LOWER CACHE CREEK
2011-2012 BASELINE MERCURY MONITORING

Final Report

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Monitoring and Report by

Darell G. Slotton, Ph.D.*
and
Shaun M. Ayers

* *(530) 756-1001*
dgslotton@ucdavis.edu

SUMMARY OF THIS STUDY AND ITS FINDINGS

- In Fall 2011, we collected fish from lower Cache Creek, to provide new data for Yolo County and to satisfy requirements to test mercury concentrations in Cache Creek biota.

- These collections were also made to provide comparison mercury data, from in-channel Cache Creek, for nearby off-channel wet gravel mining pits and future decommissioned ponds. In a change from earlier sampling, done in 1997 in the downstream Settling Basin, the new collections were made in the stretch of the creek that is next to the off-channel mining zone.

- Fish were collected from 3 in-channel sites, which were located from just above to near the bottom of the current zone of off-channel gravel mining (River Miles 28, 20, and 15). A total of 83 fish were sampled from 9 species, for analysis of fillet muscle mercury, in relation to potential human and wildlife consumption.

- At the 3 sites, small, young-of-year fish were also collected, as well as common in-stream aquatic insects, both of which will be comparable to the first biota likely to be present in the off-channel ponds (before large fish). These smaller samples can often give stronger statistics for comparisons. As young fish and aquatic insects are known to change their mercury levels fairly rapidly if conditions change, collections were made twice, 6 months apart, in Fall 2011 to reflect the previous warm season, and in Spring 2012, to reflect the cool season. 67 small fish and 34 aquatic insect samples were collected and analyzed for mercury. These samples each included multiple similar-sized individuals, improving the reliability of the data.

- The 2011 and 2012 in-channel Cache Creek collections give us a new set of mercury data for lower Cache Creek, updating the earlier 1997 baseline monitoring and studies done in 2000-2003. The new data will be a good comparison for any monitoring that may be done in nearby off-channel ponds.

- Mercury levels were highest in the fish species that feed at the top of the creek food chain, eating other fish, as is normal. These top predator, 'trophic level 4' species included smallmouth and largemouth bass and Sacramento pikeminnows. Also as is normal, the lowest concentrations were found in species feeding lower on the food chain: 'trophic level 3' species such as bluegill sunfish and Sacramento suckers, and the young fish and aquatic insects.

- As in earlier studies, Cache Creek fish were relatively high in mercury. This was not surprising, in light of the mercury mining history of the upper watershed. In the top predator bass and pikeminnows, concentrations averaged 327-782 parts per billion (ppb) mercury, with individual fish as high as 982 ppb, as compared to the 230 ppb 'target safe' goal level created in the Cache Creek TMDL for trophic level 4 fish. Average concentrations in lower food chain sunfish, suckers, etc. ranged from 138 to 540 ppb, as compared to the 120 ppb 'target safe' goal level for trophic level 3 fish. And relative to the 50 ppb TMDL target level for very small fish, the new small fish samples were mostly higher, ranging to 242 ppb.

- Comparing between the three recent sampling locations, we found the River Mile 28 site to have higher concentrations than downstream River Miles 20 or 15. These differences were statistically significant for all the comparisons we had of closely matching samples (Table S-1). To our knowledge, the River Mile 28 site, located just below the Capay Diversion Dam, has not been studied before. This location appears to be an elevated mercury zone within the already-elevated Cache Creek. This may have something to do with the dam or could be unrelated.

- Comparing the new data with earlier studies from 1997-2003, some higher concentrations were seen in large fish from the River Mile 28 site. Because of normal variability of the data, the differences were not statistically significant (Table S-2). In the River Mile 28 samples of small fish and aquatic insects that could be compared to historic data from other sites, half showed a statistically higher level in 2011-2012. In contrast, at the middle and downstream sites (River Miles 20 and 15), small fish and aquatic insect comparisons with matching historic data all showed either no change or a slight decrease from earlier levels in 1997-2003. Large fish mercury from River Miles 20 and 15 was also similar to levels found in the earlier studies.

(from Table 15 of main report)

Table S-1. Comparison of mercury levels between the three 2011-2012 Cache Creek sites, for sample types that were available at multiple sites.
(mean ng/g mercury ± standard deviation)

>> statistically higher than both other sites
> statistically higher than next site
= statistically overlapping

Sample Type	River Mile 28		River Mile 20		River Mile 15
Large Fish					
Sacramento Pikeminnow	**726** ± 142	>			**327** ± 86
Green Sunfish	**540** ± 50	>>	**138** ± 41	=	**195** ± 43
Small Fish					
Red Shiner (Spring)	**189** ± 12	>			**63** ± 6
Green Sunfish (Fall)	**139** ± 14	>>	**84** ± 4	=	**86** ± 18
Green Sunfish (Spring)	**142** ± 12	>>	**106** ± 17	>	**58** ± 14
Largemouth Bass (Fall)	**142** ± 26	>			**50** ± 24
Aquatic Insects					
Dragonflies (Fall)	**67** ± 3	>>	**34** ± 1	>	**24** ± 1
Dragonflies (Spring)	**97** ± 6	>>	**29** ± 2		**32**

(from Table 16 of main report)

Table S-2. General comparison of the new 2011-2012 mercury data with closely comparable historic data from 1997-2003. For matching sample types/sizes and closest sites *(relative statistical differences of new data vs old, 95% confidence level)*

Sample Type	River Mile 28	River Mile 20	River Mile 15
Large Fish			
Smallmouth Bass	same		
Largemouth Bass	same		
Sacramento Pikeminnow	same		same
Green Sunfish	same	same	same
Bluegill Sunfish	same		
Sacramento Sucker			same
Small Fish			
Red Shiner (Fall)	same		
Red Shiner (Spring)	**up**		same
Green Sunfish (Fall)	same	**down**	same
Green Sunfish (Spring)	**up**	same	same
Bluegill Sunfish (Fall)			**down**
Mosquitofish (Fall)			same
Speckled Dace (Spring)		same	
Aquatic Insects			
Dragonflies (Spring)		same	same
Damselflies (Fall)	same	same	**down**
Caddisflies (Spring)	**up**	same	
same			

INTRODUCTION

This work was conducted for Yolo County, to update baseline fish mercury information for lower Cache Creek. This is the second study of ambient mercury levels in Cache Creek fish pursuant to Section 10.5.517 of the Yolo County Reclamation Ordinance. The first baseline survey was conducted in September 1997 (Slotton et al. 1997). At that time, fish were collected almost entirely from the downstream Cache Creek Settling Basin. Because of the seasonally dry nature of parts of Cache Creek below Capay Dam, it was thought that a useful population of large, angling-size fish for monitoring might only be available from the downstream Settling Basin. In subsequent years, adult fish were found to be present across a wider portion of the creek. In this current work, we focused our collections on the stretch of the creek that is right next to the major off-channel gravel mining operations, to allow for better future comparisons to fish in the wet mining pits.

The County Ordinance states, in the relevant part: The County shall evaluate available data to determine significant change in ambient concentrations of mercury in fish within the Cache Creek channel (Ordinance Section 10-5.517, paragraph 2). Among other things, the purpose of this current report is to facilitate further analysis and comparison to mercury levels in fish within permitted wet pit operations conducted off-channel by the County's aggregate producers. The ordinance (Section 10-5.517(b)) specifies that wet pits approved for eventual reclamation to permanent lakes must be evaluated annually for five years after creation and biennially for ten years after reclamation is completed, for "conditions that could result in significant methylmercury production". The "statistically verified average mercury concentrations" of comparable fish in the creek is the baseline for measurement of the "average mercury content" for fish in the wet pits/lakes. If the average mercury content of fish in a wet pit exceeds the ambient mercury content for fish in the creek over two consecutive years of measurement, the operator is required to take certain actions. Sections 10-5.517 (c) through (h) identify the methodology for the pit studies and the required actions dependent on the analysis results.

Three in-channel sites were chosen for survey work in this study. They were distributed across the lower Cache Creek gravel mining region (Fig. 1), with the most upstream site at River Mile 28, located just above the mining zone below Capay Dam, and the most downstream site at River Mile

15 downstream of County Road 94B. A middle site was chosen downstream of Hwy 505 at River Mile 20. (River Mile designations start at the end/outlet of the creek near Woodland and increase moving upstream toward Clear Lake). In November and December of 2011, we collected representative fish from these sites, as available, in the larger size ranges relevant to potential angling and consumption by both people and wildlife. A total of 83 larger fish were taken for individual mercury analyses of fillet muscle, with samples coming from 9 of the most prevalent species in the creek.

Figure 1. Map of the three 2011-2012 sampling locations along lower Cache Creek

It typically takes years for large fish to reach their adult sizes and accumulate their mercury loads. It may be desirable to assess mercury exposure conditions more rapidly in decommissioned gravel mining water bodies, and/or large fish may not be present in strong numbers. We know from experience with similar habitats along the creek that the most likely early inhabitants of such places will be small/juvenile fish and aquatic insects that are common in the adjacent creek. The smaller sample types can also often give stronger statistical results than large fish. This baseline update survey of mercury levels in Cache Creek fish was expanded to include collections of small/young fish and aquatic insect samples. These can also be used as baseline samples for comparison to conditions in the creek at later dates, as well as in off-channel water bodies next to to the creek. Because mercury levels in the small fish and aquatic insects can change more rapidly than in the larger fish, collections of those samples were made at two time periods: Nov-Dec (Fall) 2011 and May-Jun (Spring) 2012, representing the general annual range of conditions. A total of 67 small fish and 34 aquatic insect samples were analyzed, in the form of multi-individual composite samples from each of the most common species.

Following, below, are the methods we used and then a presentation of the mercury data found in this new baseline survey. Large fish, small fish, and aquatic insect samples are each discussed in their own sections, first presenting the new data from this study, followed by a comparison to previous data from other studies when closely comparable data are available. Photos of the creek sites and many of the various samples can be found in the Appendix.

METHODS

Large and small fish were collected using a Smith-Root backpack electro-fishing unit, together with a variety of seines. This was done with two researchers wading in the creek, wearing non-conductive waders. Electro-fisher settings were carefully adjusted to match the conductance of the water and to minimize any effects to fish beyond brief stunning. The effective field range was app. 5 feet. Any non-targeted fish were moved away from and, if stunned, checked to assure quick recovery, and helped to revive in the unusual case where that was necessary. Aquatic insect samples were collected using a research kick screen in riffle areas and areas with submerged vegetation.

Large fish were field identified, cleaned and sorted, and stored on ice in labeled freezer weight, zip-close bags for return to the laboratory, where they were stored in a sub-zero freezer. For sample processing, fish were thawed, weighed and measured. A fillet section was dissected from the left dorso-lateral ('shoulder') region. From this fillet piece, analytical sub-samples were carefully dissected and weighed to 0.0001 g accuracy for subsequent mercury analysis.

Small fish were field identified, cleaned and sorted by species, bagged in labeled freezer weight, zip-close bags with air removed, and transported on ice to the laboratory. Prior to freezing, samples were assembled into composite groupings of similar-sized fish and total length in mm was measured for each individual. Each composite sample was frozen in doubled freezer weight bags with water surrounding and air removed, a technique my group has found to maintain natural moisture levels through the freezing process, something that can be a problem for small fish samples. Pre-analytical processing included weighing each composite group and drying the sample to constant weight in a laboratory oven at 55 °C. Solids percentage was calculated during this process, through sequential weighings of empty weigh tins, tins with wet sample, and tins with dry sample. Dried samples were homogenized to fine powders using a laboratory grinder.

Aquatic insect samples were field sorted and cleaned in laboratory pans with site water and transported to the lab on ice in glass jars with teflon lined caps. Within 24 hours, the samples were sorted into replicate, multi-individual composites, sizes and numbers were recorded, and the insects were transferred into pre-weighed vials. Weights were obtained with wet samples and following oven drying as above. Dried samples were homogenized to uniform powders using a glass mortar and pestle.

Large fish fillet muscle samples were analyzed for mercury directly, on a wet (fresh) weight basis. Small fish and aquatic insect composite samples were analyzed whole body, homogenized into dry powders for consistency as described above. Dry weight results were converted to original wet/fresh weight concentrations using the calculated % solids values. For all mercury analyses, samples were weighed into 20 ml digestion tubes and digested at 90 °C in a mixture of concentrated nitric and sulfuric acids with potassium permanganate, in a two stage process. Digested samples were then analyzed for total mercury by standard cold vapor atomic absorption (CVAA) spectrophotometry, using a dedicated Perkin Elmer Flow Injection Mercury System (FIMS) with an AS-90 autosampler. The method is a variant of EPA Method 245.6, with modifications developed by our laboratory.

Extensive Quality Assurance / Quality Control (QAQC) samples were included in all analytical runs and tracked with control charts. Results for this project were all within control limits.

For comparisons of this project's data with older studies in Cache Creek (mostly our own data sets), we were careful to only use comparable archive data, focusing on similar-sized individuals of each species, collected at the same time of year from sites within or relatively near the study zone.

RESULTS AND DISCUSSION

Large Fish Mercury

A total of 83 fish were taken for individual mercury analyses of fillet muscle. Data for each analyzed fish are presented by site and species in Tables 1-3. Reduced data are shown in Table 4. The mercury information is presented graphically in Figures 2-4. Following the presentation of the new 2011 data, we have compiled historic data (Table 4) and made a set of figures (Figs. 5a-f and 6a-c) that compare the new data to closely comparable large fish data, as available, collected from Cache Creek in two previous studies: the initial 1997 first baseline survey (Slotton et al. 1997), and the CalFed watershed study (Slotton et al. 2004a). For those comparisons, we focused on historic data that were from sites near or within the 2011 study area, and on individual fish that were in a similar size range as the 2011 samples, as possible.

The fish species present and available for collection in the 2011 study area included several species in common with the 1997 collections that were conducted primarily in the downstream Settling Basin. These included Sacramento suckers, smallmouth and largemouth bass, bluegill sunfish, Sacramento pikeminnow (formerly called squawfish), and channel catfish. However, the top predator species of bass and pikeminnow (which accumulate the highest levels of mercury) were represented by only 1-2 samples each in the earlier study, vs. 7-19 each in the current study. And several species that were well represented in the 1997 downstream Settling Basin work were simply not present in collectable numbers in the upstream environment adjacent to the gravel mining region (carp, white crappie, Sacramento blackfish, white catfish, and larger channel catfish), though other species were relatively abundant (green sunfish and Sacramento pikeminnow).

The upper site, River Mile 28 located just below Capay Dam, contained the most diverse fish fauna of the three sites in Nov-Dec 2011. We were able to obtain samples of some prime angling target species: smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*Micropterus salmoides*), as well as some small channel catfish (*Ictalurus punctatus*) and large Sacramento pikeminnow (*Ptychocheilus grandis*) in a range of sizes. Pikeminnows are native predatory fish that are high accumulators of mercury, similar to bass, and which can be present at sites without bass. We also obtained samples of bluegill sunfish (*Lepomis macrochirus*), green sunfish (*Lepomis cyanellus*), and apparent hybrids between these two species.

At the most downstream site, River Mile 15 downstream of County Road 94B, we assembled strong sets of Sacramento pikeminnow and green sunfish that can be compared to the River Mile 28 data. We also took a set of Sacramento suckers (*Catostomus occidentalis*).

Large fish were difficult to capture at the middle site, River Mile 20 downstream of Highway 505, partly due to sparser fish and partly due to a lack of cover in which to corner them while collecting. A set of green sunfish was taken, plus a black crappie (*Pomoxis nigromaculatus*).

Across all 83 of the analyzed 2011 Cache Creek fish, fillet muscle mercury concentrations ranged from a low of 93 ppb (0.093 ppm) to a high of 982 ppb (0.982 ppm). Concentrations among same species at each site generally clustered in a consistent range, with top predator species and larger/older fish within each species having the highest levels, as is typical. Highest concentrations were seen in smallmouth and largemouth bass and Sacramento pikeminnows (all fish eaters as adults), with intermediate concentrations in the panfish and small channel catfish (which eat lower on the food chain), and lowest levels in Sacramento suckers which feed still lower on the food chain.

Below, we will discuss each species, first presenting the new 2011 data and then comparing to earlier studies where closely comparable data exist. Earlier studies with large fish collections include the initial Lower Cache Creek baseline assessment that we did in 1997 (Slotton et al. 1997) and the CalFed study we conducted in 2000 and 2001, mostly in the upper watershed but with some large fish collections between Rumsey and Woodland (Slotton et al. 2004a).

Table 1. Large fish taken below Capay Dam at River Mile 28, Fall 2011

Fish Species	Fish Length (mm total)	Fish Weight (grams)	Muscle Mercury (ng/g = ppb, wet wt)
Smallmouth Bass	171	72	752
Smallmouth Bass	195	98	982
Smallmouth Bass	281	335	717
Smallmouth Bass	284	367	973
Smallmouth Bass	285	379	419
Smallmouth Bass	300	423	944
Smallmouth Bass	340	610	686
Largemouth Bass	138	35	617
Largemouth Bass	168	69	538
Largemouth Bass	171	65	536
Largemouth Bass	178	74	428
Largemouth Bass	202	117	933
Largemouth Bass	201	114	719
Largemouth Bass	204	115	723
Largemouth Bass	232	194	716
Largemouth Bass	295	453	758
Sacramento Pikeminnow	264	147	657
Sacramento Pikeminnow	285	163	676
Sacramento Pikeminnow	288	195	523
Sacramento Pikeminnow	290	209	604
Sacramento Pikeminnow	302	244	645
Sacramento Pikeminnow	308	209	671
Sacramento Pikeminnow	314	240	964
Sacramento Pikeminnow	319	299	897
Sacramento Pikeminnow	352	411	744
Sacramento Pikeminnow	387	504	878
Green Sunfish	130	34	556
Green Sunfish	142	53	579
Green Sunfish	146	55	484
Green Sunfish / Bluegill hybrid	121	28	324
Green Sunfish / Bluegill hybrid	127	35	371
Green Sunfish / Bluegill hybrid	133	37	344
Green Sunfish / Bluegill hybrid	137	45	445
Green Sunfish / Bluegill hybrid	137	46	442
Green Sunfish / Bluegill hybrid	147	62	326
Bluegill Sunfish	118	29	203
Bluegill Sunfish	128	40	219
Bluegill Sunfish	129	41	418
Bluegill Sunfish	130	42	289
Bluegill Sunfish	147	73	409

(continued)

Table 1 (continued). Large fish taken below Capay Dam at River Mile 28, Fall 2011

Fish Species	Fish Length (mm total)	Fish Weight (grams)	Muscle Mercury (ng/g = ppb, wet wt)
Channel Catfish	205	58	197
Channel Catfish	222	85	375
Channel Catfish	226	75	209
Channel Catfish	266	125	187
Channel Catfish	277	165	180

Table 2. Large fish taken below Hwy 505 at River Mile 20, Fall 2011

Fish Species	Fish Length (mm total)	Fish Weight (grams)	Muscle Mercury (ng/g = ppb, wet wt)
Green Sunfish	105	18	127
Green Sunfish	110	20	116
Green Sunfish	114	21	157
Green Sunfish	116	20	121
Green Sunfish	121	30	144
Green Sunfish	122	32	104
Green Sunfish	126	32	115
Green Sunfish	128	37	93
Green Sunfish	137	48	172
Green Sunfish	143	50	234
Black Crappie	176	59	138

Table 3. Large fish taken below Rd 94B at River Mile 15, Fall 2011

Fish Species	**Fish Length** (mm total)	**Fish Weight** (grams)	**Muscle Mercury** (ng/g = ppb, wet wt)
Sacramento Pikeminnow	240	104	251
Sacramento Pikeminnow	241	105	270
Sacramento Pikeminnow	254	133	285
Sacramento Pikeminnow	260	130	459
Sacramento Pikeminnow	265	146	261
Sacramento Pikeminnow	270	162	274
Sacramento Pikeminnow	277	171	433
Sacramento Pikeminnow	284	177	282
Sacramento Pikeminnow	285	173	430
Green Sunfish	121	30	131
Green Sunfish	127	35	248
Green Sunfish	128	32	157
Green Sunfish	131	36	202
Green Sunfish	133	39	195
Green Sunfish	135	40	151
Green Sunfish	137	42	163
Green Sunfish	138	49	232
Green Sunfish	138	50	214
Green Sunfish	143	55	255
Sacramento Sucker	243	154	136
Sacramento Sucker	263	191	134
Sacramento Sucker	264	189	138
Sacramento Sucker	277	229	140
Sacramento Sucker	287	254	135
Sacramento Sucker	288	262	170
Sacramento Sucker	290	265	159
Sacramento Sucker	298	304	135

Table 4. Large fish reduced data from individual fillet muscle samples, Fall 2011

Fish Species	**Site**	**n** (individuals)	**Avg. Length** (mm total)	**Avg. Weight** (grams)	**Hg** (ng/g = ppb, wet wt)	**Std. Dev.**
Smallmouth Bass	River Mile 28	7	265	326	782	± 204
Largemouth Bass	River Mile 28	9	199	137	663	± 150
Sac. Pikeminnow	River Mile 28	10	311	262	726	± 142
Sac. Pikeminnow	River Mile 15	9	264	145	327	± 86
Green Sunfish	River Mile 28	3	139	47	540	± 50
Green Sunfish	River Mile 20	10	122	31	138	± 41
Green Sunfish	River Mile 15	10	133	41	195	± 43
Hybrid Sunfish	River Mile 28	6	134	42	375	± 55
Bluegill	River Mile 28	5	130	45	308	± 102
Channel Catfish	River Mile 28	5	239	102	229	± 82
Black Crappie	River Mile 20	1	176	59	138	
Sac. Sucker	River Mile 15	8	276	231	143	± 14

Figure 2. Large fish muscle mercury at 3 Cache Creek sites spanning gravel zone, Fall 2011

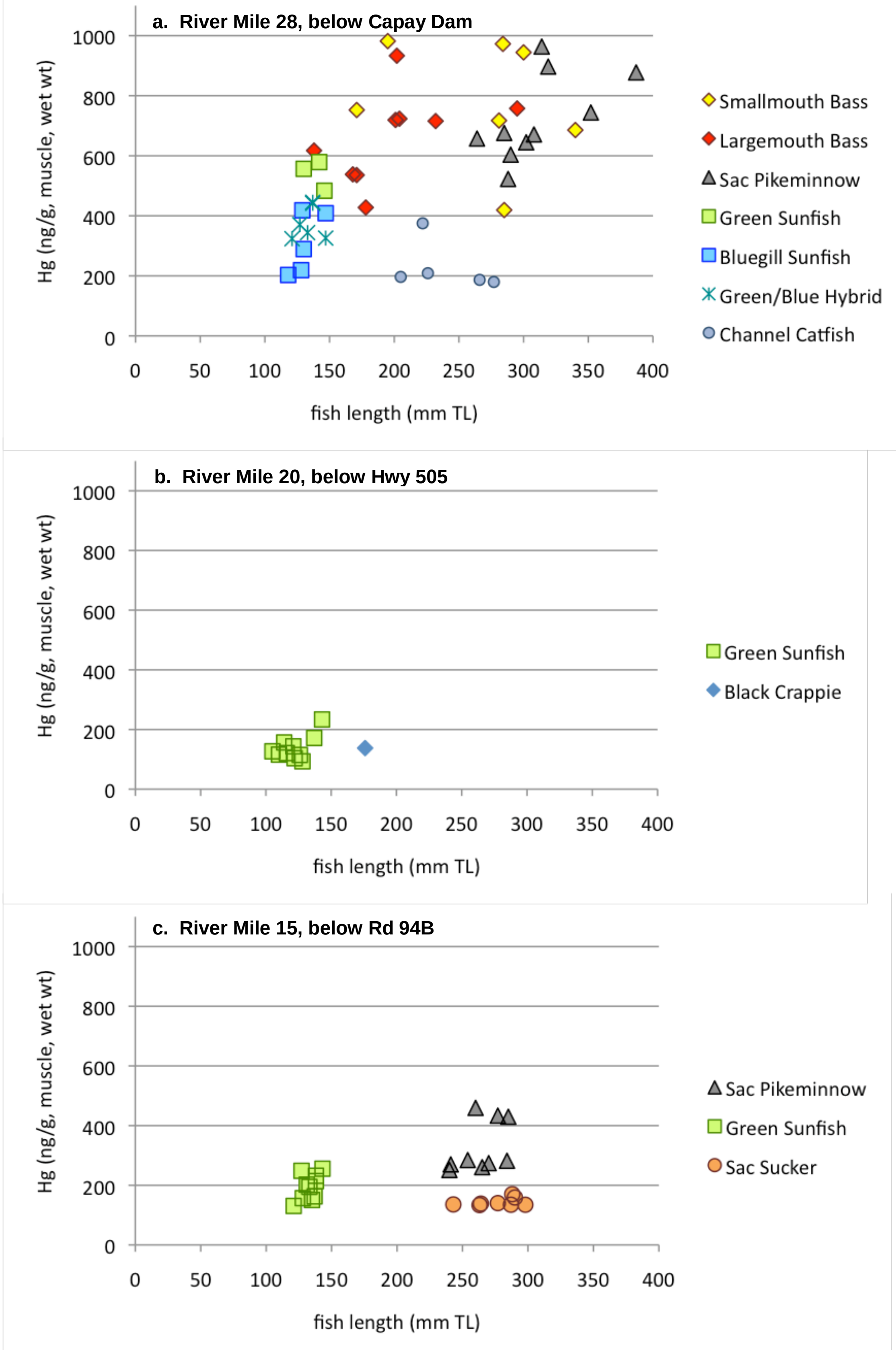
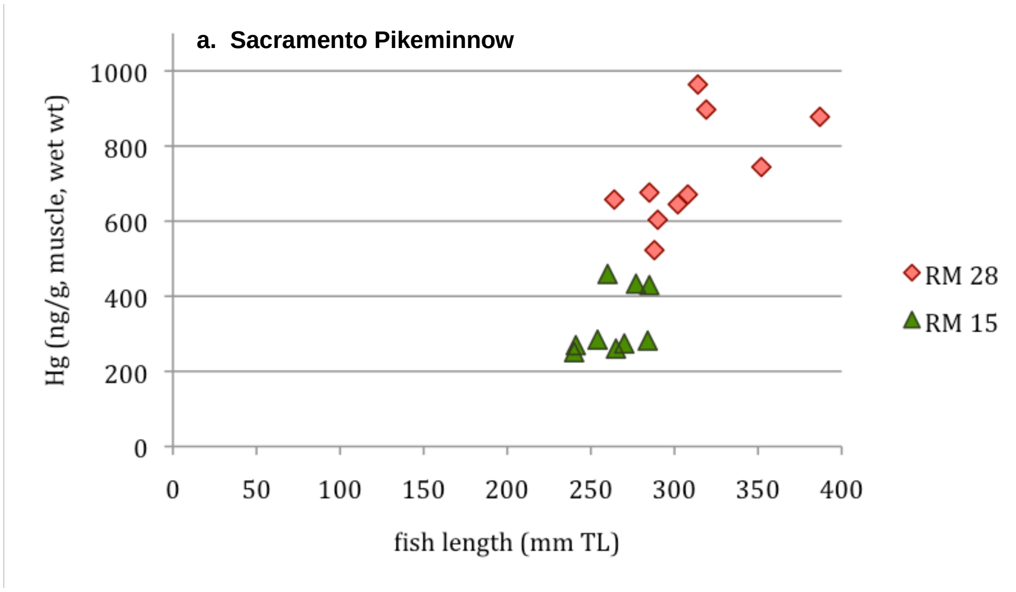


Figure 3. Large fish mercury: Comparison of same species taken at multiple sites, Fall 2011.



