MERCURY IN LOWER CACHE CREEK BIOTA:

BASELINE ASSESSMENT

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Prepared for

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Study and report by

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1. INTRODUCTION

In the work detailed in this report, we performed an assessment of current (Fall 1997) mercury levels in aquatic organisms of Lower Cache Creek. This work was performed in accordance with agreements reached by the County and representatives of the local gravel mining industry. These agreements concerned extensive new gravel mining pit lake operations proposed by the gravel mining companies, to be situated adjacent to Cache Creek in the region between Esparto and Woodland. In response to a concern over potential mercury bioaccumulation hazards associated with the new pit lakes, several actions were taken or planned: (1) An initial study was conducted within two existing pit lakes by our research group (Slotton et al. 1996b). (2) A Baseline Study of existing mercury conditions in lower Cache Creek aquatic organisms was required as was (3) Monitoring of mercury conditions within the new pit lakes after they are formed. This report details the results of the baseline study of the creek organisms. The purpose of this baseline work has been to provide a framework against which future monitoring of the pit lakes can be compared. It represents a reference baseline of existing mercury in the primary fish and other aquatic organisms of the lower Cache Creek region.

We initially sampled directly within the proposed and existing gravel mining stretch of Cache Creek, along a reach 1-3 miles upstream (west) of County Road 94B, approximately 4-6 miles west of Woodland. From this region we were able to obtain excellent samples of aquatic invertebrates for mercury analysis, directly comparable to samples we have taken from sites throughout the upper reaches of the Cache Creek watershed in another study (Slotton et al. 1997b) and throughout Northern California in related work (Slotton et al. 1995b, 1997a, Reuter et al. 1989, 1997). We also obtained a good sample of minnows (red shiners) from this location. However, larger fish were quite scarce along this stretch, presumably due to the characteristic, late season very low flows present here. Though we were able to obtain two adult smallmouth bass after extensive collecting effort, we felt that a far more useful fish sample could be obtained downstream near the Cache Settling Basin. The large fish portion of this study required a range of individuals of several major species, across a range of sizes. It was possible to collect just such a set of samples along the turbid (muddy water), pooled stretch of the lower creek that parallels County Road 102, north of Interstate Highway 5 and along the eastern margin of Woodland. This habitat may more closely approximate the conditions in the new gravel mining lakes. The data for the larger fish and the remainder of the small, composited fish species other than red shiners were obtained through five days of intensive collecting in this region, using a variety of nets and other means, as described below. A total of 64 individual larger fish were individually sampled for muscle mercury concentration (Table 1). Twenty-three samples of composited small and juvenile fish, aquatic invertebrates, and bottom sediment were also collected and analyzed (Table 2). Mercury information from the samples is presented in the data tables of Appendix A. The large fish mercury data are additionally displayed in graphic form in Appendix B. Following are a methods section and a summary of analytical results.

Table 1. Summary of lower Cache Creek fish collected in this project for analysis of muscle mercury.
(fish taken Oct-Nov 1997)

Fish Species	Number sampled	Fresh Weight (grams / pounds)	Fork Length (mm / inches)
Carp *Cyprinus carpio*	(x10)	200 - 4,650 g 0.4 - 10.3 lbs	220 - 690 mm 8.7 - 27.2 in
Sacramento Sucker *Catostomus occidentalis*	(x7)	345 - 525 g 0.7 - 1.2 lbs	310 - 358 mm 12.2 - 14.1 in
Sacramento Blackfish *Orthodon microlepidotus*	(x5)	315 - 725 g 0.7 - 1.6 lbs	282 - 368 mm 11.1 - 14.5 in
White Catfish *Ictalurus catus*	(x7)	85 - 435 g 0.2 - 1.0 lbs	192 - 300 mm 7.5 - 11.8 in
Channel Catfish *Ictalurus punctatus*	(x12)	95 - 2,035 g 0.2 - 4.5 lbs	205 - 525 mm 8.1 - 20.7 in
White Crappie *Pomoxis annularis*	(x12)	40 - 815 g 0.1 - 1.8 lbs	151 - 360 mm 5.9 - 14.2 in
Threadfin Shad *Dorosoma petenense*	(x1)	60 g 0.13 lbs	156 mm 6.1 in
Hitch *Lavinia exilcauda*	(x2)	85 g 0.2 lbs	186 - 188 mm 7.3 - 7.4 in
Bluegill Sunfish *Lepomis macrochirus*	(x3)	32 - 35 g 0.07 - 0.08 lbs	118 mm 4.6 in
Sacramento Squawfish *Ptychocheilus grandis*	(x1)	110 g 0.24 lbs	219 mm 8.6 in
Largemouth Bass *Micropterus salmoides*	(x2)	630 - 830 g 1.4 - 1.8 lbs	337 - 373 mm 13.3 - 14.7 in
Smallmouth Bass *Micropterus dolomieui*	(x2)	585 - 975 g 1.3 - 2.2 lbs	333 - 389 mm 13.1 - 15.3 in

64 individual adult/large fish sampled for muscle mercury

Table 2. Summary of lower Cache Creek composite biota and sediment collected in this project for analysis of whole body and total mercury.
(samples taken Oct-Nov 1997)

Sample Type	Number of comps	Individuals per comp
Small and Juvenile Fish		
Threadfin Shad *Dorosoma petenense*	3	(x1)
Juvenile Bluegill *Lepomis macrochirus*	3	(x7)
Bigscale Logperch *Percina macrolepida*	3	(x3-4)
Red Shiner *Notropis lutrensis*	3	(x19)
Benthic Riffle Invertebrates		
Mayfly nymphs (Baetidae)	1	(x74)
Caddisfly larvae (Hydropsychidae)	2	(x49)
Damselfly nymphs (Calopterygidae)	1	(x13)
Damselfly nymphs (Coenagrionidae)	1	(x2)
Dragonfly nymphs (Libellulidae)	1	(x2)
predatory water bugs (Naucoridae)	1	(x1)
Dobsonfly nymphs (hellgrammites) (Corydalidae)	1	(x4)
Sediment		
Surficial bottom sediment	3	–
	23 composite samples for mercury analysis	

2. METHODS

2.1 Collection Techniques

Large Fish

Fish ≥ approximately 150 mm (6 inches) were collected with multiple experimental (variable mesh size) gill nets and a baited set line. A boat equipped with an outboard motor and a long poke pole was used for this work. Four different nets, 50-150 feet in length and 6-10 feet tall, weighted at the bottom and with floats at the top, were set out at diverse locations and orientations in the collection area on each of 5 different sampling dates. The set line was baited with 24-48 various baits for catfish at intervals of 6-12 feet on three different dates. The nets and set line were checked in sequence every 30-45 minutes in order to remove fish from the nets rapidly--before they had the opportunity to damage themselves. Both the nets and the set line were moved occasionally to harvest different locations. Fish were placed in a live tank on the boat for temporary storage. Whenever 8-15 fish were accumulated in this way, the boat was quickly driven 1/2 to 1 mile away from the collecting location, to allow the eventual release of fish at a site where they would not be likely to wander back into the nets. Fish were removed from the live tank one at a time and worked on quickly. Weight was determined to the nearest 5 g with calibrated field scales. Length was measured as mm fork length on a fisheries measuring board. Fish species, weight, and fork length were recorded in a field logbook.

A small muscle tissue sample for mercury analysis (approximately the size of a raisin) was excised from each fish using clean technique, with a stainless steel scalpel. The fish was subsequently released, generally in good condition. Muscle samples were taken from the dorso-lateral ("shoulder") region, as done by the California Department of Fish and Game. The skin side of the fresh tissue sample was removed and the muscle sample was rolled on a laboratory tissue to remove extraneous moisture. The clean, skin-free sample was placed directly into a pre-weighed, acid-cleaned container, which was sealed and maintained in a sealed bag prior to transport to the analytical laboratory. The precise weight of each tissue sample was determined by weight difference. We have utilized these techniques with great success in similar work over the past 12 years (Reuter et al. 1989, 1997, Slotton 1991, Slotton et al. 1995a, 1995b, 1996a, 1996b, 1997a, 1997b).

Small and Juvenile Fish

Small and juvenile fish, generally ≤ 100 mm (≤ 4 inches), were collected with a seine with 3 mm (1/8 inch) mesh size. This net was pulled through the water and then up onto the adjacent shore by 2 researchers, trapping small fish. Individuals to be analyzed for mercury were retained on ice in sealed bags. They were later identified to species, weighed and measured, and homogenized into appropriate composite samples with a laboratory homogenizer. Small/juvenile fish mercury was determined on whole fish, multiple individual composites, as is standard.

Invertebrates

Stream invertebrates were taken from riffle habitat, i.e. from rapids or cobble bottomed stretches with maximal flow, where aquatic insects tend to be most concentrated among the rock interstices. Stream invertebrates were collected with a research kick screen. 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 directly upstream of the screen. These rocks were hand scrubbed into the flow, dislodging any clinging biota. Following the removal of the larger rocks to the side of the stretch, the underlying cobble/pebble/gravel 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 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 jars with teflon-lined caps, which were frozen and then dried at 50-60 °C. The dried sample was homogenized to a fine powder with teflon-coated instruments. All of these techniques have been well established and tested in extensive prior mercury research work throughout California (Slotton et al. 1995a, 1995b, 1996a, 1996b, 1997a, 1997b).

Sediment

Sediment samples were taken from the top centimeter of surficial sediment at the sediment/water interface. Surficial sediment samples were collected with an Ekman grab sampler and were spooned into pre-cleaned glass jars with teflon-lined caps. Sediment samples were maintained refrigerated but unfrozen (so as to not alter mineral structure) until they were analyzed for mercury concentration and water and organic percentage within 18 days of collection.

2.2 Analytical Methodology

Fish, Invertebrate, and Sediment Total Mercury

Solid samples for mercury were analyzed using homogeneous portions. Sediment was subsampled from homogenized, wet (liquefied) samples. Identical subsamples were used to determine moisture content for dry weight conversions. Fish tissue was also analyzed on wet (fresh) samples, as is the standard procedure for governmental agencies. Mercury analyses of invertebrate samples were conducted with dried and powdered samples for uniformity.

Solid samples of all types were analyzed for total mercury with standard cold vapor atomic absorption (CVAA) spectrophotometry. Extensive quality assurance/quality control (QA/QC) accompanied all analytical work, with results consistently well within tolerance.

Sediment Water and Organic Content

Moisture and organic content of sediment samples were determined by sequential weight difference following appropriate temperature oven drying.

