APPENDIX A-1

DRAFT GREAT SALT LAKE ASSESSMENT FOR MERCURY

PART 1 - 2010 STATUS OF SCOPING-LEVEL ASSESSMENT

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1. INTRODUCTION

In Utah's 2006 Integrated Report, Great Salt Lake (GSL) was not included in any assessment category. Because of the unique characteristics of GSL and the lack of assigned numeric criteria, the State's Assessment Methodology did not provide for a process to use in determining if GSL supports its assigned beneficial uses under the Clean Water Act. Public comment on the 2006 Integrated Report (IR) raised concerns about the condition of the GSL and cited evidence of potential nutrient enrichment in Farmington Bay, elevated water-column mercury concentrations, and findings of mercury accumulation in the avian species frequenting GSL. In addition, studies conducted by DWQ and our collaborators further highlighted potential problems with mercury and potential degradation of some of GSL's wetlands.

In response to these increasing concerns over water quality in the GSL, the Utah Division of Water Quality (UDWQ) and the Environmental Protection Agency (EPA) formed a collaborative workgroup to develop a framework that will ultimately allow DWQ to assess the ability of GSL to support its beneficial uses as designated under the Clean Water Act and associated Utah Administrative Rules.

The result of this collaborative effort was a draft assessment framework that identifies potential indicators of water quality for both eutrophication and mercury, and then ranks the relative strength of each indicator. This approach for assessing the GSL and its surrounding wetlands is described in Appendix A of the 2008 IR. Over the past two years the framework described in this appendix has served as a guide in the development and implementation of scientific investigations to fill key data gaps identified through the assessment methodology for the GSL. The status of these monitoring and research efforts is described in this document. The reader is directed to Utah's 2008 IR Appendix A that discusses general project planning and the initiation of these efforts.

While efforts have been made to fill data gaps for both eutrophication and mercury, DWQ has primarily focused our efforts on establishing an assessment framework for the open water of GSL for mercury, because mercury is a toxic pollutant with potentially deleterious effects to both human health and GSL biota. This document describes the preliminary findings of a scoping-level assessment of mercury in GSL in Part 1 and the approach to an ecological risk assessment in Part 2. This work is designed to determine whether mercury conditions in the GSL have impaired aquatic life uses and to identify potential remediation efforts to ensure protection of this important waterbody.

The assessment methodology outlined in this document represents the scoping level portion of the assessment process developed in 2008 (step 4 as identified in figure SS-1 – see the 2008IR). The purpose of Part 1 of this scoping level effort is to gather preliminary data and develop thresholds with which to interpret these data. This process is expected to be iterative and conclusions may change as additional data become available. The purpose of Part 2 is to develop a process to make environmental decisions using an Ecological Risk Assessment for Mercury in GSL.

Based on the available data for GSL, enough questions remain regarding the most appropriate benchmarks to use for data evaluation and the linkage between avian tissue concentrations and exposure to GSL warranting further targeted study and an ecological risk assessment prior to determining if GSL is meeting its beneficial uses. Peer review of the assessment presented in this document is required as well as expert review of the proposed benchmarks. It is expected that a final listing decision will be made by the 2012 Integrated Reporting cycle.

2. APPLICABLE BENEFICIAL USES AND NARRATIVE WATER QUALITY CRITERIA FOR GSL

The State of Utah's Rule R317-2 for Standards of Quality for Waters of the State lists GSL as a category 5 waterbody. The State of Utah reclassified the designated uses of Great Salt Lake (Class 5) in 2008 into five subclasses (5A-5E) that more accurately reflect different salinity and hydrologic regimes and the unique ecosystems associated with each of the four major bays (Gilbert, Gunnison, Bear River, and Farmington) and transitional wetlands (UAC R317-2-6). All five of these Great Salt Lake subclasses are protected for infrequent primary and secondary contact recreation, waterfowl, shore birds, and other water-oriented wildlife, including their necessary food chain. These are the GSL's beneficial uses that must be protected under the Clean Water Act.

Because of the unique and variable limnological conditions of GSL and lack of reference sites with which to compare this waterbody, expected conditions for this waterbody are difficult to define. This has slowed the establishment of numeric criteria. At present, numeric water quality criteria have not been established for the GSL for mercury, rather the State's narrative criterion applies and states:

> *"it shall be unlawful, and a violation of these regulations, for any person to discharge or place any waste or other substance in such a way as will be or may become offensive such as unnatural deposits, floating debris, oil, scum or other nuisances such as color, odor or taste; or cause conditions which produce undesirable aquatic life or which produce objectionable tastes in edible aquatic organisms; or result in concentrations or combinations of substances which produce undesirable physiological responses in desirable resident fish, or other desirable aquatic life, or undesirable human health effects, as determined by bioassay or other tests performed in accordance with standard procedures."*

3. BACKGROUND ON BENEFICIAL USE SUPPORT IMPAIRMENT DETERMINATIONS USING INDICATORS

Since GSL does not have a numeric criterion for water column mercury concentrations, assessing whether GSL supports its beneficial uses requires a methodology for interpreting Utah's narrative water quality standards. The mercury assessment framework that was developed uses multiple lines of evidence to evaluate the effects of mercury on GSL biota. The advantage of this approach is that definitive proof of mercury impairment is not needed for each indicator. Instead, the approach allows all indicators to be weighted and subsequently interpreted through a risk analysis process to evaluate whether aquatic life uses of the GSL are at risk.

3.1 INDICATORS OF BENEFICIAL USE SUPPORT

The assessment framework proposes both *direct* and *indirect* indicators of GSL ecosystem health. Thereby, multiple lines of evidence and measures were to be used to determine whether the beneficial uses are at risk.

Direct Indicators of Beneficial Use Support

The most direct evidence for determining whether a waterbody is supporting its beneficial uses associated with shorebirds and waterfowl is to measure the success of these populations directly. Examples of direct indicators include:

- *Waterfowl/ Shorebird Use Support*: Quantifiable measures of the shorebird or waterfowl population counts and documented deaths or reproductive impairment occurring in the waterbody and attributable to the GSL.

Direct indicators are often difficult to develop due to the amount of data required, the influence of multiple stressors, and the need for "reference" sites for the development of thresholds or benchmarks. Because GSL is such a unique ecosystem, biological indices for macroinvertebrates, zooplankton, and algal species are not readily available in the literature or are not applicable to GSL. Hence, it is difficult to directly assess changes in the avian food-chain productivity. Additionally, direct indicators for waterfowl and shorebird use support would involve long-term population and reproduction studies. Though some of this work is underway, results and interpretation of population studies are not available to assess GSL in the short-term.

Indirect Indicators of Beneficial Use Support

When it is difficult to gather or interpret data for direct indicators, *indirect indicators* can serve as surrogates to evaluate whether environmental conditions support an associated beneficial use. Examples of indirect indicators include the following types of measurements:

- *Waterfowl/ Shorebird Use Support*: Mercury concentrations in avian dietary items and in the livers, eggs and other tissues of birds have shown a link between mercury exposure and affects on avian reproduction and health. Hence, concentrations of mercury in the food-chain or avian species that are above thresholds or benchmarks for protection of health and reproduction of birds may be used to indicate nonsupport of this beneficial use.

For the beneficial use assessment of mercury in GSL, use of indirect indicators including the concentration of mercury in the food chain and avian tissues were used to estimate risk to the avian species frequenting GSL. The indirect indicators used in this assessment are identified in Table 1. Direct population counts and measures of avian reproductive health are not currently available.

Table 1 Draft Mercury Assessment Indicators and Availability of Benchmarks and Data for GSL

GSL All areas with waterfowl/ shorebird use							
Beneficial Use	Direct Indicators of Beneficial Use Support	Indirect Indicators applicable to the direct indicator	Utility of the Indicator (1-3 with 3 being highest)	Confidence in the Indicator (1-3 with 3 being highest)	Exposure Location/Timeframe Represented by Indicator	Benchmarks Identified for Indirect Indicator	Data Available from GSL
Support for Waterfowl and Shorebirds including their food-chain	Waterfowl and/or shorebird health	Hg in diet	3	3	GSL linked exposure	Yes	Yes
		Hg in adult kidney	1*	3	Not determined	Limited	No
		Hg in adult liver	3	3	Fairly recent exposure	Yes	Yes
		Hg in adult blood	3	3	Recent exposure – reflects dietary exposure	Yes	No
		Hg in adult feathers	2	3	Historic exposure record	Yes	Limited
		Hg in adult brain	1*	3	Not determined	Limited	No
		Hg in adult muscle	1*	3	Not determined	Not for Avian Health	Yes
	Waterfowl and/or shorebird reproductive success (hatching, fledgling)	Hg in Egg	3	3	Walsh 1990 suggested that eggs provide good indicator of mercury exposure in vicinity of nesting site in for immediate pre-laying season. (AEHHIM)	Yes	Yes
		Hg in adult diet	3	3	GSL linked exposure	Yes	Yes

		Hg in down feathers	3	3	GSL linked exposure	Yes	No
		Hg in adult liver	3	3	Fairly recent exposure	Yes	Yes
		Hg in adult brain	1*	3	Not determined	No	No
		Hg in chick blood or whole body	3	3	GSL linked exposure	Yes	No

High priority indicators are highlighted in yellow.

