CACHE CREEK NATURE PRESERVE
MERCURY MONITORING PROGRAM

YOLO COUNTY, CALIFORNIA

SIXTH SEMI-ANNUAL DATA REPORT
(SPRING-SUMMER 2003)
WITH THREE-YEAR PROJECT OVERVIEW

June 20, 2004

prepared for

Yolo County, California

Study and Report by

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

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

EXECUTIVE SUMMARY

This sixth semi-annual report is the last in the current series for this three year mercury pilot study at the Cache Creek Nature Preserve and environs, a former gravel pit mining region. In this work, mercury bioaccumulation was characterized within the newly created Nature Preserve wetlands in a total of twelve quarterly samplings over the three-year period from fall 2000 through summer 2003. A more extensive additional series of collections was made semi-annually at strategically located adjacent sites.

The data collected throughout the course of the pilot study indicate that mercury bioaccumulation in the Nature Preserve wetlands was substantially elevated over that in its source water environment (Gordon Slough), bringing it to a level similar to that found in the most elevated Cache Creek location, upstream of the project area. The Nature Preserve wetlands have thus functioned as a source of methylmercury. This is consistent with most wetland environments. Small fish mercury was greater than in comparable fish taken throughout most of the Delta region and was similar to data from sites with a known mercury problem. Small fish concentrations corresponded to “keeper” sized bass fillet mercury at well over the EPA 0.30 ppm criterion level (if such bass were present). The elevation, however, was confined mainly to the wetland itself. A localized elevation in invertebrate mercury was noted on some dates in Cache Creek immediately downstream of the Nature Preserve outlet, though not in the most recent samplings during which time there was little or no Preserve discharge to the creek. Further downstream of the Preserve, at the Cache Creek sampling site located below Gordon Slough, mercury bioaccumulation was consistently similar to or lower than in Cache Creek upstream of the project. It is unclear at this point whether long-term trends within the Nature Preserve will decline, as existing sources of inorganic mercury are depleted, or remain elevated due to sufficient new inorganic mercury depositing in particulates from source water.

A strong seasonal trend was apparent in the long-term data. Fall concentrations were generally between 50% and over 400% greater than corresponding spring levels. We believe that these trends in the fish data were actually offset by a period of one to several months from underlying cycles of mercury methylation and bioavailability. Other project data were consistent with these cycles being maximal in the mid-summer and lowest in the winter. The invertebrate data did not consistently capture these apparent seasonal trends. This may be due to a more rapid equilibration between mercury exposure and bioaccumulation in these organisms.

Methylmercury data closely followed the total mercury values, at high percentages of the total mercury concentrations. Data interpretation was very similar using either mercury parameter as a monitoring tool. Methodologies for obtaining best comparative statistics were refined over the course of the project, as well as sampling techniques that account for changing biotic populations.

This pilot mercury monitoring project provides a model for the tracking of potential mercury effects at this and similar wetland restorations in the region.

BACKGROUND AND INTRODUCTION

The Cache Creek Nature Preserve is a constructed wetland reserve in Yolo County, built in 1999-2000 at the site of a former off-channel pit gravel mining operation. It is located between Gordon Slough and Cache Creek, just west of County Road 94B and the Gordon Slough-Cache Creek confluence, on the north side of Cache Creek (Figure 1). The Preserve was built to provide new habitat for wildlife and recreational and educational opportunities for the public. A contoured pond system with several islands was created and landscaped with native vegetation. A visitor's center and a system of walkways and overlooks were built. The Preserve has attracted numerous wildlife species and has become a popular educational and recreational destination.

As constructed, the wetland was intended to occasionally have its water replenished and/or exchanged between the months of approximately April and September (irrigation season). During these months, water may be diverted from Gordon Slough to the wetland. Flushing flows may be discharged from the wetland to Cache Creek, through an outlet structure located approximately 1 km upstream of the Gordon Slough - Cache Creek confluence. Gordon Slough is a seasonally operated irrigation drainage canal, which contains agricultural return flows of water that originates from upstream Cache Creek. Initially, wetland water exchanges typically occurred for 1/2 – 2 days, several times during irrigation season. As results became available from this study, discharges from the new wetlands to Cache Creek were reduced and then eliminated.

Cache Creek is known to transport seasonally elevated loads of mercury (Hg) from historic mining districts in the upper watershed (Slotton et al. 1997, Foe and Croyle 1998, Domagalski et al. 2003, Slotton et al. 2004). Consequently, there is a general interest in mercury and mercury bioaccumulation throughout the watershed. Because wetland habitats have been demonstrated to enhance the conversion of inorganic mercury to bioaccumulating methylmercury in certain environments (Rudd 1995), it was felt that the issues of mercury and mercury bioaccumulation should be investigated at the new Cache Creek Nature Preserve, both within the Preserve wetlands and in adjacent Cache Creek upstream and downstream of the Nature Preserve outlet. Mercury dynamics in this wetland are additionally of interest as a model that may help in the planning of potential future wetland constructions at other similar sites in the region.

A three-year pilot mercury monitoring study was initiated in the fall of 2000. The primary purpose of this program has been to indicate the potential role, if any, that Nature Preserve water discharges may have on mercury levels in adjacent Cache Creek. Secondarily, the study seeked to quantify the relative changes, if any, in mercury bioaccumulation within the constructed wetland system itself, relative to conditions in both its source waters and adjacent Cache Creek. The monitoring included a series of quarterly collections, with data reports issued semi-annually. This is the sixth and final of these reports. In it, we present data from collections made in spring and summer 2003, and provide an overview of the entire mercury monitoring project to date (fall 2000 through summer 2003).

METHODS

As designed, this monitoring program focused on mercury levels in selected types of localized aquatic biota as the primary indicators of relative mercury exposure at several key locations (Figure 1). These locations were:

- Cache Creek upstream of the Preserve and the Preserve water outlet.
- Gordon Slough, near the Preserve intake and the confluence with Cache Creek.
- The Nature Preserve wetlands.
- Cache Creek downstream of Gordon Slough and the Preserve.

The Cache Creek sites for invertebrate collections were located approximately 1 km upstream of the Preserve and 1 km downstream (~0.7 km downstream of the Cache Creek - Gordon Slough confluence). Small fish were taken along the Creek from these points and continuing away from the Preserve for a further 0.3-0.7 km. An additional site was added for invertebrate sampling only at:

- Cache Creek between the Preserve outlet and the Gordon-Cache confluence.

Fish could not be effectively sampled from this intermediate site because (a) the reach between the Preserve outlet and the Cache-Gordon confluence was too small to contain sufficient, reliable samples and (b) due to fish movement, it was not possible to ensure that samples taken in this location were not derived from adjacent sites upstream and downstream. However, it was possible to collect samples of invertebrate bioindicators that we believe were representative of mercury exposure conditions at the intermediate stretch of Cache Creek just downstream of the Preserve outlet.

By comparing mercury concentrations in similar local biota taken at the different sites, we could determine whether statistically significant differences existed among the sites. The potential role of Nature Preserve water discharges on mercury levels in Cache Creek could also be assessed.

All of the sites were sampled on a semi-annual basis, once in the fall and once in the spring, between November 2000 and May 2003. Because aquatic organisms accumulate their mercury burdens over time, biotic sampling can provide information on average conditions throughout the previous months. The fall samplings were designed to integrate relative mercury bioaccumulation throughout the warm season period of irrigation flows and maximal biological activity. The spring collections monitored conditions during the previous cool season, when the Preserve was not designed to exchange water. Supplementing the primary multi-site, semi-annual collections were additional quarterly samplings from the Nature Preserve wetlands site alone, conducted in winter and summer. The final sampling was done in August 2003.

The target biota for use as mercury bioindicators in this project were small or juvenile fishes and aquatic insects that tend to remain within fairly localized ranges. These

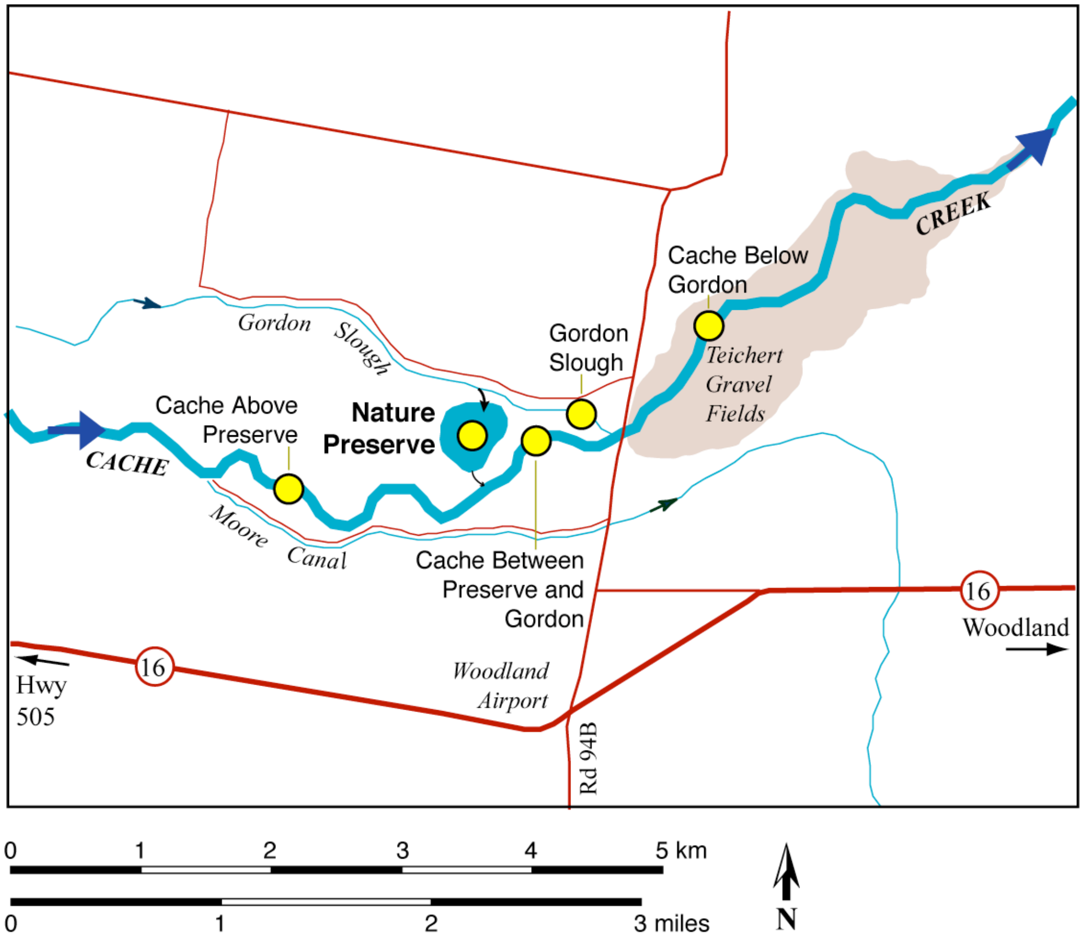


Fig. 1. Map of project area, sampling sites, and flow relations.

organisms have been found to be ideal monitoring tools to indicate relative mercury bioaccumulation between locations, in numerous research studies by the authors throughout California and by other researchers elsewhere (e.g., Slotton et al. 2004). Because these organisms are generally well under a year old when collected, they can also reflect potential seasonal changes in mercury exposure more directly than large fish. In contrast, large fish mercury burdens represent the combined mercury accumulations of several years time. Large fish are also less likely to have remained in the immediate sampling region throughout their lives.

The localized availability of potential mercury bioindicator species was determined at each of the sites in the initial fall 2000 work. Sampling was directed at taxa that were prevalent and would not be impacted by collections. Efforts were made to collect similar sample types from the different sites and between collection dates. Whenever possible, composite samples of multiple individuals were collected. For the samples that were most inter-comparable between sites and/or dates, replicate composites were taken when possible. When three or more identical composites could be taken, each containing multiple small individual fish or invertebrates, statistical confidence intervals of the mean mercury levels were determined. During the second half of the project, an alternate measure of statistical replication was achieved for low-n samples through multiple individual analyses when replicate multi-individual composites were not available.

Benthic aquatic insects were collected with research kick screens and various nets. Small fishes were taken using a backpack electro-shock unit, beach seines, and other nets. Samples were identified, measured, cleaned, and sorted using well-established laboratory protocols. Composite and individual samples were prepared and analyzed for both total and methyl mercury at the UC Davis Environmental Mercury Laboratory. Research-level Quality Assurance / Quality Control (QA/QC) was employed throughout. Composite and individual samples were all powdered and analyzed on a dry weight basis for consistency. The data, as presented, have been converted to wet (fresh) weight concentrations so as to be comparable to various guidelines. Moisture percentage was determined for each sample, providing an accurate conversion of the data from the dry, powdered samples to a fresh/wet weight basis.

Following the first year of the project, in which we analyzed strictly for total mercury according to the monitoring protocol, the concern was raised that tracking of total mercury alone in project bioindicator samples might not provide an accurate measure of methylmercury trends. We therefore conducted double analyses of all samples since that time, generating both organic (methyl) and total mercury data. Using extensively tested procedures, we analyzed both total and methyl fractions for each sample within the same analytical run, thereby further reducing potential laboratory-based variability. Additionally, because of high levels of natural variability seen occasionally in the creek invertebrate samples, the invertebrate samples were further analyzed in duplicate, using laboratory split samples. This again doubled the analytical load but improved the statistical confidence associated with each sample.

RESULTS AND DISCUSSION

This sixth and final semi-annual data report presents new data from samples taken in the spring and summer of 2003. A total of 96 fish samples, each consisting of an individual small fish or a composite of multiple similar individual small fish, were prepared and analyzed from the four fish sampling locations in spring 2003. Thirty-three composite samples of aquatic insects were assembled from the spring collections as well. Summer 2003 collections at the Nature Preserve site alone included 36 fish samples. Samples analyzed for both total and methyl mercury during this reporting period are summarized in Table 1 (below). Additional data tables and associated figures are presented below and following the text. Figures 7(a-f), 9(a-f), 12(a-e) and 13(a-c) compare selected parameters across the entire three year pilot monitoring program.

Table 1. Summary of Biological Samples Analyzed for Mercury in This Six Month Period (Spring 2003 and Summer 2003 Collections).

Site	Small Fish	Aquatic Insect	**Totals**
SPRING 2003			
Cache Ck upstream of Preserve	18	12	**30**
Gordon Slough	18		**18**
Nature Preserve Wetlands	39		**39**
Cache Ck btw. Preserve & Gordon Sl.		9	**9**
Cache Ck downstream of Gordon Sl.	16	12	**28**
TOTAL SPRING 2003 SAMPLES:	**91**	**33**	**124**
SUMMER 2003			
Nature Preserve Wetlands	36		**36**
TOTAL SUMMER 2003 SAMPLES:	**36**		**36**
TOTAL SAMPLES FOR THg:	**127**	**33**	**160**
TOTAL SAMPLES FOR MeHg:	**127**	**33**	**160**

These 160 total mercury and 160 methylmercury samples were prepared and analyzed using research levels of QA/QC. Associated QA/QC data are presented in Table 2(a-b). No problems were encountered in the analyses and the associated data for these two quarters of sampling, as those from the preceding quarters, can be treated as very reliable.

SITE TO SITE (SPATIAL) VARIATION IN MERCURY

Mercury in Small/Juvenile Fishes

The most recent multi-site fish mercury data, from Spring 2003, are presented in Tables 3-7 and are shown graphically in Figures 2-6. To place the final semi-annual information into historical perspective, data from the most widely available sample type across the project (35-50 mm red shiners) are presented from all six multi-site spatial samplings since the fall of 2000 in Figure 7(a-f). In each of the figures, data are displayed so as to allow inter-comparison of the sites for each sample type. Data trends are discussed primarily in relation to total mercury, corresponding to previous reports. Methylmercury can be seen to have basically mirrored the total mercury data, at a consistent high percentage of corresponding total mercury. Generally, identical mercury trends were described by both data sets and either would lead to the same overall conclusions.

Red shiners (Table 3, Figure 2, plus multi-year presentations in Figure 7) were initially the most readily available of the fish species present at all of the fish sampling locations. And, being an invasive, non-native species, we could sample intensively without significantly impacting the local aquatic environment. This species thus provided the strongest measure of inter-site variability in fish mercury bioaccumulation. Red shiners remained abundant at the Gordon Slough and Cache Creek sites but, over the course of the pilot project, shiners in the Nature Preserve itself declined to low densities. They were initially largely displaced by fathead minnows as the new wetlands evolved. Parallel sampling was conducted with both species, to the extent possible, during the period of overlap. It appears now that both of these indicator species may be disappearing at the Preserve site, which continues to evolve. Red shiners remain an excellent indicator species at the Gordon Slough and Cache Creek sites.

Because of the difficulty obtaining large numbers of red shiner samples at the Nature Preserve site as normal wetlands succession occurred, we instituted the approach of analyzing multiple individual fish rather than multiple composites of numerous individuals, as necessary. In the previous reporting period, we tested this approach at all of the fish sites and with all small fish samples other than the tiny mosquitofish. We were additionally interested in potential individual variation in mercury bioaccumulation among similar individuals. Up to 10 individual analyses of similar single fish were performed for each site and size class, resulting in an approximate doubling in the total number of analyses in that period. Unfortunately, individual variation was found to be greater than expected. The resulting statistical confidence intervals for those sets of fish were less precise than in previous samplings, where multiple composites, each containing numerous similar individuals, were analyzed. This was an important finding. In future related work, we would recommend preferentially utilizing multi-individual composites (taken in up to six replicates as available), with analysis of replicate individual fish only when constrained by very low sample numbers. Alternatively, if individual samples are preferred, considerably more than ten individuals may be necessary. It is notable, however, that we have found greater variation in fall samplings throughout the three monitoring years, as compared to spring samplings, even among multi-individual composites. Thus, not all of the decrease in precision noted in the fifth semi-annual data report was due to the use of individuals rather than multi-individual composites.

Spring 2003 red shiner data are shown in Table 3 and are plotted in Figure 2. Mean mercury concentrations from replicate composites or multiple individual analyses ranged between 0.04 and 0.13 ppm in all samples. The larger size class (51-65 mm, Class 3) exhibited somewhat higher concentrations than the mid-size class (36-50 mm, Class 2) as has been typical throughout the project (Figure 7). The difference between the two size classes was statistically significant only at the lower Cache Creek site. Among both size classes of shiners, spatial trends were similar to those seen in past spring samplings. Shiners from Gordon Slough and the upper and lower Cache Creek locations exhibited similar, statistically indistinguishable levels of mercury bioaccumulation. In contrast, shiners taken within the Nature Preserve contained approximately double the mercury concentrations seen at the other sites. Statistics were not available for the smaller size class due to sample numbers. However, adequate replication was possible for the larger class of shiners. At the 95% level of significance, Nature Preserve Class 3 shiners were statistically elevated over identical fish from Gordon Slough and both Cache Creek locations. This trend has been repeated in each of the three spring season samplings to date, becoming somewhat more pronounced over time (Figure 7).

As compared to corresponding samples from the previous fall sampling, May 2003 shiner concentrations were notably lower, by approximately 30-80%, across all of the sampling sites and size classes. This spring low and fall high mercury bioaccumulation trend has been consistent across the entire three-year span of the study (Figure 7a-f). The observed sharp seasonal variation indicates that mercury bioaccumulation is not constant throughout the year, instead peaking in the warm season and minimal in the cool season. Fall season spatial trends among the sites differed somewhat from those seen in the spring. In addition to greater overall concentrations in the fall, the relationship among the non-Preserve locations changed. Gordon Slough generally exhibited the lowest concentrations, followed by the downstream Cache Creek site. The upstream Cache Creek site located above the Preserve was consistently higher each fall. During the three years of the study, the relative position of the Nature Preserve fall concentrations changed from being similar to the Gordon Slough low concentration inflow site to being similar to the highest concentration upstream Cache Creek site. This change occurred as the Nature Preserve developed from a bare pond into a more highly vegetated wetlands system.

It is important to note that, within Cache Creek, shiner mercury was consistently not elevated at the downstream location as compared to the site above the Preserve. This was the case through the early portion of the project when some discharge was routine, as well as later when discharges were curtailed.

Red shiner methylmercury trends corresponded very closely to those seen for total mercury, both spatially and seasonally, with methylmercury at a high percentage of total mercury.

