the potential mercury outputs of that town. Site 5, at Russell Ranch, was located downstream of several miles of agricultural land and accompanying drainage, as was Site 6 at Pedrick Road. The Pedrick Road site was additionally of interest as a control relative to UCD property downstream. Site 7 was located immediately upstream of the outfall of the UC Davis wastewater treatment plant, capturing any potential UCD-related mercury inputs from upstream of this inflow. Site 8 was located a short distance downstream of the wastewater treatment outfall, adjacent to the LEHR site and just downstream of Old Davis Road. Site 9, capturing potential mercury effects of both the wastewater and LEHR inputs, was located 0.5-1.0 mile downstream of the LEHR site. Site 10 was several miles downstream of UC Davis at Mace Road. The most downstream site, Site 11, was located approximately 6 miles below UC Davis at and downstream of Road 106A, very near the creek's outflow into the Yolo Bypass.

Adult fish were sampled from all sites which were sufficiently spaced (or blocked by barrier) to achieve meaningful separation. This included Sites 1-6 and 9-11 (9 total). Small and juvenile fish and aquatic insects, which exhibit greater site fidelity than adult fish, were taken at all sites where they were present and available to our collection techniques. This included, for small fish, Sites 1 and 3-11 (10 sites total) and, for aquatic insects, Sites 1, 3-7, and 10-11 (8 sites total). Crayfish were taken from 10 sites: 1-6 and 8-11.

2.2 Collection and Sample Preparatory Techniques

2.2.1 Fish

Adult fish for muscle (fillet) mercury analysis were taken primarily with several large experimental gill nets containing a wide range of mesh sizes. These were deployed from a small boat equipped with an outboard motor. In several cases the boat needed to be dragged overland a considerable distance to reach the water. Once deployed, nets were monitored closely and were harvested frequently so as to avoid fish mortality. Fish were maintained live in holding tanks and were rapidly processed on the boat and then released, generally in good condition. Processing included species identification, measurement of standard and fork length, weighing, and careful removal of a small sample of fillet muscle (0.20 grams, similar in size to a raisin). Fish were released approximately 0.5 km from their capture point so as not to be re-netted. Multiple days of sampling were required at several of the sites.

Tissue samples for mercury analysis were excised using clean technique, with stainless steel scalpels. Muscle samples were taken from the dorso-lateral ("shoulder") region, as done by the California Department of Fish and Game. A small patch of skin/scales was pulled back to obtain the clean muscle sample. Extraneous surface moisture was blotted off with a laboratory tissue and the sample was placed directly into a pre-weighed laboratory digestion tube, which was capped with a teflon liner. The precise weight of each tissue sample was determined by weighing the tubes containing samples (together with pre-weighed blanks) and subtracting the initial empty weights. We have utilized these non-destructive sampling techniques with great success in similar work over the past 15 years (Reuter *et al.* 1989, 1998, Slotton 1991, Slotton *et al.* 1995a,b, 1996, 1997a,b,c).

2.2.3 Small and juvenile fish

Small and juvenile fish were taken from stream sites, where present, utilizing both a research electroshocker and seines which were pulled through certain stretches to trap fish. Individuals to be analyzed for mercury were held on ice in sealed bags. They were later (within 24 hours) cleaned in DI water at the UCD laboratory, identified, weighed and measured, and homogenized into appropriate composite samples with a laboratory homogenizer. An aliquot of the homogenized sample was precisely weighed into a laboratory digestion tube, which was capped with a teflon liner.

2.2.3 Invertebrates

Stream invertebrates were taken from riffle habitat at each of the sites where they were present, i.e. from rapids or cobble bottomed stretches with maximal flow, where aquatic insects tend to be most concentrated among the rock interstices and other debris. Stream invertebrates were collected primarily with the use of a research kick screen. At each site, one researcher spread and positioned the screen perpendicular to the flow, bracing the side dowels against the bottom, while the other researcher overturned boulders and cobble or dislodged debris piles directly upstream of the screen. These were hand scrubbed into the flow, dislodging any clinging biota. Following the removal of the larger rocks/branches to the side of the stretch, the underlying substrate was disrupted by shuffling the boots repeatedly. Invertebrates were washed into the screen by the current. The screen was then lifted out of the current and taken to the shore, where forceps were used to pick macro-invertebrates from the screen into collection jars. This process was repeated at each site until a sufficient sample size of each taxon of interest was accumulated to permit analysis for mercury.

Samples were maintained in their collection jars on ice, and then cleaned in fresh water within 24 hours of collection. Cleaning was accomplished by suspending sample organisms in fresh water and, as necessary, shaking individuals in the water with teflon-coated forceps to remove any significant clinging surficial material. Cleaned organisms were stored in pre-cleaned glass jars with teflon-lined caps, which were frozen (to kill humanely) and then dried at 50-60 °C. The dried sample was homogenized to a fine powder with teflon-coated instruments and precisely weighed into a laboratory digestion tube, as above. All of these techniques have been well established and tested in extensive prior mercury research work throughout California (Slotton *et al.* 1995a, 1996, 1997a,b,c).

2.2.4 Crayfish

Collection of sufficient crayfish for meaningful inter-site comparison required the overnight setting of numerous baited crayfish traps on many different occasions for each site throughout the fall of 1998. Traps were retrieved and re-set daily. Any captured individuals were retained on ice. Live crayfish were sorted and identified to species (Light 1994). Weight and carapace length (standard crayfish morphometrics) were obtained. After freezing and re-thawing, a sample of tail muscle was excised, using clean technique, with a stainless steel scalpel. Due to variation encountered in the moisture content of these samples, crayfish muscle samples were dried for uniformity. Dry weight concentrations were corrected for individual moisture percentage so as to present this data (for a potential human consumption item) in the same units used for edible fish tissue (fresh/wet weight parts per million mercury).

2.3 Analytical Methodology

Fish were analyzed on a wet (fresh) basis, as is the standard procedure for governmental agencies. Mercury analyses of invertebrate samples were conducted with dried and powdered samples for uniformity, as described in Slotton *et al.* (1995a).

Solid samples of all types were processed by first digesting in concentrated sulfuric and nitric acids, under pressure, at 80-100 °C, followed by refluxing with potassium permanganate in a two stage, three hour process. Digests were subsequently analyzed for total mercury using a well-established modified cold vapor atomic absorption (CVAA) micro-technique, described in Slotton *et al.* (1995b). The level of detection for this technique is app. 0.01 $\mu g\ g^{-1}$ (ppm), sufficient to provide above-detection results for nearly all environmental samples from this region.

2.4 Quality Assurance/Quality Control (QA/QC)

Extensive QA/QC accompanied all of the total mercury analyses. For each sample batch of approximately 40 samples, at least 16 QA/QC samples were included through all phases of the digestion and analysis procedures. These included a minimum of: 1 blank and 7 aqueous mercury standards, 2 pairs of samples of standard reference materials (4 total) with known mercury concentrations, 2 duplicates of analytical samples, and 2 spiked analytical samples. These 16+ additional samples per analytical run were used, as always, to ensure the reliability of the data generated. The QA/QC results for the analytical work are summarized in Table 2.

The extensive set of aqueous standards was used to construct an accurate curve of mercury concentraiion vs atomic absorbence for each analytical run. The standard curve R^2 values for the mercury runs utilized in this project all fell between 0.997 and 1.000, well above the control range of ≥ 0.975. The reference material samples included two different fish standards. All recoveries were well within the 75-125% control levels, at 89-113% (mean recoveries 95-106%). Sample duplication in laboratory splits was excellent, with relative % difference (RPD) having a mean value of 4.9% among 40 sets of paired samples. Independent field duplicates were also very close, with RPDs of 11 sets of paired, independent field samples averaging 6.2%. Spike recoveries were consistently good, with recoveries of 84-109% (mean = 98.3% for 20 spikes used in the project), as compared to control tolerances of 75-125%.

Table 2. Laboratory QA/QC Summary for Total Mercury Analyses (from 9 analytical runs)

	Std Curve R^2	Spike Recoveries	Field Dup. RPD	Lab Split RPD	*Standard Reference Materials* BCR Cod	DOLT-2 Dogfish
Certified Level (ppm)					0.56	2.14
Ideal Recovery	1.000	(100%)	(0%)	(0%)	(100%)	(100%)
Control Range (%)	≥0.975	75-125%	≤25%	≤25%	75-125%	75-125%
Control Range (ppm)					0.42-0.70	1.60-2.68
Recoveries (%)	0.997-1.000	84-109%	0.2-17.8%	0.3-22.9%	89-105%	99-113%
Recoveries (ppm)					0.50-0.59	2.11-2.53
(n)	n=9	n=20	n=11	n=40	n=18	n=18
Mean Recoveries (%)	0.999	98.3%	6.2%	4.9%	95.5%	105.8%
Mean Recoveries (ppm)					0.53	2.27

3. RESULTS AND DISCUSSION

3.1 Adult Fish

Muscle mercury data from the adult fish samples are presented in Table 3. The data are plotted graphically by sampling site in Figures 3(a-i), with all individuals and species from a given site plotted together (each species with its own symbol). This allows the inter-site comparison of overall mercury levels in all the fish taken and also displays the relative mercury levels of different species within each site. In Figures 4(a-j), the data are plotted by fish species, with each sampling site having a different symbol. This allows consistent comparison of the various sites. Because mercury concentration frequently varies with size/age of fish, particularly for predatory species, mercury data are plotted against fish weight. Data for individual sites can be compared to the general size:mercury trend for the species. Sites with significantly different mercury exposure levels would be expected to demonstrate correspondingly different fish muscle mercury concentrations, relative to the general size:mercury trend for a given species among all the sites.

The Putah Creek fish muscle mercury data provide comparative information to muscle mercury data from numerous UC Davis research projects conducted over the past 15 years throughout the mercury and gold mining regions of Northern California (Reuter *et al.* 1989, 1996, 1998, Slotton *et al.* 1991, 1995a,b, 1996, 1997a,c, Suchanek *et al.* 1993, 1997, TSMP 1990-1997), as well as the large data base that exists for edible fish fillet tissue throughout the state of California, assembled by the Toxic Substances Monitoring Program (TSMP 1990-1997). The fish muscle mercury data collected in this project supplement the preliminary Putah Creek work done by the ATSDR and EPA Region 9 (ATSDR 1997, 1998, NAREL 1997) and characterize, for the entire Putah Creek study region between Lake Berryessa and the Yolo Bypass, mercury levels in the edible tissue of most numerically significant species, including those commonly taken for human consumption. Fish muscle mercury data will be discussed in relation to two primary considerations: (1) absolute mercury levels in edible muscle tissue, with regard to human health issues, and (2) relative spatial differences in fish mercury concentrations, primarily in relation to potential effects related to UC Davis.

As is typical, muscle mercury concentrations were lowest in fish species which feed on low trophic level food items such as plankton and small aquatic insects and were highest in large individuals of top predator species which feed primarily on other fishes. Intermediate mercury levels were seen in species which feed on intermediate trophic level food items such as large aquatic insects and juvenile fish. Because of the changing nature of Putah Creek across the study region, different assemblages of fish species occur in different reaches. This phenomenon is typical of most creeks/rivers and has been studied intensively in Putah Creek by UC Davis ichthyologist Dr. Peter Moyle and his graduate students for many years (Moyle *et al.* 1998). The upper reaches of the creek between Monticello Dam and Lake Solano (Sites 1-3) are dominated by introduced rainbow trout and several native species. Native species such as Sacramento sucker, Sacramento squawfish, and hitch dominate the central region to approximately Russell Ranch (Site 5). Warm water, introduced game fish species such as largemouth bass, white crappie, bluegill, white catfish, and channel catfish occur primarily in the bottom reaches of Putah Creek, near UC Davis and downstream (Sites 6-11).

The different fish assemblages resident in different reaches of the creek make it difficult to assess potential inter-site differences in mercury exposure levels. In particular, because large individuals of top predatory species occur primarily in the lower portion of the creek, downstream sites demonstrate some of the highest levels of individual fish muscle mercury. However, as highest levels are expected to occur in precisely these individuals, the relatively elevated concentrations found in these particular fish do not, in themselves, indicate any enhanced level of mercury exposure associated with those sites. In order to accurately compare the relative mercury exposures at the various sites, it is critical to compare same or similar test organisms. While this was not always possible with the adult fish sampling, the fish data provide a number of useful comparisons between different sets of sites along Putah Creek. In following sections of the report, we present data from alternate bioindicator organisms, some of which provide enhanced levels of both site-specificity and consistency of sample organism between sites. Below, the fish muscle mercury data for the most numerically significant types are discussed by species, in approximate order of increasing mercury concentration.

Rainbow Trout (*Salmo gairdneri*, Fig. 4a): Some of the lowest muscle mercury in the study region was found in rainbow trout above Lake Solano, which we know to subsist almost entirely on tiny, herbivorous mayflies which are low in mercury. Concentrations of 0.05-0.15 ppm were found in trout to 580 g (1.3 lb), with levels of 0.05-0.07 ppm in all individuals under 1 lb. In trout taken immediately below Lake Solano, concentrations were also relatively low (0.08-0.12 ppm), but were somewhat elevated relative to the small size of the fish (Fig. 4a), as compared to the fish taken upstream of Lake Solano.

Hitch (*Lavinia exilicauda*, Fig. 4b): Hitch, a native planktivore, had relatively low muscle mercury, at ~0.09 ppm, in a group of 5 individuals taken below UC Davis at Site 9.

A single individual taken upstream from Lake Solano was somewhat elevated at 0.12 ppm, particularly in relation to the size of the fish (95 g, vs 305-360 g at Site 9).

Sacramento blackfish (*Orthodon microlepidotus*, Fig. 4c): Planktivorous Sacramento blackfish were relatively low in muscle mercury throughout, with 19 of 20 individuals having concentrations ≤ 0.15 ppm. Mean blackfish mercury levels increased slightly across a range of sizes (200-1200 g), from ~0.06 ppm to ~0.10 ppm, with an overall mean of approximately 0.08 ppm. Consistent samples of this species were taken at Site 6 (above UC Davis near Pedrick Rd), Site 9 (0.5-1.0 mile downstream of the UC Davis water treatment outflow and the LEHR site), and Site 11 (6 miles downstream of UCD at Rd 106A). Concentrations from Sites 6 and 9, above and below UC Davis, fell within an identical size:Hg pattern, indicating very similar levels of mercury exposure/uptake in these two reaches of the creek. At the furthest downstream site (Site 11, 6 miles downstream of UC Davis), the blackfish data indicate a possible elevation in localized mercury exposure/uptake. Of the seven fish sampled at that site, one exhibited an anomalously elevated concentration (600 g, 0.23 ppm Hg) and slightly above-trend concentrations were apparent in some of the others.

Sacramento sucker (*Catostomus occidentalis*, Fig. 4d): This species is a native bottom fish which feeds primarily on small bottom-dwelling invertebrates. Adult Sacramento suckers were available for collection only at sites located above UC Davis. Individuals taken from Sites 3, 5, and 6 (below Lake Solano to just above UC Davis) had a very similar pattern of concentrations (0.10-0.18 ppm Hg in all 9 individuals, 100-900 g). Mean levels increased slightly with size of fish. The sample of five suckers taken from within Lake Solano (Site 2) was significantly elevated in muscle mercury relative to the trend seen at the other sites (0.32-0.52 ppm Hg in all 5 fish). While these lake-dwelling individuals were also significantly larger (1,100-1,900 g) than the individuals collected from the downstream creek, their muscle mercury concentrations were clearly elevated above the trend line described by the creek population.

Carp (*Cyprinus carpio*, Fig. 4e): Fifteen large, adult carp were sampled from Putah Creek, primarily from downstream sites, within the extended size range of 500-4,900 g (1.1-10.8 lbs). All of these individuals exhibited low to moderate muscle mercury concentrations between 0.12 and 0.25 ppm, consistent with their relatively low trophic position, consuming small benthic invertebrates and plant material from the bottom (Moyle 1976). Little or no size-based increase in concentrations was noted, with mean levels remaining at approximately 0.18 ppm Hg throughout. Only one of the sampled large carp was taken from upstream of UC Davis. This individual contained 0.22 ppm muscle Hg, among the 4 highest concentrations in the total data set. While all samples from Site 6 (above the University) and Sites 9 and 11 (below the University) contained Hg within the same 0.12-0.25 range and demonstrated no significant differences between sites, the two highest numbers came from individuals taken at the furthest downstream site (Site 11).

Sunfish (*Lepomis macrochirus*, etc. Fig. 4f): Five bluegill sunfish were taken from Site 9 below UC Davis and 7 bluegill, one redear sunfish, and a hybrid sunfish were sampled upstream of UCD at Site 6. The fish were small to medium in size (20-160 g). Muscle mercury ranged between 0.12 and 0.33 ppm, with a mean of approximately 0.20 ppm Hg. Across the size range available, no size:Hg relationship was apparent. Sunfish taken above and below UC Davis exhibited muscle mercury in an identical range. These water column fish feed on zooplankton and a variety of larger invertebrates. They are perhaps the creek fish most frequently taken by anglers, particularly young anglers.

White catfish, channel catfish (*Ictalurus catus*, *Ictalurus punctatus*, Fig. 4g): Catfish are popular gamefish which are bottom feeding predators with a varied diet. White catfish were present only at the most downstream sites (9 and 11). Channel catfish were also taken at those sites, as well as from Site 6 upstream of the University. The data for both species fall within the same general size:Hg relationship, with a slight increase in mean muscle mercury with size. Concentrations ranged between 0.07 and 0.34 ppm in both species, with 19 of 21 individuals having $\leq$ 0.20 ppm, including the largest individuals (1,200-2,700 g; 2.6-5.9 lbs; n=7). Channel catfish were more variable in their concentrations (0.07-0.34 ppm); white catfish mercury ranged between 0.10 and 0.19 ppm. The 2 highest catfish mercury levels (0.23 and 0.34 ppm) were found in individuals taken at Pedrick Rd, well upstream of the university. Downstream collections exhibited no relative elevation in muscle mercury concentrations, even in the largest fish sampled (2,700 g, 0.20 ppm Hg, Site 9).

Sacramento squawfish (*Ptychocheilus grandis*, Fig. 4h): The squawfish is a native top predator species that preys upon other fish when adult. Squawfish are not typically targets of anglers, are difficult to catch, and infrequently eaten. Individuals larger than juvenile size were taken at two sites: Site 5 (Russell Ranch, between Winters and Davis) and Site 11, the furthest downstream site. The samples from Russell Ranch included 3 smaller individuals (105-150 g) which had muscle mercury at 0.17-0.29 ppm, increasing with size, and a single full-sized adult weighing 990 g (2.2 lbs) and containing 0.48 ppm muscle mercury. While this sample was not sufficient to produce a tight size:Hg relationship for the species, the two fish taken at Site 11 appear to demonstrate relatively elevated muscle mercury levels. At 165 and 250 g, these two fish had very similar, very high muscle mercury levels (0.72, 0.73 ppm), notably elevated above the apparent relationship seen at Site 5.

White crappie, black crappie (*Pomoxis annularis, Pomoxis nigromaculatus*, Fig. 4i): Crappie become predators of other fish as adults and are prized by anglers. A single large individual (735 g) was taken at Site 11, 6 miles below UC Davis at Rd. 106A. This individual contained one of the highest muscle mercury concentrations found in the study (0.63 ppm). Comparable, large individual crappie were not available from other sites. A sample of 3 young individuals was collected from Site 6, upstream of the university (48-83 g, 0.15-0.19 ppm Hg), together with a slightly larger black crappie (103 g, 0.33 ppm Hg). As no fish of intermediate size were collected, it is not clear whether the downstream adult represented anomalously high, site-specific levels or an elevation solely attributable to size and feeding habits. A very steep size:Hg relationship, with similar high top-end levels, was found in collections we made for Yolo County in the lower portion of Cache Creek (Slotton *et al.* 1997c).

Largemouth bass, smallmouth bass (*Micropterus salmoides, Micropterus dolomieui*, Fig. 4j): These prized, warmwater gamefish species use their large mouths to capture other fish and a variety of large prey items. Adult largemouth bass are one of the primary top predator fish species in the lower portion of the creek. Collections at upstream sites yielded only juveniles and post-juveniles (40-110 g) of either species, which had muscle mercury at 0.15-0.35 ppm. Four adult largemouth bass of 600-2,000 g were taken at Site 9 approximately 1 mile downstream of UC Davis. The two smaller individuals of these adults had mercury concentrations similar to the smaller bass (0.20-0.23 ppm), while the larger, piscivorous (fish-eating) individuals demonstrated a typical predatory size:Hg relationship (1,120 g and 0.34 ppm Hg, 1,920 g and 0.62 ppm Hg). Two 900-1,000 g adult largemouth bass were taken at the most downstream site (Site 11). At 0.63 and 0.73 ppm Hg, the concentrations from this site appear to be elevated above the general size:Hg relationship described by bass data from the other sites.