3. RESULTS

3.1 Large Fish

Data for muscle mercury concentration, species, weight, and length are presented in Appendix A, Table 3 for the individual large fish analyzed in this work. Except for the 2 smallmouth bass taken from above Road 94B, all of these fish were collected just above the Cache Settling Basin on lower Cache Creek just east of Woodland, adjacent to Road 102 and several miles above the outflow of Cache Creek into the Yolo Bypass. The data are additionally presented in graphic plots of fish size vs mercury concentration in Figures 1-9, found in Appendix B. The data is displayed both in terms of weight vs mercury and length vs mercury. Six species were taken in sufficient numbers to permit the construction of approximate size vs mercury curves of best visual fit, estimating the general relationship between fish size and mercury accumulation for each numerically abundant species (Figures 1-7). These were carp, Sacramento sucker, Sacramento blackfish, white catfish, channel catfish, and white crappie. Other fish taken in lesser numbers and plotted together in Figures 8 and 9 included bluegill sunfish, threadfin shad, hitch, squawfish, largemouth bass, and smallmouth bass.

Of the 64 individual fish analyzed for muscle mercury concentration, an even 50% (32) contained concentrations ≥ 0.30 ppm mercury, 31% (20) had concentrations ≥ 0.40 ppm, and 20%

(13) were at or above the 0.50 ppm level which is utilized as a consumption guideline by the State of California and most countries. Two individuals (3%), a large smallmouth bass and a large white crappie, were above the 1.00 ppm U.S. FDA action guideline of 1.00 ppm. The higher concentration fish were not randomly distributed but, as is typical, coincided with larger/older individuals of the higher trophic level (more predatory) species.

Below, we briefly characterize the muscle mercury levels present in each of the fish species sampled. Natural history notes for the various species come from personal experience and Moyle (1980 and personal communication).

<u>Carp</u> (*Cyprinus carpio*): A total of 10 carp were taken at the primary fish location, across a range of sizes from 200 to 4,700 grams (0.4-10.4 pounds). By length, these fish ranged from 220-690 mm (9 to over 27 inches). These large, benthic detritivore/omnivores feed on small invertebrates and plant material and are typically relatively low in mercury. The size vs muscle mercury relationship described by the data (Figure 1) indicates that, generally, only very large fish (> ~3,700 g, 620 mm; > ~8 pounds and 24 inches) accumulate muscle mercury to levels approaching or surpassing the 0.50 ppm health guideline. Individuals under ~2,000 g and 450 mm (< ~5 pounds and 24 inches) generally demonstrated muscle mercury in the range of 0.10-0.30 ppm. An anomalous individual was taken, missing its anal fin. For its size (580 g, 279 mm; 1.3 lbs, 11 inches), the 0.47 ppm muscle mercury level was elevated relative to the rest of the carp. We hypothesize that this deformed individual may be unable to feed properly and has possibly developed an alternative feeding style that includes higher mercury food items. Though interesting, this is not highly relevant to a general characterization of carp mercury.

<u>Sacramento Sucker</u> (*Catostomus occidentalis*): Seven individuals of this native species were taken within a fairly restricted range of sizes: 350-530 g, 300-360 mm (0.8-1.2 pounds, 12-15 inches). Because these individuals were so similar in size, it was difficult to predict an extended size vs muscle mercury relationship (Figure 2). Concentrations in these 7 individuals ranged between 0.19 and 0.35 ppm, similar to the carp. This is consistent with their similar benthic feeding niche. The data indicate that the 0.50 ppm health guideline would be reached or surpassed only in very large suckers > ~900 g (~2 pounds) and > ~550 mm (~22 inches).

<u>Sacramento Blackfish</u> (*Orthodon microlepidotus*): Five of these native, midwater, large minnows were taken in two apparent size classes which may represent different year classes (Figure 3). Three of the blackfish were 315-355 g and ~280 mm (0.7-0.8 lbs, 11 inches) and two were larger, at 485-725 g and 370-385 mm (1.1-1.6 lbs, 15 inches). Interestingly, the two size classes were quite different in their muscle mercury accumulations. The smaller fish were consistently relatively low in mercury, at 0.13-0.20 ppm, whereas the two larger individuals had concentrations of 0.46

and 0.51 ppm, right at the health guideline level. It is not clear whether fish of intermediate or larger size exist or if these are two dominant year classes. The sharp increase in muscle mercury levels in the larger individuals relative to the smaller ones suggests a possible dietary change with age, with the larger fish feeding on higher trophic level food items that are, in turn, higher in mercury. However, Moyle (1980) reports that Sacramento blackfish are primarily filter feeders of low-level plankton, primarily phytoplankton. The relatively elevated accumulations of muscle mercury in the larger individuals is curious, in relation to the very low trophic level food, and may indicate that the planktonic food web is more efficient here in transferring mercury to fish than the benthic (bottom) food web occupied by the carp and suckers.

White Catfish (*Ictalurus catus*): White and channel catfish were prevalent in the study region. Both are omnivorous bottom feeders that take a range of live and dead food items. The smaller white catfish were taken in a range of sizes between 75-420 g, 185-300 mm (0.2-1.0 lb, 7.5-12 inches). All were between 0.25 and 0.40 ppm in muscle mercury concentration. The data indicate that white catfish over approximately 550 g and 350 mm (1.2 lbs and 14 inches) are likely to be at or over the 0.50 ppm health guideline level in muscle mercury. The prevalent smaller size taken at this time (75-205 g, 180-250 mm; 0.2-0.5 lbs, 7.5-10 inches) were fairly consistent in their mercury levels, at 0.25 - 0.35 ppm.

Channel Catfish (*Ictalurus punctatus*): Channel catfish (Figure 5) were the most prevalent catfish within the study region. This species, common in Clear Lake upstream, reaches larger sizes than the white catfish. A range of smaller sizes were taken: 10 individuals between 95 and 580 g (0.2-1.3 lbs) in weight and between 205 and 365 mm (8.1-14.3 inches) in length. Two much larger individuals were taken at 1,800-2,035 g (4.0-4.5 lbs) and 525-551 mm (20-22 inches). The larger individuals were both over the 0.50 ppm health guideline, at 0.52 and 0.77 ppm muscle mercury. Despite many repeated fishing attempts, it was not possible to obtain intermediate size classes of channel catfish at the time of this sampling. Thus, the estimated size:mercury relationships shown in Figure 5 assume that individuals intermediate in size would demonstrate muscle mercury intermediate in concentration, as compared to both large and small size classes. This estimated relationship indicates that this species is likely to approach or exceed the 0.50 ppm level in muscle mercury in fish ≥ ~1,400 g (3 lbs) and 450 mm (18 inches). For purposes of baseline mercury characterization, the range of smaller channel catfish (≤ 600 g, 370 mm; ≤ 1.3 lbs, 15 inches) were very consistent in their muscle mercury concentrations, at 0.15-0.22 ppm.

White Crappie (*Pomoxis annularis*): Twelve individual white crappie were sampled in this study. White crappie were found to be the predominant panfish of angling-relevant size within the study region. It was possible to obtain a good distribution of sizes. This large-mouthed, midwater predator, similar in prey choice to bass, demonstrated steep increases in muscle mercury with size (Figures 6a and 6b), with more than half the sampled fish (7 of 12) either closely approaching or exceeding the 0.50 ppm guideline concentration. The data set as a whole indicate that this 0.50 ppm guideline level will generally be reached at a size of approximately 300 g (0.65 lb) and 250 mm (10 inches) in lower Cache Creek. Individuals over 550 g (1.25 lbs) and 300 mm (12 inches) can be expected to contain highly elevated mercury, at concentrations approaching or exceeding the US Food and Drug Administration (FDA) Action Guideline of 1.00 ppm muscle mercury.

The remaining fish in this section were taken in reduced numbers (1-3 individuals each) relative to the more prevalent species described above. Data are graphically plotted together in Figures 7a-b.

Threadfin Shad (*Dorosoma petenense*): While we typically analyze this small, introduced, schooling planktivore species in whole-body composites (see next section), a single much larger threadfin shad was collected and analyzed for muscle mercury, for direct comparison with the larger fishes. This 60 g, 156 mm individual (0.13 lb, 6.1 inches) had muscle mercury at 0.23 ppm.

Hitch (*Lavinia exilcauda*): Hitch are a native species of omnivorous, midwater and surface-feeding large minnow which can reach sizes of over 450 g and 300 mm (1 pound and 12 inches). Two smaller individuals were taken in this work, both approximately 85 g (0.2 lb) and 187 mm (7.4 inches). Muscle mercury was moderate in one of these, at 0.23 ppm, and relatively elevated in the other: 0.42 ppm.

Bluegill Sunfish (*Lepomis macrochirus*): While present in juvenile size classes (see next section), adult bluegill in a size range likely to be kept by anglers were not found in this work. The 3 largest individuals encountered were analyzed for muscle mercury, however these were quite small (~33 g and 118 mm; ~0.07 lb and 4.6 inches). Two of these individuals had moderate muscle mercury levels (0.16-0.23 ppm), while the third was relatively elevated at 0.43 ppm. Bluegill are a midwater planktivorous/insectivorous species. The data suggest that if larger bluegill were present at sizes ≥ approximately 200 g (0.5 lb) and 200 mm (8 inches), they would be likely to approach or exceed the 0.50 ppm muscle mercury concentration.

Sacramento Squawfish (*Ptychocheilus grandis*): This native species is known to be a voracious predator; larger individuals could be expected to accumulate mercury to concentrations as high or higher than any other local species. Only a single, juvenile squawfish was taken in this work. However, this 110 g, 219 mm (0.24 lb, 8.6 inch) individual contained muscle mercury exactly at the 0.50 ppm level, suggesting that adult squawfish may be quite elevated in accumulated mercury within this system.

Largemouth Bass (*Micropterus salmoides*): Both largemouth and smallmouth bass are voracious, introduced, midwater predators which, like the squawfish and crappie, can be expected to accumulate mercury to high levels, relative to the less predatory species. Bass were not prevalent in the main fish collection location, with only two adult individuals taken in five days of intensive sampling. The smaller of these, at 630 g and 337 mm (1.4 lbs, 13.3 inches) had muscle mercury at 0.54 ppm. From a human health standpoint, it would probably be advisable not to consume any legal sized (> 12 inches) bass from this region. However, the larger individual, at 830 g and 373 mm (1.8 lbs, 14.7 inches) demonstrated muscle mercury at only 0.21 ppm. This was anomalously low, as compared to the other bass and the other predatory fish samples in general. This demonstrates the occasionally large range of variation possible among individual fish, and highlights the benefit of obtaining mercury data from numerous individuals when possible. Largemouth bass, in particular, are known to develop individualized feeding preferences, with some individuals becoming fish predators while others become experts at, for instance, preying on adult damselfies (which are much lower in mercury).