* These may be reasonable indirect indicators; but, few literature benchmarks were identified for these tissues and/or limited data are available for GSL.

4. WEIGHT OF EVIDENCE DECISION MAKING APPROACH AND PROJECT PLAN

Using a weight of evidence approach, one would identify the important direct and indirect indicators needed to assess beneficial use attainment, identify thresholds for those indicators, and use the preponderance of evidence to make a conclusion regarding impairment. Using the weight of evidence approach, it is not necessary to prove beyond any doubt that a particular contaminant is impacting a beneficial use but rather to demonstrate, using multiple lines of evidence that the beneficial use is likely at risk.

In this case, direct evidence of impairment would include changes in avian populations or reproduction which is not available. Hence, the approach taken for this initial assessment of GSL was to determine if GSL is posing a risk to avian species as indicated by mercury concentrations in the GSL food chain and in multiple types of tissues in birds inhabiting the GSL. The assumption is that if high concentrations of mercury (above applicable pub lished threshold levels for mercury effects) are found in the food chain of GSL as well as in avian tissues of birds feeding at GSL, it is likely that GSL is posing a risk to those species. If GSL is posing a risk to bird species, it should be considered impaired under the Clean Water Act based on the State's narrative criteria described previously.

In order to implement the weight of evidence approach, this scoping level assessment focused on two activities: 1) identifying published mercury thresholds or benchmarks to be used in determining risk for both acute and chronic mercury impacts to avian species; and 2) gathering mercury data from the food chain and birds from GSL to be compared to these benchmarks. Data associated with high priority indicators shown in Table 1 were gathered or assembled from published information. Some data gaps exist and will be discussed in more detail.

5. IDENTIFICATION AND SELECTION OF MERCURY BENCHMARKS

The workgroup with support from the US Fish and Wildlife Service (FWS) undertook an extensive literature review to identify potential benchmarks for mercury impairment in avian species. Benchmark selection is ongoing as additional published information becomes available. Hence, this compendium of literature values will continue to be refined. In addition, expert opinion is being sought to assist in the final selection of benchmarks for this study. This document provides an opportunity for comment on the completeness of the benchmark identification and choice of benchmarks for this scoping level assessment of risk.

Evers et al. (2004) has undertaken extensive studies with Loons in the Northeast to determine mercury benchmarks and risk ranges for this species. Evers proposes risk ranges (hereafter ERRs) from low to extra high for dietary exposures, egg concentrations, blood concentrations, and feather concentrations. Of these indicators, diet, blood, and egg risk ranges are of interest for this assessment as there are data available for GSL that may be compared to these ranges.

Evers et al. (2004) was selected for this iteration because:

- The loon is an aquatic-dependent species.
- The ranges are the result of an extensive compilation of studies.
- The ranges provide convenient categories.

The applicability of these ranges to GSL is currently undetermined. Several uncertainties must be addressed prior to making any conclusions using Evers et al. (2004). For instance, how are freshwater exposures different than the high salinity waters of GSL?

Tables 2, 3, and 4 provide a summary of the identified benchmarks for the avian receptors for this assessment (including nonpiscivorus birds) as compared to the risk ranges proposed by Evers for Loons (piscivorous birds). The table header provides the ranges proposed by Evers and the body of the table provides other benchmarks identified in the literature. Currently, these risk ranges and benchmarks are undergoing peer review to refine the selection process. It should be noted that the benchmarks that are listed against the risk ranges were not necessarily used by Evers in establishing his ranges. These tables are provided to illustrate the other benchmarks that are available and how they compare to ERRs.

Evers provides risk ranges for mercury concentrations found in the diet, blood, and eggs for loons. Besides these types of data, liver concentrations of mercury were also measured for GSL species; but, risk ranges for liver concentrations were not identified by Evers for this indicator. Hence, the workgroup applied the concept of risk ranges to the available literature benchmarks to establish low, moderate, high, and extra high concentrations for mercury in avian livers. The benchmarks plotted in Table 5 were used to establish the risk ranges shown in the table header. Again, these are draft risk ranges that are being peer reviewed and should not be used to draw conclusions regarding an impairment of GSL.

6. COMPARISON OF GSL DATA AGAINST PROPOSED RISK RANGES AND BENCHMARKS

Assuming that the risk ranges proposed by Evers et al. (2004) and the workgroup are reasonable for a first-cut assessment, we have compared the available data for GSL against these ranges to illustrate the estimated risk posed by mercury concentrations for the indicators of choice. Evers risk ranges are based on data reported on a wet weight basis yet all data used in this report were reported as dry weight. To convert from dry weight to wet weight, multiply the dry weight measurement by (1- percent moisture/100). Percent moisture values for each data set are provided in the sections below.

All data in this report are illustrated with Box and Whisker plots to show the distribution of mercury data. The median is the line between the blue and gray portions. The blue portion is the upper quartile and the gray portion is the lower quartile. The upper line extends to the highest data point and the lower line to the sample minimum. The diamonds represent the average of the data set. The number of samples (n) and the geometric mean (geomean) are also provided. The geometric mean is a measure of central tendency and dampens the effects of outliers. Often aquatic life data are summarized by using the geometric mean as noted in the benchmarks tables. Note that the mercury concentrations sometime vary extensively depending upon the source of the data. Further investgations are needed to evaluate whether these differences are real or an artifact of differing field or laboratory methods; nevertheless, the published values from all sources are reported here.

6.1 COMPARISON OF GSL AVIAN LIVER DATA AGAINST PROPOSED RISK RANGES AND BENCHMARKS

Table 6 provides a summary of the available avian liver data associated with the GSL and compared to the very preliminary ERRs.

6.1.1 Common Goldeneye Liver Data

From the data reported by Vest et al. 2009, the Common Goldeneye liver results have geometric mean values that fall within the high to extra high risk categories (See Table 6). The values noted for some individuals are above benchmark levels (based on published values by Heinz 1974, Barr 1986, and Scheuhammer 1997) for frank health effects in birds. Common Goldeneye are migratory waterfowl that spend the winter at GSL and feed primarily on brine fly larvae (Vest, 2008). Further analyses are needed to evaluate the linkage of the Common Goldeneye body burdens reflected in the liver concentrations to time spent at GSL, the possible protective effects of selenium interactions with mercury in these birds, and the GSL dietary exposure route and nesting areas for this species. However, one can conclude from these results that further investigation is warranted for this species whether or not their mercury exposure is from GSL or other sites encountered during migration.

6.1.2 Northern Shoveler Liver Data

Figure 1 and Table 6 provide the RGI grant data gathered for Northern Shovelers from Farmington Bay, Ogden Bay and Bear River Bay collected from October to December, 2008. This data was collected by the USFWS and the Utah Division of Wildlife Resources per the RGI grant. An average percent liver moisture content of 71% was calculated from the percent moisture results from the USGS Wisconsin laboratory. The geometric mean body burdens of methyl mercury in the liver for Northern Shovelers fall within the low risk range (values less then 0.89 parts per million (ppm) wet weight (ww)). These results are significantly lower than the methyl mercury concentrations reported by Vest et al. 2009 (see Table 6). Those data report geometric mean methyl mercury liver concentrations within the moderate to high risk range. It will be important in future analyses to determine whether the apparent differences in mercury concentrations between Northern Shovelers collected by Vest from 2004 to 2006 as opposed to RGI data collected in 2008 are due to analytical procedures, exposure differences, time of collection, or location.