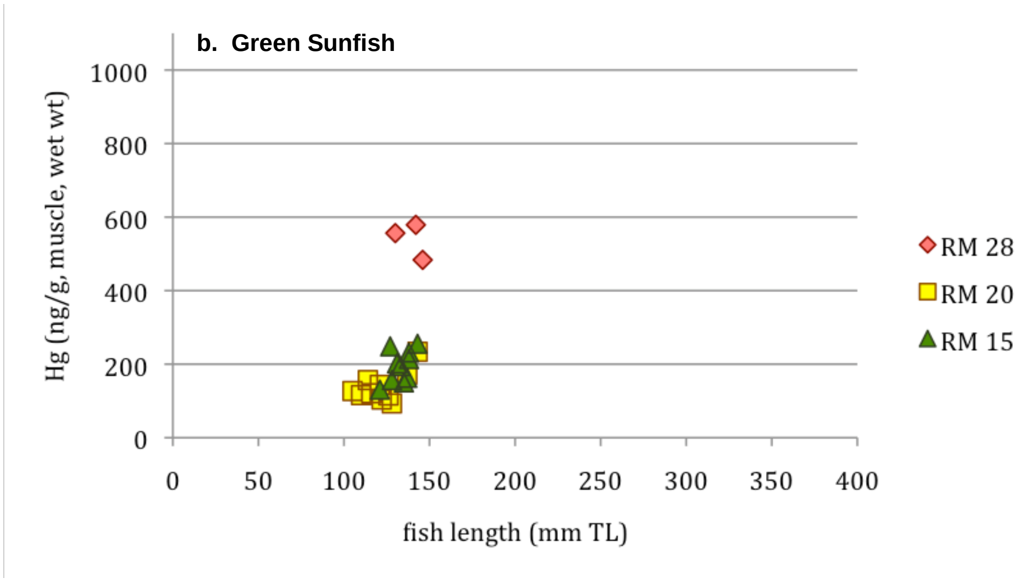
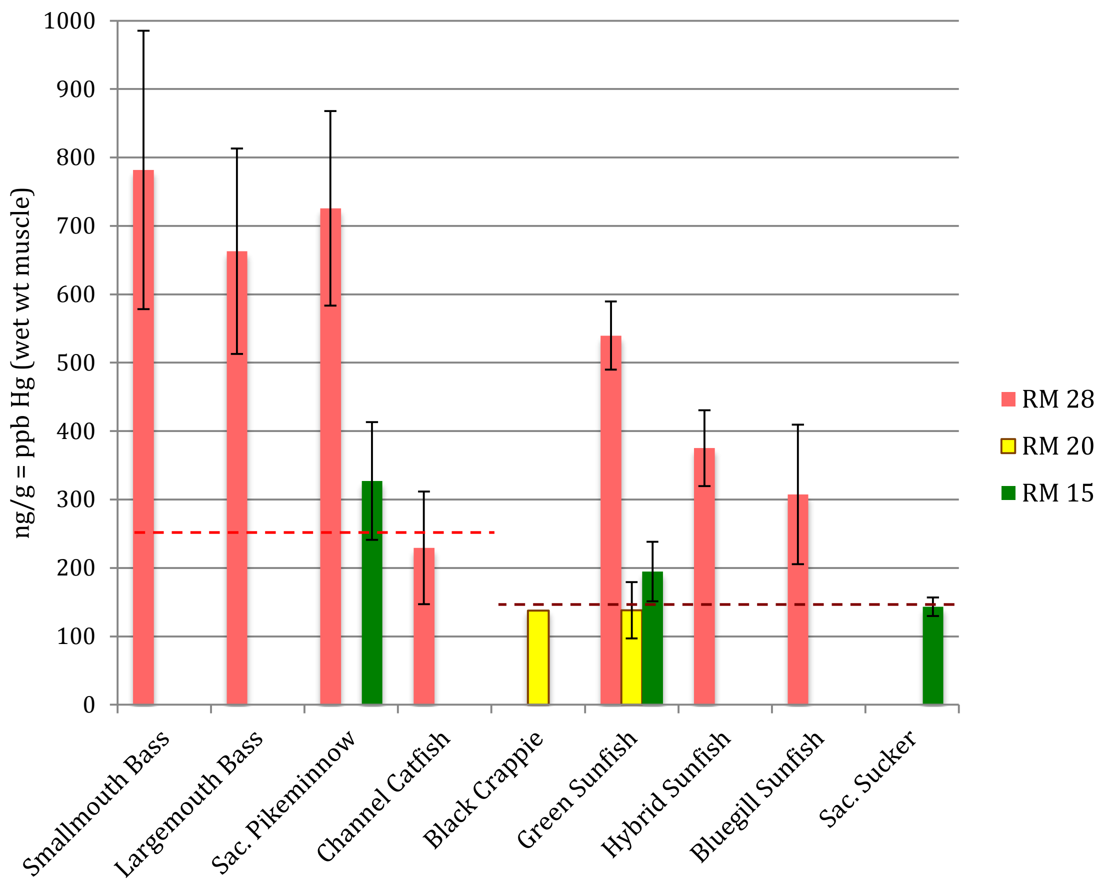


Figure 4. Large fish reduced summary data from Fall 2011 collections, mean muscle mercury ± standard deviations.
(with 230 ppb trophic level 4 and 120 ppb trophic level 3 TMDL 'target wildlife-safe' levels)



Smallmouth Bass (*Micropterus dolomieu*). Bass are top predator fish, eating other fish and accumulating among the highest concentrations of mercury relative to other fish species. They are classified as being in 'Trophic Level 4'. Seven smallmouth bass were collected for analysis in 2011, all from the upper, River Mile 28 site. They ranged in size from 171-340 mm (7-13 inches). Though these were not particularly large bass individuals, their mercury averaged 782 ppb (0.782 ppm), with a range of 419-982 ppb. These are high concentrations, above most consumption guideline levels. For comparison, the Cache Creek TMDL 'Target Safe' mercury level for Trophic Level 4 fish has been set at 230 ppb (0.230 ppm). High mercury concentrations in Cache Creek fish are not surprising, in light of the historic legacy of mercury mining in the upper watershed.

There are several historic sample sets of smallmouth bass to compare to. Three sets of smallmouth bass were analyzed in the CalFed 2000 study at sites in or near the 2011 study area and 2 bass were taken at River Mile 15 in the 1997 study. Compared to the 2011 average mercury concentration at River Mile 28 (782 ppb), all of the 2000 CalFed average levels were lower: 452 ppb at Rumsey, 444 ppb at River Mile 20, and 390 ppb at River Mile 8. The two fish taken at River Mile 15 in 1997 averaged higher, at 939 ppb, but the fish were also considerably larger. In the CalFed study, to help in the comparison of often different-sized fish, bass were size-normalized to a single inter-comparable size that could be used to compare sites. In Figure 6a, the 2011 River Mile 28 sample data are normalized to the same 270 mm bass comparison size and compared to the CalFed and 1997 data. The size-normalized 2011 River Mile 28 smallmouth bass mercury level (786 ppb) was higher than the 2000 levels at Rumsey (405 ppb) and River Mile 20 (476 ppb) or River Mile 8 (435 ppb), and higher than the 1997 River Mile 15 value (311 ppb). The elevated concentrations in smallmouth bass at River Mile 28 in the current study could be due to a general increase in Cache Creek mercury since 2000, or it may be due to that particular site, located immediately below the Capay Diversion Dam, being a relative 'hot spot'. To help answer that question, it would be ideal to have similar 2011 samples from a range of Cache Creek sites, and to have similar 2011 samples from some of the same sites sampled in the earlier studies. That was not possible in this study for adult bass, which were only available at River Mile 28, but it was for other large fish, small fish, and aquatic insects (below).

Largemouth Bass (*Micropterus salmoides*). This other bass species was also present and collected at the River Mile 28 location. Nine fish ranging in size from 138 to 295 mm (5-12 inches) were analyzed. The largemouth bass were similarly elevated in mercury, averaging 663 ppb (0.663 ppm), with a range of 428-933 ppb.

There is a single historic sample of largemouth bass to compare to from near the study area, 2 fish taken at River Mile 3 (in the Settling Basin) in 1997. Those 1997 fish, despite being much larger, had considerably lower mercury levels, averaging 375 ppb.

Sacramento Pikeminnow (*Ptychocheilus grandis*). This native species is also a Trophic Level 4 fish predator. In the 2000/2001 CalFed work, we found pikeminnows and bass to show similar mercury trends at same sites. This was also the case in the 2011 study. At the River Mile 28 site where the bass were taken, 10 adult pikeminnows were also collected. Samples from RM 28 averaged 726 ppb (0.726 ppm), with a range of 523-964 ppb, elevated similarly to the bass. A pikeminnow sample of nine fish was also taken at the downstream site at River Mile 15. These fish had mercury between 251 and 459 ppb, with an average of 327 ppb (0.327 ppm). The 327 ppb average concentration at River Mile 15 was less than half the 726 ppb average from River Mile 28. The difference was statistically significant.

There are some historic data sets of mercury in pikeminnows from sites in or near the study area. From the 2000 CalFed study, there are data from Rumsey and River Mile 20, including 8 fish at each site in a size range similar to the 2011 fish. The 2000 Rumsey sample averaged 622 ppb and the 2000 sample from River Mile 20 averaged 509 ppb. A single, smaller pikeminnow was analyzed from the Settling Basin (River Mile 3) in 1997, with a concentration of 499 ppb. In comparison to the historic samples, the 2011 fish at River Mile 28 were higher (726 ppb) and the River Mile 15 fish were lower (327 ppb). As done with the bass in the CalFed study, to help in the comparison of often different-sized fish, the pikeminnows of each sample set were size-normalized to a single inter-comparable size and mercury concentration. In Figure 6b, the 2011 data are normalized to the same 270 mm comparison size and compared to the earlier data. The trends are the same as described above for the average concentrations. The size-normalized 2011 River Mile 28 pikeminnow mercury level (618 ppb) was higher than the 2000 levels at Rumsey (443 ppb) and

River Mile 20 (473 ppb). At River Mile 15, the size-normalized 2011 mercury level (329 ppb) was lower than the historic data.

Channel Catfish (*Ictalurus punctatus*). Five catfish were collected from the upstream River Mile 28 location. They were all young individuals for this species, ranging in size from 205-277 mm (8-11 inches). The 5 young channel catfish had mercury at 180-375 ppb with an average of 229 ppb (0.229 ppm), right at the TMDL Trophic Level 4 target wildlife-safe target level (230 ppb). Larger catfish can be expected to have higher concentrations.

Historic comparison data are only available from larger catfish. The 2011 average (229 ppb) was nearly identical to individual 2000 fish data from Rumsey and River Mile 20 (both 225 ppb) and similar to 1997 River Mile 3 (Settling Basin) data which averaged 174 ppb in 10 fish that were under 400 mm (16 inches). Two much larger channel catfish taken in the 1997 survey (523 and 544 mm, 21-22 inches) had much higher levels, 524 and 772 ppb.

Black Crappie (*Pomoxis nigromaculatus*). Crappie are panfish that are classified into Trophic Level 3 in the Cache Creek TMDL. The Cache Creek Mercury TMDL created a 'target wildlife-safe' goal level for Trophic Level 3 fish of 120 ppb (0.120 ppm). That is a comparison level for crappie and all remaining species listed below. Of the local trophic level 3 species, crappie and green sunfish tend to feed a little higher on the food chain and accumulate somewhat higher mercury levels. Only a single crappie was taken in the course of this 2011 survey, from the middle site at River Mile 20. This 176 mm (7 inch) fish had a mercury level of 138 ppb (0.138 ppm).

Historic comparison data are available from the 1997 Settling Basin (River Mile 3) collections. The 2011 River Mile 20 fish, at 138 ppb, was lower than the 1997 average concentration in the 6 smallest Settling Basin fish (161-239 mm, 6-11 inches, 300 ppb) and much lower than the levels in the 6 largest 1997 fish (308-387 mm, 12-15 inches, 655 ppb).

Green Sunfish (*Lepomis cyanellus*). Green sunfish, similar to crappie, are categorized toward the top of trophic level 3. It was possible to collect samples at all three of the 2011 creek sites. Three fish from the upstream River Mile 28 site had the highest concentrations we found for this species in this study, averaging 540 ppb (0.540 ppm), with a range of 484-579 ppb. At River Miles 20 and 15, we were able to collect sample sets of ten fish each. The RM 20 green sunfish exhibited muscle mercury ranging from 93-234 ppb, with an average concentration of 138 ppb (0.138 ppm). At the downstream RM 15 site, similar samples had concentrations of 131-255 ppb, with an average of 195 ppb (0.195 ppm). The middle and downstream sites both averaged less than half the mercury level we found at the upstream RM 28 site. This was consistent with the spatial pattern seen in the Sacramento pikeminnows (above). The green sunfish difference between the upper site and the two lower sites was strongly significant statistically.

Green sunfish were not available in the 1997 Settling Basin work. However, this species was found in this study to be one of the dominant fish present in the creek adjacent to the gravel mining zone, and should be part of any future monitoring in that particular region. In the 2000-2001 CalFed study, there was a set of 4 green sunfish taken at River Mile 20. Those samples averaged 271 ppb mercury. The recent sample from that same site, averaging 138 ppb, was lower by approximately half, though the difference could not be statistically verified.

Bluegill Sunfish (*Lepomis macrochirus*). Bluegill feed mainly on small invertebrates and are classified in Trophic Level 3. A sample of 5 bluegill was taken from the upstream site at River Mile 28. Mercury ranged from 203 to 418 ppb, with an average of 308 ppb (0.308 ppm).

This was very similar to the 160-430 ppb levels found for this species in the 1997 survey, though from a different location (Settling Basin, RM 03). Also from a different location, 1 bluegill was analyzed from River Mile 20 in 2000. It had a mercury level of 350 ppb, within the range found in the 1997 and 2011 samples.

Hybrid Bluegill/Green Sunfish (*Lepomis cyanellus x macrochirus*). The sunfish individuals that were apparent hybrids between these two species, taken at River Mile 28, had mercury levels that were intermediate between those of the bluegill and green sunfish taken at the same site. Concentrations in the 6 hybrids ranged between 324 and 445 ppb, averaging 375 ppb (0.375 ppm). That level was higher than the bluegill average (308 ppb) and lower than the green sunfish average (540 ppb). Hybrid sunfish were not collected or analyzed in the earlier studies.

Sacramento Sucker (*Catostomus occidentalis*). A sample of 8 Sacramento suckers was collected at the downstream, River Mile 15 site. Suckers are bottom-feeding detritivores/insectivores and are classified by the Water Board as Trophic Level 3. Mercury concentrations clustered closely between 134 and 170 ppb, with an average of 143 ppb (0.143 ppm). While lower than the other fish species, this level was above the target wildlife-safe mercury level of 120 ppb in trophic level 3 fish.

The 143 ppb average for Sacramento suckers at River Mile 15 in 2011 was lower than the 190-350 ppb range (av. 263 ppb) found in the Settling Basin in 1997, though those fish were larger. Sacramento suckers were also sampled throughout the Cache Creek watershed in the 2000 CalFed collections. The samples from Rumsey, River Mile 20, and River Mile 8 are most relevant to the current study. The 2011 samples from River Mile 15 (av. 143 ppb) averaged slightly lower than the 2000 RM 20 sample (154 ppb), lower than the 2000 Rumsey sample (198 ppb), and considerably lower than the 2000 samples from downstream River Mile 8 (339 ppb). In the CalFed study, to help in the comparison of often different-sized fish as done with the bass and pikeminnows, Sacramento suckers were size-normalized to a single inter-comparable size that could be used to compare sites. In Figure 6c, the 2011 River Mile 15 sample data are normalized to the same 290 mm comparison size and compared to the CalFed and 1997 data. The size-normalized 2011 River Mile 15 sucker mercury level (145 ppb) was very similar to the 2000 level at Rumsey (148 ppb) and lower than at River Mile 20 (182 ppb) or River Mile 8 (208 ppb), and lower than the 1997 Settling Basin value (217 ppb).

In addition to providing new baseline data for each of these species in lower Cache Creek, these findings indicate that fish mercury was highest at the upstream River Mile 28 site and lower at the middle (Rivr Mile 20) and downstream (River Mile 15) locations.

LARGE FISH: COMPARISONS TO PREVIOUS CACHE CREEK STUDIES

Table 5. Large fish 2011 reduced data, with comparable data from 1997 and 2000.
(fillet muscle samples, ordered from upstream to downstream sites)

Fish Species	**Site**	**Year**	**n** (individuals)	**Av Length** (mm total)	**Av Weight** (grams)	**Hg** (ng/g = ppb, wet wt)	**Std. Dev.**
Smallmouth Bass	Rumsey	2000	15	271	302	452	± 215
Smallmouth Bass	**RM 28**	**2011**	**7**	**265**	**326**	**782**	**± 204**
Smallmouth Bass	RM 20	2000	7	234	183	444	± 66
Smallmouth Bass	RM 15	1997	2	383	780	939	± 390
Smallmouth Bass	RM 08	2000	2	231	165	390	± 57
Largemouth Bass	**RM 28**	**2011**	**9**	**199**	**137**	**663**	**± 150**
Largemouth Bass	RM 03	1997	2	369	730	375	± 229
Sac. Pikeminnow	Rumsey	2000	8	327	304	622	± 341
Sac. Pikeminnow	**RM 28**	**2011**	**10**	**311**	**262**	**726**	**± 142**
Sac. Pikeminnow	RM 20	2000	8	269	147	509	± 244
Sac. Pikeminnow	**RM 15**	**2011**	**9**	**264**	**145**	**327**	**± 86**
Sac. Pikeminnow	RM 03	1997	1	241	110	499	
Channel Catfish	Rumsey	2000	1	411	565	225	
Channel Catfish	**RM 28**	**2011**	**5**	**239**	**102**	**229**	**± 82**
Channel Catfish	RM 20	2000	1	368	380	225	
Channel Catfish	RM 03	1997	10	336	304	174	± 26
Black Crappie	**RM 20**	**2011**	**1**	**176**	**59**	**138**	
White Crappie	RM 03	1997	6	208	95	300	± 141
Green Sunfish	**RM 28**	**2011**	**3**	**139**	**47**	**540**	**± 50**
Green Sunfish	RM 20	2000	4	132	41	271	± 223
Green Sunfish	**RM 20**	**2011**	**10**	**122**	**31**	**138**	**± 41**
Green Sunfish	**RM 15**	**2011**	**10**	**133**	**41**	**195**	**± 43**
Hybrid Sunfish	**RM 28**	**2011**	**6**	**134**	**42**	**375**	**± 55**
Bluegill	**RM 28**	**2011**	**5**	**130**	**45**	**308**	**± 102**
Bluegill	RM 20	2000	1	115	30	350	
Bluegill Sunfish	RM 03	1997	3	125	33	270	± 140
Sac. Sucker	Rumsey	2000	6	328	396	198	± 98
Sac. Sucker	RM 20	2000	5	253	174	154	± 27
Sac. Sucker	**RM 15**	**2011**	**8**	**276**	**231**	**143**	**± 14**
Sac. Sucker	RM 08	2000	4	319	336	339	± 164
Sac. Sucker	RM 03	1997	5	343	402	263	± 55

Figure 5. Large fish data compared to previous Cache Creek studies.
*(mean Hg ± std. dev.***,** *directly comparable, similar sized samples; by river mile site and year; with 230 ng/g trophic level 4 'target wildlife-safe' level shown)*

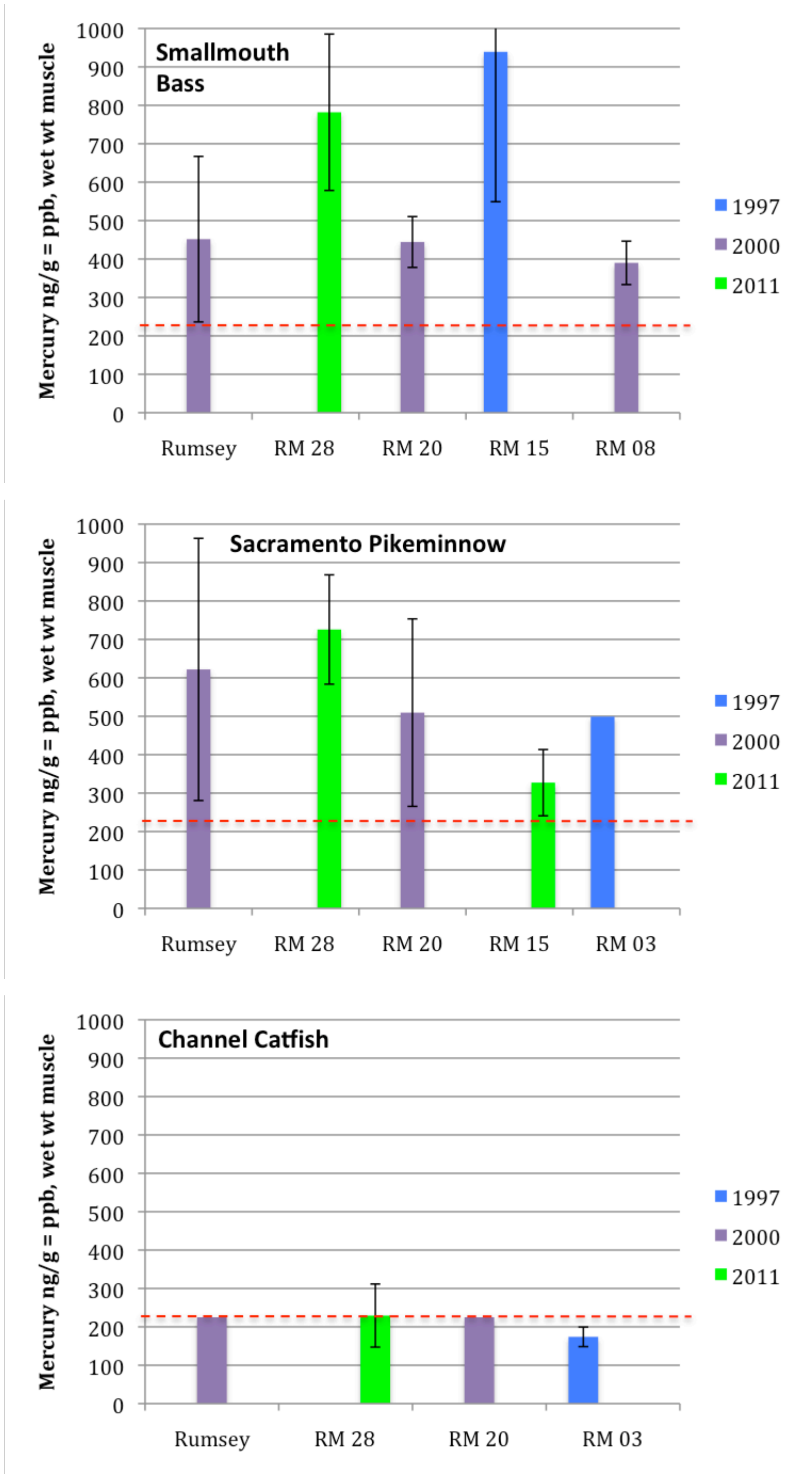
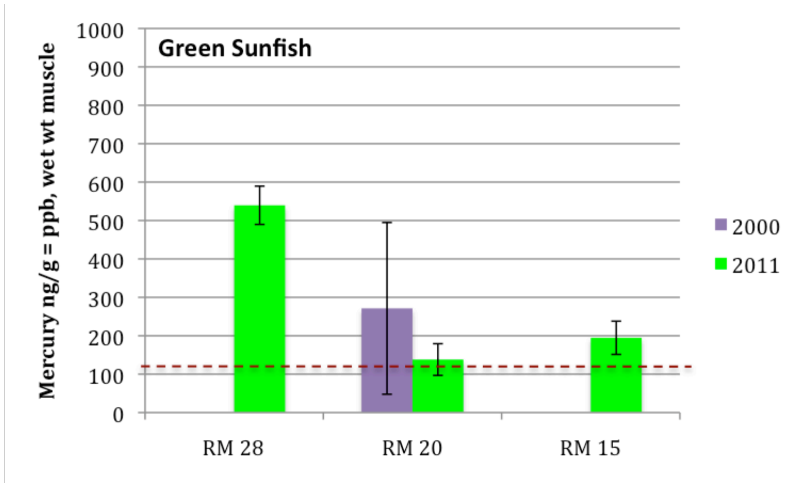
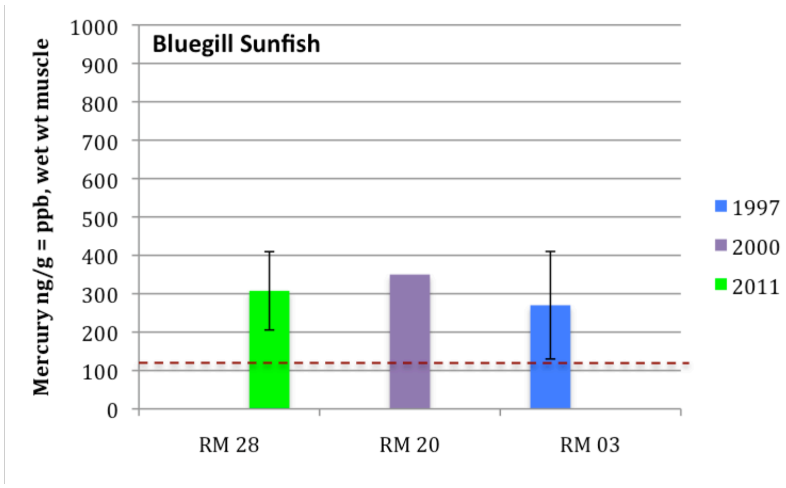


Figure 5. (cont.) Large fish data compared to previous Cache Creek studies.