Table 3. Putah Creek Fish Muscle (Fillet) Mercury.
(fresh/wet weight ppm Hg)

Site #	Site Description	Fish Species	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)
1	Putah Ck below L. Berryessa	Rainbow Trout	82	192	**0.07**
1	Putah Ck below L. Berryessa	Rainbow Trout	159	225	**0.07**
1	Putah Ck below L. Berryessa	Rainbow Trout	205	245	**0.06**
1	Putah Ck below L. Berryessa	Rainbow Trout	215	259	**0.07**
1	Putah Ck below L. Berryessa	Rainbow Trout	425	337	**0.05**
1	Putah Ck below L. Berryessa	Rainbow Trout	505	348	**0.08**
1	Putah Ck below L. Berryessa	Rainbow Trout	580	383	**0.15**
2	In Lake Solano	Hitch	95	194	**0.12**
2	In Lake Solano	Sac. Sucker	1,115	434	**0.42**
2	In Lake Solano	Sac. Sucker	1,300	467	**0.32**
2	In Lake Solano	Sac. Sucker	1,425	462	**0.41**
2	In Lake Solano	Sac. Sucker	1,660	481	**0.46**
2	In Lake Solano	Sac. Sucker	1,910	511	**0.52**
3	Putah Ck below L. Solano	Sac. Sucker	430	335	**0.16**
3	Putah Ck below L. Solano	Rainbow Trout	60	166	**0.12**
3	Putah Ck below L. Solano	Rainbow Trout	72	189	**0.10**
3	Putah Ck below L. Solano	Rainbow Trout	75	185	**0.09**
3	Putah Ck below L. Solano	Rainbow Trout	105	193	**0.08**
4	Putah Ck below Winters	Tule Perch	16	90	**0.11**
4	Putah Ck below Winters	Tule Perch	42	129	**0.15**
4	Putah Ck below Winters	Green Sunfish	23	108	**0.19**
4	Putah Ck below Winters	Green Sunfish	25	108	**0.15**
4	Putah Ck below Winters	Largemouth Bass	110	194	**0.15**
5	Putah Ck at Russell Ranch	Sac. Sucker	115	217	**0.10**
5	Putah Ck at Russell Ranch	Sac. Sucker	550	371	**0.12**
5	Putah Ck at Russell Ranch	Sac. Sucker	680	379	**0.11**
5	Putah Ck at Russell Ranch	Sac. Sucker	800	388	**0.18**
5	Putah Ck at Russell Ranch	Sac. Sucker	810	405	**0.13**
5	Putah Ck at Russell Ranch	Sac. Sucker	860	408	**0.11**
5	Putah Ck at Russell Ranch	Smallmouth Bass	40	143	**0.25**
5	Putah Ck at Russell Ranch	Squawfish	107	232	**0.17**
5	Putah Ck at Russell Ranch	Squawfish	135	257	**0.26**
5	Putah Ck at Russell Ranch	Squawfish	150	270	**0.29**
5	Putah Ck at Russell Ranch	Squawfish	990	453	**0.48**

(continued)

Table 3. Putah Creek Fish Muscle (Fillet) Mercury. ***(continued)***
(fresh/wet weight ppm Hg)

Site #	Site Description	Fish Species	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)
6	Putah Ck 2 mi above UCD	Sac. Blackfish	580	335	**0.06**
6	Putah Ck 2 mi above UCD	Sac. Blackfish	630	335	**0.09**
6	Putah Ck 2 mi above UCD	Sac. Blackfish	700	366	**0.09**
6	Putah Ck 2 mi above UCD	Sac. Blackfish	920	379	**0.09**
6	Putah Ck 2 mi above UCD	Sac. Blackfish	1,000	397	**0.10**
6	Putah Ck 2 mi above UCD	Sac. Sucker	470	377	**0.13**
6	Putah Ck 2 mi above UCD	Sac. Sucker	625	364	**0.13**
6	Putah Ck 2 mi above UCD	Carp	1,520	435	**0.22**
6	Putah Ck 2 mi above UCD	Redear Sunfish	153	192	**0.15**
6	Putah Ck 2 mi above UCD	Sunfish (Hybrid)	131	178	**0.19**
6	Putah Ck 2 mi above UCD	Bluegill	50	135	**0.19**
6	Putah Ck 2 mi above UCD	Bluegill	55	140	**0.22**
6	Putah Ck 2 mi above UCD	Bluegill	75	135	**0.20**
6	Putah Ck 2 mi above UCD	Bluegill	85	147	**0.14**
6	Putah Ck 2 mi above UCD	Bluegill	85	148	**0.24**
6	Putah Ck 2 mi above UCD	Bluegill	112	177	**0.32**
6	Putah Ck 2 mi above UCD	Bluegill	112	153	**0.18**
6	Putah Ck 2 mi above UCD	Channel Catfish	205	256	**0.13**
6	Putah Ck 2 mi above UCD	Channel Catfish	710	365	**0.34**
6	Putah Ck 2 mi above UCD	Channel Catfish	750	378	**0.11**
6	Putah Ck 2 mi above UCD	Channel Catfish	1,110	437	**0.23**
6	Putah Ck 2 mi above UCD	Channel Catfish	1,280	413	**0.17**
6	Putah Ck 2 mi above UCD	Channel Catfish	1,570	470	**0.12**
6	Putah Ck 2 mi above UCD	Channel Catfish	1,660	510	**0.07**
6	Putah Ck 2 mi above UCD	Channel Catfish	1,970	500	**0.18**
6	Putah Ck 2 mi above UCD	White Crappie	48	165	**0.19**
6	Putah Ck 2 mi above UCD	White Crappie	50	167	**0.15**
6	Putah Ck 2 mi above UCD	White Crappie	83	190	**0.16**
6	Putah Ck 2 mi above UCD	Black Crappie	103	192	**0.33**
6	Putah Ck 2 mi above UCD	Smallmouth Bass	100	209	**0.35**
6	Putah Ck 2 mi above UCD	Largemouth Bass	52	160	**0.34**

(continued)

Table 3. Putah Creek Fish Muscle (Fillet) Mercury. *(continued)*
(fresh/wet weight ppm Hg)

Site #	Site Description	Fish Species	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)
9	Putah Ck. 0.7 mi blw UCD	Clam (Proptera)		75x56	**0.03**
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	290	272	**0.04**
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	430	311	**0.05**
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	505	319	**0.05**
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	555	355	**0.09**
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	685	354	**0.07**
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	790	377	**0.07**
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	820	365	**0.11**
9	Putah Ck. 0.7 mi blw UCD	Sac. Blackfish	1,140	419	**0.08**
9	Putah Ck. 0.7 mi blw UCD	Hitch	305	274	**0.10**
9	Putah Ck. 0.7 mi blw UCD	Hitch	315	278	**0.07**
9	Putah Ck. 0.7 mi blw UCD	Hitch	345	288	**0.09**
9	Putah Ck. 0.7 mi blw UCD	Hitch	355	294	**0.08**
9	Putah Ck. 0.7 mi blw UCD	Hitch	360	306	**0.11**
9	Putah Ck. 0.7 mi blw UCD	Carp	555	311	**0.16**
9	Putah Ck. 0.7 mi blw UCD	Carp	1,060	398	**0.12**
9	Putah Ck. 0.7 mi blw UCD	Carp	1,450	429	**0.22**
9	Putah Ck. 0.7 mi blw UCD	Carp	2,025	460	**0.15**
9	Putah Ck. 0.7 mi blw UCD	Carp	2,800	525	**0.13**
9	Putah Ck. 0.7 mi blw UCD	Carp	3,300	541	**0.21**
9	Putah Ck. 0.7 mi blw UCD	Carp	4,900	620	**0.21**
9	Putah Ck. 0.7 mi blw UCD	Bluegill	22	104	**0.12**
9	Putah Ck. 0.7 mi blw UCD	Bluegill	29	109	**0.25**
9	Putah Ck. 0.7 mi blw UCD	Bluegill	30	117	**0.16**
9	Putah Ck. 0.7 mi blw UCD	Bluegill	35	119	**0.16**
9	Putah Ck. 0.7 mi blw UCD	Bluegill	45	142	**0.33**
9	Putah Ck. 0.7 mi blw UCD	Channel Catfish	310	294	**0.09**
9	Putah Ck. 0.7 mi blw UCD	Channel Catfish	340	310	**0.10**
9	Putah Ck. 0.7 mi blw UCD	Channel Catfish	2,700	539	**0.20**
9	Putah Ck. 0.7 mi blw UCD	White Catfish	595	332	**0.13**
9	Putah Ck. 0.7 mi blw UCD	White Catfish	610	340	**0.19**
9	Putah Ck. 0.7 mi blw UCD	White Catfish	655	348	**0.12**
9	Putah Ck. 0.7 mi blw UCD	White Catfish	720	359	**0.13**
9	Putah Ck. 0.7 mi blw UCD	White Catfish	745	360	**0.10**
9	Putah Ck. 0.7 mi blw UCD	White Catfish	1,310	413	**0.11**
9	Putah Ck. 0.7 mi blw UCD	White Catfish	1,390	431	**0.16**
9	Putah Ck. 0.7 mi blw UCD	Largemouth Bass	635	342	**0.23**
9	Putah Ck. 0.7 mi blw UCD	Largemouth Bass	705	321	**0.20**
9	Putah Ck. 0.7 mi blw UCD	Largemouth Bass	1,120	394	**0.34**
9	Putah Ck. 0.7 mi blw UCD	Largemouth Bass	1,920	474	**0.62**

(continued)

Table 3. Putah Creek Fish Muscle (Fillet) Mercury. ***(continued)***
(fresh/wet weight ppm Hg)

Site #	Site Description	Fish Species	Weight *(g)*	Length *(mm)*	Muscle Hg *(wet wt ppm)*
11	Putah Ck. at Rd. 106A	Sac. Blackfish	285	276	**0.07**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	315	284	**0.08**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	355	303	**0.12**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	385	303	**0.07**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	505	338	**0.06**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	600	367	**0.23**
11	Putah Ck. at Rd. 106A	Sac. Blackfish	840	398	**0.14**
11	Putah Ck. at Rd. 106A	Carp	535	333	**0.23**
11	Putah Ck. at Rd. 106A	Carp	805	362	**0.14**
11	Putah Ck. at Rd. 106A	Carp	1,040	411	**0.15**
11	Putah Ck. at Rd. 106A	Carp	1,210	402	**0.15**
11	Putah Ck. at Rd. 106A	Carp	1,280	432	**0.20**
11	Putah Ck. at Rd. 106A	Carp	1,440	427	**0.16**
11	Putah Ck. at Rd. 106A	Carp	1,750	457	**0.25**
11	Putah Ck. at Rd. 106A	Channel Catfish	480	349	**0.08**
11	Putah Ck. at Rd. 106A	Channel Catfish	740	394	**0.07**
11	Putah Ck. at Rd. 106A	White Catfish	545	320	**0.18**
11	Putah Ck. at Rd. 106A	Largemouth Bass	930	387	**0.73**
11	Putah Ck. at Rd. 106A	Largemouth Bass	970	385	**0.63**
11	Putah Ck. at Rd. 106A	White Crappie	735	359	**0.63**
11	Putah Ck. at Rd. 106A	Squawfish	165	252	**0.72**
11	Putah Ck. at Rd. 106A	Squawfish	250	318	**0.73**