Fathead minnow data from the Spring 2003 collections are displayed in Table 4 and are shown graphically in Figure 3. This species was available only from the Nature Preserve wetlands, and it was nearly absent there as well. With much work, it was possible to obtain three individuals from the 51-65 mm size class. These were analyzed individually. Concentrations averaged 0.10 ppm. As compared to red shiners of the same size from the Nature Preserve site, the Spring 2003 fathead minnows were approximately 24 % lower in overall mercury levels (0.10 vs 0.13 ppm). This was consistent with the relationship seen between the two species throughout the project. The same trends were apparent in the methylmercury data. Fathead minnows have been sampled primarily as an alternate to the red shiners at the Nature Preserve site, where the shiners have been declining. However, it appears that both species are now largely absent from that site. Because of the normal successional evolution of newly created wetland systems, it will be important to utilize an adaptive monitoring system in any similar monitoring, expecting changes in available bioindicator species until an equilibrium is developed.

Juvenile green sunfish (Table 5, Figure 4) were taken at all four of the fish sampling sites in the Spring 2003 sampling, primarily in the 51-80 mm size class. They were analyzed in numbers sufficient to provide statistical confidence intervals for all of the sites in this size class. Green sunfish mercury concentrations from Spring 2003 ranged between 0.06 and 0.15 ppm. As in the previous two spring seasons, concentrations were generally reduced as compared to the previous fall sampling, though the seasonal variation was less than that seen in the red shiners. Spatially, lowest concentrations occurred at Gordon Slough and Cache Creek below Gordon Slough, as has been typical. Also as has been typical, the upper Cache Creek location was elevated somewhat over those sites. The difference was statistically significant relative to the Gordon Slough location. Concentrations from within the Nature Preserve wetlands were the most highly elevated. The difference was statistically significant relative to all three of the additional sites for total mercury and for Gordon Slough and the downstream Cache Creek site for methylmercury. As noted for the other fish species, mercury elevations were not found within Cache Creek in relation to potential discharge from the Preserve wetlands. Methylmercury trends followed those noted for total mercury, continuing as in previous samplings at a high percentage of total mercury (89-98%).

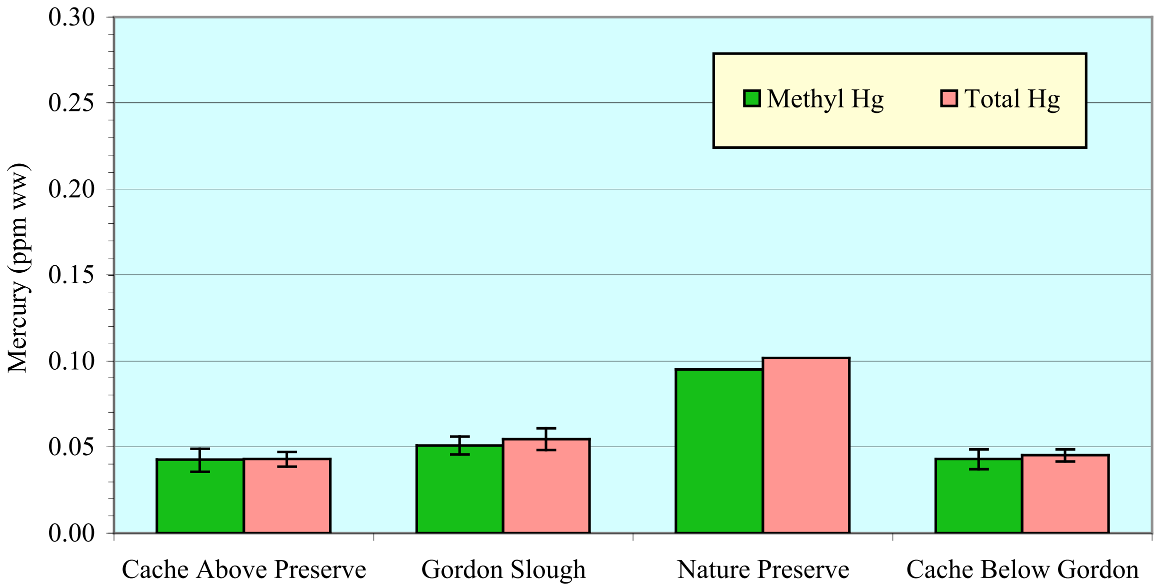
Mosquitofish (Table 6, Figure 5). This species has been very difficult to obtain during spring collections. However, conditions throughout the warm season frequently allowed the establishment of good populations at each of the sites for the fall collections. Mosquitofish thus were used mainly as indicators of warm season conditions, sampled in the fall. During the May 2003 sampling, we were able to obtain replicate composite samples of the smaller size class (20-30 mm) only from within the Nature Preserve wetlands. Replicate composite samples of the mid (31-40 mm) and larger (41-50 mm) size classes were taken from both the Preserve and Gordon Slough, but were not available from the Cache Creek sites. Concentrations in the abbreviated Spring 2003 collections ranged between 0.05 and 0.11 ppm. Nature Preserve samples were not statistically distinguishable from those of Gordon Slough. Interestingly among the Nature Preserve samples, the youngest, smallest fish (Size Class 1, 20-30 mm) demonstrated significantly greater concentrations than the mid size class (Size Class 2, 31-40 mm). This pattern is characteristic of recently increasing exposure conditions and may provide additional evidence that wetlands methylmercury production in this region begins to ramp up in the spring. Mosquitofish methylmercury concentrations closely followed total mercury, at a high percentage of total mercury (86-89%).

<u>Inland Silverside</u> (Table 7, Figure 6). As the Nature Preserve wetlands continue to evolve, the fish assemblage there continues to change. Some of the originally prevalent species have become scarce, while several other species have colonized and gradually or rapidly increased. Inland silversides, in particular, have become populous enough to sample to some extent in the Nature Preserve, though they remain uneven or absent at the creek and slough sites. Like the other species utilized in this project for long-term bioindicator monitoring, silversides are also a non-native, introduced fish species. Ten fish were collected in the 66-80 mm size class and were analyzed individually. Concentrations averaged 0.16 ppm. Comparable samples were taken at this site in the previous two seasonal samplings, with mean levels of 0.19 ppm in fall 2002 and 0.07 ppm in spring 2002. Following a dramatic, 270% increase between spring 2002 and fall 2002, the most recent spring 2003 samples indicate an apparent maintenance of relatively elevated concentrations, as compared to Spring 2002. Methylmercury was found at a high percentage of total mercury (mean = 96%). Silversides exhibited the highest mercury content of any of the small fish sampled from the Nature Preserve in Spring 2003. This was also the case in the prior sampling.

The silverside data provide us with a direct link to extensive monitoring of this species conducted by UC Davis throughout the Sacramento-San Joaquin Delta region (Slotton et al. 2002). It is notable that silversides from the Cache Creek Nature Preserve wetlands exhibited mercury bioaccumulation at 2-3 times greater concentrations than those across the majority of the Delta, a region currently being assessed for mercury-based consumption guidelines. The Nature Preserve levels were similar to concentrations seen at relatively highly contaminated sites such as the Cosumnes River, Mud Slough, and portions of Cache Creek. To place the small fish data into another context, “keeper” sized adult piscivorous fish such as largemouth bass in such a system could be expected to contain fillet mercury to 2-4 fold greater than the 0.30 ppm EPA criterion level.

Fig. 2. FISH Composite Hg (wet wt ppm) VS LOCATION
<u>Red Shiner</u> (*Notropis lutrensis*), May 2003
(mean values plotted for replicate composites)
(95% confidence intervals shown for samples with ≥3 replicates)

2(a). Red Shiner 36-50 mm size class.



2(b). Red Shiner 51-65 mm size class.

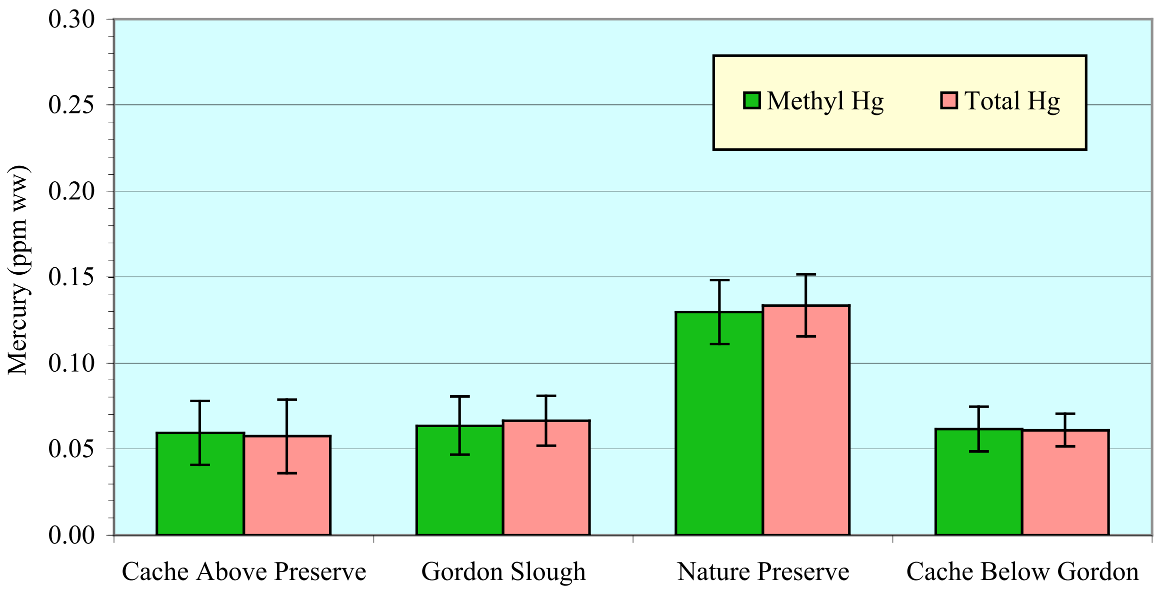
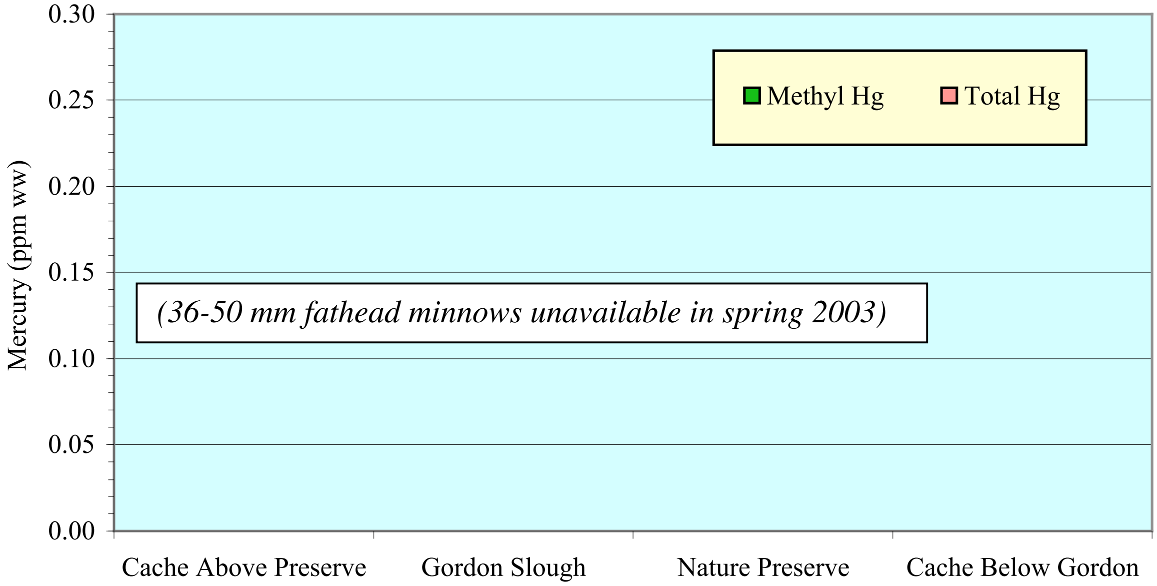


Fig. 3. FISH Composite Hg (wet wt ppm) VS LOCATION
Fathead Minnow (*Pimephales promelas*), May 2003
(mean values plotted for replicate composites)
(95% confidence intervals shown for samples with ≥3 replicates)

3(a). Fathead Minnow 36-50 mm size class.



3(b). Fathead Minnow 51-65 mm size class.

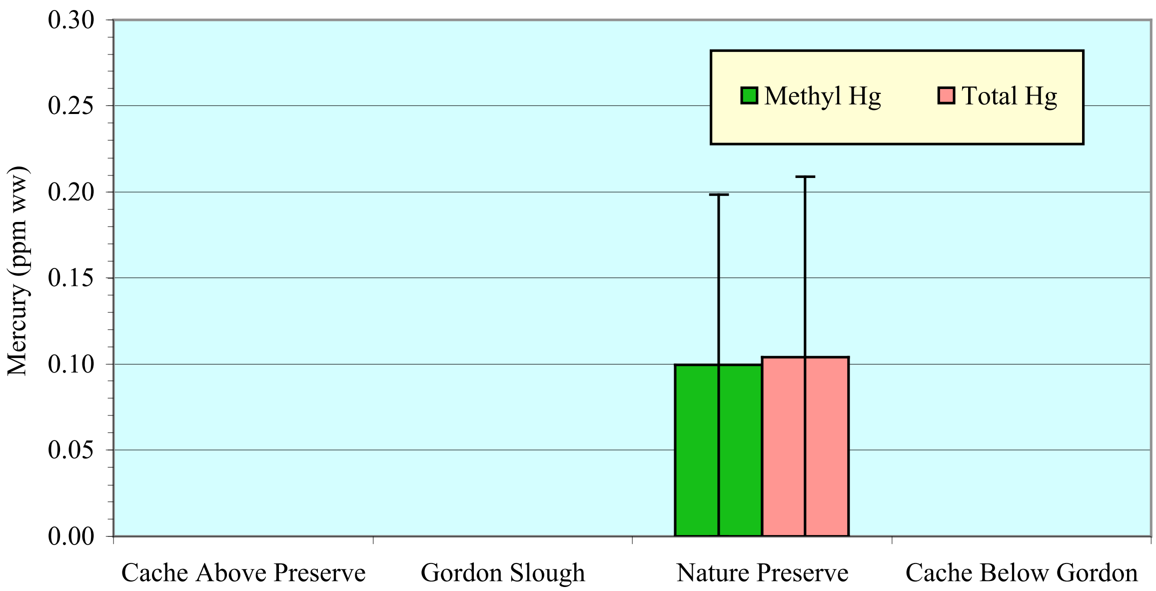
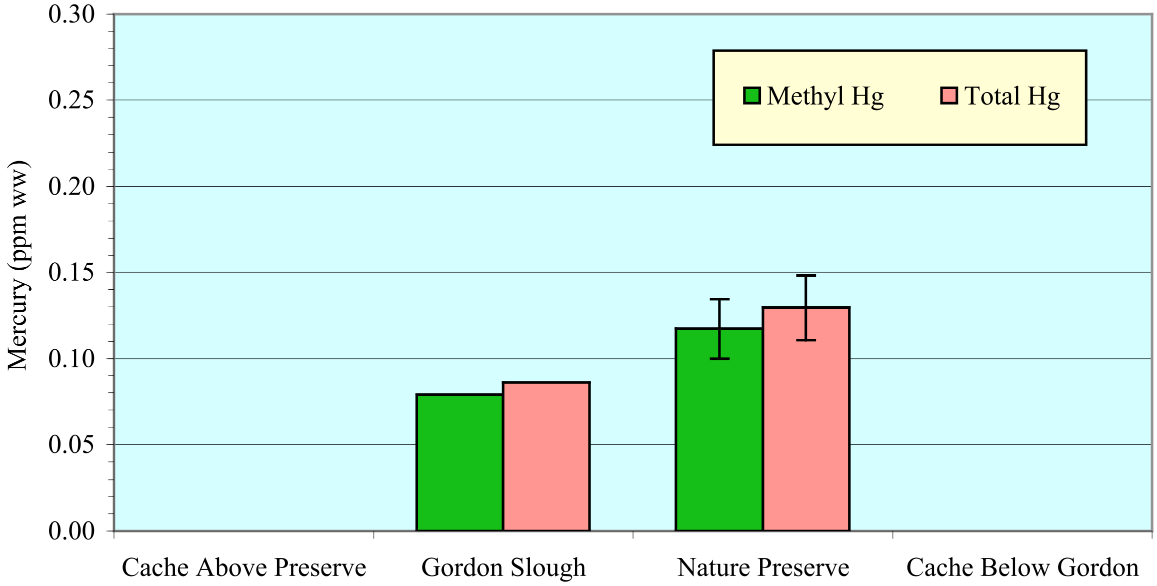


Fig. 4. FISH Composite Hg (wet wt ppm) VS LOCATION
<u>Green Sunfish</u> (*Lepomis cyanellus*), May 2003
(mean values plotted for replicate composites)
(95% confidence intervals shown for samples with ≥3 replicates)

4(a). Green Sunfish 25-50 mm size class.



4(b). Green Sunfish 51-80 mm size class.

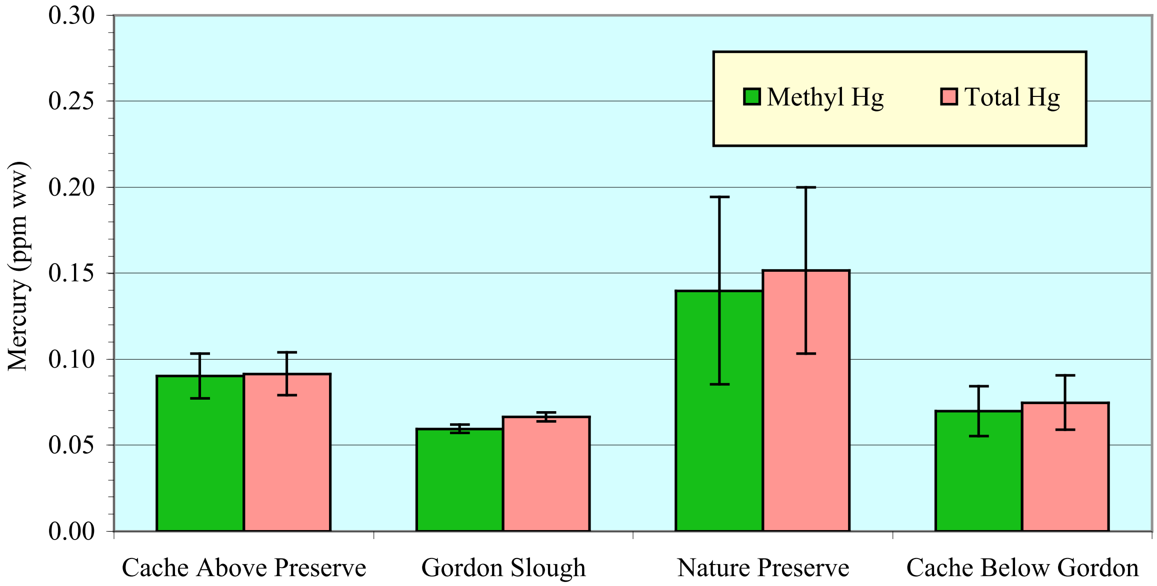
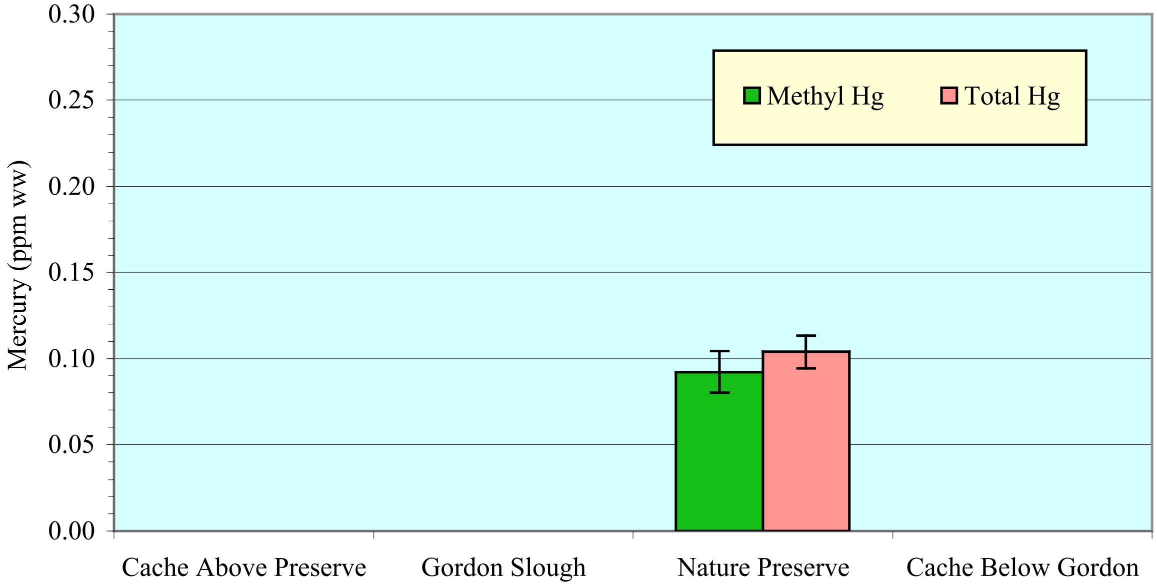
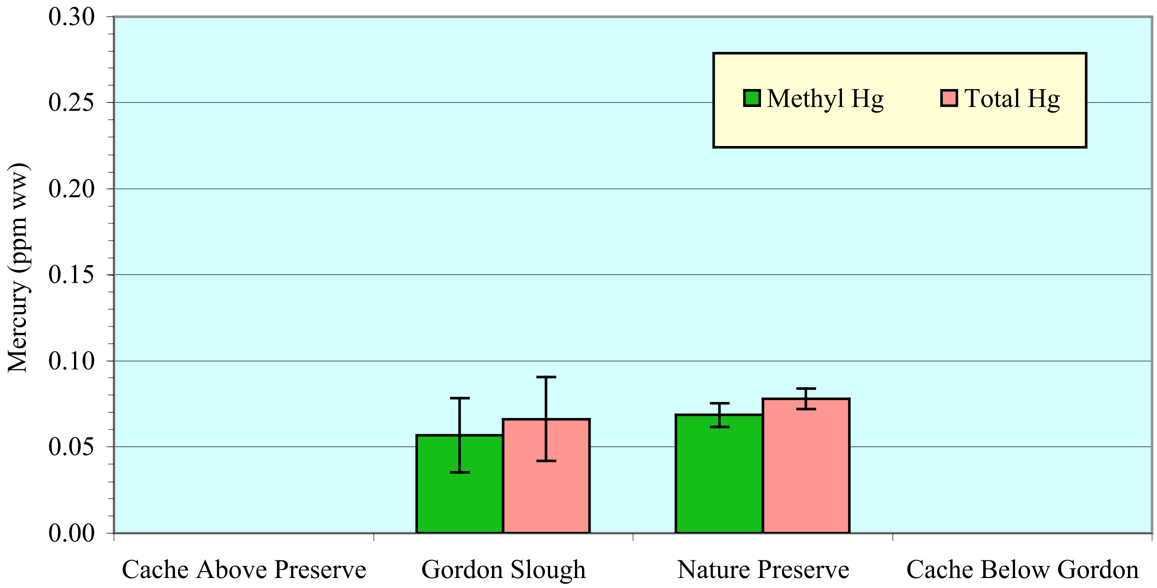