(directly comparable, similar sized samples; by river mile site and year; with 120 ng/g trophic level 3 'target wildlife-safe' level shown)





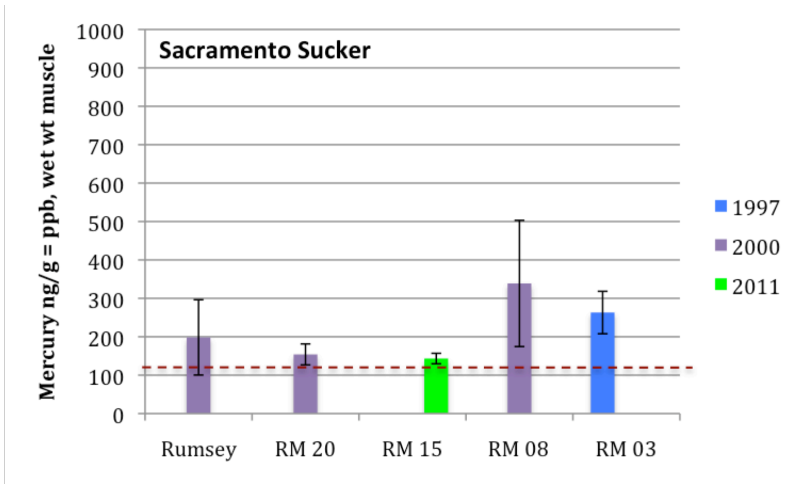
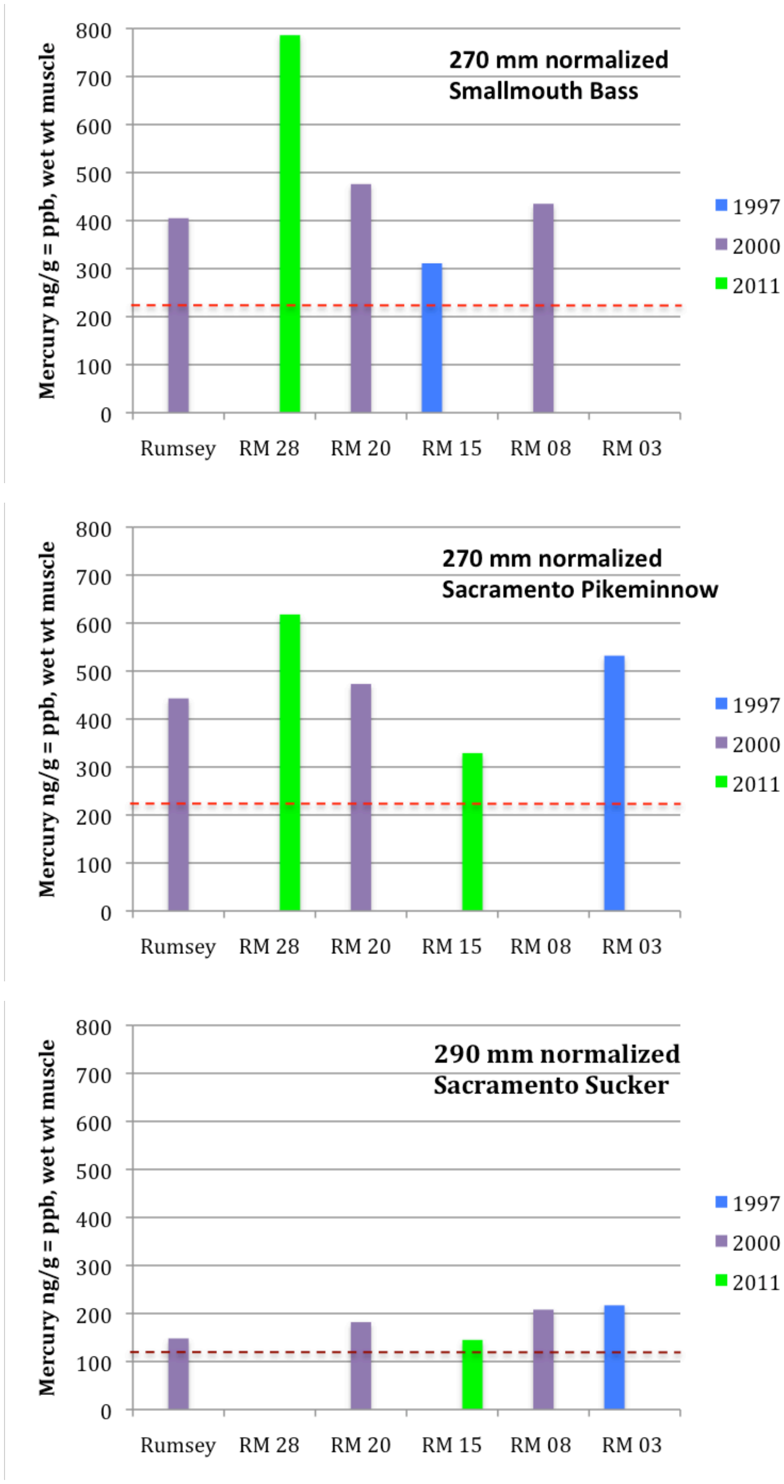


Figure 6. Large fish site and year comparisons, <u>standardizing to specific, inter-comparable sizes</u>. *(with 230 ng/g trophic level 4 and 120 ng/g trophic level 3 'target wildlife-safe' levels shown).*



Small Fish Mercury

Small fish were taken in two seasons, to capture the expected range in mercury exposure conditions and associated bioaccumulation in these small/young, potentially rapidly changing biosentinels. Prior work in and around the Cache Creek Nature Preserve found small fish and aquatic insects to have highest mercury levels in the fall and lowest in the spring. So, in addition to the Nov-Dec 2011 period that coincided with the large fish collections (Fall), a second round of sampling was conducted in May-June 2012 (Spring). Samples were combined into replicate, multi-individual composites for each species, site, and season. An effort was made to collect intercomparable samples at each of the sites and seasons where possible, and to target species most likely to also be found in off-channel gravel mining ponds. Data for each of the replicate composite samples are presented in Tables 6 (Fall 2011) and 7 (Spring 2012). Reduced data are given in Table 8. The small fish mercury results are shown graphically in Figures 7a and 7b. The new data are then shown together with comparable historic data, as available, in Tables 9-10 and Figures 8-9.

Small and juvenile fish typically have lower mercury concentrations than corresponding larger/older fish. Their mercury levels are still well above detection though, and the relative differences between sites and times can often be seen clearly, if they are present. Small fish have proven to be excellent measures of short term seasonal and annual variation in mercury exposure levels, as well as spatial variability to a finer scale than is often possible with large fish. They often can provide stronger statistical comparisons between sites and seasons. Small fish are also useful as direct measures of wildlife exposure, being the targets of fish eating birds in particular. The Cache Creek TMDL created a 'target safe' mercury concentration for small fish under 150 mm in length. That target level is 50 ppb (0.050 ppm) in whole fish.

Across the 67 small fish composite samples analyzed, concentrations ranged from a low of 35 ppb to a high of 284 ppb (0.035-0.284 ppm). The general concentration ranges for each species can be used as baseline comparisons with other years in the creek, and with small fish likely to be present in the off-channel wet pits and reclaimed lakes. Below, we will discuss the new data from each small fish species sampled, and include comparisons to earlier projects where there are closely

Table 6. Small fish, multi-individual, whole body composite samples, taken Fall 2011

Fish Species	Site	n (indivs. in comp)	Avg. Length (mm total)	Avg. Weight (grams)	Whole Body Mercury (ng/g = ppb, wet wt)
Green Sunfish	River Mile 28	4	44.0	1.52	123
Green Sunfish	River Mile 28	4	49.3	2.07	132
Green Sunfish	River Mile 28	4	56.3	3.16	156
Green Sunfish	River Mile 28	4	63.5	4.49	143
Green Sunfish	River Mile 20	4	52.8	2.44	87
Green Sunfish	River Mile 20	4	55.0	2.93	84
Green Sunfish	River Mile 20	4	58.0	3.27	88
Green Sunfish	River Mile 20	4	64.3	4.84	78
Green Sunfish	River Mile 15	4	48.5	1.98	111
Green Sunfish	River Mile 15	5	53.6	2.60	86
Green Sunfish	River Mile 15	5	58.8	3.49	76
Green Sunfish	River Mile 15	4	64.3	4.53	71
Bluegill Sunfish	River Mile 28	2	49.5	1.78	133
Bluegill Sunfish	River Mile 28	2	73.0	6.18	140
Bluegill Sunfish	River Mile 15	4	59.6	3.88	53
Bluegill Sunfish	River Mile 15	4	64.6	4.92	56
Bluegill Sunfish	River Mile 15	4	69.8	6.73	48
Bluegill Sunfish	River Mile 15	4	74.2	8.29	52
Largemouth Bass	River Mile 28	5	64.6	3.66	137
Largemouth Bass	River Mile 28	5	71.2	4.25	133
Largemouth Bass	River Mile 28	5	77.8	5.58	119
Largemouth Bass	River Mile 28	3	88.3	9.16	179
Largemouth Bass	River Mile 15	1	90.0	9.55	78
Largemouth Bass	River Mile 15	1	92.0	9.29	35
Largemouth Bass	River Mile 15	1	97.0	11.69	38
Red Shiner	River Mile 28	10	42.4	0.70	200
Red Shiner	River Mile 28	10	46.2	0.81	230
Red Shiner	River Mile 28	10	49.6	1.12	254
Red Shiner	River Mile 28	10	53.4	1.36	284
Hitch	River Mile 20	5	61.0	1.68	78
Hitch	River Mile 20	5	68.2	2.57	83
Hitch	River Mile 20	5	71.6	2.85	81
Hitch	River Mile 20	5	75.4	3.36	73
Mosquitofish	River Mile 15	10	25.4	0.19	62
Mosquitofish	River Mile 15	10	28.4	0.24	77
Mosquitofish	River Mile 15	1	46.0	1.08	104
Mosquitofish	River Mile 15	1	49.0	1.36	170

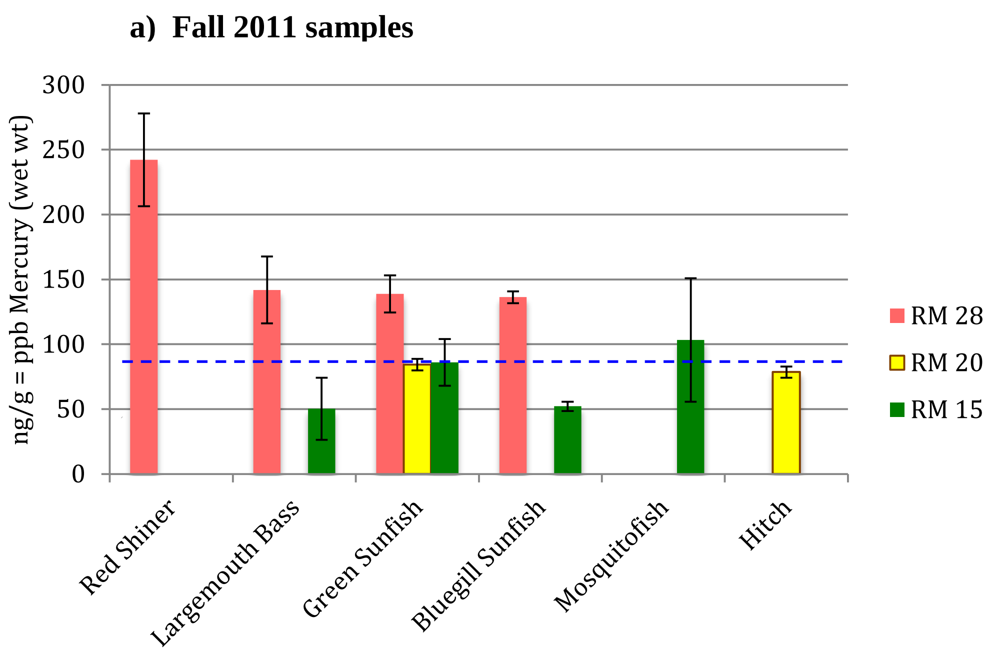
Table 7. Small fish, multi-individual, whole body composite samples, taken Spring, 2012

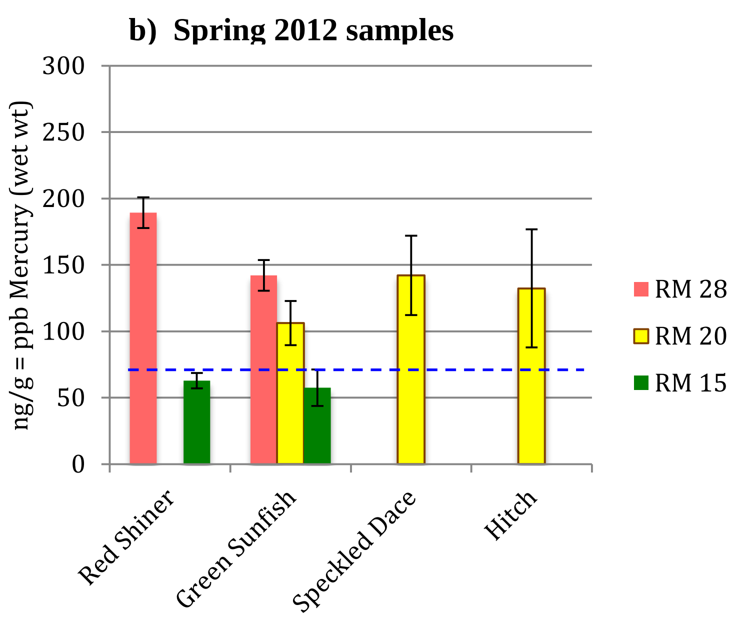
Fish Species	Site	n (indivs. in comp)	Avg. Length (mm total)	Avg. Weight (grams)	Whole Body Mercury (ng/g = ppb, wet wt)
Green Sunfish	River Mile 28	5	57.8	4.12	143
Green Sunfish	River Mile 28	5	62.2	5.07	158
Green Sunfish	River Mile 28	5	72.0	8.18	131
Green Sunfish	River Mile 28	4	79.3	11.45	136
Green Sunfish	River Mile 20	1	74.0	9.67	112
Green Sunfish	River Mile 20	1	75.0	9.38	87
Green Sunfish	River Mile 20	1	77.0	10.21	119
Green Sunfish	River Mile 15	3	58.7	3.92	58
Green Sunfish	River Mile 15	2	63.0	5.12	49
Green Sunfish	River Mile 15	3	69.0	6.85	46
Green Sunfish	River Mile 15	3	82.0	11.87	77
Red Shiner	River Mile 28	6	43.2	0.95	170
Red Shiner	River Mile 28	6	46.3	1.10	188
Red Shiner	River Mile 28	6	49.3	1.38	204
Red Shiner	River Mile 28	6	52.7	1.66	186
Red Shiner	River Mile 28	6	55.5	2.05	196
Red Shiner	River Mile 28	6	60.7	2.61	193
Red Shiner	River Mile 15	6	43.7	0.97	56
Red Shiner	River Mile 15	6	47.8	1.22	58
Red Shiner	River Mile 15	6	50.2	1.46	59
Red Shiner	River Mile 15	6	53.7	1.85	66
Red Shiner	River Mile 15	6	57.3	2.24	67
Red Shiner	River Mile 15	6	62.2	2.98	71
Speckled Dace	River Mile 20	3	50.7	1.42	115
Speckled Dace	River Mile 20	5	57.2	2.07	119
Speckled Dace	River Mile 20	5	60.0	2.35	159
Speckled Dace	River Mile 20	5	62.6	2.79	176
Hitch	River Mile 20	4	76.0	3.96	85
Hitch	River Mile 20	4	82.0	5.17	138
Hitch	River Mile 20	4	97.0	8.01	174

Table 8. Small fish reduced data from replicate multi-individual, whole body composites

Fish Species	**Site**	**n** (comps)	**n** (inds/ comp)	**Avg. Length** (mm total)	**Avg. Weight** (grams)	**Hg** (ng/g = ppb, wet wt)	**Std. Dev.**
Fall 2011 samples							
Green Sunfish	RM 28	4	4	53	2.8	139	± 14
Green Sunfish	RM 20	4	4	57	3.4	84	± 4
Green Sunfish	RM 15	4	4-5	56	3.2	86	± 18
Bluegill Sunfish	RM 28	2	2	61	0.9	136	± 5
Bluegill Sunfish	RM 15	4	4	67	6.0	52	± 4
Largemouth Bass	RM 28	4	3-5	76	5.7	142	± 26
Largemouth Bass	RM 15	3	1	93	10.2	50	± 24
Red Shiner	RM 28	4	10	48	1.0	242	± 36
Hitch	RM 20	4	5	69	2.6	79	± 4
Mosquitofish	RM 15	4	1-10	37	0.7	103	± 48
Spring 2012 Samples							
Green Sunfish	RM 28	4	4-5	68	7.2	142	± 12
Green Sunfish	RM 20	3	1	75	9.7	106	± 17
Green Sunfish	RM 15	4	3	68	6.9	58	± 14
Red Shiner	RM 28	6	6	51	1.6	189	± 12
Red Shiner	RM 15	6	6	53	1.8	63	± 6
Speckled Dace	RM 20	4	5	58	2.2	142	± 30
Hitch	RM 20	3	4	85	5.7	132	± 4

Figure 7. Mean mercury in __2011/2012 small fish__ composite samples, ± standard deviations
(including Cache Creek TMDL 50 ppb 'target wildlife safe' concentration)





comparable data. Previous projects with some comparable small fish data include the initial Lower Cache Creek baseline assessment (Slotton et al. 1997), the CalFed 2000/2001 study (Slotton et al. 2004a) and, particularly for red shiners and green sunfish, the work in and around the Cache Creek Nature Preserve in 2000-2003 (Slotton et al. 2004b).

Red Shiner (*Cyprinella lutrensis*). This small, fast-growing species showed the highest overall small fish mercury levels, with mean concentrations of 242 ppb at River Mile 28 in Fall 2011 and 189 ppb at the same site in Spring 2012. Comparable samples were available at the downstream River Mile 15 site in Spring 2012. They exhibited much lower levels, averaging 63 ppb (0.063 ppm), 1/3 the concentration seen upstream at River Mile 28. This difference between sites was strongly significant statistically.

We have a considerable amount of historic data for this species, from the 1997 baseline study, the 2000-2001 CalFed project and, particularly, from the 2000-2003 work in and around the Cache Creek Nature Preserve. We extracted data for shiners of a size similar to those used in the current study, from same seasons, and from in-channel sites within or relatively near to the study region. Those data are presented for comparison in Table 9 (Fall) and Table 10 (Spring) and, graphically, in Figures 8a and 9a.

The Fall 2011 red shiners from River Mile 28 (242 ppb) were similar to the 2001 River Mile 17 sample (232 ppb) and higher than River Mile 17 in 2000 (162 ppb) and 2002 (164 ppb), and higher than at River Mile 15 in 1997 (159 ppb). The Fall 2011 River Mile 28 sample was higher by a statistically significant amount than River Mile 20 in 2000 (166 ppb), River Mile 15 in 2000-2002 (100-118 ppb), and RIver Mile 8 in 2000 (123 ppb).

The Spring 2012 red shiners from River Mile 28 (189 ppb) were statistically higher than the historic samples from other sites, including River Mile 20 in 2000 (70 ppb), River Mile 17 in 2001-2003 (57-67 ppb), River Mile 15 in 2001-2003 (46-61 ppb), and River Mile 8 in 2000 (81 ppb). The Spring 2012 red shiners from downstream River Mile 15 (63 ppb) were statistically indistinguishable from historic data from other sites, including 2000 data for Rumsey (69 ppb), River Mile 20 (70 ppb), and River Mile 8 (81 ppb), and 2001-2003 data from River Mile 17 (57-67 ppb). In direct comparisons with historic data from the same River Mile 15 site, the 2012 level (63 ppb) was statistically somewhat higher than in 2001 (46 ppb) and statistically unchanged from 2002 (57 ppb) and 2003 (61 ppb).

Largemouth Bass (*Micropterus salmoides*) (juvenile). Young-of-year juvenile largemouth bass were taken at both River Miles 28 and 15 in Fall 2011. Mean mercury concentrations were 142 ppb (0.142 ppm) at River Mile 28, vs. 50 ppb (0.050 ppm) at River Mile 15.

Green Sunfish (*Lepomis cyanellus*) (juvenile). Juvenile green sunfish provide the largest data set of the 2011/12 small fish collections, with good samples from all three sites in both sampled seasons. Mean concentrations ranged between 58 and 142 ppb (0.058-0.142 ppm). Comparing sites, these data are consistent with the large fish findings and those noted above for red shiners and juvenile bass. In both seasons, the most upstream site, River Mile 28, exhibited the highest concentrations, averaging 139 ppb in Fall 2011 and a very similar 142 ppb in Spring 2012. Corresponding samples from the River Mile 20 site were lower, averaging 84 ppb in Fall 2011 (statistically significant) and 106 ppb in Spring 2012. At the most downstream site at River Mile 15, corresponding samples averaged 86 ppb in Fall 2011 and 58 ppb in Spring 2012, both significantly lower than at RM 28.

As for red shiners, we have a fair amount of historic data for juvenile green sunfish, particularly from the 2000-2003 work in and around the Cache Creek Nature Preserve. As with red shiners, we extracted data for young green sunfish samples of a size similar to those used in the current study and from same time periods. These data all come from River Miles 17 and 15, within the study reach and including an overlapping site (RM 15). Those data are presented for comparison in Tables 9 (Fall) and 10 (Spring) and, graphically, in Figures 8b and 9b.

For the Fall fish, 2011 green sunfish from River Mile 28 (139 ppb) were at a level similar or lower than historic samples from River Mile 17 (138-217 ppb) and a little higher than historic samples from River Mile 15 (110-126). 2011 green sunfish from River Mile 20 (84 ppb) and River Mile 15 (86 ppb) were both lower than the historic samples. In same-site comparisons at River Mile 15, the

2011 level (86 ppb) was lower than recorded in 2000-2002 (110-126 ppb) though not statistically different.

In the Spring fish, 2012 green sunfish from River Mile 28 (142 ppb) were statistically higher in mercury than any of the historic Spring samples from River Miles 15 and 17 (70-91 ppb). The 2011 River Mile 20 sample (106 ppb) was higher, but the difference was not statistically significant. The 2011 River Mile 15 sample was lower, also not statistically significant.

Bluegill Sunfish (*Lepomis macrochirus*) (juvenile). Young bluegill were collected at River Miles 28 and 15 in Fall 2011. The upstream composites averaged 136 ppb mercury, while corresponding River Mile 15 samples averaged only 52 ppb, despite being larger fish. The difference between sites was statistically significant.

There are historic data for similar-sized, fall season, juvenile bluegill from 1997, taken just above the Settling Basin at River Mile 5 (Fig. 8c). The 1997 fish averaged 79 ppb in 3 composite samples. In comparison, the 2011 bluegill from River Mile 28 were significantly higher (136 ppb) and the 2011 River Mile 15 bluegill were significantly lower (52 ppb).

Mosquitofish (*Gambusia affinis*). This small species is also likely to end up in the off-channel wet pits / reclaimed lakes. During these collections, they could only be obtained from one creek site and season (Fall 2011, River Mile 15, averaging 103 ppb).

Comparable fall season, historic data for similar sized fish are available from 2002 at the identical site (River Mile 15, 91 ppb) and from River Mile 17 (175 ppb). The 2011 fish from River Mile 15 (103 ppb) were similar in level to the 2002 same-site fish (no statistical difference) and statistically lower than the 2002 River Mile 17 sample.

Hitch (*Lavinia exilicauda*) (juvenile). Juvenile hitch were available from the middle location at River Mile 20. Small hitch averaged 79 ppb in Fall 2011 and 132 ppb in Spring 2012. This rise may have been a function of fish growth between those times.

Speckled Dace (*Rhinichthys osculus*). Speckled dace were available at the middle location at River Mile 20 in the Spring 2012 sampling. The Spring 2012 speckled dace sample averaged 142 ppb.

This 142 ppb average in 2011 was somewhat higher than historic data (Fig. 9c) from similar sized dace from Rumsey in 2000 (112 ppb) and 2001 (106 ppb) and from River Mile 17 in 2001 (113 ppb). The difference was not statistically significant.

SMALL FISH: COMPARISONS TO PREVIOUS CACHE CREEK STUDIES

Table 9. Small fish reduced Fall 2011 data, with closely comparable data from 1997, 2000, and 2000-2002 Cache Creek studies. *(whole body composite samples)*

Fish Species	**Site**	**Year**	**n** (comps)	**n** (inds/ (comp)	**Av Lgth** (mm total)	**Av Wt** (grams)	**Hg** (ng/g = ppb, wet wt)	**Std. Dev.**
Red Shiner	Rumsey	2000	1	3	38	0.5	91	
Red Shiner	**RM 28**	**2011**	**4**	**10**	**48**	**1.0**	**242**	**± 36**
Red Shiner	RM 20	2000	3	9	42	0.6	166	± 3
Red Shiner	RM 17	2000	3	10	39	0.5	162	± 20
Red Shiner	RM 17	2001	3	12	44	0.8	232	± 15
Red Shiner	RM 17	2002	6	1	44	0.7	164	± 64
Red Shiner	RM 15	1997	3	19	37	0.5	159	± 24
Red Shiner	RM 15	2000	3	10	40	0.5	118	± 5
Red Shiner	RM 15	2001	3	25	44	0.9	100	± 13
Red Shiner	RM 15	2002	6	1	46	0.8	106	± 26
Red Shiner	RM 08	2000	4	10	42	0.7	123	± 16
Green Sunfish	**RM 28**	**2011**	**4**	**4**	**53**	**2.8**	**139**	**± 14**
Green Sunfish	**RM 20**	**2011**	**4**	**4**	**58**	**3.4**	**84**	**± 4**
Green Sunfish	RM 17	2000	2	9	60	3.6	185	± 19
Green Sunfish	RM 17	2001	1	6	60	4.0	138	
Green Sunfish	RM 17	2002	6	1	70	6.0	217	± 60
Green Sunfish	RM 15	2000	2	6	63	4.3	110	± 0
Green Sunfish	RM 15	2001	1	8	67	6.2	126	
Green Sunfish	RM 15	2002	6	1	68	5.6	111	± 21
Green Sunfish	**RM 15**	**2011**	**4**	**4-5**	**56**	**3.1**	**86**	**± 18**
Bluegill Sunfish	**RM 28**	**2011**	**2**	**2**	**61**	**0.9**	**136**	**± 5**
Bluegill Sunfish	**RM 15**	**2011**	**4**	**4**	**67**	**6.0**	**52**	**± 4**
Bluegill Sunfish	RM 08	1997	3	7	52	2.5	79	± 6
Mosquitofish	RM 17	2000	1	5	32	0.3	146	
Mosquitofish	RM 17	2002	4	4	34	0.4	175	± 5
Mosquitofish	RM 15	2002	4	5	35	0.4	91	± 11
Mosquitofish	**RM 15**	**2011**	**4**	**1-10**	**37**	**0.7**	**103**	**± 48**

Table 10. **<u>Small fish reduced Spring 2012 data</u>, with closely comparable data from 1997, 2000, and 2001-2003 Cache Creek studies.** *(whole body composite samples)*

Fish Species	**Site**	**Year**	**n** (comps)	**n** (inds/ (comp)	**Av Lgth** (mm total)	**Av Wt** (grams)	**Hg** (ng/g = ppb, wet wt)	**Std. Dev.**
Red Shiner	Rumsey	2000	1	2	50	1.1	69	
Red Shiner	**RM 28**	**2012**	**6**	**6**	**51**	**1.6**	**189**	**± 12**
Red Shiner	RM 20	2000	3	9	43	0.7	70	± 11
Red Shiner	RM 17	2001	3	13	51	2.0	63	± 13
Red Shiner	RM 17	2002	4	13	58	2.2	67	± 10
Red Shiner	RM 17	2003	4	3	53	1.8	57	± 13
Red Shiner	RM 15	2001	3	12	58	2.2	46	± 3
Red Shiner	RM 15	2002	5	15	57	2.3	57	± 6
Red Shiner	RM 15	2003	4	5	53	1.9	61	± 6
Red Shiner	**RM 15**	**2012**	**6**	**6**	**52**	**1.8**	**63**	**± 6**
Red Shiner	RM 08	2000	3	10	46	1.1	81	± 11
Green Sunfish	**RM 28**	**2012**	**4**	**4-5**	**68**	**7.2**	**142**	**± 12**
Green Sunfish	**RM 20**	**2012**	**3**	**1**	**75**	**9.7**	**106**	**± 17**
Green Sunfish	RM 17	2001	1	17	75	6.4	79	
Green Sunfish	RM 17	2002	3	4	66	6.1	83	± 2
Green Sunfish	RM 17	2003	10	1	65	5.4	91	± 12
Green Sunfish	RM 15	2001	1	14	65	5.8	70	
Green Sunfish	RM 15	2002	3	2	68	6.2	70	± 10
Green Sunfish	RM 15	2003	8	1	58	3.8	75	± 16
Green Sunfish	**RM 15**	**2012**	**4**	**2-3**	**68**	**6.9**	**58**	**± 14**
Speckled Dace	Rumsey	2000	2	10	56	2.0	112	± 2
Speckled Dace	Rumsey	2001	3	12	59	2.2	106	± 10
Speckled Dace	**RM 20**	**2012**	**4**	**3-5**	**58**	**2.2**	**142**	**± 30**
Speckled Dace	RM 17	2001	3	8	61	2.5	113	± 11

