Draft for Water Quality Standards Workgroup Discussion
Proposed Prioritization of Brine Shrimp and Brine Fly Bioassay Test Pollutants
June 17, 2013

Problem Statement: The Utah Division of Water Quality (Division) intends to derive water quality criteria specific to the Great Salt Lake in accordance with the draft Great Salt Lake Water Quality Strategy (DWQ, 2012). The Division is implementing a grant from the Utah Water Quality Board to conduct toxicity testing on brine flies and brine shrimp. Because resources are limited, the top pollutants need to be prioritized for additional testing and research.

Conclusion: Pollutants are recommended to be evaluated in the following order of priority: ammonia, methylmercury, arsenic, copper, and lead. This recommendation is based on the data currently available and is subject to change based on future data. The prioritization of the remaining priority pollutants is deferred.

Background

The Division received a grant from the Utah Water Quality Board to conduct bioassays (specifically toxicity testing) using brine shrimp and brine flies as test organisms. This testing is identified as a critical step in deriving numeric criteria in the Great Salt Lake Water Quality Strategy, Strategy for Developing Numeric Criteria (DWQ, 2012). The testing will also provide data useful for setting Utah Pollution Discharge Elimination System permit effluent limits and assessing water quality.

Methods

In 2011, the Division commenced analyzing samples collected from the each of Great Salt Lake's bays, twice per year. One use of the data generated by these efforts was to prioritize pollutants for bioassay testing. Although additional data from the past 10-15 years is available, this data was not used pending validation. Great Salt Lake water is prone to causing analytical interferences and historical analytical data should be validated prior to using. The pedigree of the 2011-2012 data is known and is representative of current conditions.

Table 1 shows the summary statistics for the 2011-2012 monitoring. Target analytes for the 2011 and 2012 monitoring were arsenic, cadmium, copper, lead, total mercury, methylmercury, selenium, thallium, and ammonia. At each monitoring location, samples were collected 1 meter from the surface and 1 meter from the bottom. At some locations, the bottom sample was collected from the deep brine layer. The concentrations of some analytes increase markedly in the denser, deep brine layer. The deep brine layer is inhospitable to brine shrimp and brine flies because of the higher salinity and low dissolved oxygen. Therefore, the concentrations measured in the deep brine layer are not representative of potential exposures to brine flies and brine shrimp. Although brine flies and brine shrimp are not known

to inhabit the deep brine layer, some mixing of the deep brine layer with the overlying oxic stratum does occur (Belovsky et al., 2011).. To include this potential reservoir of some pollutants in the pollutant prioritization, pollutant concentrations in both the oxic stratum and deep brine stratum were considered.

The arithmetic mean concentrations from both the oxic and deep brine strata from 2011-2012 were compared to freshwater and marine chronic benchmarks which were either 1) Utah freshwater 4-day criteria, 2) USEPA marine chronic continuous criteria, or 3) other sources. The mean concentrations in Gilbert Bay were divided by the freshwater or marine benchmarks and were ranked according to the resulting quotient (Tables 2 and 3, respectively). The benchmarks were selected because they are readily available for USEPA Priority Pollutants but their applicability to brine shrimp and brine flies is unknown. This ranking was then modified by reviewing existing toxicity studies using brine flies and brine shrimp and consideration of other factors such as known discharges.

Results

The ranking of pollutants for additional toxicity testing in order of priority are: ammonia, methylmercury, arsenic, copper, and lead. Prioritizing the following pollutants is deferred: zinc, total mercury, cadmium, selenium, and thallium. The rationale for each of the rankings is presented beginning on page 6.

Table 1

Summary Statistics for Gilbert Bay Samples Collected

July, 2011; October, 2011; June, 2012; and October, 2012

All Samples

Analyte	Average (µg/l)	Minimum (µg/l)	Maximum (µg/l)	Std Dev (µg/l)	Count
As	78.119	27.900	157.000	25.543	67
Cd	0.045	0.010	0.280	0.064	67
Cu	2.525	0.175	15.000	2.683	67
Hg	0.0089	0.001	0.047	0.013	67
Me	0.0048	0.00015	0.00293	0.0084	66
Pb	2.074	0.439	13.400	2.488	67
Se	0.378	0.197	0.776	0.112	67
Tl	0.038	0.010	0.113	0.015	67
Ammonia	2.24	0.67	10.1	2.4	48

Oxic Stratum

Analyte	Average (µg/l)	Minimum (µg/l)	Maximum (µg/l)	Std Dev (µg/l)	Count
As	69.739	27.900	102.000	19.323	48
Cd	0.020	0.010	0.048	0.013	48
Cu	1.841	0.880	3.750	0.583	48
Hg	0.004	0.001	0.017	0.003	48
Me	0.001	0.000	0.005	0.001	48
Pb	1.095	0.439	1.490	0.204	48
Se	0.356	0.197	0.756	0.092	48
Tl	0.034	0.010	0.045	0.007	48
Ammonia	1.278	2.02	0.67	0.38	36

Deep Brine Stratum

Analyte	Average (µg/l)	Minimum (µg/l)	Maximum (µg/l)	Std Dev (µg/l)	Count
As	103.125	45.800	157.000	26.906	16
Cd	0.122	0.010	0.280	0.094	16
Cu	4.677	0.175	15.000	4.907	16
Hg	0.025	0.002	0.047	0.018	16
Me	0.016	0.001	0.029	0.010	16
Pb	5.177	1.060	13.400	3.688	16
Se	0.446	0.238	0.776	0.145	16
Tl	0.052	0.023	0.113	0.024	16
Ammonia	5.14	10.1	0.905	3.3	12

Table 2
Comparison of Gilbert Bay Mean Concentrations from 2011-2012 to Freshwater Benchmarks

Rank	Analyte	Mean, oxic stratum (µg/l)	Chronic Benchmark (µg/l)	Ref.	Ratio
1	Ammonia	1.278	2.21	1	0.6
2	As	69.739	150	1	0.5
3	MeHg	0.001	0.0028	2	0
4	Hg	0.004	0.012	1	0.3
5	Se	0.356	4.6	1	0.08
6	Cu	1.841	30.5	1	0.06
7	Pb	1.095	18.6	1	0.06
8	Cd	0.020	0.76	1	0.03
9	Tl	0.034	18	2	0.002