Fig. 3(a) Fish muscle mercury
SITE 1: TROUT WATERS JUST BELOW LAKE BERRYESSA

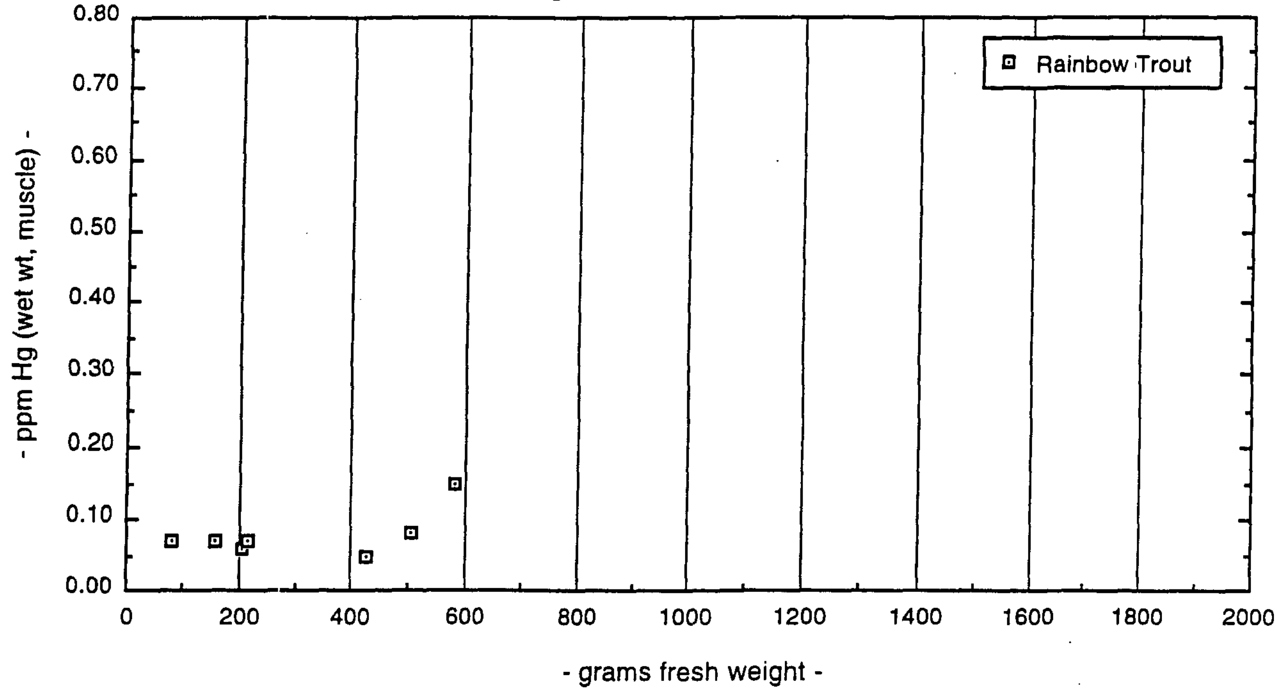


Fig. 3(b) Fish muscle mercury
SITE 2: IN LAKE SOLANO

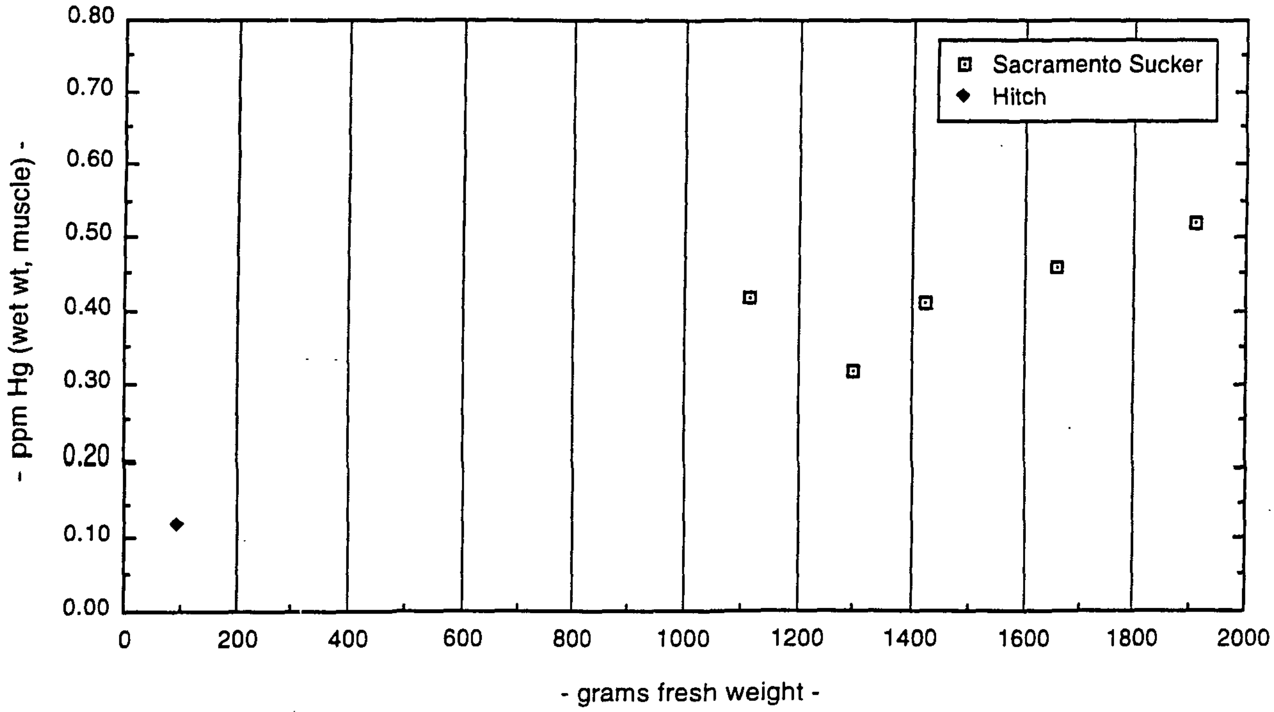


Fig. 3(c) Fish muscle mercury
SITE 3: JUST BELOW LAKE SOLANO

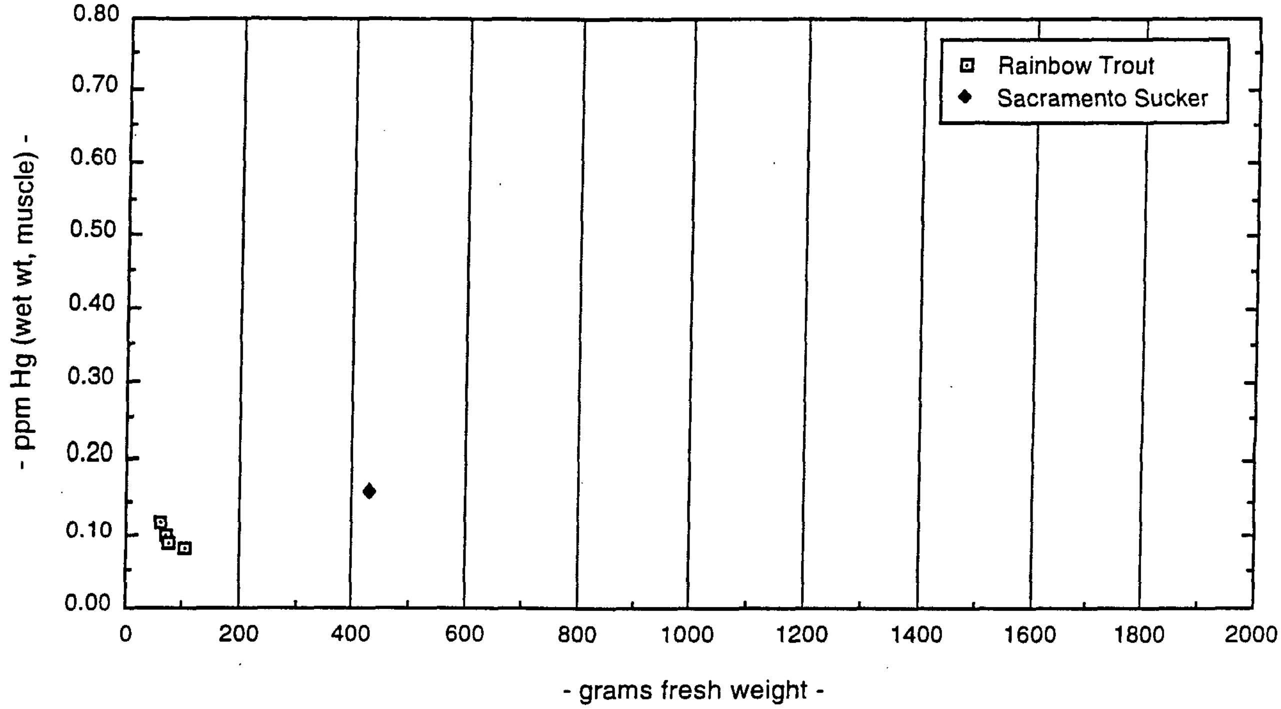


Fig. 3(d) Fish muscle mercury
SITE 4: BELOW WINTERS AT HIGHWAY 505

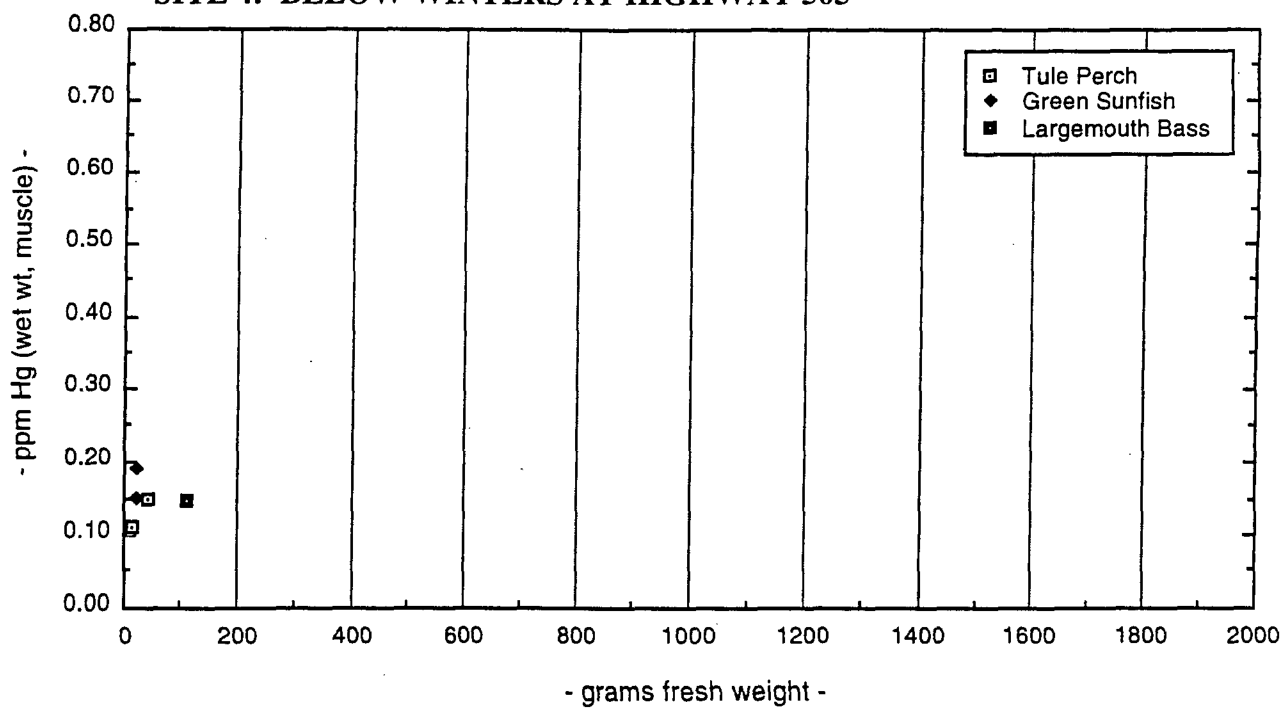


Fig. 3(e) Fish muscle mercury
SITE 5: AT RUSSELL RANCH

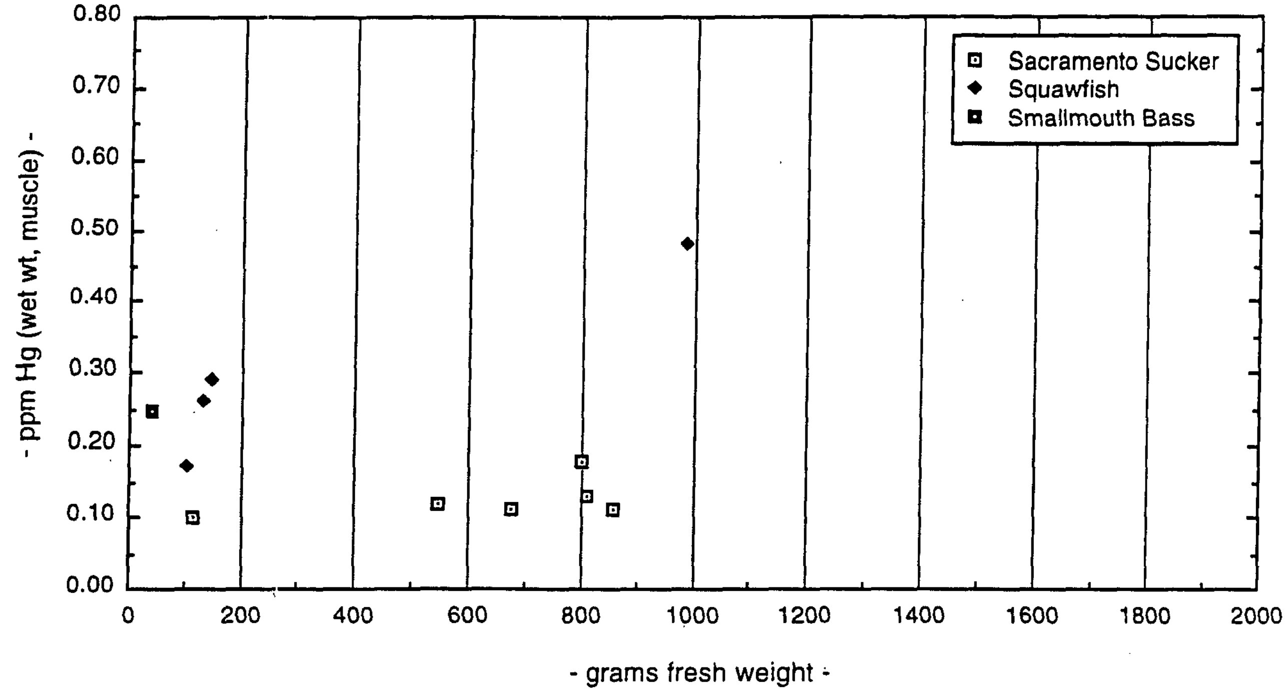


Fig. 3(f) Fish muscle mercury
SITE 6: UPSTREAM OF UC DAVIS NEAR PEDRICK ROAD

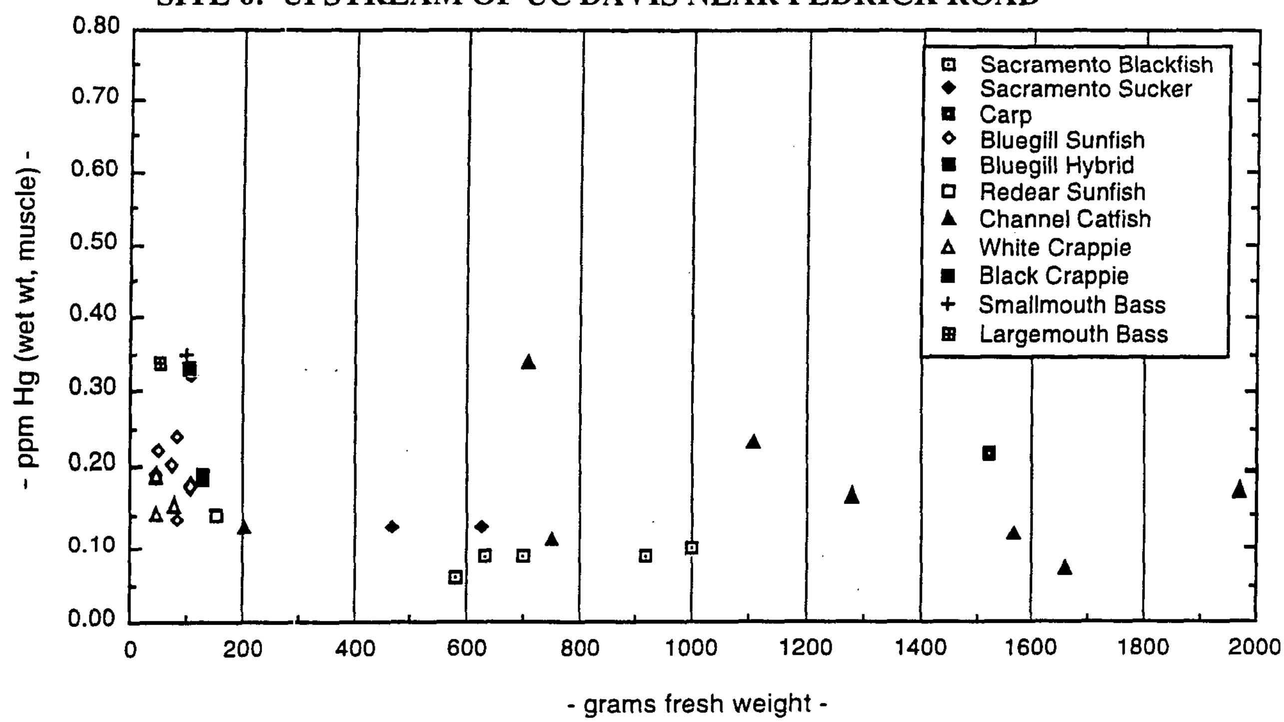


Fig. 3(g) Fish muscle mercury
SITE 9: 0.5-1.0 MILE BELOW LEHR (Fish ≤2,000 g)

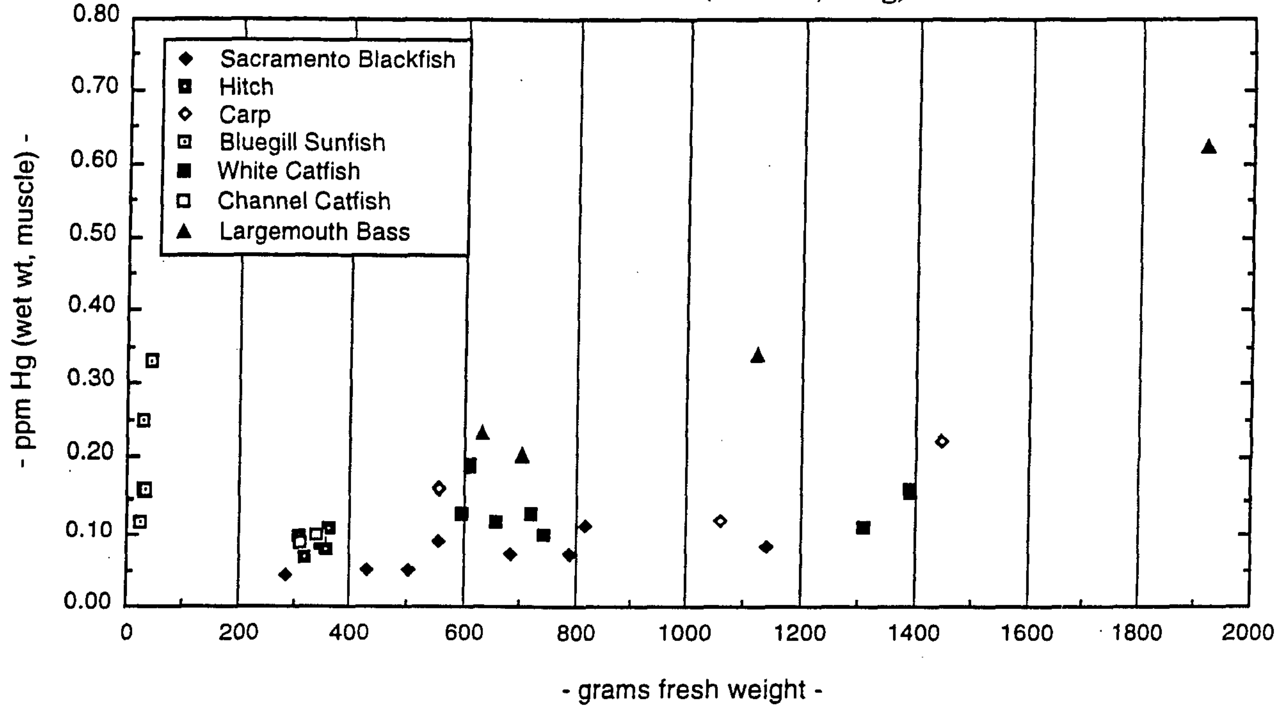


Fig. 3(h) Fish muscle mercury
SITE 9: 0.5-1.0 MILE BELOW LEHR (all fish: to 5,000 g)