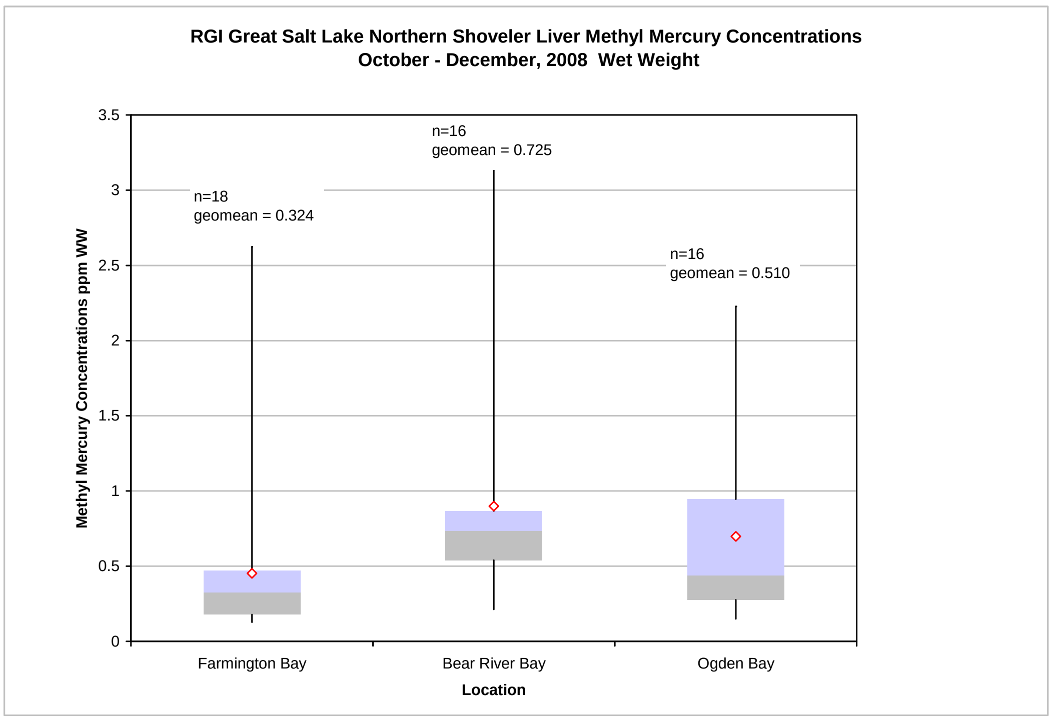

Figure 1 **Northern Shoveler Liver Methyl Mercury Concentrations (ppm ww) from Farmington Bay, Bear River Bay and Ogden Bay in October-December, 2008 collected per the RGI Grant**

6.1.3 Cinnamon Teal Liver Data

Figure 2 and Table 6 provide the data gathered for Cinnamon teal from Farmington Bay, Ogden Bay and Bear River Bay wetlands around GSL by the month they were collected. These data were collected by the USFWS and Utah Division of Wildlife Resources per the RGI Grant. An assumed percent liver moisture content of 68% was used as reported by USFWS, 2009 for Cinnamon Teal. At all sites, the average and the geometric mean body burdens of methyl mercury in the liver for Cinnamon teal fall within the low risk range (values less then 0.89 ppm wet weight). It will be important in future analyses to determine whether or not the apparent differences in mercury concentrations between Common Goldeneye and Cinnamon Teal are related to feeding regimes, time spent at GSL as opposed to elsewhere in their migration, or species differences.

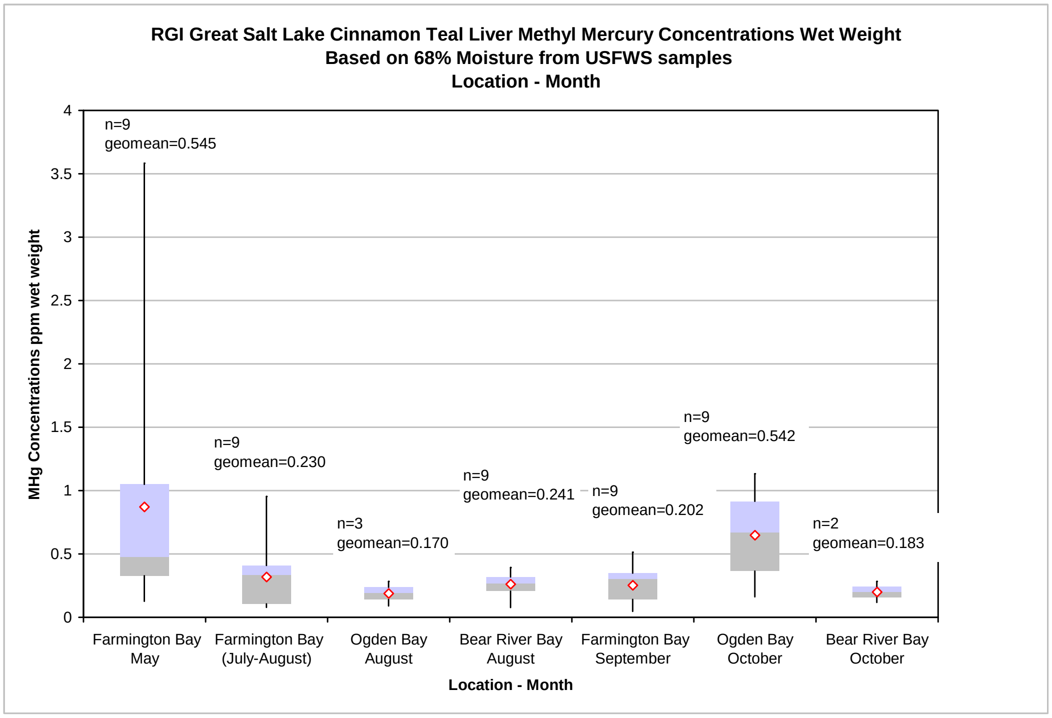

Figure 2 Cinnamon Teal Liver Methyl Mercury Concentrations (ppm ww) from Farmington Bay, Bear River Bay and Ogden Bay in May-October, 2008 collected per the RGI Grant

Some individuals sampled from Ogden Bay (Howard Slough) and Farmington Bay wetlands had liver mercury concentrations in the medium to high risk ranges. At Ogden Bay there were 2 samples out of a total 12 samples that fell within the medium risk range. At Farmington Bay three samples out of 27 fell within the medium risk range and one was in the high risk range. Again the relationship between these findings and mercury availability in the sampling locations need to be evaluated in detail.

6.1.4 Eared Grebe Liver Data

Figure 3 and Table 6 provides Eared Grebe liver data collected by USFWS in 1997, 1998, 2000 and 2006 from Gilbert Bay. Eared Grebes are an important species for this assessment as they arrive at GSL in the early fall and spend 3 to 4 months on the lake feeding almost exclusively on brine shrimp. It could be possible that increases in Eared Grebe liver concentrations of mercury over these 3 to 4 months reflect dietary exposure from GSL.

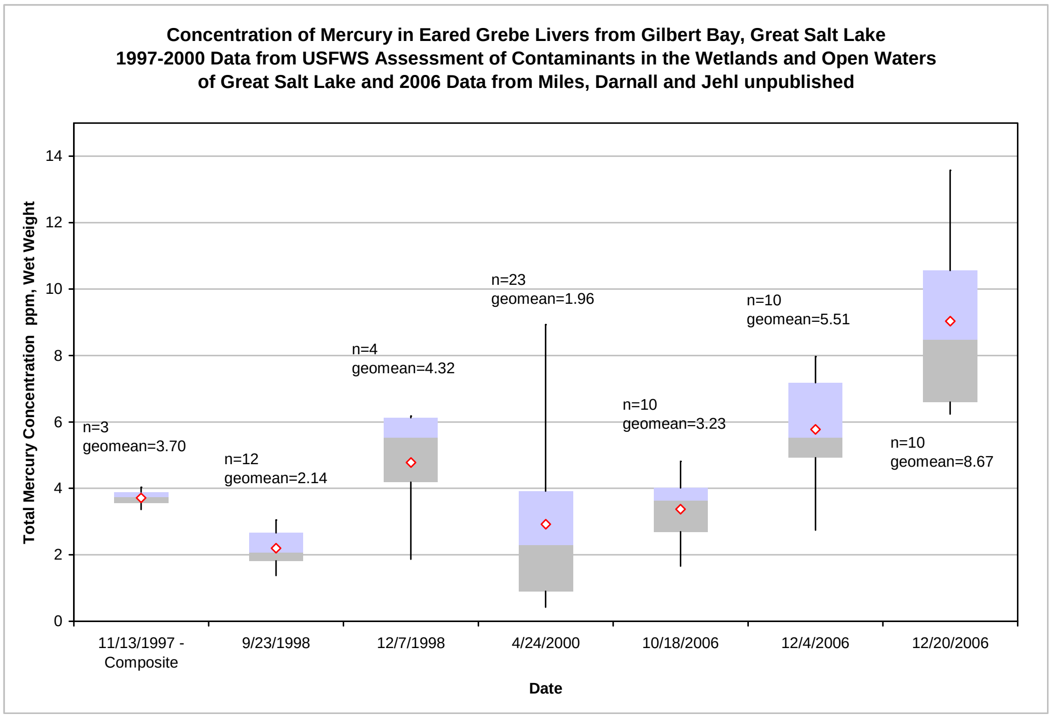

Figure 3 **Eared Grebe Total Mercury Concentration (ppm ww) collected by USFWS from Gilbert Bay in 1996-2000 and 2006**

For the Eared Grebe data, geometric mean liver concentrations were within the moderate risk range in May, 2000 and September 1998. In November 1997, October 2006 and early December 2006, the geometric mean liver concentrations were within the high risk range and in December 2006 they were in the extra high risk range. It appears in 2006 that there is a trend for increasing liver concentrations in Eared Grebes throughout the fall as the length of time they have spent feeding on the lake increases. This suggests that time spent at GSL may result in an increased body burden of mercury for Eared Grebes. In addition these data indicate that the median liver concentration for Eared Grebes populations may be increasing over the years. Additional data are needed to confirm these trends and the link between adult brine shrimp mercury concentrations.