Rank	Analyte	Mean, deep brine stratum (µg/l)	Chronic Benchmark (µg/l)	Ref.	Ratio
1	MeHg	0.016	0.0028	2	6
2	Ammonia	5.14	2.21	1	2
3	Hg	0.025	0.012	1	2
4	As	103.125	150	1	0.7
5	Pb	5.177	18.6	1	0.3
6	Cd	0.122	0.76	1	0.2
7	Cu	4.677	30.5	1	0.2
8	Se	0.446	4.6	1	0.1
9	Tl	0.052	18	2	0.003

Notes:
1: Utah (freshwater) 4-day criterion, adjusted to 400 mg/l hardness when appropriate. Ammonia benchmark based on pH of 8 and temperature 18˚C
2: LANL, 2009 Tier II value for protection of aquatic life communities

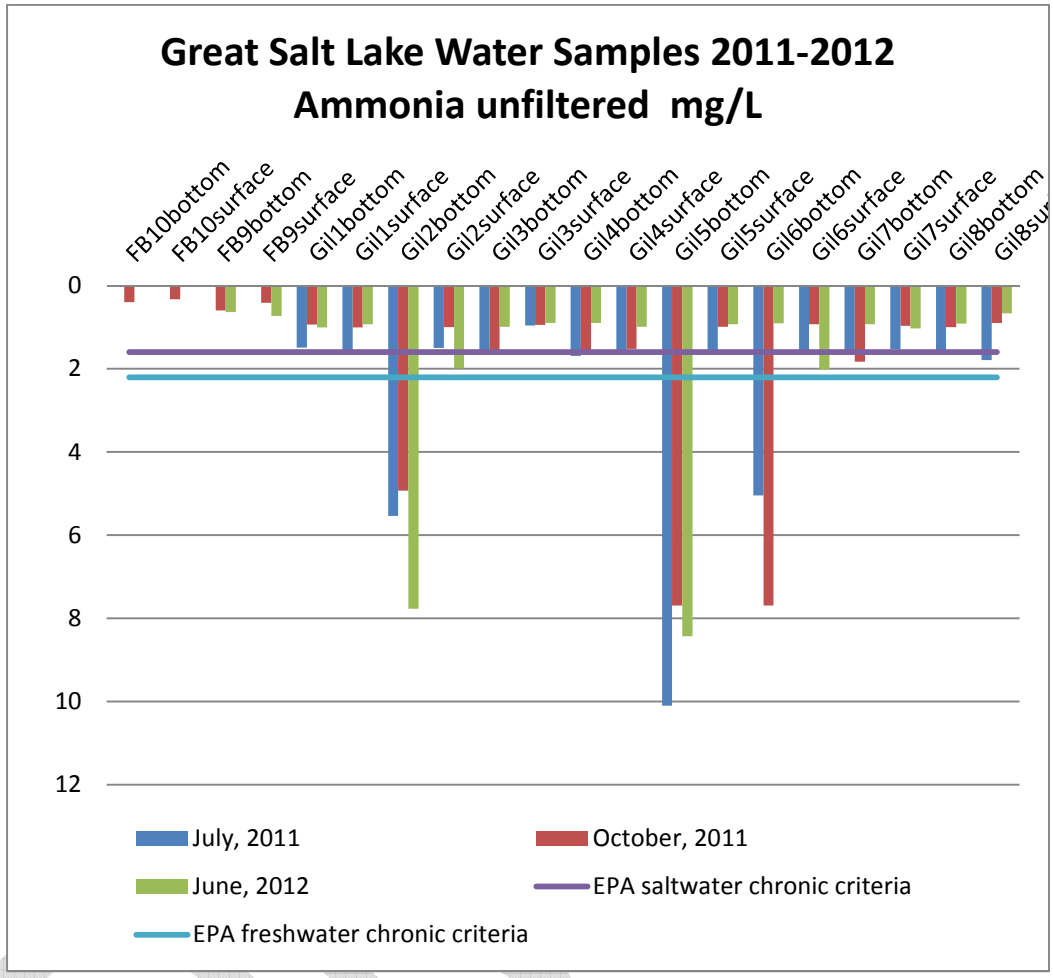
Table 3
Comparison of Gilbert Bay Mean Concentrations from 2011-2012 to Marine Benchmarks

Rank	Analyte	Mean, oxic stratum (µg/l)	Chronic Benchmark (µg/l)	Ref.	Ratio
1	As	69.739	36	3	2
2	Ammonia	1.278	1.6	3	0.8
3	Cu	1.841	3.1	3	0.6
4	Pb	1.095	8.1	3	0.1
5	Se	0.356	71	3	0.01
6	Hg	0.004	0.94	3	0.004
7	Cd	0.020	8.8	3	0.002

Rank	Analyte	Mean, deep brine stratum (µg/l)	Chronic Benchmark (µg/l)	Ref.	Ratio
1	Ammonia	5.14	1.6	3	3
2	As	103.125	36	3	3
3	Cu	4.677	3.1	3	2
4	Pb	5.177	8.1	3	0.6
5	Hg	0.025	0.94	3	0.03
6	Cd	0.122	8.8	3	0.01
7	Se	0.446	71	3	0.01

Notes:
4-USEPA 4-day chronic marine criteria, Ammonia benchmark based on pH of 8 and temperature 18˚C