Figure 8. Small fish <u>Fall</u> seasonal data compared to previous Cache Creek studies: mean Hg ± std. dev. *(directly comparable samples; by river mile site and year, with 50 ng/g small trophic level 3 target wildlife-safe level shown)*

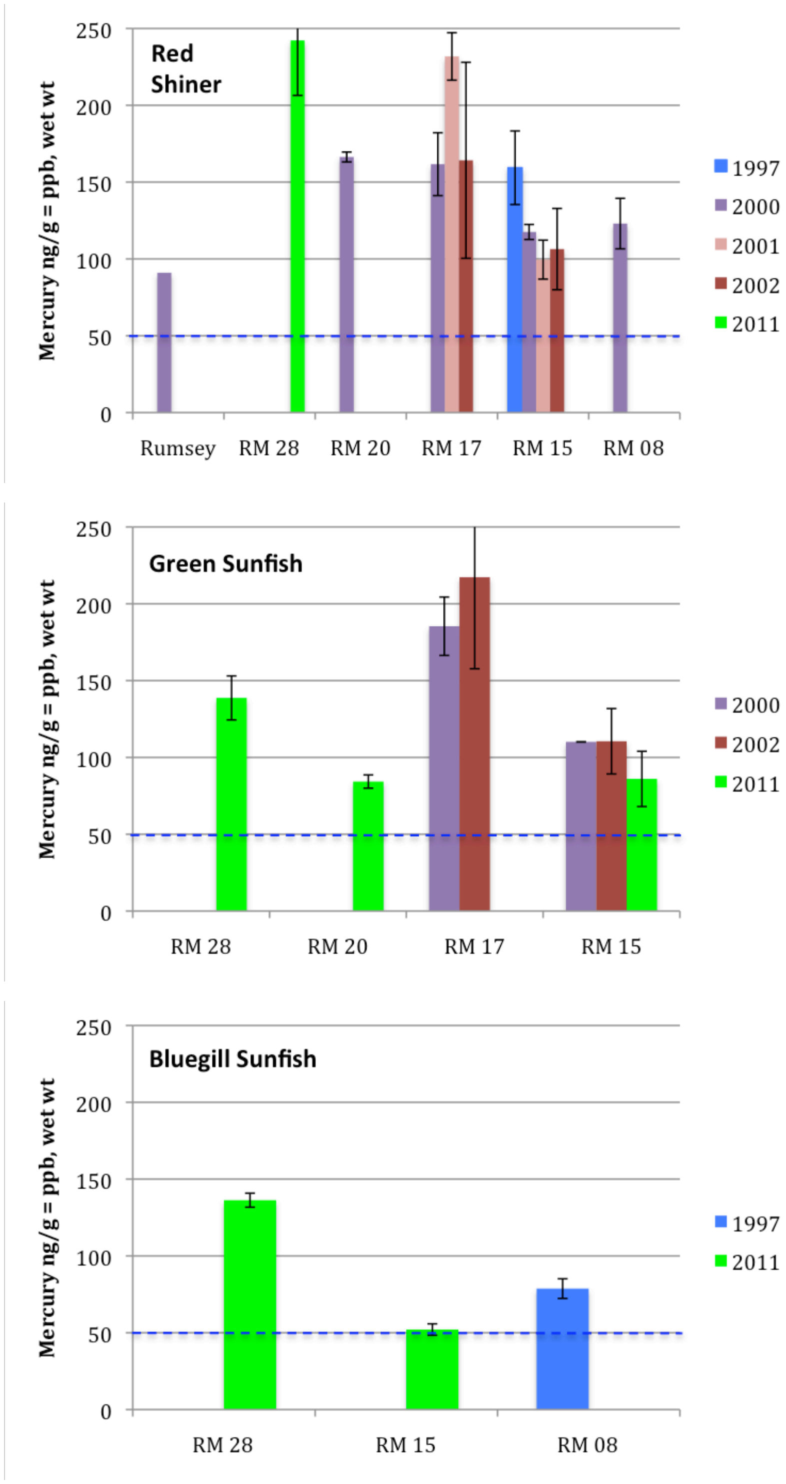
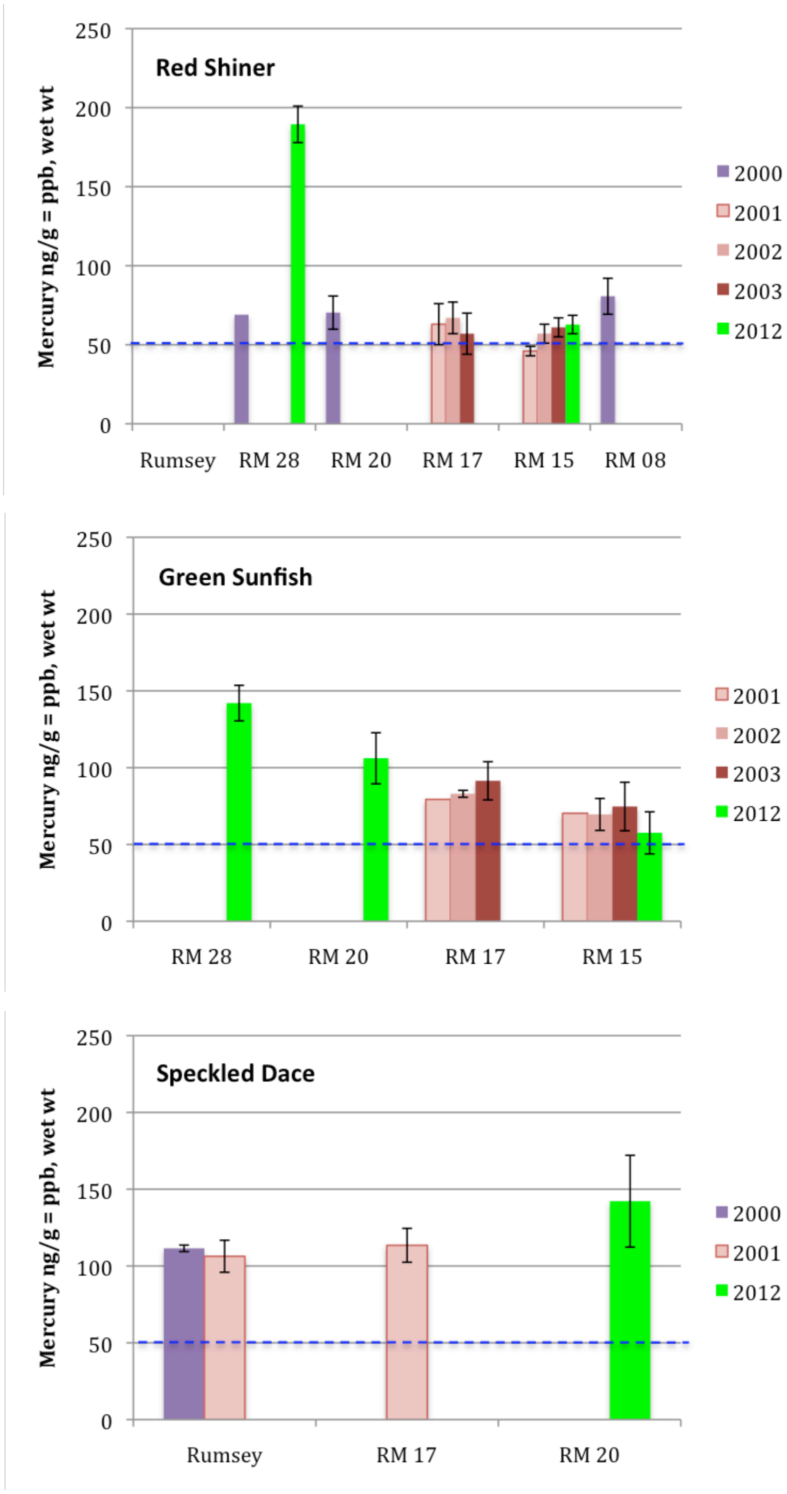


Figure 9. Small fish Fall seasonal data compared to previous Cache Creek studies: mean Hg ± std. dev. *(directly comparable samples; by river mile site and year, with 50 ng/g small trophic level 3 target wildlife-safe level shown)*



Aquatic Insect Mercury

Aquatic insects were collected as a final measure of relative mercury exposure in lower Cache Creek. Certain stream insects can function as excellent biosentinels of short-term exposure and can often show spatial patterns betwen sites to a very fine scale. They can provide strong statistical measures of comparison. We have used them effectively throughout the Sierra Nevada gold country, as well as in Cache Creek and many other watersheds. They were also of interest for potential future comparison with off-channel mining lakes, as aquatic invertebrates may be the only macro-biota available for some monitoring. Mercury concentrations are typically lower than those in the small fish but, as with those samples, relative differences between sites and seasons may often be readily measured.

We were able to accumulate good, triplicate sets of composite samples of Libellulid dragonfly nymphs from all three sites and in both seasons, except for the Spring 2012 River Mile 15 collection with a single composite. Calopterygid damselfy nymphs were available for triplicate composites at all sites in Fall 2011, as were Hydropsychid caddisfly larvae in Spring 2012. Detailed data from each analyzed composite sample are presented in Table 11. Reduced data are shown in Table 12 and, graphically, in Figures 10a and 10b. The data are compared to closely comparable data from earlier studies, as available, in Tables 13-14 and Figures 11-12.

The 2011/12 aquatic insect data were all very similar within each set of replicate samples, partly a function of the high 'n' (number of near-identical individuals used in each composite). The results are consistent with the trends noted for both large fish and small fish. Below, we will discuss the new data from each sample type, and include comparison to earlier projects where there are closely comparable data. Previous projects with some comparable aquatic insect data from single composite samples include the initial Lower Cache Creek baseline assessment (Slotton et al. 1997) and the CalFed 2000/2001 study (Slotton et al. 2004a). The most extensive previous aquatic insect information was accumulated in work around the Cache Creek Nature Preserve in 2000-2003 (Slotton et al. 2004b).

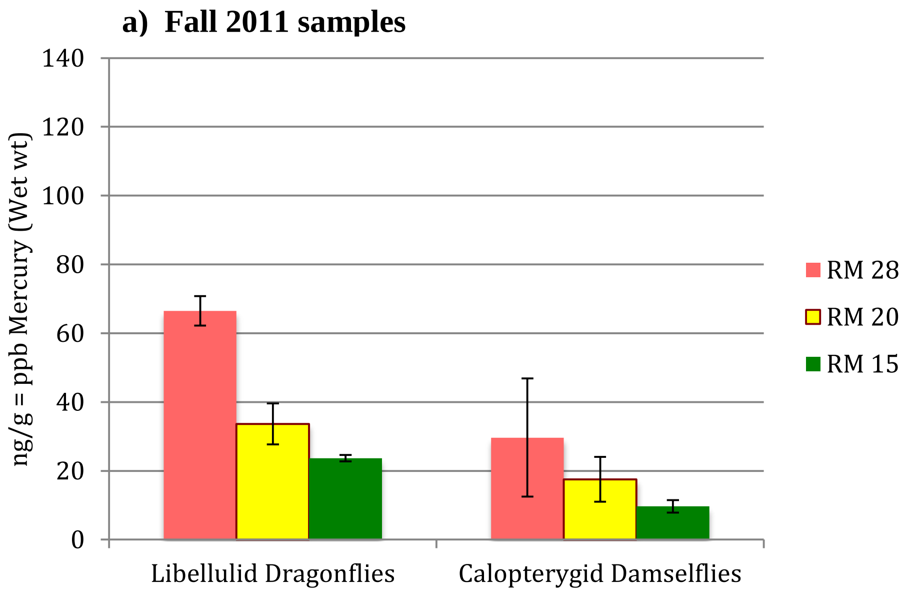
Table 11. Aquatic insects, multi-individual, whole body composite samples.

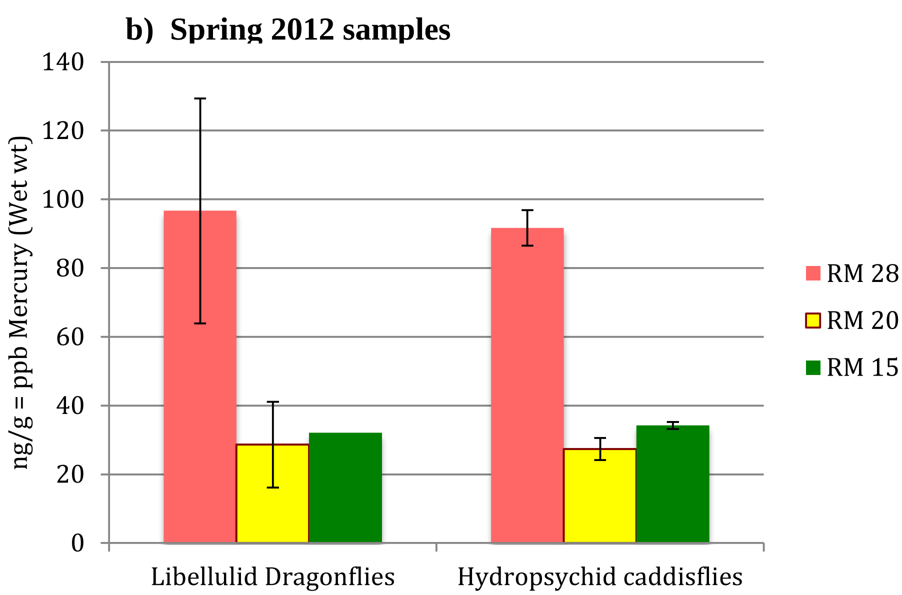
Aquatic Insect Type	Site	n (indivs. in comp)	Avg. Length (mm total)	Avg. Weight (grams)	Whole Body Mercury (ng/g = ppb, wet wt)
Fall 2011 samples					
Libellulid Dragonflies	River Mile 28	17	16.5	0.19	69
Libellulid Dragonflies	River Mile 28	17	16.5	0.20	63
Libellulid Dragonflies	River Mile 28	17	16.5	0.20	67
Libellulid Dragonflies	River Mile 20	14	15.5	0.16	35
Libellulid Dragonflies	River Mile 20	14	15.5	0.16	33
Libellulid Dragonflies	River Mile 20	14	15.5	0.16	33
Libellulid Dragonflies	River Mile 15	14	17.5	0.21	25
Libellulid Dragonflies	River Mile 15	14	17.5	0.21	22
Libellulid Dragonflies	River Mile 15	14	17.5	0.20	24
Calopterygid Damselflies	River Mile 28	20	24.0	0.07	29
Calopterygid Damselflies	River Mile 28	20	24.0	0.07	33
Calopterygid Damselflies	River Mile 28	20	24.0	0.07	27
Calopterygid Damselflies	River Mile 20	20	25.0	0.11	17
Calopterygid Damselflies	River Mile 20	20	25.0	0.10	16
Calopterygid Damselflies	River Mile 20	20	25.0	0.10	20
Calopterygid Damselflies	River Mile 15	20	25.0	0.07	10
Calopterygid Damselflies	River Mile 15	20	25.0	0.07	10
Calopterygid Damselflies	River Mile 15	20	25.0	0.09	9
Spring 2012 samples					
Libellulid Dragonflies	River Mile 28	10	20.5	0.36	95
Libellulid Dragonflies	River Mile 28	10	20.5	0.37	104
Libellulid Dragonflies	River Mile 28	10	20.5	0.35	92
Libellulid Dragonflies	River Mile 20	10	20.0	0.44	26
Libellulid Dragonflies	River Mile 20	10	20.0	0.42	27
Libellulid Dragonflies	River Mile 20	10	20.0	0.42	33
Libellulid Dragonflies	River Mile 15	2	21.0	0.46	32
Hydropsychid caddisflies	River Mile 28	45	11.0	0.03	94
Hydropsychid caddisflies	River Mile 28	45	11.0	0.02	91
Hydropsychid caddisflies	River Mile 28	45	11.0	0.03	90
Hydropsychid caddisflies	River Mile 20	50	11.0	0.03	30
Hydropsychid caddisflies	River Mile 20	50	11.0	0.03	27
Hydropsychid caddisflies	River Mile 20	50	11.0	0.03	26
Hydropsychid caddisflies	River Mile 15	45	15.0	0.04	35
Hydropsychid caddisflies	River Mile 15	45	15.0	0.04	34
Hydropsychid caddisflies	River Mile 15	45	15.0	0.04	33

Table 12. Aquatic insects, reduced data from replicate multi-individual, whole body composites

Aquatic Insect Type	**Site**	**n** (comps)	**n** (inds/ comp)	**Av. Size** (mm total)	**Av. Wt** (grams)	**Hg** (ng/g = ppb, wet wt)	**Std. Dev.**
Fall 2011 samples							
Libellulid Dragonflies	RM 28	3	17	16.5	0.20	67	± 3
Libellulid Dragonflies	RM 20	3	14	15.5	0.16	34	± 1
Libellulid Dragonflies	RM 15	3	14	17.5	0.20	24	± 1
Calopterygid Damselflies	RM 28	3	20	24.0	0.07	30	± 3
Calopterygid Damselflies	RM 20	3	20	25.0	0.10	18	± 2
Calopterygid Damselflies	RM 15	3	20	25.0	0.09	10	± 1
Spring 2012 Samples							
Libellulid Dragonflies	RM 28	3	10	20.5	0.35	97	± 6
Libellulid Dragonflies	RM 20	3	10	20.0	0.42	29	± 4
Libellulid Dragonflies	RM 15	1	2	21.0	0.46	32	
Hydropsychid caddisflies	RM 28	3	45	11.0	0.03	92	± 2
Hydropsychid caddisflies	RM 20	3	50	11.0	0.03	27	± 2
Hydropsychid caddisflies	RM 15	3	45	15.0	0.04	34	± 1

Figure 10. Mean mercury in aquatic insect composite samples, ± standard deviations





Dragonfly nymphs (Libellulidae). The Fall 2011 samples from the upstream River Mile 28 site ranged tightly between 63 and 69 ppb, averaging 67 ppb (0.067 ppm). At the middle site at River Mile 20, corresponding concentrations averaged 34 ppb, approximately half the upstream level, with individual composites ranging tightly between 33 and 35 ppb. At the downstream River Mile 15 site, corresponding concentrations were even lower at 22-25 ppb, averaging 24 ppb. The differences between sites in the fall were all statistically significant. In the Spring 2012 collections, the dragonfly nymphs from the upstream River Mile 28 site were higher in mercury than in Nov-Dec, with concentrations of 92-104 ppb, averaging 97 ppb (0.097 ppm). This statistically significant seasonal increase may have been due in part to the individuals being larger and older. However, similar growth was noted at the other two sites (size data in Tables 8 and 9), with mercury levels remaining low relative to River Mile 28 samples. The Spring 2011 River Mile 20 samples had 26-33 ppb mercury, with an average of 29 ppb, significantly lower. The River Mile 15 single sample had 32 ppb, also much lower.

There are several historic samples to compare to, mostly single composites from 1997-2003. The Fall 2011 dragonflies from River Mile 28 (67 ppb) were at a similar level as River Mile 15 in 1997 (63 ppb) and River Mile 17 in 2001 (56 ppb), and higher than the remaining historic samples from Rumsey in 2000 (18 ppb), RM 17 in 2000 (44 ppb), and RM 15 in 2001 (28 ppb). The Fall 2011 sample from River Mile 20 (34 ppb) was lower than earlier samples from nearby River Mile 17 (44-56 ppb). The Fall 2011 dragonflies from River Mile 15 (24 ppb) had direct comparisons from the same site and were substantially lower than the 1997 sample (63 ppb) and similar to the 2001 sample (28 ppb).

The Spring data for dragonflies also have some historic comparative information. The Spring 2012 sample from River Mile 28 (97 ppb) was higher than a 2001 River Mile 17 sample (53 ppb) and much higher than the 5 other historic samples taken between River Miles 20 and 15 (22-33 ppb). However, the Spring 2011 collections from the lower two sites of the current study, River Mile 20 (29 ppb) and River Mile 15 (32 ppb), fell within the historic range.

Damselfly nymphs (Calopterygidae). Very closely matching samples of Calopterygid damselfly nymphs were collected from each of the sites in Fall 2011, with triplicate composites of 20 individuals each from each location. The upstream River Mile 28 set averaged 30 ppb (0.030 ppm), with a range of 27-33 ppb. This was a low concentration relative to the dragonflies from the same site, but high relative to the matching damselfly collections from downstream. At River Mile 20, concentrations averaged 18 ppb, with a range of 16-20 ppb. At River Mile 15, levels were lower still at 9-10 ppb. The differences between each of the sites were all statistically significant.

A fair amount of fall season historic data are available, particularly from the 2000-2003 Nature Preserve area study. There are 9 historic fall sample sets, 6 with multiple replicates that can be compared statistically to the 2011 samples. The 2011 River Mile 28 sample (30 ppb) was at a similar level or lower than 4 of the 9 historic samples (26-40 ppb) and higher than the other 5 historic samples (12-22 ppb). The elevation was statistically significant over the lowest historic sample (RM 15, 2002, 12 ppb). The 2011 downstream sample from River Mile 20 (18 ppb) was lower than 7 of 9 historic samples (12-40 ppb total range); the difference was significantly lower in 4 comparisons. The Fall 2011 River Mile 15 damselflies (10 ppb) were lower in mercury than any of the historic samples, including 4 historic sets from the exact same location (12-34 ppb). The 2011 River Mile 15 level was within the lower end of the historic range statistically for the same site, and was statistically lower than the historic data from upstream River Mile 17.

Caddisfly larvae (Hydropsychidae). Hydropsychid caddisfly larvae were taken from all three sites in Spring 2102, with matching triplicate sets of 45-50 individuals per composite sample. Mercury in the upstream River Mile 28 set ranged between 90 and 94 ppb, averaging 92 ppb (0.092 ppm). At River Mile 20, levels were much lower at 26-30 ppb, averaging 27 ppb. At the downstream site at River Mile 15, sets of larger individuals than at the other two sites ranged from 33-35 ppb, averaging 34 ppb. The River Mile 17 and River Mile 15 caddisflies were both significantly lower in mercury than those from upstream River Mile 28.

Historic spring data were also available for these insects, particularly from the 2000-2003 Nature Preserve area study. Like the Spring 2011 dragonflies, the Spring 2011 caddisflies from upstream River Mile 28 (92 ppb) were substantially higher in mercury than any of the other 2011 or historic samples (20-44 ppb in 8 of 9 historic samples, 59 ppb at River Mile 8 in 2000). The elevation was significant for the 5 historic comparisons that could be made statistically. Also like the other invertebrate samples, the Spring 2012 caddisflies from downstream River Mile 20 (27 ppb) and River Mile 15 (34 ppb) fell within the historic range seen along that portion of the creek (20-44 ppb). In same-site comparisons at River Mile 15, the 2011 average (34 ppb) was a little lower than 2001 (37 ppb) and a little higher than 2002 and 2003 (20-26 ppb, statistically significant). The slightly larger/older nature of the 2011 caddisflies may have contributed to the slight apparent mercury elevation.

AQUATIC INSECTS: COMPARISONS TO PREVIOUS CACHE CREEK STUDIES

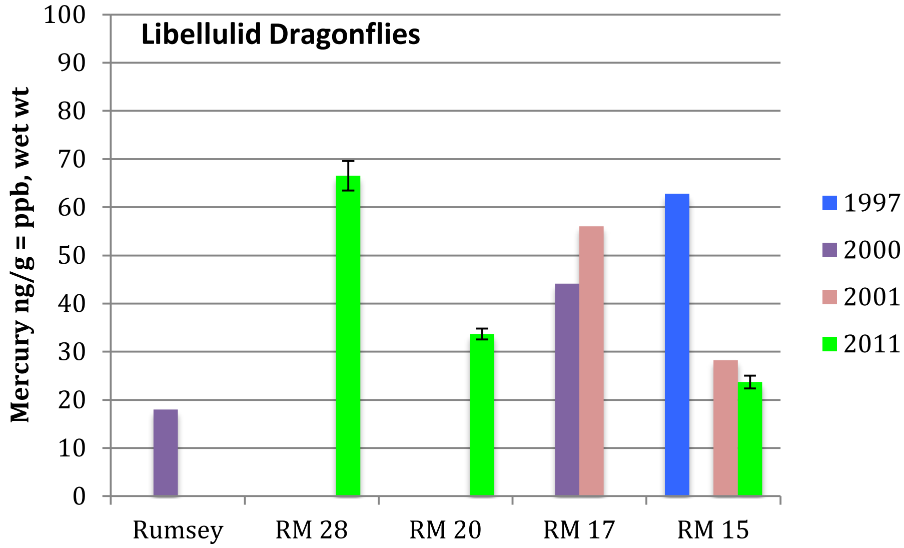
Table 13. Aquatic insect reduced Fall 2011 data, with closely comparable data from 1997, 2000, and 2000-2002 Cache Creek studies.
(whole body composite samples; Libellulid dragonfly and Calopterygid damselfly nymphs)

Aquatic Insect Type	Site	Year	n (comps)	n (inds/ (comp)	Av Lgth (mm total)	Av Wt (grams)	Hg (ng/g = ppb, wet wt)	Std. **Dev.**
Dragonflies	Rumsey	2000	1	31	14		18	
Dragonflies	**RM 28**	**2011**	**3**	**17**	**17**	**0.19**	**67**	**± 3**
Dragonflies	**RM 20**	**2011**	**3**	**14**	**16**	**0.16**	**34**	**± 1**
Dragonflies	RM 17	2000	1	11	15		44	
Dragonflies	RM 17	2001	1	16	15		56	
Dragonflies	RM 15	1997	1	2	18		63	
Dragonflies	RM 15	2001	1	5	16		28	
Dragonflies	**RM 15**	**2011**	**3**	**14**	**18**	**0.20**	**24**	**± 1**
Damselflies	**RM 28**	**2011**	**3**	**20**	**24**	**0.07**	**30**	**± 3**
Damselflies	RM 20	2000	1	18	23		22	
Damselflies	**RM 20**	**2011**	**3**	**20**	**25**	**0.10**	**18**	**± 2**
Damselflies	RM 17	2000	3	23	23		22	± 1
Damselflies	RM 17	2001	3	13	21		40	± 14
Damselflies	RM 17	2002	4	16	23		30	± 4
Damselflies	RM 15	1997	1	13	28		34	
Damselflies	RM 15	2000	3	9	22		26	± 5
Damselflies	RM 15	2001	3	16	24		21	± 4
Damselflies	RM 15	2002	4	28	23		12	± 0
Damselflies	**RM 15**	**2011**	**3**	**20**	**25**	**0.08**	**10**	**± 1**
Damselflies	RM 08	2000	1	20	23		15	

Table 14. Aquatic insect reduced Spring 2012 data, with closely comparable historic data from 1997, 2000, and 2001-2003 Cache Creek studies.
(whole body composite samples; Libellulid dragonfly nymphs and Hydropsychid caddisfly larvae)