6.2 COMPARISON OF GSL AVIAN EGG DATA AGAINST PROPOSED RISK RANGES AND BENCHMARKS

6.2.1 Cinnamon Teal Egg Data

Figure 4 shows Cinnamon Teal egg data collected from May 2 to July 1, 2008 from Bear River Bay (Unit 5C), Ogden Bay (Howard Slough) and Farmington Bay (Turpin Unit) around GSL. These data were collected by the USFWS and Utah Division of Wildlife Resources per the RGI Grant. Table 8 provides a summary of this egg data. For Cinnamon teal eggs, all geometric mean values for mercury concentrations were in the low risk range (values less then 0.5 ppm ww).

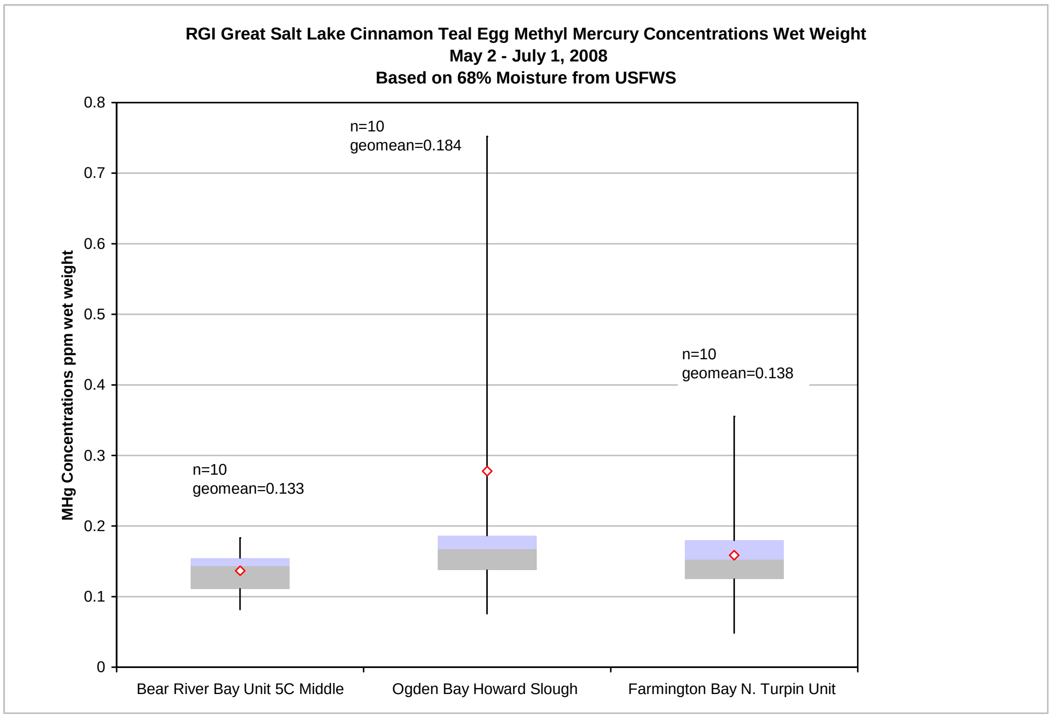

Figure 4 **Cinnamon Teal Methyl Mercury Egg Concentrations (ppm ww) from Farmington Bay, Bear River Bay and Ogden Bay in May-July, 2008 collected per the RGI Grant**

From these data, one would not expect reproductive effects for these species if these data are representative. Additional egg samples should be collected for species such as the Eared Grebe and the Common Goldeneye which have shown liver concentrations in the higher risk ranges. In addition, the relationship between feeding regimes, nesting areas and mercury concentrations in eggs should be evaluated.

6.3 COMPARISON OF GSL AVIAN BLOOD DATA AGAINST PROPOSED RISK RANGES AND BENCHMARKS

6.3.1 Blood Data for Eared Grebe

Table 8 provides a summary of the available avian blood data for the GSL.

Conover and Vest (2000) report blood concentrations for Eared Grebes sampled during the fall of 2006. In general, geometric mean values for both adults and juveniles fall in the moderate risk range.

6.4 COMPARISON OF GSL BRINE SHRIMP DATA AGAINST PROPOSED DIETARY RISK RANGES AND BENCHMARKS

6.4.1 Brine Shrimp Data

Brine shrimp represent one of the major dietary routes of mercury that must be evaluated for birds frequenting GSL. Other food-chain components including wetland macroinvertebrates, brine flies, brine fly larvae, and other items need to be sampled to provide a more complete picture of the avian dietary exposure path. Data from these other food sources were not available at the time of this report's preparation. Figures 5 and 6 illustrate the total mercury concentrations by month over all locations for cysts/napulii and adults respectively. Figures 7 and 8 illustrate the total mercury concentrations by location over all months for cysts/napulii and adults respectively. These data were collected by the Utah Division of Wildlife Resources/Great Salt Lake Ecosystem Program per the RGI Grant. Brine Table 9 provides a summary of these brine shrimp data. A 90% moisture content was used to convert from dry weight to wet weight based on the average percent moisture of 68 Brine shrimp samples reported in the USFWS in the Assessment of Contaminants in the Wetlands and Open Water of the Great salt Lake, Utah 1996-2000.

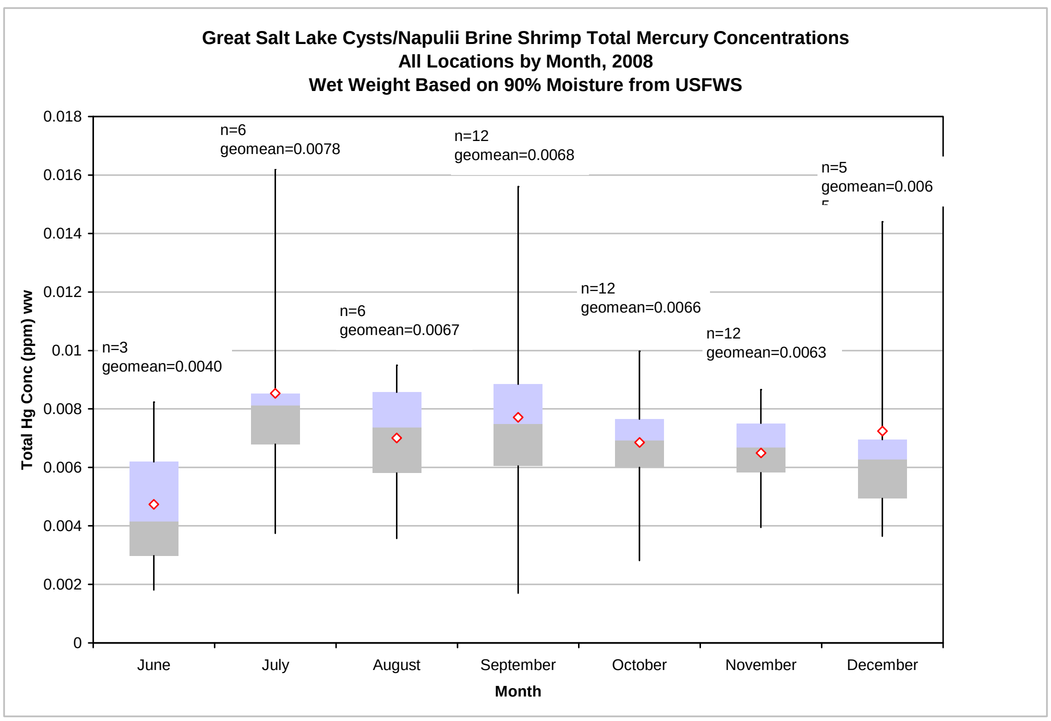

Figure 5 **Brine Shrimp Cysts/Napulii Total Mercury Concentrations (ppm ww) from Gilbert Bay in July-December, 2008 collected per the RGI Grant**

