

5.0 GREAT SALT LAKE OPEN WATER (GILBERT BAY) AND SOUTH SHORE DELTAS (1996-2000)

5.1 Introduction

The open waters of the Great Salt Lake play a central role in the global ecology of many avian species. Although the biological community within the lake is quite simple (algae and other phytoplankton, brine shrimp, and brine flies), it supplies an abundant food resource for birds that stop over at the lake during migration. Several species such as northern shoveler (*Anas clypeata*) and common goldeneye (*Bucephala clangula*) spend much of the winter on the lake after the fresher waters in Farmington Bay and Bear River Bay have frozen over. One species, the eared grebe (*Podiceps nigricollis*), utilizes the lake for both food and protection from predators during a protracted fall migratory stop-over. These birds arrive on the lake in late September when brine shrimp populations are peaking, and spend up to six weeks feeding on the lake while they undergo a complete feather molt before continuing on to their wintering grounds in December-January. While the open waters of the lake are distant from the mouths of rivers that carry effluents into the lake, there is a concern regarding the accumulation of metals and other contaminants into a water body with no outlet. As discussed in Section 2.0, the objective of the GSL Open Water survey was to assess one of the important open-water areas of the lake (Gilbert Bay, located in the southern half of the GSL) by sampling over a broad area within a time frame relevant to migratory birds to get a “snapshot” of potential contaminant risks to birds.

Initial sampling of the open waters of the GSL was carried out in 1996-1997 and addressed sediments, brine shrimp and eared grebes (liver tissue); additional eared grebe liver samples were collected in 1998. Based on concerns arising from review of the results of this sampling round, combined with the identification of data gaps in discussions of lake management with other agencies, additional sediment, brine shrimp and eared grebe liver samples were collected in 2000 (see Table 2-2 for a summary of sample sites and media). Sampling locations for these are shown in **Figure 5-1** (sediment and brine shrimp) and **Figure 5-2** (eared grebes).

Sediment samples were collected with a ponar dredge (in open water areas) or composited from an approximately 1 m² area (for shallowly submerged sediments) using equipment and methods described in Section 3.0. Brine shrimp, either adults or cysts (eggs) were sampled by towing plankton nets through the top meter of lake depth until sufficient sample mass had been collected. Eared grebes were collected with stainless steel shot, placed immediately in coolers on wet ice, and transported back to the Service’s field laboratory in Salt Lake City where livers were dissected out. Samples of all media were stored at -10° C prior to shipment to analytical laboratories (see Section 3.0). Livers from eared grebes collected in 1997 (n=22) were composited into three samples representing distinct geographic areas of the lake (Figure 5-2), which were split and submitted separately for analysis of metals, organochlorines (OC) and dioxins/furans. Livers from eared grebes collected in 1998 and 2000 were submitted individually for analysis. Samples (all media) collected from 1998-2000 were analyzed only for metals. A complete count of sample media, numbers, types (individual vs. composite) and analytes is presented in **Table 5-1**.

Sample analysis, data reduction and statistical methods used in this study were generally the same as outlined for the GSL Wetlands assessment (Section 3), with Student’s T-test used to compare concentrations in sediments collected closer to the south shore of the GSL (“on-shore”, defined by a transect imposed on the data post-hoc and shown in Figure 5-1) compared to those collected further out in the lake (“off-shore”). Trace element concentrations in sediments were also compared to the same threshold effect concentrations (TECs) and probable effect concentrations (PECs) ((MacDonald et al. 2000) used in the GSL Wetlands analysis. Concentrations of selenium were compared to sediment guidelines concentrations published by the DOI’s Irrigation Water Quality Program (National Irrigation Water Quality Program 1998). It is unknown how well these benchmarks predict sediment toxicity in the