Fig. 5. FISH Composite Hg (wet wt ppm) VS LOCATION
Mosquitofish (*Gambusia affinis*), May 2003
(mean values plotted for replicate composites)
(95% confidence intervals shown for samples with ≥3 replicates)

5(a). Mosquitofish 20-30 mm size class.



5(b). Mosquitofish 31-40 mm size class.



5(c). Mosquitofish 41-50 mm size class.

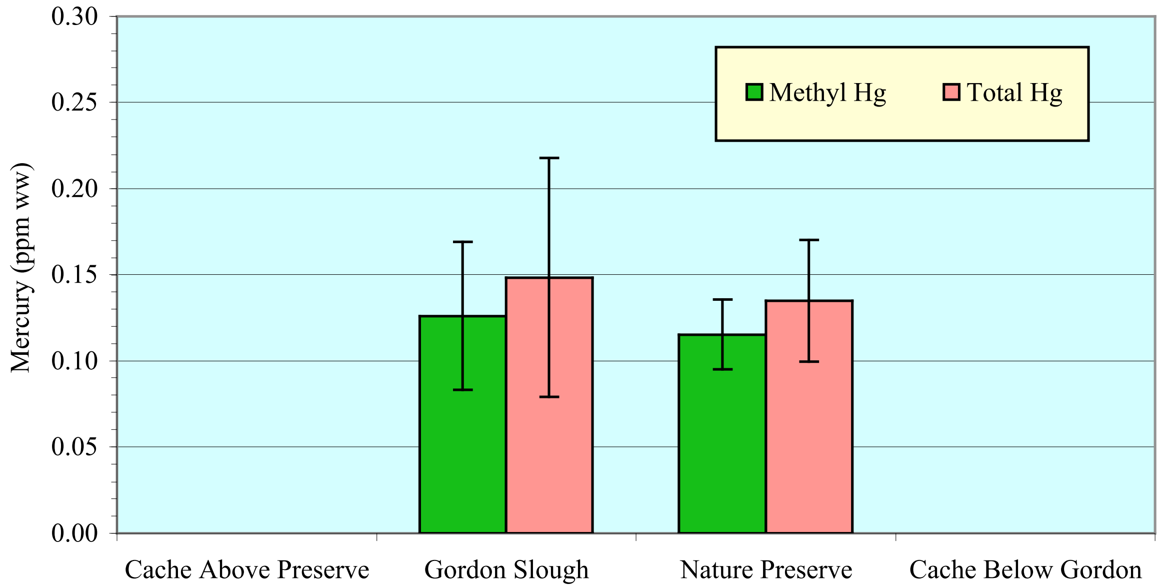


Fig.6. FISH Composite Hg (wet wt ppm) VS LOCATION
<u>Inland Silverside</u> (*Menidia beryllina*), May 2003
(mean values plotted for replicate composites)
(95% confidence intervals shown for samples with ≥3 replicates)

Inland Silverside 66-80mm size class.

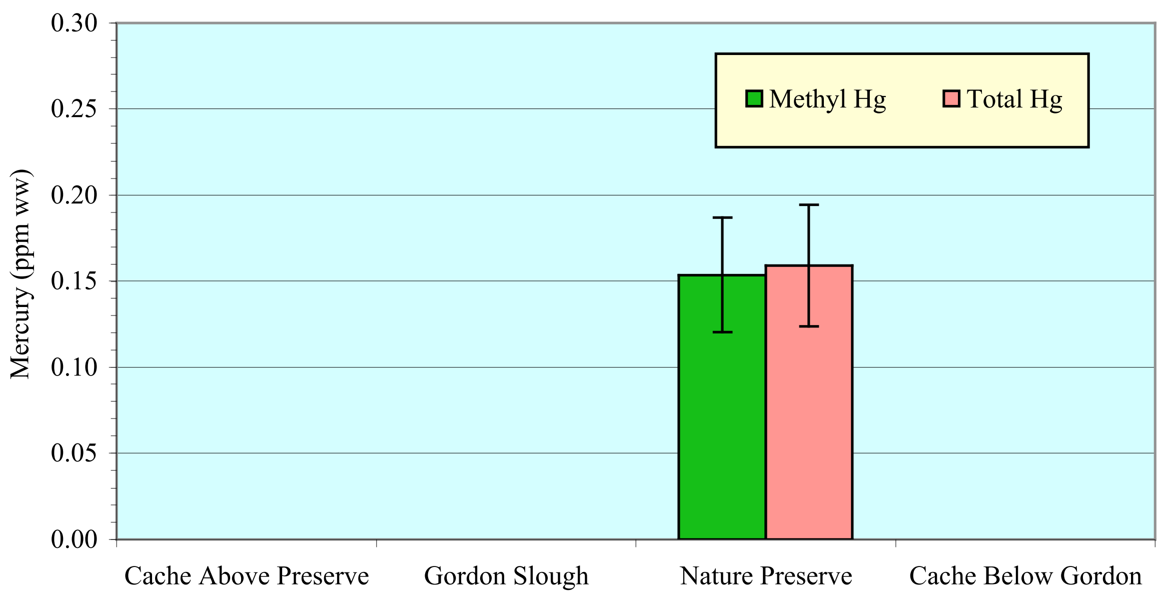
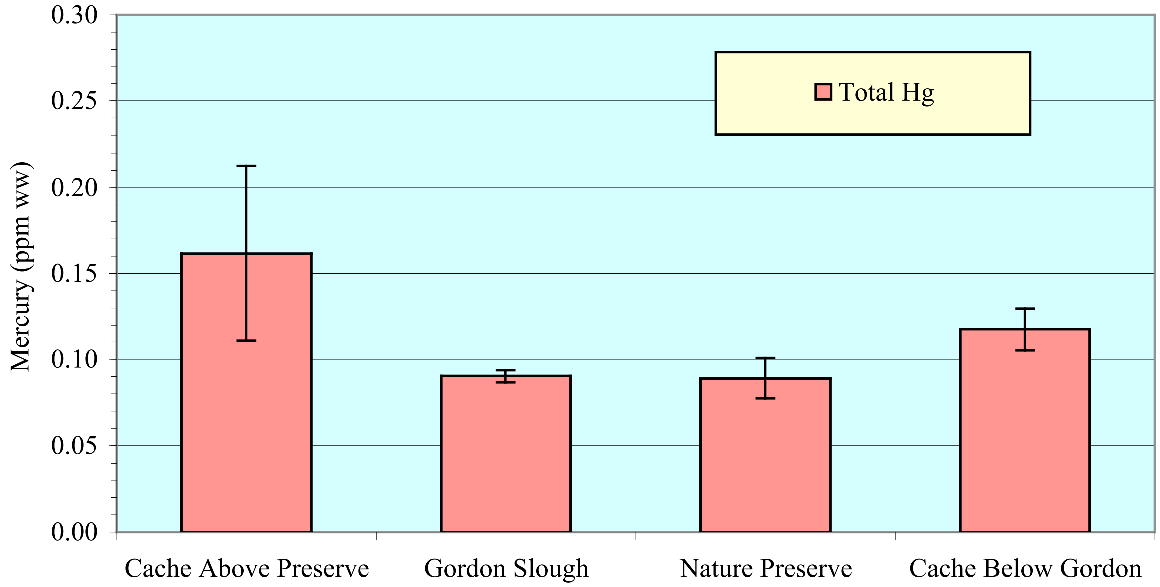


Fig. 7. STANDARDIZED FISH Composite Hg (wet wt ppm) VS LOCATION
35-50 mm Red Shiner (*Notropis lutrensis*) SPATIAL TIME SERIES
(mean values plotted for replicate composites)
(95% confidence intervals shown for samples with ≥3 replicates)

7(a). 35-50 mm Red Shiner Hg: November 2000.



7(b). 35-50 mm Red Shiner Hg: May 2001.

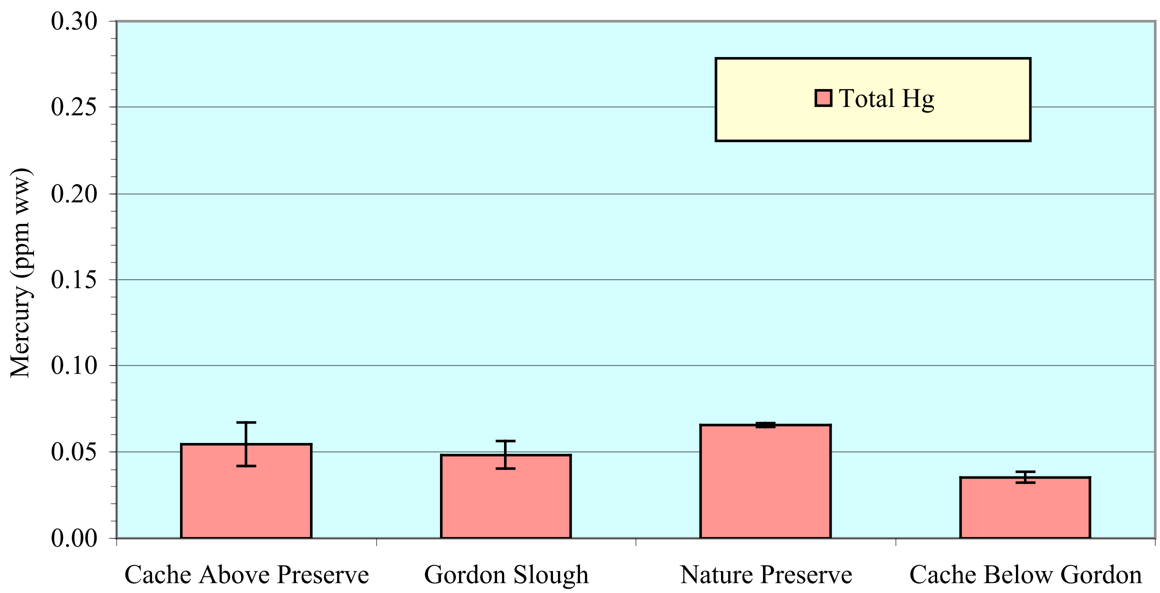
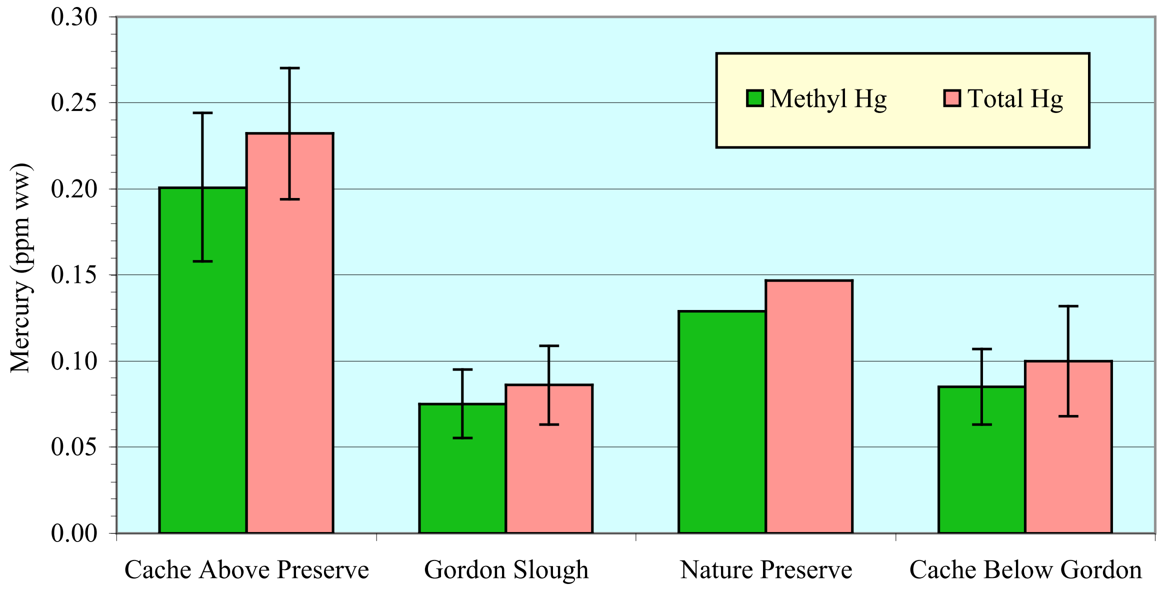


Fig. 7. (continued)

7(c). 35-50 mm Red Shiner Hg: <u>November 2001</u>.



7(d). 35-50 mm Red Shiner Hg: <u>May 2002</u>.

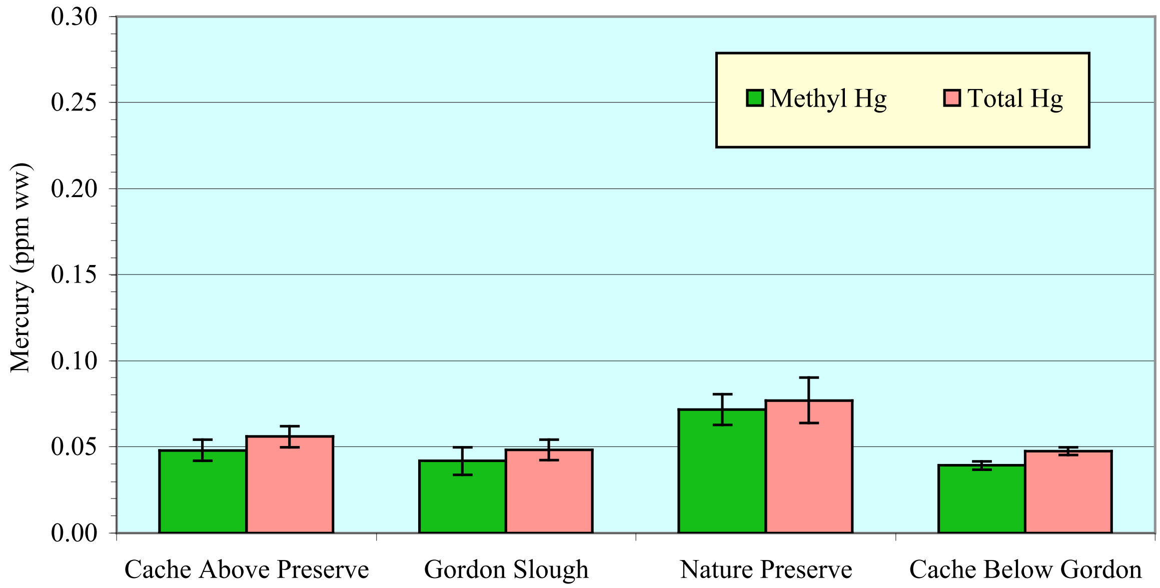
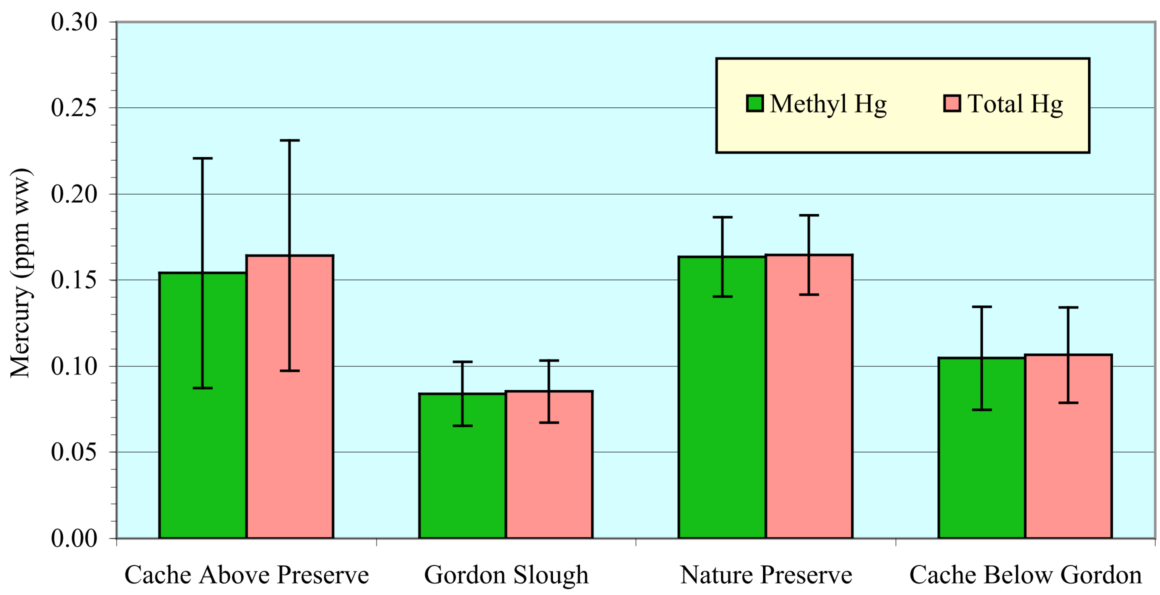
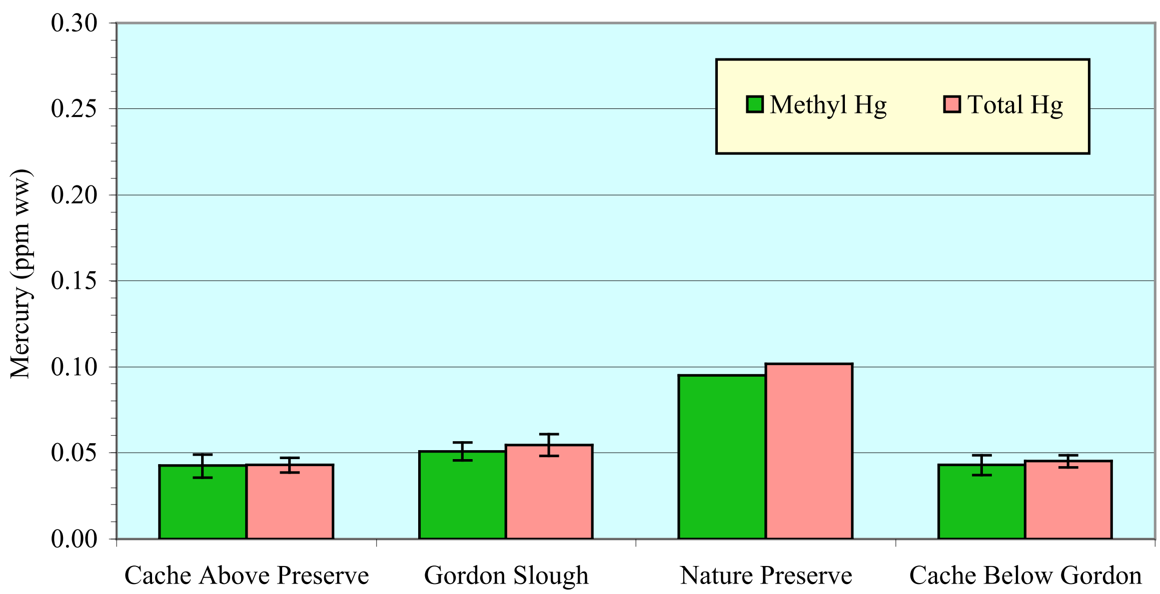


Fig. 7. (continued)

7(e). 35-50 mm Red Shiner Hg: November 2002.