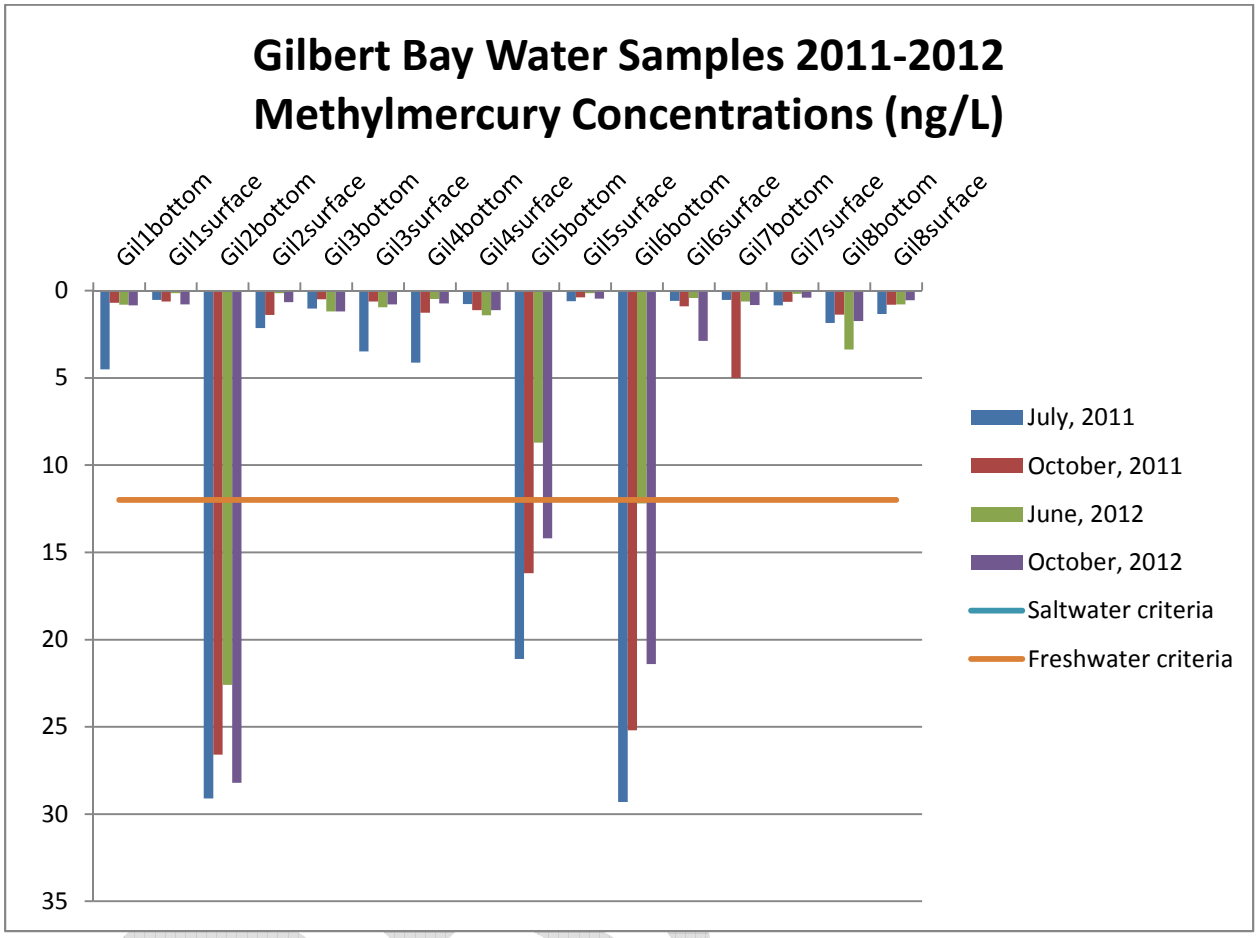
Priority 1. Ammonia



Ammonia

Ammonia is a USEPA priority pollutant. Existing discharges to Gilbert Bay do not include publicly-owned treatment works or other sources of anthropogenic ammonia but inputs may occur from the other Bays. Elevated ammonia is common in terminal lakes and the brine shrimp and brine flies can be a source of ammonia (Belovsky et al., 2011). The concentrations in the deep brine layer are notably higher than in the oxic waters. When compared to freshwater benchmarks, ammonia in the oxic stratum and deep brine layer had the highest ratio and 2nd highest ratios, respectively. When compared to the marine benchmarks, ammonia in the oxic stratum and deep brine layer had the 2nd highest and highest quotient, respectively. No toxicity tests are available for ammonia on brine shrimp and brine flies and the highest quotients. Ammonia is selected as the highest priority because of its high ranking when compared to benchmarks and the lack of data on the specific sensitivity of brine shrimp and brine flies.

Priority 2. Methylmercury



Methylmercury

Mercury, which includes methylmercury, is a USEPA priority pollutant. Methylmercury is not an expected pollutant in Utah Pollution Discharge Elimination System (UPDES) discharges to Gilbert Bay but discharges do contain mercury. The methylmercury concentrations increase markedly in the deep brine layer relative to the oxic stratum. Methylmercury is readily absorbed by organisms resulting in biomagnification between trophic levels often resulting in the higher trophic levels having the highest exposures.

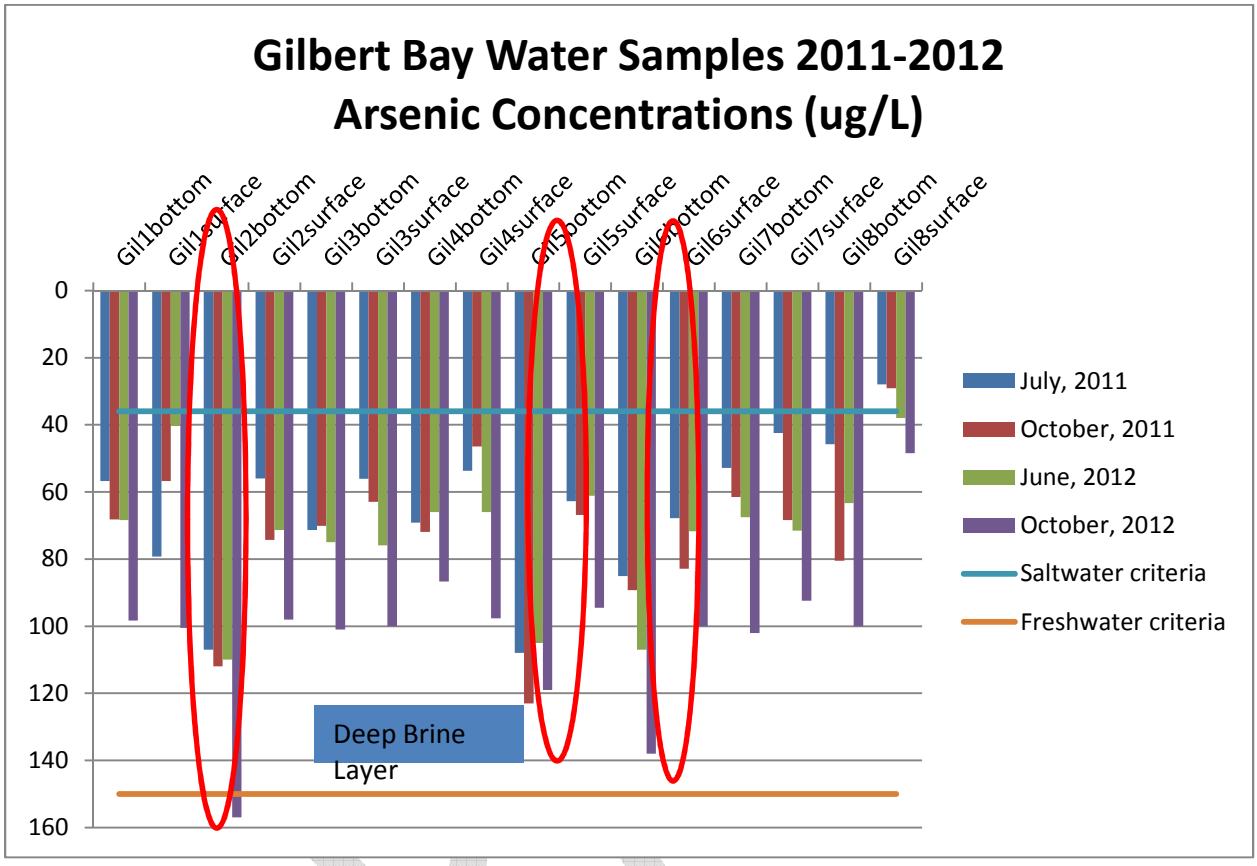
Some of the analytical results for the 2011-2012 are anomalous. Specifically, for several samples the concentrations of methylmercury exceeded total mercury concentrations. Total mercury includes methylmercury, so methylmercury concentrations should never exceed total mercury. These data meet all analytical quality controls and are not qualified. The mean concentration in the oxic layer from the 2011-2012 data was 0.001 µg/l. This concentration is consistent with those measured by Wurtsbaugh et

