7.0 Quantitative Conceptual Model Results

This section provides a summary of results from the quantitative conceptual model described in Section 6.0.

7.1 Introduction

A quantitative conceptual model, described in Section 6.0 of this report, was developed to integrate the observations and data collected as part of the research program in 2006 and 2007 to allow a user to relate water, diet, and egg selenium concentrations in Great Salt Lake. The model includes two components: (1) Mass Balance Model and (2) Bioaccumulation Model. Each of these components includes various inputs, outputs, and alternatives from which the user may select.

The Science Panel agreed that a selenium water quality standard that prevents impairment of beneficial uses of open waters of Great Salt Lake would be defined by a waterborne or tissue concentration that is represented within a range of 3.6 through 5.7 mg Se/kg for bird diet and 6.4 through 16 mg Se/kg for eggs. This range was selected as the basis for evaluation in the research program and largely frames the alternatives considered by the Science Panel. While numerous alternatives are discussed herein, the model allows the user to select his or her own custom scenarios to complete sensitivity analyses and estimate results. The user should use caution as the model was developed from data from a specific period in time (May 2006 through July 2007) for the conditions present in Great Salt Lake during that time. The following presents a summary of results from the quantitative conceptual model.

7.2 Mass Balance Model

As described in Section 6.0, the Mass Balance Model was constructed to link measured and estimated selenium loads, loss fluxes, and internal cycling to estimate waterborne selenium concentrations for Great Salt Lake. The model estimates waterborne selenium concentrations from the data collected and allows the user to create a custom scenario to evaluate. Guidelines are included within the model to describe the uncertainty of data collected and estimated. It should be noted that the Science Panel expressed caution in the use of the Mass Balance Model as it represents conditions from only 12 months of data. Further work is needed before the model can be used to predict future conditions and account for long-term cycling of selenium in Great Salt Lake.

Table 7-1 shows measured and modeled waterborne concentrations for 2006 and 2007. Predictions averaged within 0.388 µg Se/L of measured values on a monthly basis and were very close (0.003 µg/L) for an annual average, indicating the general ability of the model to mimic field conditions.

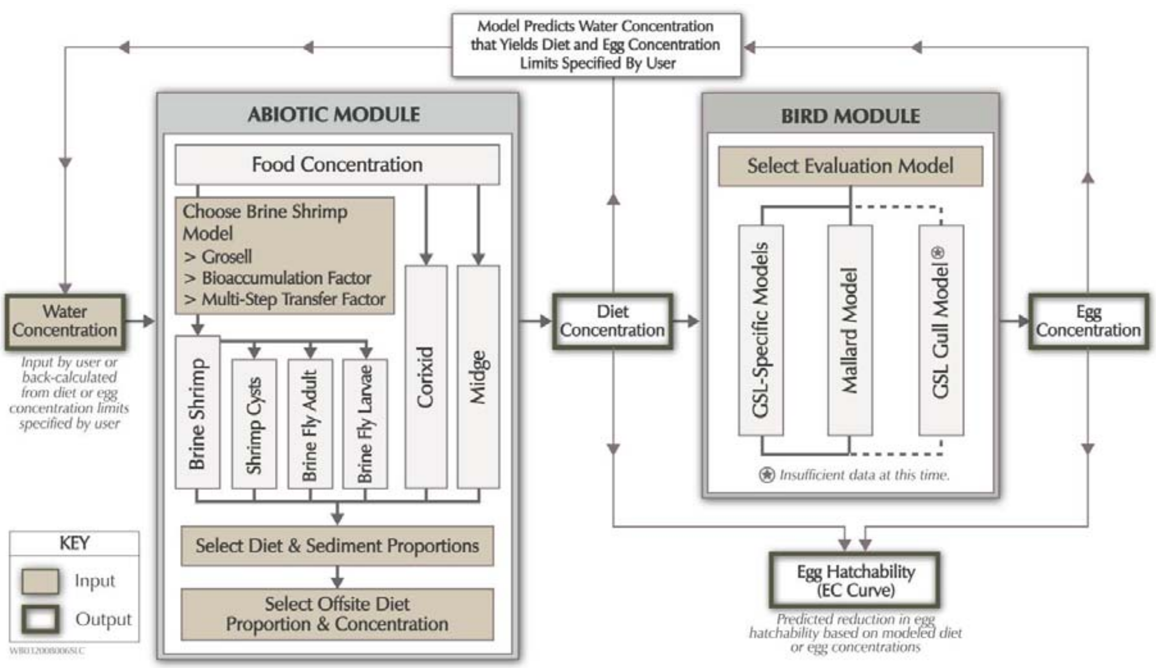
TABLE 7-1
Measured versus Modeled Monthly Average Total Selenium Concentrations in Water (μg Se/L)