7(f). 35-50 mm Red Shiner Hg: May 2003.



Mercury in Aquatic Insects

Aquatic insect mercury data from the Spring 2003 collections are presented in Tables 8-10 and Figures 8(a-d). These data, as initiated in Year 2 of the project, are displayed in units of *fresh/wet weight* parts per million total or methyl mercury, corresponding to the fish data. We have developed an accurate methodology to sequentially obtain the fresh and then dry weights of each invertebrate sample. This allows us to directly convert the invertebrate mercury dry weight, powdered concentrations, as analyzed, to a wet weight basis, for comparability with the fish. Because of the generally lower range of mercury concentrations in the invertebrate samples relative to the fish, the invertebrate data are graphically plotted with 0.00-0.10 ppm axes rather than the 0.00-0.30 range generally used for the fish figures, and the data are discussed at the ±0.001 ppm level.

As in previous samplings, aquatic insects were not available from the Nature Preserve or Gordon Slough in sufficient densities for meaningful comparative analysis. Spring 2003 aquatic insect data therefore come from the strategic series of Cache Creek sites including: Cache Creek above the Nature Preserve, Cache Creek between the Nature Preserve outlet and Gordon Slough, and Cache Creek below Gordon Slough. To place the creek invertebrate data into historical perspective, spatial data for the most consistently available type, Hydropsychid caddisfly larvae, are presented in Figure 9(a-f) across all six of the seasonal samplings conducted between November 2000 and May 2003.

<u>Hydropsychid caddisfly larvae</u> (Table 8, Figure 8a and seasonal series in Figure 9a-f) were taken in 3-4 replicate composite samples, each composed of numerous individuals (40-70 each) from each of the three Cache Creek sites. These intensive collections again resulted in good accuracy and precision in the statistics generated. May 2003 caddisfly mercury ranged very narrowly between 0.023 and 0.029 ppm among all 10 of the composites. On this sampling date, the three sequential Cache Creek locations exhibited very similar caddisfly mercury concentrations throughout. In previous samplings (Figure 9a-f), the two upstream locations (above the Preserve and between the Preserve and Gordon Slough) often had higher caddisfly mercury than the Cache Creek site located below Gordon Slough. On two of the six semi-annual samplings, the statistically highest concentrations occurred at the intermediate Cache Creek site located between the Preserve and Gordon Slough. In all six of the semi-annual samplings, the caddisfly indicators were never statistically elevated at the downstream location below Gordon Slough, relative to corresponding samples taken upstream of the Preserve. Methylmercury generally mirrored total mercury, though at a lower percentage of total mercury as compared to fish (56-76% in the May 2003 samples). This is typical and a function of relative trophic position in the food web. The higher up the food web an organism feeds, typically the closer the methylmercury:total mercury ratio comes to 100%.

Calopterygid damselfly nymphs (Table 9, Figure 5b) were also taken from each of the three Cache Creek invertebrate sampling locations, with composites of multiple individuals (14-20 each) collected at each of the sites. Only the downstream site yielded sufficient numbers to provide triplicate composites, though damselflies have been more prevalent in some previous samplings throughout the project. May 2003 Calopterygid mercury ranged extremely narrowly between 0.013 and 0.015 ppm. As seen in the caddisfly data, concentrations were very similar at this time across the transect. Also similar to the caddisflies, the damselfly indicators exhibited prior spatial patterns including statistically elevated concentrations at the upstream sites but never at the downstream site. Methylmercury trends generally tracked those seen for total mercury. The methyl:total mercury ratio was 79-100% in the May 2003 samples.

Libellulid dragonfly nymphs (Table 10, Figure 8c) were also taken at each of the three Cache Creek invertebrate sampling locations in the May 2003 collections. Dragonfly nymphs have been available as mercury bioindicators for the project on most sampling dates, though frequently not in sufficient densities to generate multiple replicate composite samples. In the May 2003 sampling, excellent quadruplicate samples of 19-20 individual dragonfly nymphs each were collected from the upper two sites, yielding tight statistical confidence intervals. Mean concentrations were very similar at these two sites, at 0.027-0.029 ppm. Mean dragonfly mercury was somewhat higher, at 0.033 ppm, at the downstream Cache Creek site below Gordon Slough. However, samples were relatively scarce at that location, with extensive sampling yielding triplicate composites of 6 individuals each. The resulting 95% statistical confidence interval for the mean concentration at this site was consequently substantially less precise than those for the upper two sites which had more intensive collections (Figure 8c). The difference was not significant. The overall mercury concentrations for dragonfly nymphs throughout the project were notably greater than those of corresponding Hydropsychid caddisflies, which were in turn higher than corresponding Calopterygid damselflies. This reflects their relative trophic feeding position, the dragonflies being larger predators. As in the other invertebrate indicators, dragonfly methylmercury followed total mercury patterns. The mean methyl:total mercury percentage of the May 2003 dragonfly samples ranged from 83-99%.

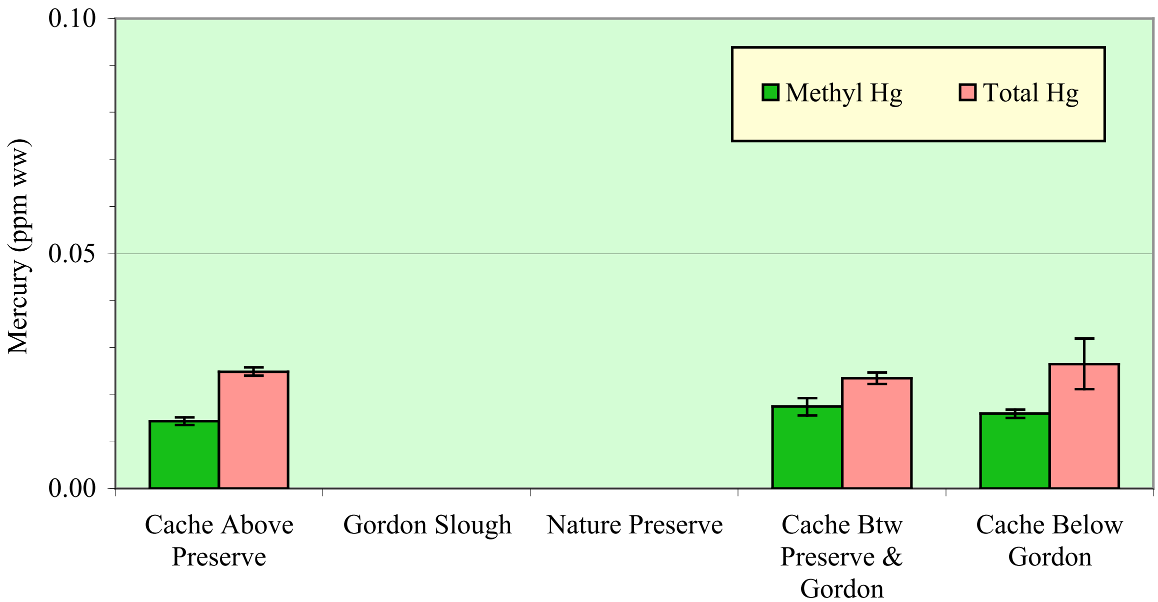
Naucorid predaceous water bugs (Table 11, Figure 8d), when present, typically exhibited the very highest mercury accumulations of the aquatic insect indicator species used in this project. In the May 2003 samplings, mean concentrations were 0.073 at the upstream Cache Creek site above the Preserve, 0.064 ppm at the intermediate site between the Preserve and Gordon Slough, and 0.056 ppm at the downstream site below Gordon Slough. Triplicate composites of 15 (upstream) to 27 (downstream) individuals each were obtained from the upper and lower sites. However, the downstream set was quite variable. As a result, the declining mercury trend, moving downstream, was not significant at the 95% confidence level. Methylmercury trends generally followed those of total mercury throughout the project. The Naucorid mean methyl:total mercury ratio ranged between 65% and 80% in the May 2003 collections.

Fig. 8. INVERTEBRATE Composite Hg (WET wt ppm) VS LOCATION, May 2003

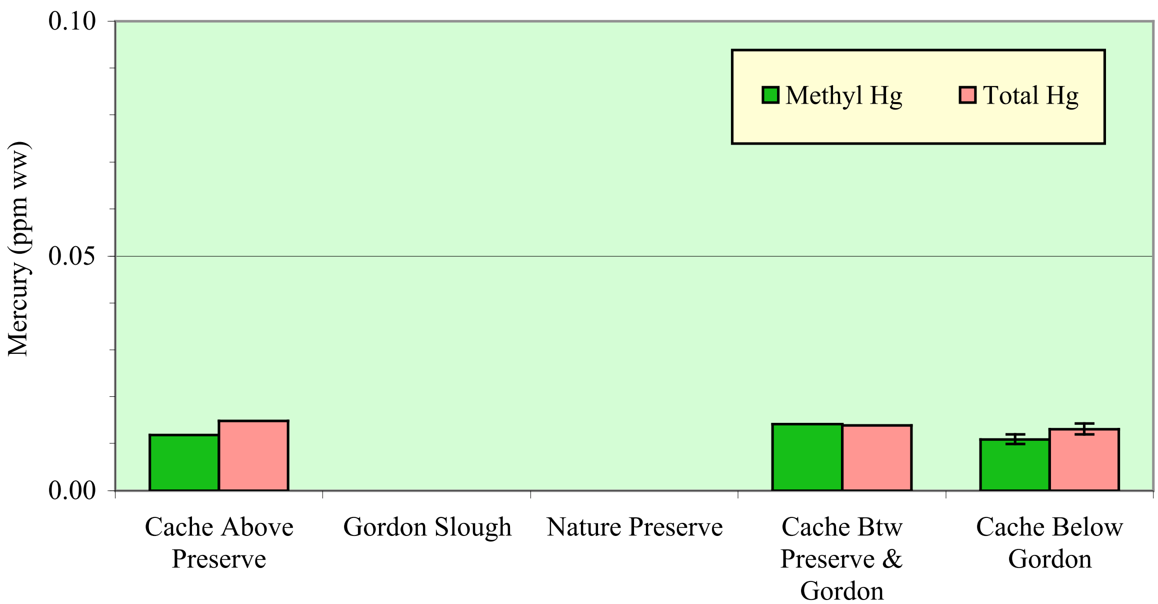
(mean values plotted for replicate composites)

(95% confidence intervals shown for samples with ≥3 replicates)

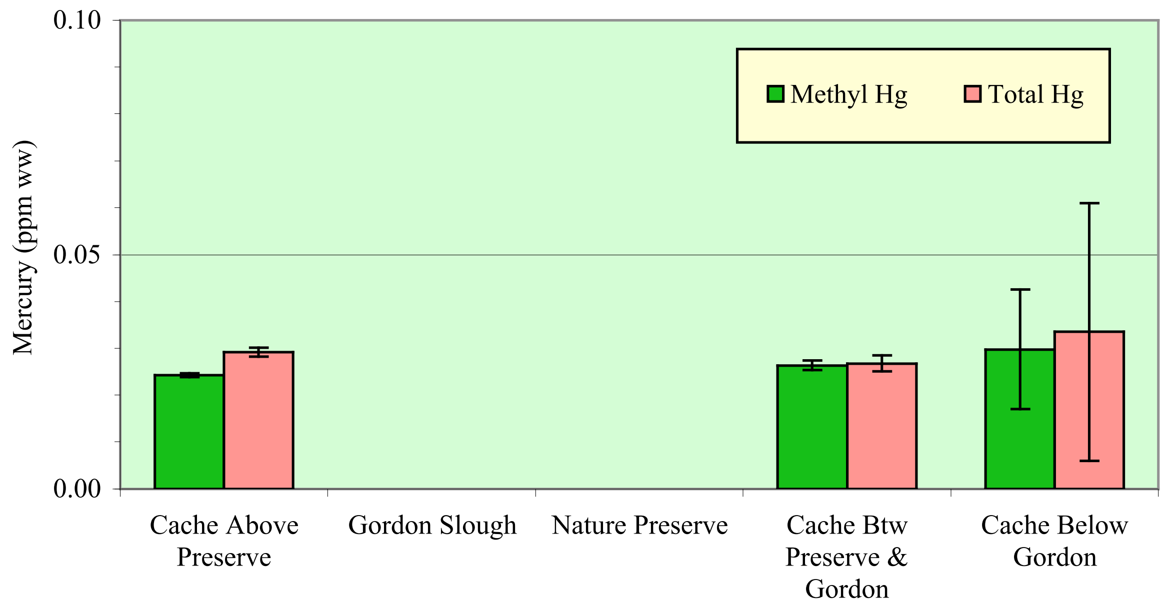
8(a). Hydropsychidae (caddisfly larvae, omnivores).



8(b). Calopterygidae (damselfly nymphs, omnivorous type).



8(c). Libellulidae (predatory dragonfly nymphs).



8(d). Naucoridae (predaceous creeping water bugs).

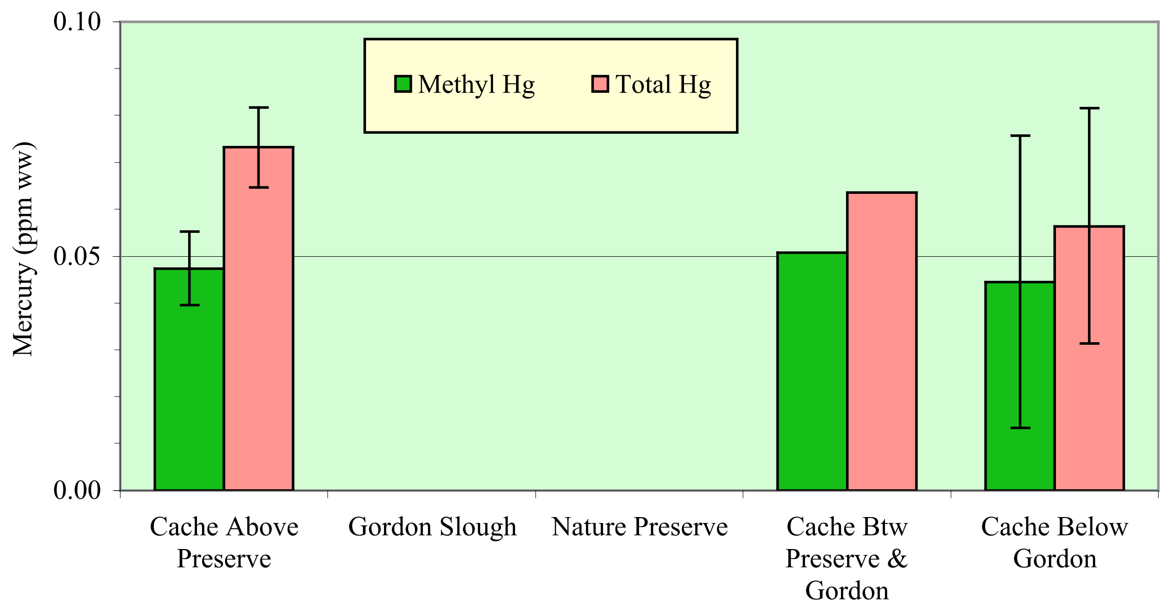
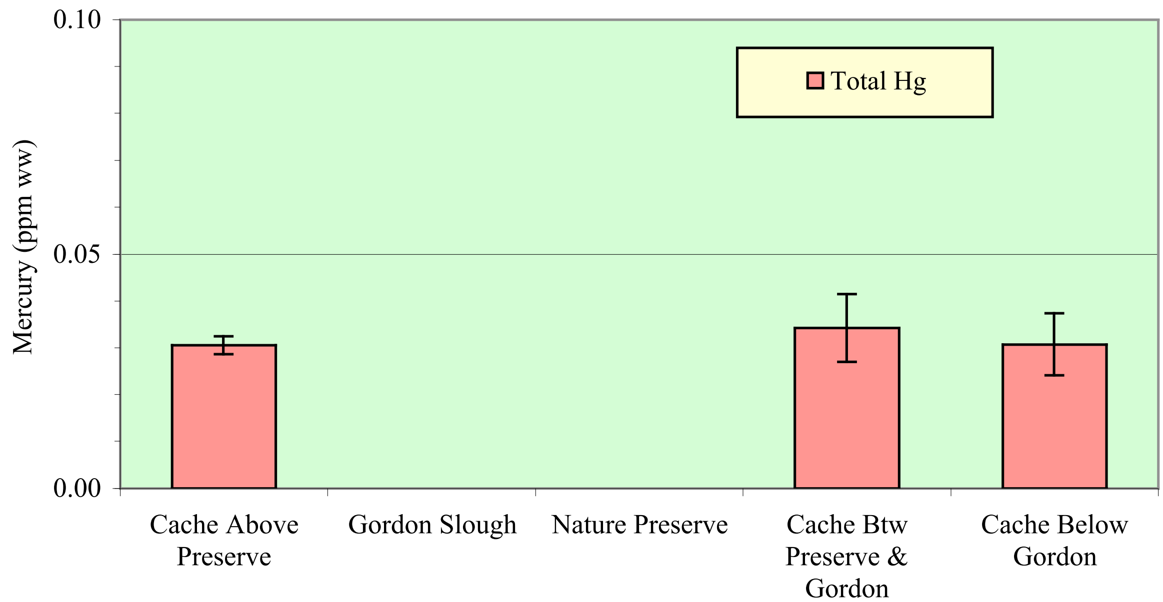


Fig. 9. STANDARDIZED INVERTEBRATE Composite Hg (wet wt ppm) VS LOCATION: HYDROPSYCHIDAE SPATIAL TIME SERIES

(mean values plotted for replicate composites)

(95% confidence intervals shown for samples with ≥3 replicates)

9(a). Hydropsychidae (caddisfly larvae, omnivores): November 2000.



9(b). Hydropsychidae (caddisfly larvae, omnivores): May 2001.