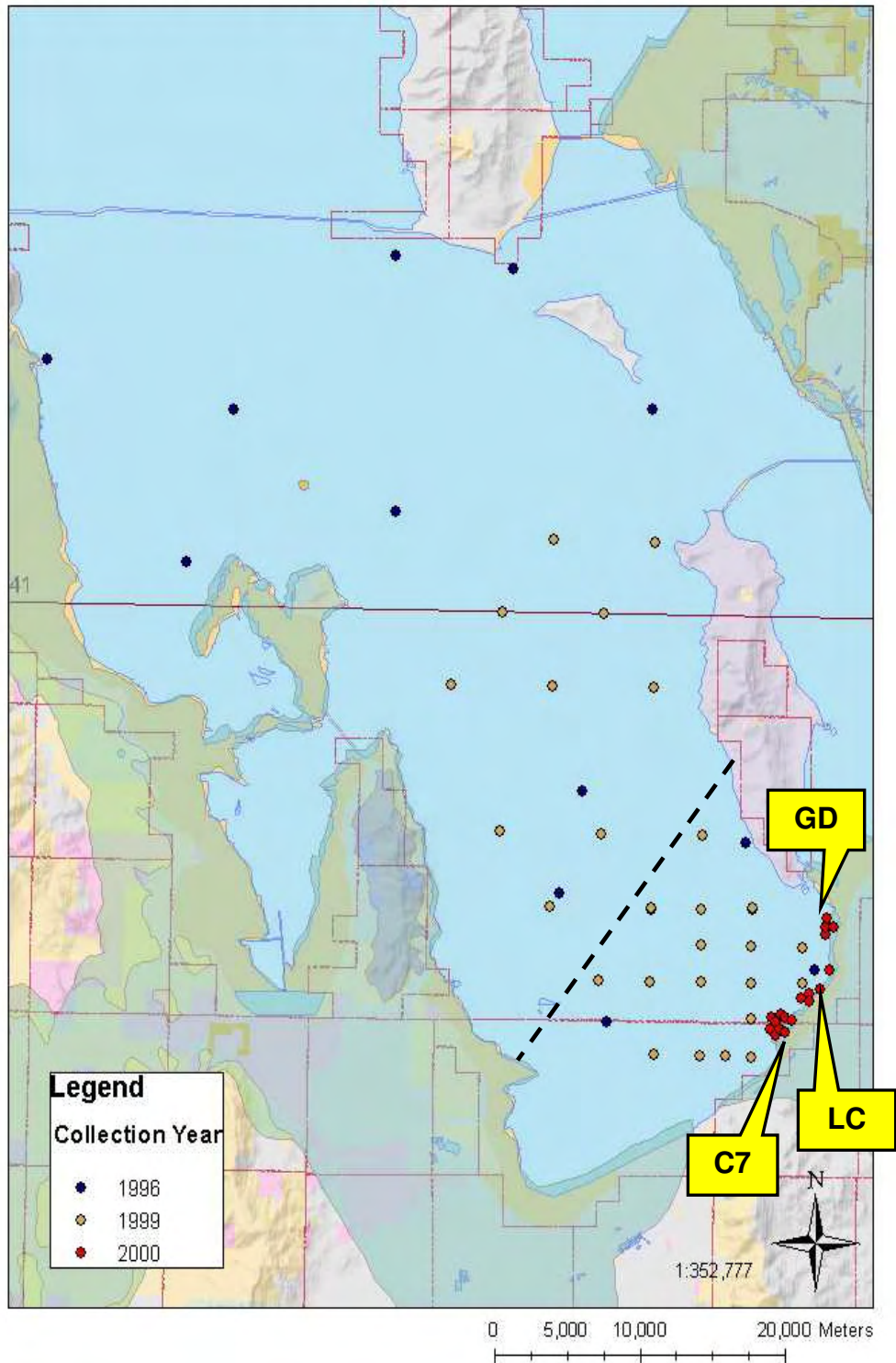


Figure 5-1 Sediment and Brine Shrimp Samples collected in Gilbert Bay (1996 and 1999) and Sediment Samples collected at South Shore Delta Locations (2000; GD = Goggin Drain, LC = Lee Creek, C7 = C7 Ditch), Great Salt Lake Open Water (Gilbert Bay) Survey (1996-2000). Dashed line is a (post-hoc) transect separating sediment samples (1996 and 1999) into “onshore” and “offshore” groups

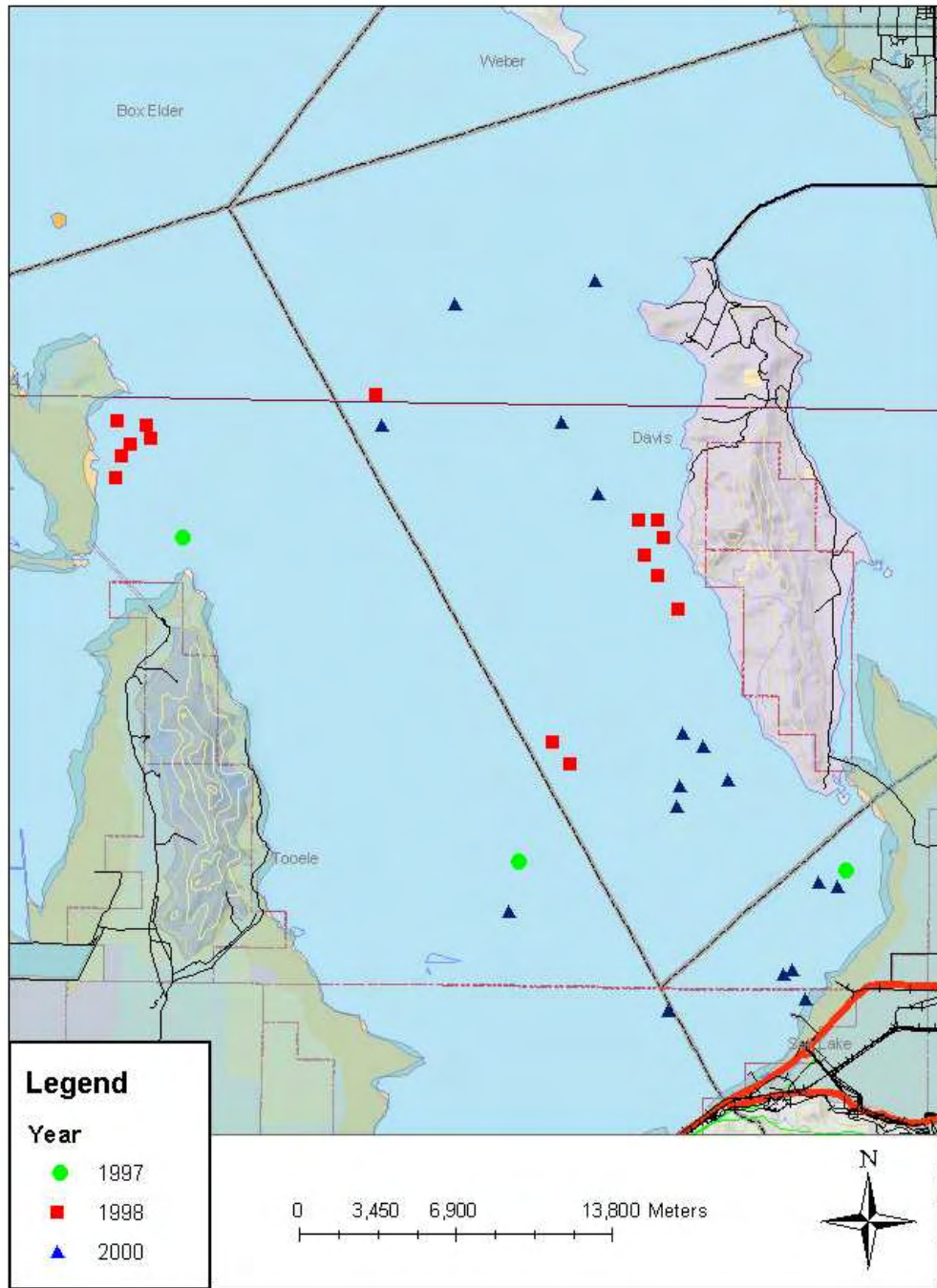


Figure 5-2 Locations of Eared Grebes (*Podiceps nigricollis*) collected in 1997 (composite samples) 1998 and 2000 (individual samples); Great Salt Lake Open Water (Gilbert Bay) Survey (1996-2000)

Table 5-1 Media, numbers and constituents analyzed, Great Salt Lake Open Water (Gilbert Bay) Survey (1996-2000)

| Location | Loc. Code | Year | Sample number (n) | Matrix | Analytes |
|---|-----------|------|-------------------|---------------------|--------------|
| <i>Gilbert Bay (Open Waters)</i> | | | | | |
| USGS Sites | GU | 1996 | 10 | Sediment (indiv) | MET |
| | “ | “ | 12 | Brine shrimp- adult | MET |
| | “ | “ | 4 | Brine shrimp- cysts | MET |
| FWS Sites | GG | 1997 | 3 | EAGR liver (comp) | MET, D/F, OC |
| | “ | 1998 | 16 | EAGR liver (indiv) | MET |
| | “ | 1999 | 28 | Sediment | MET |
| | “ | “ | 28 | Brine shrimp- adult | MET |
| | “ | “ | 4 | Brine shrimp- cysts | MET |
| | “ | 2000 | 28 | Brine shrimp- adult | MET |
| | “ | “ | 24 | EAGR liver (indiv) | MET |
| <i>South Shore “Deltas”</i> | | | | | |
| C7 Ditch Delta | GC | 2000 | 9 | Sediment (comp) | MET |
| Goggin Drain Delta | GG | 2000 | 4 | Sediment (comp) | MET |
| Lee Creek Delta | GL | 2000 | 5 | Sediment (comp) | MET |

NOTES and ABBREVIATIONS:

USGS Sites: established by U.S. Geological Service Utah Water Resources Division for Great Salt Lake Hydrologic and Limnologic Investigations
 FWS Sites: established by U.S. Fish and Wildlife Service Utah Field Office for GSL Contaminants Assessment
 MET: trace elements (metals)
 D/F: dioxins and furans
 OC: Organochlorine
 EAGR: Eared grebe
 Comp: composite sample
 Indiv: individual sample

highly saline conditions of the GSL, but they are useful for comparability with the GSL wetlands assessment. They may also be more applicable to sediments in the GSL “delta” areas, since freshwater inflows in these areas may form fresh- or brackish-water delta systems when the GSL is below its long-term average of 1,280 meters (4,200 feet) above sea level. Concentrations of trace elements in brine shrimp were compared to relevant avian dietary levels of concerns used in the GSL wetlands assessment, and on-shore/off-shore concentrations were evaluated with Students t-test. Concentrations of trace elements and OCs (where available) were compared to concentrations in avian livers found to be associated with adverse effects to avian growth, reproduction and/or survival, including no observed adverse effects levels (NOAELs) and lowest observed adverse effects levels (LOAELS) in published scientific literature.