Smallmouth Bass (*Micropterus dolomieui*): Two adult smallmouth bass were taken from the region upstream of County Road 94B. The sizes were similar to those obtained for largemouth bass downstream: 585 g (1.3 lbs), 333 mm (13.1 inches) and a larger individual of 975 g (2.2 lbs), 389 mm (15.3 inches). The smaller of the two smallmouth bass was similar in muscle mercury concentration to the smaller largemouth bass taken downstream: 0.66 ppm. The larger individual, however, was dramatically elevated in mercury, at 1.21 ppm, and was in fact the highest-mercury fish individual taken in the entire project. Again, these data indicate that any legal "keeper" bass (> 12 inches) of either species from the creek are probably better to be released and not consumed. While the small number of individuals taken of each of the bass species does not permit a statistical comparison, the data leave open the possibility that differences in relative mercury bioavailability and uptake by fishes may exist within different regions of the creek with different water quality. We note that the water quality conditions at the site upstream of Road 94B (clear water, relatively stagnant pools) were considerably different than those present downstream (very turbid/muddy water--likely due to the rooting behavior of the population of large carp--in a lake-like environment). Other research we have conducted in the region over the years suggests that mercury may partition more readily into aquatic organisms in clearer-water systems. The red shiner whole-body composite data (see next section) is not inconsistent with this hypothesis. However, insufficient data is available at this time to assess this possibility within Cache Creek.

3.2 Small and Juvenile Fish

Mercury levels from small and juvenile fish are typically analyzed in whole body, multi-individual composites, as was done here for comparability. Data appear in Table 4. Small and juvenile fish composites for mercury can be very useful monitoring tools in new systems before larger fish become established, and in general as more accurate monitors of relative year-to-year variation in mercury conditions. Whole body mercury from the different species sampled can be briefly characterized as follows:

Threadfin Shad (*Dorosoma petenense*): Threadfin shad are a small, planktivorous, introduced species which are prevalent in dense schools throughout much of the Delta and the upper waterways of the Sacramento-San Joaquin system. Several small, composite-size individuals were taken in the coarse of this sampling and analyzed for whole-body mercury. Shad within the range of 7-14 g (0.25-0.50 ounce) and 84-102 mm (3.3-4 inches) had uniformly very low whole-body mercury, at 0.03 ppm fresh weight. This is consistent with their low trophic (feeding) level, being midwater planktivores.

Juvenile Bluegill (*Lepomis macrochirus*): Three composite, whole-body samples of juvenile bluegill sunfish were collected and analyzed, each with 7 individual juvenile fish of approximately 2.6 g (0.1 ounce) in weight and 52 mm (~2 inches) in length. These samples contained mercury very consistently at approximately 0.08 ppm. This value, higher than that of the shad, is consistent with the fact that bluegill take larger invertebrates in their diet, in addition to plankton.

Bigscale Logperch (*Percina macrolepida*): Three independent whole-body composites were collected of 3-4 individuals each. These fish were approximately 4.4 grams in weight (0.15 ounce) and 85 mm in length (3.4 inches). This is typical adult size for this small, introduced bottom dweller. Mercury levels ranged from 0.09 to 0.11 ppm, with a mean of 0.10 ppm. Logperch consume a variety of small invertebrate organisms.

Red Shiner (*Notropis lutrensis*): Red shiners are a small, introduced minnow species that are taking over the smaller-sized fish populations of middle Cache Creek (Dr. Peter Moyle, U.C. Davis, personal communication). These samples were taken west of Woodland near County Road 94B. Triplicate composite samples of 19 individual shiners each were taken and analyzed, with mean weight being 0.5 g (0.02 ounce) and length averaging 37 mm (1.5 inch). Whole-body mercury averaged 0.16 ppm, with a range of 0.14-0.18 ppm. This was higher than the whole body mercury found in small and juvenile fish taken below Woodland at the primary fish collection location and, similar to the discussion for smallmouth bass from the same location, brings up the possibility of localized variability in mercury bioavailability and bioaccumulation under different water quality conditions along the creek.

3.3 Benthic Invertebrates

Dry weight mercury concentrations in composites of seven different types of aquatic invertebrates taken west of Road 94B are presented in Table 5. Levels ranged between 0.12 and 0.37 ppm mercury, with a mean concentration of 0.26 ppm among all the composites. Levels were generally lower in organisms such as mayflies which are low on the food chain (herbivores) and generally higher in the larger predatory forms such as hellgrammites. These concentrations were very similar to levels found upstream at several sites along the main channel of Cache Creek in earlier work (Slotton et al. 1997b), suggesting that mercury bioavailability may remain relatively constant across most of the length of the main stem of Cache Creek, from the Clear Lake headwaters to the Yolo Bypass outflow.

3.4 Bottom Sediment

Three independent samples were taken of Cache Creek bottom sediment in the region east of Road 102 where the majority of the fish were taken. Data from these sediment samples is presented in Table 6. The samples were dominated by fine sand, with some coarse sand and some finer silt and organic material. Moisture percentage was typical of material of this grain size, at 30-38% (mean = 34.8%). The organic percentage was relatively low at 1.9-2.4% (mean = 2.2%), typical of regions that receive frequent scouring from high flows, as opposed to purely depositional areas such as the still bottoms of lakes. Mercury was present at 0.08-0.20 ppm on a wet weight basis (mean = 0.12 ppm), 0.13-0.28 ppm when corrected to dry weight (mean = 0.19 ppm). These levels are somewhat elevated relative to uncontaminated areas but are quite low in comparison to concentrations typical in upstream regions nearer the mercury mine sources such as Davis Creek Reservoir (mean = ~4 ppm) and Clear Lake (mean = ~8 ppm). Though Cache Creek is clearly a major conduit of mine-derived mercury to the San Francisco Bay-Delta, concentrations in depositing sediments at this downstream locale are apparently largely diluted by other, non-mercury erosional sediment carried in the flow and bedload. However, the fish mercury data indicate that sufficient mercury is available for uptake to result in moderate to relatively elevated accumulations in local fish.

4. CONCLUSIONS

The biotic mercury data included in this report form a baseline of characterizing information. Aquatic biota which colonize or are introduced into the new gravel mining lakes will likely consist of a subset of these organisms or very similar organisms. They can be monitored, following the formation of the new gravel mining lakes, and compared to this baseline information to assess resulting levels of mercury bioaccumulation in the new systems relative to those typical of the adjacent creek.

5. LITERATURE CITED

Moyle, P.B. 1976. *Inland fishes of California.* University of California Press, Berkeley, Los Angeles, London. 405 pp.

Reuter, J.E., D.G. Slotton, R.P. Axler, and C.R. Goldman. 1989. Analysis of the Long-Term Environmental Monitoring Program for Davis Creek Watershed Surface Waters--January 1, 1982 - June 30, 1989. *Report for Yolo County.* 268 pp.

Reuter, J.E., D.G. Slotton, S.M. Ayers, and C.R. Goldman. 1997. Seasonal dynamics of mercury in sediment and biota in Davis Creek and Davis Creek Reservoir. *Report for Yolo County.* 146 pp. (Similar reports from 1987-1988, 1990-1996).

Slotton, D.G. 1991. Mercury bioaccumulation in a newly impounded Northern California reservoir. *Doctoral dissertation, University of California, Davis.* 363 pp.

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1995a. Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams. *Technical Completion Report for the University of California Water Resources Center, Project W-816*, August 1995, 46 pp.

Slotton, D.G., J.E. Reuter, and C.R. Goldman. 1995b. Mercury uptake patterns of biota in a seasonally anoxic northern California reservoir. *Water, Air, and Soil Pollution*, 80:841-850.

Slotton, D.G., S.M. Ayers, and J.E. Reuter. 1996a. Marsh Creek watershed 1995 mercury assessment project. *Final Report for Contra Costa County*, March 1996, 66 pp.

Slotton, D.G., S.M. Ayers, and J.E. Reuter. 1996b. Off-channel gravel pit lakes -- mercury considerations; lower Cache Creek, Yolo County, California. Preliminary Study. *Report for Yolo County*, April 1996, 31 pp.

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1997a. Sacramento River watershed mercury control planning project--UC Davis biotic component. *Final Report for the Sacramento Regional County Sanitation District*, March 1997, 74 pp.

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1997b. Cache Creek watershed preliminary mercury assessment, using benthic macro-invertebrates. *Final Report for the Central Valley Regional Water Quality Control Board and the National Science Foundation*, June 1997, 36 pp.

Appendix A.

Tabular Mercury and Size Data for Samples Taken In This Project

Table 3. Muscle mercury concentrations and size data for lower Cache Creek Fish.
(fish taken Oct-Nov 1997, due east of Road 102 except as noted)
(muscle mercury concentrations ≥ 0.50 ppm are denoted in bold type)

Fish Species	Fresh Weight (grams)	Fresh Weight (pounds)	Fork Length (mm)	Fork Length (inches)	Mercury (ppm, fresh wt)
Carp	200	0.44	220	8.7	0.13
Carp	640	1.41	340	13.4	0.18
(abnormal) Carp	580	1.28	279	11.0	0.47
Carp	830	1.83	358	14.1	0.21
Carp	1,050	2.31	387	15.2	0.36
Carp	1,325	2.92	426	16.8	0.25
Carp	1,575	3.47	450	17.7	0.15
Carp	1,780	3.92	478	18.8	0.30
Carp	2,530	5.58	520	20.5	**0.60**
Carp	4,650	10.25	690	27.2	0.38
Sacramento Sucker	345	0.76	310	12.2	0.25
Sacramento Sucker	380	0.84	315	12.4	0.31
Sacramento Sucker	400	0.88	333	13.1	0.33
Sacramento Sucker	430	0.95	331	13.0	0.19
Sacramento Sucker	455	1.00	333	13.1	0.23
Sacramento Sucker	500	1.10	334	13.1	0.35
Sacramento Sucker	525	1.16	358	14.1	0.33
Sacramento Blackfish	315	0.69	282	11.1	0.13
Sacramento Blackfish	335	0.74	285	11.2	0.20
Sacramento Blackfish	355	0.78	281	11.1	0.15
Sacramento Blackfish	485	1.07	384	15.1	0.46
Sacramento Blackfish	725	1.60	368	14.5	**0.51**
White Catfish	85	0.19	192	7.6	0.29
White Catfish	95	0.21	205	8.1	0.35
White Catfish	100	0.22	190	7.5	0.28
White Catfish	125	0.28	210	8.3	0.25
White Catfish	175	0.39	234	9.2	0.32
White Catfish	205	0.45	248	9.8	0.33
White Catfish	435	0.96	300	11.8	0.40
Channel Catfish	95	0.21	207	8.1	0.16
Channel Catfish	135	0.30	234	9.2	0.15
Channel Catfish	210	0.46	257	10.1	0.18
Channel Catfish	245	0.54	270	10.6	0.15
Channel Catfish	265	0.58	272	10.7	0.18
Channel Catfish	290	0.64	290	11.4	0.22
Channel Catfish	310	0.68	306	12.0	0.20
Channel Catfish	355	0.78	307	12.1	0.15
Channel Catfish	550	1.21	349	13.7	0.20
Channel Catfish	580	1.28	364	14.3	0.16
Channel Catfish	1,800	3.97	551	21.7	**0.77**
Channel Catfish	2,035	4.49	525	20.7	**0.52**