al. (2011) and Naftz et al. (2011) suggesting the outliers in the 2011-2012 dataset did not adversely affect the representativeness of the mean.

When compared to freshwater benchmarks, methylmercury in the oxic and deep brine layer have the 3rd highest and highest ratios, respectively. The freshwater benchmark is not a USEPA or Utah numeric criterion. Utah does not have a methylmercury criterion and the USEPA criterion is a fish tissue concentration based on human health. The comparison value is for protection of aquatic life based on a database that included fish, daphnids, and algae (LANL, 2009). No benchmarks specific to marine waters were identified.

Methylmercury's transfer into birds feeding at Great Salt Lake is being actively investigated by the Division and other researchers. In other aquatic systems such as the Great Lakes, biomagnification of methylmercury resulted in the criteria being based on protection of birds (USEPA, 1995). However, Great Salt Lake's food web is simpler and the biomagnification could be less than the observed for the Great Lakes resulting in the brine files and brine shrimp being more sensitive than birds. No toxicity data for brine shrimp and brine flies are available. Therefore, methylmercury is the 2nd highest priority to determine the sensitivity of the aquatic life and to elucidate if birds or the aquatic life are more sensitive to the effects of methylmercury.

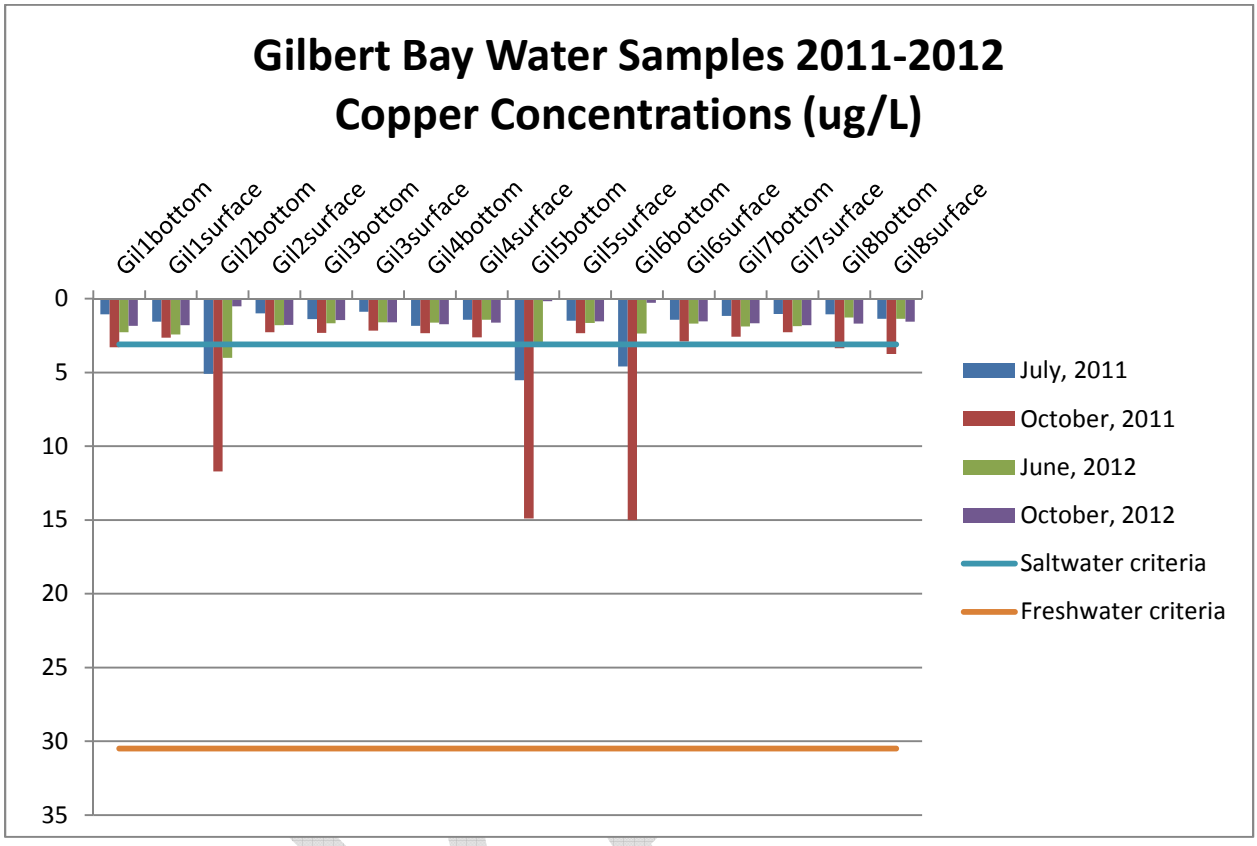
Priority 3. Arsenic



Arsenic