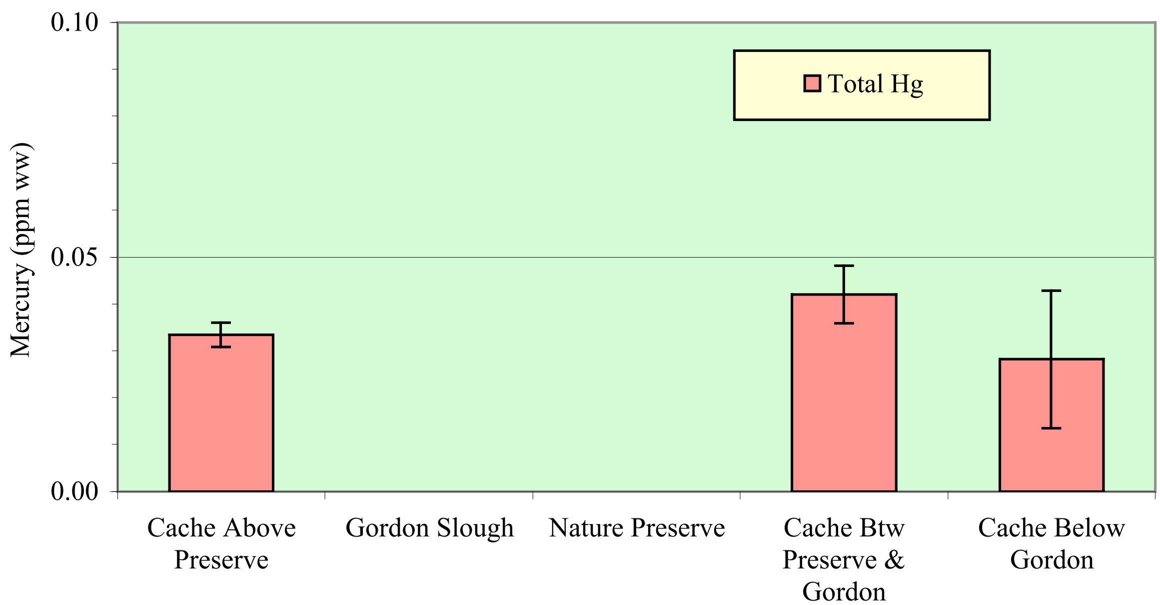
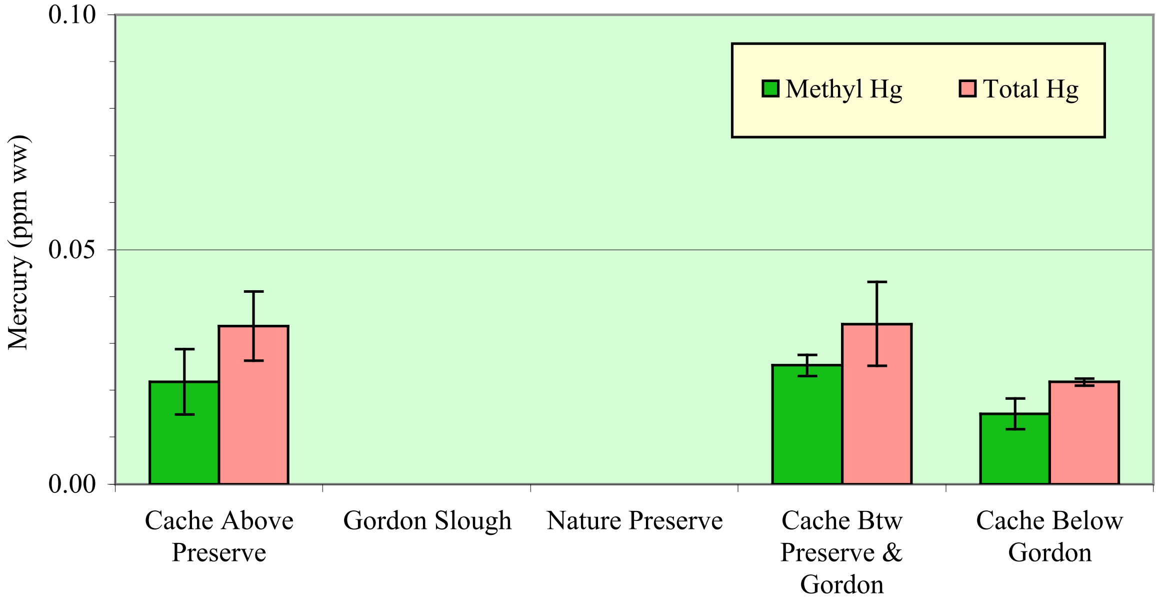


Fig. 9. (continued)

9(c). Hydropsychidae (caddisfly larvae, omnivores): November 2001.



9(d). Hydropsychidae (caddisfly larvae, omnivores): May 2002.

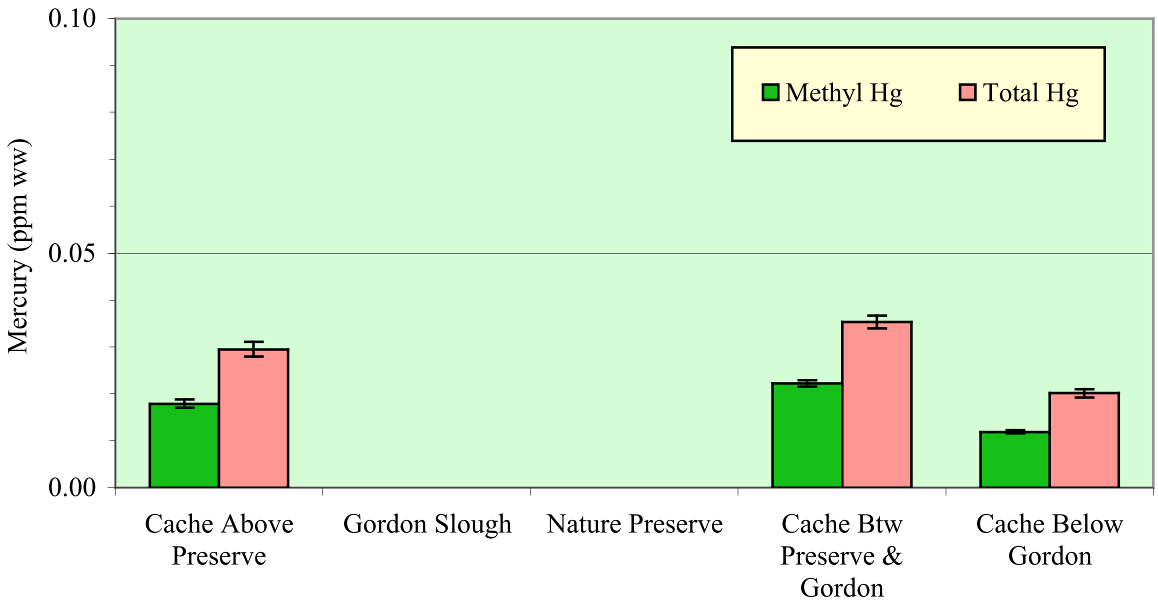
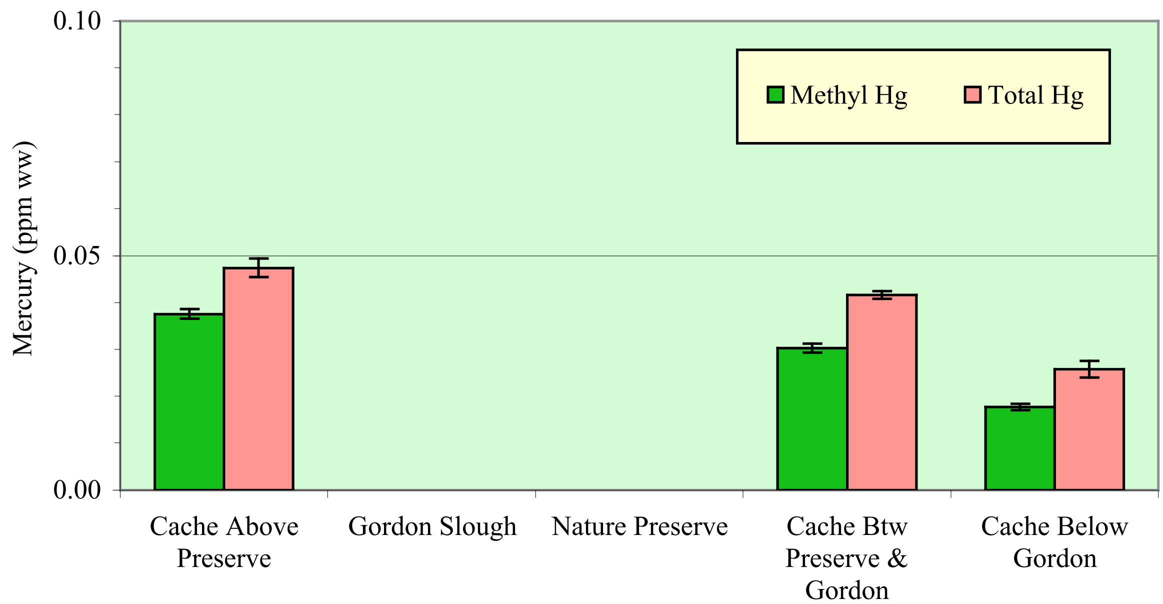
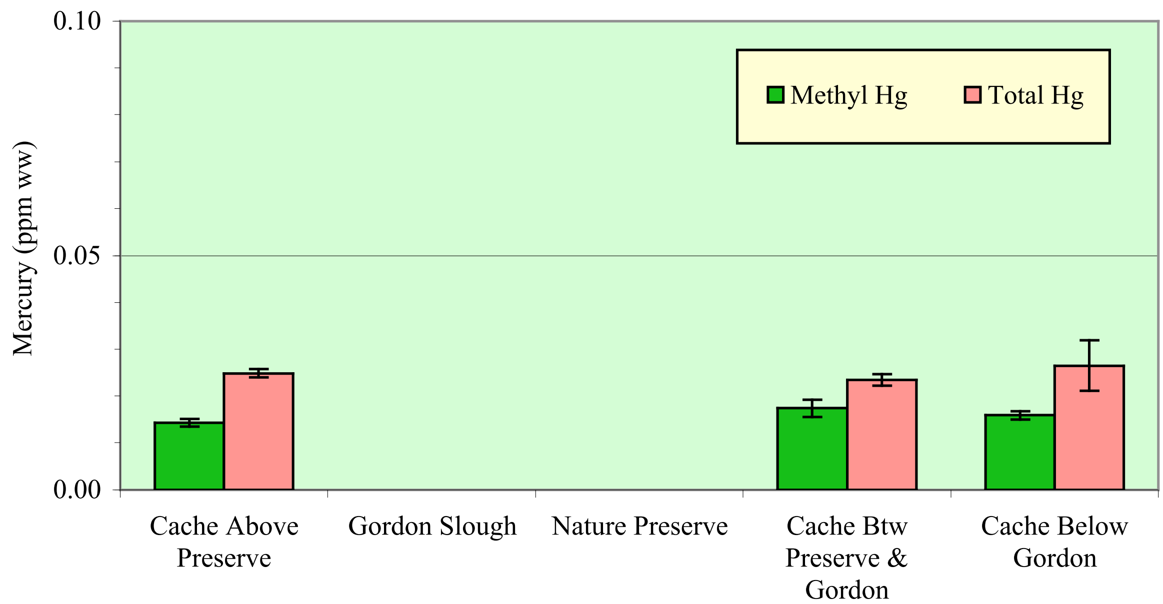


Fig. 9. (continued)

9(e). Hydropsychidae (caddisfly larvae, omnivores): November 2002.



9(f). Hydropsychidae (caddisfly larvae, omnivores): May 2003.



Mercury in Water

The monitoring protocol utilized aquatic organisms as integrating bioindicators of recent mercury exposure. The biotic sampling was supplemented with water collections on several occasions when water was being flushed through the Preserve. Water flushing takes inflows from Gordon Slough and discharges on the opposite side of the Preserve to Cache Creek. In 2001, several flushing events of 1/2 to 2 days duration were conducted between the months of April and September (irrigation season, when source water was available in Gordon Slough). Water was sampled on three occasions. In 2002, the Preserve was replenished and flushed on April 17-18, at which time samples were taken. No significant discharges were made subsequent to that date, though Gordon Slough water has occasionally been diverted into the Preserve to raise water levels.

Aqueous (Water) Sampling of Methylmercury in Spring-Summer 2001

Water data from spring-summer 2001 sampling are presented in Figure 10(a-c) and Table 12. Raw methylmercury was measured in inflowing vs outflowing water at the Nature Preserve on May 8 (first flush), July 26 (mid-summer), and September 26 (last flush). In the July and September samplings, a suite of ancillary water quality parameters were assessed as well. Additionally during the final sampling in September, methylmercury and ancillary parameters were assessed from all five of the biota sampling sites.

During the initial flushing event in May 2001, Nature Preserve inflow from Gordon Slough was nearly identical to outflow to Cache Creek (0.35 vs 0.38 ng MeHg/L). In September, however, outflow remained as before at 0.38 ng/L, but this was now more than double the concentration in the inflowing water (0.17 ng/L). The contrast was greatest at mid-summer in late July, with inflow methylmercury at 0.20 ng/L and outflow at 0.49 ng/L.

Additionally, September samples from main stem Cache Creek at the two sites below the Preserve (0.21 and 0.22 ng/L) were elevated relative to the upstream samples from Cache Creek (0.12 ng/L) and Gordon Slough (0.17 ng/L). It should be noted that this late September sampling represented a condition of maximal proportional effect of Preserve outflow on Cache Creek as, at that time, flows in the Creek had declined to only 15 cubic feet per second (cfs) relative to the approximately 8 cfs of Preserve outflow during the flushing. Preserve outflows would contribute a smaller proportion of Cache Creek volume during 1-2 day flushing events conducted at other times during the irrigation season.

We analyzed suspended solids in the water samples to see if the variation in Preserve inflow vs outflow methylmercury concentrations might be attributable to suspension of bottom sediments from the Preserve. This was not found to be the case; outflow TSS was approximately half that of the inflow on both dates tested. This indicates that the Preserve wetlands acted as a relative sink for sediment, as is to be expected, but also apparently as a relative source of aqueous methylmercury during the warm season.

Aqueous (Water) Sampling of Methylmercury in Spring 2002

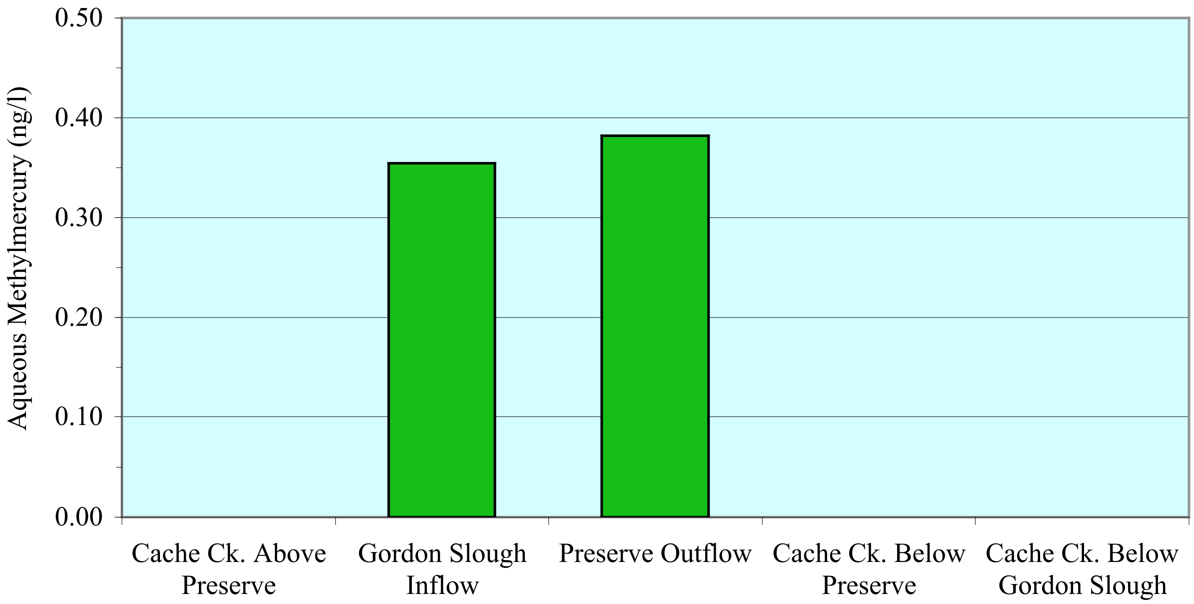
As in September, water was investigated at five strategically located sites in the system on April 18, 2002, during a brief period of flushing flows through the Nature Preserve wetlands. A variety of aqueous parameters were measured in the field. Laboratory samples were collected for analysis of methylmercury (Battelle Laboratories) and total suspended solids (UC Davis). Data are presented in Figure 11 and Table 13.

Interestingly, on this date, Gordon Slough water contained approximately twice as much methylmercury as upstream Cache Creek, though this could be attributed to 14 fold greater suspended solids in the Gordon Slough water. Most importantly, aqueous methylmercury in the Nature Preserve wetlands increased by approximately 30% between the Gordon Slough inflow and the wetlands outflow. This increase could not be attributed to changes in suspended solids, which remained steady. Methylmercury levels in Cache Creek below the Preserve outflow showed no substantial change, consistent with the small proportional input in that season relative to the flow in Cache Creek. Gordon Slough inputs resulted in downstream Cache Creek increases roughly proportional to relative flows. Preserve-flushing flows occurred for two days in April and were then discontinued through the remainder of 2002, during which time herbicide was used to kill off pond macrophytes (large aquatic weeds). No further wetlands flushing events were conducted for the remainder of the pilot monitoring period through August 2003.

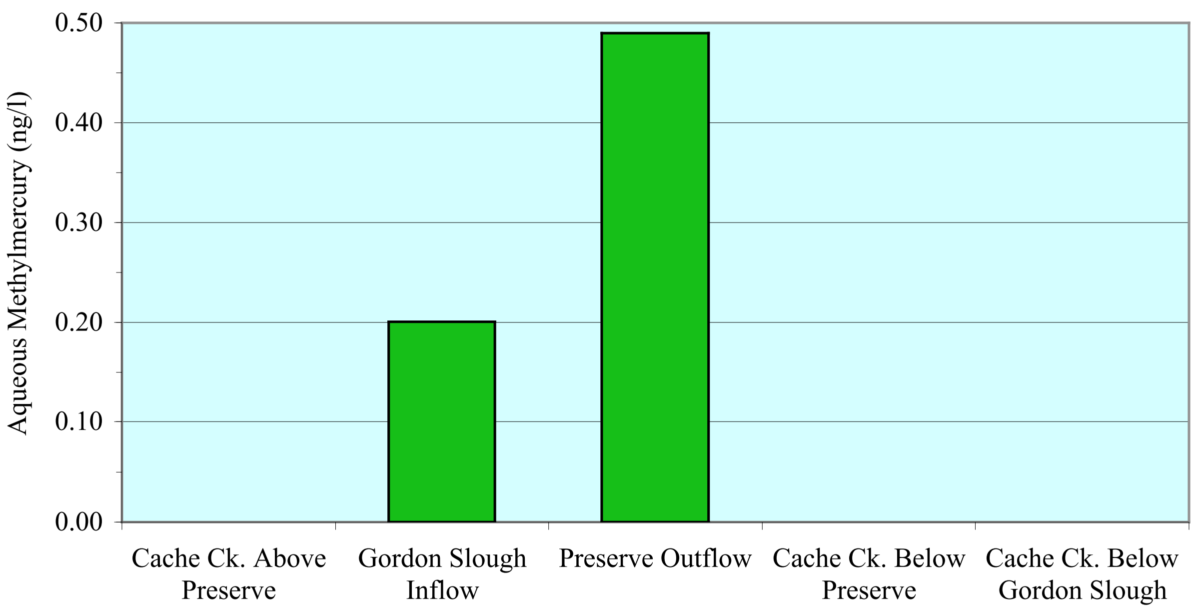
The September 2001 and April 2002 water samples from Cache Creek were not consistent with the typical spatial pattern seen in the biota, where upstream Cache Creek was typically elevated relative to downstream. This may have been a function of fluctuating water conditions, as compared to biotic accumulations that integrated exposure over substantial time periods.