NOTE EXPANDED X-AXIS

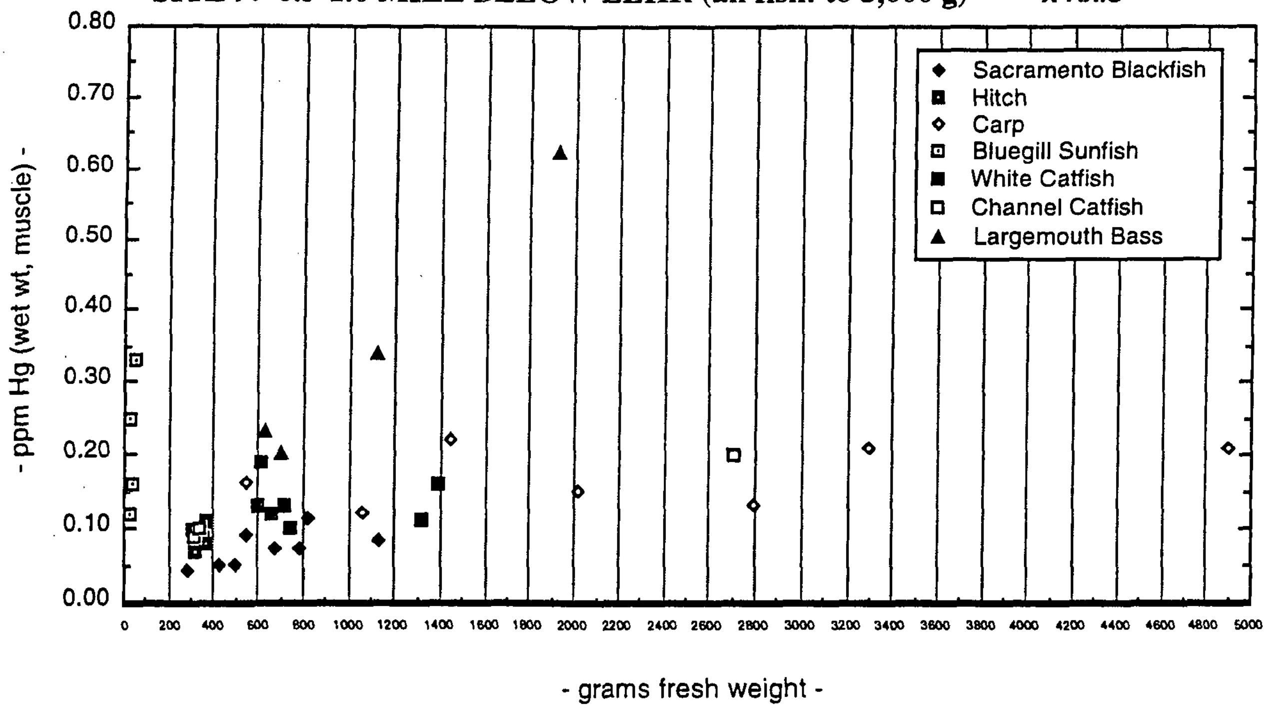


Fig. 3(i) Fish muscle mercury
SITE 11: AT ROAD 106A

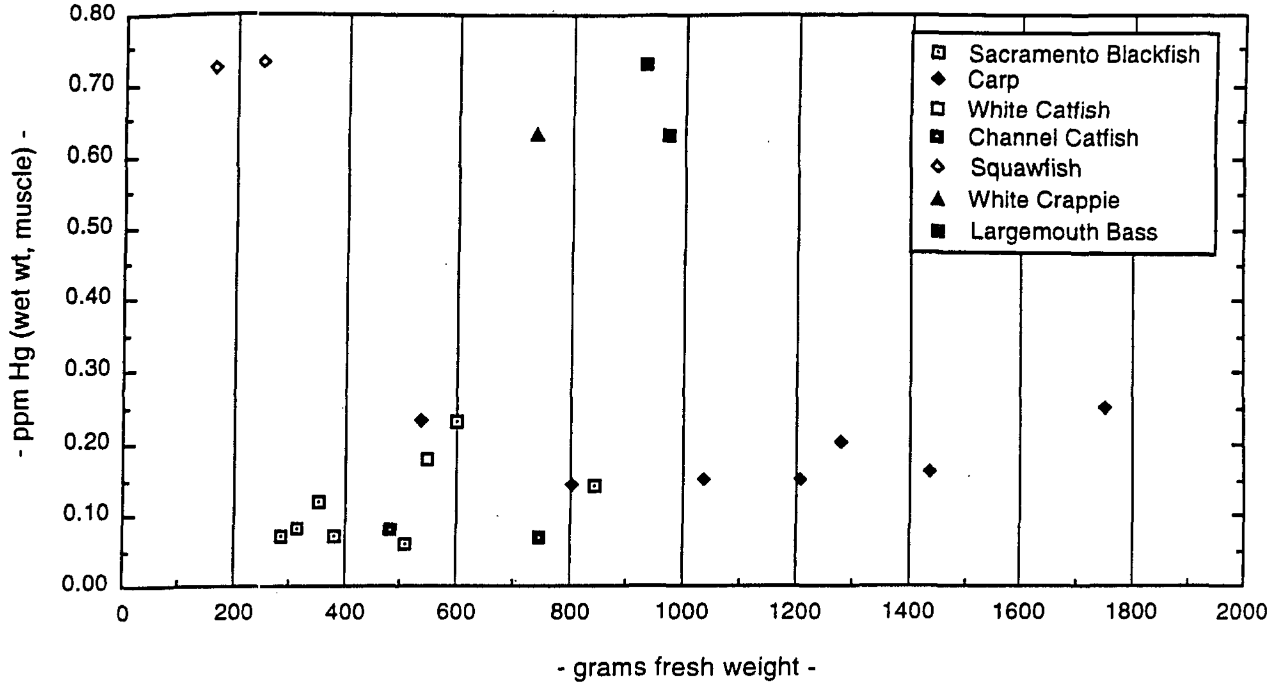


Fig. 4(a)
RAINBOW TROUT

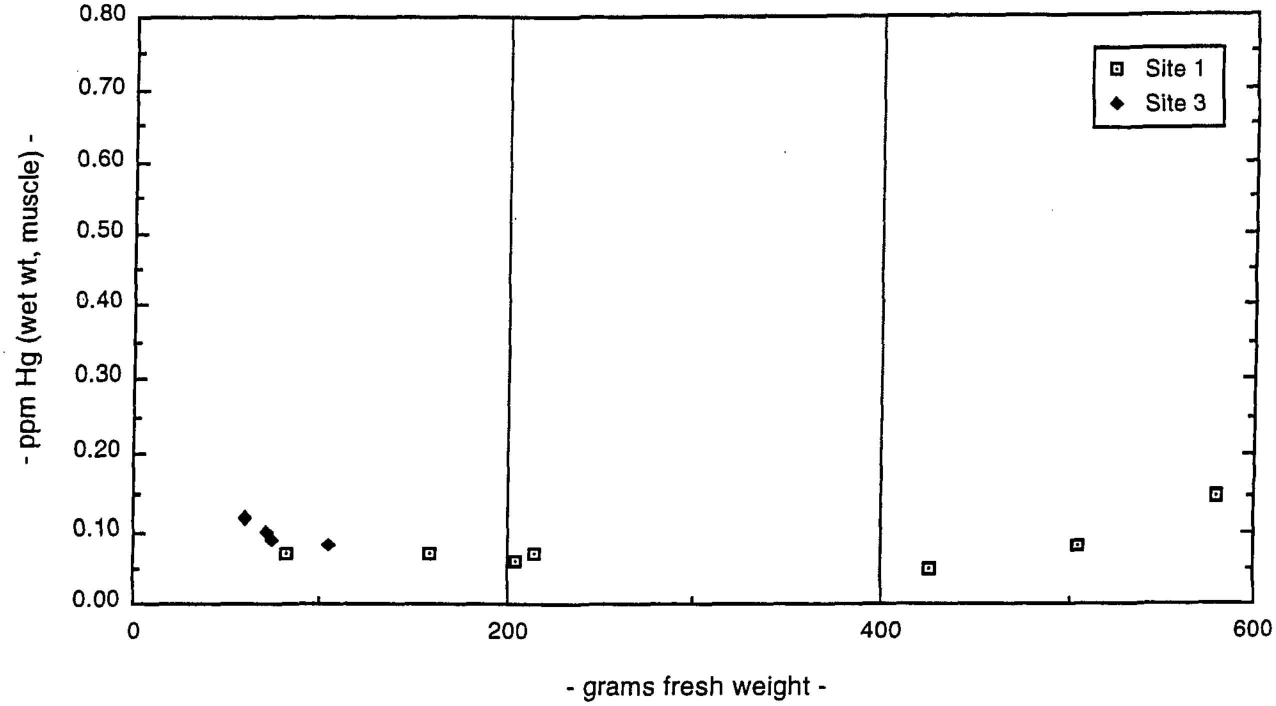


Fig. 4(b)
HITCH

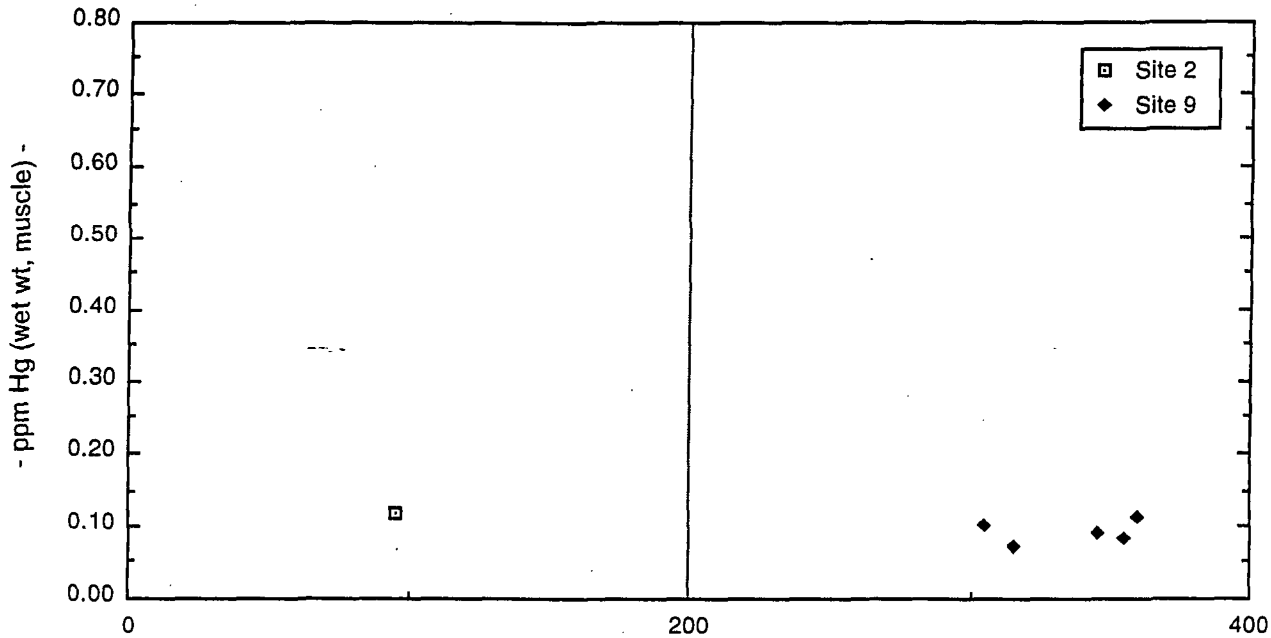


Fig. 4(c)
SACRAMENTO BLACKFISH

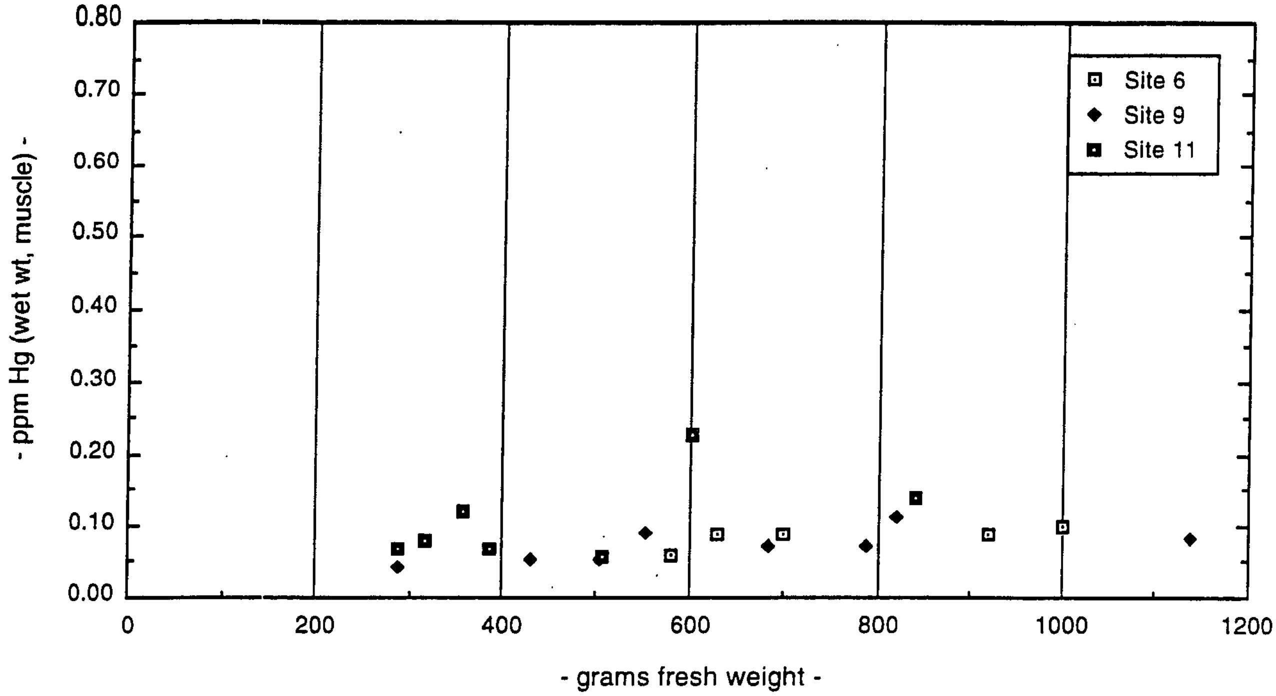


Fig. 4(d)
SACRAMENTO SUCKER

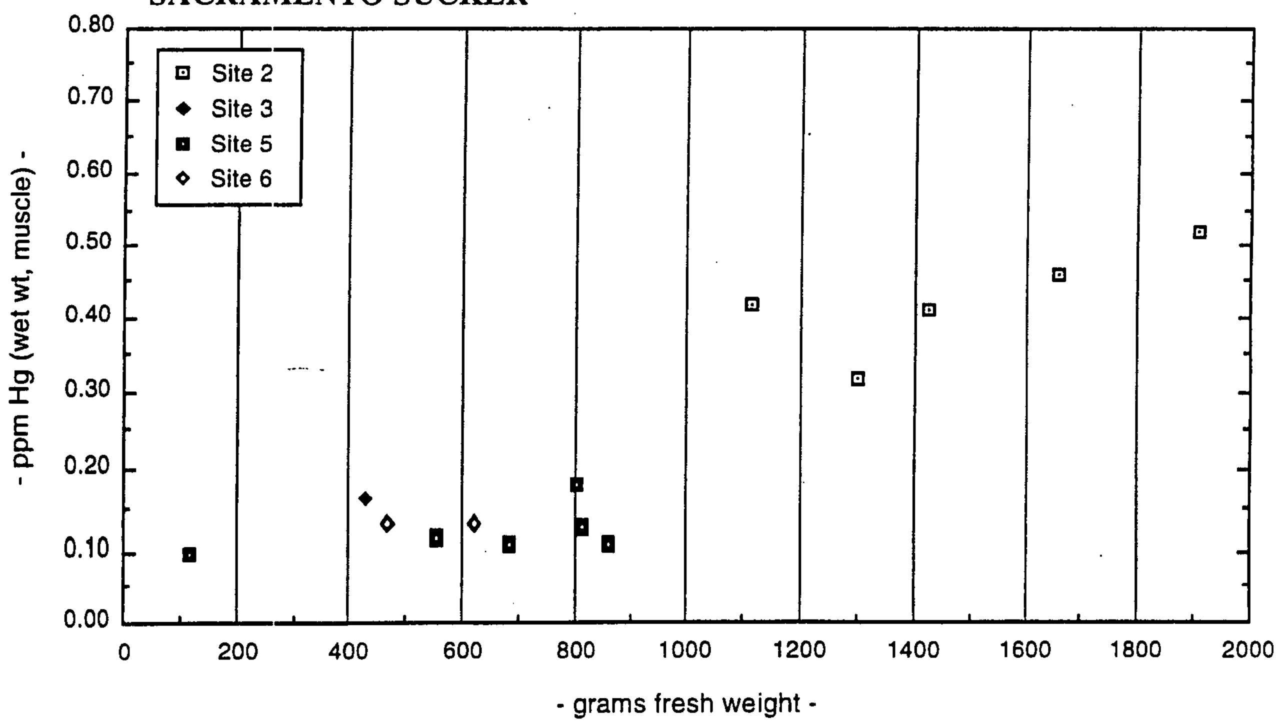


Fig. 4(e)
CARP

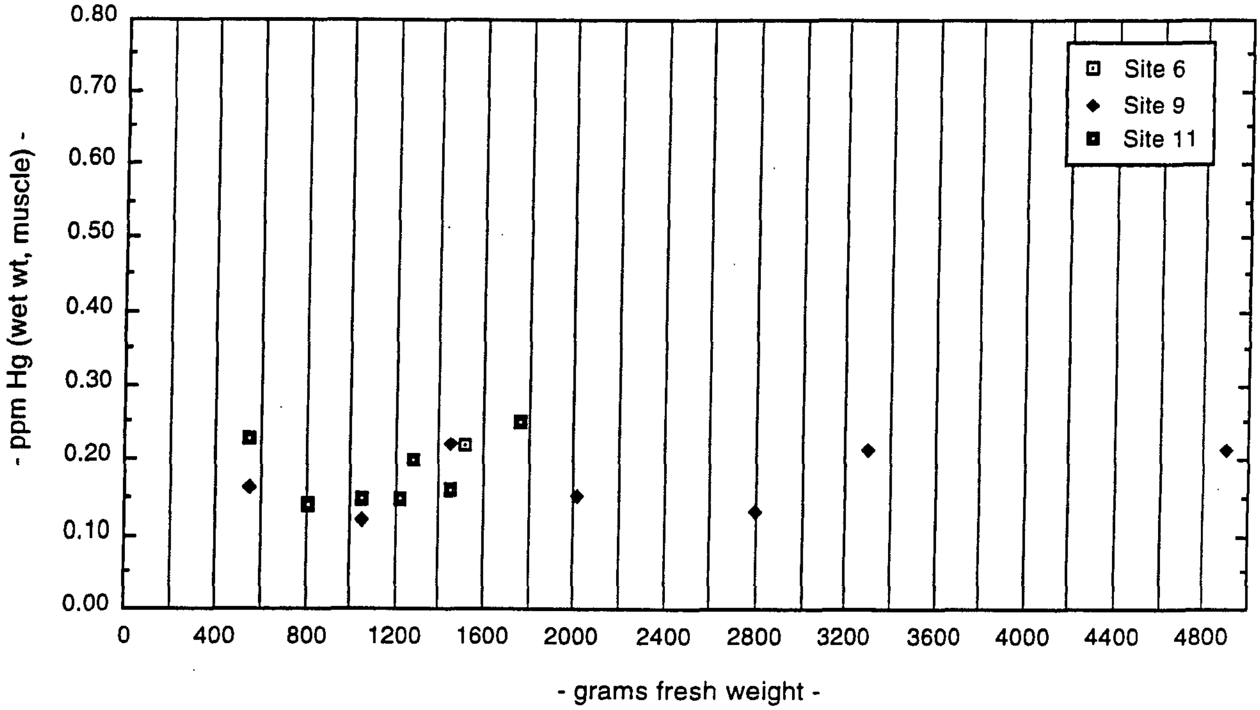


Fig. 4(f)
SUNFISH

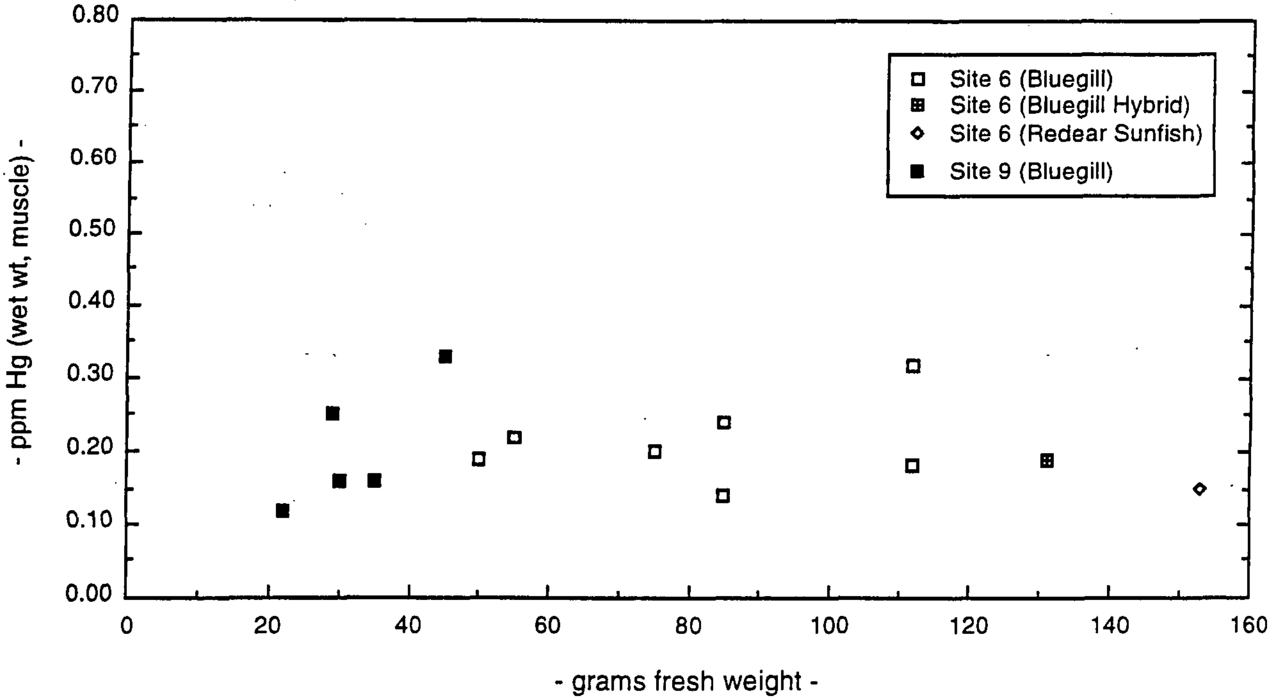


Fig. 4(g)
CATFISH

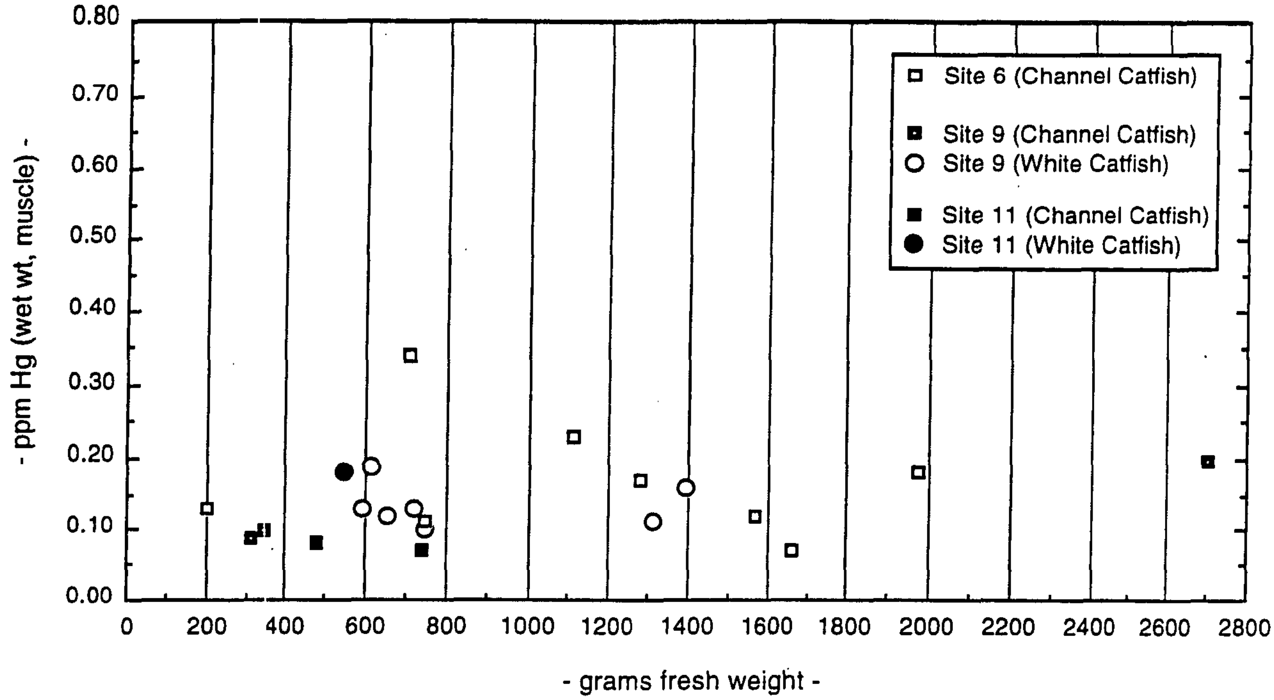


Fig. 4(h)
SQUAWFISH

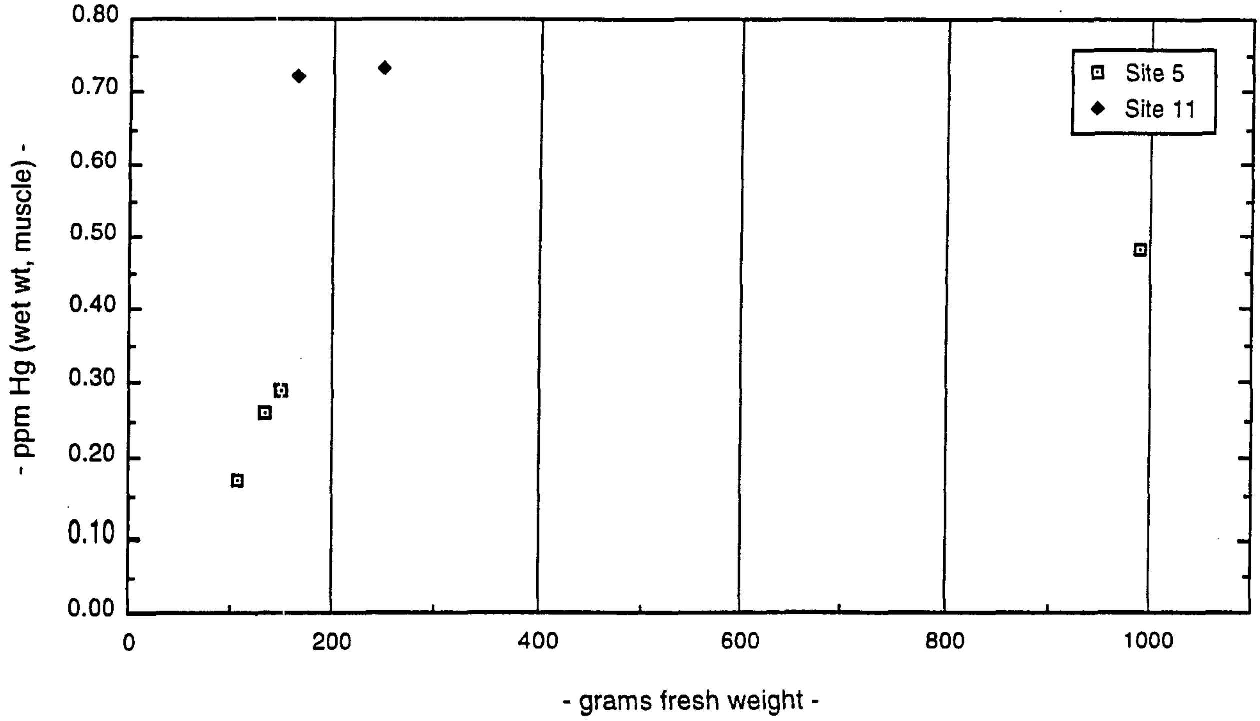


Fig. 4(i)
CRAPPIE

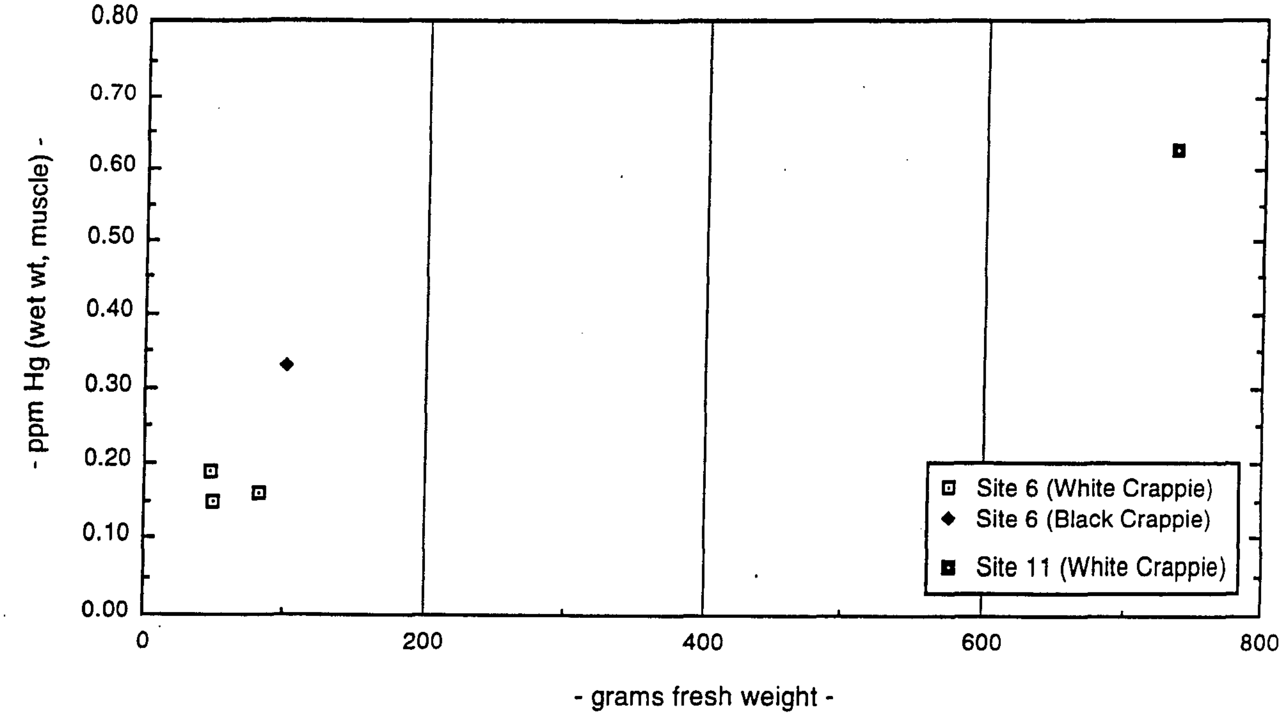
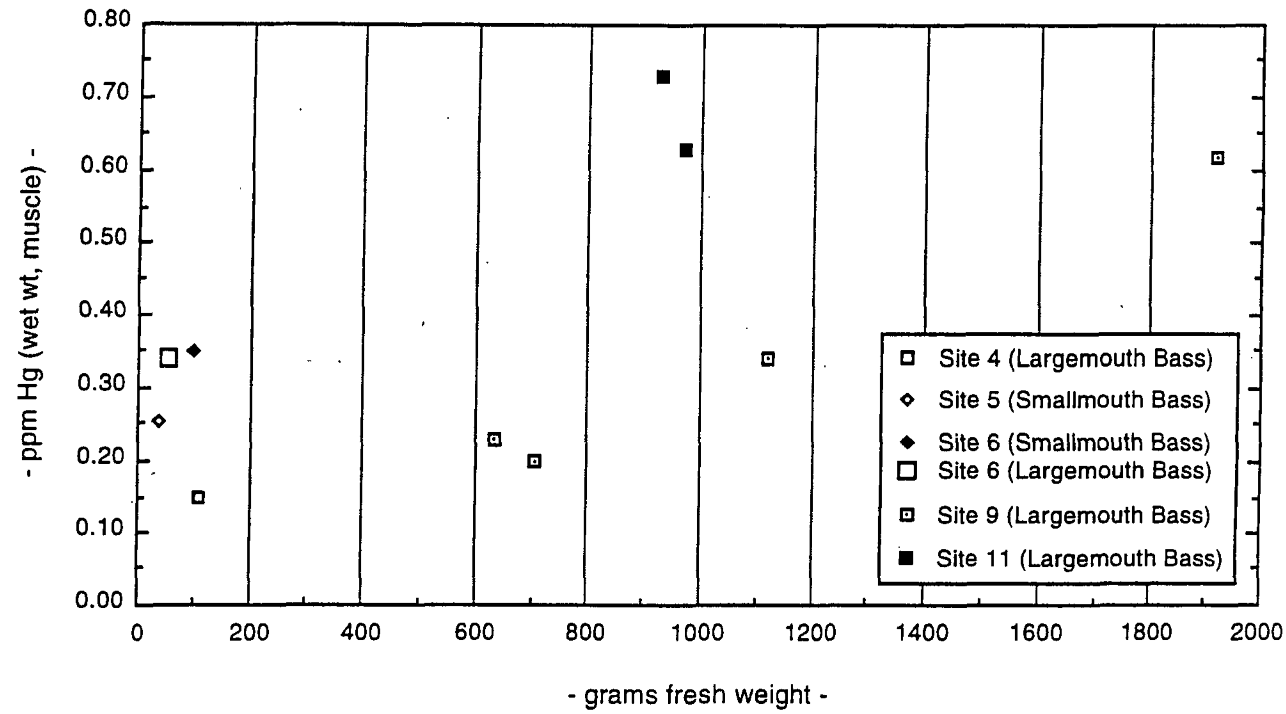


Fig. 4(j)
BASS



3.2 Small and Juvenile Fish

Twelve species of small or juvenile fish (≤15 g and 10 cm), together with bullfrog tadpoles, were collected for the project in 48 composite samples of multiple individuals. Whole fish, multi-individual compositing is a technique commonly used in other metals biomonitoring work in California (Hellawell 1986, Reuter *et al.* 1989, 1998, Bodega Research Associates 1998). Composites, within each species, were made of similar sized individuals. While these samples typically contain lower mercury concentrations than the larger fish muscle samples, they provide a more site-specific measure of relative localized mercury exposure and uptake. Because these fish and tadpoles are generally a year or less in age, the assumption can be made that they accumulated the majority of their mercury loads at or relatively near the site of capture. Data from composite small and juvenile whole fish and tadpole samples are presented in Table 4. The table is arranged so as to portray the relative distributions of the various species across the sampling sites. Just as seen for the larger fishes, these species include types found only in the upper reaches, others found in mid-reach sites, and others only in the lower sites. None of the species was found in sufficient numbers for analysis at all of the sites. However, relative to the question of potential UC Davis influences, five species were collected at sites both above and below the University and provide excellent additional information. Table 4 is arranged to facilitate mercury comparisons in several ways: (1) between sites, looking at all species/samples from each site together; (2) between species, both within individual sites and all sites combined; and most importantly (3) between sites, within individual species. In Figure 5, the small/juvenile fish data are plotted on a map of the region to demonstrate general, relative levels between sites.