	Annual Average	July 06	Aug. 06	Sept. 06	Oct. 06	Nov. 06	Dec. 06	Jan. 07	Feb. 07	Mar. 07	Apr. 07	May 07	June 07
Measured	0.600	0.396	0.780	0.614	0.569	0.525	0.566	0.608	0.649	0.690	0.773	0.705	0.717
Modeled	0.597	0.562	0.392	0.780	0.594	0.546	0.502	0.548	0.595	0.631	0.670	0.763	0.697
Measured - Modeled	0.003	-0.166	0.388	-0.166	-0.025	-0.021	0.064	0.060	0.054	0.059	0.103	-0.058	0.020

7.3 Bioaccumulation Model

The Bioaccumulation Model (also described in Section 6.0) was constructed to allow the user to estimate bird diet and egg selenium concentrations from an assumed waterborne selenium concentration (see Figure 7-1). The model also allows the user to back-calculate a waterborne selenium concentration from an assumed bird diet or egg selenium concentration. The model may be thought to generally have two steps in relating selenium concentrations: (1) water to diet and (2) diet to egg. Each step has various inputs, outputs, and alternatives from which the user may select. The following provides a comparison of alternative relationships used in each of these two steps as well as a summary of estimated bird diet and egg selenium concentrations from an assumed waterborne selenium concentration and vice versa.

FIGURE 7-1
Bioaccumulation Model Flow Chart



7.3.1 Water to Diet

The calculation of a bird diet concentration from an assumed waterborne concentration (and vice versa) includes numerous inputs and alternatives that the user may select. The Science Panel has decided to assume that all birds consume only items they can obtain from the open waters of Great Salt Lake. Further, they have assumed that gulls consume a diet of 100 percent brine shrimp and shorebirds consume a diet of 100 percent brine fly larvae and 5 percent sediment. While the user may change these diet combinations, all results presented herein rely upon these assumptions.

Selenium concentrations for brine shrimp cysts and brine fly larvae and adults are derived from a relationship that relates their selenium concentration directly to the selenium concentration in adult brine shrimp. Thus, the estimated bird diet selenium concentration used for the water quality standard depends on the relationship selected by the user to estimate the selenium concentration in brine shrimp.

Three relationships that relate an assumed waterborne concentration to the brine shrimp concentration are included in the Bioaccumulation Model. These relationships are described in Section 6.0 and are as follows: (1) Grosell's Model (developed from laboratory studies relating selenium concentrations in water and algae to adult brine shrimp), (2) BAF (bioaccumulation factor relating total selenium concentration in water directly to adult brine shrimp), and (3) MS-TF (a multi-step transfer factor model that relates total to dissolved selenium concentration in water to seston [brine shrimp food source] and then from seston to adult brine shrimp). Each relationship is unique and generates a different result. Figure 7-2 illustrates how results from the three relationships compare.

After a review of each of the models, the Science Panel decided to use the MS-TF relationship for recommending the water quality standard. As described in Section 6.0, the MS-TF relationship comes closest to predicting brine shrimp selenium concentrations on a monthly basis for the study period (see Figure 6.2) and its mechanistic, multi-step process most closely resembles the transfer of selenium from water to brine shrimp in Great Salt Lake.