Arsenic is selected as the pollutant with the 3rd highest priority. When compared to the freshwater benchmark, arsenic in the oxic stratum and deep brine layer had had the 3rd and 4th highest quotients, respectively. When compared to the marine benchmarks, arsenic in the oxic stratum and deep brine layer and the highest and 2nd highest quotients, respectively. UPDES discharges to Gilbert Bay contain arsenic. Based on the comparison to the benchmarks, arsenic would be ranked higher. However, the results of a full life cycle test conducted with brine shrimp, sodium arsenate, and Gilbert Bay dilution water suggests that brine shrimp are relatively insensitive to arsenic (Brix et al., 2003). However, no toxicity data are available for brine flies. The lack of data for the sensitivity of brine flies to arsenic and the results of the benchmark comparisons warrants arsenic as the third highest priority pollutant.

Priority 4. Copper

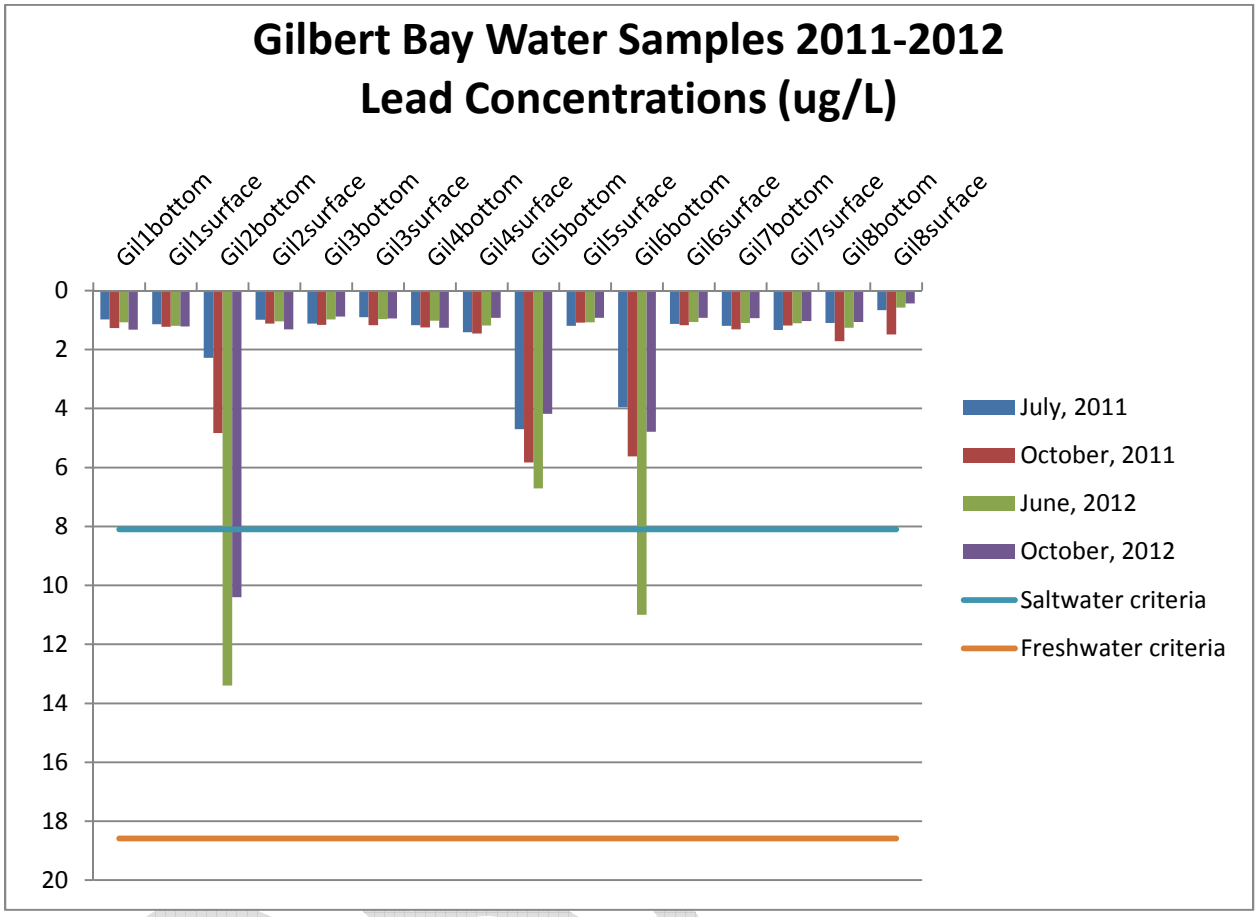


Copper

Copper was assigned the 4th highest priority for testing after ammonia, methylmercury, and arsenic. Copper is a USEPA priority pollutant and is present in UPDES discharges to Gilbert Bay. When compared to the freshwater benchmarks, copper in the oxic stratum and deep brine layer had the 6th and 7th highest quotients, respectively. When compared to the marine benchmarks, copper had the third highest quotients for both the oxic and deep brine strata.

Brix et al., (2006) measured an EC_{50} for Great Salt Lake brine shrimp exposed to copper. The EC_{50} with laboratory dilution was 12 µg/l and 68 µg/l when Great Salt Lake was the source of the dilution water. These EC_{50}s support that the site-specific chemistry of Gilbert Bay waters decreases the observed toxicity of copper compared to laboratory water. However, no data were available for brine flies and an EC_{50} is not applicable for deriving chronic numeric criteria resulting in copper being the 4th highest priority.