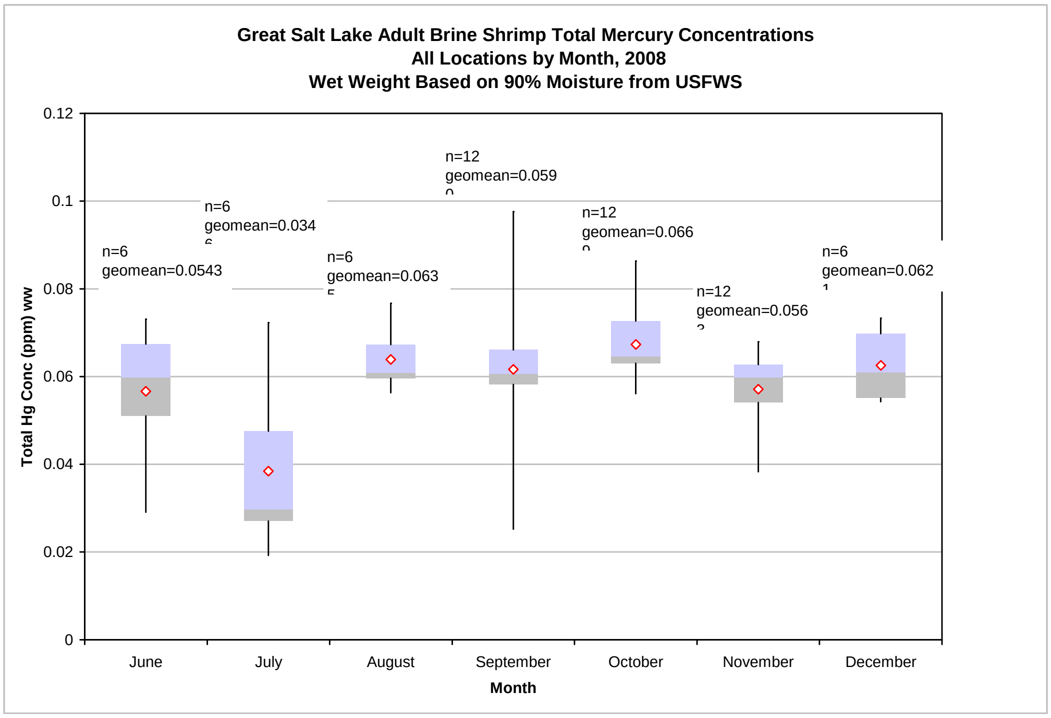

Figure 6 **Brine Shrimp Adults Total Mercury Concentrations (ppm ww) from Gilbert Bay in July-December, 2008 collected per the RGI Grant**

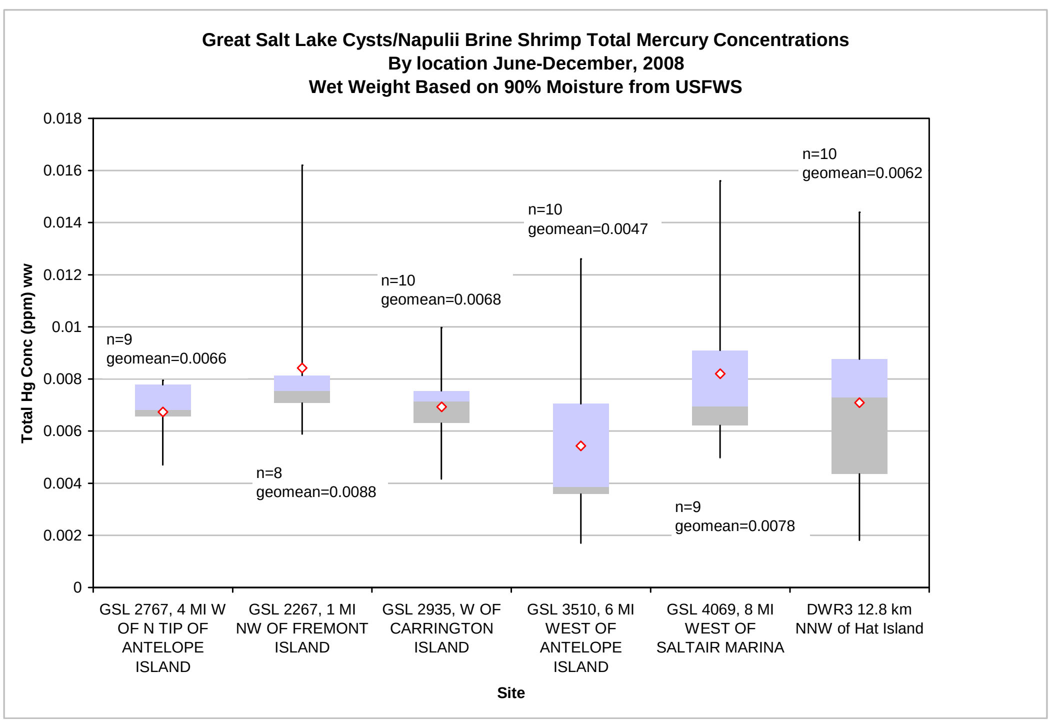

Figure 7 **Brine Shrimp Cysts/Napulii Total Mercury Concentrations (ppm ww) from Gilbert Bay in July-December, 2008 by location collected per the RGI Grant**

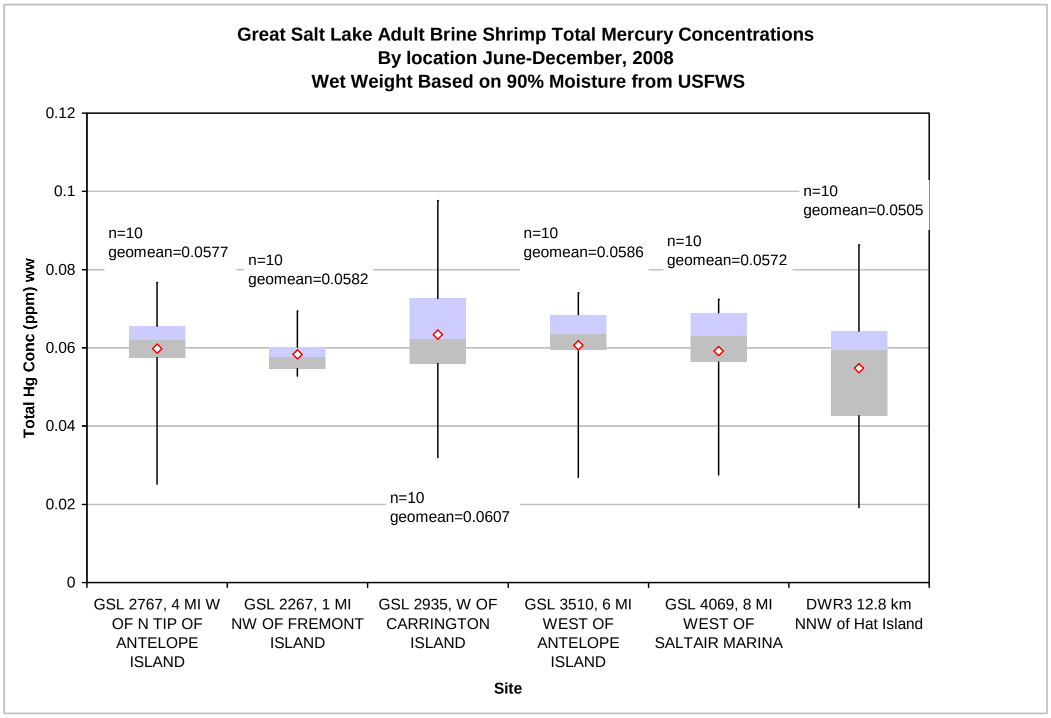

Figure 8 **Brine Shrimp Cysts/Adults Total Mercury Concentrations (ppm ww) from Gilbert Bay in July-December, 2008 by location collected per the RGI Grant**

Adult Brine Shrimp geometric mean values measured from June though December, 2008 fall within the low end of the moderate risk range. Cyst geometric mean concentrations are well within the low risk range. The geometric mean brine shrimp mercury concentrations did not vary between locations. Future analyses would determine if brine shrimp accumulate more mercury in the early season.

7. CONCLUSIONS

This section of the report provides available avian mercury data for GSL. It demonstrates the progress made to gather additional data for GSL and move forward in assessing this waterbody.

There are mixed findings associated with the potential for mercury risk to avian receptors at GSL. Based on the available data, Cinnamon teal body burdens and egg concentrations suggest that they are not at risk from mercury exposure. The link between the low risk tissue values and time spent at GSL has not been established. Hence it is not clear how long the sampled birds had been at the lake, what they were consuming, and the concentration of mercury in their food-chain.