7.3.2 Diet to Egg

The Bioaccumulation Model includes two alternatives to estimate egg selenium concentrations from bird diet concentrations (and vice versa): the GSL-specific Model option (including the Shorebird Model [a regression model developed from collocated shorebird diet and egg samples) and Gull Transfer Factor Model [a direct ratio between the geometric means of gull diet and egg concentrations]) and the Mallard Model (a regression model developed from six toxicological studies completed in the laboratory using mallards). As described in Section 6.0, other relationships were also developed but not included as alternatives in the Bioaccumulation Model. These other relationships include the Gull Model (a regression model developed from gull food items and eggs) and shorebird transfer factor (a direct ratio between the geometric mean of shorebird diet and egg concentrations).

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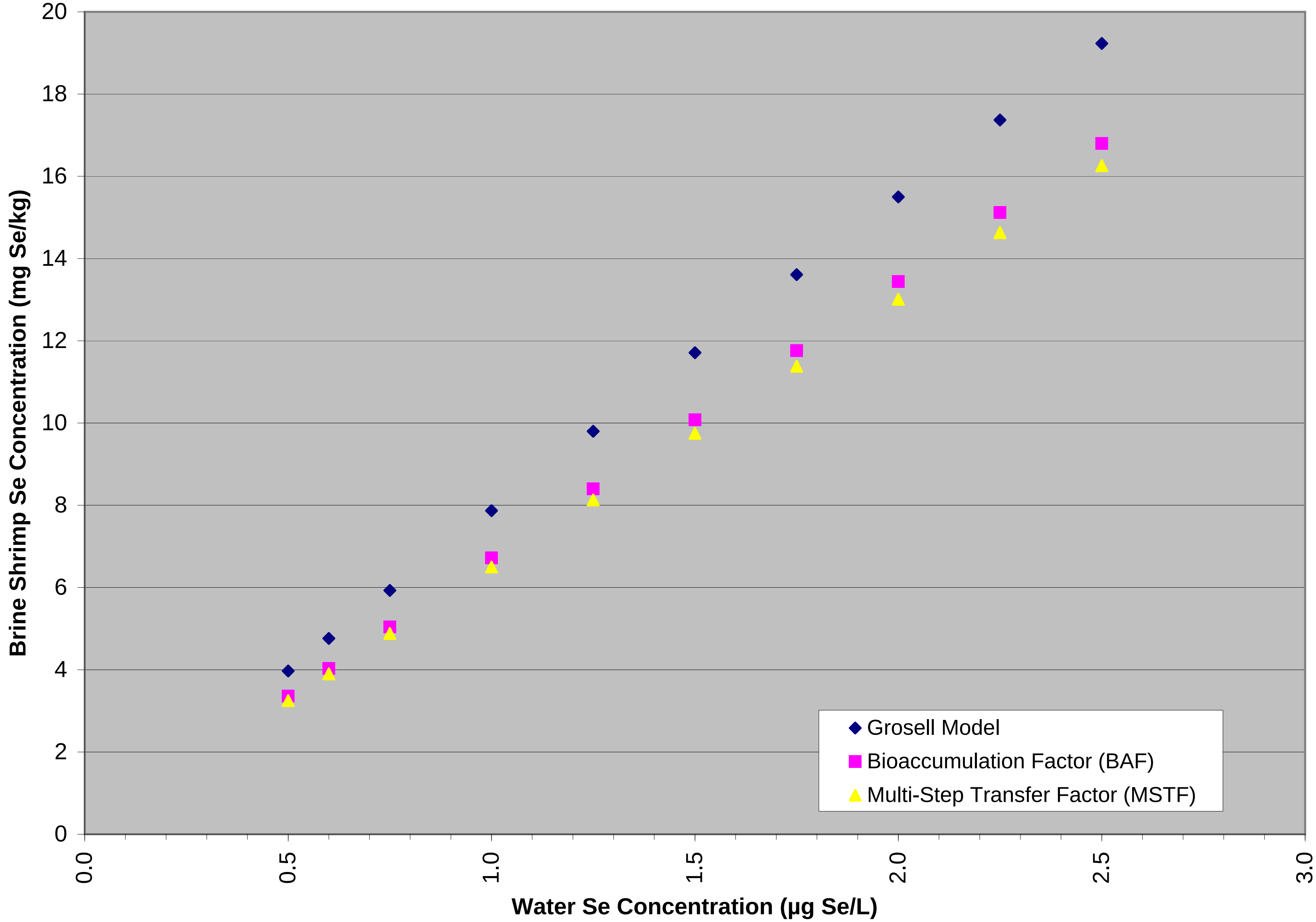
FIGURE 7-2
Comparison of Three Brine Shrimp Models