Aquatic Insect Type	**Site**	**Year**	**n** (comps)	**n** (inds/ (comp)	**Av Lgth** (mm total)	**Av Wt** (grams)	**Hg** (ng/g = ppb, wet wt)	**Std. Dev.**
Dragonflies	**RM 28**	**2012**	**3**	**10**	**21**	**0.36**	**97**	**± 6**
Dragonflies	Rm 20	2000	1	17	19		24	
Dragonflies	**RM 20**	**2012**	**3**	**10**	**20**	**0.43**	**29**	**± 4**
Dragonflies	RM 17	2001	1	3	21		53	
Dragonflies	RM 17	2002	1	14	18		29	
Dragonflies	RM 17	2003	4	20	22		29	± 1
Dragonflies	RM 15	2002	1	5	18		22	
Dragonflies	RM 15	2003	3	6	22		33	± 11
Dragonflies	**RM 15**	**2012**	**1**	**2**	**21**	**0.46**	**32**	
Caddisflies	Rumsey	2000	1	163	11		38	
Caddisflies	**RM 28**	**2012**	**3**	**45**	**11**	**0.03**	**92**	**± 2**
Caddisflies	Rm 20	2000	1	91	12		44	
Caddisflies	**RM 20**	**2012**	**3**	**50**	**11**	**0.03**	**27**	**± 2**
Caddisflies	RM 17	2001	3	80	10		43	± 1
Caddisflies	RM 17	2002	4	42	11		29	± 1
Caddisflies	RM 17	2003	4	70	12		25	± 1
Caddisflies	RM 15	2001	3	50	12		37	± 8
Caddisflies	RM 15	2002	4	50	12		20	± 1
Caddisflies	RM 15	2003	3	49	12		26	± 2
Caddisflies	**RM 15**	**2012**	**3**	**45**	**15**	**0.04**	**34**	**± 1**
Caddisflies	RM 08	2000	1	30	10		59	

Figure 11. Aquatic Insect <u>Fall</u> seasonal data compared to previous Cache Creek studies.
(mean Hg ± std. dev., directly comparable samples; by river mile and year)



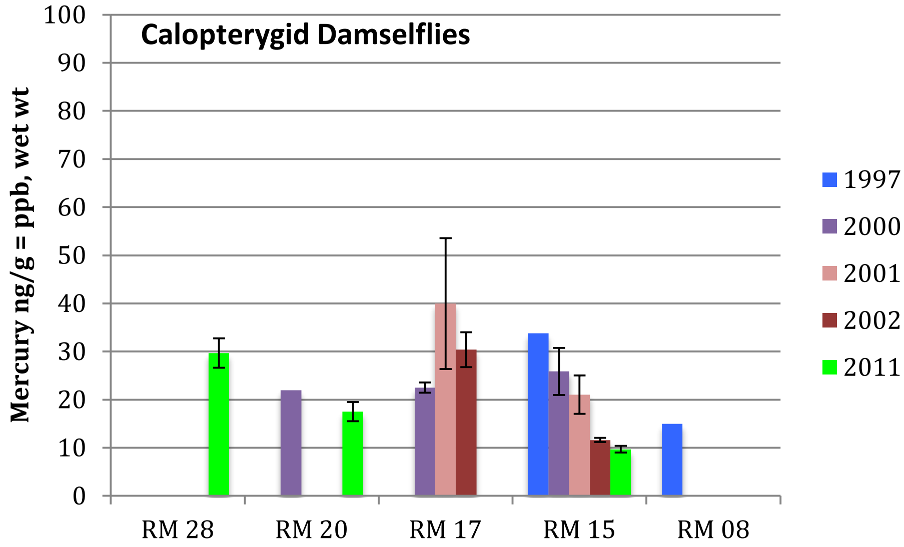
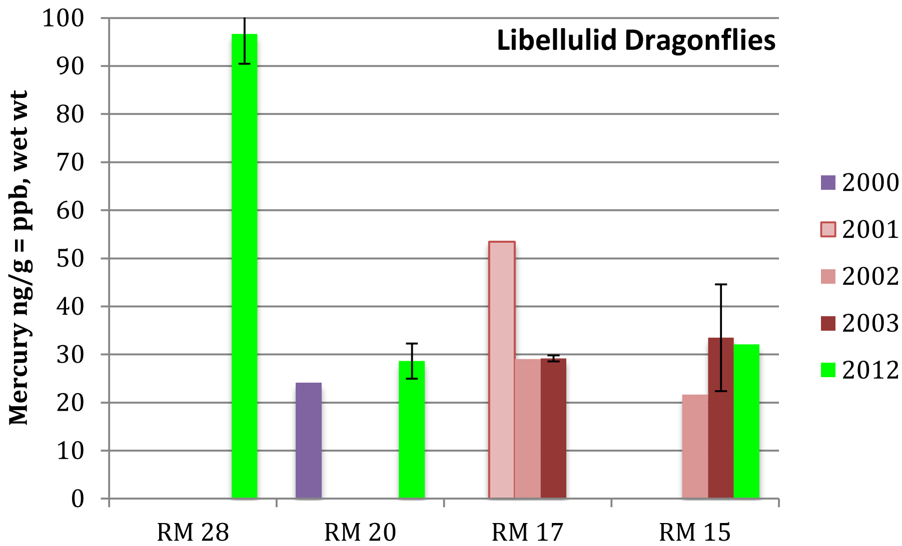
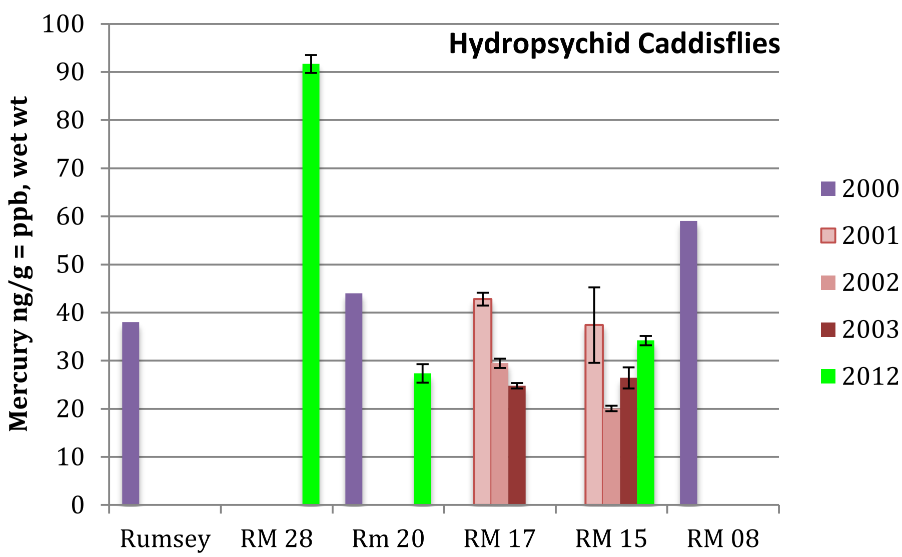


Figure 12. Aquatic Insect Fall seasonal data compared to previous Cache Creek studies.
(mean Hg ± std. dev., directly comparable samples; by river mile and year)





Conclusions

The mercury data collected in this study from large fish, small fish, and aquatic insects provide a new addition and update to the set of baseline mercury information available for lower Cache Creek. By shifting the sampling zone to the River Mile 15 through River Mile 28 stretch, we have added data for the portion of creek that is right next to the off-channel gravel mining zone, rather than the downstream Settling Basin location used in 1997. These data can be used as a new benchmark for comparisons with future monitoring in that portion of Cache Creek, as well as in off-channel gravel mining ponds. The types of samples we were able to collect from that portion of the creek include the species most likely to colonize the nearby off-channel ponds.

In addition to providing new mercury data in general, this study also lets us make several comparisons, including: 1) a spatial comparison between the three sites River Miles 28, 20, and 15, 2) a seasonal comparison for small fish and aquatic insects taken in Fall 2011 and Spring 2012, and 3) a long-term comparison of the new data with historic data from 1997-2003.

Comparison of Sites. The new sets of data are consistent across all three sample types in showing an interesting spatial trend in biotic mercury across the lower creek below Capay Dam. All direct comparisons, where it was possible to collect closely matching samples, indicate highest exposure and bioaccumulation at River Mile 28 at the top of this stretch (just below Capay Dam), with lower levels at the downstream sites between Hwy 505 and Woodland (River Miles 20 and 15). The differences were all statistically significant (Table 15). This included the large fish Sacramento pikeminnows and green sunfish, the small fish red shiners and juveniles of green sunfish, largemouth bass, and bluegill sunfish, as well as the dragonfly, damselfy, and caddisfly aquatic insect samples.

Comparison of Seasons (Fall 2011 vs Spring 2012). Large fish do not normally show dramatic changes in their mercury levels seasonally, because their mercury levels are an average of accumulation across years. Small fish and aquatic insects, in contrast, are typically only months old, so their mercury levels strongly reflect recent conditions. In previous work in and

Table 15. Comparison of mercury levels between the three 2011-2012 Cache Creek sites, for sample types that were available at multiple sites.
(mean ng/g mercury ± standard deviation)

>> statistically higher than both other sites
> statistically higher than next site
= statistically overlapping

Sample Type	River Mile 28		River Mile 20		River Mile 15
Large Fish					
Sacramento Pikeminnow	**726** ± 142	>			**327** ± 86
Green Sunfish	**540** ± 50	>>	**138** ± 41	=	**195** ± 43
Small Fish					
Red Shiner (Spring)	**189** ± 12	>			**63** ± 6
Green Sunfish (Fall)	**139** ± 14	>>	**84** ± 4	=	**86** ± 18
Green Sunfish (Spring)	**142** ± 12	>>	**106** ± 17	>	**58** ± 14
Largemouth Bass (Fall)	**142** ± 26	>			**50** ± 24
Aquatic Insects					
Dragonflies (Fall)	**67** ± 3	>>	**34** ± 1	>	**24** ± 1
Dragonflies (Spring)	**97** ± 6	>>	**29** ± 2		**32**

around the Cache Creek Nature Preserve (Slotton et al. 1994b), we found fall samples to often be highest in mercury and spring samples lowest. In the 2011-2012 work, spring small fish samples were lower than matching fall samples for red shiners at River Mile 28 and young green sunfish at River Mile 15, though the differences were not statistically significant. In the other two matching seasonal small fish comparisons, spring mercury levels were either unchanged vs fall (green sunfish at River Mile 28) or slightly higher (green sunfish at River Mile 20). Among the aquatic insect samples, dragonflies were taken in both seasons: at River Miles 28 and 15, concentrations were higher in the spring; at River Mile 20, they were lower. None of the aquatic insect seasonal differences were statistically significant. So, though we have shown significant seasonal differences in other years along this portion of Cache Creek, that was not the case in 2011-2012.

Comparison of 2011-2012 data with historic data from 1997-2003.

Comparison with older studies is complicated by project-based differences in sampling sites and differences in species and sizes of individuals available for analysis. Each of these factors can be critical, making it difficult or impossible to make direct comparisons. For example, the 2011 large fish collections between River Miles 15 and 28 found different species and different sizes than were present in the initial 1997 study in the downstream Settling Basin. The 2000-2001 CalFed Study and 2000-2003 Nature Preserve Study included several identical sample types, but only one site each that matched the new project. In the discussion sections above, we have presented the best comparison data we could assemble in Tables 5, 9, 10, 13, and 14, and in Figures 5, 6, 8, 9, 11, and 12. In Table 16, we have reduced and summarized all of the meaningful comparisons with historic data, listing for each sample type and site whether the new data are statistically higher, lower, or unchanged relative to the 95% level of significance. Higher concentrations were seen for many sample types in 2011-2012 at River Mile 28 in comparison to historic data, but that site was not sampled in the earlier studies. Because of normal variability in the large fish data, comparison with historic numbers from other sites located between Rumsey and the Settling Basin showed no statistical differences. However, small fish and aquatic insect samples are often able to better show differences, where they exist. Among the River Mile 28 samples of small fish and aquatic insects that could be compared to historic data from the other sites, half showed a statistically higher level in 2011-2012. In contrast, at the middle and downstream sites (River Miles 20 and 15), of 13 small

Table 16. General comparison of the new 2011-2012 mercury data with closely comparable historic data from 1997-2003. For matching sample types/sizes and closest sites *(relative statistical differences of new data vs old, 95% confidence level)*

Sample Type	River Mile 28	River Mile 20	River Mile 15
Large Fish			
Smallmouth Bass	same		
Largemouth Bass	same		
Sacramento Pikeminnow	same		same
Green Sunfish	same	same	same
Bluegill Sunfish	same		
Sacramento Sucker			same
Small Fish			
Red Shiner (Fall)	same		
Red Shiner (Spring)	**up**		same
Green Sunfish (Fall)	same	**down**	same
Green Sunfish (Spring)	**up**	same	same
Bluegill Sunfish (Fall)			**down**
Mosquitofish (Fall)			same
Speckled Dace (Spring)		same	
Aquatic Insects			
Dragonflies (Spring)		same	same
Damselflies (Fall)	same	same	**down**
Caddisflies (Spring)	**up**	same	
same			

fish and aquatic insect comparisons with closely corresponding historic data, 10 showed no change and 3 were statistically lower than historic data from 1997-2003.

Based on the comparison between sites in the new work, and comparison with historic data, the River Mile 28 site appears to be elevated in its mercury exposure level to local biota, even in relation to Cache Creek in general being high in mercury. This may be in some way related to conditions created by the Capay Diversion Dam, or could be unrelated. To our knowledge, this site has not been studied before. In any case, at the middle (River Mile 20) and downstream (River Mile 15) sites, mercury levels appear to be stabilized at or below levels recorded in earlier monitoring.

References Cited

Cooke, J., C. Foe, S. Stanish, and P. Morris. 2004. Cache Creek, Bear Creek, and Harley Gulch TMDL for Mercury, Staff Report. *California Environmental Protection Agency, Regional Water Quality Control Board, Central Valley Region*. 135 pp.

Slotton, D.G., S.M. Ayers, and J.E. Reuter. 1997. Mercury in lower Cache Creek biota: baseline assessment, Fall 1997. *Report prepared for Yolo County Planning Dept.*, December 1997, 28 pp.

Slotton, D.G., S.M. Ayers, T.H. Suchanek, R.D. Weyand, and A.M. Liston. 2004(a). Mercury bioaccumulation and trophic transfer in the Cache Creek watershed of California, in relation to diverse aqueous mercury exposure conditions. *Report for the CALFED Bay-Delta Agency*. 137 pp.

Slotton, D.G., and S.M. Ayers. 2004(b). Cache Creek Nature Preserve pilot mercury monitoring program: sixth and final semi-annual data report, spring - summer 2003, with three-year project overview. *Report for Yolo County*. 56 pp.

APPENDIX I

Photographs of sampling sites and biological samples analyzed for this report

Figure A1. Nov-Dec 2011 large fish for individual muscle mercury analyses, RM28 site.

a. Collecting fish from Cache Creek just below Capay Dam

b. River Mile 28 smallmouth bass

c. River Mile 28 largemouth bass

(continued)

Figure A1 (cont.). Nov-Dec 2011 RM28 large fish for individual muscle mercury analyses.

d. River Mile 28 Sacramento pikeminnows

e. River Mile 28 channel catfish

e. River Mile 28 larger sunfish: bluegill, blue-green hybrids, and green sunfish

Figure A2. Nov-Dec 2011 large fish for individual muscle Hg analyses, River Miles 20 and 15.

a. River Mile 20 site of Cache Creek below Hwy 505, Nov-2011

b. River Mile 20 black crappie and green sunfish

c. River Mile 15 site of Cache Creek below Co, Rd. 94B, Dec-2011

(continued)

Figure A2 (cont). Nov-Dec 2011 River Mile 20 and 15 large fish for Hg analyses.

d. River Mile 15 Sacramento pikeminnows

e. River Mile 15 green sunfish

f. River Mile 15 Sacramento suckers

Figure A3. Nov-Dec 2011 small bioentinel fish and insect collections; representative samples.

a. Juvenile sunfish and bass from River Mile 28, before sorting and separating into comps

b. Juvenile bass, sunfish, and hitch from River Mile 20

c. Juvenile bluegill and green sunfish from River Mile 15

d. Representative aquatic insect samples prior to separating into composites: Libellulid dragonfly nymphs (back), Lestid damselfy nymphs; from River Mile 28

Figure A4. May-June 2012 small bioentinel fish and insect collections at River Mile 28.

a. Collecting small fish below Capay Dam

b. Juvenile green sunfish, red shiners

c. Hydropsychid caddisfly larva composites

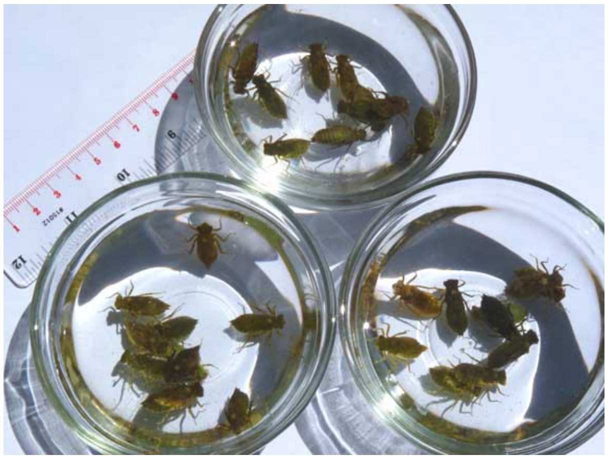
d. Libellulid dragonfly nymph composites

Figure A5. May-June 2012 small bioentinel fish and insect collections at River Mile 20.

a. Sampling small fish at River Mile 20

b. Juv. green sunfish, hitch, speckled dace

c. Hydropsychid caddisfly larva composites



d. Libellulid dragonfly nymph composites

Figure A6. May-June 2012 small bioentinel fish and insect collections at River Mile 15.

a. Collecting samples at River Mile 15

b. Hydropsychid caddisfly larva composites

c. Red shiners

d. Juvenile green sunfish

APPENDIX II

Slides from "Baseline Mercury" Presentation
July 9, 2013

LOWER CACHE CREEK 2011-2012 BASELINE MERCURY MONITORING

Final Report
June 2013

Monitoring and Report by

Darell G. Slotton, Ph.D.
and
Shaun M. Ayers

Mercury Talk Overview:

- **Some basics on mercury in general and the California mercury situation**

- **<u>Results of this latest set of creek collections</u> and how this information might be used**

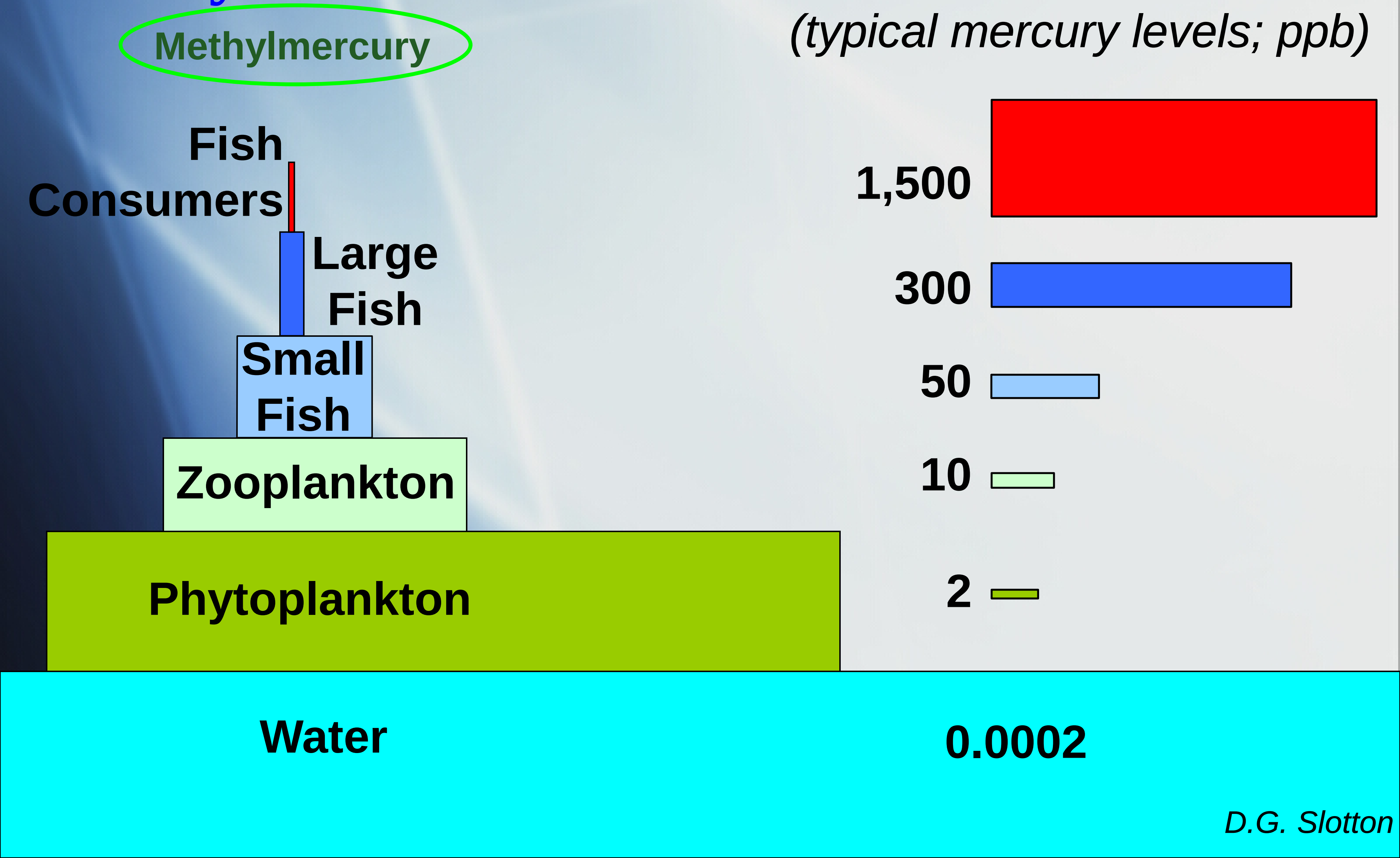
- **(Mercury research in the Cache Creek watershed)**

- **Q & A**

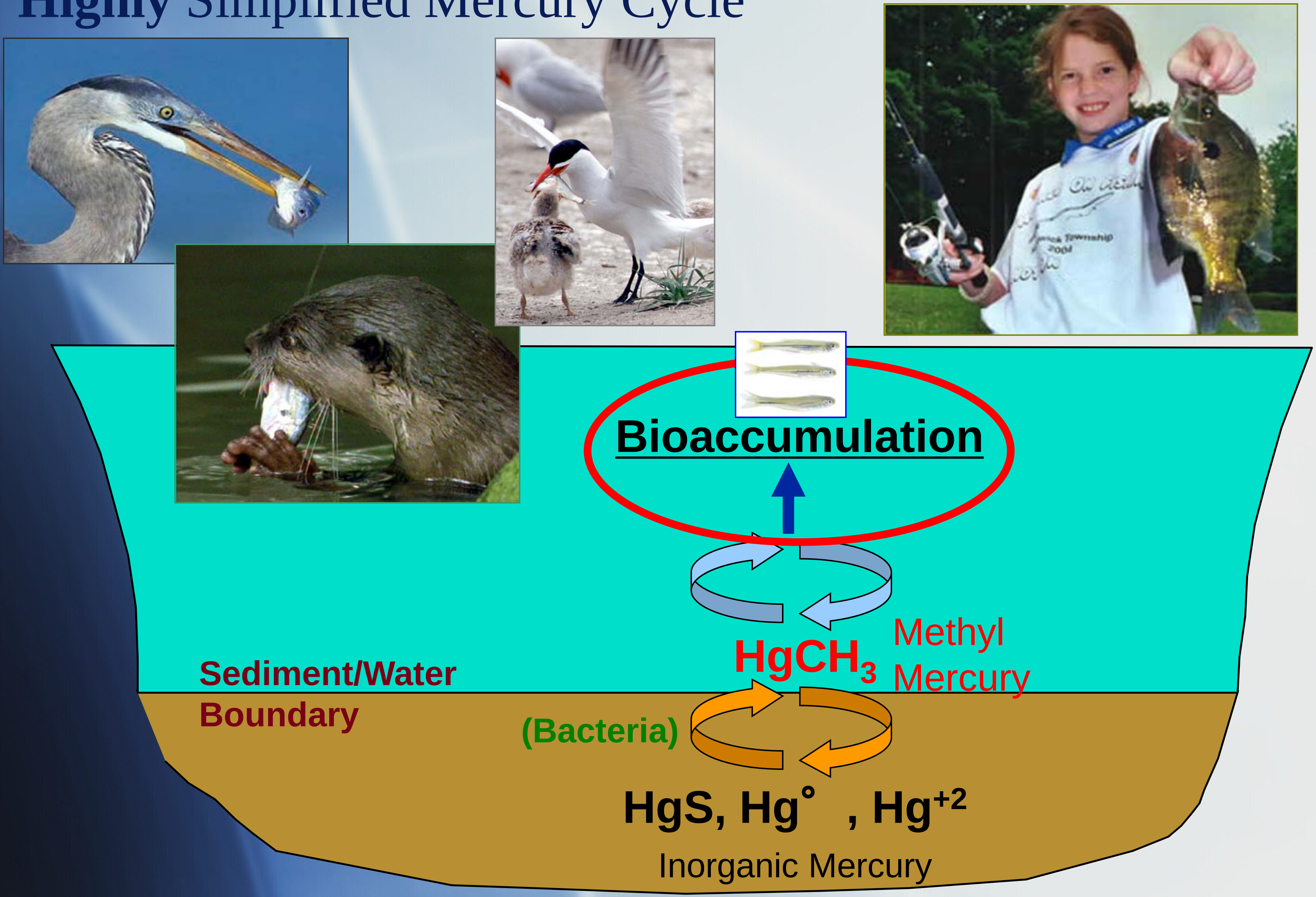
California: Bulk Mercury Contamination

• UC Davis Mercury Projects

Trophic Mercury "Pyramid"