Complete analytical results for these samples are presented in Appendix B, as follows:

- Appendix Table B-1 Trace Elements in Sediments, GSL Open Waters and South Shore Deltas
- Appendix Table B-2 Trace Elements in Brine Shrimp Cysts and Adults, GSL Open Waters
- Appendix Table B-3 Trace Elements in Eared Grebe Livers, GSL Open Waters
- Appendix Table B-4 Organochlorines and Dioxins/Furans in Eared Grebe Livers, GSL Open Waters

All trace element analyses are presented and discussed in terms of mg/kg dry weight, organic compounds in eared grebe livers, are presented in terms of mg/kg wet weight.

5.2 Trace Elements in Sediments- GSL Open Waters and South Shore Deltas

A total of 38 sediment samples were collected from the open waters of Gilbert Bay in 1996 and 1999 at locations throughout the southern portion of the GSL. Ten samples were collected in 1996 at standardized sampling locations established by the USGS Water Resources Division (Salt Lake City, Utah). An additional 28 samples were collected in 1999 at points established by Rich (2002) to evaluate the distribution and movement of sediments in response to circulation and currents in the lake. These samples were collected at points on a systematic grid with particular emphasis along the western shore of Antelope Island, with approximately half located southwest (“onshore”) of a transect (established post-hoc) centered approximately halfway along the length of Antelope Island and extending southwest (Figure 5-1). This transect was used to divide “on-shore” samples collected closer to the south shore of the GSL (of concern due to industrial and agricultural effluents that enter the GSL in this location) from “off-shore” samples more representative of the deeper waters of the open lake.

In comparison to freshwater SQGs, only copper (Cu) exceeded the upper PECs with any frequency, in one of 10 samples in 1996 and 12 of 28 samples in 1999 exceeding the PEC of 149 mg/kg (**Table 5-2**). In addition to copper, concentrations of lead, mercury and selenium frequently exceeded the lower TECs. Samples collected in 1999 tended to have higher concentrations with higher maximum and geometric mean concentrations for all elements compared to 1996 samples. However, this was biased by the fact that many of the samples collected in 1996 were collected further out in the central & northern portions of Gilbert Bay, while samples collected in 1999 were concentrated near the south shore area of the lake, near the outfall of the C7 Ditch (**Figure 5-1**). This ditch is a wastewater discharge canal that originates from the Kennecott Utah Copper Corporation (KUCC) metals smelting and refining facility, and carries process waters (after treatment at an onsite treatment plant) from the facility’s tailings pile and smelting operations. The C7 Ditch has been in existence since the early-mid 20th century, and while it is currently in compliance with Clean Water Act requirements, water quality monitoring records maintained in the U.S. EPA’s STORET database (accessed at <http://www.epa.gov/storpubl/legacy/gateway.htm>) indicate that it has historically carried wastewaters with much higher concentrations of metals associated with copper refining, including Cu, As, Cd and Se .

Copper concentrations were not significantly elevated in on-shore sediment samples (geometric mean 147 mg/kg) compared to off-shore samples (49.5 mg/kg; $P = 0.059$). However two samples collected just offshore of the C7 Ditch outfall had concentrations that were outliers compared to the rest of the on-shore samples, with 620 and 1,083 mg/kg Cu, respectively (**Figure 5-3**). The geometric mean concentration of arsenic was also higher in the on-shore samples (21.0 mg/kg) compared to off-shore (18.3 mg/kg) with the highest concentrations again concentrated around the C7 Ditch, but the difference was not significant ($P = 0.325$). Selenium exceeded the DOI background concentration of 1.0 mg/kg in all 38 samples, but did not exceed the toxicity threshold of 4.0 mg/kg. One sample with relatively high Se (3.08 mg/kg) was collected near the C7 Ditch outfall, but the maximum detected concentration of Se (3.34 mg/kg) was observed about 20 km to the northwest, just on the other side of the off-shore dividing line. Mercury was detected in only half of the off-shore samples compared to 65% of on-shore samples, and the geometric mean of on-shore samples (0.201 mg/kg) was greater than in off-shore samples (0.186² mg/kg). The four highest Hg concentrations (0.385 – 0.414 mg/kg) were observed in off-shore sediments, but statistical comparison was not possible because of the low Hg detection frequency in the off-shore samples.

2 Calculated using a value of 0.1 mg/kg (half of the detection limit of 0.2 mg/kg) to estimate concentrations in samples with <0.2 mg/kg

Table 5-2 Summary of selected trace elements (mg/kg, dry weight) compared to freshwater sediment screening benchmarks, Great Salt Lake Open Water (Gilbert Bay) Survey (1996-2000)

| Trace Element | | Gilbert Bay | |
|----------------------|--------------------|-------------------|------------------|
| | | 1996 ¹ | Gilbert Bay 1999 |
| | | <i>n</i> = | |
| Arsenic | Gmean | 15.8 | 21.3 |
| <i>TEC / PEC</i> | Max | 29.6 | 45.6 |
| [9.8 / 33.0] | #>Ref ² | [8 / 0] | [28 / 1] |
| Cadmium | GMean | NC | 0.32 |
| <i>TEC / PEC</i> | Max | 0.27 | 1.71 |
| [0.99 / 4.98] | #>Ref | [0 / 0] | [1 / 0] |
| Chromium | GMean | 7.37 | 10.2 |
| <i>TEC / PEC</i> | Max | 17.1 | 58.9 |
| [43.4 / 111] | #>Ref | [0 / 0] | [1 / 0] |
| Copper | GMean | 36.2 | 120. |
| <i>TEC / PEC</i> | Max | 233. | 1083. |
| [31.6 / 149] | #>Ref | [5 / 1] | [23 / 12] |
| Lead | GMean | 44. | 65.7 |
| <i>TEC / PEC</i> | Max | 129. | 145. |
| [35.8 / 128] | #>Ref | [7 / 1] | [23 / 2] |
| Mercury | GMean | NC | 0.220 |
| <i>TEC / PEC</i> | Max | 0.373 | 0.414 |
| [0.18 / 1.06] | #>Ref | [2 / 0] | [20 / 0] |
| Selenium | GMean | 1.67 | 2.03 |
| <i>BG / Toxicity</i> | Max | 2.50 | 3.34 |
| [1.0 / 4.0] | #>Ref | [10 / 0] | [28 / 0] |
| Zinc | GMean | 58.2 | 78.5 |
| <i>TEC / PEC</i> | Max | 145. | 154. |
| [121 / 459] | #>Ref | [2 / 0] | [3 / 0] |