Priority 5. Lead



Lead

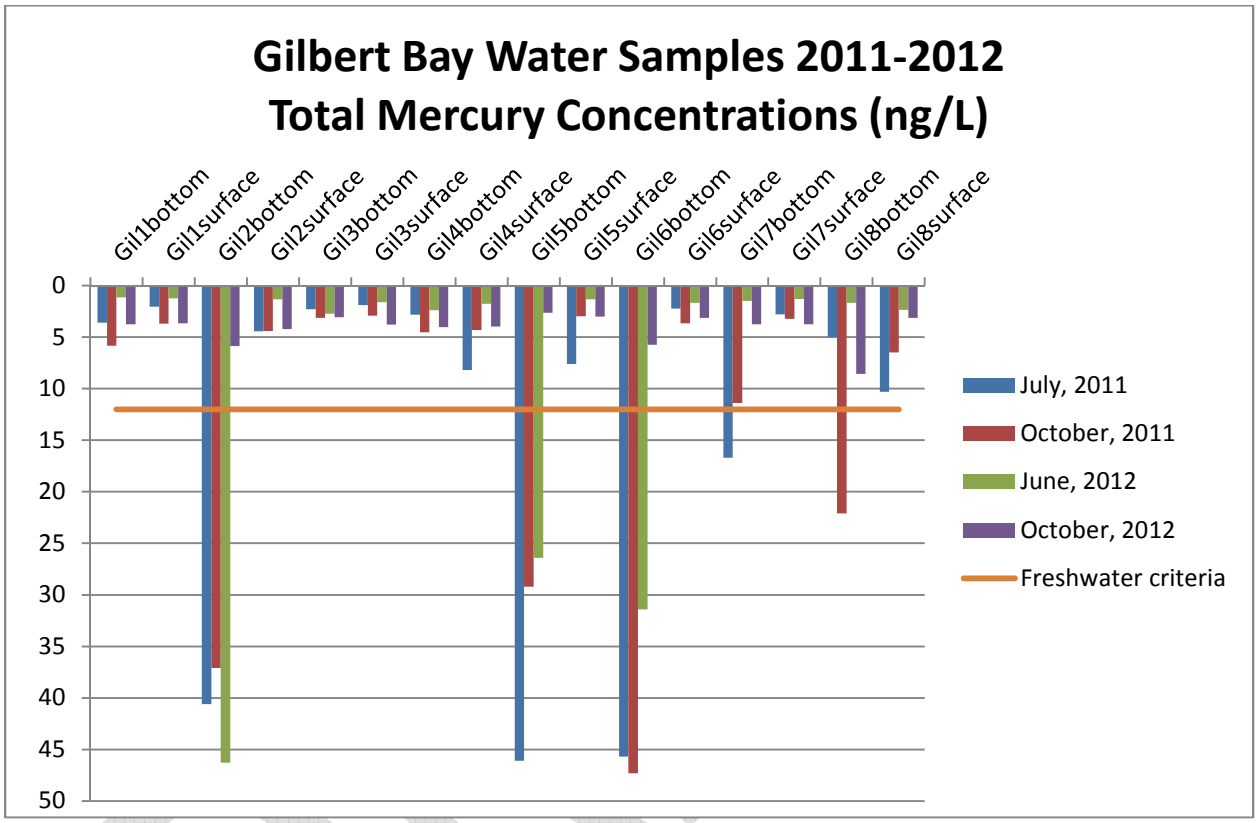
Lead is a USEPA priority pollutant and is a pollutant in UPDES discharges to Gilbert Bay. When Gilbert Bay mean concentrations for surface-only and all samples were compared to the freshwater benchmark, lead was ranked 7th and 6th, respectively. When the mean concentrations were compared to the marine benchmark, lead was ranked the third highest. In a test using San Francisco Bay brine shrimp, Gajbhiye and Hirota (1990) ranked lead higher in toxicity when compared to cadmium, copper, nickel, zinc, and manganese. Therefore, lead is ranked 5th for additional testing with brine shrimp and brine flies.

Zinc (deferred)

Zinc

Zinc is a USEPA priority pollutant but was not a target analyte for the 2011 and 2012 sampling. Zinc is present in UPDES discharges to Gilbert Day. Analytical data from DWQ's Bluefish Database indicate that the mean concentrations in Gilbert Bay are 3 µg/l. Utah's 4-hour freshwater criterion is 7,400 µg/l (100 mg/l hardness), the USEPA marine criterion is 81 µg/l, and Brix et al. (2006) EC_{50} for Great Salt Lake brine shrimp was 300 µg/l . Based on a comparison of these benchmarks to Gilbert Bay concentrations, zinc would not be one of the top five pollutants had recent data on Gilbert Bay concentrations been available. Zinc is a target analyte for future monitoring.

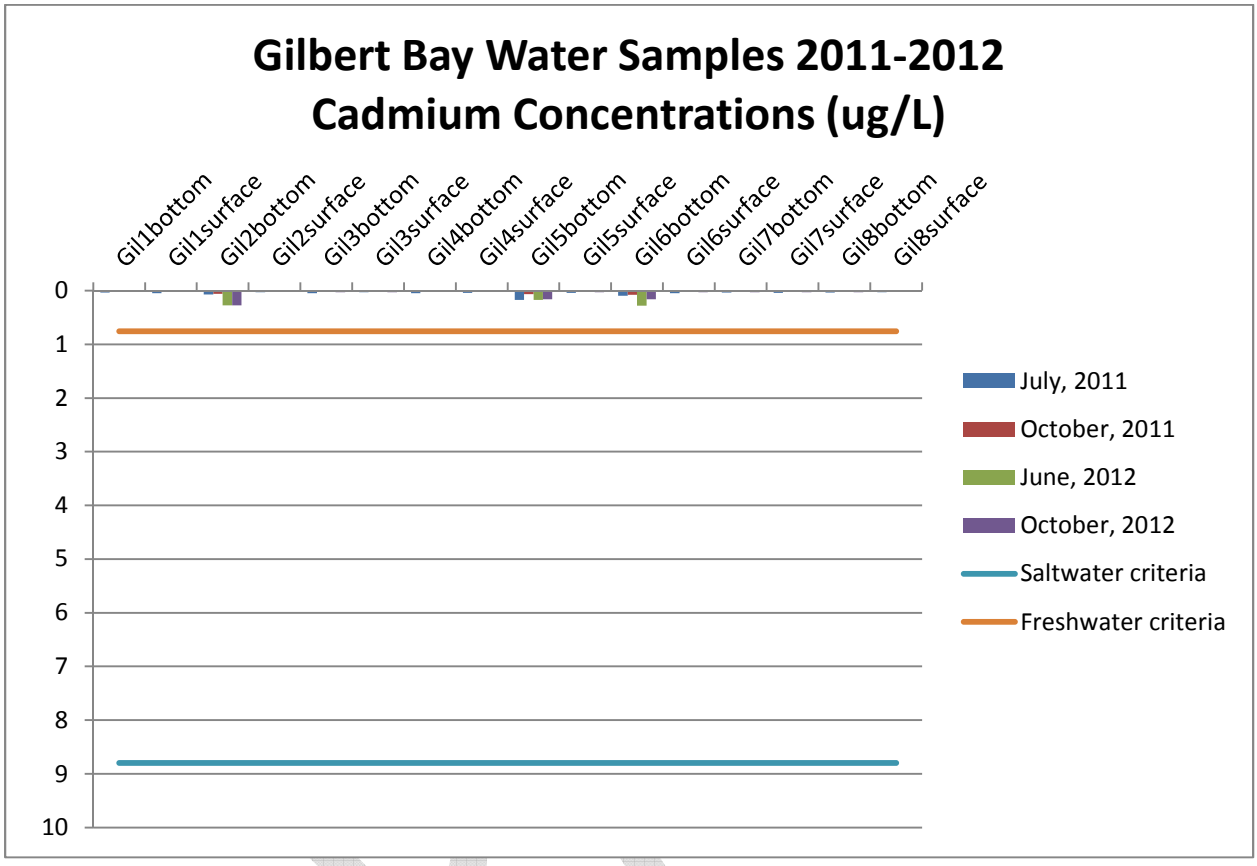
Total Mercury (deferred)