Highly Simplified Mercury Cycle



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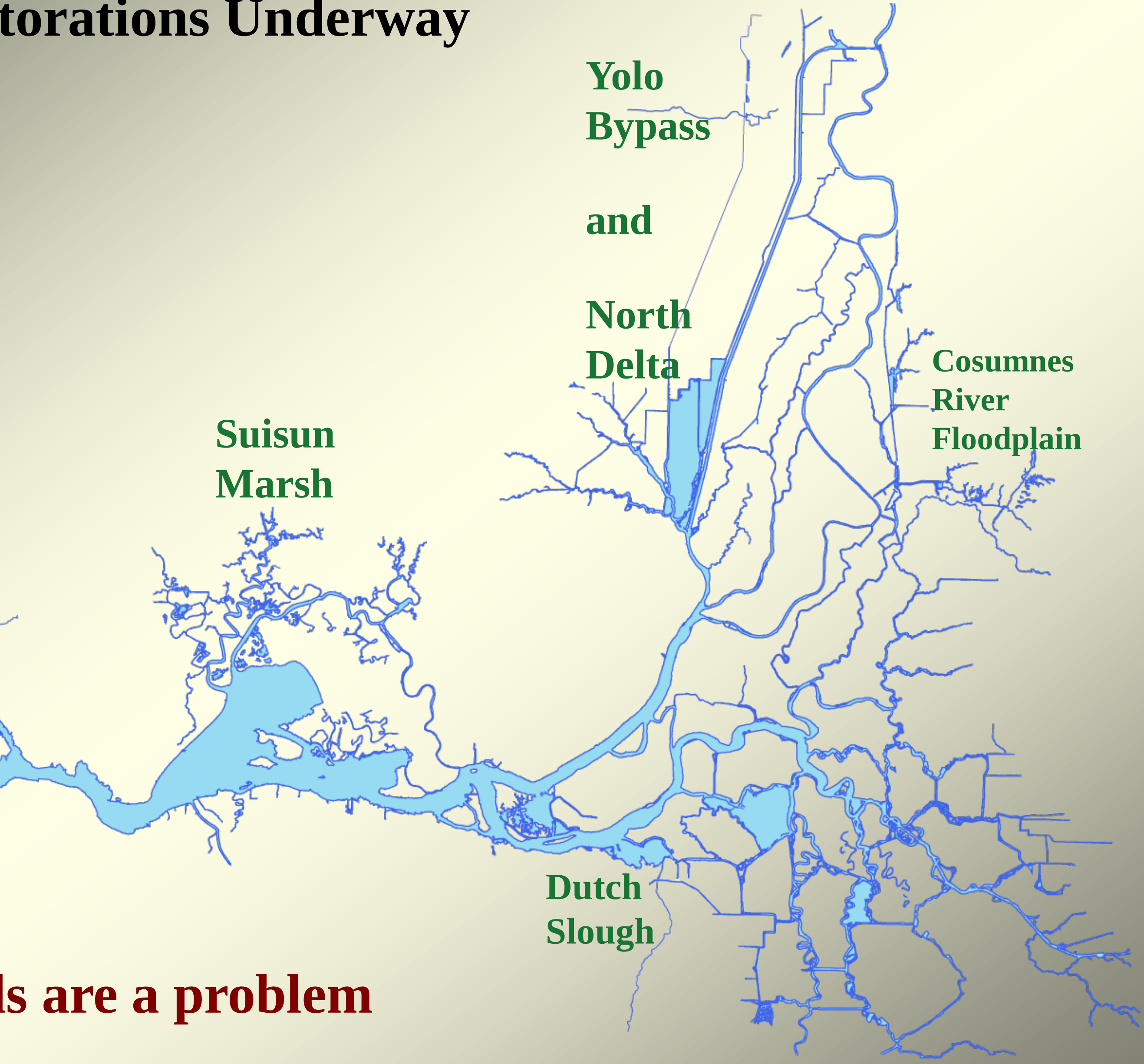
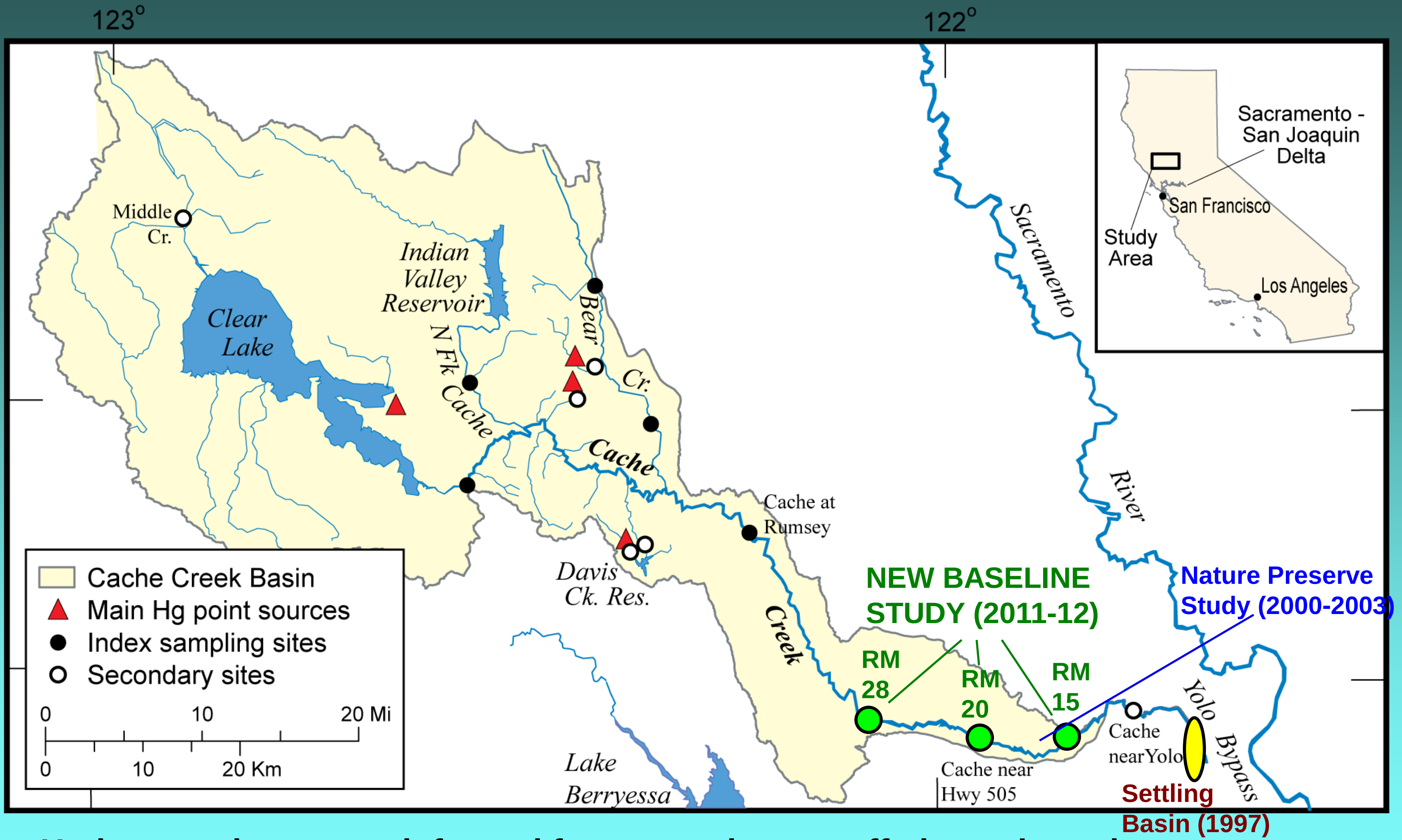
Large Wetland Restorations Underway



- Not all wetlands are a problem
- Seasonal drying and flooding is key

Cache Creek watershed, CalFed project (2000-2001)

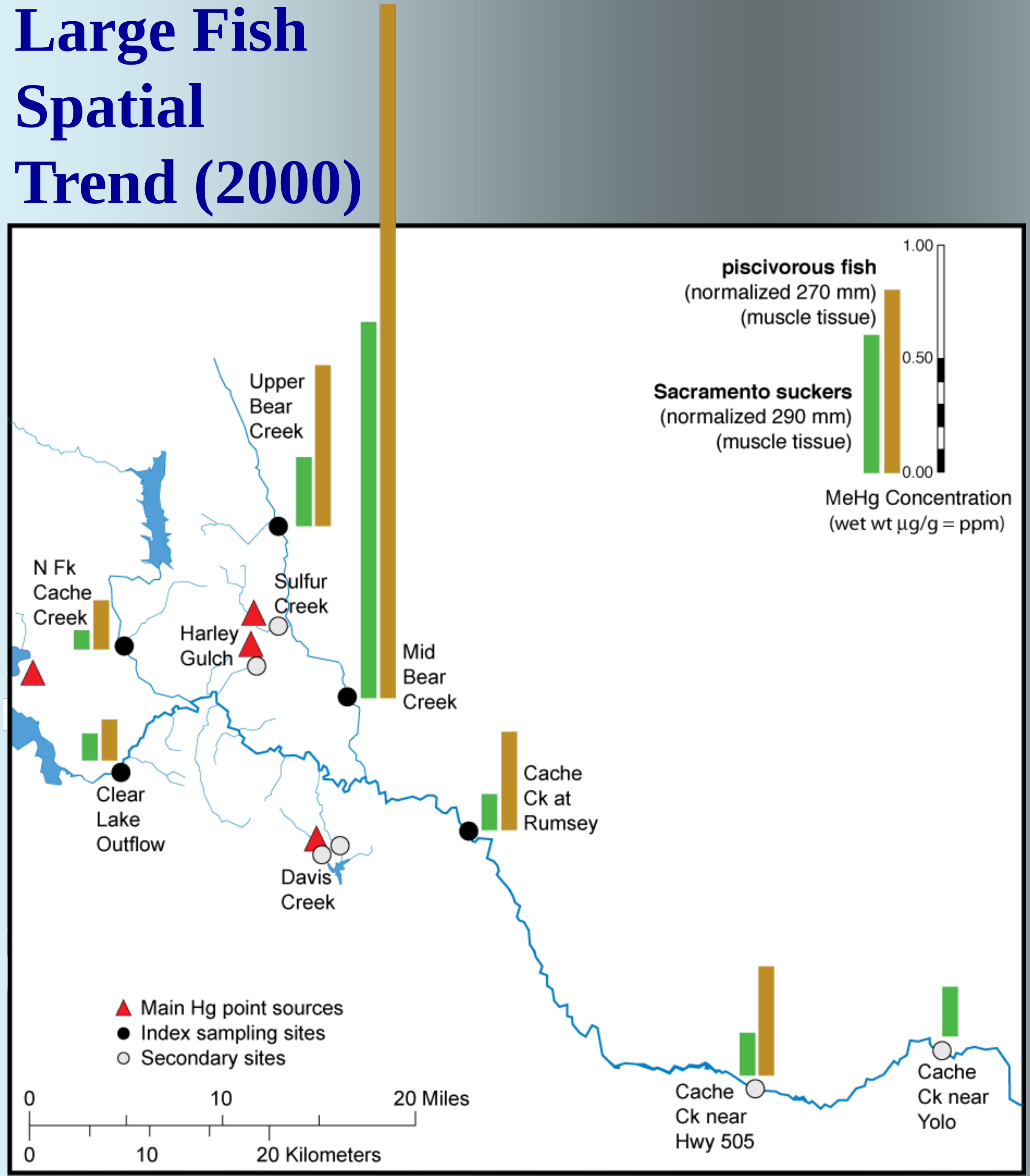


- **Update creek mercury info, and for comparison to off-channel ponds**
- **Compare between the three River Mile sites**
- **Compare the new creek numbers with older (1997-2003) data from other projects**

(with photos)

- Update creek mercury info, and for comparison to off-channel ponds
- Compare between the three River Mile sites
- Compare the new creek numbers with older (1997-2003) data from other projects

Large Fish Spatial Trend (2000)



- Bear Creek highly elevated
- Main inflows low
- App. doubling of fish Hg well downstream of point sources

- **Cache Settling Basin large fish mercury 1997**
  - **64 samples, 12 species**
  - **0.15-1.21 ppm (150-1,210 ppb)**
  - **mostly catfish, crappie, and carp**

New collections

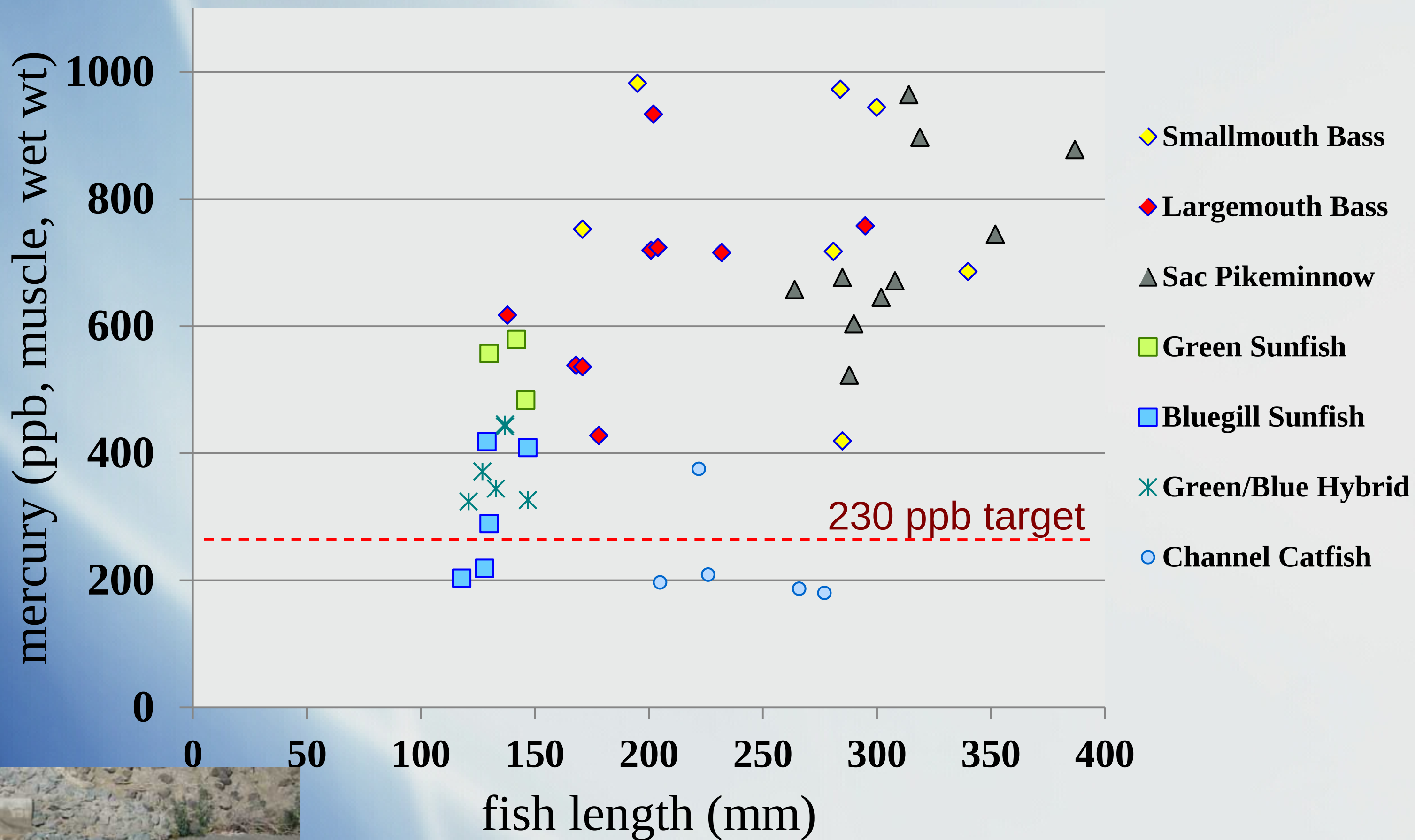
Large Fish

Small Fish

Aquatic Insects

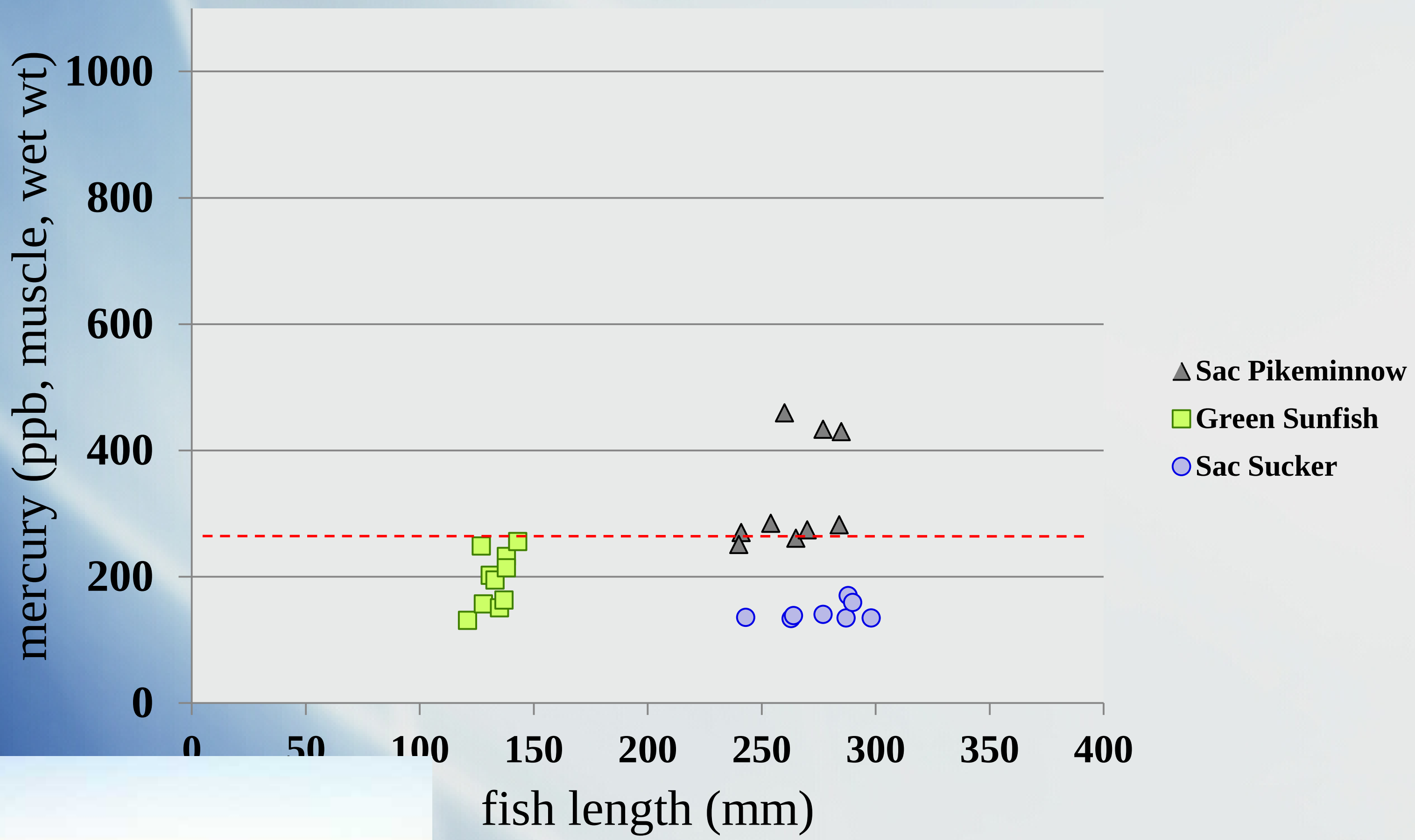
- First into ponds
- Often best comparisons to creek
- Quick feedback

<u>Large fish</u> at River Mile 28: Size vs Mercury



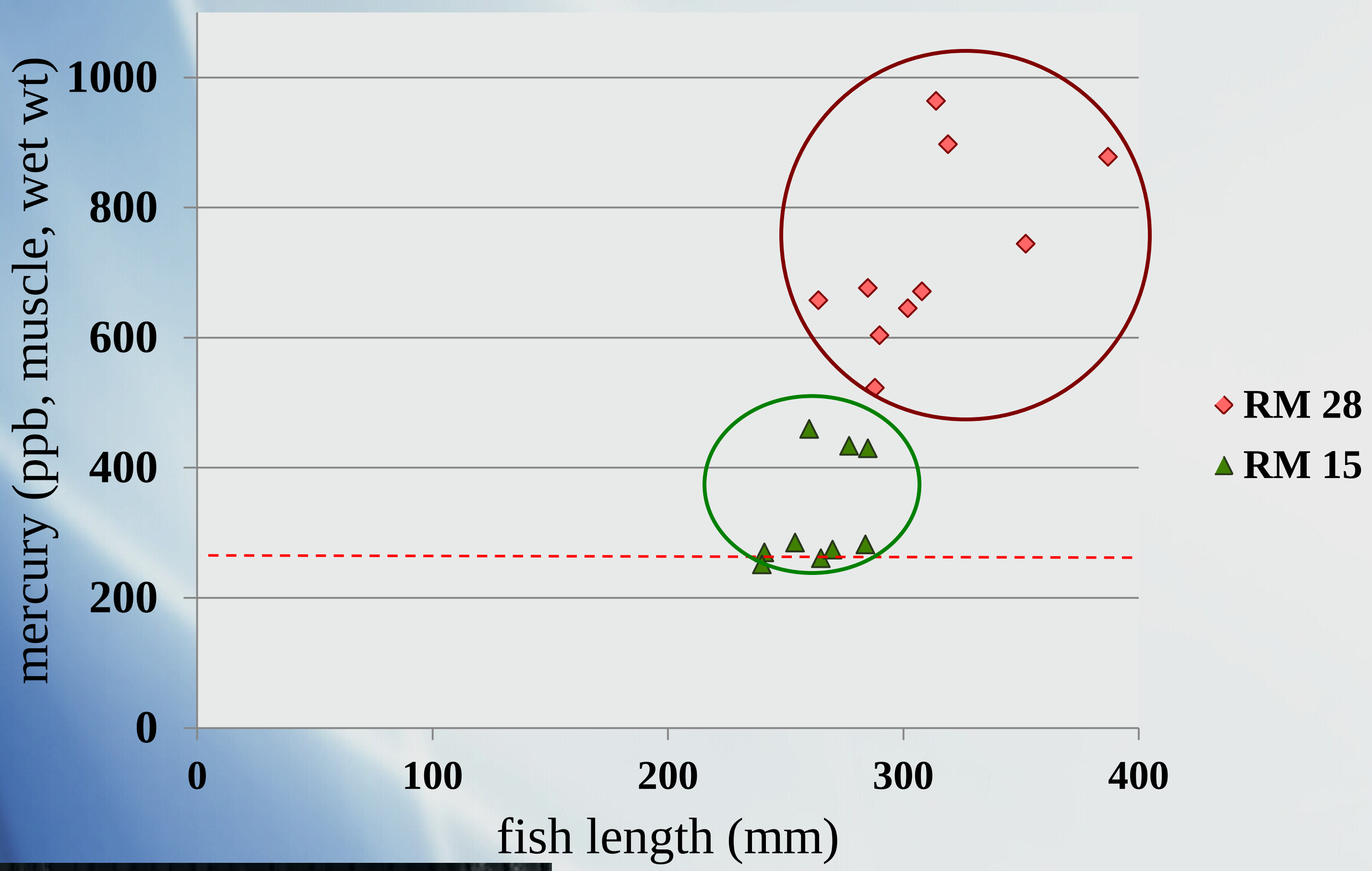
- A range of fish species
- Some high mercury levels

Large fish at River Mile 15: Size vs Mercury



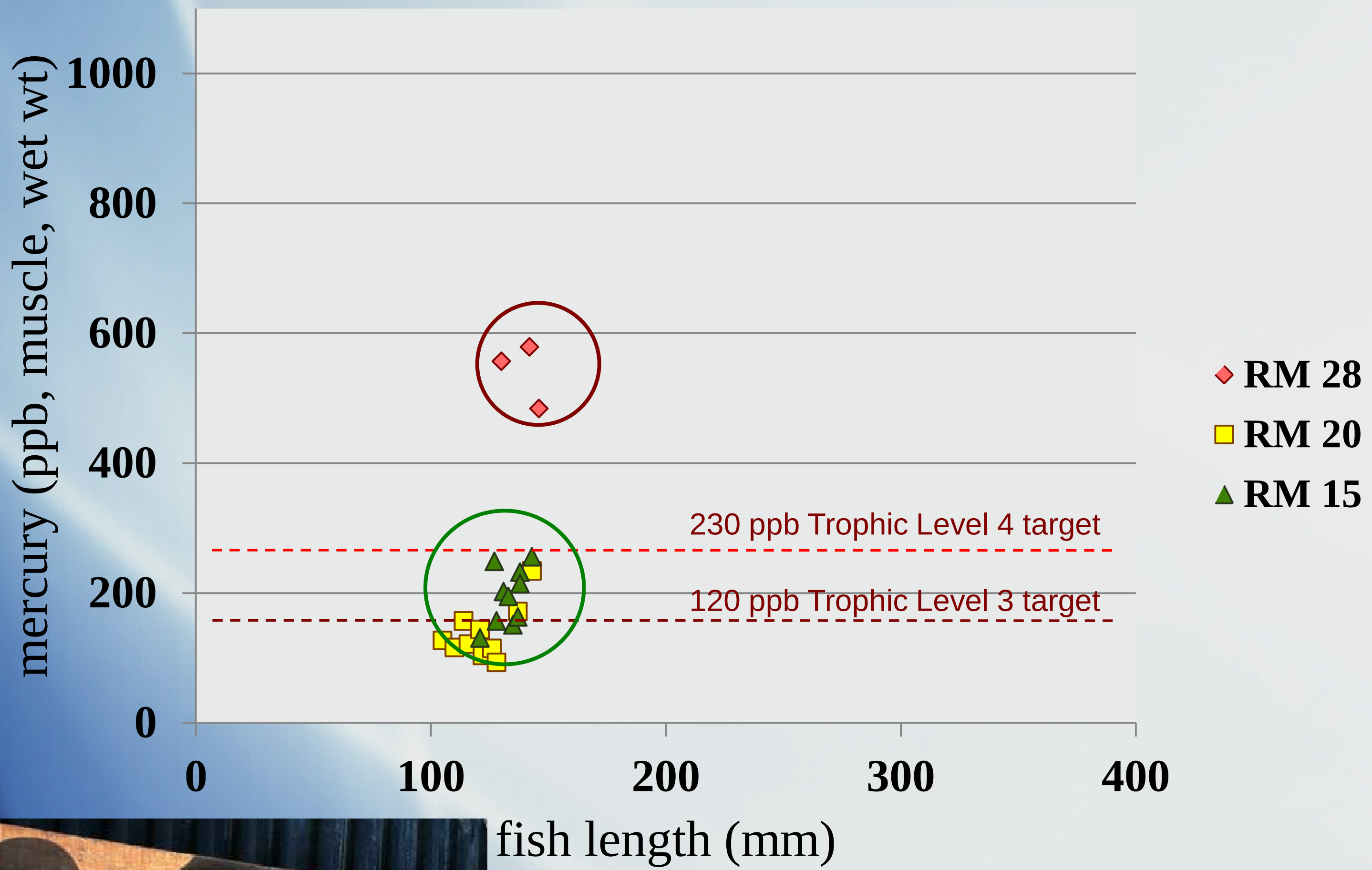
- **Much lower mercury at RM 15**

Pikeminnow mercury at two 2011 sites



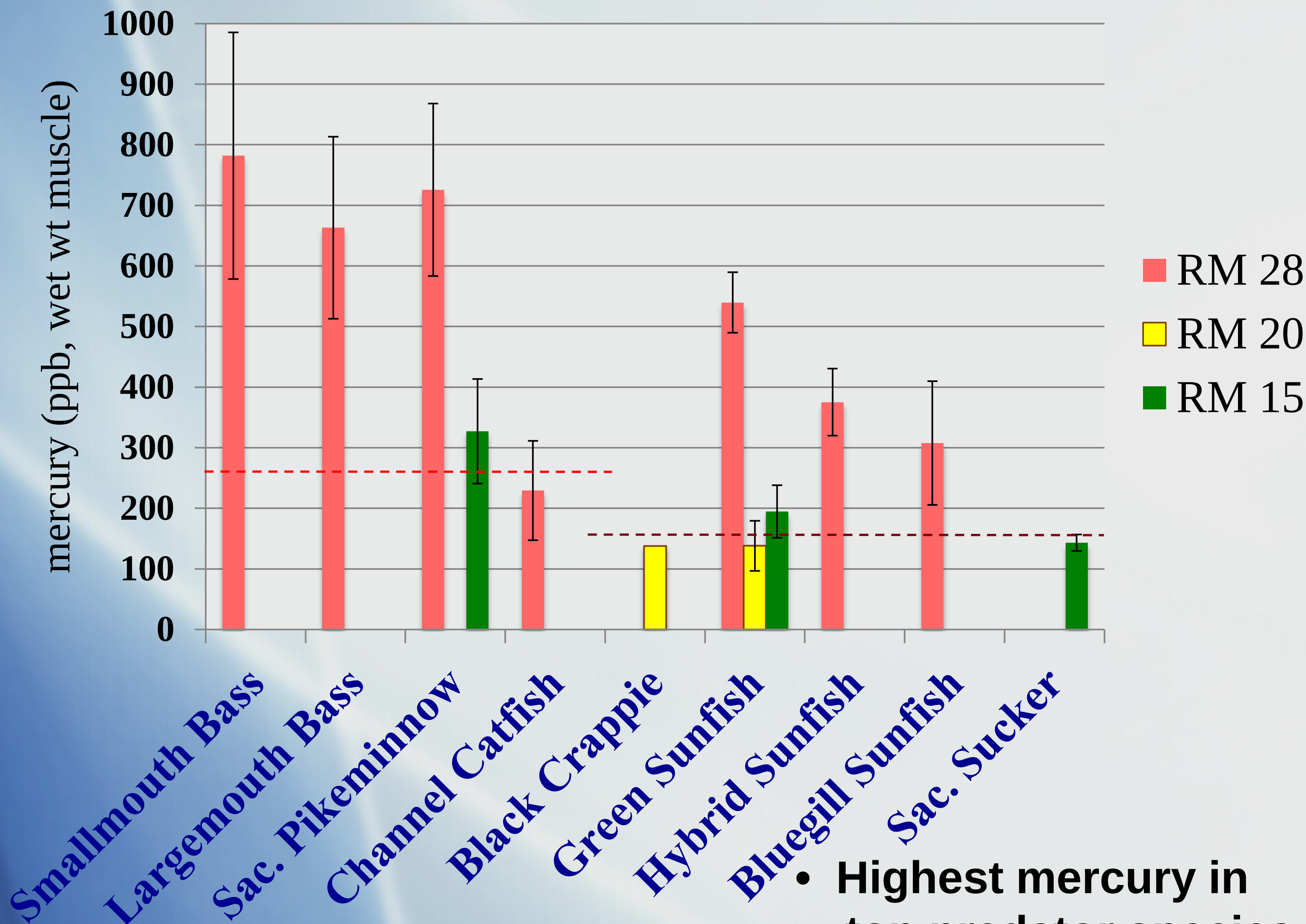
- **Higher mercury at RM 28**
- **Lower at RM 15**