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The Science Panel decided to eliminate the Gull Model from consideration at this time due to a lack of relationship between diet and egg selenium concentrations for gulls from Great Salt Lake. Further research is needed before the Gull Model may be applied for decision-making purposes. The shorebird transfer factor provides a useful relationship, although relationships based upon regression equations are generally considered to be more representative of datasets. As such, the Science Panel decided to include only the GSL-specific Model and Mallard Model as options in the Bioaccumulation Model.

Figure 7-3 illustrates a comparison of the Shorebird Model, Mallard Model, and shorebird transfer factor relationships for shorebirds. Figure 7-4 illustrates a comparison of the Shorebird Model, Mallard Model, and gull transfer factor relationships for gulls. Both figures illustrate estimates of egg selenium concentration from a waterborne selenium concentration.

The Mallard Model is generally more conservative (that is, it generally estimates a higher egg selenium concentrations than the Shorebird Model does for a given bird diet selenium concentration). The Shorebird and Mallard Models both estimate higher egg selenium concentrations than are estimated by the two transfer factor relationships. The Science Panel decided to use the Shorebird Model as the preferred relationship for shorebirds because it is site-specific and more representative of Great Salt Lake than the generalized Mallard Model. The Science Panel decided to use the gull transfer factor model as the preferred relationship for gulls because it is site-specific and more representative of gulls on Great Salt Lake than the Shorebird Model or the generalized Mallard Model. The Shorebird Model estimates higher egg selenium concentrations for gulls than observed on Great Salt Lake. The transfer factors illustrated in Figures 7-3 and 7-4 and discussed in the following subsection are considered useful complements to the regression models for some purposes. Thus, the Science Panel decided to use the GSL-specific Model for recommending the water quality standard.

7.3.3 Variability of Modeling Terms

Table 7-2 shows the variability in monthly values as used in creating the selenium food web model (that is, water to diet). Various values of these parameters could be substituted into the model to examine effects on "downstream" (including higher trophic level) calculated values. For example, entering 25th or 75th percentile water values instead of means would affect predictions of selenium concentrations in sediment, seston, invertebrate dietary items, and bird eggs. Entering new dietary item values would affect the estimation of concentrations in bird eggs.

It should be noted that the Bioaccumulation Model should <u>not</u> be used for waterborne selenium concentrations greater than 2.5 µg Se/L. Further, the Bioaccumulation Model was developed using data collected during the 2006 through 2007 study period. Waterborne selenium concentrations for the study period ranged from 0.4 to 0.8 µg Se/L. Predictions of bird diet and egg selenium concentrations for waterborne selenium concentrations greater than 0.8 µg Se/L should be used with caution.