Table 3 (continued)

Fish Species	Fresh Weight (grams)	Fresh Weight (pounds)	Fork Length (mm)	Fork Length (inches)	Mercury (ppm, fresh wt)
White Crappie	40	0.09	151	5.9	0.17
White Crappie	55	0.12	170	6.7	0.18
White Crappie	80	0.18	198	7.8	0.31
White Crappie	110	0.24	208	8.2	0.33
White Crappie	140	0.31	220	8.7	**0.55**
White Crappie	145	0.32	223	8.8	0.25
White Crappie	325	0.72	287	11.3	0.49
White Crappie	360	0.79	294	11.6	**0.62**
White Crappie	385	0.85	291	11.5	**0.57**
White Crappie	490	1.08	306	12.0	0.46
White Crappie	590	1.30	338	13.3	**1.03**
White Crappie	815	1.80	360	14.2	**0.76**
Threadfin Shad	60	0.13	156	6.1	0.23
Hitch	85	0.19	186	7.3	0.23
Hitch	85	0.19	188	7.4	0.42
Bluegill Sunfish	32	0.07	118	4.6	0.23
Bluegill Sunfish	32	0.07	118	4.6	0.43
Bluegill Sunfish	35	0.08	118	4.6	0.16
Squawfish	110	0.24	219	8.6	**0.50**
Largemouth Bass	630	1.39	337	13.3	**0.54**
Largemouth Bass	830	1.83	373	14.7	0.21
Smallmouth Bass*	585	1.29	333	13.1	**0.66**
Smallmouth Bass*	975	2.15	389	15.3	**1.21**

* Smallmouth bass taken 1 mile upstream of Road 94B, west of Woodland.

Table 4. Whole-body mercury concentrations and size data for lower Cache Creek small fish.
(fish taken Oct-Nov 1997, due east of Road 102 except Red Shiners taken 1 mile west of Rd 94B).

Composite Identification	Average Weight (grams)	Average Weight (ounces)	Average Length (mm)	Average Length (inches)	Mercury (ppm, fresh wt)
(collected due east of Rd 102, east of Woodland)					
Threadfin Shad (n=1)	7.2	0.25	84	3.3	0.03
Threadfin Shad (n=1)	11.2	0.39	96	3.8	0.03
Threadfin Shad (n=1)	13.5	0.48	102	4.0	0.03
				mean =	**0.03**
Juvenile Bluegill (n=7)	2.7	0.09	53	2.1	0.07
Juvenile Bluegill (n=7)	2.5	0.09	52	2.1	0.08
Juvenile Bluegill (n=7)	2.5	0.09	51	2.0	0.08
				mean =	**0.08**
Bigscale Logperch (n=4)	4.4	0.15	85	3.3	0.11
Bigscale Logperch (n=4)	4.2	0.15	85	3.4	0.09
Bigscale Logperch (n=3)	4.5	0.16	86	3.4	0.11
				mean =	**0.10**
(collected 1 mile west of Rd 94B, west of Woodland)					
Red Shiner (n=19)	0.5	0.02	37	1.5	0.14
Red Shiner (n=19)	0.5	0.02	37	1.5	0.18
Red Shiner (n=19)	0.5	0.02	37	1.5	0.16
				mean =	**0.16**

Table 5. Whole-body dry wt mercury concentrations in lower Cache Creek aquatic insects.
(aquatic insects taken 1-3 miles west of Rd 94B, west of Woodland).

Composite Identification	# in Composite	Average Length (mm)	Average Length (inches)	Mercury (ppm, *dry wt*)
Herbivores				
Baetid Mayfly nymphs	(n=74)	8	0.3	0.12
Drift-feeding Omnivores				
Hydropsychid Caddisfly larvae	(n=98)	12	0.5	0.24
Small-item Predators				
Calopterygid Damselfly nymphs	(n=13)	28	1.1	0.18
Coenagrionid Damselfly nymphs	(n=2)	19	0.7	0.35
Large-item Predators				
Libellulid Dragonfly nymphs	(n=2)	18	0.7	0.25
Naucorid predatory water bugs	(n=1)	11	0.4	0.37
Large Corydalid Hellgrammites	(n=4)	65	2.6	0.29

Table 6. Mercury concentrations in lower Cache Creek surficial bottom sediment.
(sediment taken due east of Rd 102, east of Woodland).

Identification	% Water	% Organic	Mercury (ppm, *wet wt*)	Mercury (ppm, *dry wt*)
Sediment #1	36.2%	1.9%	0.09	0.14
Sediment #2	37.9%	2.4%	0.08	0.13
Sediment #3	30.4%	2.3%	0.20	0.28
(means:)	**34.8%**	**2.2%**	**0.12**	**0.19**

Appendix B.

Graphic Plots of Size vs Muscle Mercury for Larger Fish Sampled In This Project

Muscle mercury for each species is plotted against both:

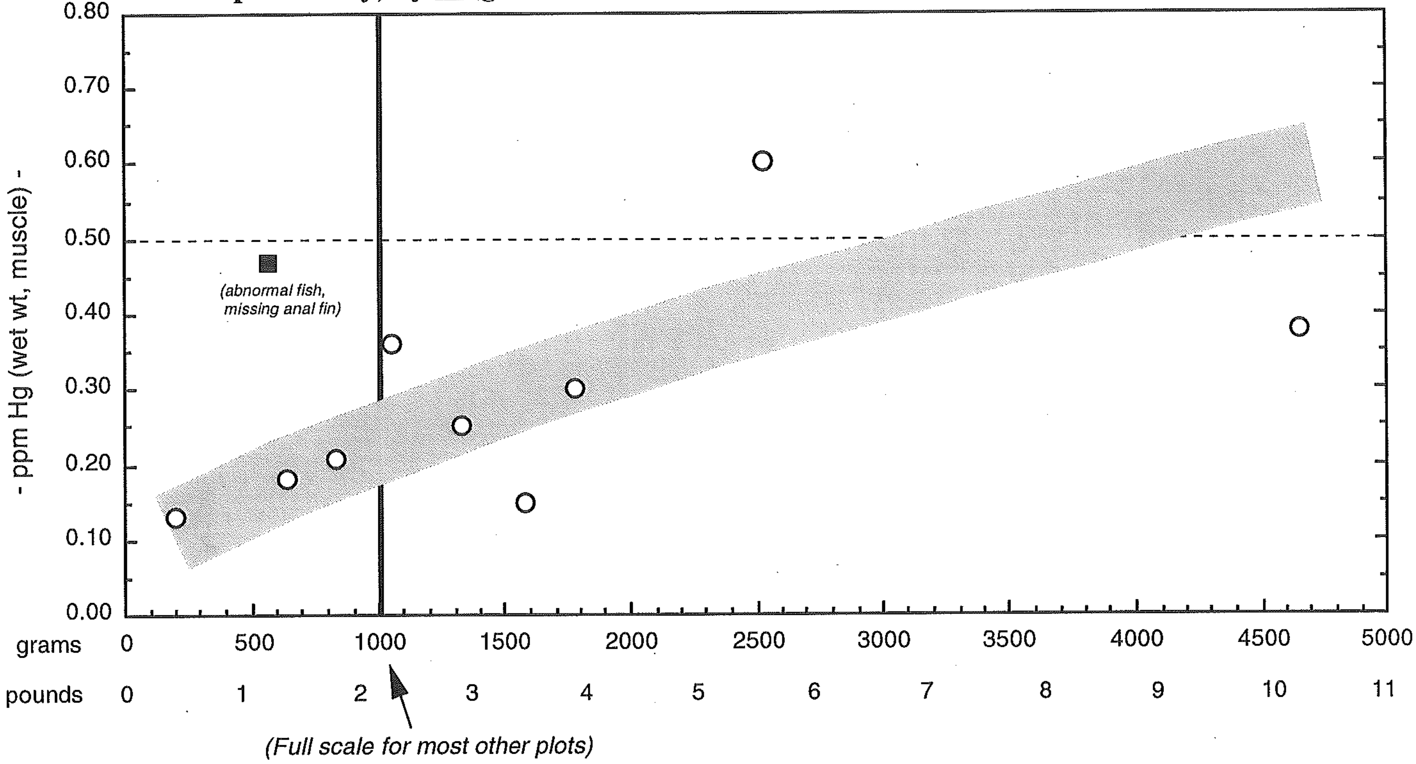
- weight (grams and pounds) and
- length (mm and inches fork length)

"Fork Length" = length from tip of snout to fork in hind edge of caudal (tail) fin.

Trend curves of best visual fit have been superimposed on the plots; representing approximate size vs mercury relationships indicated for each species by the available data.