In addition to providing biomonitoring information on relative mercury exposure/uptake between sites, the absolute mercury levels in these small fish are of interest from a wildlife consumption perspective. Just as the large fish fillet muscle data correspond to human health exposure, these small fish are primary prey of egrets, herons, and other species of wildlife. Whole fish mercury concentrations, as analyzed for these samples, provide the most ecologically relevant information.

The small fish and tadpole mercury data sets span a relatively small range of concentrations (0.02-0.23 ppm), with 46 of the 48 samples (96%) between 0.02 and 0.12 ppm. Juvenile squawfish taken just downstream of Lake Solano (Site 3) were relatively elevated at 0.17 ppm Hg. Concentrations in all four small fish species taken at the most downstream site (Site 11) were somewhat to highly elevated relative to their species data from other Putah Creek sites: juvenile bluegill--0.11 ppm vs 0.05-0.11 ppm at 6 other sites, Mississippi silverside--0.12 ppm vs 0.06-0.10 ppm at 5 other sites, red shiner--0.08 ppm vs 0.02-0.03 at 3 other sites, and mosquitofish—most anomalous at 0.23 ppm vs 0.03-0.08 ppm at 5 other sites.

The remaining 43 composite samples all contained mercury within the relatively narrow range of 0.02-0.12 ppm. Some of the lowest levels for a variety of species were found at Sites 7-10, located between a half mile upstream and 3 miles downstream of the UC Davis wastewater treatment plant outfall and the LEHR site. Higher mercury was seen upstream of these areas for logperch, bullfrog tadpoles, juvenile bluegill, and mosquitofish. Silversides were similar in both regions. The juvenile and small fish data indicate that the region adjacent to and within 3 miles downstream of the University had reduced levels of biological mercury exposure and uptake, relative to upstream sites. The data also indicate that enhanced exposure/uptake was associated with the furthest downstream site (Site 11) and, to a lesser extent, possibly at the site immediately below Lake Solano (Site 3).

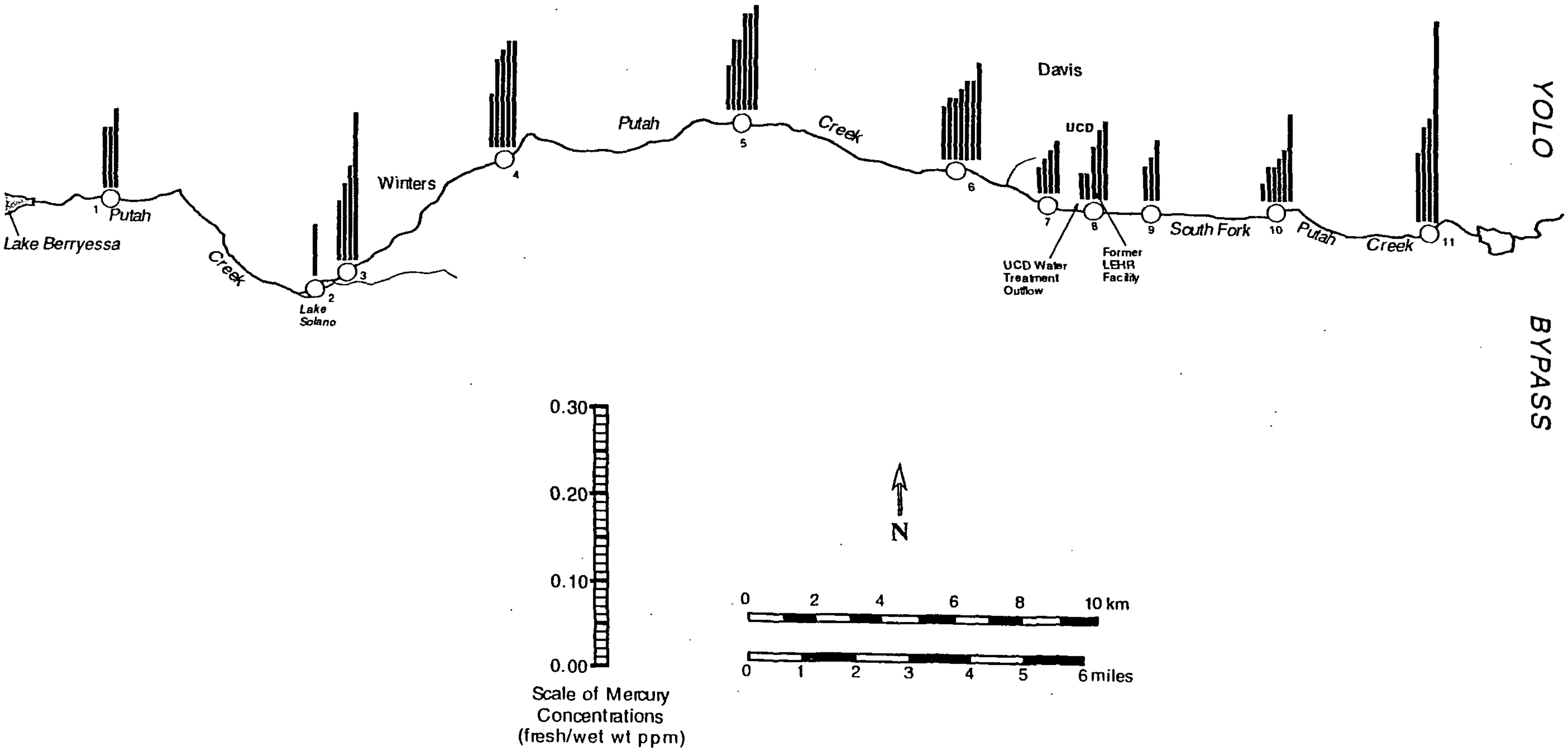
Table 4. **Putah Creek Small and Juvenile Fish (+ bullfrog tadpoles) Mercury Data.**
(Wet/fresh wt ppm Hg in multi-individual, homogenized, whole-body composites)

Site #	Site Description	Stickleback	Sculpin	Sac Sucker	Hitch	Squawfish	SM Bass	LM Bass	Logperch	BF Tadpole	Bluegill	Mosquitofish	Silverside	Red Shiner
1	Below Berryessa	0.07	0.07	0.09										
2	In Lake Solano	0.06												
3	Below L. Solano		0.09	0.07	0.11	0.17								
4	Below Winters			0.06	0.12		0.12	0.11	0.10					
5	At Russell Ranch					0.11		0.08	0.12	0.05	0.11	0.08		
6	At Pedrick Rd					0.11		0.09	0.08	0.06	0.09	0.07	0.07	
7	0.5 mi above UCD									0.04	0.05	0.03	0.06	
8	At LEHR/UCD								0.08		0.06	0.03	0.09	0.03
9	0.7 mi blw LEHR										0.05		0.07	0.03
10	At Mace Blvd								0.06	0.04	0.05	0.04	0.10	0.02
11	At Rd 106A										0.11	0.23	0.12	0.08

Stickleback: Three-spined Stickleback, *Gasterosteus aculeatus*
Sculpin: Riffle Sculpin, *Cottus gulosus*
Sac Sucker: Sacramento Sucker, *Catostomus occidentalis*, (young-of-year)
Hitch: Hitch, *Lavinia exilicauda*, (young-of-year)
Squawfish: Sacramento Squawfish, *Ptychocheilus grandis*, (young-of-year)
SM Bass: Smallmouth Bass, *Micropterus dolomieui*, (young-of-year)
LM Bass: Largemouth Bass, *Micropterus salmoides*, (young-of-year)
Logperch: Bigscale Logperch, *Percina macrolepida*
BF Tadpole: Bullfrog Tadpoles, *Rana catesbeiana*
Bluegill: Bluegill Sunfish, *Lepomis macrochirus*, (young-of-year)
Mosquitofish: Mosquitofish, *Gambusia affinis*
Silverside: Mississippi Siverside, *Menidia audens*
Red Shiner: Red Shiner, *Notropis lutrensis*

Figure 5. Lower Putah Creek Juvenile and Small Fish Composite Mercury

(each bar represents data for an individual species at each site)
(multi-individual, whole fish composites; data in fresh/wet weight ppm Hg)



3.3 Aquatic Insects

Aquatic insect samples were taken to supplement the adult fish and small/juvenile fish studies. Native in-stream aquatic insects have proven to be excellent monitors of mercury bioavailability in California streams and rivers (Slotton *et al.* 1995a, 1996, 1997a,b,c). These organisms are ideal indicators of highly localized conditions, as compared to adult fish which can and often do migrate extensively. The benthic insect species we collected in this work typically remain within a very limited area throughout their lives. They thus function as relatively static biological probes of the fraction of mercury in the system that is bioavailable. As the organisms sampled are typically a year or less in age, they also integrate mercury availability conditions specific to the year collected. Mercury data for the Putah Creek aquatic insect samples are presented in Table 5 and Figure 6. It is important to note that the aquatic insect data are given on a dry weight basis and are not directly comparable to the fresh/wet weight concentration units utilized for the other sample types. Multi-individual composites of each collected species were dried and powdered for uniformity. This was also done in order to bring the low mercury levels of these samples into a range well above detection (drying concentrates the samples 5-10 fold). The primary purpose of the insect collections was to provide an additional measure for inter-site comparisons of relative mercury exposure/uptake.

As found for both the adult and small/juvenile fishes, different portions of the creek supported different assemblages of macro-invertebrates. None were present at all stations and most were found in sufficient numbers for analysis at fewer than 50% of the stations. Additionally, typical riffle and debris habitats, where benthic aquatic insects aggregate and are most readily available for collection, were not present throughout the entire study region. In the downstream portions of the creek, adjacent to and downstream of the University, riffle habitat was essentially absent. Thus, only three samples of readily comparable organisms were available from the area downstream of the University. However, the aquatic insect data provide some useful information.

The data are arranged by trophic level of the organisms. The herbivore group was represented only by a very small species of Baetid mayfly, which was present at five of the sites in numbers sufficient for analysis. Mercury levels were uniformly very low, from below detection (<0.01 ppm) to 0.02 ppm in all of the samples. No trend was apparent. The sample taken from Site 11, six miles downstream of UC Davis, had mercury below 0.01 ppm.

Drift feeding omnivores included a sample of Simuliid blackfly larvae at Site 1 and Hydropsychid caddisfly larvae at seven of the sites. The blackfly sample, taken 1-2 miles below the Lake Berryessa outflow (Site 1), was relatively elevated at 0.20 ppm. However, no comparable samples were available from downstream sites. In contrast, Hydropsychid caddisflies were the most consistently available of all the aquatic insect samples, and this data set provides the best relative information among the insects for spatial variation in mercury exposure/uptake along the creek. Mercury was quite similar among all the caddisfly samples, ranging between 0.04 and 0.12 ppm. Highest concentrations were found at Sites 1, 3, and 5, located in the upper and middle sections of the creek. A caddisfly sample was obtained from three miles downstream of UC Davis near Mace Rd (Site 10). This sample, at 0.08 ppm, indicated no relative elevation. 0.08 ppm Hg was the mean level in caddisfly larvae from all seven sites where they were sampled.

"First order" (small prey) predators, typically represented by stonefly nymphs in headwater reaches, were not consistently available for flow-based kick-screen collection within the study region, primarily due to habitat changes throughout the stretch. Seven adequate composite samples were taken among five of the sites. These came from four different families: Perlodid stonefly nymphs (Site 1), Coenagrionid (Site 7) and Calopterygid (Sites 4, 5, and 7) damselfly nymphs, and Sialid alderflies which are small megalopterans (Sites 3 and 5). Damselfly mercury ranged from 0.04 to 0.09 ppm, with the highest levels, identical in both species at 0.09 ppm, at Site 7, upstream of the UC Davis water treatment outfall and the LEHR site. Small Perlodid stoneflies were collected only at the most upstream site (Site 1). These were apparently somewhat elevated at 0.16 ppm, though comparable samples were not present downstream. Sialid alderfly nymphs contained 0.08 ppm Hg at Site 3 below Lake Solano and exhibited an anomalously elevated level (0.27 ppm) at Russell Ranch (Site 5).

"Second order" (larger prey) predators, typically represented by hellgrammites in headwater reaches, consisted in this study of Tipulid cranefly larvae from Site 3 and Libellulid dragonfly nymphs at Sites 5, 6, 7, and 10. The Site 3 cranefly sample had 0.15 ppm mercury. Libellulid dragonfly nymphs were present both above the university inputs (Sites 5, 6, and 7) and three miles downstream at Site 10. Highest dragonfly mercury was found at Russell Ranch (Site 5, 0.15 ppm). Sites 6 and 7 had relatively lower levels of 0.07 and 0.09 ppm, and Site 10 below the University had the lowest level, at 0.04 ppm.

Similar, comparative data exist for aquatic insect mercury bioindicator organisms throughout California from our various projects, already cited. The levels summarized in Table 5 are not notably elevated for this region of California. Dramatically higher concentrations are typical closer to mining-related sources of mercury, both in the Coast Range and in the Sierra Nevada. As indicators, though, of relative levels of exposure or biological uptake between sites, these Putah Creek collections indicate no elevation in relation to potential University inputs.

Table 5. Putah Creek Aquatic Insect Mercury Data.
(DRY ppm Hg in multi-individual, homogenized, whole-body composites)

		HERBIVORES	DRIFT COLLECTORS		FIRST ORDER PREDATORS				SECOND ORDER PREDATORS	
Site #	Site Description	Baetidae	Simuliidae	Hydropsychidae	Small Perlodidae	Coenagrionidae	Calopterygidae	Sialidae	Libellulidae	Tipulidae
1	Below L. Berryessa		0.20	0.11	0.16					
3	Just Below L. Solano	0.02		0.12				0.08		0.15
4	Below Winters			0.06			0.04			
5	At Russell Ranch	BD*		0.11			0.06	0.27	0.15	
6	At Pedrick Rd	0.01		0.07					0.07	
7	0.5 mi above UCD	0.01		0.04		0.09	0.09		0.09	
10	At Mace Blvd			0.08					0.04	
11	At Rd 106A	BD*								

* BD = Below Detection

Baetidae: Mayfly nymphs (tiny species)

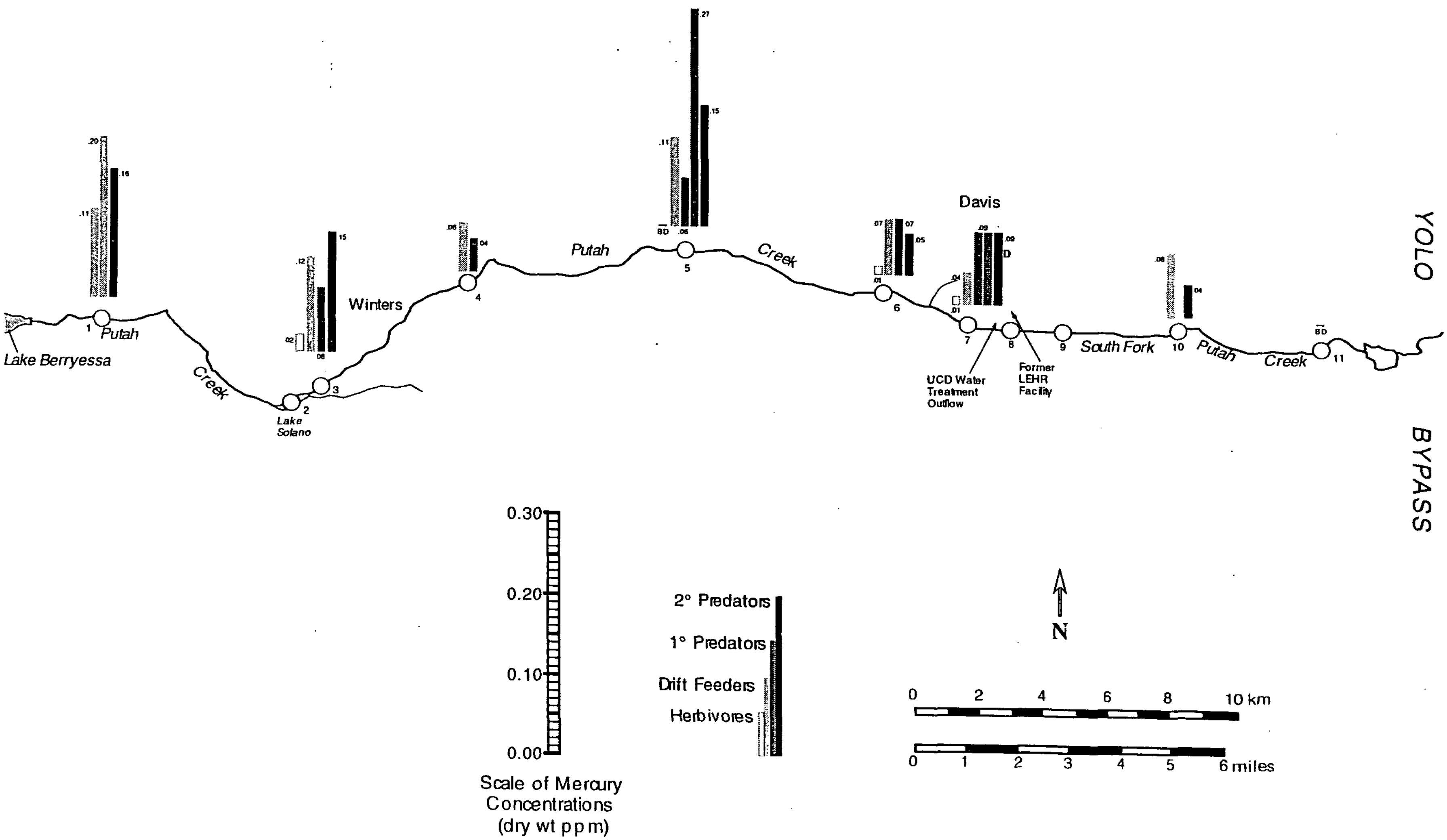
Simuliidae: Blackfly larvae
Hydropsychidae: Net spinning caddisfly larvae

Small Perlodidae: Stonefly nymphs (juveniles)
Coenagrionidae: Damselfly nymphs
Calopterygidae: Damselfly nymphs
Sialidae: Alderflyfly nymphs (small Megaloptera)

Libellulidae: Dragonfly nymphs
Tipulidae: Cranefly larvae

Figure 6. Lower Putah Creek Aquatic Insect Mercury

(each bar represents data for an individual species at each site, keyed to family)
(multi-individual, whole body composites; data in dry weight ppm Hg)



3.4 Crayfish

This Putah Creek mercury study was extended into the fall of 1998 in order to supplement the existing adult fish, small fish, and aquatic insect data bases with an intensive study of Putah Creek crayfish. Crayfish were of particular interest for a variety of reasons: (1) they exhibit strong site fidelity while providing mercury uptake and accumulation levels similar to adult fishes and (2) they represent important consumption endpoints for both humans and wildlife. Approval for this addition to the project was given only after the seasonal behavioral cycles of the crayfish made them relatively difficult to obtain (in late October 1998). However, it was possible, with many repeated days of sampling at each site, to obtain adequate, representative samples of adult crayfish throughout the study region between the Lake Berryessa outflow and the Yolo Bypass.

Crayfish tail muscle mercury data are presented in a variety of formats. Individual data appear in Table 6 and are plotted, by sampling site, in Figures 7 (a-j). Reduced crayfish data, including means of multiple individual analyses and 95% confidence intervals of the means, are shown in Tables 7a (arranged by sampling site) and 7b (arranged by species). Mean data are plotted against sampling location in Figure 8 and on a map of the region in Figure 9.

Adult crayfish within similar size ranges were collected from ten sites encompassing the entire study region. Three different species of crayfish were resident, all with similar body type and benthic feeding behavior. All were captured in identically baited traps. None were present at all of the sites, though two of the species were taken from sites upstream, adjacent to, and downstream of the university. Once again, the changing character of the creek habitat throughout the study region resulted in a partitioning between the resident species. The native species *Pacifasticus leniusculus* (signal crayfish) was the only species present at Sites 1-4 (Berryessa outflow to Highway 505 downstream of Winters). The introduced, red-colored Louisiana swamp crayfish (*Procambarus clarkii*) occurred at Sites 5-11 (Russell Ranch to the Yolo Bypass), dominating in the lower reaches of the creek. A second introduced species, *Orconectes virilis*, co-occurred with *Procambarus* and was most prevalent in the middle reaches of the creek (Sites 5-9). In Figure 10, the body proportion relationships of the three species are compared, using carapace length and body weight. *Pacifasticus* and *Orconectes* follow identical trends, while the slimmer *Procambarus* demonstrate somewhat lower weights relative to carapace length.