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FIGURE 7-3

Comparison of Three Shorebird Egg Models

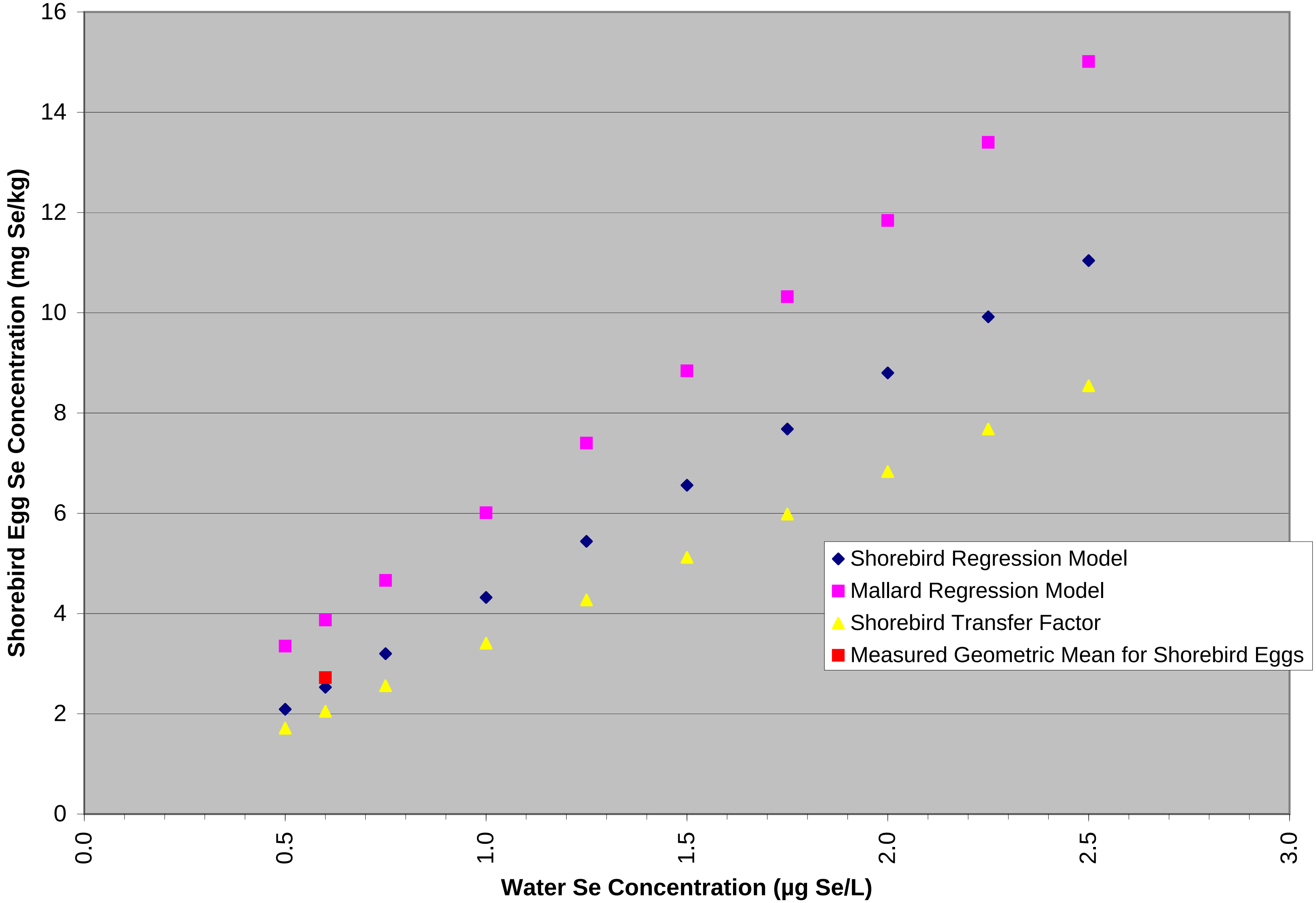

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FIGURE 7-4
Comparison of Three Gull Egg Models