Figure 1. CARP MERCURY

1a. Carp mercury, by weight



1b. Carp mercury, by length

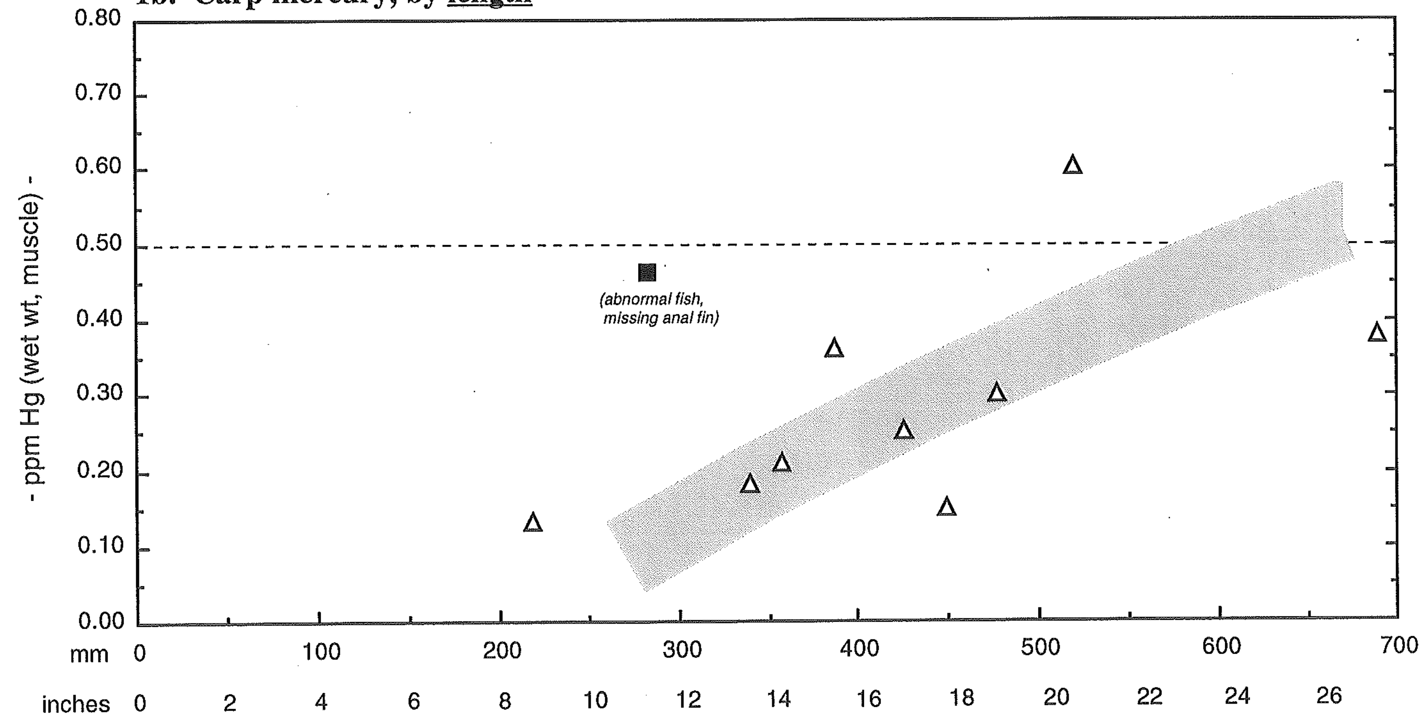
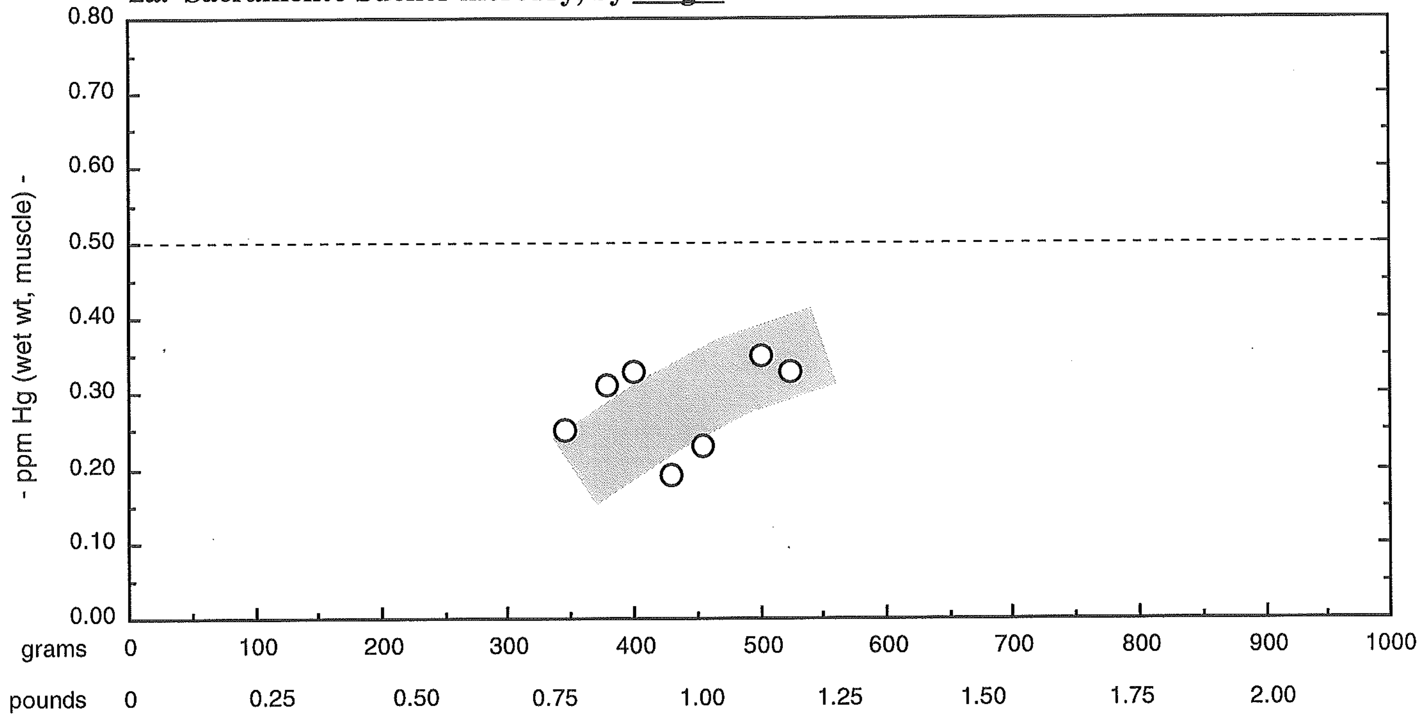


Figure 2. SACRAMENTO SUCKER MERCURY

2a. Sacramento Sucker mercury, by weight



2b. Sacramento Sucker mercury, by length

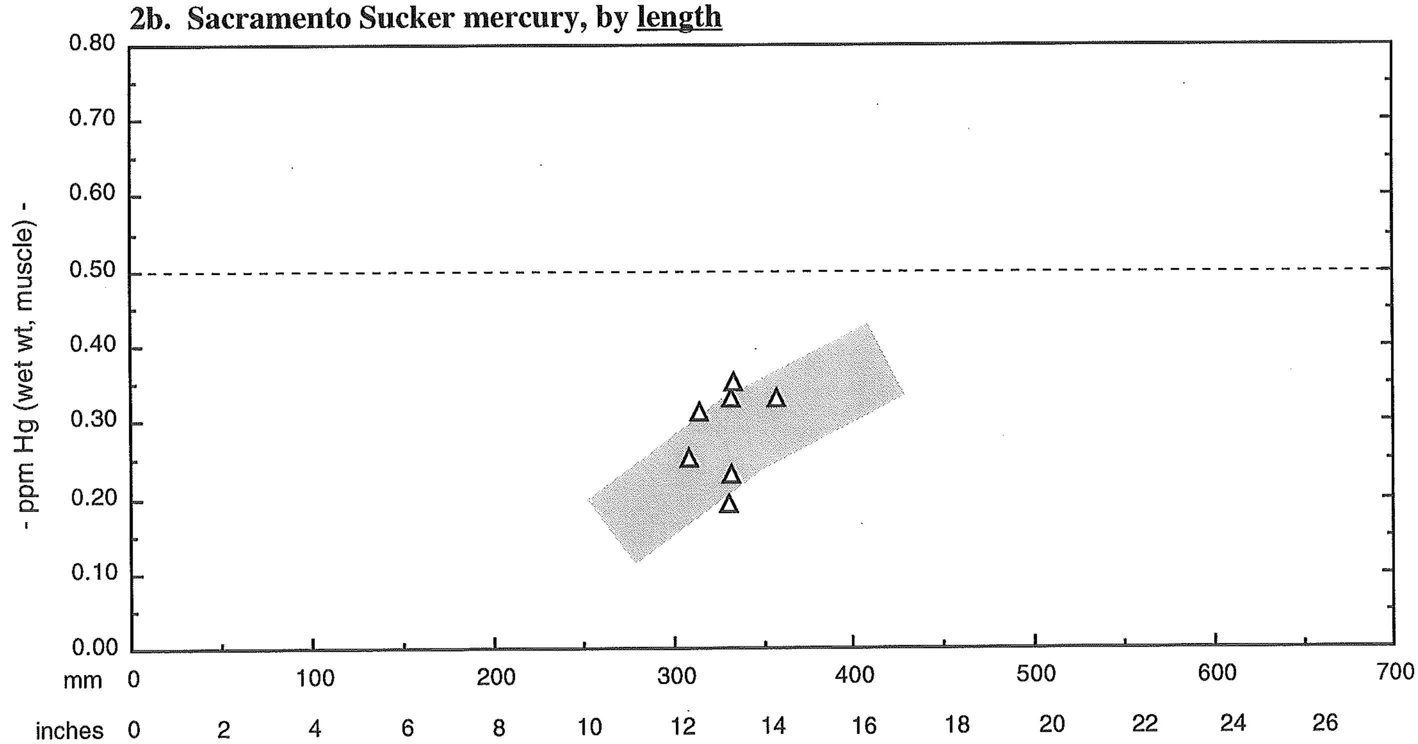
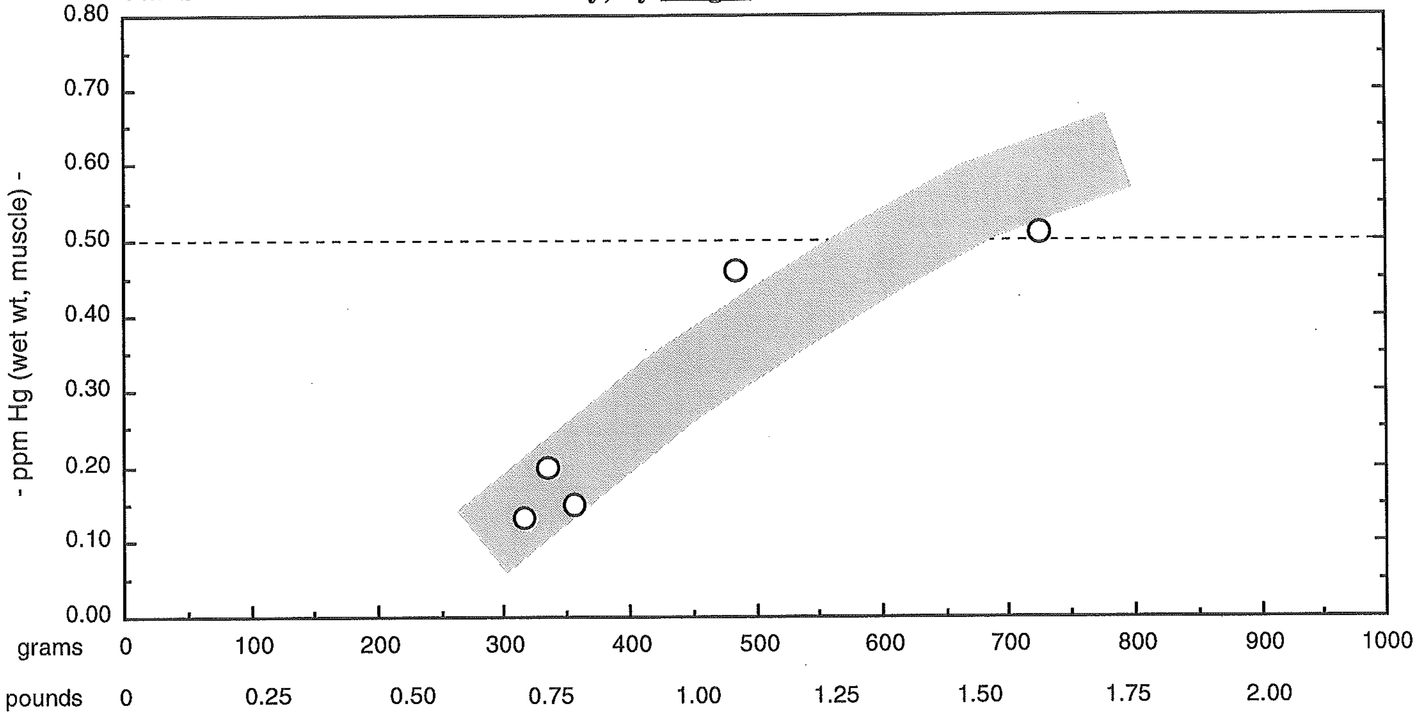