Fig. 10 (a-c). METHYLMERCURY IN WATER, May-September 2001
(raw aqueous methylmercury, analyzed by Battelle Labs, Sequim, WA)

10a. May 8, 2001 (First Flush)



10b. July 26, 2001 (Mid-Summer)



10c. September 26, 2001 (Last Flush, 2001)

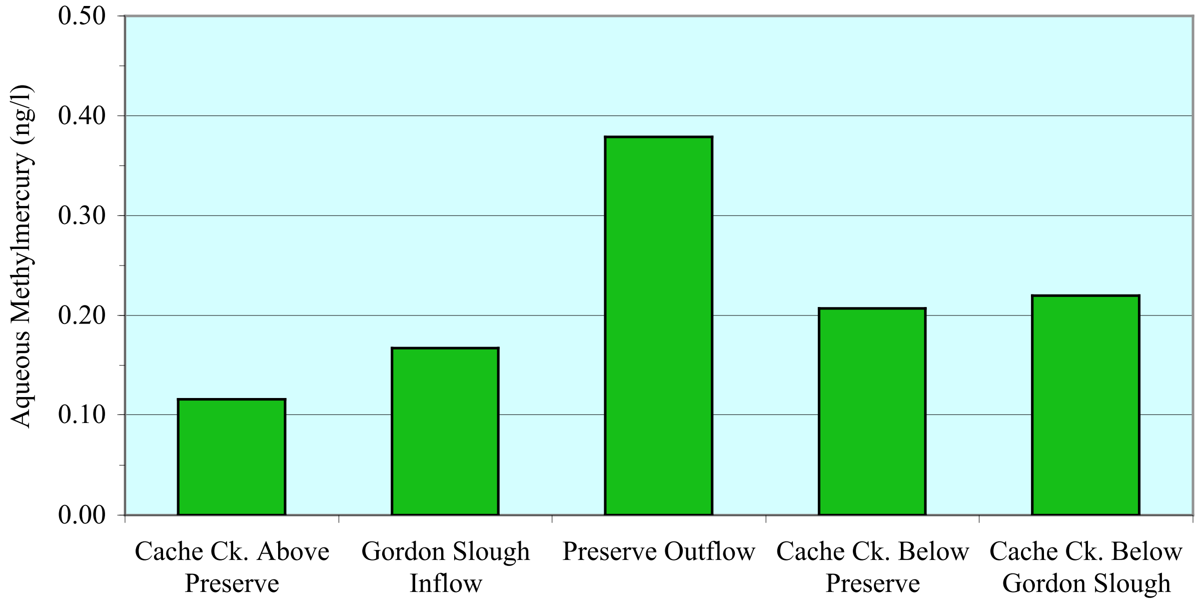
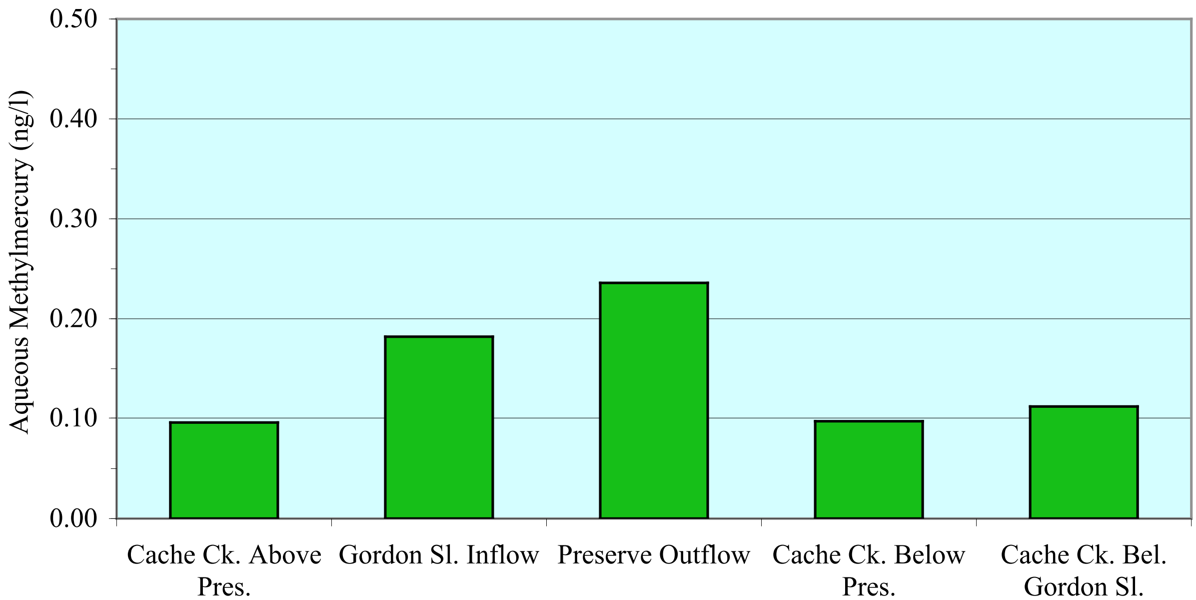


Fig. 11. 2002 METHYLMERCURY IN WATER (1 date only)
(raw aqueous methylmercury, analyzed by Battelle Labs, Sequim, WA)

April 18, 2002 (= First and Only Flush, 2002)



SEASONAL VARIATION IN MERCURY LEVELS

In addition to the multi-site primary sampling of May 2003, a final summer sampling of biota was made at the Nature Preserve wetlands site in August 2003. Data from that sampling are presented in Table 14. With the completion of this initial monitoring project, we now have six semi-annual data sets from the Cache Creek and Gordon Slough sites (Fall 2000, Spring 2001, Fall 2001, Spring 2002, Fall 2002, and Spring 2003) and twelve quarterly collections from the Nature Preserve (Fall 2000, Winter, Spring, Summer, and Fall 2001, Winter, Spring, Summer, and Fall 2002, and Winter, Spring, and Summer 2003). Graphic comparisons of selected, sequential, semi-annual fish data from Cache Creek and Gordon Slough are shown in Figures 12a, 12b, and 12c. Graphic comparisons of selected Nature Preserve fish data from all twelve seasonal samplings to date are displayed in Figures 12d and 12e. The seasonal trends for invertebrates from the series of three Cache Creek sampling locations are plotted in Figures 13(a-c).

The fish data from all of the sites, when viewed across the three years of this initial project, demonstrate a consistent, strong seasonal pattern. This cycle includes a maximum in the fall, and a distinctive minimum level of fish mercury concentrations in the spring samplings. Where sufficient numbers of replicate composites have been available for statistical comparison, this fall high vs. spring low phenomenon was typically significant at the 95% confidence level. The seasonal fluctuation in mercury content was relatively enormous, with fall levels typically ranging from 50% to over 400% greater than corresponding concentrations measured in the spring. All three fall samplings to date (2000, 2001, and 2002) exhibited this distinctive elevation elative to the immediately following spring data. The most recent contrast between Fall 2002 and Spring 2003 concentrations are discussed above within the spatial treatment of individual species. The higher resolution quarterly data from the Nature Preserve wetlands provide additional information, also describing an annual pattern of minimal fish mercury concentrations in spring, increasing toward maximal concentrations in fall, with transitions between the spring low and fall high levels generally present in the winter and summer.

As fish accumulate mercury over time, it is likely that these peaks and lows exhibited in their concentrations are not precisely matched with the underlying seasonal cycles in methylmercury production and bioavailability. It is likely that those processes somewhat precede their appearance in the fish tissue record; i.e. lowest in the winter and highest in the summer. This would be consistent with the data set we have for methylmercury in water.

In contrast to the dramatic seasonal trends noted nearly uniformly for fish, the invertebrate seasonal data (Figures 13a-c) exhibited a less consistent trend. In some cases, spring concentrations were higher than corresponding fall levels. For most sites and/or organisms, however, spring data were lower than fall values.. In the case of Spring 2001 Hydropsychidae (caddisfly larvae) at the upstream Cache Creek site, this apparent spring increase was statistically significant. A significant inter-annual decline in concentrations was noted in the previous report in all but one of the comparisons where statistics were available, between Spring 2001 and Spring 2002. Data from the second half of the project period more closely resemble the fish trends, with characteristically lower levels in the spring and higher levels in the fall, particularly at the upstream and intermediate locations. Most seasonal shifts at these sites from Spring 2002 to Fall 2002 and finally to Spring 2003 were statistically significant at the 95% confidence level.

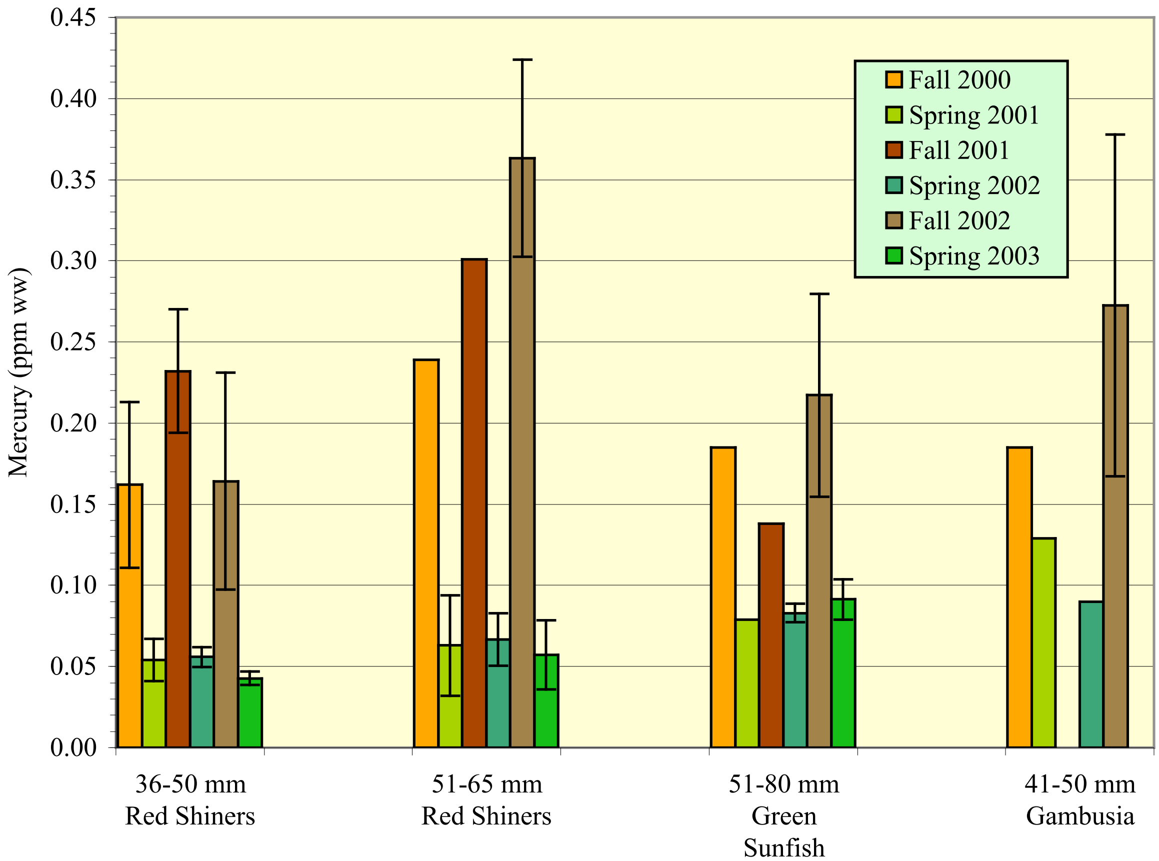
The invertebrate mercury concentrations were generally more consistent than the fish across seasons. This runs counter to what we would intuitively expect. The relative muting or lack of a strong seasonal pattern in most of the Cache Creek invertebrate data may be due to a different invertebrate response to changes in localized methylmercury exposure, relative to the small fishes. Some of our other recent research in the watershed and elsewhere suggests that this difference is related to a more rapid invertebrate response to changing mercury exposure conditions. Under this scenario, methylmercury production and exposure may indeed be maximal in the summer and at lowest levels in the winter. The fish may be taking a period of one to several months for their accumulated mercury burdens to reflect recent conditions, while the invertebrates may change more rapidly. This could be due to physiological differences or simply greater relative growth rates and turnover in the seasonal invertebrates as compared to the fish. Exposure and rapid equilibration in mercury accumulations may be fairly similar for the invertebrates in the beginning of the warm season in the spring and at the end of the warm season in the fall.

Inter-Annual and Long-Term Trends

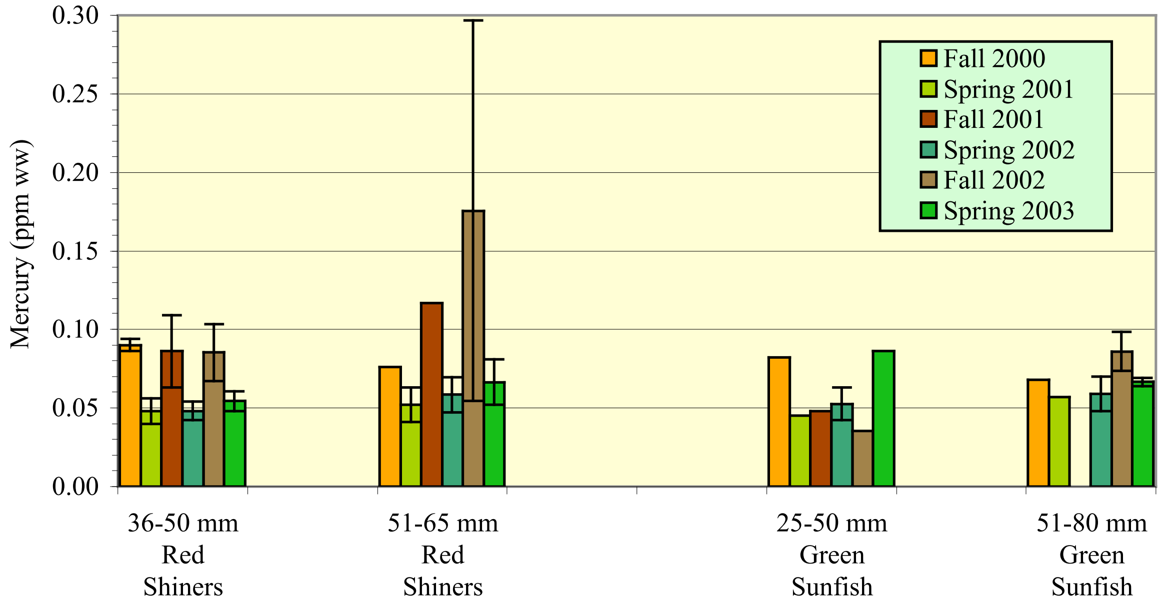
Data from some of the primary bioindicators indicate an increasing warm season trend in mercury bioaccumulation in the Nature Preserve Wetlands over the three years of the project. This could be reflective of increasingly favorable conditions for the microbial production of methylmercury in the evolving system during that time. Alternatively, there may have been a more regional phenomenon, as indicated by similar increases at other sites unaffected by Nature Preserve water (upstream Cache Creek and Gordon Slough). It is unclear at this time what trajectory methylmercury production and bioaccumulation will take in the Nature Preserve (and similar) wetlands. Levels may gradually decline over time as existing sources of inorganic mercury for methylation are exhausted in the wetland sediments. Alternatively, if sufficient new mercury is added to the system on a regular basis, methylmercury production, exposure, and bioaccumulation could remain elevated indefinitely. Water analyses demonstrated that the Preserve functions as a sediment trap, as is typical. Though Gordon Slough source water is low in mercury, it is not devoid of it. Particulate mercury routinely depositing into the Preserve bottom sediments from Gordon Slough source water may be sufficient to support moderate to high levels of methylmercury production into the future. Some level of continuation monitoring could provide useful insights into the long-term trajectories of these types of systems.

Fig. 12 (a-e). FISH Composite Hg VS SEASON
(mean values plotted for replicate composites)
(95% confidence intervals shown for samples with ≥3 replicates)

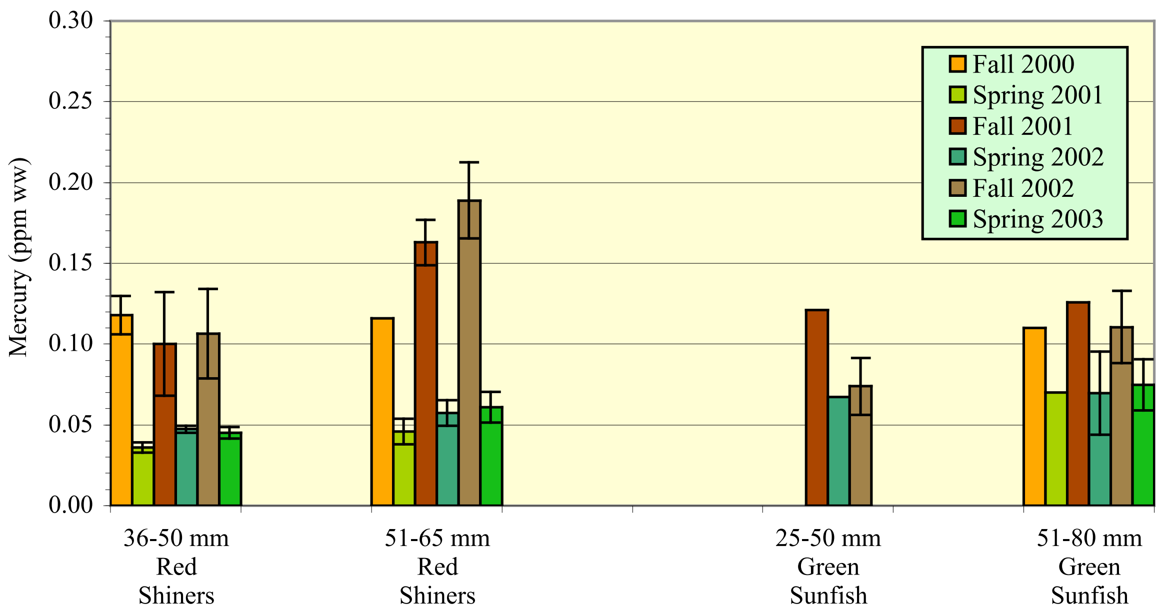
12(a). Cache Creek above Nature Preserve.
(note extended concentration axis, this site only, proportional to succeeding plots)



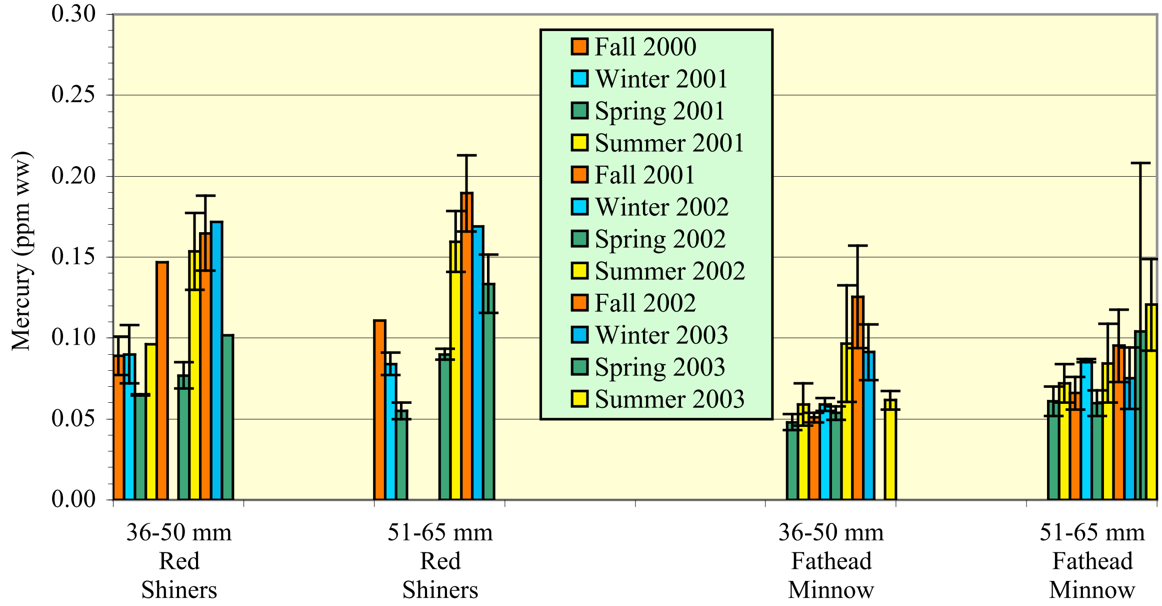
12(b). Gordon Slough.



12(c). Cache Creek below Gordon Slough.



12(d). Nature Preserve: Red Shiners and Fathead Minnows.



12(e). Nature Preserve: Green Sunfish and Mosquitofish.