Several species tested including the Common Goldeneye and Eared Grebe present body burdens that suggest the potential for moderate to high risk for health or reproductive effects. For the Common Goldeneye, the link between body burdens and time spent at GSL has not been established. However, the liver concentrations found in the Common Goldeneye are concerning. Northern Shoveler data collected from 2004 to 2006 as reported by

Vest 2008 show body burdens that indicate a moderate to high risk while the samples collected in 2008 per the RGI indicates there is low risk from Mercury exposure. It is not clear whether the differences are due to analytical procedures, exposure differences, time of collection, and location

For Eared Grebes, it appears that time spent at GSL consuming brine shrimp poses a risk for this species. The presence of selenium in the environment at GSL may help mitigate the toxic effects of mercury in adult birds (selenium and mercury tend to have antagonistic effects in adult birds). This possibility has not been evaluated in detail. Some literature suggests that the protection offered by selenium in the adult birds does not extend to the egg or hatchlings. Hence, egg samples for Eared Grebe and Common Goldeneye would be very useful.

Enough questions remain regarding the most appropriate benchmarks to use for data evaluation and the linkage between avian tissue concentrations and exposure to GSL to warrant further targeted study prior to listing of the waterbody on the 303(d) list. Peer review of the assessment presented in this document is required as well as expert review of the proposed benchmarks. It is expected that a listing decision can be made by the 2012 Integrated Reporting cycle.

8. NEXT STEPS

Expert support will be sought to develop a focused project plan to answer the questions that remain for this assessment. Based on the results of this initial effort, a detailed ecological risk assessment for mercury in the GSL is merited and an approach is presented in Part 2 of this document. The risk assessment will include milestones at which time stakeholders and experts will be given the opportunity to review and provide input.

Through this scoping level assessment, the workgroup has identified several important information/data gaps that must be addressed to move forward with the GSL assessment. Additional data to establish the food-chain mercury concentrations for Cinnamon teal, Common Goldeneye, Northern Shoveler, and other representative species, are required. Species sensitivity to mercury must be considered for additional data collection to ensure that the range of sensitive species is reflected in the assessment.

The relationship between food-chain exposure and body burden as determined from liver samples may be required. Additional blood samples should be collected as they reflect mercury exposures from recent feeding and will help to link body-burden data with time spent at GSL. Additionally, targeted egg samples should be collected as they reflect mercury exposure at the time of production and best predict reproductive risk levels. This will be important for species in which adult body burdens are elevated.

Various laboratories were used to analyze Mercury concentrations in the biological tissues presented in this assessment. Studies performed by USFWS and Vest used different laboratories then the RGI data. A laboratory round robin should be conducted to compare analytical results from these laboratories so that the data presented here can be verified.

This list of data gaps is not all inclusive and will be refined as the project plan is developed for the next phase of this assessment.

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Table 2 DIET - Evers Risk Levels Compared to Other Literature Benchmarks

DIET - Evers Risk Levels Compared to Other Literature Benchmarks **(Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)**					
Reference	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	Organism
Barr 1986				0.3 to 0.4 ww – reduced productivity; >0.4 complete reproductive failure	Common loon
Heinz studies 1974, 1975, 1976a, b, 1979				0.5 ppm fresh weight in diet LOAEL[4] (Heinz reports this as equivalent to 0.1 ppm in actual diet based on ww calc.) for reproductive effects in 2nd and 3rd generation	Mallard
BHRN 1996[3]				3 ww Impact on reproduction 10 ww Lethal level	Threshold for birds in general
Borg et al 1970				10 and 13 Behavior impacts	Goshawks
Bouton et				0.5	Threshold for

DIET - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)					
Reference	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	Organism
al (1999)				LOAEL[4] Behavioral changes	birds in general
Burgess and Meyer 2008			0.21 EC50[5] Production	0.41 EC100[6] Estimate for reproductive failure for population	Common loon
Eisler 1987		0.1 ww LOAEL[4] for dietary impacts			Birds in General
Evers 2003, 2004		0.05 - 0.15 20% decrease in reproduction	>0.15 37% decrease in reproduction		Common loon
Fimreite 1971				2 to 3 Reproductive effects	Pheasants
Findley and Stendell 1978				3 Egg hatching and chick survival impacted	Black ducks

DIET - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)					
Reference	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	Organism
Finley et al 1979				40 Lethal level	Cowbirds, grackles, starlings, black birds
Gardiner 1972				32 LC90[7]	Pheasants
Gullvag et al 1978				8 Liver cell damage	Quail
Chan et al_2003		0.1 LOAEL[4] Reproduction			Birds in general
Heinz and Hoffman 1998				10 Embryo deformities	Mallard

DIET - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)					
Reference	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	Organism
Koeman et al, 1971)				13.3 LC90[7]	Kestrels
Meyer 2006		0.08 ww NOAEL[8] Behavioral/neurological effects		0.4 ww LOAEL[4] for neurological impacts in chicks	Common loon – controlled feeding study
Nicholson and Osborn 1984				1.1 Nephrotoxic lesions	Starlings
Scheuhammer (1988), Spalding et al (2000)				5 LOAEL[4] Neurological impacts	Birds in General
Schuhammer 1991				>1 dw (need to	Piscivorous

DIET - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)					
Reference	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	Organism
concluded this from Heinz and Barr studies				translate to ww) Sublethal effects	Birds in general
Spalding et al 2000a				0.5 LOAEL[4] Behavior, Growth, Immune function, Histological changes, Biochemical changes	Great Egrets
Spann et al 1972				4.2 Lethal level	Ring-necked pheasants
Burgess_2008			0.21 EC50[5] Productivity	0.41 EC100[6] Productivity	Common Loon
Eisler 1987, Fimreite1				2.2 to 28.3 (check ww or dw) LD50[9] or greater	Mallard, Norther

DIET - Evers Risk Levels Compared to Other Literature Benchmarks **(Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)**					
Reference	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	Organism
979, Scheuhammer 1987					n bobwhite, quail
Thompson 1996				0.6 Threshold for impaired reproduction	Birds in general

1 mHg = methyl mercury

2 ppm (ww) = parts per million wet weight

3 Beyer, Heinz, Redmon, Norwood 1996

4 LOAEL = lowest observed adverse effect level

5 EC50 = effective concentration 50% of test organisms

6 EC100 = effective concentration 100% of test organisms

7 LC90 = lethal concentration 90% of test organisms

8 NOAEL = no observed adverse effect level

9 LD50 = lethal dose 50% of test organisms

Table 3 EGG - Evers Risk Levels Compared to Other Literature Benchmarks

EGG - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)					
Reference	Low Risk in Eggs 0 – 0.5 mHg[1] ppm (ww)[2]	Moderate Risk in Eggs 0.5 – 1.3 mHg[1] ppm (ww)[2]	High Risk in Eggs 1.3 -2.0 mHg[1] ppm (ww)[2]	Extra High Risk in Eggs >2.0 mHg[1] ppm (ww)[2]	Organism/ Notes
Barr 1986	0.2 – 0.3 LOAEL[5] Reproduction				Loon
BHRN 1996[3]		0.5 LOAEL[5] Reproduction			General Bird
BHRN 1996[3]		0.5 to 2.0 Range where reproductive effects noted			General Bird
Borg 1969			1.3 – 2.0 Impacts on hatch rate		Ring-necked pheasants

EGG - Evers Risk Levels Compared to Other Literature Benchmarks **(Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)**					
Reference	Low Risk in Eggs 0 – 0.5 mHg[1] ppm (ww)[2]	Moderate Risk in Eggs 0.5 – 1.3 mHg[1] ppm (ww)[2]	High Risk in Eggs 1.3 -2.0 mHg[1] ppm (ww)[2]	Extra High Risk in Eggs >2.0 mHg[1] ppm (ww)[2]	Organism/ Notes
Eisler 1996			>0.9 to 2.0 Threshold of reproductive impacts		General Bird
Evers 2003			1.3 reproductive impacts		Common Loon
Fimreite 1971		0.5 LOAEL[5] Reproduction			Birds reproduction in general
Heinz 1974, 1976 a and b, 1979		0.5 LOAEL[5] Reproduction, behavior, growth			Mallard