Figure 3. SACRAMENTO BLACKFISH MERCURY

3a. Sacramento Blackfish mercury, by weight



3b. Sacramento Blackfish mercury, by length

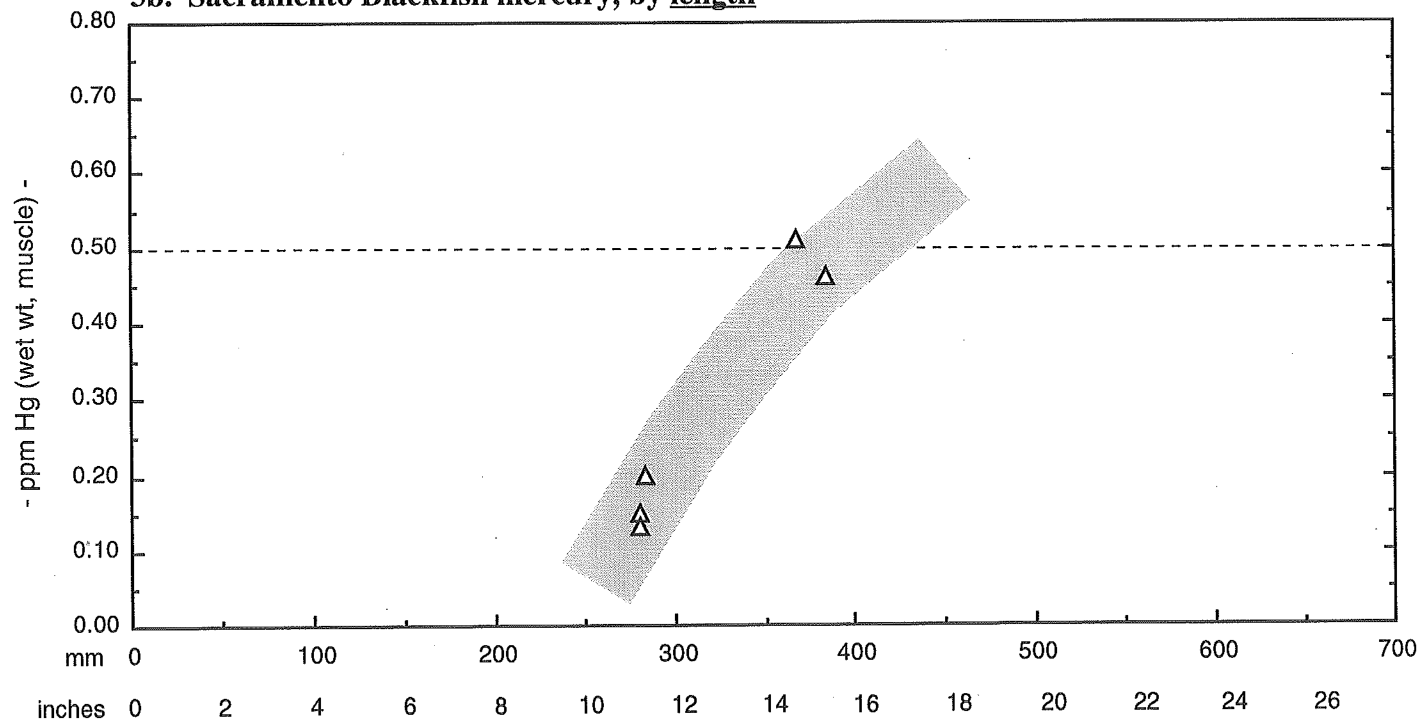
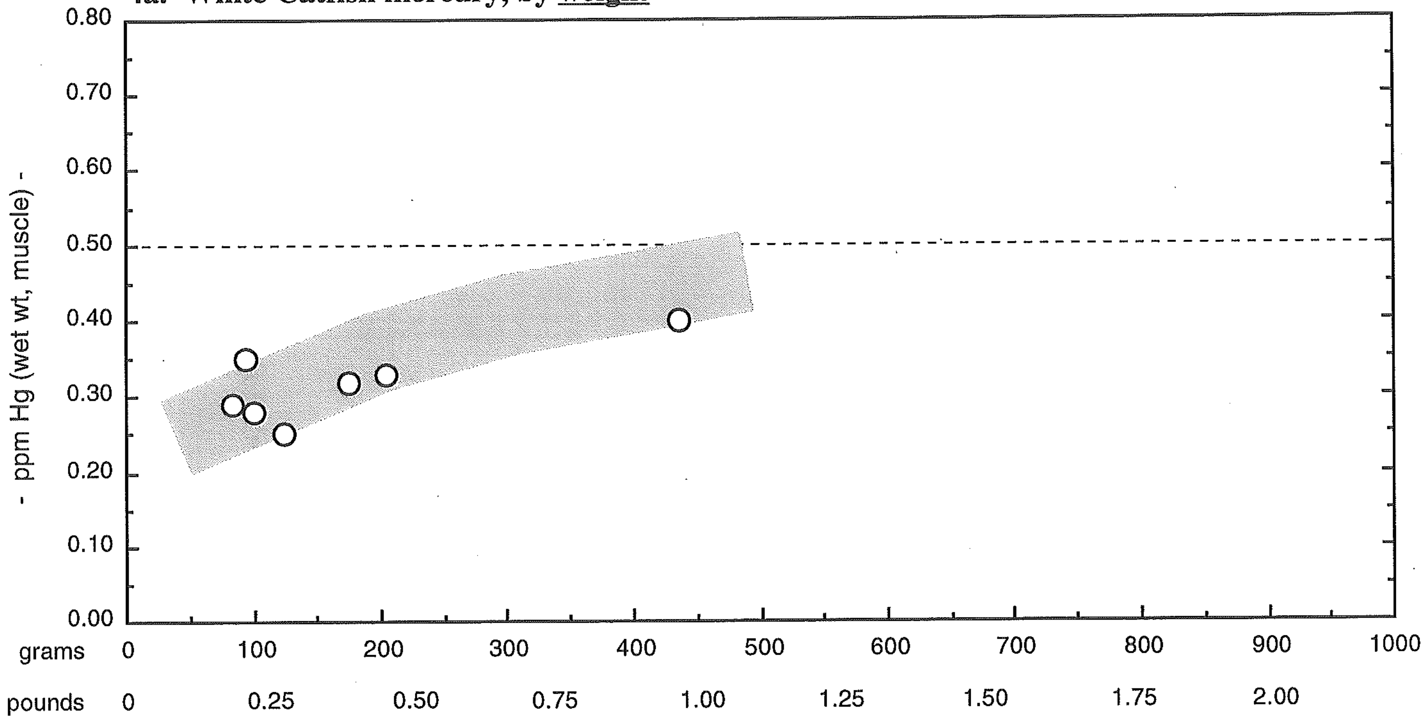