Green Sunfish mercury at three 2011 sites



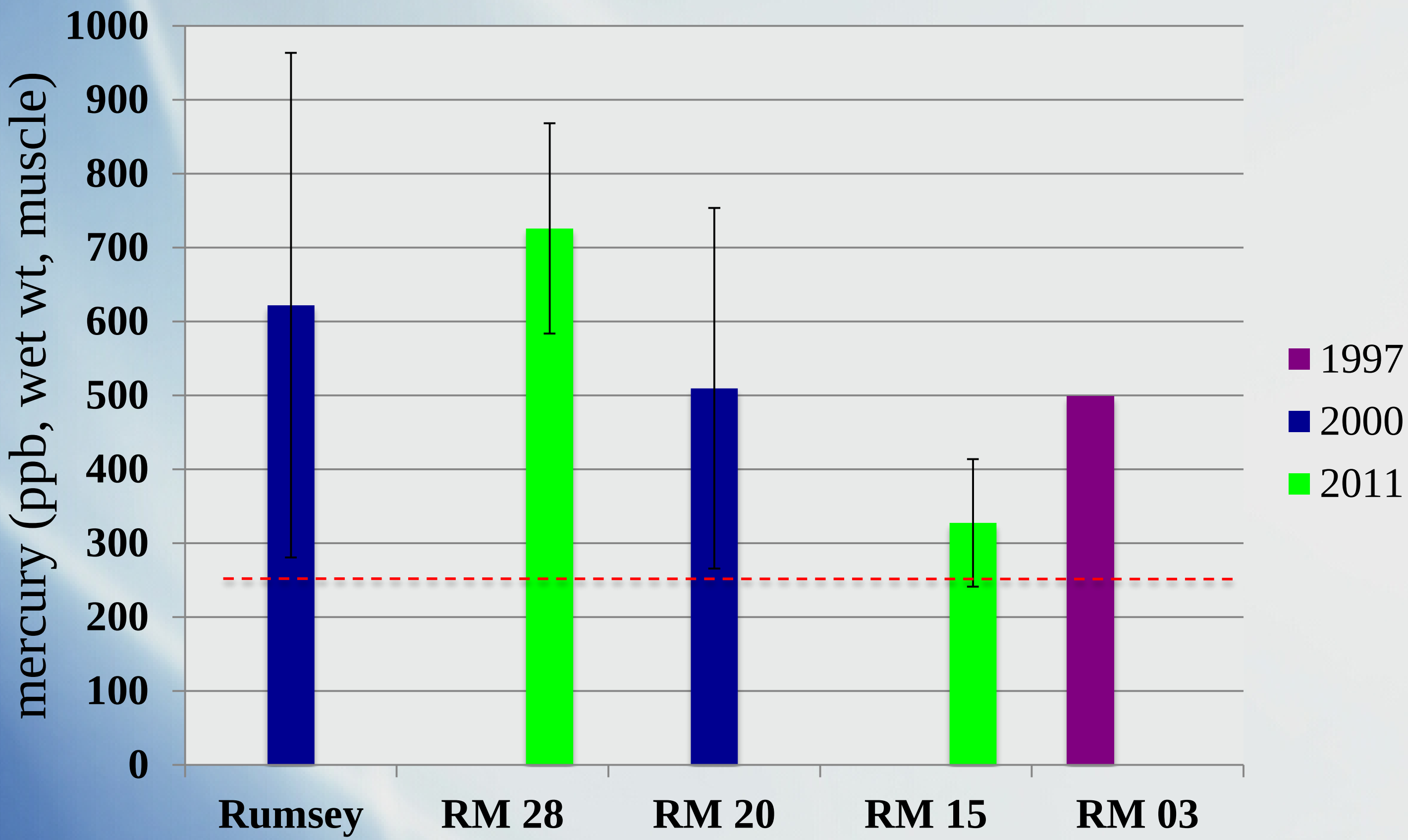
- **Higher mercury at RM 28**
- **Lower at RM 20 and 15**

Summary New Fish Data, all large species



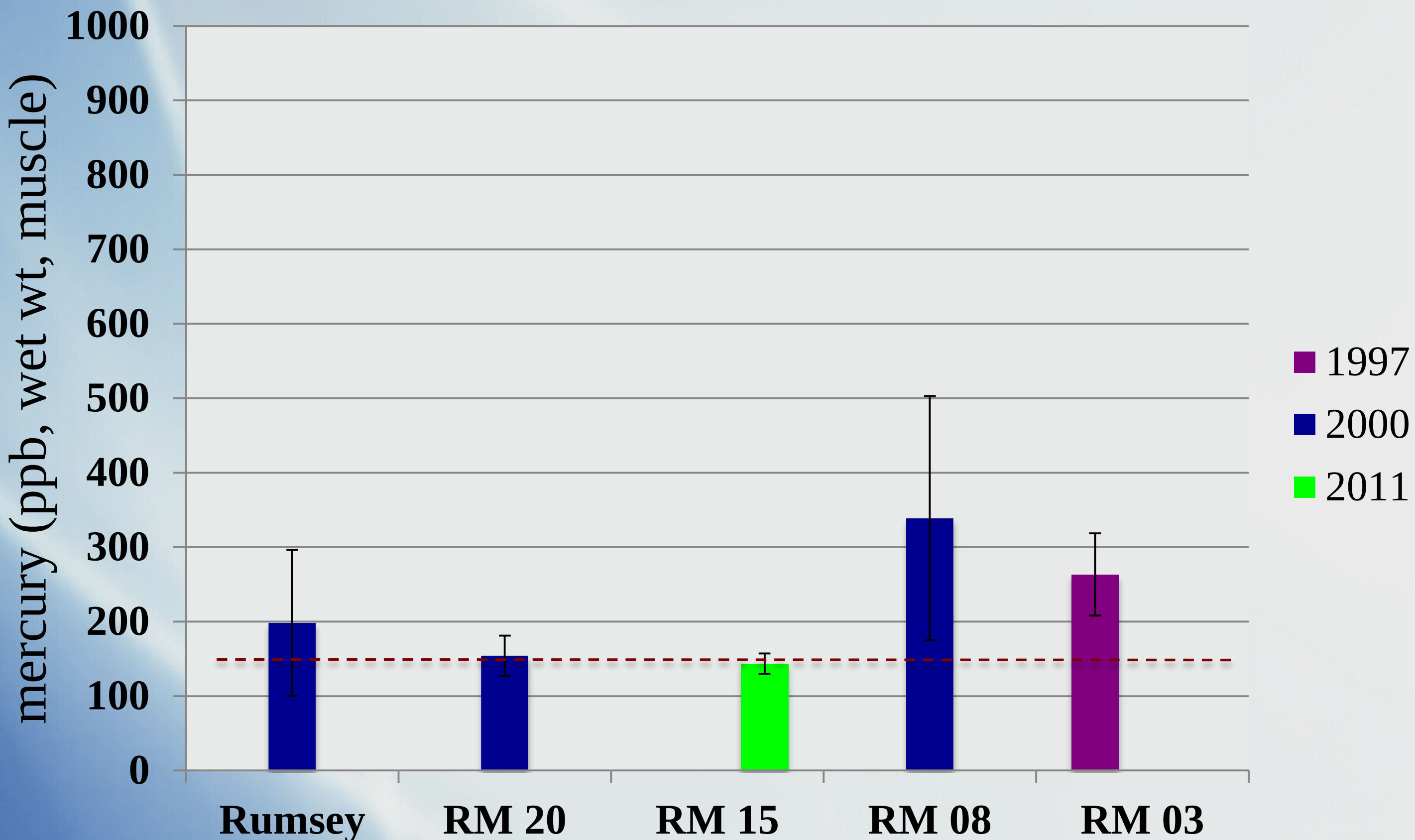
- Highest mercury in top predator species
- River Mile 28 higher

Sacramento Pikeminnow: recent mercury vs 1997-2000



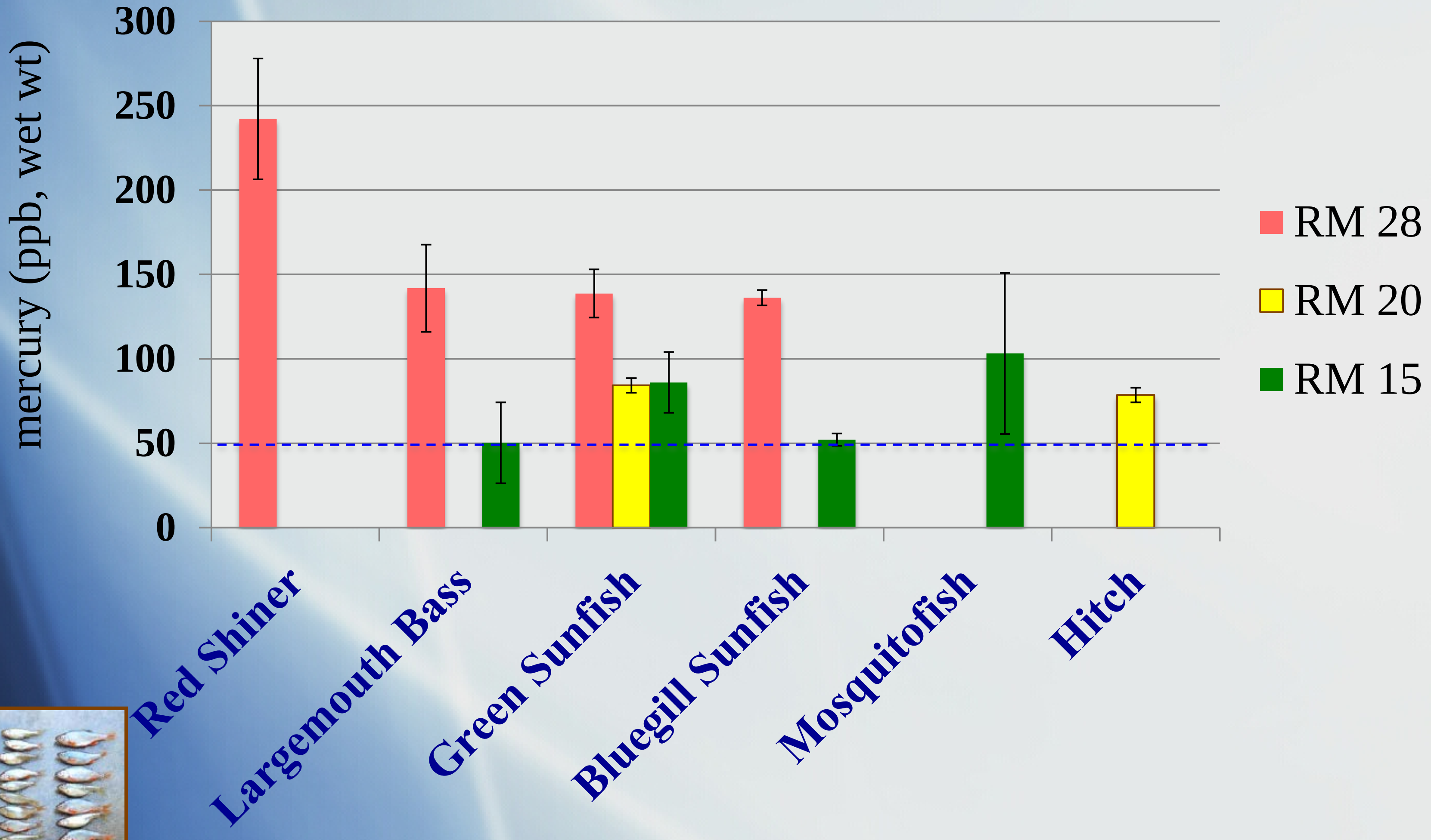
- **RM 28 a little higher, RM 15 a little lower, than older data.**
- **Statistically, no difference.**

Sacramento Sucker: recent mercury vs 1997-2000



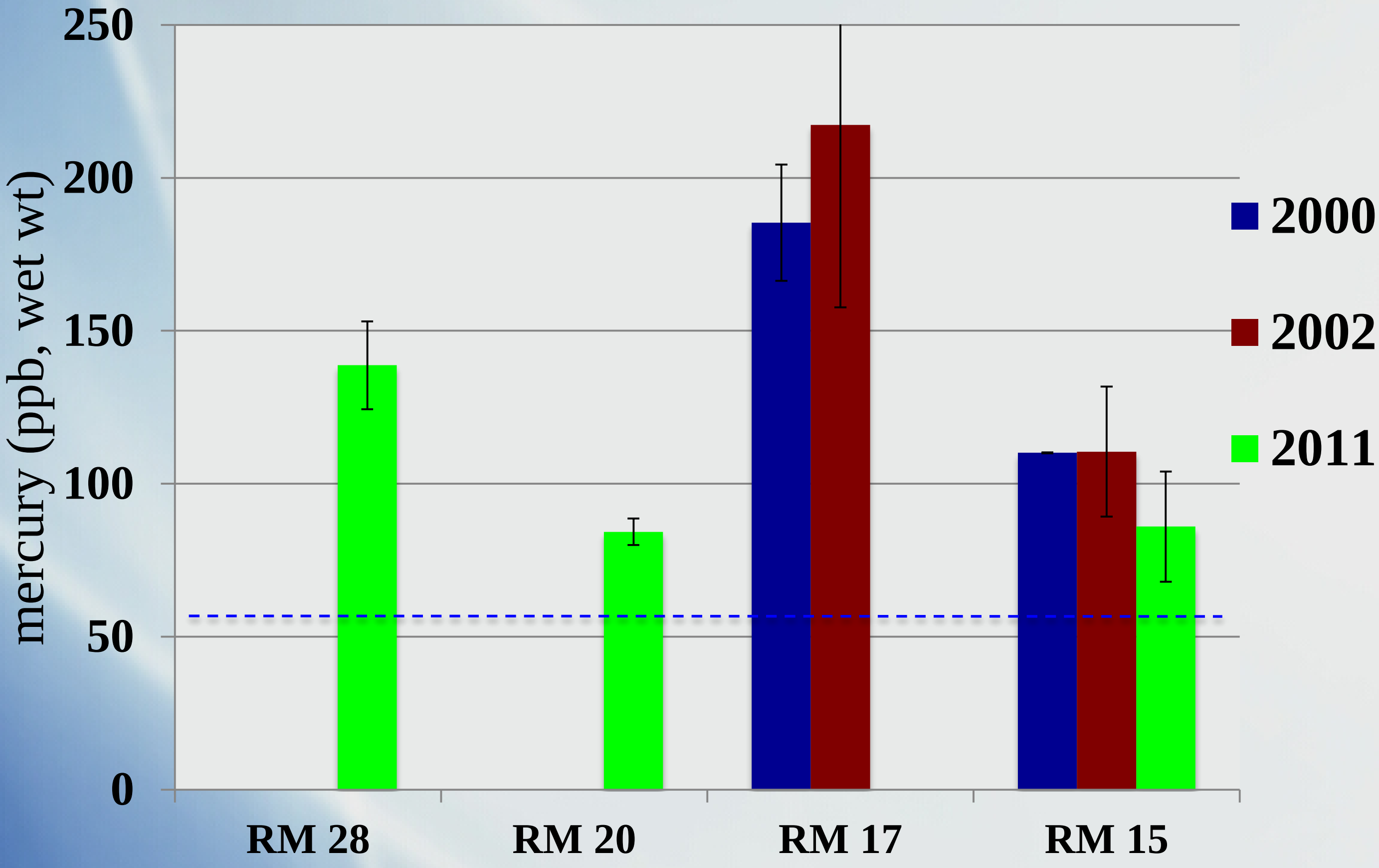
- RM 15 on the low end, compared to older data from nearby sites.

Small Fish mercury at the three 2011 sites



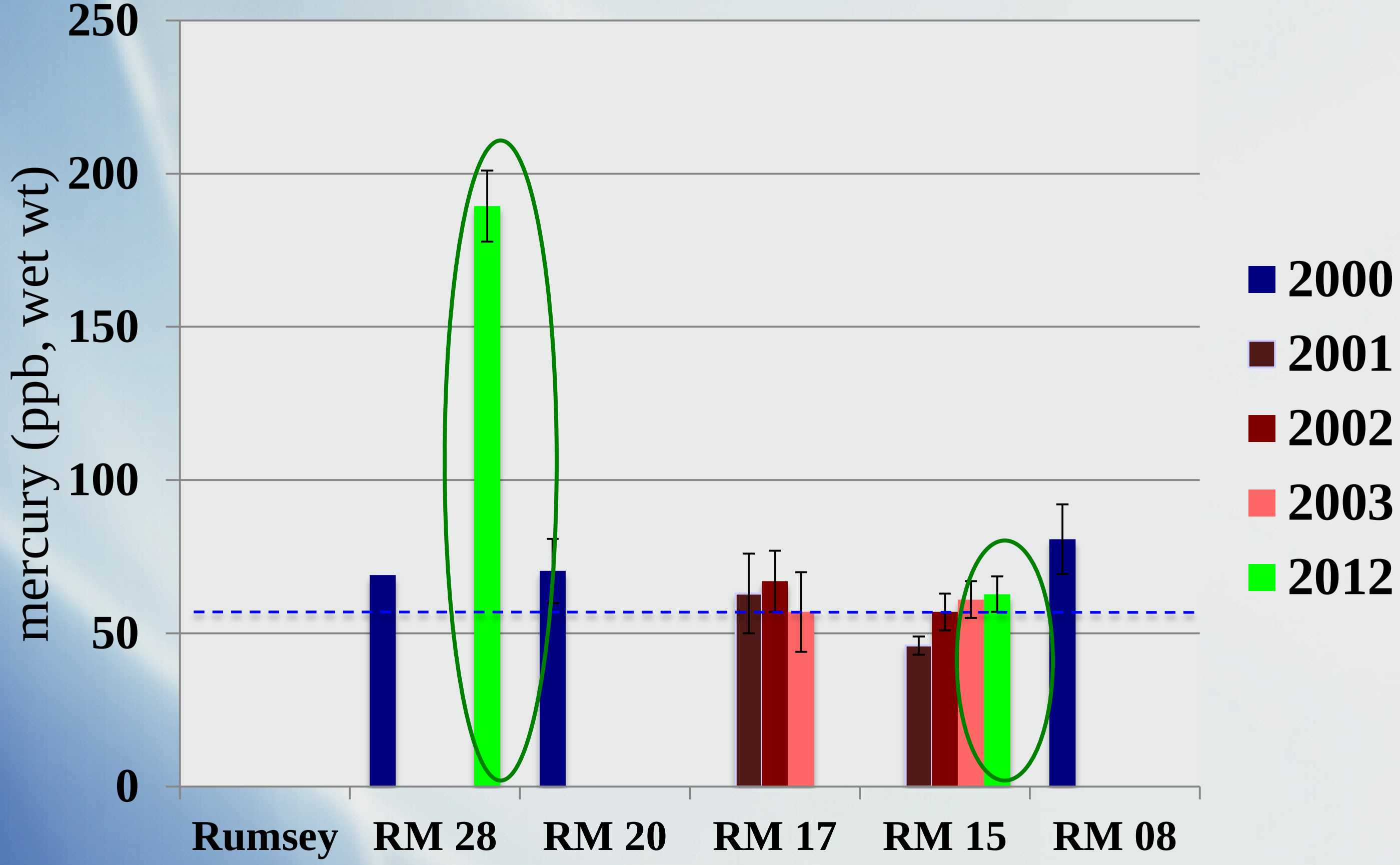
- **Statistically significant differences in the small fish (between sites and vs old data).**

Young Green Sunfish: recent mercury vs 2000-2002



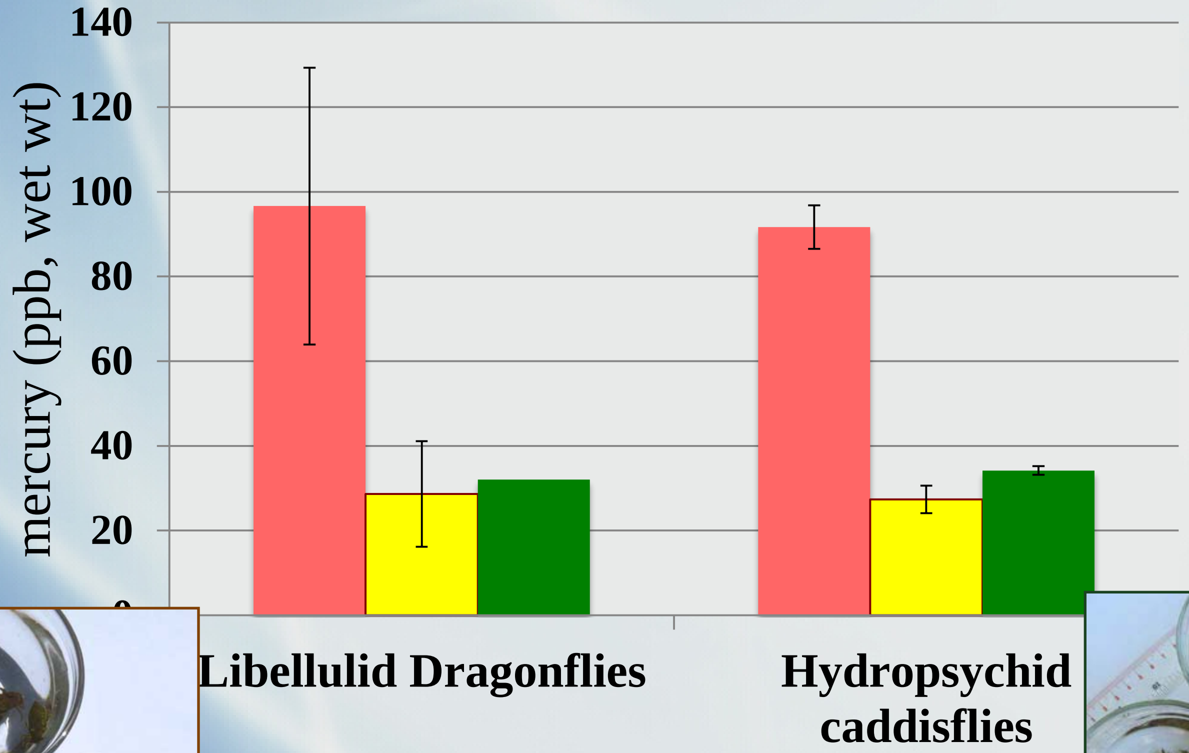
- **All within historical range, with RM 28 highest.**

Red Shiners: recent mercury vs 2000-2003



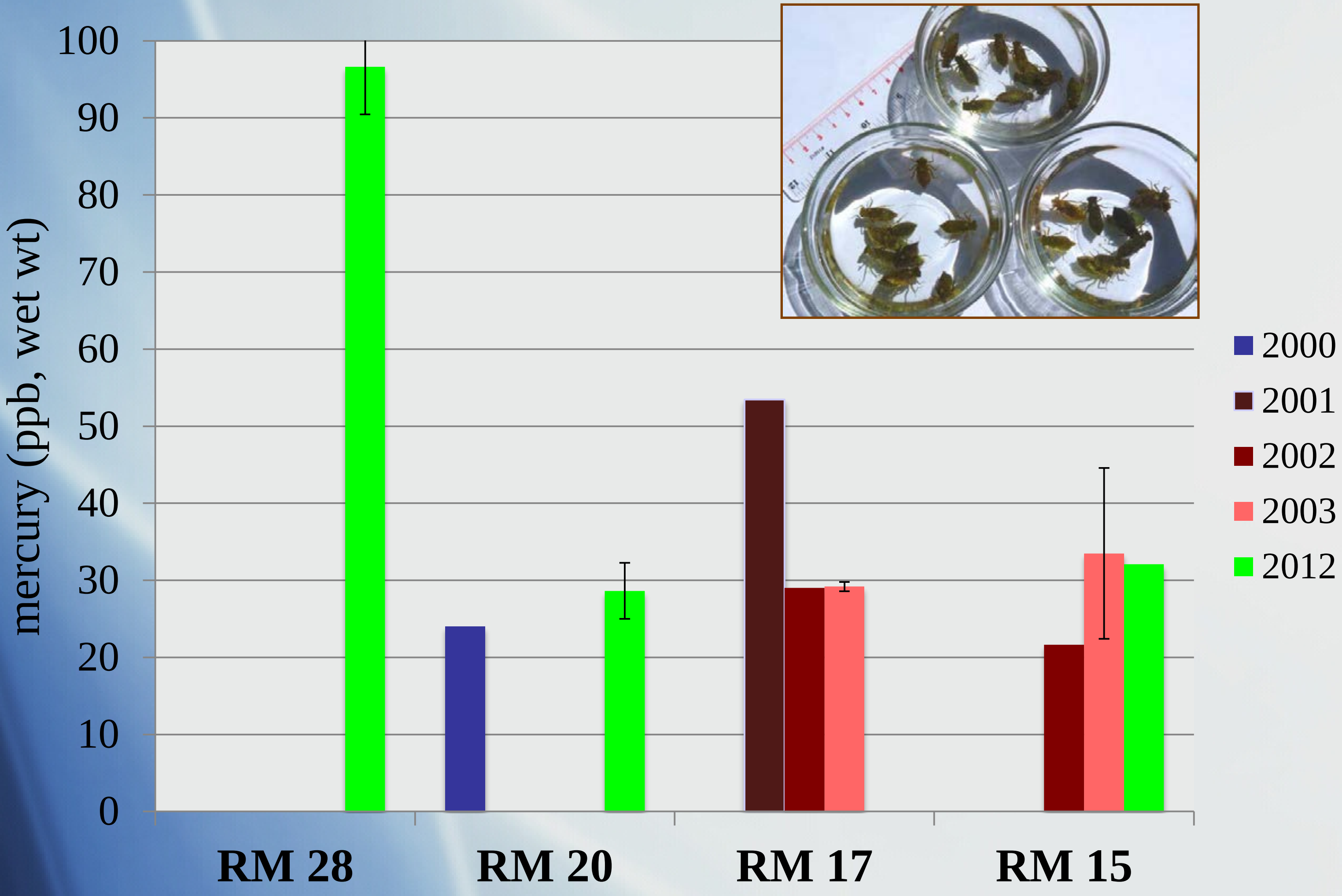
- RM 28 high
- RM 15 in line with historical data