Total Mercury

Mercury is a USEPA priority pollutant and is present in UDPES discharges to Gilbert Bay. When compared to the freshwater benchmark, mercury in the oxic stratum and deep brine layer had the 4th and 3rd highest quotients, respectively. When compared to the marine benchmark (0.94 µg/l, not shown on above figure), the quotients for mercury in the oxic stratum and deep brine layer were 6th and 5th highest respectively. Total mercury was assigned a lower priority than suggested by the comparisons to the benchmarks for two reasons. First, methylmercury was selected as the 2nd highest priority and methylmercury is more toxic than the inorganic forms of mercury potentially included with total mercury. The average fraction of methylmercury to total mercury in the oxic stratum of Gilbert Bay is 25-35% (DWQ, 2011-2012 monitoring; Naftz et al., 2011; Wurtsbaugh, 2011) supporting that the majority of potential toxicity of mercury will be attributable to the methylated fraction. For example,, the screening benchmark used for methylmercury is 2.8 ng/l while the USEPA chronic continuous criterion for total mercury is 770 ng/l. The second reason is that the high ranking from the comparison to the freshwater benchmark (Utah's freshwater criterion) is an artifact because the criterion is based on human consumption of fish, not aquatic life.

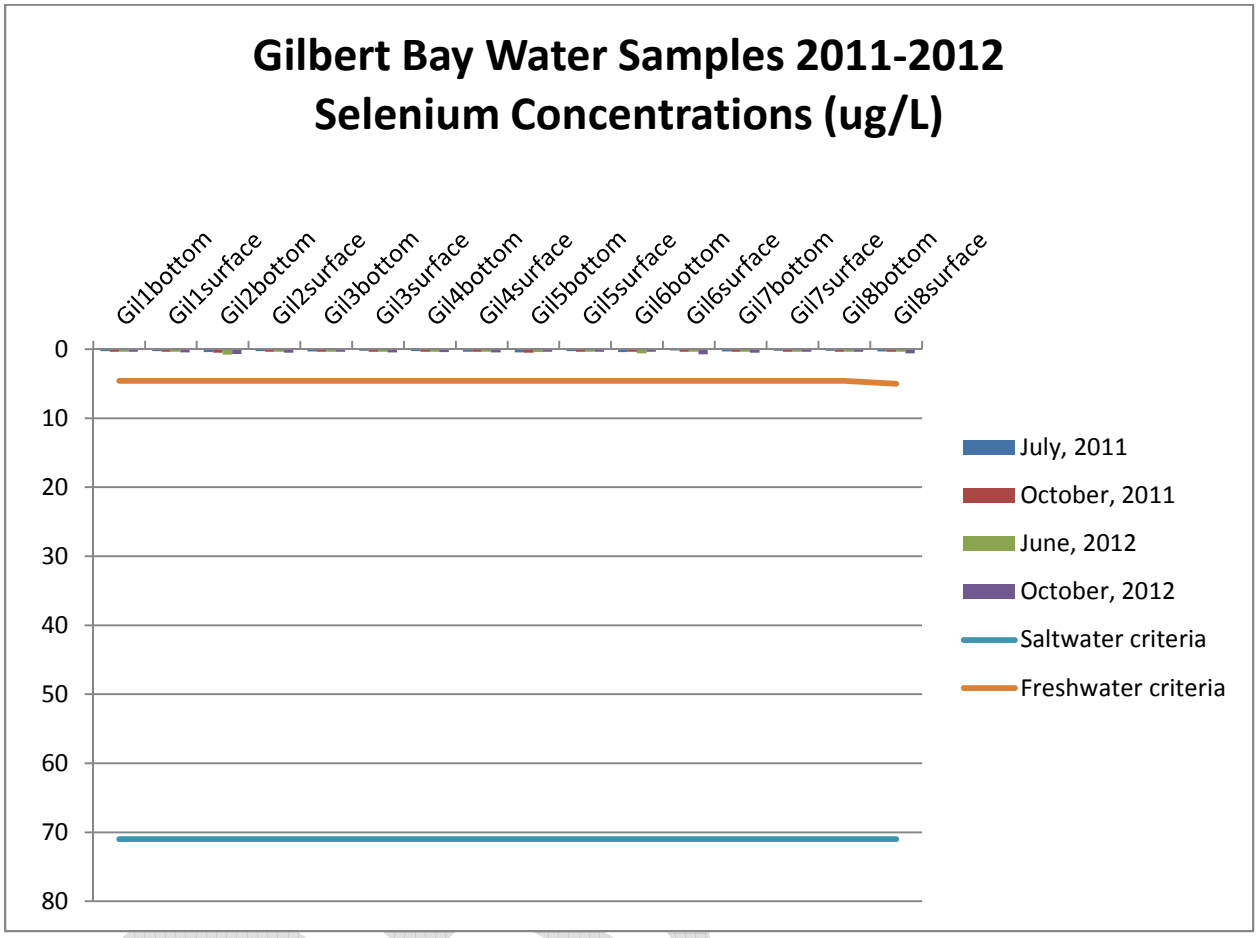
Cadmium (deferred)