Native signal crayfish (*Pacifasticus*) exhibited relatively high and variable mercury levels at the most upstream site (Site 1, Berryessa outflow: mean = 0.34 ppm). Concentrations were less variable in the three downstream sites and exhibited steadily declining mean mercury levels (Site 2, Lake Solano: 0.23 ppm; Site 3: 0.20 ppm, Site 4, Hwy 505: 0.16 ppm). This was in spite of the fact that the mean sizes of the sampled individuals increased moving downstream. Mercury levels in individual *Pacifasticus* varied between 0.08 and 0.61 ppm. Signal crayfish were not present in the creek at Sites 5-11; thus, inter-site comparisons using this species can only be made among upstream Sites 1-4. We hypothesize that the elevated, variable concentrations from upstream Site 1 may indicate consumption by some of the *Pacifasticus* of highly mercury-elevated Sacramento suckers which make upstream spawning runs out of Lake Solano.

Louisiana swamp crayfish (*Procambarus*) contained mercury in a range considerably lower than that found upstream in samples of *Pacifasticus*. Individual *Procambarus* mercury ranged between 0.05 and 0.28 ppm, with site means ranging between 0.10 and 0.19 ppm. Within this relatively narrow range, highest levels were seen at Site 9 (0.7 miles downstream of UC Davis, 0.19 ppm), Site 10 (3 miles downstream of UC Davis, 0.16 ppm), and Site 6 (upstream of the University at Pedrick Rd, 0.15 ppm). The individuals taken at Sites 9 and 10 were, on average, considerably larger than *Procambarus* taken at other sites. Lowest mean levels were found at Site 5 (Russell Ranch, 0.10 ppm), Site 8 (directly adjacent to the LEHR site and downstream of the UC Davis wastewater treatment outfall, 0.12 ppm), and at the most downstream site (Site 11 at Rd 106A, 0.13 ppm). These data indicate no significant locational trend in mercury exposure/uptake between Sites 5 and 11.

The third species, *Orconectes*, was notable in containing considerably higher mercury concentrations than *Procambarus* at the sites where both species occurred. This was a consistent phenomenon, with *Orconectes* mercury typically 2-3 times greater than the levels seen in co-occurring *Procambarus*. The probable explanation is that these species, while both being bottom feeding omnivores with very similar body types and physiology, must to some extent partition the food resources at the sites where they overlap. The data suggest that *Orconectes* consume more high trophic level (animal) food on average, while the *Procambarus* diet may contain a substantial fraction of low trophic level (plant-based) food items. Mercury in individual *Orconectes* ranged between 0.18 and 0.52 ppm. Mean levels were highest and similar at Site 5 (Russell Ranch, 0.35 ppm), Site 6 (upstream of the University at Pedrick Rd, 0.32 ppm), and Site 9 (0.7 miles downstream of UC Davis, 0.33 ppm). Lowest *Orconectes* mercury was sampled at Site 8 (adjacent to the LEHR site and downstream of the UC Davis water treatment outfall, 0.22 ppm), and at the most downstream site (Site 11 at Rd 106A, 0.27 ppm). Similar to the *Procambarus* data, these relative concentrations indicate no significant locational trend in mercury exposure/uptake between Sites 5 and 11.

Table 6. Putah Creek Individual Crayfish Tail Muscle Mercury Data.

Site #	Site Description	Crayfish Species	Weight (g)	Carapace Length (mm)	Muscle Hg (wet wt ppm)
1	Below L. Berryessa	*Pacifasticus*	31	10.9	**0.11**
1	Below L. Berryessa	*Pacifasticus*	34	14.4	**0.45**
1	Below L. Berryessa	*Pacifasticus*	39	18.2	**0.44**
1	Below L. Berryessa	*Pacifasticus*	45	31.7	**0.14**
1	Below L. Berryessa	*Pacifasticus*	46	36.8	**0.35**
1	Below L. Berryessa	*Pacifasticus*	48	26.2	**0.61**
1	Below L. Berryessa	*Pacifasticus*	45	38.3	**0.33**
1	Below L. Berryessa	*Pacifasticus*	47	37.0	**0.24**
1	Below L. Berryessa	*Pacifasticus*	55	70.4	**0.51**
1	Below L. Berryessa	*Pacifasticus*	60	97.7	**0.22**
2	In Lake Solano	*Pacifasticus*	36	15.7	**0.18**
2	In Lake Solano	*Pacifasticus*	37	19.5	**0.23**
2	In Lake Solano	*Pacifasticus*	47	38.2	**0.20**
2	In Lake Solano	*Pacifasticus*	49	48.2	**0.26**
2	In Lake Solano	*Pacifasticus*	53	53.4	**0.27**
3	Just Below L. Solano	*Pacifasticus*	37	17.5	**0.12**
3	Just Below L. Solano	*Pacifasticus*	47	40.4	**0.16**
3	Just Below L. Solano	*Pacifasticus*	50	42.5	**0.13**
3	Just Below L. Solano	*Pacifasticus*	51	47.1	**0.16**
3	Just Below L. Solano	*Pacifasticus*	51	38.6	**0.18**
3	Just Below L. Solano	*Pacifasticus*	53	54.9	**0.29**
3	Just Below L. Solano	*Pacifasticus*	53	57.5	**0.23**
3	Just Below L. Solano	*Pacifasticus*	60	71.5	**0.34**
4	Below Winters	*Pacifasticus*	48	36.6	**0.11**
4	Below Winters	*Pacifasticus*	50	36.7	**0.10**
4	Below Winters	*Pacifasticus*	51	49.3	**0.13**
4	Below Winters	*Pacifasticus*	54	56.6	**0.08**
4	Below Winters	*Pacifasticus*	56	57.6	**0.28**
4	Below Winters	*Pacifasticus*	64	95.7	**0.21**
4	Below Winters	*Pacifasticus*	66	106.2	**0.17**
5	At Russell Ranch	*Procambarus*	30	5.0	**0.06**
5	At Russell Ranch	*Procambarus*	43	20.6	**0.10**
5	At Russell Ranch	*Procambarus*	51	33.4	**0.10**
5	At Russell Ranch	*Procambarus*	52	28.3	**0.14**
5	At Russell Ranch	*Orconectes*	39	20.5	**0.22**
5	At Russell Ranch	*Orconectes*	39	21.5	**0.32**
5	At Russell Ranch	*Orconectes*	42	25.2	**0.52**
5	At Russell Ranch	*Orconectes*	43	26.0	**0.22**
5	At Russell Ranch	*Orconectes*	44	28.0	**0.29**
5	At Russell Ranch	*Orconectes*	46	33.5	**0.49**
5	At Russell Ranch	*Orconectes*	45	35.1	**0.41**

(continued)

Table 6. Putah Creek Individual Crayfish Tail Muscle Mercury Data. *(continued)*

Site #	Site Description	Crayfish Species	Weight (g)	Carapace Length (mm)	Muscle Hg (wet wt ppm)
6	At Pedrick Rd	*Procambarus*	31	8.9	**0.05**
6	At Pedrick Rd	*Procambarus*	37	11.4	**0.06**
6	At Pedrick Rd	*Procambarus*	45	20.0	**0.12**
6	At Pedrick Rd	*Procambarus*	43	17.0	**0.13**
6	At Pedrick Rd	*Procambarus*	45	18.9	**0.28**
6	At Pedrick Rd	*Procambarus*	45	25.6	**0.12**
6	At Pedrick Rd	*Procambarus*	49	26.2	**0.22**
6	At Pedrick Rd	*Procambarus*	50	25.1	**0.17**
6	At Pedrick Rd	*Procambarus*	53	43.2	**0.17**
6	At Pedrick Rd	*Orconectes*	31	8.8	**0.18**
6	At Pedrick Rd	*Orconectes*	43	26.0	**0.45**
8	At LEHR/UCD	*Procambarus*	41	20.2	**0.10**
8	At LEHR/UCD	*Procambarus*	43	27.2	**0.10**
8	At LEHR/UCD	*Procambarus*	45	22.6	**0.10**
8	At LEHR/UCD	*Procambarus*	48	32.1	**0.14**
8	At LEHR/UCD	*Procambarus*	54	35.4	**0.10**
8	At LEHR/UCD	*Procambarus*	48	28.5	**0.18**
8	At LEHR/UCD	*Procambarus*	52	31.7	**0.14**
8	At LEHR/UCD	*Orconectes*	47	39.4	**0.26**
8	At LEHR/UCD	*Orconectes*	48	35.7	**0.19**
8	At LEHR/UCD	*Orconectes*	47	36.7	**0.22**
9	0.7 mi blw LEHR/UCD	*Procambarus*	47	26.7	**0.20**
9	0.7 mi blw LEHR/UCD	*Procambarus*	48	36.9	**0.15**
9	0.7 mi blw LEHR/UCD	*Procambarus*	50	39.5	**0.20**
9	0.7 mi blw LEHR/UCD	*Procambarus*	55	36.5	**0.19**
9	0.7 mi blw LEHR/UCD	*Orconectes*	48	39.3	**0.31**
9	0.7 mi blw LEHR/UCD	*Orconectes*	48	40.2	**0.36**
10	At Mace Blvd	*Procambarus*	46	24.8	**0.14**
10	At Mace Blvd	*Procambarus*	51	39.1	**0.14**
10	At Mace Blvd	*Procambarus*	48	29.8	**0.19**
10	At Mace Blvd	*Procambarus*	49	36.2	**0.17**
10	At Mace Blvd	*Procambarus*	52	40.7	**0.17**
11	At Rd 106A	*Procambarus*	33	9.1	**0.16**
11	At Rd 106A	*Procambarus*	35	10.8	**0.07**
11	At Rd 106A	*Procambarus*	40	14.5	**0.10**
11	At Rd 106A	*Procambarus*	47	25.3	**0.12**
11	At Rd 106A	*Procambarus*	49	27.5	**0.18**
11	At Rd 106A	*Procambarus*	56	43.2	**0.12**
11	At Rd 106A	*Orconectes*	42	24.7	**0.27**

Table 7. Putah Creek Crayfish Tail Muscle Mercury: Reduced Data.
(A) Sorted by Sampling Location

Site #	Site Description	Crayfish Species	n	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)	95% Confid. Int. of mean Hg (wet wt ppm)
				(mean values ± std. deviation)			
BY SITE							
1	Below L. Berryessa	*Pacifasticus*	10	45.0 ± 8.8	38.2 ± 26.8	**0.341** ± 0.162	0.225 - 0.457
2	In Lake Solano	*Pacifasticus*	5	44.4 ± 7.5	35.0 ± 16.9	**0.229** ± 0.038	0.182 - 0.276
3	Below L. Solano	*Pacifasticus*	8	50.3 ± 6.5	46.3 ± 15.9	**0.201** ± 0.076	0.137 - 0.265
4	Below Winters	*Pacifasticus*	7	55.6 ± 7.0	62.7 ± 27.6	**0.156** ± 0.070	0.092 - 0.220
5	At Russell Ranch	*Procambarus*	4	44.0 ± 10.2	21.8 ± 12.4	**0.101** ± 0.029	0.055 - 0.147
5	At Russell Ranch	*Orconectes*	7	42.6 ± 2.8	27.1 ± 5.6	**0.353** ± 0.123	0.240 - 0.467
6	At Pedrick Rd	*Procambarus*	9	44.2 ± 6.7	21.8 ± 10.1	**0.149** ± 0.073	0.093 - 0.205
6	At Pedrick Rd	*Orconectes*	2	37.0 ± 8.5	17.4 ± 12.2	**0.318** ± 0.191	(0.318)
8	At LEHR/UCD	*Procambarus*	7	47.3 ± 4.7	28.2 ± 5.4	**0.124** ± 0.032	0.094 - 0.153
8	At LEHR/UCD	*Orconectes*	3	47.3 ± 0.6	37.3 ± 1.9	**0.222** ± 0.037	0.130 - 0.313
9	0.7 mi blw LEHR/UCD	*Procambarus*	4	50.0 ± 3.6	34.9 ± 5.6	**0.186** ± 0.023	0.150 - 0.222
9	0.7 mi blw LEHR/UCD	*Orconectes*	2	48.0 ± 0.0	39.8 ± 0.6	**0.334** ± 0.038	(0.334)
10	At Mace Blvd	*Procambarus*	5	49.2 ± 2.4	34.1 ± 6.7	**0.160** ± 0.023	0.131 - 0.189
11	Below Rd 106A	*Procambarus*	6	43.3 ± 8.9	21.7 ± 12.9	**0.125** ± 0.041	0.082 - 0.168
11	Below Rd 106A	*Orconectes*	1	42.0 -	24.7 -	**0.270** -	(0.270)

(continued)

Table 7. Putah Creek Crayfish Tail Muscle Mercury: Reduced Data. ***(continued)***
(B) Sorted by Species

Site #	Site Description	Crayfish Species	n	---------- *(mean values ± std. deviation)* ---------- Weight *(g)*	Length *(mm)*	Muscle Hg *(wet wt ppm)*	95% Confid. Int. of mean Hg *(wet wt ppm)*
BY SPECIES							
1	Below L. Berryessa	*Pacifasticus*	10	45.0 ± 8.8	38.2 ± 26.8	**0.341** ± 0.162	0.225 - 0.457
2	In Lake Solano	*Pacifasticus*	5	44.4 ± 7.5	35.0 ± 16.9	**0.229** ± 0.038	0.182 - 0.276
3	Below L. Solano	*Pacifasticus*	8	50.3 ± 6.5	46.3 ± 15.9	**0.201** ± 0.076	0.137 - 0.265
4	Below Winters	*Pacifasticus*	7	55.6 ± 7.0	62.7 ± 27.6	**0.156** ± 0.070	0.092 - 0.220
5	At Russell Ranch	*Procambarus*	4	44.0 ± 10.2	21.8 ± 12.4	**0.101** ± 0.029	0.055 - 0.147
6	At Pedrick Rd	*Procambarus*	9	44.2 ± 6.7	21.8 ± 10.1	**0.149** ± 0.073	0.093 - 0.205
8	At LEHR/UCD	*Procambarus*	7	47.3 ± 4.7	28.2 ± 5.4	**0.124** ± 0.032	0.094 - 0.153
9	0.7 mi blw LEHR/UCD	*Procambarus*	4	50.0 ± 3.6	34.9 ± 5.6	**0.186** ± 0.023	0.150 - 0.222
10	At Mace Blvd	*Procambarus*	5	49.2 ± 2.4	34.1 ± 6.7	**0.160** ± 0.023	0.131 - 0.189
11	Below Rd 106A	*Procambarus*	6	43.3 ± 8.9	21.7 ± 12.9	**0.125** ± 0.041	0.082 - 0.168
5	At Russell Ranch	*Orconectes*	7	42.6 ± 2.8	27.1 ± 5.6	**0.353** ± 0.123	0.240 - 0.467
6	At Pedrick Rd	*Orconectes*	2	37.0 ± 8.5	17.4 ± 12.2	**0.318** ± 0.191	(0.318)
8	At LEHR/UCD	*Orconectes*	3	47.3 ± 0.6	37.3 ± 1.9	**0.222** ± 0.037	0.130 - 0.313
9	0.7 mi blw LEHR/UCD	*Orconectes*	2	48.0 ± 0.0	39.8 ± 0.6	**0.334** ± 0.038	(0.334)
11	Below Rd 106A	*Orconectes*	1	42.0 -	24.7 -	**0.270** -	(0.270)