EGG - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)					
Reference	Low Risk in Eggs 0 – 0.5 mHg[1] ppm (ww)[2]	Moderate Risk in Eggs 0.5 – 1.3 mHg[1] ppm (ww)[2]	High Risk in Eggs 1.3 -2.0 mHg[1] ppm (ww)[2]	Extra High Risk in Eggs >2.0 mHg[1] ppm (ww)[2]	Organism/ Notes
Heinz et al, 2008[4]	0.12 LC50[6] White Ibis, Falcon; 0.15 LC50[6] Snowy egret; 0.18 LC50[6] Osprey; 0.22 LC50[6] Tri-colored heron; 0.44 LC50[6] Ring-necked pheasant and Chicken	0.97 LC50[6] Canada Goose; 1.23 LC50[6] Hooded Merganser;	1.53 LC50[6] Lesser scaup 1.79 LC50[6] Mallard		LC50 for mHg to embryos of injected eggs
Heinz et al, 2008[4]	0.26 LC50[6] Common grackle; 0.28 LC50[6] Herring gull; 0.32 LC50[6] Tree swallow; 0.33 LC50[6]Clapper rail; 0.40 LC50[6] Royal Tern	0.56 LC50[6] Anhinga; 0.76 LC50[6] Sandhill crane; 0.87 LC50[6] Common Tern; 0.89 LC50[6] Brown Pelican; 1.25 LC50[6] Laughing gull		2.42 LC50[6] Double-crested cormorant; 4.33 LC50[6] American avocet	LC50 for mHg to embryos of injected eggs

EGG - Evers Risk Levels Compared to Other Literature Benchmarks

(Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)

Reference	Low Risk in Eggs 0 – 0.5 mHg[1] ppm (ww) [2]	Moderate Risk in Eggs 0.5 – 1.3 mHg[1] ppm (ww) [2]	High Risk in Eggs 1.3 -2.0 mHg[1] ppm (ww) [2]	Extra High Risk in Eggs >2.0 mHg[1] ppm (ww) [2]	Organism/ Notes
Fimreite 1974		1.0 LOAEL[5] Reproduction		3.5 73% hatch failure	Common Tern reproduction
Heinz and Hoffman 2003				2.3 neurological impacts	Mallards
Keck et al. 1982	0.1 – 0.3 Egg sterility				Peregrine Falcon
Newton & Hass 1988		0.6 decreased brood size			Merlin

EGG - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers et al. 2004)					
Reference	Low Risk in Eggs 0 – 0.5 mHg[1] ppm (ww)[2]	Moderate Risk in Eggs 0.5 – 1.3 mHg[1] ppm (ww)[2]	High Risk in Eggs 1.3 -2.0 mHg[1] ppm (ww)[2]	Extra High Risk in Eggs >2.0 mHg[1] ppm (ww)[2]	Organism/ Notes
Nyanza River Eco Risk Assess.	0.09 NOAEL[7] Reproduction; 0.16 LOAEL[5] Reproduction				Bird Thresholds in general
Wiemer et al. 2007	0.18 – 0.47 NOAEL[7]				American White Pelican
Wolfe et al. 1998		1.0 – 3.6 range of significant toxic effects			Water birds in General

Reported values for effect levels may be based upon total mercury analysis if methyl mercury not analyzed. These then are conservative values when compared to methyl mercury benchmarks.

1 mHg = methyl mercury

2 ppm (ww) = parts per million wet weight

3 Beyer, Heinz, Redmon, Norwood 1996

4 Heinz et al. 2008 egg injection study. Heinz reports that toxicity of mHg injected into egg is greater than same concentration deposited via mother. These benchmarks may overestimate impacts to embryos.

5 LOAEL = lowest observed adverse effect level

6 LC50 = lethal concentration 50% of test species

7 NOAEL = No observed adverse effect level

Table 4 BLOOD - Evers Risk Levels Compared to Other Literature Benchmarks

BLOOD - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers 2004)					
Reference	Low Risk in Blood 0 - <1.0 mHg[1] ppm (ww)[2]	Moderate Risk in Blood 1.0 – <3.0 mHg[1] ppm (ww)[2]	High Risk in Blood 3.0 – <4.0 mHg[1] ppm (ww)[2]	Extra High Risk in Blood >4.0 mHg[1] ppm (ww)[2]	Organism/ Notes
Evers 2008	<1.0 NOAEL[4] # Fledglings produced				Common Loon

BLOOD - Evers Risk Levels Compared to Other Literature Benchmarks (Evers Risk Categories based on body of Evers' Literature and ranges published in Evers 2004)					
Reference	Low Risk in Blood 0 - <1.0 mHg[1] ppm (ww)[2]	Moderate Risk in Blood 1.0 – <3.0 mHg[1] ppm (ww)[2]	High Risk in Blood 3.0 – <4.0 mHg[1] ppm (ww)[2]	Extra High Risk in Blood >4.0 mHg[1] ppm (ww)[2]	Organism/ Notes
Nocera and Taylor – Nyanza River ERA		1.25 LOAEL[3] for Chick Behavior			Common Loon
Evers 2008			>3.0 LOAEL[3] L for #Fledglings produced (41% reduction as compared to <1.0 NOAEL[4])		Common Loon
Burgess 2008			4.3 in adult EC50[5] for #Chicks produced per pair		Common Loon
Burgess 2008				8.6 in adult EC100[6] (no chicks produced per pair)	Common Loon
Spalding et. al 2000				12 LOAEL[3] for Juvenille behavior	Great White Egrets

1 mHg = methyl mercury

2 ppm (ww) = parts per million wet weight

3 LOAEL = lowest observed adverse effect level

4 NOAEL = No observed adverse effect level

5 EC50 = effective concentration 50% of test organisms

6 EC100 = effective concentration 100% of test organisms

Table 5 LIVER - GSL Team Risk Levels Compared to Literature Benchmarks

LIVER - GSL Team Risk Levels Compared to Literature Benchmarks					
Reference	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	Organism/ Notes
Heinz 1976a		0.89 (mHg) LOAEL[3] reproductive impacts			Mallards
Gochfeld 1980		1.06 NOAEL[4]			Common tern

LIVER - GSL Team Risk Levels Compared to Literature Benchmarks					
Reference	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	Organism/ Notes
Scheuhammer 1987			2.0 Reproductive impacts		Pheasants
Fimreite 1971; Heinz 1976 a,b			2 to 12 impact on reproduction and mortality		Pheasants and Mallards
Zillioux et al 1993			5.0 Conservative threshold for sign. toxic effects		Birds in general
Barr 1986			3.0 to 13.7 decreased hatchability		Common loon

LIVER - GSL Team Risk Levels Compared to Literature Benchmarks					
Reference	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	Organism/ Notes
Spalding et al 1994				>6 Correlated with mortality from chronic disease	Great white heron
Spalding et al 1991				7.2 increased disease and emaciation	Great white heron
Finley and Stendell 1978				9.08 Reduced nesting success	Common tern
Spalding et al. 2000				15 impacts on growth, appetite, hygiene	Great egrets

LIVER - GSL Team Risk Levels Compared to Literature Benchmarks					
Reference	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	Organism/ Notes
Finley and Stendall 1978				20.7 Reduced hatching success	Common tern
Thompson 1996				20 – 30 range of significant toxic effect	Non-marine birds
Spalding et al. 1994				27.5 10%-12% fledge rate	Common tern
Barr 1986				29.7 Reduced nesting success	Common loon
Heinz 1974				30 Threshold neurological effects	Birds in general

LIVER - GSL Team Risk Levels Compared to Literature Benchmarks					
Reference	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	Organism/ Notes
BHRN 1996[6]				30 Threshold for survival	Birds in general
Scheuhammer 1991				30 Frank neurological effects	Birds in general
Weimeyer et al. 1987				35 death	Osprey
Barr 1986				51.9 Reduced hatching success	Common loon
Finley et al 1979				54.5 LD33[5]	Common grackle

* Low risk – below LOEL for Mallard reproductive impacts

**Medium risk – From LOAEL to threshold for sublethal effects noted by several authors including Fimreite 1971, Heinz 1976 a, b; Scheuhammer 1987

***High Risk – from sublethal effects threshold to the threshold for major toxic effects suggest by Zillioux et al. 1993 and Spalding et al. 1994.