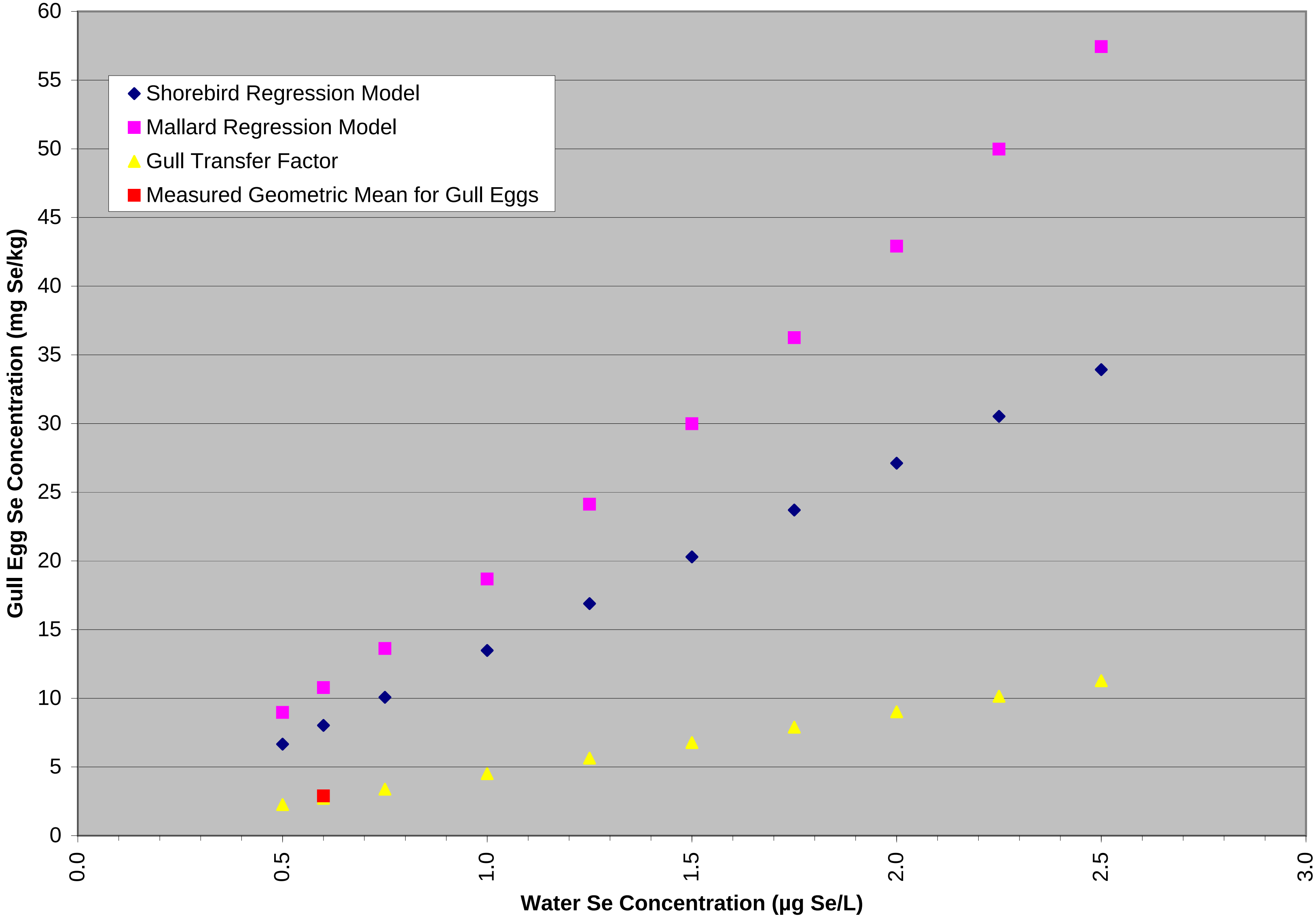

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TABLE 7-2
Variability of Monthly Geometric Means Used as Modeling Terms*

Term	Mean	Range (low/high)	25 Percentile Value	Median (50 percentile)	75 Percentile Value	Upper 95% Upper Confidence Limit of Mean	Lower 5% LCL of mean
Total Se concentration in water (µg/L)	0.634	0.374/0.873	0.512	0.648	0.759	0.737	0.533
Dissolved Se concentration in water (µg/L)	0.497	0.278/0.773	0.376	0.514	0.584	0.594	0.399
Seston (mg Se/kg dw)	0.950	0.419/2.945	0.651	0.893	0.1.345	1.474	0.426
Periphyton (mg Se/kg dw)	0.977	0.630/1.20	0.630	1.100	1.200	1.733	0.221
Adult brine flies (mg Se/kg dw)	1.933	1.200/3.100	1.650	1.800	2.200	2.589	1.277
Adult brine shrimp (mg Se/kg dw)	3.425	1.42/6.555	2.6514	3.722	4.7094	4.171	2.679

NOTE:
*Except for brine shrimp, which are modeled based on water and seston means and bioaccumulation equations from the laboratory study.