Fig. 7(a) Crayfish
SITE 1: TROUT WATERS JUST BELOW LAKE BERRYESSA

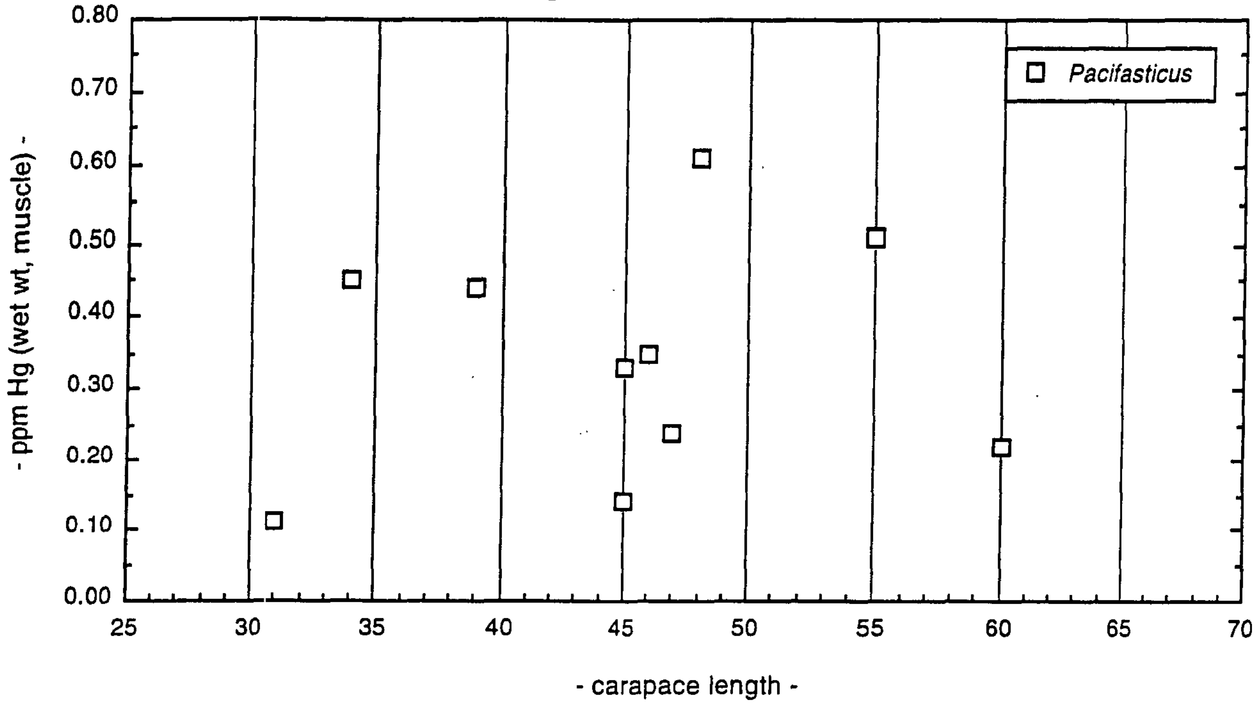


Fig. 7(b) Crayfish
SITE 2: IN LAKE SOLANO

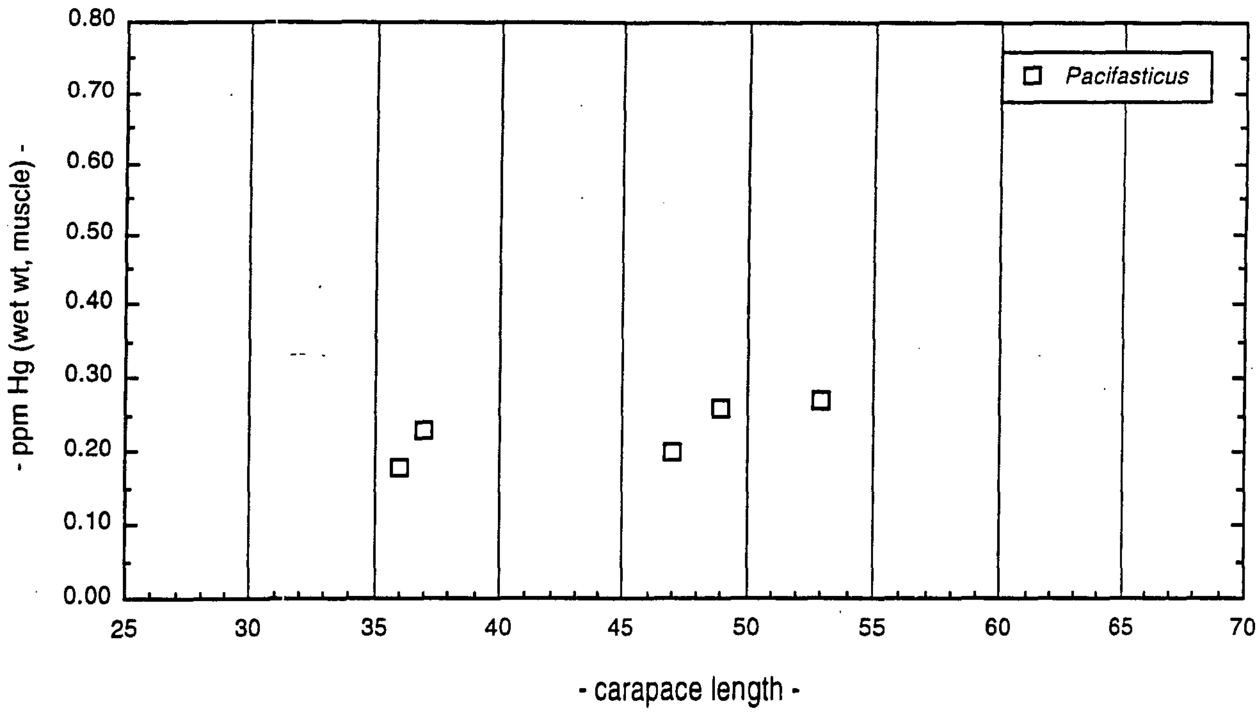


Fig. 7(c) Crayfish
SITE 3: JUST BELOW LAKE SOLANO

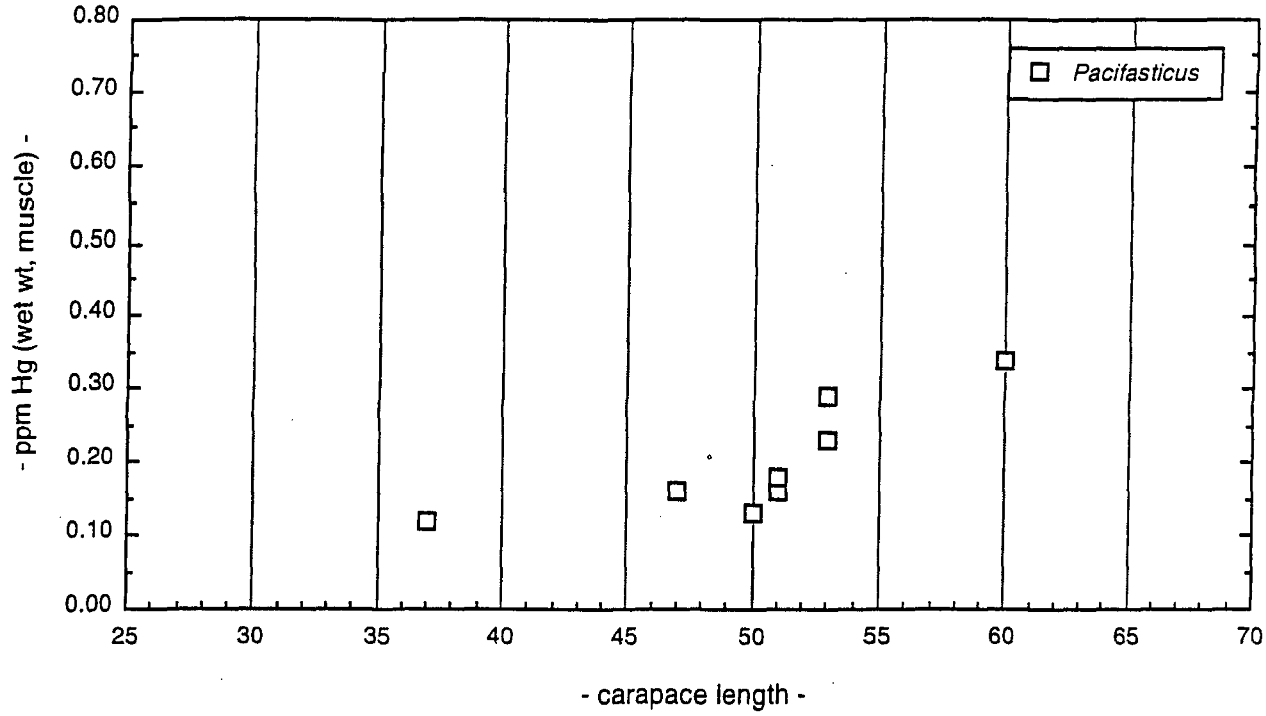


Fig. 7(d) Crayfish
SITE 4: BELOW WINTERS AT HIGHWAY 505

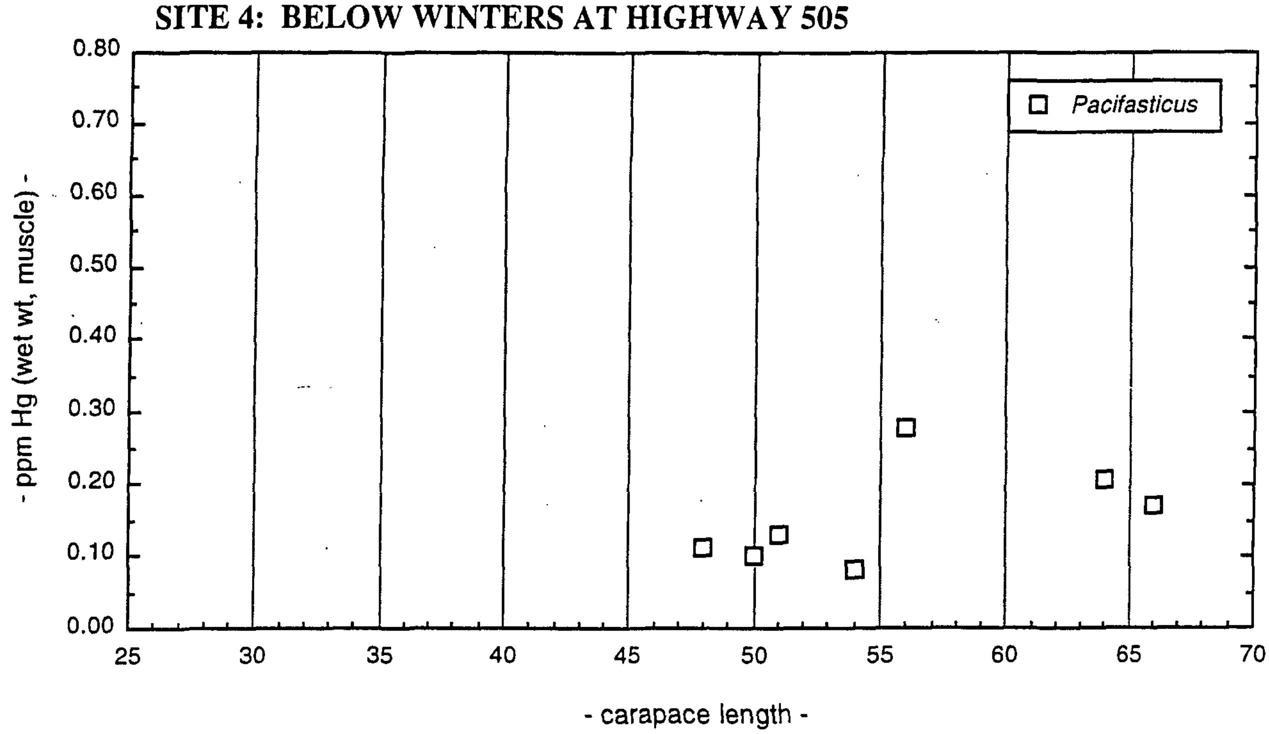


Fig. 7(e) Crayfish
SITE 5: AT RUSSELL RANCH

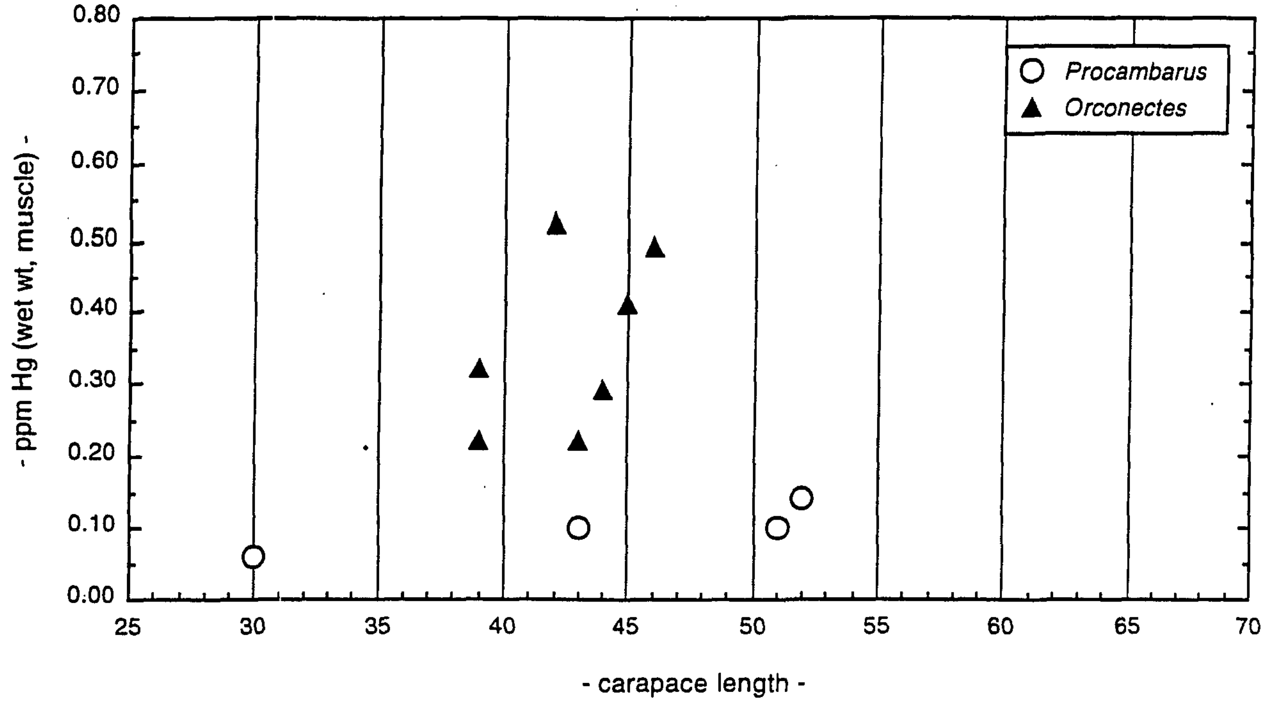


Fig. 7(f) Crayfish
SITE 6: ABOVE UC DAVIS AT PEDRICK ROAD

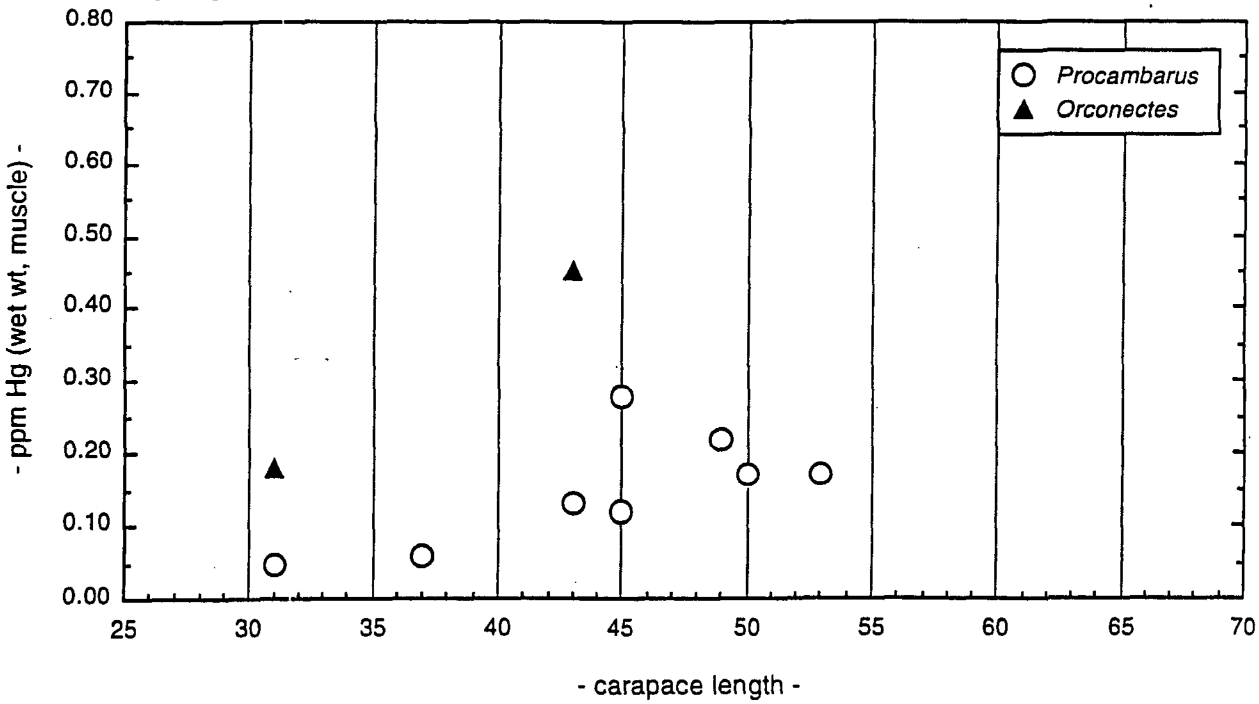


Fig. 7(g) Crayfish
SITE 8: ADJACENT TO LEHR SITE, BELOW OLD DAVIS RD

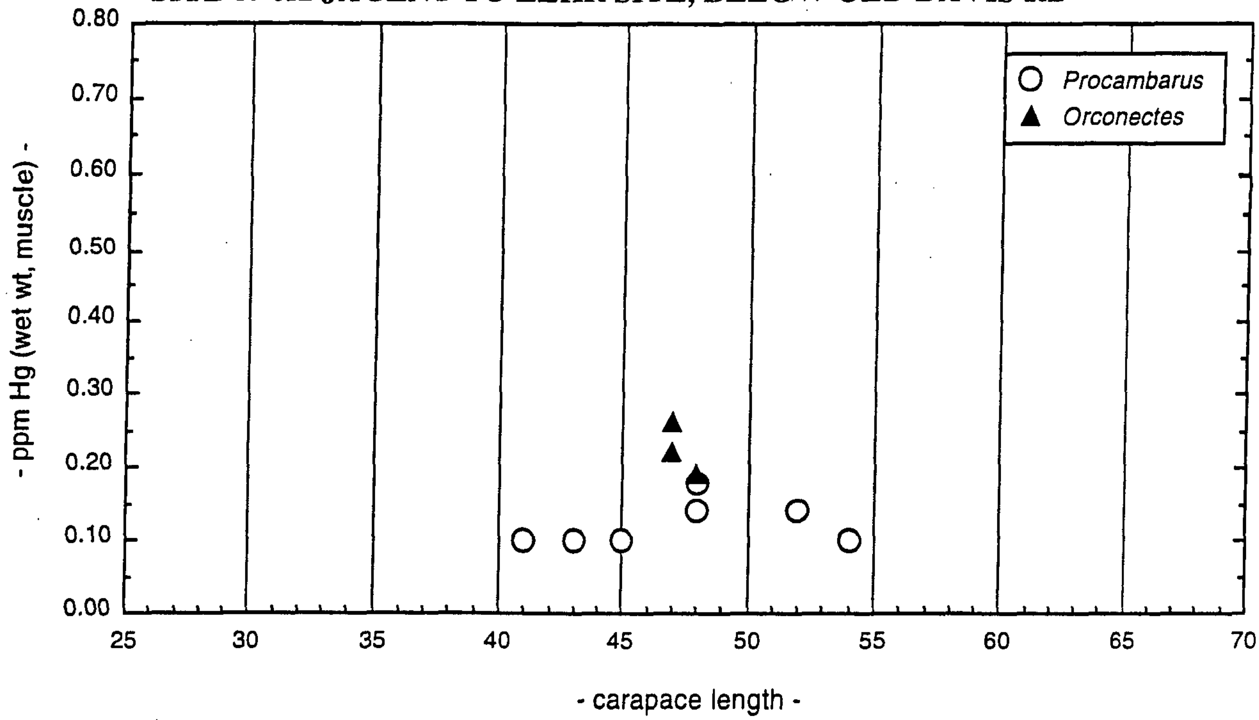


Fig. 7(h) Crayfish
SITE 9: 0.7 MILE DOWNSTREAM OF LEHR SITE

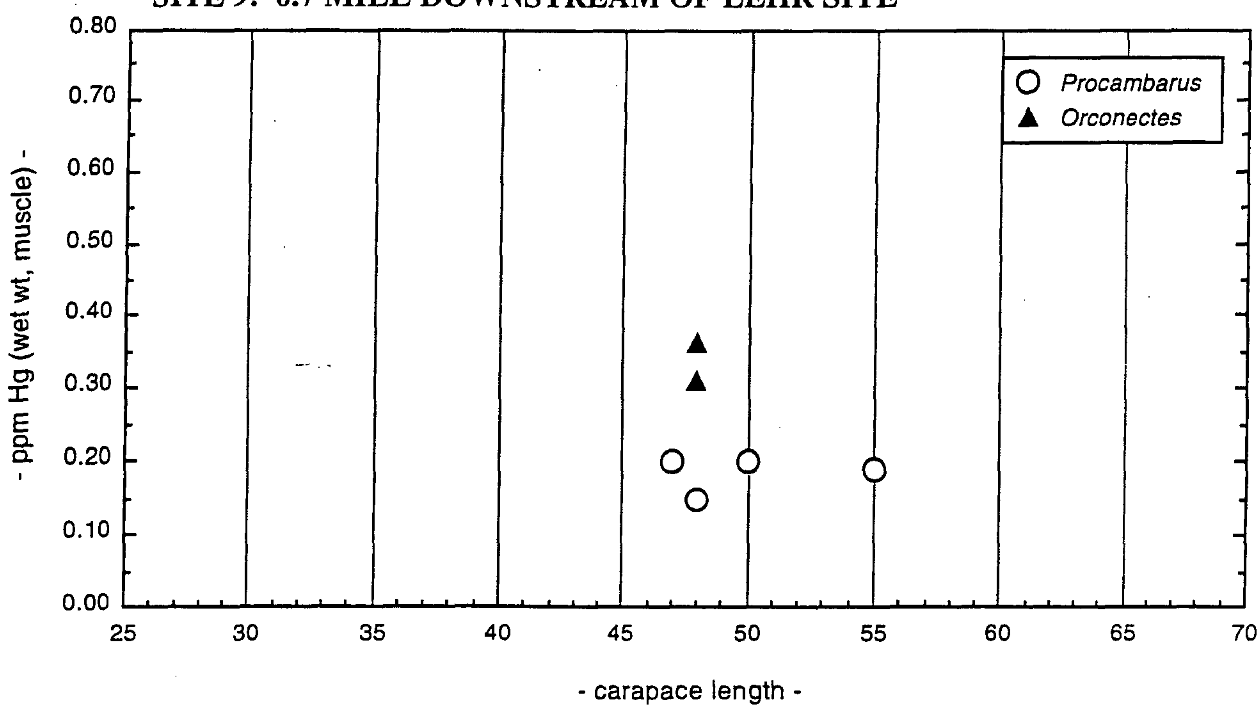


Fig. 7(i) Crayfish
SITE 10: ~3 MILES BELOW UC DAVIS AT MACE RD

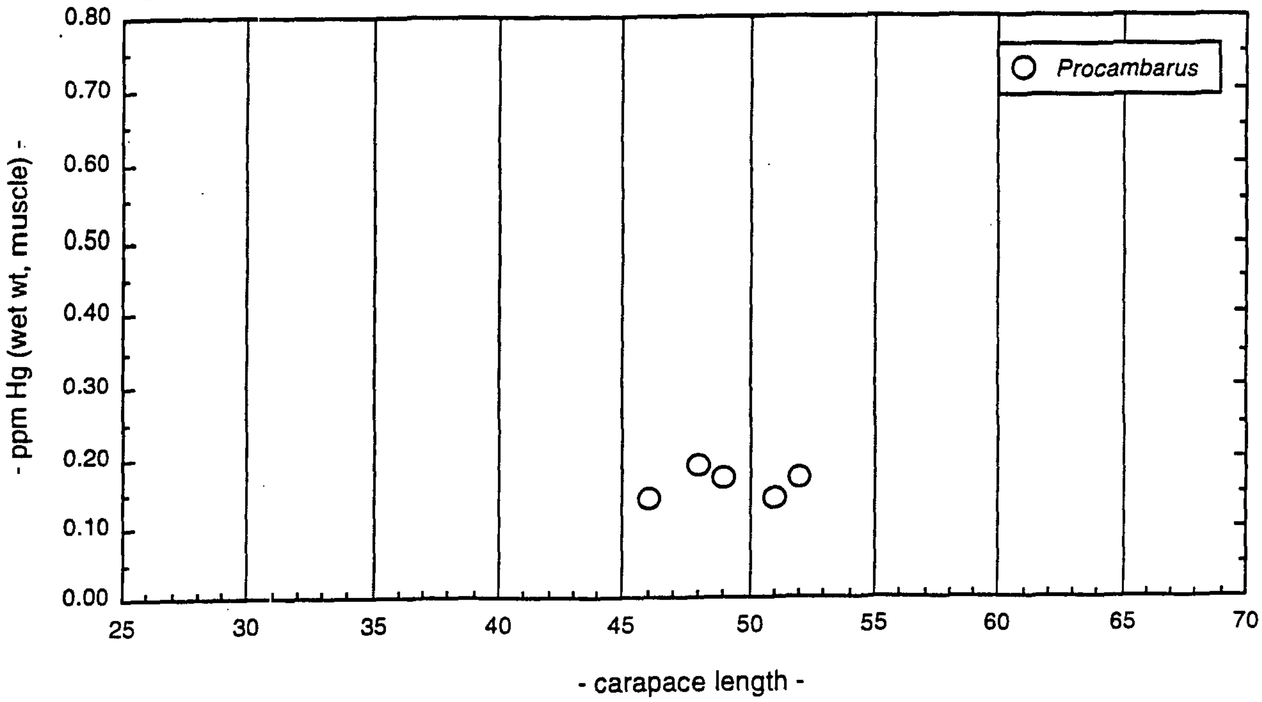


Fig. 7(j) Crayfish
SITE 11: AT AND BELOW ROAD 106A

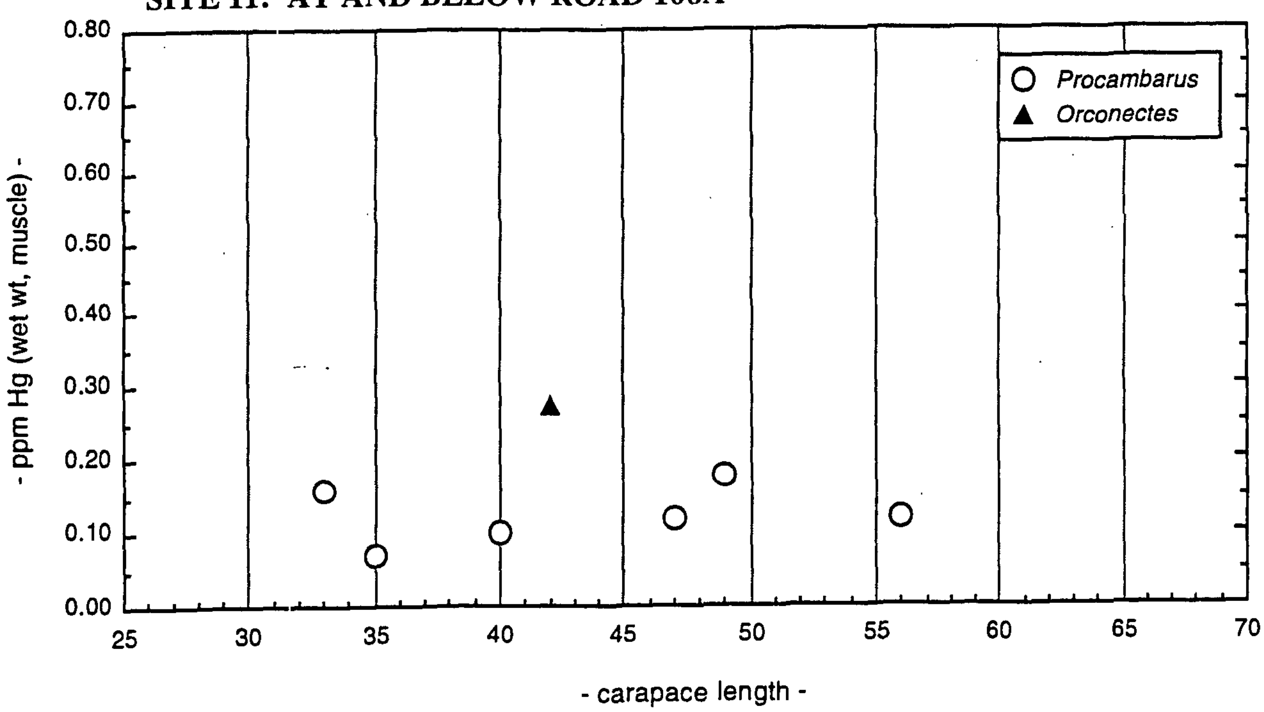


Fig. 8. Putah Creek Reduced (Mean) Crayfish Mercury Data Across the Range of Sampling Sites