Figure 4. WHITE CATFISH MERCURY

4a. White Catfish mercury, by weight



4b. White Catfish mercury, by length

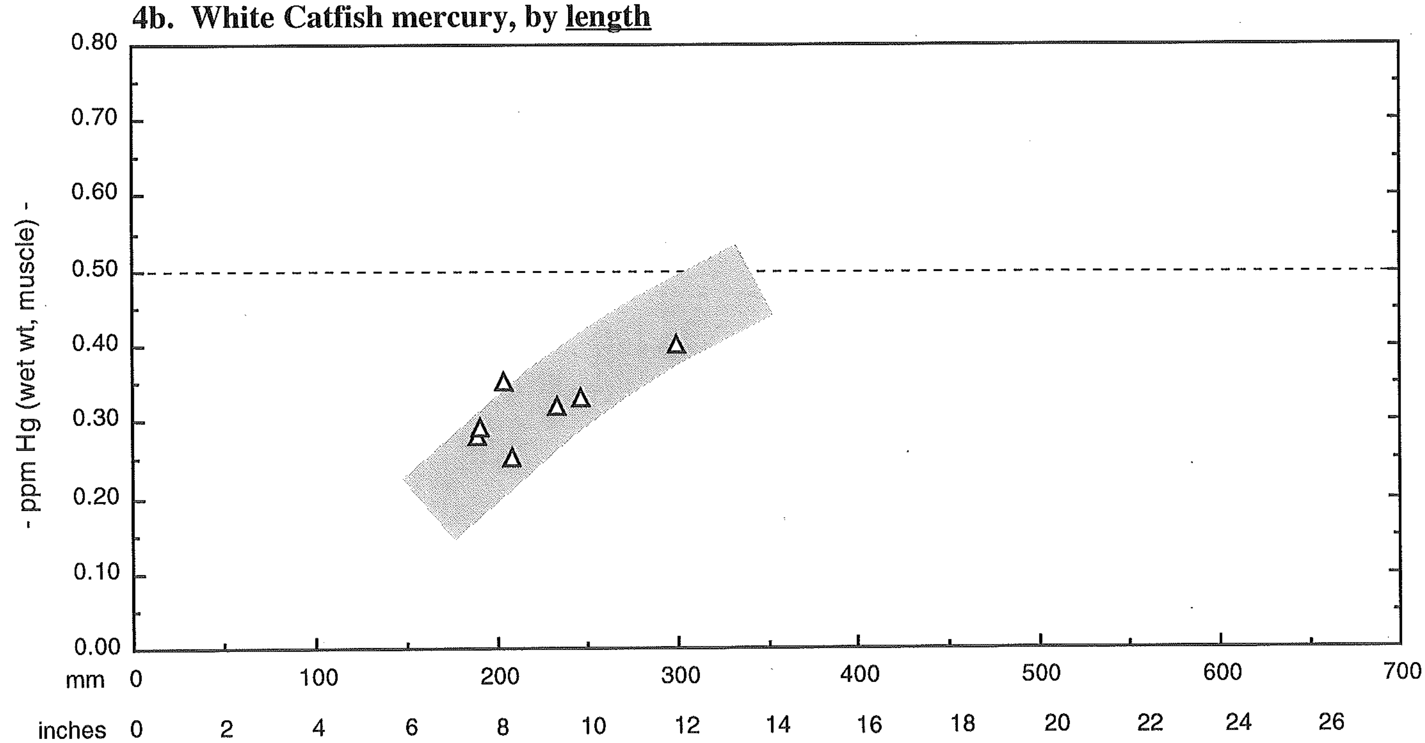
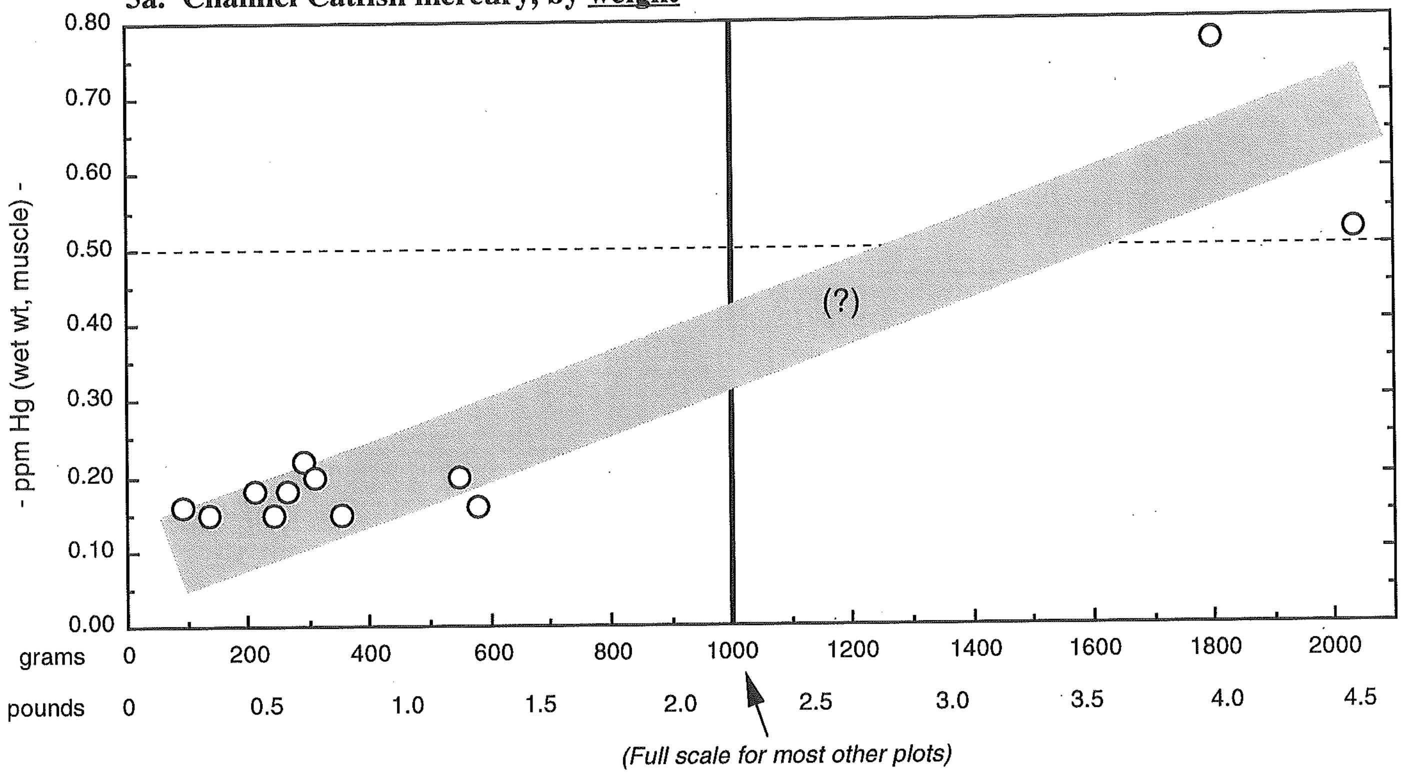