Key and Abbreviations

#>Ref [TEC / PEC]: Number of samples that exceed Threshold Effects Concentration (TEC) and Probable Effects Concentration (PEC) (MacDonald et al. 2000). For Se, BG = Se background, Toxicity = Se toxicity threshold (National Irrigation Water Quality Program 1998)

Gmean: geometric mean concentration for sample year

Gmean: Gmean>TEC

NC = geometric mean not calculated (i.e., more than 50% of values <detection limit)

ND = all samples were less than the detection limit

¹ This column includes one sample collected in 1997

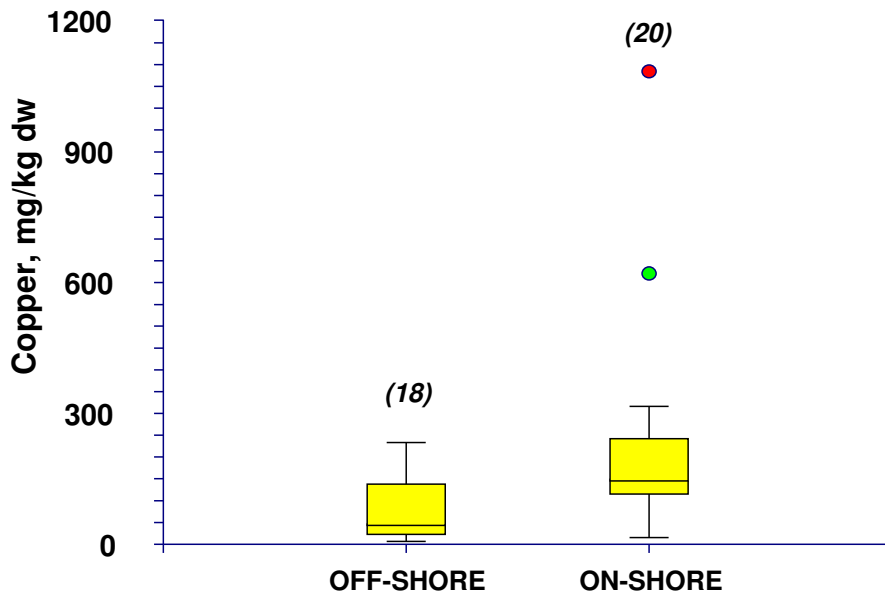


Figure 5-3. Copper in sediments from the open waters of Gilbert Bay in the Great Salt Lake, Utah, 1996-1999, “on-shore”(near the lake’s south shore) compared to deeper waters. Sample numbers shown in parentheses.

South Shore Delta Sediment Samples, 2000

Based in part on the elevated concentrations of trace metals observed within and off-shore of the C7 Ditch, as well as within the nearby Goggin Drain, additional sediment samples were collected on the alluvial sediment fans (deltas) located at the mouths of these channels, as well as at a third channel located between these two, Lee Creek. While the C7 Ditch is an industrial effluent channel, the Goggin Drain and Lee Creek carry primarily irrigation return flow into the GSL, and are located within lands that are managed as wetland mitigation banks which provide high quality foraging and nesting habitat to migratory birds. Nine samples were collected on the C7 Ditch Delta (C7), while four and five samples were collected on the Goggin Drain (GD) and Lee Creek (LC) deltas, respectively (locations shown on Figure 5.1)

In general, concentrations of trace elements of concern in the deltas were lower than either the on-shore or off-shore sediments discussed above. Mean concentrations of copper were elevated compared to TECs in both the C7 and GD deltas, with one of the samples from C7 exceeding the PEC almost 10-fold (1,308 mg/kg vs. the PEC of 149 mg/kg). However, geometric mean concentrations of Cu in both deltas were lower than the on-shore open water sediment samples. Concentrations of lead were higher at the GD delta, with the geometric mean (95.6 mg/kg) and all four of the samples collected exceeding the PEC. The mean concentration of Pb at the GD delta was greater than the mean Pb concentration in the on-shore open water sediments. This may be due to past land uses at the GD site, which included waterfowl hunting the mid 1990’s, when the property upland of the delta was acquired by a conservation organization as a wetland mitigation site. The Lee Creek Delta (LC) was comparatively clean, with only

Table 5.3 Concentrations of trace elements in Sediments , South Shore “Deltas” Compared to Sediment Screening Benchmark Concentrations and to Geometric Mean Concentrations of Sediments Collected in the Open Waters of Gilbert Bay, Great Salt Lake, Utah, 2000.

| | As | Cd | Cu | Pb | Hg | Se | Zn |
|----------------------------------|-------------|-------------|--------------|------------|-------------|------------|------------|
| <i>TEC</i> | 9.8 | 0.99 | 31.6 | 35.8 | 0.18 | 1.0 | 121 |
| <i>PEC</i> | 33.0 | 4.98 | 149 | 128 | 1.06 | 4.0 | 459 |
| <i>Geometric Mean, off-shore</i> | 18.4 | 0.25 | 49.5 | 51.0 | 0.186 | 1.88 | 65.4 |
| <i>Geometric mean, on-shore</i> | 21.0 | 0.39 | 147 | 67.4 | 0.201 | 1.97 | 79.6 |
| <i>C7 Ditch Delta; 2000</i> | | | | | | | |
| <i>C7, n=9</i> | | | | | | | |
| <i>geometric mean</i> | 11.9 | [---] | 86.6 | 18.9 | [---] | [---] | 47.3 |
| <i>maximum</i> | 33.7 | 0.252 | 1,308 | 55.4 | ND | 2.01 | 124. |
| <i>Det. Frequency</i> | 9/9 | 2/9 | 9/9 | 9/9 | 0/9 | 3/9 | 9/9 |
| <i>% > PEC</i> | 11% | 0 | 33% | 0 | 0 | 0 | 0 |
| <i>TEC < % < PEC</i> | 56% | 0 | 33% | 11% | 0 | 33% | 11% |
| <i>Goggin Drain Delta; 2000</i> | | | | | | | |
| <i>GD, n=4</i> | | | | | | | |
| <i>geometric mean</i> | 16.6 | [---] | 94.8 | 95.6 | [---] | [---] | 159 |
| <i>maximum</i> | 22.4 | 0.851 | 228 | 170 | ND | 1.04 | 242 |
| <i>Det. Frequency</i> | 4/4 | 2/4 | 4/4 | 4/4 | 0/4 | 1/4 | 4/4 |
| <i>% > PEC</i> | 0 | 0 | 25% | 50% | 0 | 0 | 0 |
| <i>TEC < % < PEC</i> | 100% | 0 | 75% | 50% | 0 | 25% | 75% |
| <i>Lee's Creek Delta; 2000</i> | | | | | | | |
| <i>LC, n=5</i> | | | | | | | |
| <i>geometric mean</i> | 9.25 | [---] | 41.4 | 22.9 | [---] | [---] | 27.8 |
| <i>maximum</i> | 10.5 | ND | 146 | 28.9 | ND | 1.2 | 51.8 |
| <i>Det. Frequency</i> | 5/5 | 0/5 | 5/5 | 5/5 | 0/5 | 1/5 | 5/5 |
| <i>% > PEC</i> | 0 | ND | 0 | 0 | ND | 0 | 0 |
| <i>TEC < % < PEC</i> | 40% | ND | 20% | 0 | ND | 20% | 0 |