****Extra High Risk – includes concentrations above which long term survival significantly impacted.

1 mHg = methyl mercury

2 ppm (ww) = parts per million wet weight

3 LOAEL = lowest observed adverse effect level

4 NOAEL = No observed adverse effect level

5 LC33 = lethal concentration 33% of test species

6 Beyer, Heinz, Redmon, Norwood 1996

Table 6 GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
Common Goldeneye	Nov 20 – Dec 31 2004-2006	GSL			Females 3.1 geometric mean 0.9 – 13.8 range 2.3 – 4.2 95% CI males 4.4 geometric mean 0.9 – 33.7 range 3.2 – 6.1, 95% CI n=40		Vest et al. 2009

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
	Jan 1 – Feb 27 2004-2006	GSL				Females 14.0 geometric mean 0.4 – 38. range 10.1 – 19.4 95% CI Males 14.6 geometric mean 1.4–31.9 range 10.4 – 20.3 95% CI males n=37	Vest et al. 2009

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
	Feb 28-April 5 2004 - 2006	GSL				females 8.5 geometric mean 1.0 – 46.1 range 6.3 – 11.6 95% CI males 13.7 geometric mean 0.3 – 71.5 range 10.0 – 18.7 95% CI n = 43	Vest et al. 2009

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
Northern Shovelers	November 2004-2006	Open Waters		1.79 geometric mean 0.18 to 15.2 range (n=13)			Vest et al. 2009
	December 2004-2006	Open Waters			3.86 geometric mean 0.86 to 10.73 range (n=42)		Vest et al. 2009
	February 2004-2006	Open Waters			3.64 geometric mean 1.19 to 11.9 range (n=28)		Vest et al. 2009

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
	October – December, 2008	Bear River	0.725 geomean mHg 0.212 to 3.161 range mHg; (n=16)				RGI Data
	October – December, 2008	Ogden Bay	0.510 geomean mHg 0.149 to 2.227 range mHg; (n=16)				RGI Data

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
	October – December, 2008	Farmington Bay	0.324 geomean mHg 0.127 to 2.625 range mHg; (n=18)				RGI Data
Cinnamon Teal	August and October 2008	Bear River Wetlands	August: 0.241 geomean mHg 0.078 to 0.394 range mHg; (n=9)				RGI Data

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
			October 0.183 geomean mHg 0.118 to 0.283 range mHg; (n=2)				
	August and October 2008	Ogden Bay: Howard Slough	August: 0.170 geomean mHg 0.090 to 0.284 range mHg; (n=3)				RGI Data

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
			October: 0.542 geomean mHg 0.163 to 1.133 range mHg; (n=2)				
	May, July-August, September 2008	Farmington Bay Wetlands	May: 0.545 geomean mHg 0.178 to 3.584 range mHg; (n=9)				RGI Data

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
			July-August: 0.230 geomean mHg 0.079 to 0.954 range mHg; (n=9)				
			September: 0.202 geomean mHg 0.464 to 0.515 range mHg; (n=9)				

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww) [2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww) [2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww) [2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww) [2]	References/Notes
Eared Grebe	Nov 1997	Gilbert Bay			3.7 geomean mHg 3.36 to 4.03 range mHg; (n= 3 composites sample)		FWS Report 2009
	Sept 1998	Gilbert Bay		2.14 geomean mHg 1.38 to 3.04 range mHg; (n= 12)			
	Dec 1998	Gilbert Bay			4.32 geomean mHg 1.87 to 6.18 range mHg; (n= 4)		

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww)[2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww)[2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww)[2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww)[2]	References/Notes
	May 2000	Gilbert Bay		1.96 geomean mHg 0.425 to 8.93range mHg; (n= 23)			
	October 2006	Gilbert Bay		3.23 geomean mHg 1.66 to 4.81range mHg; (n= 10)			USFWS Data from Miles, Darnall and Jehl (unpublished)
	December 4 2006	Gilbert Bay			5.51 geomean mHg 2.74 to 7.96 range mHg; (n= 10)		USFWS Data from Miles, Darnall and Jehl (unpublished)

GSL Avian Liver Data Comparison with Liver Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	*Low Risk in Liver <0.89 Hg[1] ppm (ww) [2]	**Moderate Risk in Liver 0.89 – <2.0 Hg[1] ppm (ww) [2]	***High Risk in Liver 2.0 -6.0 Hg[1] ppm (ww) [2]	****Extra High Risk in Liver >6.0 Hg[1] ppm (ww) [2]	References/Notes
	December 20 2006	Gilbert Bay				8.67 geomean mHg 6.24 to 13.58range mHg; (n= 10)	USFWS Data from Miles, Darnall and Jehl (unpublished)

Table 7 GSL Egg Data Comparison with Egg Risk Ranges for Hg

GSL Egg Data Comparison with Egg Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	Low Risk in Eggs 0 – 0.5 mHg[1] ppm (ww)[2]	Moderate Risk in Eggs 0.5 – 1.3 mHg[1] ppm (ww)[2]	High Risk in Eggs 1.3 -2.0 mHg[1] ppm (ww)[2]	Extra High Risk in Eggs >2.0 mHg[1] ppm (ww)[2]	References
	May 2 to July 1 2008	Bear River Wetlands	0.133 geomean mHg 0.082 to 0.183 range mHg; (n= 10)				
Cinnamon Teal	May 2 to July 1 2008	Ogden Bay: Howard Slough	0.18 geomean mHg 0.08 to 0.75range mHg; (n= 10)				RGI Grant
	May 2 to July 1 2008	Farmington Bay Wetlands	0.138 geomean mHg 0.05 to 0.36range mHg; (n= 10)				

Table 8 GSL Blood Data Comparison with Evers Risk Ranges for Hg

GSL Blood Data Comparison with Evers Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	Low Risk in Blood 0 - <1.0 mHg[1] ppm (ww)[2]	Moderate Risk in Blood 1.0 – <3.0 mHg[1] ppm (ww)[2]	High Risk in Blood 3.0 – <4.0 mHg[1] ppm (ww)[2]	Extra High Risk in Blood >4.0 mHg[1] ppm (ww)[2]	References
Eared Grebes adults	Fall 2006	Antelope Island	0.86 geomean (n=30)				Conover & Vest 2009
	Fall 2006	Stansbury Island		2.02 geomean (n=30)			
	Sept. 2006	Antelope & Stansbury Island		1.12 geomean (n=30)			
	Nov. 2006	Antelope & Stansbury Island		1.68 geomean (n=30)			
Eared Grebes juvenile	Fall 2006	Antelope & Stansbury Island		1.10 geomean			
Eared Grebes adult	Fall 2006	Antelope & Stansbury Island		1.68 geomean			

Table 9 GSL Diet Data Comparison with Evers Risk Ranges for Hg

GSL Diet Data Comparison with Evers Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – < 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	References
			Cysts/Napulii	Adults			
Brine Shrimp	June – December 2008	DWR3 12.8 km NNW of Hat Island	0.0062 tHg geomean 0.0018 to 0.0014 tHg range (n=10)	0.0505 tHg geomean 0.0192 to 0.0863 tHg range (n=10)			RGI Grant
	June, July, Aug, Oct, Nov 2008	GSL Streak 1 - cysts	0.0091 tHG geomean 0.006 to 0.0126 tHg range (n=7)				
	June – Oct 2008	GSL Streak 2- cysts	0.0092 tHg geomean 0.006 to 0.0116 tHg range (n=9)				
	June, Sept, Oct 2008	GSL Streak 3- cysts	0.0089 tHg geomean 0.0052 to 0.0123 tHg range (n=5)				
	Nov 2008	GSL USU2	0.0117 tHg geomean				

GSL Diet Data Comparison with Evers Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – < 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	References
			0.0108 to 0.0863 tHg range (n=2)				
	June – December 2008	GSL 2267 1 mi NW of Fremont Island–	Cysts/Napulii 0.0088 tHg geomean 0.0059 to 0.0162 tHg range (n=10)	Adults 0.0582 tHg geomean 0.0528 to 0.0694 tHg range (n=10)			
	June – December 2008	GSL 2767 4 mi W of North Tip Antelope Island–	Cysts/Napulii 0.0066 tHg geomean 0.0047 to 0.0080 tHg range (n=10)	Adults 0.0577 tHg geomean 0.0252 to 0.0767 tHg range (n=10)			
	June – December 2008	GSL 2935 W of Carrington Island–	Cysts/Napulii 0.0068 tHg geomean 0.0042 to 0.0099 tHg range (n=10)	Adults 0.0607 tHg geomean 0.0319 to 0.0976 tHg range (n=10)			

GSL Diet Data Comparison with Evers Risk Ranges for Hg

Organism	Date Sampled	Location Sampled	Low Risk in Diet < 0.05 mHg[1] ppm (ww)[2]	Moderate Risk in Diet 0.05 – < 0.15 mHg[1] ppm (ww)[2]	High Risk in Diet 0.15 – 0.3 mHg[1] ppm (ww)[2]	Extra High Risk in Diet >0.3 mHg[1] ppm (ww)[2]	References
	June – December 2008	GSL 3510 8 mi West of Antelope Island–	Cysts/Napulii 0.0047 tHg geomean 0.0017 to 0.0013 tHg range (n=10)	Adults 0.0586 tHg geomean 0.0269 to 0.074 tHg range (n=10)			
	June – December 2008	GSL 4069 8 mi West of Saltair Marina	Cysts/Napulii 0.0078 tHg geomean 0.0050 to 0.00160 tHg range (n=10)	Adults 0.0572 tHg geomean 0.0275 to 0.0724 tHg range (n=10)			