Aquatic Insect mercury at the three 2011-12 sites



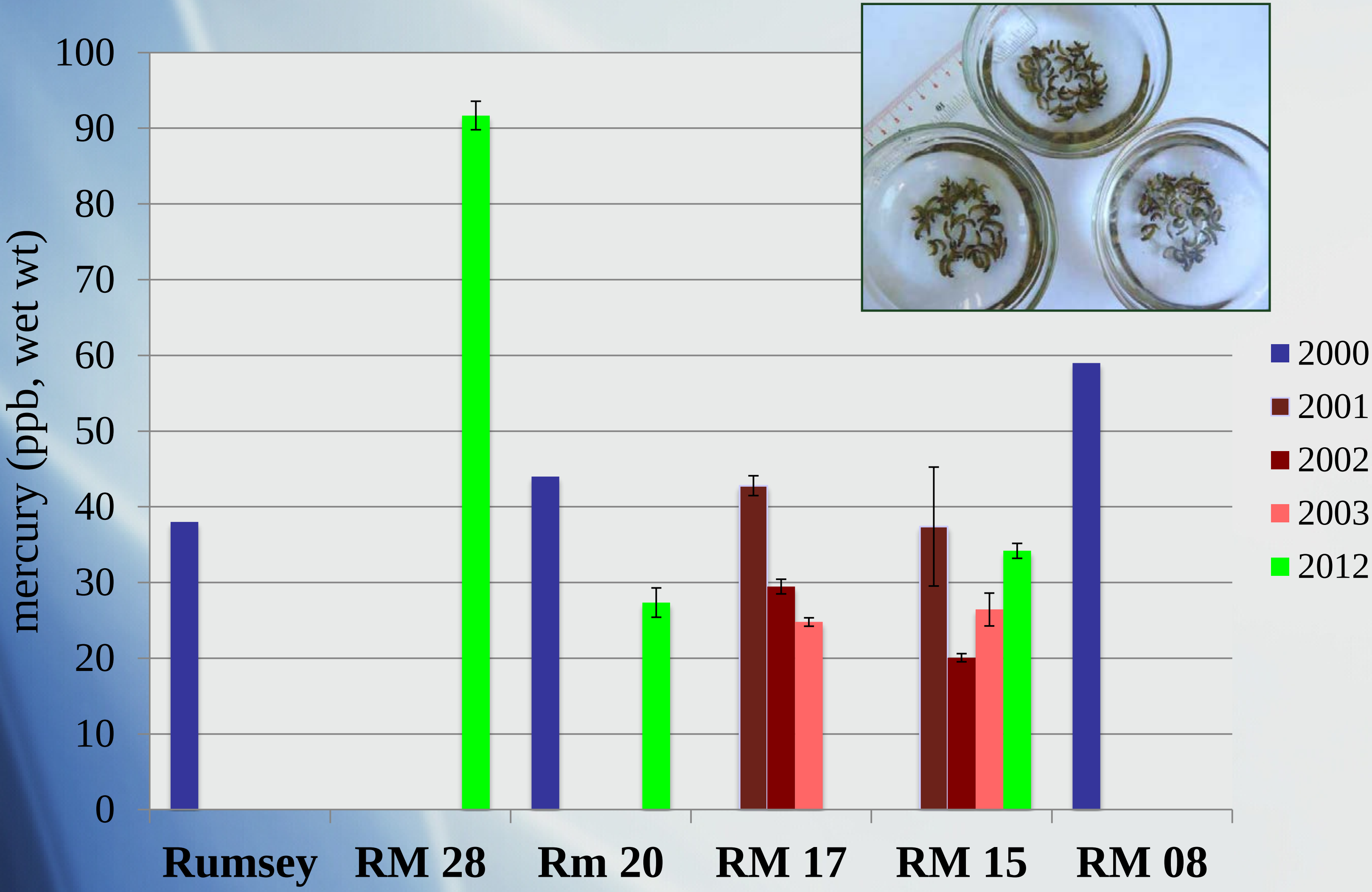
- Similar trends, also statistically significant.

Dragonfly nymphs: recent mercury vs 2000-2003



- **Again, RM 28 high, RM 20 and 15 in line with historical data.**

Caddisfly larvae: recent mercury vs 2000-2003



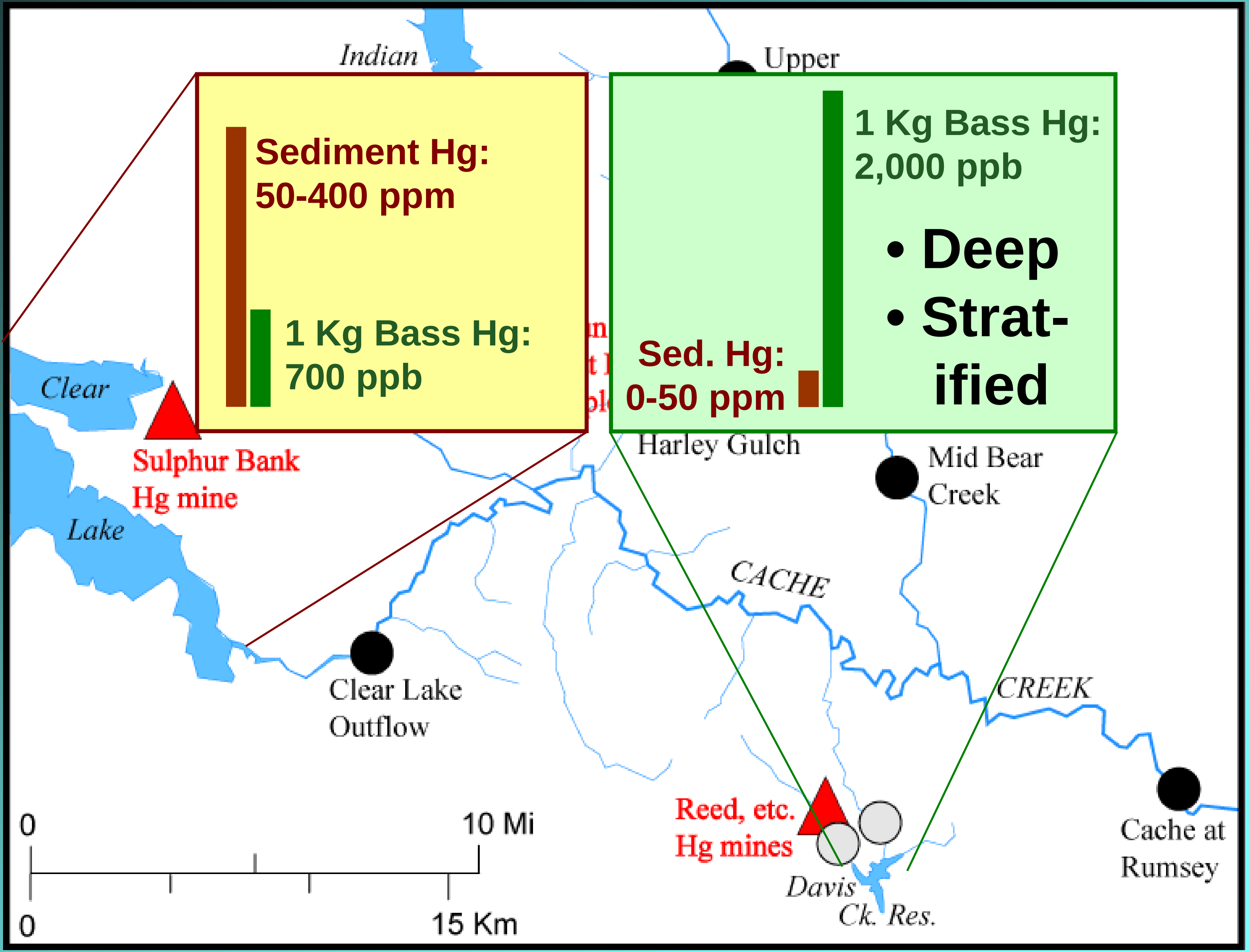
- **Same for caddisflies.**

Bottom line of recent monitoring:

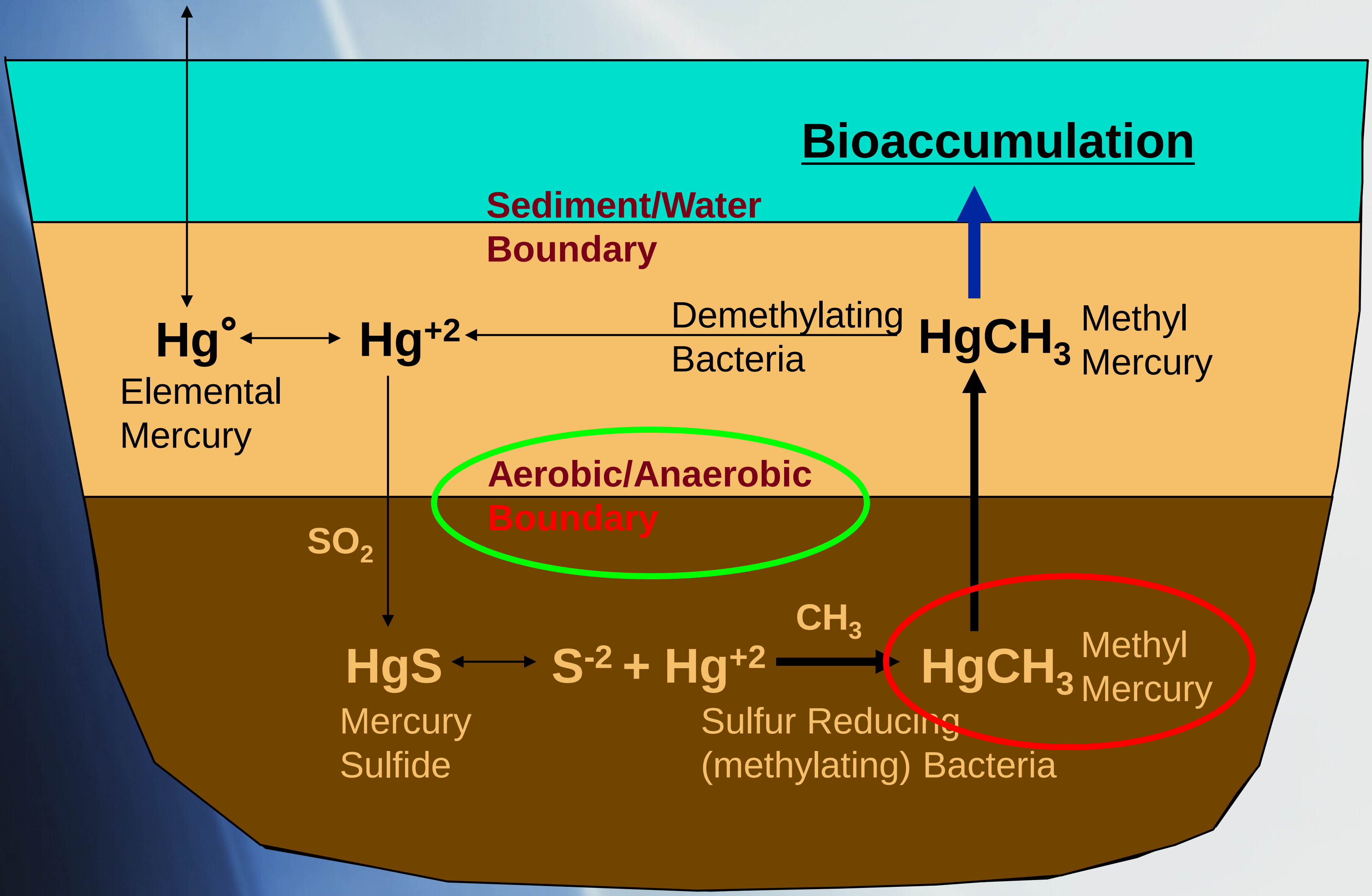
- A new set of biological creek data from the gravel mining section, including types most likely to be in the off-channel ponds.
- The River Mile 28 site, below the Capay Dam, was identified as a higher mercury zone.
- In all direct comparisons, the new data from RM 15 and 20 were statistically unchanged or lower than in earlier monitoring 10-16 years ago.
- This creek information can be compared to any monitoring in the off-channel ponds.

Other Cache Creek Work Over the Years

Clear Lake vs. Davis Creek Reservoir



Schematic Mercury Cycle -- Aerobic Water Column



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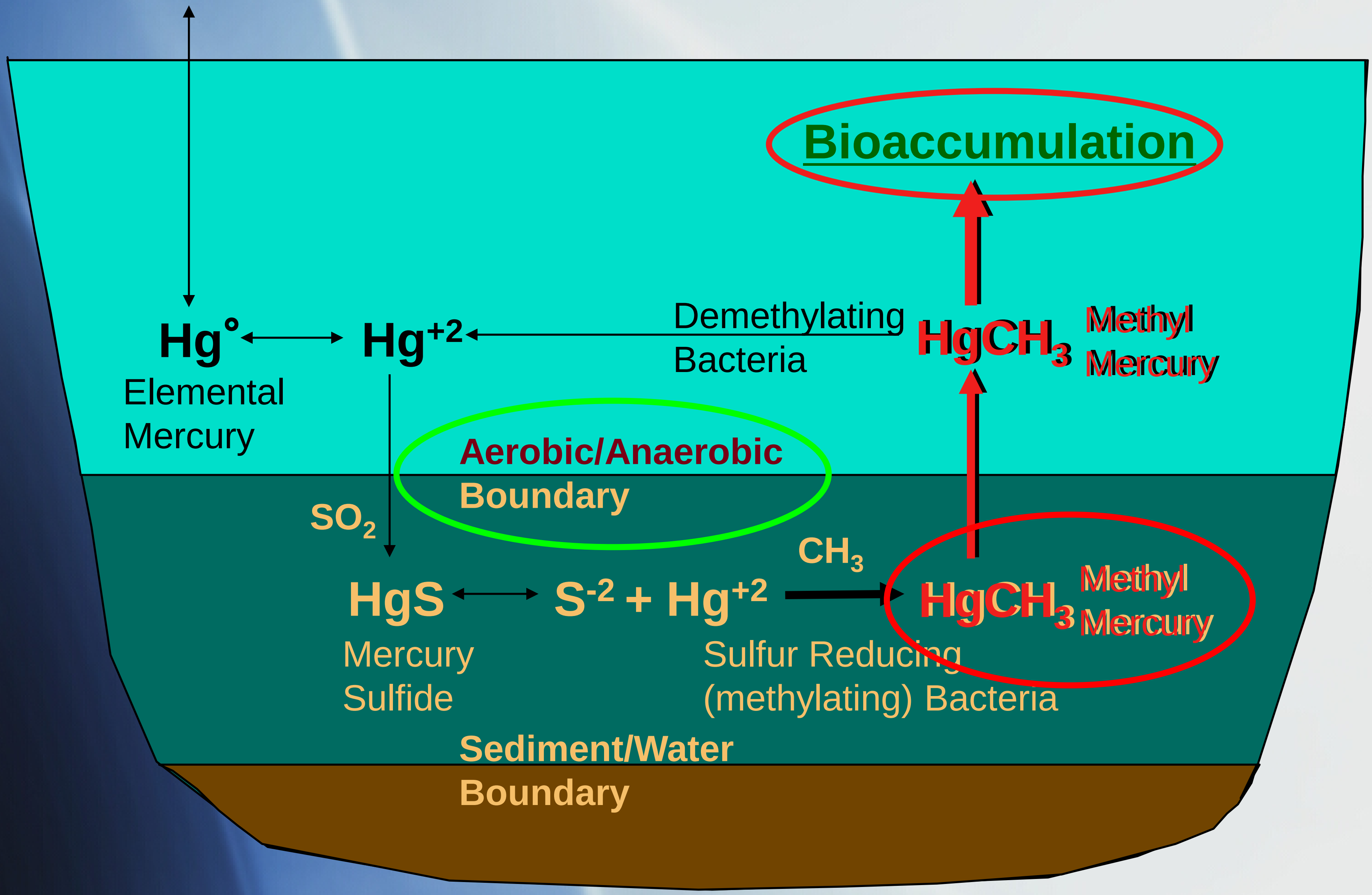
Schematic Mercury Cycle -- Anaerobic Bottom Water



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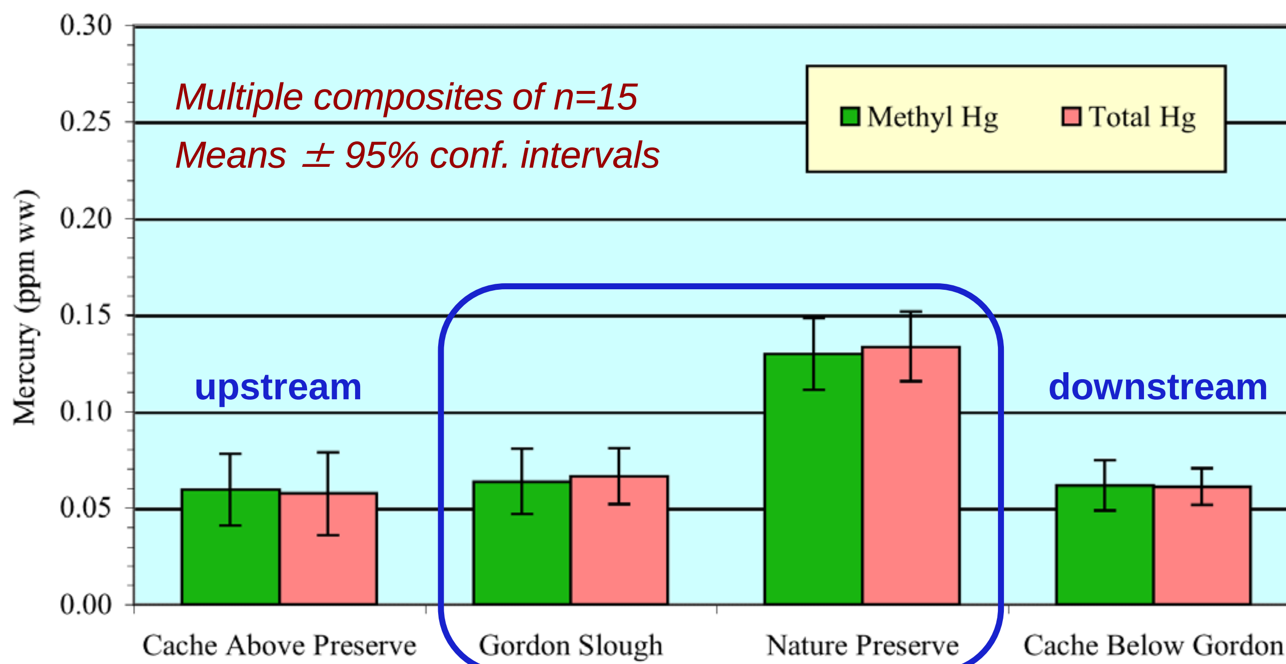
Cache Creek Nature Preserve: Pilot Case

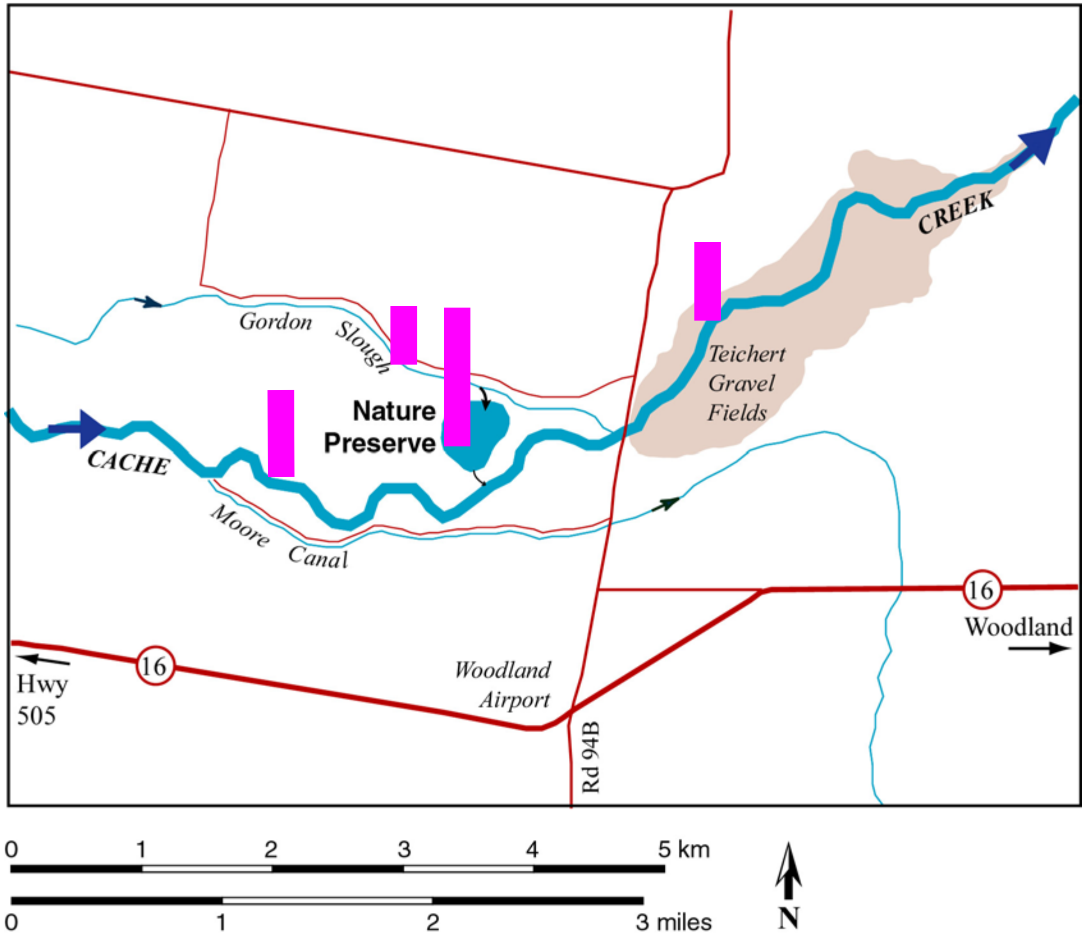
Pilot Wetland Restoration
Cache Creek Nature Preserve

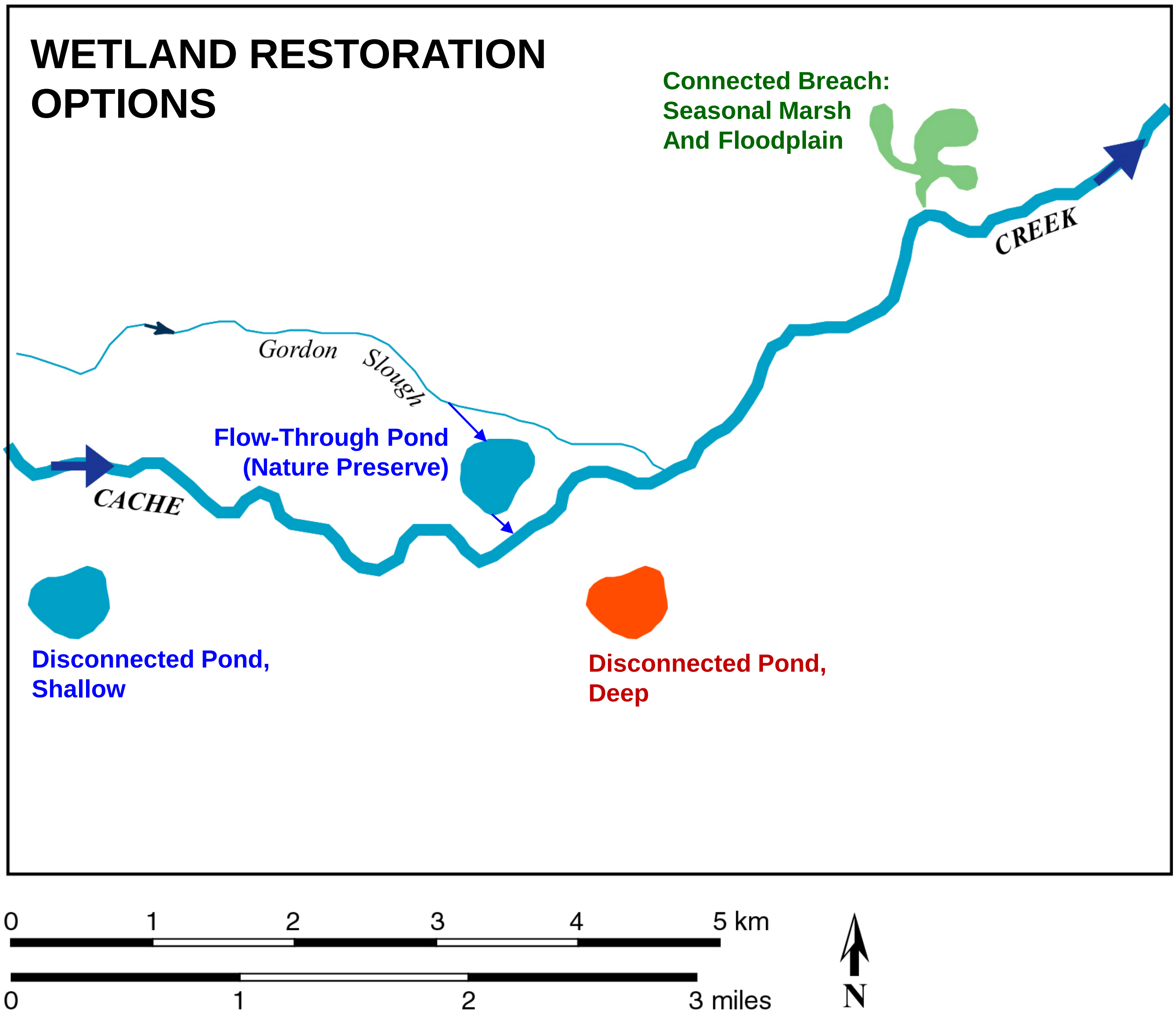
Bioaccumulation Signal

51-65 mm red shiners, (May 2003)



Small Fish
Mercury Signal
51-65 mm red shiners




WETLAND RESTORATION OPTIONS
Connected Breach: Seasonal Marsh And Floodplain
CREEK
Gordon Slough
Flow-Through Pond (Nature Preserve)
CACHE
Disconnected Pond, Shallow
Disconnected Pond, Deep
0 1 2 3 4 5 km
0 1 2 3 miles
N

Conclusions/Recommendations

- Wetlands can increase methylmercury production and bioaccumulation in fish.
- The effect is largest with seasonal flooding of dry, vegetated areas.
- Downstream effects can be minimized or eliminated by timing or stopping outflow.
- Methylmercury production in deep ponds can be reduced by disrupting bottom anoxia.
- Projects can be managed to balance mercury concerns and habitat benefits.