Notes and Abbreviations:

TEC: Threshold Effect Concentration

PEC: Probable Effect Concentration (both (MacDonald et al. 2000)

Value: Concentration > PEC

Value: Concentration ≥ TEC but < PEC

ND: Not Detected

[---]: Value not calculated because of insufficient detection frequency

occasional exceedences of TECs, and no exceedences of PECs. Areas upland of the LC delta are also currently being managed as a wetland mitigation bank, operated by KUCC as the “Inland Sea Shorebird Reserve.” This property encompasses several hundred acres, and water from Lee Creek is being used to create and manage both ponded and emergent wetland habitat that is of high value to a large number of migratory birds, waterfowl and raptors.

5.3 Trace Elements in Brine Shrimp and Brine Shrimp Cysts, GSL Open Waters

A total of 68 samples of brine shrimp and cysts (eggs) collected between 1996 and 2000 were evaluated for trace metals, with data for those elements that exceeded avian dietary screening benchmarks summarized in **Table 5-4**. Complete analytical results are presented in **Appendix Table B-2**. Samples of adult brine shrimp and cysts were collected at the same time and location as the sediment samples discussed above, with samples collected in 1996 distributed broadly across Gilbert Bay, and samples collected in 1999 focused more tightly on the southern portion of the lake near the south shore (see Section 5.1 and **Figure 5-1**). Samples in both 1997³ and 1999 were collected in the fall (September – October) in order to evaluate dietary exposure to birds using the lake as a fall migratory stop-over (e.g. eared grebes). However, based on concentration trends observed in those years, and also to characterize exposure to birds using the GSL during spring migration, additional samples of adult brine shrimp were collected in May 2000, at the same locations sampled the previous fall.

Viewed in total (**Table 5-4**), only boron (B), mercury (Hg) and selenium (Se) exceeded avian dietary effects levels in brine shrimp adults. Brine shrimp cysts did not exceed these levels, but are less of a food source for birds. Mean concentrations of B in brine shrimp adults exceeded the LOAEL of 30 mg/kg associated with reduced weight in mallard ducklings (Smith & Anders 1989) in samples collected in the fall (September-October) in both 1996 and 1999, but were less than the LOAEL in the spring (May 2000). Mean concentrations of Hg in the fall of 1996 nearly exceeded the LOAEL of 0.4 mg/kg associated with behavioral and reproductive effects in mallards (Heinz 1979). Mercury was not detected (DL<0.2 mg/kg) in brine shrimp collected during the spring of 2000 but was detected in all samples from 1999 (autumn) and in all but one sample in 1996. Concentrations of Hg in fall brine shrimp samples (1996 and 1999) were significantly higher than in samples collected in the spring of 2000 ($P < 0.0001$; **Figure 5-4**). Mercury was not detected in any sample of brine shrimp cysts. Mean Se concentrations were below the avian LOAEL of 3.0 mg/kg for reproductive failure in fish and wildlife; (Lemly 1996), but individual samples exceeded this level, particularly in samples collected in the fall of 1999 (10 of 28 samples). Concentrations in cysts were significantly lower than in shrimp ($P < 0.0001$) and on average contained half as much Se as adult brine shrimp.

Both Hg and Se are of concern because they are bioaccumulative, leading to an increased potential for exposure in birds that spend long periods of time on the lake feeding only on this food. To evaluate this, samples collected in September (1996 and 1999, n=20) were compared to samples collected in October (n=20). In this comparison, Se was significantly elevated in October (2.96 mg/kg) compared to September (2.56 mg/kg; $P = 0.012$, Students' T-test), but Hg was not significantly different within this interval. While Hg concentrations were significantly lower in brine shrimp collected in the spring compared to those collected in the fall, Se was not (Table 5-5).

Given that the freshwater tributaries to the south arm of the GSL are potential sources of contaminants to the open waters of the lake, a post-hoc comparison was made between the concentrations of Hg and Se in brine shrimp collected at on-shore locations and those collected from off-shore locations (See Section 5.1 above). Comparison across the entire data set was limited by small and uneven sample sizes (e.g., in September 1996, only one brine shrimp sample was collected on-shore compared to four collected off-shore, while in October 1999 there were 11 on-shore samples but only two off-shore samples). In pooled data from fall collections (1996 and 1999), mean offshore Hg and Se concentrations (0.374 mg/kg and 2.92 mg/kg) were greater than on-shore concentrations (0.320 mg/kg Hg, 2.64 mg/kg Se) but were insignificant at $\alpha=0.05$ ($P = 0.062$ and $P = 0.069$, respectively). Mercury could not be evaluated for onshore/offshore differences in the spring (May 2000) because all samples were <DL, and there was no

³ One sample of brine shrimp cysts collected in February 1997 was grouped with three other samples collected in October 1996 for analysis, see Table 5-4.

Table 5-4 Summary of selected trace elements (mg/kg, dry weight) in brine shrimp and brine shrimp cysts compared to avian dietary effect thresholds, Great Salt Lake Open Water (Gilbert Bay) Survey, 1996-2000.