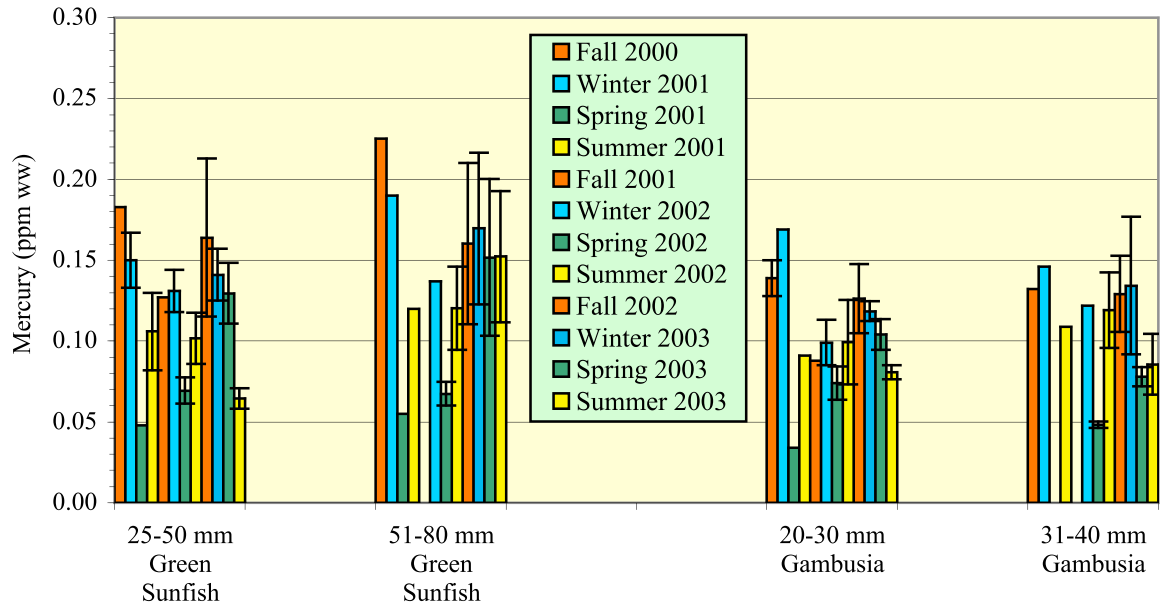
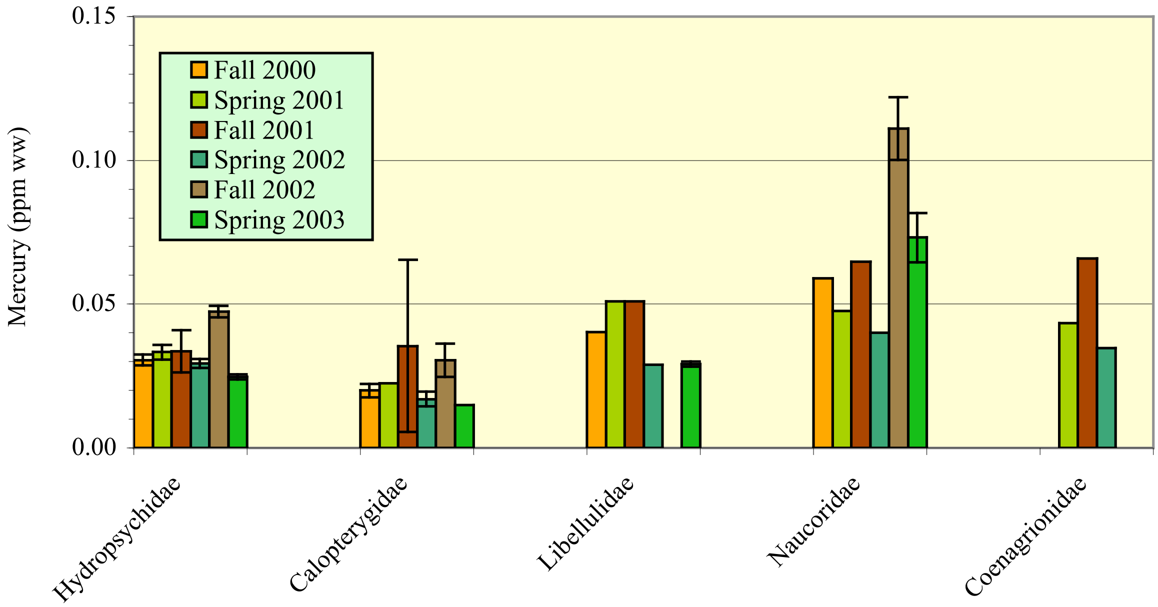
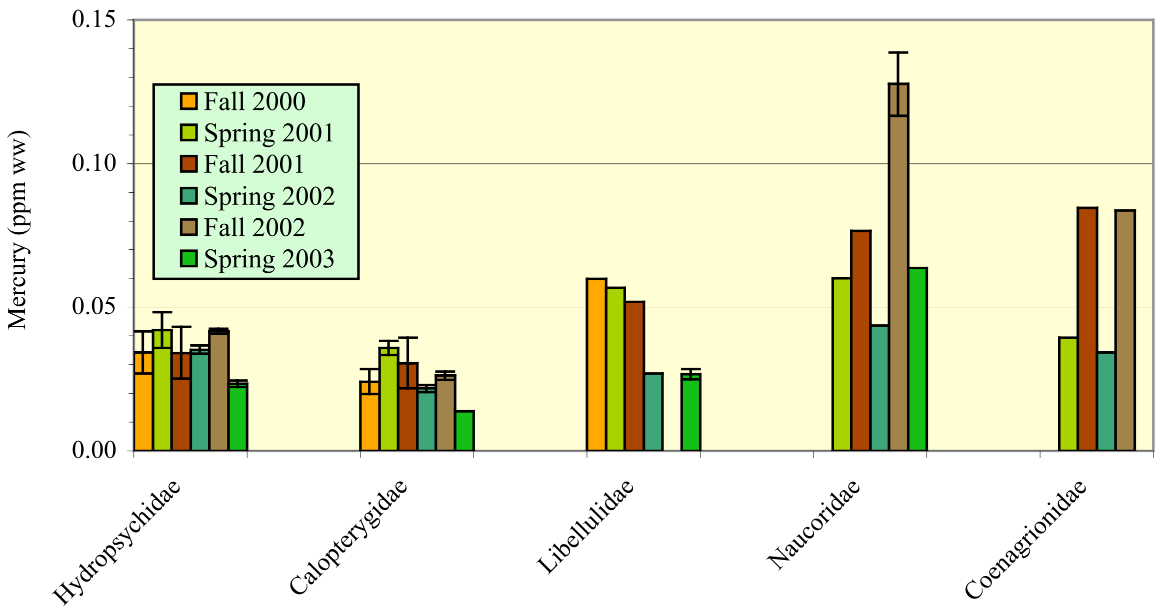


Fig. 13 (a-c). INVERTEBRATE Composite Hg VS SEASON
(mean values plotted for replicate composites)
(95% confidence intervals shown for samples with ≥3 replicates)

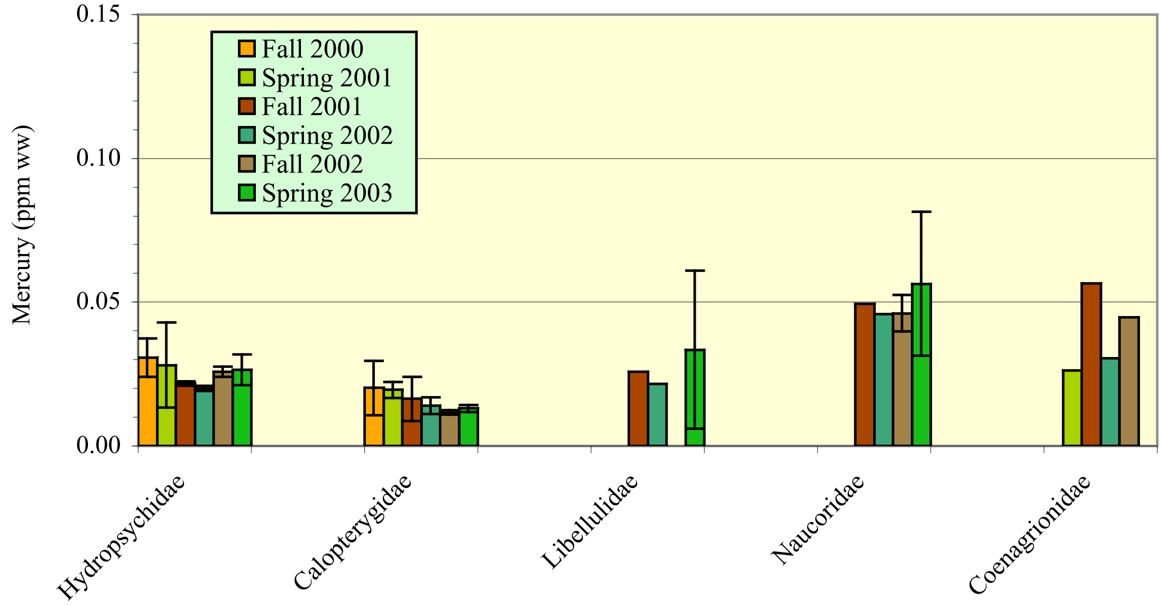
13(a). Cache Creek above Nature Preserve.



13(b). Cache Creek between Nature Preserve and Gordon Slough.



13(c). Cache Creek below Gordon Slough.



CONCLUSIONS--SIXTH AND FINAL SEMI-ANNUAL REPORT

With the completion of this pilot three-year mercury monitoring program, we have accumulated a sizeable database of inter-comparable mercury bioaccumulation information from the newly restored Cache Creek Nature Preserve wetlands and related adjacent sites. With some difficulty, it was possible to collect a series of closely corresponding fish samples from the Preserve and three additional fish locations throughout the course of the three years. Corresponding aquatic insect bioindicators were not available among all of the sites, although several taxa were consistently taken at a series of three Cache Creek locations.

The following points can be made about the data collected in this three-year project:

- Of the sites sampled throughout the project area, Gordon Slough and Cache Creek downstream of Gordon Slough exhibited the lowest levels of mercury bioaccumulation in fish. Highest concentrations were consistently observed at the upstream Cache Creek site located above the Nature Preserve, as well as within the restored Nature Preserve wetlands which were the focus of the study.

- Over the course of the fall season collections, when highest concentrations were consistently observed, the primary indicator fish taken within the Nature Preserve exhibited mercury bioaccumulation at increasingly elevated levels. These elevated Nature Preserve concentrations, while similar to those from the most elevated creek site, represented a substantial increase over conditions in Gordon Slough, which provides the source water for the Nature Preserve. In the series of spring season collections, when all of the sites showed relative reductions in fish mercury bioaccumulation, the Nature Preserve wetlands consistently had the highest concentrations. The data indicate that the restored wetlands provided an elevated methylmercury exposure environment relative to the adjacent Gordon Slough source water environment. Data from water sampling were consistent with this conclusion, showing elevated aqueous methylmercury in Preserve water relative to Gordon Slough source water. Small fish mercury in the Preserve was 2-3 times higher than in corresponding samples taken by UC Davis throughout most of the Sacramento-San Joaquin Delta and were consistent with co-occurring large fish (bass) fillet concentrations to approximately 2-4 times the EPA screening criterion level of 0.30 ppm, if bass were present in the system.

- While the Nature Preserve wetlands demonstrated a relatively elevated methylmercury exposure environment, the possible extension of this effect to downstream Cache Creek was found to be either highly localized or undetectable. Over the years, several of the Cache Creek aquatic insect samples demonstrated an elevation in concentrations at the intermediate site located immediately downstream of the Nature Preserve discharge. This elevation did not persist as far as the downstream station below Gordon Slough, which typically exhibited lower concentrations than the Cache Creek site located upstream of the Nature Preserve. The occasional relative concentration elevation at the intermediate Cache Creek site might be attributable to elevated methylmercury discharge from the Nature Preserve. However, it is significant that some of the elevated concentrations at the intermediate site, located just downstream of potential Nature Preserve discharges, occurred following long periods with no Preserve discharge. This, together with the typical spatial pattern of elevated bioaccumulation at the Cache Creek site upstream of the Preserve, suggests that some or all of the apparent trend seen along the Cache Creek transect may have been due to factors unrelated to the off-channel Nature Preserve wetlands. In any case, the fish data, collected from upstream of the Preserve and downstream of the Preserve and Gordon Slough, indicated a consistent spatial pattern, with the downstream location never significantly elevated relative to the site upstream of the Preserve and, instead, frequently statistically lower.

- Mercury in small fish bioindicators exhibited a consistent, strong seasonal pattern, with maximum concentrations in the fall and minimum concentrations in the spring. We believe that this actually represents a delayed measure of underlying cycles of mercury methylation and methylmercury bioavailability, which likely peak in the summer and reach low points in the winter. The water data supported this conclusion. Invertebrate bioindicators, as sampled, did not consistently demonstrate this pattern; related data from other research suggests that this may be due to different bioaccumulation dynamics in the invertebrates (more rapid equilibration) and not to a different underlying trend in seasonal biological mercury exposure. The invertebrate bioindicators, however, can be used as highly accurate measures of fine scale spatial differences in relative mercury exposure, as well as short-term changes over time. Seasonally changing patterns of mercury bioaccumulation must be taken into account when interpreting monitoring results. They also highlight the importance of developing a multi-season, multi-year data base when possible.

- Interannual data for some of the fish taken within the Nature Preserve wetlands indicate an increasing warm season trend in mercury bioaccumulation over the three years of the project. This may be reflective of increasingly favorable conditions for methylmercury production within the young wetlands as they evolved. Alternatively, the apparent annual increase may have been due to other, more regional factors, as indicated by the similar increasing trends noted in some biota at sites with no influence from the Nature Preserve (upstream Cache Creek and Gordon Slough). This highlights the importance of sampling appropriate control sites in addition to the site of primary interest. It is unclear at this point whether long-term trends will decline, as existing sources of inorganic mercury are depleted, or remain elevated due to sufficient new inorganic mercury depositing in particulates from source water. Some level of ongoing monitoring could provide important insights into the long-term behavior of this and similar constructed wetland systems in the region.

- The organic (methyl) mercury analyses conducted throughout the second and third years of the project indicate that methylmercury constituted the majority of the mercury measured in whole small fish (app. 80-100%) and invertebrates (app. 60-90%) from the project region. The methylmercury data generally mirrored the total mercury results. Identical or very similar trends and conclusions were supported by either parameter.

- The occasional experimental use of multiple whole individual fish samples rather than replicate composites, each of numerous individuals, was found to result in less precise statistical differentiation of average concentrations. We conclude that greater than 10 individual analyses are required to achieve the precision of 3-5 replicate composite samples, each containing multiple individuals. This is important information. In some situations, small numbers of available specimens would preclude the replicate composite technique.

- This pilot mercury monitoring program provides a model for similar future wetlands monitoring.

LITERATURE CITED

Domagalski, J.L., C.N. Alpers, D.G., Slotton, T.H. Suchanek, and S.M. Ayers. 2003. Mercury and methylmercury concentrations and loads in the Cache Creek watershed, California, January 2000 through May 2001. *Report for the CALFED Bay-Delta Agency*. 105 pp. http://loer.tamug.tamu.edu/calfed/FinalReports.htm

Foe, C., and W. Croyle. 1998. Mercury concentrations and loads from the Sacramento River and from Cache Creek to the Sacramento-San Joaquin Delta estuary. *Central Valley Regional Water Quality Control Board staff report*, 101 pp.

Rudd, J.W.M. 1995. Sources of methyl mercury to freshwater ecosystems: A review. *Water, Air and Soil Pollution*, 80:697-713.

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

Slotton, D.G., S.M. Ayers, T.H. Suchanek, R.D. Weyand, and A.M. Liston, C. Asher, D.C. Nelson, and C. Asher. 2002. The effects of wetlands restoration on the production and bioaccumulation of methylmercury in the Sacramento-San Joaquin Delta, California. *Report for the CALFED Bay-Delta Agency*. 76 pp. http://loer.tamug.tamu.edu/calfed/FinalReports.htm

Slotton, D.G., S.M. Ayers, T.H. Suchanek, R.D. Weyand, and A.M. Liston. 2004. 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. http://loer.tamug.tamu.edu/calfed/FinalReports.htm

Table 2a.
Laboratory QA/QC Summary for UC Davis Total Mercury Analyses Used in This Most Recent Semi-Annual Period (Spring-Summer 2003).
(Method Detection Limit (MDL) = 0.005 µg THg/g (ppm))

	Std Curve R^2	Blanks re µg/g	Lab Split RPD	Spike Recoveries	Lab Control Std. Recoveries	Cont. Calib. Validation
Ideal Recovery	1.000	0.0000	(0%)	(100%)	(100%)	(100%)
Control Range Tracking Method	≥0.975 Control Chart	-0.0200-0.0200 Control Chart	≤25% Control Chart	75-125% Control Chart	75-125% Control Chart	75-125% Control Chart
Recoveries	0.9994-0.9996	-0.0057-0.0053	0.0-3.1%	91.3-98.4%	95.5-105.4%	97.7-100.7%
(n)	n=5 (8 aq Hg stds/run)	n=28	n=9	n=20	n=20	n=28
Mean Recoveries	0.9995	0.0000	2.3**%**	95.0%	100.2%	99.4%

		Standard Reference Materials	
	NIST 2976 Mussel	TORT-2 Lobster	DOLT-3 Dogfish liver
Certified Level (ppm THg) Ideal Recovery	0.061±0.004 (100%)	0.27±0.02 (100%)	3.37±0.14 (100%)
Control Range (%) Tracking Method Control Range (ppm)	75-125% Control Chart 0.046-0.076	75-125% Control Chart 0.20-0.34	75-125% Control Chart 1.61-2.68
Recoveries (%) Recoveries (ppm) (n)	99.4-113.1% 0.061-0.069 n=10	98.5-103.2% 0.268-0.280 n=15	89.6-95.0% 3.02-3.20 n=13
Mean Recoveries (%) Mean Recoveries (ppm) 0.064	104.7% 0.271	100.3% 3.083	91.5%

Table 2b.
Laboratory QA/QC Summary for UC Davis Methyl Mercury Analyses Used in This Most Recent Semi-Annual Period (Spring-Summer 2003).

(Method Detection Limit (MDL) = 0.005 µg MeHg/g (ppm))

	Std Curve R^2	Blanks re µg/g	Lab Split RPD	Spike Recoveries	Lab Control Std. Recoveries	Cont. Calib. Validation
Ideal Recovery	1.000	0.0000	(0%)	(100%)	(100%)	(100%)
Control Range	≥0.975	-0.0200-0.0200	≤25%	75-125%	75-125%	75-125%
Tracking Method	Control Chart	Control Chart	Control Chart	Control Chart	Control Chart	Control Chart
Recoveries	0.9994-0.9996	-0.0104-0.0030	0.3-4.8%	90.0-109.7%	95.5-105.4%	95.7-101.7%
(n)	n=5 (8 aq Hg stds/run)	n=28	n=10	n=20	n=20	n=28
Mean Recoveries	0.9995	-0.0012	2.3**%**	102.5%	100.2%	99.5%

	Standard Reference Materials		
	NIST 2976 Mussel	TORT-2 Lobster	DOLT-3 Dogfish liver
Certified Level (ppm THg)	0.0278±0.0011	0.152±0.013	1.590
Ideal Recovery	(100%)	(100%)	(100%)
Control Range (%)	75-125%	75-125%	75-125%
Tracking Method	Control Chart	Control Chart	Control Chart
Control Range (ppm)	0.0208-0.0348	0.114-0.190	1.193-1.988
Recoveries (%)	50.5-111.9%	91.8-105.2%	82.5-95.7%
Recoveries (ppm)	0.0140-0.0311	0.139-0.160	1.312-1.522
(n)	n=10	n=15	n=13
Mean Recoveries (%)	89.0%	98.4%	90.3%
Mean Recoveries (ppm) 0.0247	0.150	1.436	

Table 3. May 2003 Fish Mercury:
RED SHINER (*Notropis lutrensis*).
(Mean values of multiple (n) whole body individual analyses)
(wet weight = fresh weight, µg mercury per gram = parts per million)

Size Class	(n)	Mean Fish Size wt (g)	Mean Fish Size lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
				Cache Creek Above Preserve			
2 (36-50 mm)	(15)	0.9	44		0.048	0.046	104%
2 (36-50 mm)	(15)	0.9	44		0.041	0.043	96%
2 (36-50 mm)	(15)	0.9	44		0.041	0.041	99%
2 (36-50 mm)	(15)	1.0	44		0.039	0.041	95%
				Means:	**0.042**	**0.043**	**99%**
				95% Conf. Intervals:	± 0.007	± 0.004	±6%
3 (51-65 mm)	(3)	1.8	53		0.076	0.077	99%
3 (51-65 mm)	(3)	1.8	53		0.054	0.050	108%
3 (51-65 mm)	(3)	1.9	53		0.056	0.054	104%
3 (51-65 mm)	(3)	1.9	53		0.050	0.048	104%
				Means:	**0.059**	**0.057**	**104%**
				95% Conf. Intervals:	± 0.019	± 0.021	±6%
				Gordon Slough			
2 (36-50 mm)	(15)	1.1	47		0.054	0.059	91%
2 (36-50 mm)	(15)	1.0	47		0.047	0.050	94%
2 (36-50 mm)	(15)	1.1	47		0.049	0.053	92%
2 (36-50 mm)	(15)	1.0	47		0.053	0.056	95%
				Means:	**0.051**	**0.054**	**93%**
				95% Conf. Intervals:	± 0.005	± 0.006	±3%
3 (51-65 mm)	(4)	2.1	56		0.057	0.065	88%
3 (51-65 mm)	(4)	2.3	56		0.079	0.079	100%
3 (51-65 mm)	(4)	2.3	56		0.062	0.063	98%
3 (51-65 mm)	(4)	2.1	56		0.056	0.058	96%
				Means:	**0.063**	**0.066**	**95%**
				95% Conf. Intervals:	± 0.017	± 0.015	±8%

(continued)

Table 3. (Continued).