Cadmium

Cadmium is a USEPA priority pollutant but discharges to Gilbert Bay only contain trace amounts. When compared to the freshwater benchmark, cadmium concentrations in the oxic stratum and deep brine layer had the 8th and 6th highest quotients of 9, respectively. When compared to the marine benchmark, cadmium concentrations in the oxic stratum and deep brine layer had the 7th and 6th highest quotients of 7, respectively. Brix et al., (2006) measured an EC_{50} of 11,859 µg/l for Great Salt Lake brine shrimp exposed to cadmium that indicates brine shrimp are relatively insensitive to cadmium. No toxicity data were found for brine flies. The maximum concentration measured in 2011 and 2012 was 0.28 µg/l which is several orders of magnitude below the brine shrimp EC_{50}. Therefore, prioritization for cadmium is deferred.

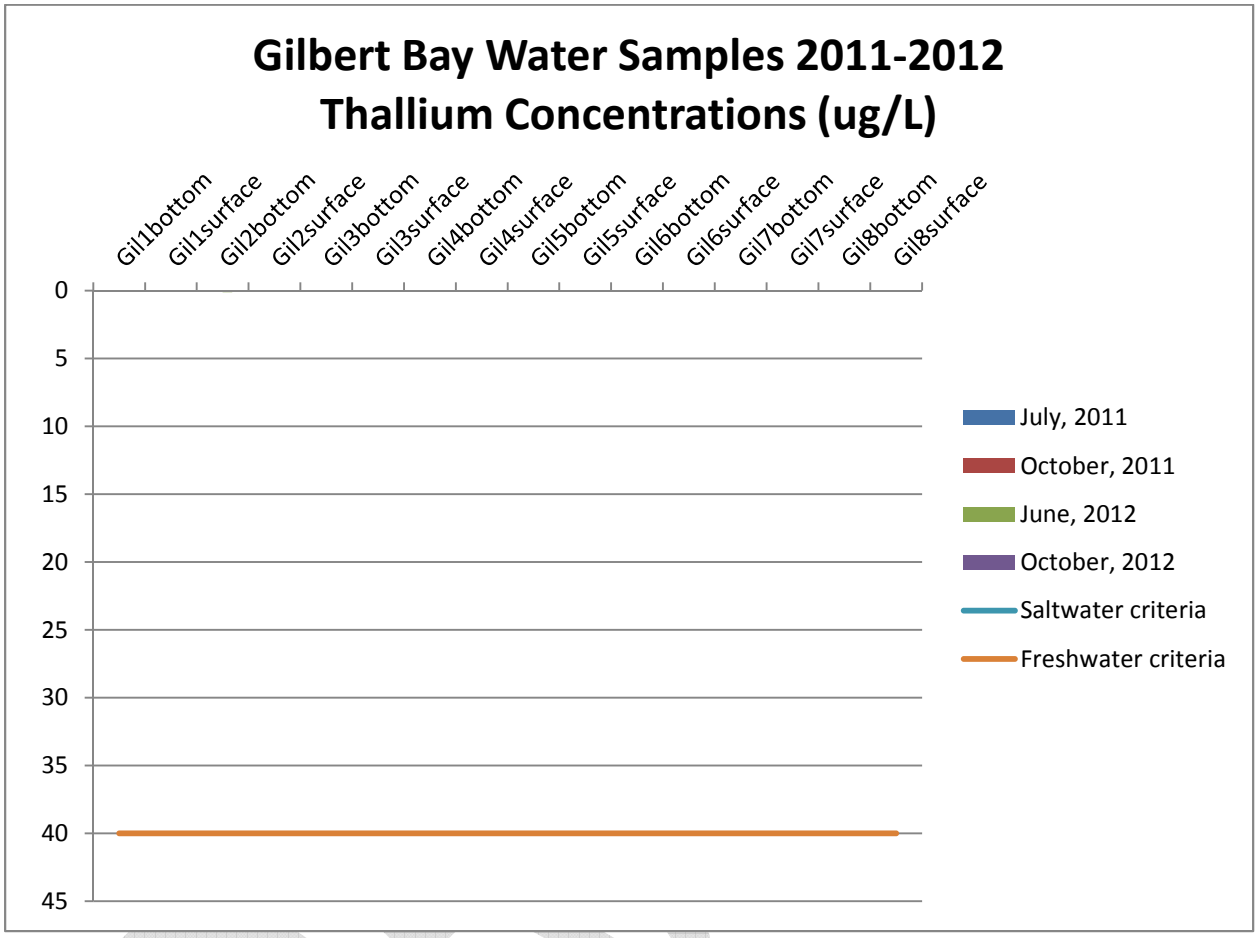
Selenium (deferred)



Selenium

Selenium is a USEPA priority pollutant and UDPES discharges do contain selenium. When compared to freshwater benchmarks, selenium in the oxic stratum and deep brine layer had the 5th and 8th highest quotients of 9, respectively. When compared to the marine benchmarks, selenium in the oxic stratum and deep brine layer ahd the 5th and 7th highest quotients of 8, respectively Gilbert Bay has a Utah numeric criterion based on bird egg tissue because bird reproduction was determined to be the most sensitive toxic endpoint for selenium (DWQ, 2008). Brix et al., (2004) conducted acute tests on selenate with brine shrimp, brine flies, and algae. Of the three organisms, brine shrimp were the most sensitive, followed by the algae, and then brine flies. Additional testing for selenium is a low priority.

Thallium (deferred)



Thallium

Thallium was a target analyte for the 2011 and 2012 monitoring but is not a USEPA priority pollutant. Mean thallium concentrations in Gilbert Bay were 0.034 µg/l and 0.058 µg/l for the oxic stratum and deep brine layer, respectively. LANL (2009) gives a Tier II chronic concentration of 18 µg/l for the protection of aquatic life that was used as a freshwater benchmark. No marine benchmarks were available. Thallium is given a low priority because it is not a USEPA priority pollutant and concentrations measured in Gilbert Bay were orders of magnitude lower than the benchmark.

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