(means ± 95% confidence intervals for multiple individual samples for each site/species)
(fresh/wet weight mercury concentrations in tail muscle)

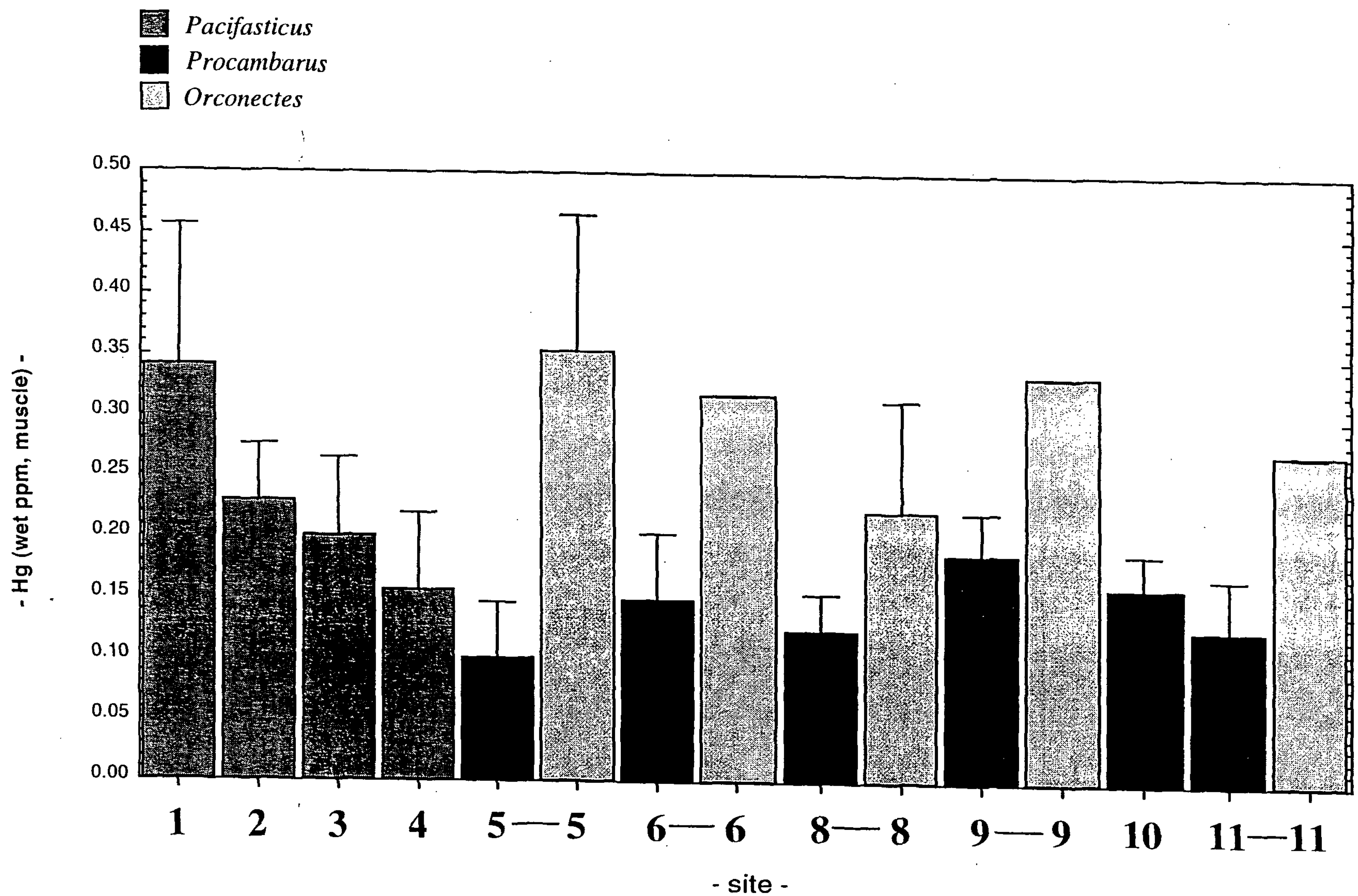


Figure 9. Lower Putah Creek Crayfish Tail Muscle Mercury

(each bar represents mean data for an individual species at each site)
(means of multiple individual samples; data in fresh/wet weight ppm Hg)

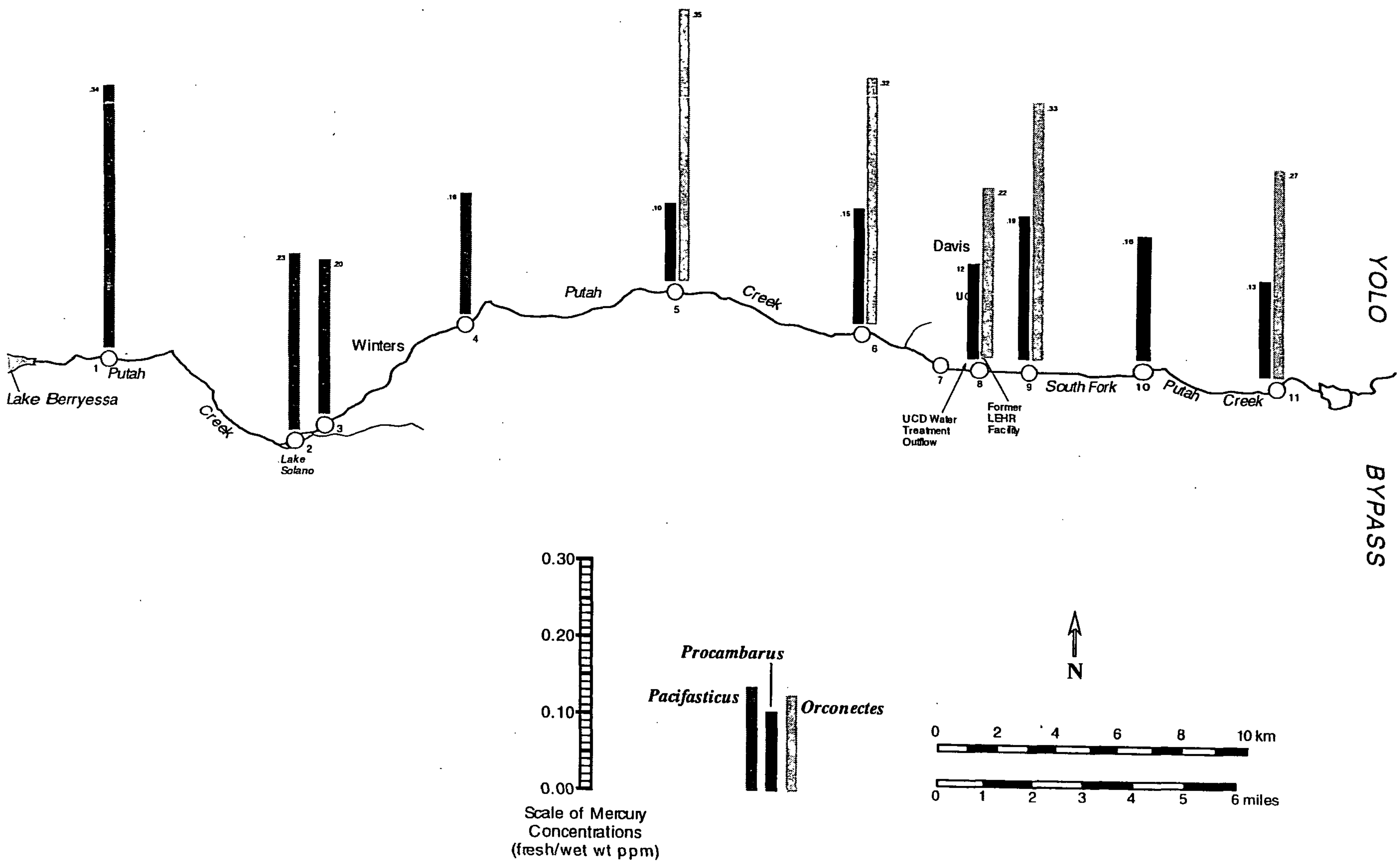
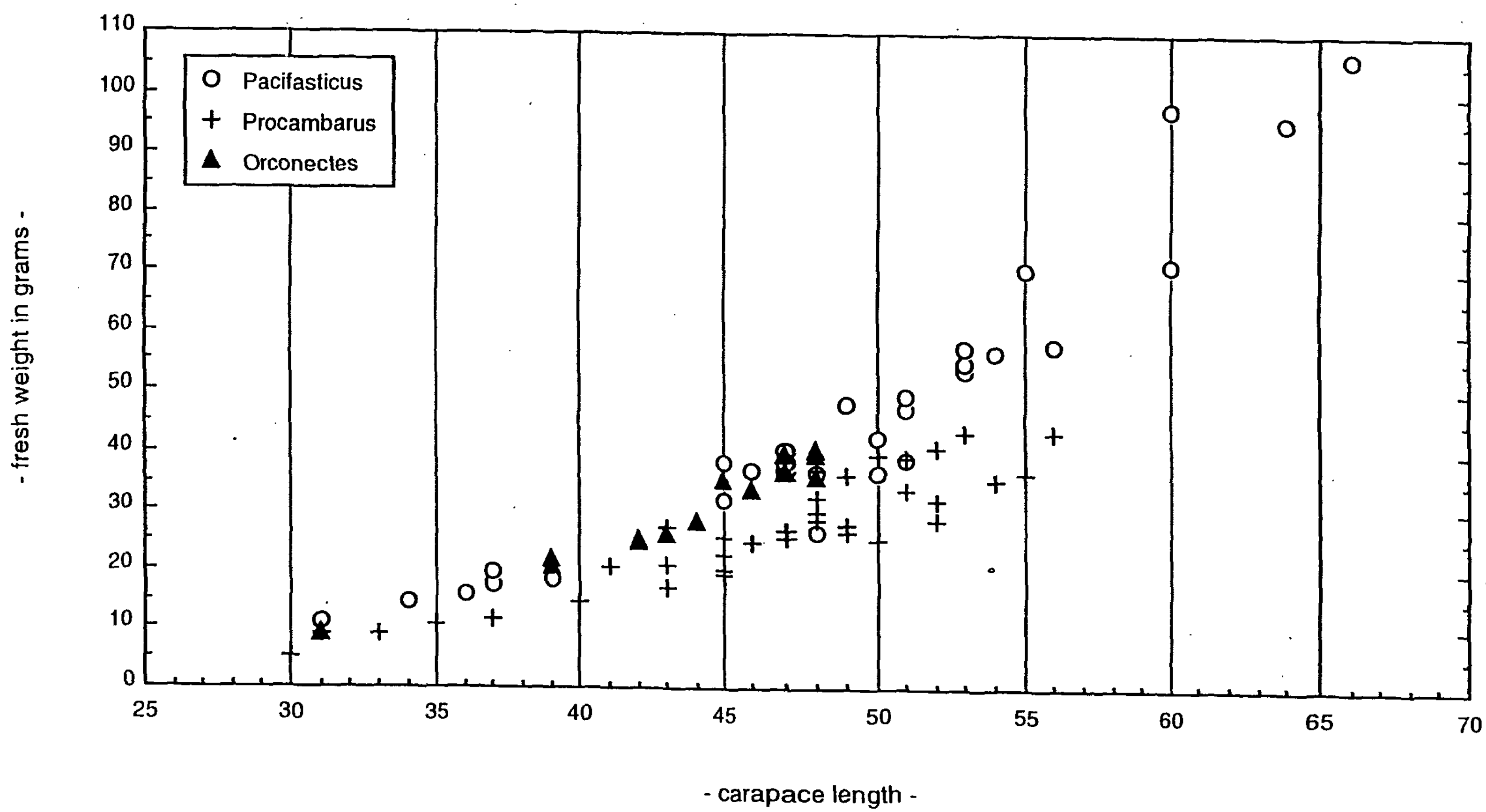


Fig. 10

**Carapace Length : Body Weight Relations
For The Three Putah Creek Crayfish Species**



4. CONCLUSIONS

The data collected in this study provide new information on mercury concentrations in Putah Creek biota. Depending on the criterion used, many of the Putah Creek fish species contained mercury concentrations in edible muscle at levels of potential concern, with larger individuals of the top predatory species most highly contaminated. This supports the findings of previous work conducted by the ATSDR and is consistent with similar ranges of fish mercury concentrations found in other California aquatic systems with mining-related histories of bulk mercury contamination. The data further indicate that certain Putah Creek crayfish may represent a hazard for both human and wildlife consumption and that certain small or juvenile fish may represent a chronic hazard to fish-eating wildlife.

While it was not possible to obtain identical samples throughout the entire, varied stretch studied, numerous upstream/downstream comparative samples were obtained. Relatively elevated mercury exposure, uptake, and accumulation was indicated for certain biota in and around Lake Solano and in the extended pool region at the most downstream reach of the creek near the Yolo Bypass. We note that these are the two most extensive depositional regions along the lower creek, where flow is dramatically reduced in most seasons, organic material and mercury-containing sediment can most readily accumulate, low oxygen conditions develop, and a healthy population of mercury-methylating bacteria become established. Mercury was elevated, relative to the extended data sets, in Sacramento suckers and hitch within Lake Solano, in signal crayfish in and, particularly, upstream of Lake Solano, and in juvenile squawfish and trout immediately below. At the downstream site near the Yolo Bypass, highest overall fish levels were found and relatively elevated mercury occurred in several individual adult fish of different species and in all four of the small and juvenile fish composites, though (curiously) not in the crayfish.

With the exception of these two areas, similar ranges of accumulated mercury generally occurred among same species throughout the entire stretch of Putah Creek below Lake Berryessa. This included adult fish muscle, composite small/juvenile fish, aquatic insect composites, and crayfish tail muscle. Highest levels occurred in larger individuals of top predator species, wherever they were present. Neither the town of Winters, the agricultural fields, nor the UC Davis region of the creek were found to significantly alter biological mercury trends in any of the organisms sampled, including those which exhibit high levels of site fidelity. Where closely comparable data could be collected, the stretch of Putah Creek adjacent to the University and downstream to a distance of at least 3 miles frequently contained among the lowest relative levels. Though the most extensive pooled areas of the downstream creek occurred below this region at and near Site 11, considerable pooled stretches were also present between the UC Davis wastewater treatment outflow and Sites 8, 9, and 10. The relatively unchanged or lower mercury contents of bioindicator organisms from those sites indicate that this outflow does not have a major effect on mercury dynamics in the creek. It is possible that relatively enhanced levels of mercury methylation may occur at Site 11 downstream and that this may be partially related to the presence of surface-covering mats of water hyacinth plants there, which may promote local anoxic zones either in the water column or at the bottom when the plants die and sink. Nutrients from the University outflow may contribute somewhat to the hyacinth growth, though the entire creek below Lake Berryessa is high in nutrients.

Biotic mercury accumulations found in this Putah Creek study were similar to and somewhat lower than those found in research conducted on the lower portion of Cache Creek (Slotton *et al.* 1997c). Aquatic insect mercury concentrations from lower Putah Creek were considerably lower than levels seen in comparable organisms in the upstream watersheds of both Cache Creek (Reuter *et al.* 1996, 1998, Slotton *et al.* 1997b) and Putah Creek (study in progress). It is clear to us that the predominant source of bioavailable mercury in both watersheds can be traced to historic mercury mining and now-abandoned mercury mines. Cache Creek, which remains un-dammed below Clear Lake and Indian Valley Reservoir, is currently believed to be the single most significant conduit of mercury to the San Francisco Bay-Delta. A very intensive, multi-investigator research project is being developed at this time for the State, to study this phenomenon and the possibilities for cost-effective remediation of key mine-related sources (Stephenson *et al.* 1999).

While Lake Berryessa now lies between the lower portion of Putah Creek and upstream historic mercury mining zones, it is important to note that the dam and reservoir were not present throughout the period of active mining in the late 19th and early to mid 20th centuries. Figure 11 shows some of the more important mercury mines in the upper Putah watershed, including the Oat Hill Mine, second largest in all of California and largest in Northern California. Historic mercury production in the Putah Creek watershed was more than double that in the Cache Creek watershed (USDCMG 1997). Before Monticello Dam was built in the 1950s, Putah Creek undoubtedly constituted at least as great of a "mercury conduit" as present day Cache Creek. While the ongoing downstream transport of this material may have been greatly diminished by the dam and reservoir, remnant mercury must certainly be present within the stream bed and adjacent banks of lower Putah Creek. This material is re-exposed, transported, and re-distributed during high flow events. The results of this study are consistent with remnant, mining-derived mercury (together with some level of ongoing transfer through Lake Berryessa) constituting the primary source of ongoing mercury contamination in lower Putah Creek.

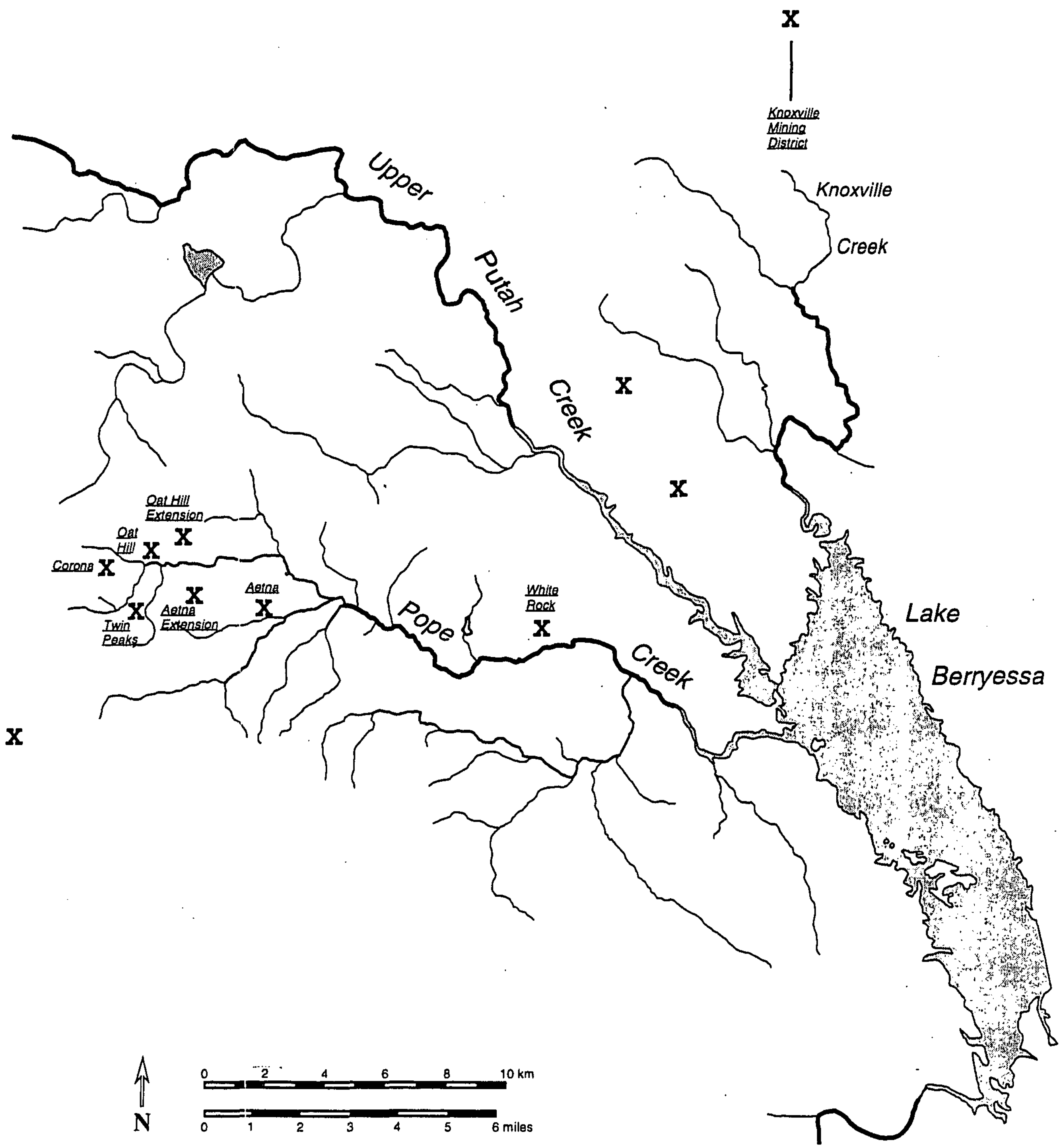


Fig. 11. Portions of the Upper Putah Creek Watershed, with Primary Abandoned Mercury Mines

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