| Metal | | Brine Shrimp | | | Cysts | Cysts |
|----------|-----------------------|------------------|------------------|-------------|------------------------------|------------------|
| | | Sept/Oct 1996 | Sept/Oct 1999 | May 2000 | Oct/Feb 1996 ¹ | Sept/Oct 1999 |
| | <i>n</i> = | 12 | 28 | 28 | 4 | 4 |
| Aluminum | <i>Gmean</i> | 294 | 58.2 | 38.9 | 31.6 | 149 |
| | <i>Max</i> | 757 | 199 | 120 | 45.9 | 196 |
| | Ref = 5000 [#>Ref] | [0] | [0] | [0] | [0] | [0] |
| Arsenic | <i>Gmean</i> | 9.26 | 16.0 | 10.5 | 9.87 | 10.2 |
| | <i>Max</i> | 13.0 | 18.7 | 15.3 | 10.6 | 12.7 |
| | Ref= 30 [#>Ref] | [0] | [0] | [0] | [0] | [0] |
| Boron | <i>Gmean</i> | 44.9 | 42.3 | 29.4 | 38.9 | 75.2 |
| | <i>Max</i> | 66.7 | 69.5 | 41.5 | 69.1 | 87.2 |
| | Ref= 30 [#>Ref] | [5] | [28] | [12] | [3] | [4] |
| Chromium | <i>Gmean</i> | 1.72 | NC | NC | 0.48 | 0.80 |
| | <i>Max</i> | 3.1 | 1.45 | 3.77 | 0.72 | 0.98 |
| | Ref = 10 [#>Ref] | [0] | [0] | [0] | [0] | [0] |
| Copper | <i>Gmean</i> | 11.2 | 8.58 | 12.7 | 5.58 | 9.17 |
| | <i>Max</i> | 17.8 | 13.9 | 15.2 | 8.94 | 10.8 |
| | Ref= 200 [#>Ref] | [0] | [0] | [0] | [0] | [0] |
| Lead | <i>Gmean</i> | 1.30 | NC | NC | NC | 1.83 |
| | <i>Max</i> | 2.75 | 1.66 | ND | 1.5 | 2.12 |
| | Ref = 5 [#>Ref] | [0] | [0] | [0] | [0] | [0] |
| Mercury | <i>Gmean</i> | 0.39 | 0.32 | NC | NC | NC |
| | <i>Max</i> | 0.60 | 0.38 | ND | ND | ND |
| | Ref= 0.4 [#>Ref] | [6] | [0] | [0] | [0] | [0] |
| Selenium | <i>Gmean</i> | 2.42 | 2.85 | 2.63 | 1.74 | 1.42 |
| | <i>Max</i> | 3.81 | 3.59 | 3.05 | 2.15 | 1.63 |
| | Ref= 3 [#>Ref] | [2] | [10] | [2] | [0] | [0] |
| Zinc | <i>Gmean</i> | 75.9 | 55.8 | 115 | 57.3 | 36.0 |
| | <i>Max</i> | 106 | 69.2 | 140 | 76 | 46.7 |
| | Ref= 178 [#>Ref] | [0] | [0] | [0] | [0] | [0] |

Key and Abbreviations:

Gmean geometric mean concentration for sample year

Gmean *Gmean*>referenced avian dietary threshold

NC Geometric mean not calculated (i.e., more than 50% of values <detection limit)

ND All samples < detection limit

#>Ref The number of samples that exceed the referenced avian dietary threshold: **Al**--No observed effect level (Sparling 1990); **As**-- Reduced weight in mallard ducklings (Camardese et al. 1990); **B**-- Reduced weight in mallard ducklings (Smith & Anders 1989); **Cr, Cu, Pb, Zn**--Levels of concern (2000); **Hg**-- Behavioral and reproductive effects in mallards (Heinz 1979); **Se**--Reproductive failure in fish and wildlife; (Lemly 1996).

¹ This column includes one sample collected in February 1997

Table 5-5 Seasonal trends in concentrations of bioaccumulative metals in adult brine shrimp from the open waters of the Great Salt Lake, 1996 – 2000. All concentrations are given in mg/kg dw,

| | September (96+99) <i>n</i> =20 | October (96+99) <i>n</i> =20 | <i>P</i> = | FALL Sept-Oct (’96 + ’99) <i>n</i> =40 | SPRING (May 2000) <i>n</i> =28 | <i>P</i> = |
|----------|--------------------------------------|------------------------------------|------------|--|--------------------------------------|------------|
| Mercury | 0.339 | 0.350 | 0.698 | 0.344 | 0.1 (ND) | <0.0001* |
| Selenium | 2.56 | 2.96 | 0.012* | 2.77 | 2.64 | 0.199 |

NOTES:

“ * “ Significant difference, Students’ T-test, $\alpha=0.05$ (significantly higher concentrations shown in **bold**)

ND Mercury not detected (detection limit = 0.2 mg/kg) in all samples. 0.5 x detection limit (0.1 mg/kg) used for purposes of calculation and statistical comparison.

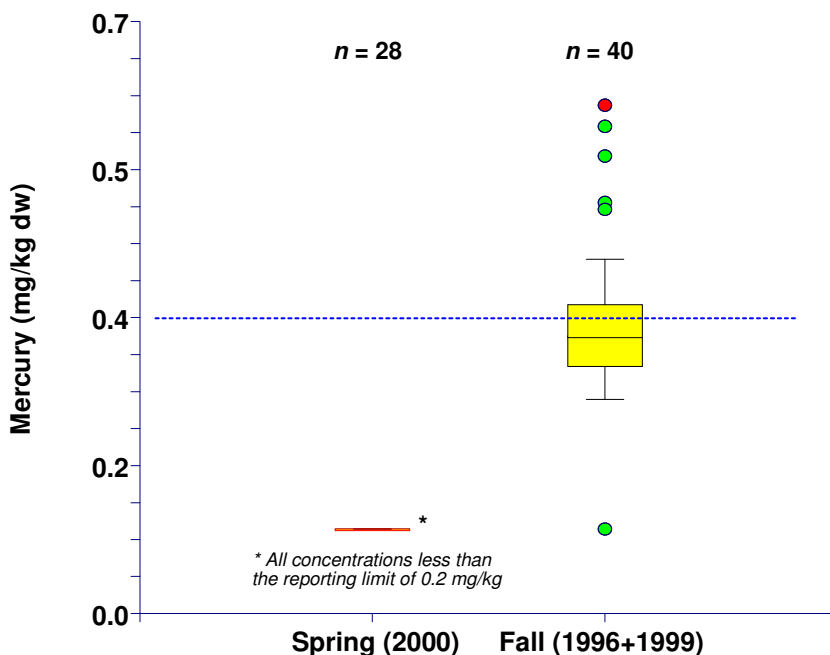


Figure 5-4 Mercury in adult brine shrimp collected from the open waters of the Great Salt Lake in Spring (May 2000) compared to Fall (September and October of 1996 and 1999). Dashed line indicates avian dietary level of concern.

difference in Se concentrations ($P = 0.241$). Based on this limited spatial analysis concentration gradients of bioaccumulative metals in brine shrimp associated with contaminant inputs cannot be ruled out, but research that has been conducted on the lake subsequent to this survey has indicated that there are several unique transport mechanisms within the GSL that may play a stronger role in distributing contaminants within the lake. These include a hypersaline “dense brine layer” at the bottom of the lake which flows along density as well as topographic gradients on the lake’s bottom, and mixing events that occur across this “halocline”, both of which play a major role in the distribution and availability of contaminants (particularly Hg) to organisms in the upper water column (Naftz et al. 2008).