Size Class	(n)	Mean Fish Size wt (g)	Mean Fish Size lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
			Nature Preserve Wetlands				
2 (36-50 mm)	1	1.0	44		0.095	0.102	94%
3 (51-65 mm)	10	1.9	58	**Means:**	**0.130**	**0.134**	**97%**
				SD:	0.026	0.025	6%
				95% Conf. Intervals:	± 0.019	± 0.018	±4%
			Cache Creek Below Gordon Slough				
2 (36-50 mm)	(12)	0.9	44		0.039	0.042	92%
2 (36-50 mm)	(12)	0.8	44		0.043	0.045	95%
2 (36-50 mm)	(12)	0.8	44		0.042	0.045	93%
2 (36-50 mm)	(12)	0.8	44		0.047	0.048	99%
				Means:	**0.043**	**0.045**	**95%**
				95% Conf. Intervals:	± 0.006	± 0.004	±5%
3 (51-65 mm)	(5)	2.0	53		0.066	0.062	106%
3 (51-65 mm)	(5)	1.9	53		0.054	0.057	95%
3 (51-65 mm)	(5)	1.8	53		0.055	0.056	99%
3 (51-65 mm)	(5)	1.9	53		0.071	0.069	103%
				Means:	**0.062**	**0.061**	**101%**
				95% Conf. Intervals:	± 0.013	± 0.010	±7%

Table 4. May 2003 Fish Mercury:
FATHEAD MINNOW (*Pimephales promelas*).
(Mean values of multiple (n) whole body individual analyses)
(wet weight = fresh weight, µg mercury per gram = parts per million)

Size Class	(n)	Mean Fish Size wt (g)	Mean Fish Size lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
Nature Preserve Wetlands							
3 (51-65 mm)	3	1.7	51	**Means:**	**0.099**	**0.104**	**96%**
				SD:	0.040	0.042	1%
				95% Conf. Intervals:	± 0.099	± 0.105	±2%

Table 5. May 2003 Fish Mercury:
GREEN SUNFISH (*Lepomis cyanellus*).
(Mean values of multiple (n) whole body individual analyses)
(wet weight = fresh weight, µg mercury per gram = parts per million)

Size Class	(n)	Mean Fish Size wt (g)	Mean Fish Size lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
				Cache Creek Above Preserve			
2 (51-80 mm)	10	5.4	65	**Means:**	**0.090**	**0.091**	**98%**
				SD:	0.018	0.017	5%
				95% Conf. Intervals:	± 0.013	± 0.012	±4%
				Gordon Slough			
1 (25-50 mm)	1	1.88	47		**0.079**	**0.086**	**92%**
2 (51-80 mm)	(3)	4.7	62		0.059	0.068	88%
2 (51-80 mm)	(2)	5.0	62		0.060	0.066	91%
2 (51-80 mm)	(2)	4.8	62		0.058	0.066	89%
				Means:	**0.059**	**0.066**	**89%**
				95% Conf. Intervals:	± 0.002	± 0.003	±4%

(continued)

Table 5. (Continued).

Size Class	(n)	Mean Fish Size wt (g)	lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
				Nature Preserve Wetlands			
1 (25-50 mm)	(4)	1.8	47		0.123	0.135	91%
1 (25-50 mm)	(4)	1.9	47		0.119	0.132	90%
1 (25-50 mm)	(4)	1.7	47		0.109	0.121	90%
				Means:	**0.117**	**0.130**	**91%**
				95% Conf. Intervals:	± 0.017	± 0.019	±1%
2 (51-80 mm)	(6)	5.8	67		0.153	0.160	96%
2 (51-80 mm)	(6)	5.7	67		0.152	0.166	92%
2 (51-80 mm)	(6)	6.1	67		0.114	0.130	88%
				Means:	**0.140**	**0.152**	**92%**
				95% Conf. Intervals:	± 0.055	± 0.048	±9%
				Cache Creek Below Gordon Slough			
2 (51-80 mm)	8	3.8	58	**Means:**	**0.070**	**0.075**	**93%**
				SD:	0.017	0.019	3%
				95% Conf. Intervals:	± 0.015	± 0.016	±3%

Table 6. May 2003 Fish Mercury:
MOSQUITOFISH (*Gambusia affinis*).
(composite samples of (n) whole individuals)
(wet weight = fresh weight, µg mercury per gram = parts per million

Size Class	(n)	Mean Fish Size wt (g)	Mean Fish Size lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
			Gordon Slough				
2 (31-40 mm)	(3)	0.6	36		0.064	0.075	85%
2 (31-40 mm)	(3)	0.7	36		0.047	0.055	85%
2 (31-40 mm)	(3)	0.6	36		0.059	0.068	87%
				Means:	**0.057**	**0.066**	**86%**
				95% Conf. Intervals:	± 0.021	± 0.024	±2%
3 (41-50 mm)	(3)	1.1	44		0.075	0.086	87%
3 (41-50 mm)	(3)	1.1	44		0.113	0.125	90%
3 (41-50 mm)	(3)	0.9	44		0.070	0.081	86%
				Means:	**0.086**	**0.097**	**88%**
				95% Conf. Intervals:	± 0.058	± 0.060	±5%
			Nature Preserve Wetlands				
1 (20-30 mm)	(13)	0.2	25		0.088	0.100	88%
1 (20-30 mm)	(13)	0.2	25		0.091	0.104	88%
1 (20-30 mm)	(13)	0.2	25		0.098	0.108	91%
				Means:	**0.092**	**0.104**	**89%**
				95% Conf. Intervals:	± 0.012	± 0.009	±4%
2 (31-40 mm)	(11)	0.6	34		0.074	0.082	90%
2 (31-40 mm)	(11)	0.5	34		0.067	0.076	88%
2 (31-40 mm)	(11)	0.6	34		0.063	0.074	86%
2 (31-40 mm)	(11)	0.6	34		0.070	0.081	87%
				Means:	**0.068**	**0.078**	**88%**
				95% Conf. Intervals:	± 0.007	± 0.006	±3%
3 (41-50 mm)	(4)	1.2	44		0.098	0.111	89%
3 (41-50 mm)	(4)	1.2	44		0.094	0.110	86%
3 (41-50 mm)	(4)	1.2	44		0.076	0.090	85%
				Means:	**0.089**	**0.103**	**86%**
				95% Conf. Intervals:	± 0.030	± 0.030	±5%

Table 7. May 2003 Fish Mercury:
INLAND SILVERSIDE (Menidia beryllina)
(Mean values of multiple (n) whole body individual analyses)
(wet weight = fresh weight, µg mercury per gram = parts per million)

Size Class	(n)	Mean Fish Size wt (g)	Mean Fish Size lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
			Nature Preserve Wetlands				
3 (66-80 mm)	10	2.2	76	**Means:**	**0.154**	**0.159**	**96%**
				SD:	0.047	0.046	4%
				95% Conf. Intervals:	± 0.033	± 0.033	±3%

**Table 8. May 2003 Invertebrate Mercury:
Primary Indicator Samples From Cache Creek Transect;
HYDROPSYCHIDAE (Caddisfly Larvae, Omnivores).**
(composite samples of multiple (n) whole individuals)
(WET weight µg mercury per gram = parts per million)

(n)	Size (mean mm)	µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
		Cache Creek Above Preserve		
(70)	12	0.014	0.025	57%
(70)	12	0.014	0.025	58%
(70)	12	0.014	0.024	56%
(70)	12	0.015	0.025	59%
	Means:	**0.014**	**0.025**	**57%**
	95% Conf. Intervals:	± 0.001	± 0.001	±2%
		Cache Creek Between Nature Preserve and Gordon Slough		
(65)	12	0.017	0.024	72%
(65)	12	0.017	0.023	74%
(65)	12	0.018	0.024	76%
	Means:	**0.017**	**0.023**	**74%**
	95% Conf. Intervals:	± 0.002	± 0.001	±6%
		Cache Creek Below Gordon Slough		
(49)	12	0.016	0.029	56%
(49)	12	0.015	0.024	63%
(49)	12	0.016	0.026	60%
	Means:	**0.016**	**0.026**	**60%**
	95% Conf. Intervals:	± 0.001	± 0.005	±9%

Table 9. May 2003 Invertebrate Mercury:
Primary Indicator Samples From Cache Creek Transect;
CALOPTERYGIDAE (Damselfly Nymphs, Omnivorous Type).
(composite samples of multiple (n) whole individuals)
(WET weight µg mercury per gram = parts per million)

(n)	Size (mean mm)	µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
		Cache Creek Above Preserve		
(14)	29	0.012	0.015	79%
		Cache Creek Between Nature Preserve and Gordon Slough		
(14)	28	0.014	0.014	102%
		Cache Creek Below Gordon Slough		
(20)	29	0.011	0.013	83%
(20)	29	0.011	0.014	84%
(20)	29	0.011	0.013	83%
	Means:	**0.011**	**0.013**	**83%**
	95% Conf. Intervals:	± 0.001	± 0.001	±1%

Table 10. May 2003 Invertebrate Mercury:
LIBELLULIDAE (Dragonfly Nymphs, Predator).
(composite samples of multiple (n) whole individuals)
(WET weight µg mercury per gram = parts per million)

Insect Family	Description	Trophic Level	(n)	Size (mm)	Wet ppm Hg METHYL	Wet ppm Hg TOTAL	Percent Methyl
Cache Creek Above Preserve							
Libellulidae	dragonfly nymph	lg predator	(20)	22	0.024	0.029	85%
			(20)	22	0.024	0.030	82%
			(20)	22	0.024	0.030	81%
			(20)	22	0.025	0.029	85%
				Means:	**0.024**	**0.029**	**83%**
				95% Conf. Intervals:	± 0.000	± 0.001	±4%
Cache Creek Between Nature Preserve and Gordon Slough							
Libellulidae	dragonfly nymph	lg predator	(19)	22	0.026	0.028	91%
			(19)	22	0.026	0.026	101%
			(19)	22	0.027	0.026	104%
			(19)	22	0.027	0.027	99%
				Means:	**0.026**	**0.027**	**99%**
				95% Conf. Intervals:	± 0.001	± 0.002	±9%
Cache Creek Below Gordon Slough							
Libellulidae	dragonfly nymph	lg predator	(6)	22	0.029	0.029	98%
			(6)	22	0.035	0.046	77%
			(6)	22	0.025	0.025	100%
				Means:	**0.030**	**0.033**	**92%**
				95% Conf. Intervals:	± 0.013	± 0.028	±32%

**Table 11. May 2003 Invertebrate Mercury:
NAUCORIDAE (Creeping Water Bug, Predator).**
(composite samples of multiple (n) whole individuals)
(WET weight µg mercury per gram = parts per million)

Insect Family	Description	Trophic Level	(n)	Size (mm)	Wet ppm Hg METHYL	Wet ppm Hg TOTAL	Percent Methyl
				Cache Creek Above Preserve			
Naucoridae	water bug	lg predator	(15)	10	0.044	0.076	58%
			(15)	10	0.050	0.069	72%
			(15)	10	0.049	0.074	65%
				Means:	**0.047**	**0.073**	**65%**
				95% Conf. Intervals:	± 0.008	± 0.008	±17%
				Cache Creek Between Nature Preserve and Gordon Slough			
Naucoridae	water bug	lg predator	(18)	10	0.051	0.064	80%
				Cache Creek Below Gordon Slough			
Naucoridae	water bug	lg predator	(27)	11	0.059	0.068	87%
			(27)	11	0.036	0.053	68%
			(27)	11	0.038	0.048	79%
				Means:	**0.044**	**0.056**	**78%**
				95% Conf. Intervals:	± 0.031	± 0.025	±23%

Table 12. Spring/Summer 2001 Water Sampling Data.

(Methylmercury analyzed by Battelle Labs, Sequim, WA)
(TSS analyzed by DG Slotton Lab)
(Peripheral analyses measured directly in field with YSI meters)

WATER PARAMETER	Cache Ck Above Pres.	Gordon Sl. Inflow	Preserve Outflow	Cache Ck Below Pres.	Cache Ck Bel. Gordon Sl.
		May 8, 2001 (First Flush)			
Raw Methylmercury (ng/L)		**0.35**	**0.38**		
		July 26, 2001 (Mid-Summer)			
Raw Methylmercury (ng/L)		**0.20**	**0.49**		
TSS (mg/L)		61.9	29.8		
Temperature (°C)		24.5	27.9		
Dissolved Oxygen (mg/L)		11.5	14.9		
D.O. (% of saturation)		138%	190%		
Conductivity (mS/cm)		0.332	0.460		
Tot. Diss. Solids (g/L)		0.218	0.283		
pH		8.19	8.83		
Oxid./Red. Potential		186	155		
Turbidity (NTU)		78.4	42.4		
Chlorophyll (µg/L)		3.3	9.3		
		September 26, 2001 (Last Flush)			
Raw Methylmercury (ng/L)	**0.12**	**0.17**	**0.38**	**0.21**	**0.22**
TSS (mg/L)	0.7	26.8	12.7	*(bottle broke)*	6.2
Temperature (°C)	25.7	20.1	21.2	25.6	25.2
Dissolved Oxygen (mg/L)	13.0	8.6	9.1	10.5	11.2
D.O. (% of saturation)	164%	94%	100%	128%	137%
Conductivity (mS/cm)	0.714	0.343	0.442	0.578	0.637
Tot. Diss. Solids (g/L)	0.464	0.223	0.275	0.381	0.414
pH	8.20	8.09	8.27	8.31	8.30
Oxid./Red. Potential	119	107	116	101	98

Table 13. Spring 2002 Water Sampling Data.

(First flush through Nature Preserve in 2002: samples collected April 18, 2002)
(NOTE: No additional Year 2002 flushes, due to invasive weeds in Preserve)

(Methylmercury analyzed by Battelle Labs, Sequim, WA)
(TSS analyzed by DG Slotton Lab)
(Peripheral analyses measured directly in field with YSI meters)

WATER PARAMETER	Cache Ck Above Pres.	Gordon Sl. Inflow	Preserve Outflow	Cache Ck Below Pres.	Cache Ck Bel. Gordon Sl.
			April 18, 2002		
Raw Methylmercury (ng/L)	**0.096**	**0.182**	**0.236**	**0.097**	**0.112**
TSS (mg/L)	1.9	26.2	27.5	4.1	4.7
Temperature (°C)	17.04	12.47	15.05	17.41	18.4
Dissolved Oxygen (mg/L)	12.8	10.5	10.1	11.8	11.8
D.O. (% of saturation)	132%	99%	100%	125%	125%
Conductivity (mS/cm)	0.589	0.392	0.460	0.581	0.567
Tot. Diss. Solids (g/L)	0.383	0.255	0.299	0.378	0.370
pH	8.17	7.91	8.37	8.21	8.29
Oxid./Red. Potential	-200	-201	-206	-191	-146
Turbidity (NTU)					
Chlorophyll (µg/L)					

Table 14. Summer 2003 Fish Mercury:
Nature Preserve Wetlands Only
(Mean values of multiple (n) whole body individual analyses or replicatee composite samples of (n) whole individuals each)
(wet weight = fresh weight, µg mercury per gram = parts per million)

Size Class	n	Mean Fish Size wt (g)	Mean Fish Size lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
			FATHEAD MINNOW (*Pimephales promelas*)				
2 (36-50 mm)	(5)	0.9	48		0.060	0.064	93%
2 (36-50 mm)	(5)	1.0	48		0.053	0.059	89%
2 (36-50 mm)	(5)	1.0	48		0.055	0.062	89%
				Means:	**0.056**	**0.062**	**91%**
				95% Conf. Intervals:	± 0.008	± 0.006	±5%
3 (51-70 mm)	(7)	2.0	59		0.119	0.132	90%
3 (51-70 mm)	(7)	2.0	59		0.095	0.109	87%
3 (51-70 mm)	(7)	2.1	59		0.107	0.121	88%
				Means:	**0.107**	**0.121**	**89%**
				95% Conf. Intervals:	± 0.030	± 0.028	±4%
			GREEN SUNFISH (*Lepomis cyanellus*)				
1 (25-50 mm)	(10)	1.0	40		0.059	0.067	87%
1 (25-50 mm)	(10)	0.9	40		0.058	0.065	89%
1 (25-50 mm)	(10)	1.0	40		0.052	0.059	89%
1 (25-50 mm)	(10)	0.9	40		0.059	0.067	89%
				Means:	**0.057**	**0.064**	**88%**
				95% Conf. Intervals:	± 0.005	± 0.006	±1%
2 (51-80 mm)	(7)	4.3	66		0.117	0.137	85%
2 (51-80 mm)	(7)	4.9	66		0.168	0.190	88%
2 (51-80 mm)	(7)	4.3	66		0.130	0.141	92%
2 (51-80 mm)	(7)	4.4	66		0.125	0.141	88%
				Means:	**0.135**	**0.152**	**88%**
				95% Conf. Intervals:	± 0.036	± 0.041	±4%

(continued)

Table 14. (Continued).

Size Class	n	Mean Fish Size wt (g)	Mean Fish Size lgth (mm)		µg/g METHYL Hg in WET Sample	µg/g TOTAL Hg in WET Sample	% Methyl Hg of Total Hg
MOSQUITOFISH (*Gambusia affinis*)							
1 (20-30 mm)	(25)	0.21	26		0.074	0.084	88%
1 (20-30 mm)	(25)	0.20	26		0.070	0.078	89%
1 (20-30 mm)	(25)	0.20	26		0.071	0.080	89%
1 (20-30 mm)	(25)	0.19	26		0.069	0.080	86%
				Means:	**0.071**	**0.081**	**88%**
				95% Conf. Intervals:	± 0.004	± 0.004	±2%
2 (31-40 mm)	(6)	0.41	32		0.076	0.087	87%
2 (31-40 mm)	(6)	0.40	32		0.083	0.092	89%
2 (31-40 mm)	(6)	0.43	32		0.068	0.078	88%
				Means:	**0.075**	**0.086**	**88%**
				95% Conf. Intervals:	± 0.018	± 0.019	±3%
3 (41-50 mm)	4	1.1	47	**Means:**	**0.113**	**0.126**	**90%**
				SD:	0.025	0.027	3%
				95% Conf. Intervals:	± 0.039	± 0.044	±4%
INLAND SILVERSIDE (*Menidia beryllina*)							
2 (51-65 mm)	(8)	1.23	60		0.167	0.186	90%
2 (51-65 mm)	(8)	1.20	60		0.161	0.177	91%
2 (51-65 mm)	(8)	1.27	60		0.157	0.169	93%
				Means:	**0.162**	**0.177**	**91%**
				95% Conf. Intervals:	± 0.013	± 0.022	±4%
3 (66-80 mm)	(8)	1.75	68	**Means:**	**0.195**	**0.209**	**93%**