Figure 5. CHANNEL CATFISH MERCURY

5a. Channel Catfish mercury, by weight



5b. Channel Catfish mercury, by length

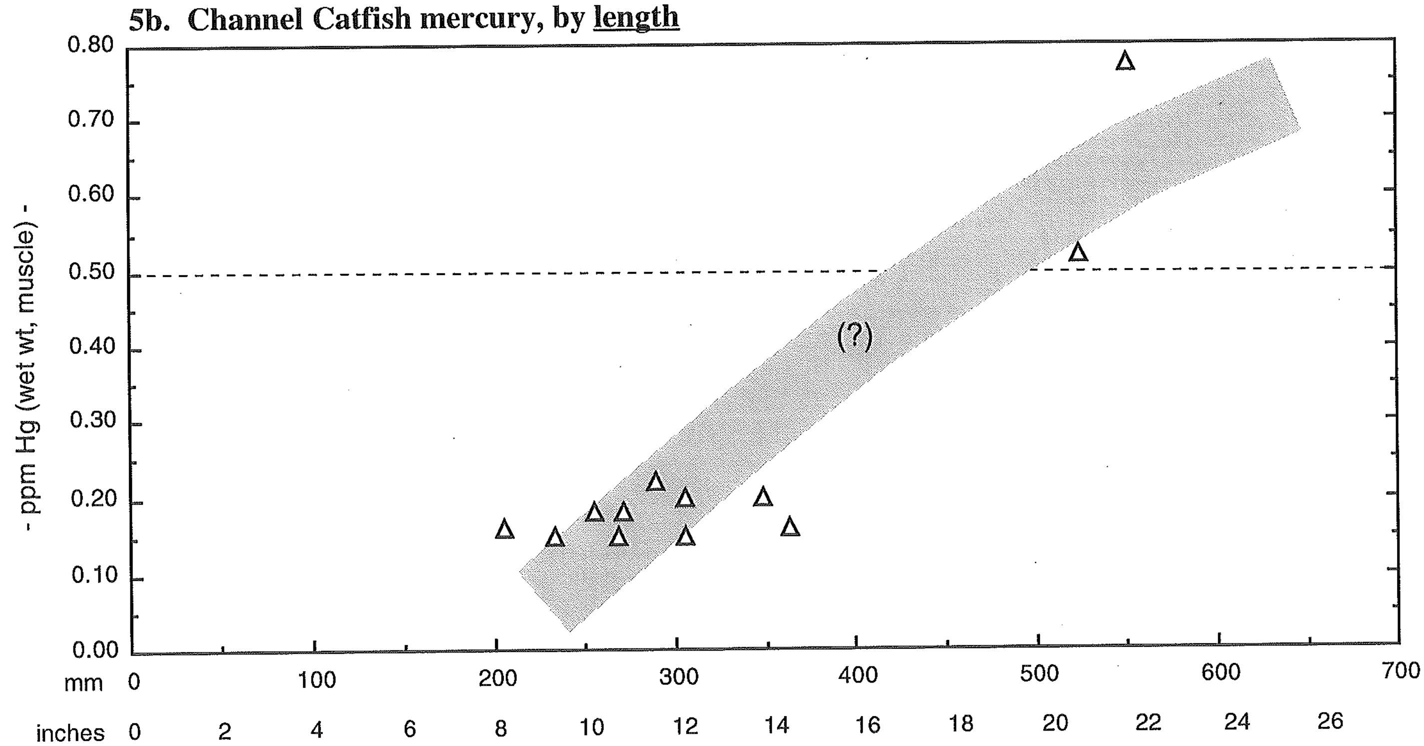
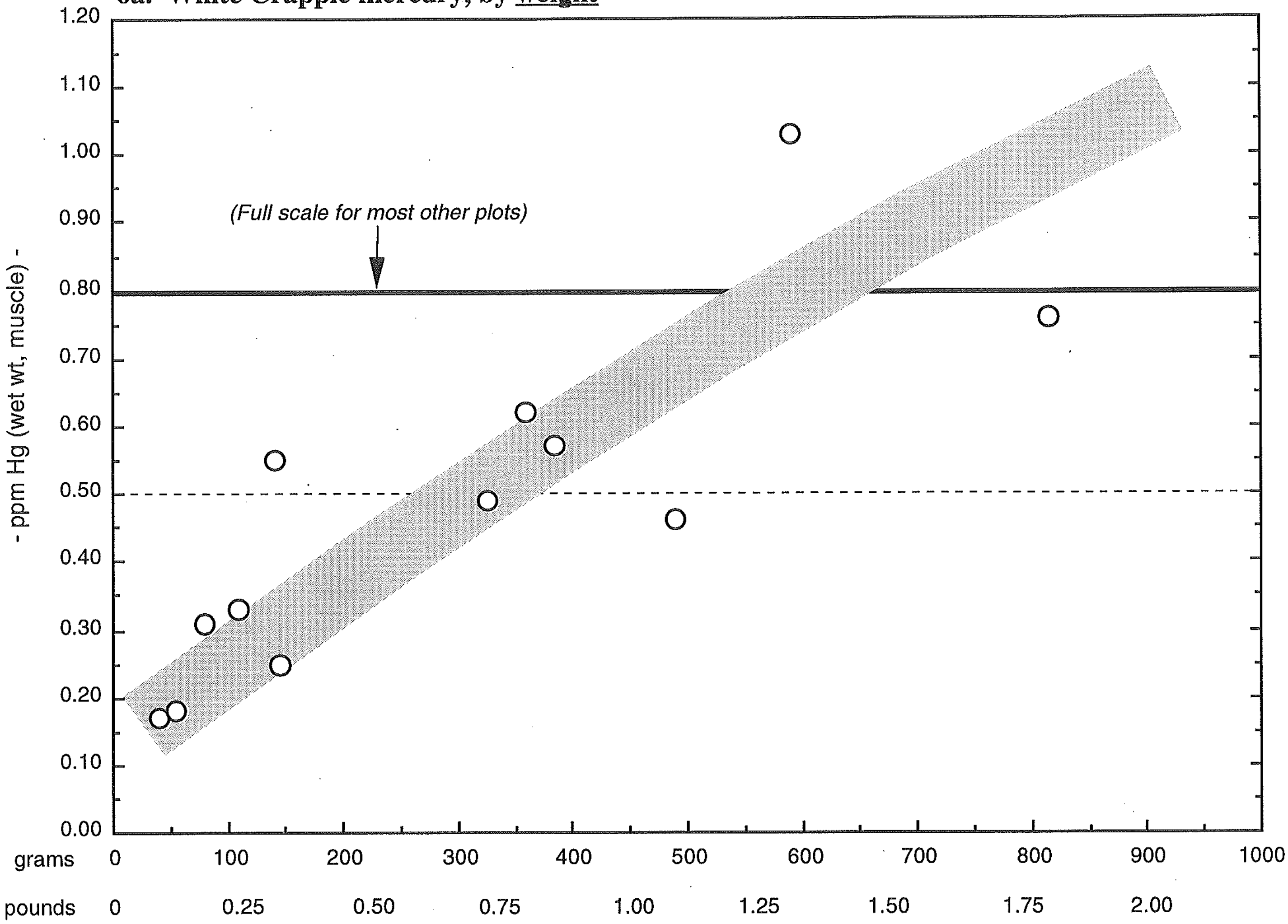
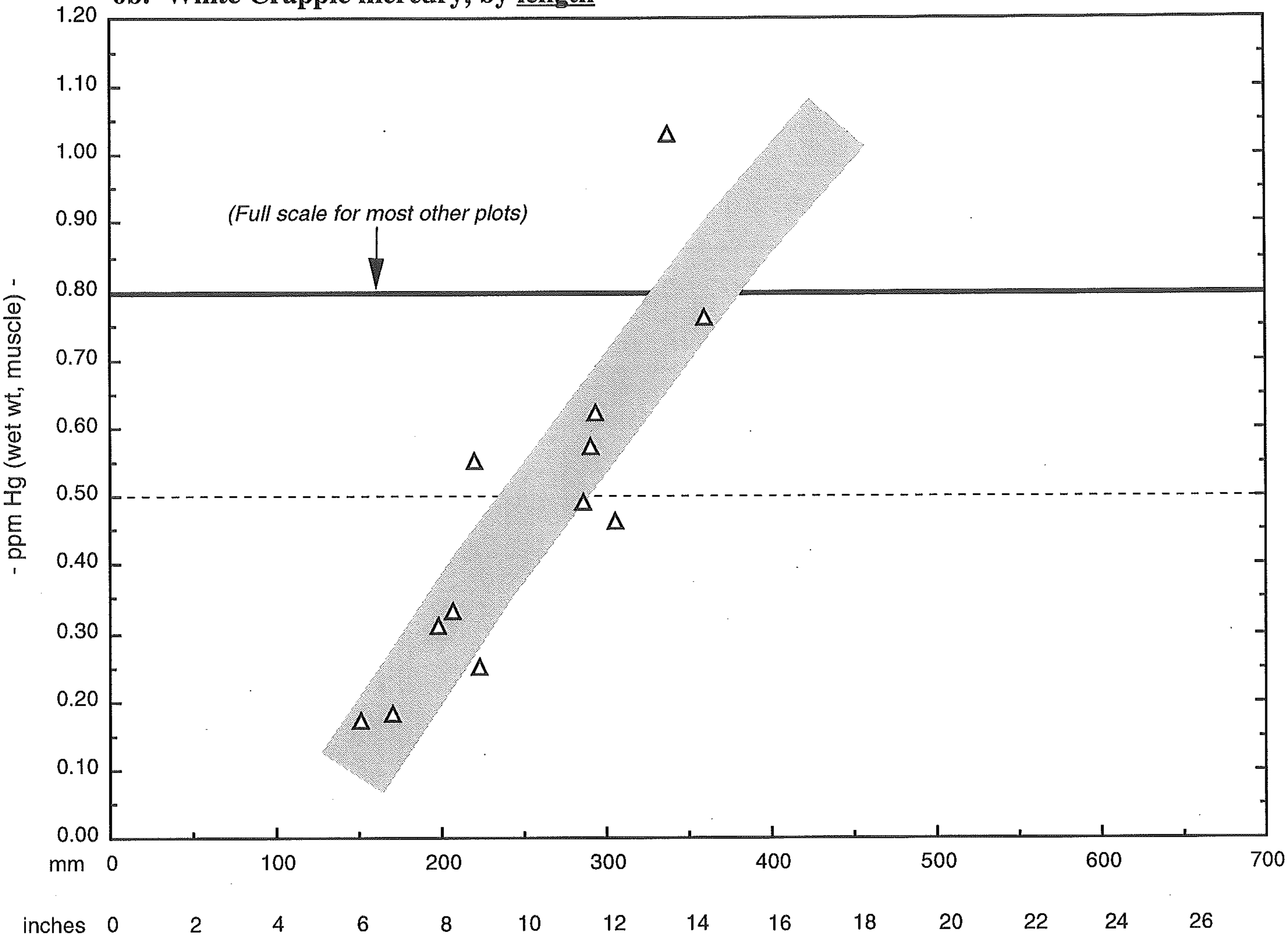


Figure 6. WHITE CRAPPIE MERCURY

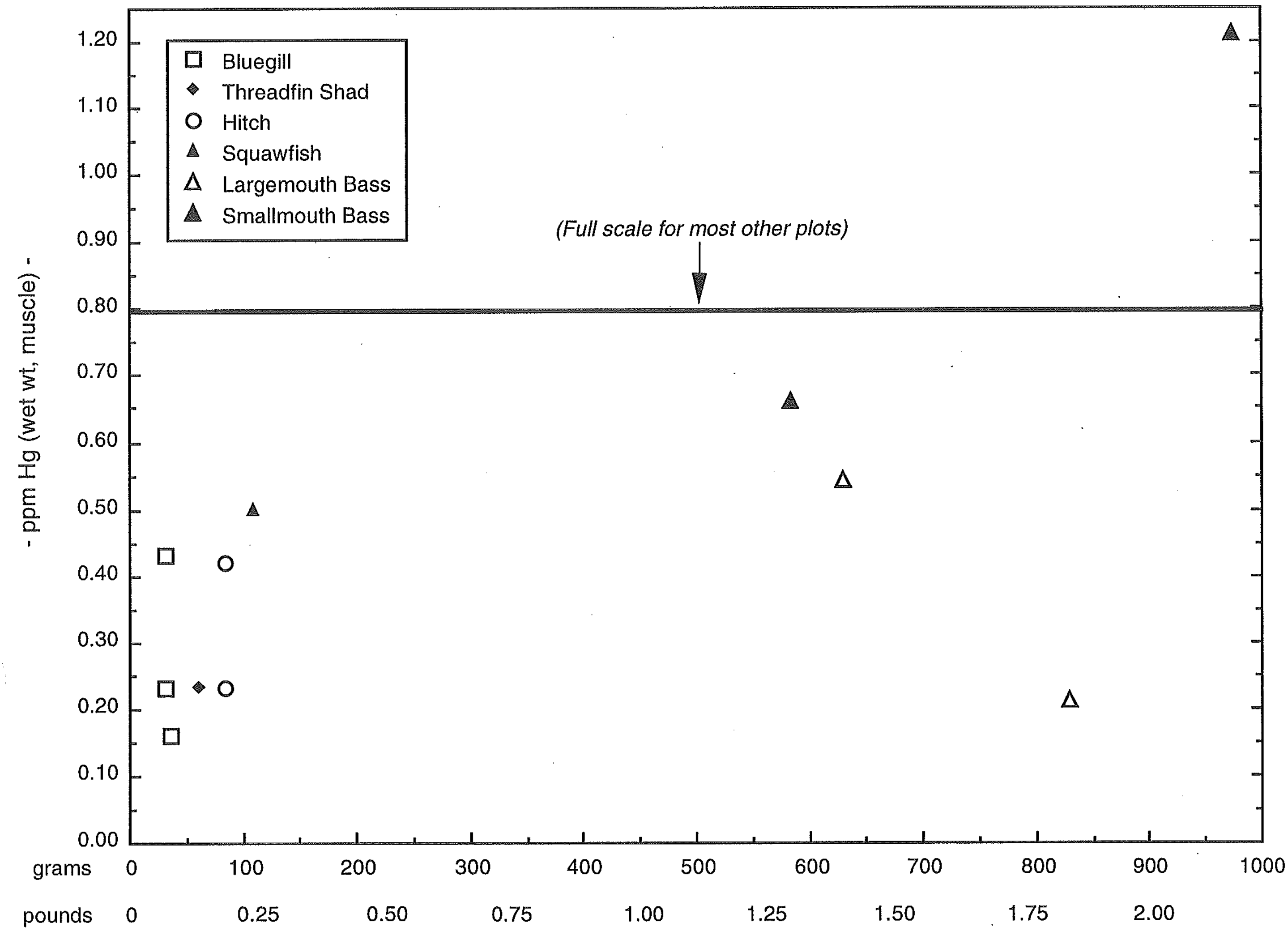
6a. White Crappie mercury, by weight



6b. White Crappie mercury, by length



7a. Additional Fish mercury, by weight



7b. Additional Fish mercury, by length