5.4 Trace Elements and Organochlorines in Livers of Eared Grebes

With the exception of arsenic and mercury, metal concentrations in the grebe livers collected between 1997 and 2000 were less than the levels of concern identified in the literature (**Table 5-6**). Elevated arsenic concentrations were observed in one of the three composited liver samples analyzed in 1997 (6.83 mg/kg). This indicates that at least one, or some of the birds comprising the composite sample had much higher concentrations, and was one of the factors that led to the decision to submit samples collected after 1997 individually (as well as the need to characterize variability in metals concentrations). However, the maximum concentration of As observed in subsequent sampling events was much less (3.30 mg/kg, in December 1998). Mercury in grebe livers exceeded the level of concern (16.7 mg/kg) in two of four birds collected in December 1998 (19.1 and 19.3 mg/kg), and in one bird collected in May 2000 (20.5 mg/kg).

While the highest concentration of mercury was observed in a bird collected in the spring, the geometric mean concentration of all grebes ($n=21$) collected in May 2000 was 1.96 mg/kg, which was the lowest mean concentration for all collection periods (Figure 5-5). Concentrations of Se, the other metal of concern with regard to bioaccumulation, did not exceed the LOC of 30 mg/kg in any of the birds collected. Boron, which was present in concentrations exceeding the avian dietary LOC in brine shrimp (Section 5.2) was only detected in four samples (the three composite samples from 1997 and in one sample from December 1998), just above the detection limit of 0.2 mg/kg.

While the lowest mean concentration of Hg was observed in the spring (May 2000), the highest mean Hg concentration was observed in December 1998. These data, combined with evidence of accumulation of Hg and Se in brine shrimp (above) indicated the possibility of seasonal bioaccumulation of Hg, and to a less clearly defined extent, eared grebes foraging on the GSL. This possibility is consistent with the foraging ecology of eared grebes, which arrive on the GSL in the early fall (birds begin arriving about late September). Individual birds spend approximately 6-12 weeks on the GSL, during which time they undergo a complete feather molt, along with a complicated physiological process involving loss of flight muscle, building up of fat reserves (at about the same time new feathers are being grown) and then redevelopment of flight muscles. The birds stay on the open waters of the lake during this entire process, foraging exclusively on brine shrimp, whose annual population numbers are peaking at the same time. Peak numbers of grebes occur on the GSL from late November to mid-December, with the large majority leaving in late December to early January.

To evaluate seasonal accumulation of Hg and Se, data were grouped by seasons where possible for statistical analysis. Data from April and May 2000 were similar for both Hg and Se (Students’ T-test, $P < 0.05$), and so were pooled for analysis (“Spring”, $n=24$). Both Se and Hg data for livers collected in November (1997) and December (1998) were also similar, and so were also pooled (“Winter”, $n=7$). Data for both Hg and Se in livers collected in September (1998) were different from both Spring and Winter, and so were treated as “Fall” ($n=12$) for ANOVA. The maximum detected Hg concentration observed in one of the samples collected in May 2000 was $< (2 \times \text{standard deviation on the mean})$, and also outside the 95% upper confidence limit on all Hg data combined, and so was removed from the seasonal ANOVA. Mercury in grebe livers collected during the spring was significantly lower than either Fall or Winter ($P < 0.001$), and concentrations in Winter were significantly greater than those observed in

Table 5-6 Summary of trace elements (mg/kg, dry weight) in livers of eared grebes (*Podiceps nigricollis*) compared to levels of concern. Great Salt Lake Open Water (Gilbert Bay) Survey, 1997 – 2000.

| Metal | | November 1997 | September 1998 | December 1998 | April 2000^b | May 2000^b |
|-----------------|-------------------|--------------------------|---------------------------|--------------------------|-----------------------------------|---------------------------------|
| | <i>n</i> = | 3 ^a | 12 | 4 | 3 | 21 |
| Arsenic | <i>GMean</i> | 5.91 | 1.31 | 2.24 | 1.18 | 1.62 |
| | <i>std. error</i> | (0.51) | (0.12) | (0.52) | (0.52) | (0.14) |
| | <i>Max</i> | 6.83 | 2.20 | 3.30 | 2.79 | 2.9 |
| Ref= 6.6 | [#>Ref] | [1] | [0] | [0] | [0] | [0] |
| Cadmium | <i>GMean</i> | 1.82 | 1.43 | 1.1 | 3.59 | 4.07 |
| | <i>std. error</i> | (0.14) | (0.48) | (0.58) | (3.57) | (0.90) |
| | <i>Max</i> | 2.09 | 6.54 | 3.06 | 12.7 | 17.9 |
| Ref- 33.3 | [#>Ref] | [0] | [0] | [0] | [0] | [0] |
| Copper | <i>GMean</i> | 15.1 | 10.5 | 10.3 | 13.0 | 12.8 |
| | <i>std. error</i> | (0.67) | (0.34) | (0.70) | (2.83) | (1.16) |
| | <i>Max</i> | 16.3 | 12.2 | 11.7 | 19.2 | 30.2 |
| Ref= NA | [#>Ref] | [--] | [--] | [--] | [--] | [--] |
| Mercury | <i>GMean</i> | 11.6 | 6.69 | 13.5 | 4.39 | 1.96 |
| | <i>std. error</i> | (0.61) | (0.48) | (3.16) | (1.90) | (1.00) |
| | <i>Max</i> | 12.6 | 9.51 | 19.3 | 8.72 | 20.5 |
| Ref= 16.7 | [#>Ref] | [0] | [0] | [2] | [0] | [1] |
| Selenium | <i>GMean</i> | 10.1 | 6.23 | 10.5 | 10.5 | 7.05 |
| | <i>std. error</i> | (0.60) | (0.39) | (2.62) | (3.76) | (0.69) |
| | <i>Max</i> | 11.3 | 8.16 | 15.5 | 18.9 | 17.0 |
| Ref= 30 | [#>Ref] | [0] | [0] | [0] | [0] | [0] |
| Zinc | <i>GMean</i> | 117 | 75.1 | 81.9 | 128 | 110 |
| | <i>std. error</i> | (3.28) | (4.08) | (6.77) | (19.5) | (8.56) |
| | <i>Max</i> | 122 | 116 | 99.1 | 169 | 190 |
| Ref= 2,100 | [#>Ref] | [0] | [0] | [0] | [0] | [0] |

Key and Abbreviations

- Gmean geometric mean concentration for sample year
- Gmean** Gmean>referenced avian threshold
- NC Geometric mean not calculated (i.e., more than 50% of values <detection limit)
- ND All samples < detection limit
- no toxicity reference value available for comparison
- #>Ref The number of samples that exceed the referenced avian dietary threshold:
As: Reduced weight gain in adult birds; delayed egg laying; (Stanley et al. 1994);
Cd: Probable Cd contamination; Eisler (1993);
Hg: Threshold for adult waterbirds (5 ppm, ww; assume 70% moisture for dw); (Zillioux et al. 1993);
Se: Sublethal; (National Irrigation Water Quality Program 1998);
Zn: Toxicity threshold (National Irrigation Water Quality Program 1998).

(a) composites of 22 individuals

the Fall ($P < 0.001$) (Figure 5-5). The highest concentration of Se also occurred in a bird collected in the spring, although not in the same bird with the maximum Hg concentration. The highest geometric mean occurred in the Winter (December 1998). Concentrations of Se did not differ between years, and there was no difference between Spring and Fall concentrations, but concentrations in Winter were significantly higher than those in Fall ($P = 0.017$) (Figure 5-6).

Mercury and selenium can be bound to one another in the liver, with various interpretations as to whether Hg is actively scavenged from the liver by Se, whether Se concentrations can increase in the liver in response to mercury exposure, the capacity of this mechanism is to protect against mercury, and how much Se can be accumulated in the liver before it too reaches toxic levels (Eagles-Smith et al. 2009). While a number of metals have been observed to decrease in grebe livers during migration (Rattner & Jehl 1997), it appears that both of these metals may increase in the livers of birds that use the GSL for migratory stop-over habitat, at least in the fall. Based on this data, it is not possible to determine whether Se concentrations in eared grebe livers increase in response to Hg exposure, or if it increases due to exposure to Se in brine shrimp also.

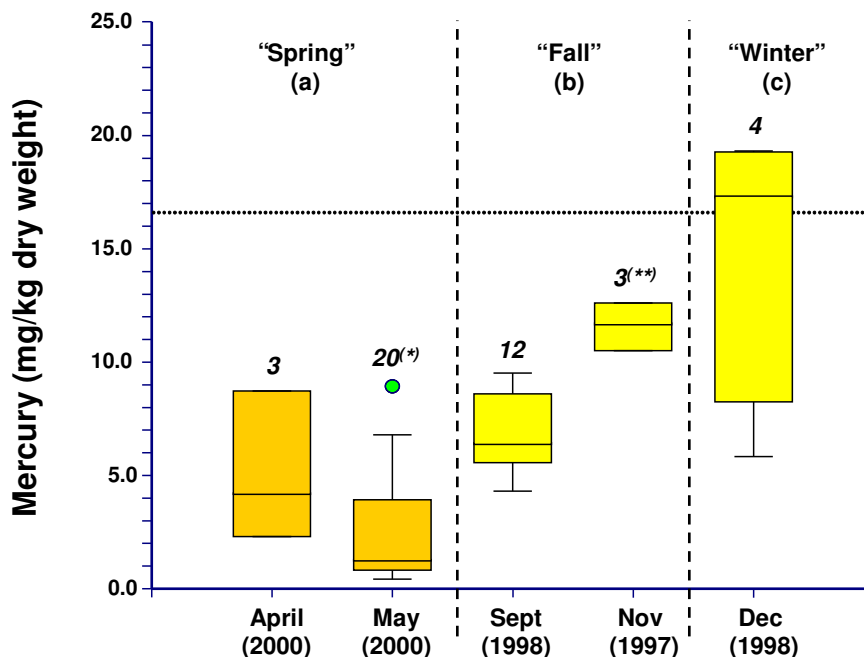


Figure 5-5 Seasonal trends in mercury in eared grebe (*Podiceps nigricollis*) livers, Great Salt Lake Open Water (Gilbert Bay) Survey, 1996-2000. Letters in parentheses indicate significantly different concentrations ($P < 0.05$). “*”: one sample removed because of outlying value (see text); “**”: composite samples.

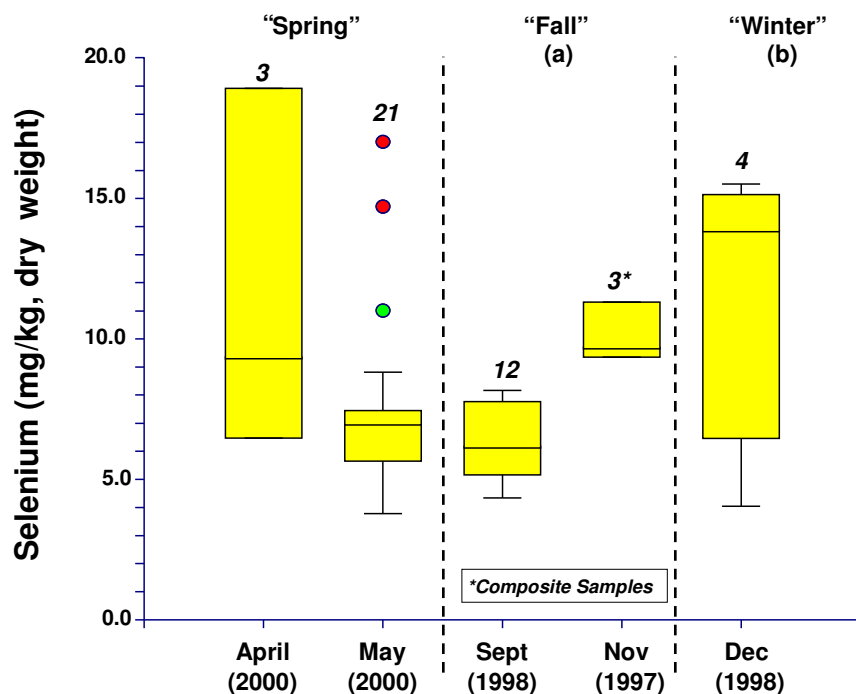


Figure 5-6 Selenium concentrations by month in eared grebe (*Podiceps nigricollis*) livers, Great Salt Lake Open Water (Gilbert Bay) Survey, 1996-2000. Letters in parentheses indicate significantly different concentrations ($P < 0.05$).

Organochlorine Compounds in Eared Grebe Livers

Organic constituents were not routinely analyzed in the sediment samples collected in the open water (Gilbert Bay) portions of the GSL. However, due to concerns that arose surrounding the U.S. Magnesium Facility located on the west shore of the GSL, whose air emissions were reported to potentially contain elevated levels of dioxins and other chlorinated hydrocarbons (See Section 4., three composite liver samples from eared grebes that were collected in Gilbert Bay in 1997 were analyzed for organochlorines and dioxins and furans. The complete analytical results for these samples are presented in **Appendix Table B-4**.

Only two compounds, total PCBs and *p,p'*-DDE, were detected, in two of the three samples. The maximum detected concentration of t-PCB was 0.116 mg/kg (wet weight), well below a literature-based threshold effect level for PCBs in avian tissue of 4.58 mg/kg (Tillitt et al. 1992). By comparison, green-backed herons in northeastern Louisiana had 0.2 ppm total PCBs in liver tissue, along with 0.1 ppm in breast muscle (Niethammer et al. 1984), and mallards collected from a PCB-contaminated site in New York had 1.0 ppm total PCBs in liver tissue (Eisler 1986). Only one of the two isomers of DDE was detected, ranging from 0.0095 to 0.0387 mg/kg wet weight. This was well below a published threshold effect concentration of 100 mg/kg in avian liver identified as a minimum critical level at which productivity is affected (Noble and Elliot, 1990).