7.3.4 Summary of Results

Table 7-3 provides a summary of estimated bird diet and egg concentrations from assumed waterborne selenium concentrations. The range of waterborne selenium concentrations included in Table 7-3 spans 0.5 to 2.5 µg Se/L. The table includes estimates of diet selenium concentration using all three brine shrimp relationships. The table also includes estimates of egg selenium concentration for the four different diet-to-egg relationships using only the MS-TF brine shrimp relationship.

The geometric mean for waterborne selenium concentrations for the study period was 0.6 µg Se/L. The geometric mean for shorebird egg selenium concentrations was 2.72 mg Se/kg and for gull egg selenium concentrations was 2.89 mg Se/kg. As summarized in Table 7-3, the resulting estimated egg selenium concentration using 0.6 µg Se/L for water was 2.53 mg Se/kg for shorebird eggs and 2.71 mg Se/kg for gull eggs (this assumes the Science Panel's recommendation of using the MS-TF brine shrimp model and GSL-specific Model are used). The estimated egg selenium concentration for shorebirds was within 8 percent of the measured geometric mean, whereas the estimated egg selenium concentration for gulls was within 6 percent of the measured geometric mean.

Table 7-4 provides a summary of estimated waterborne and diet selenium concentrations from assumed egg selenium concentrations. The range of egg selenium concentrations included in Table 7-4 spans 3.0 to 16.5 mg Se/kg. A mean egg selenium concentration of 3.0 mg Se/kg has been identified as a likely background level for eggs (Skorupa and

Ohlendorf, 1991). The geometric mean for shorebird egg selenium concentrations in this research program was 2.72 mg Se/kg. The geometric mean for gull egg selenium concentrations in this research program was 2.89 mg Se/kg. The Science Panel identified the range of 6.4 to 16 mg Se/kg as the range to be considered for the water quality standard.

Table 7-5 provides a summary of estimated selenium concentrations for water and diet for assumed egg concentrations within the range identified by the Science Panel and using the relationships selected by the Science Panel.

TABLE 7-3

Diet and Egg Concentrations Calculated from Assumed Water Concentration

From Bioaccumulation Model v 4.3

Water Concentration	Estimates for Diet Concentrations (mg/kg)				Estimates for Egg Concentrations (mg/kg)					
	Brine Shrimp Model			BF larvae from MS-TF BS Model	Shorebird Model		Mallard Model		Shorebird	Gull
(µg/L)	Grosell	BAF	MS-TF		Shorebird	Gull	Shorebird	Gull	Transfer Factor	Transfer Factor
0.5	4.0	3.4	3.3	1.1	2.1	6.7	3.4	9.0	1.7	2.3
0.6	4.8	4.0	3.9	1.3	2.5	8.0	3.9	11	2.0	2.7
0.8	5.9	5.0	4.9	1.6	3.2	10	4.7	14	2.6	3.4
1.0	7.9	6.7	6.5	2.1	4.3	13	6.0	19	3.4	4.5
1.3	9.8	8.4	8.1	2.7	5.4	17	7.4	24	4.3	5.6
1.5	12	10	9.8	3.2	6.6	20	8.8	30	5.1	6.8
1.8	14	12	11	3.7	7.7	24	10	36	6.0	7.9
2.0	16	13	13	4.3	8.8	27	12	43	6.8	9.0
2.3	17	15	15	4.8	9.9	31	13	50	7.7	10
2.5	19	17	16	5.3	11	34	15	57	8.5	11

NOTES:

Mean values for study period: water = 0.6 µg/L, shorebird diet = 1.7 mg/kg, shorebird egg = 2.7 mg/kg, gull diet (from Conover) = 4.2 mg/kg, gull egg = 2.9 mg/kg

GSL during period when we collected co-located bird diet/egg samples had a water concentration closer to 0.4 µg/L

Used the MS-TF brine shrimp model to estimated egg concentrations.

Used default values prescribed by Science Panel for bird diet mix (100 percent brine shrimp for gulls, 100 percent brine fly larvae for shorebirds with 5 percent sediment)

Shorebird and Gull transfer factors are not alternatives available on Bioaccumulation Model main page but are found within the Bird Model tabs

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TABLE 7-4
Water and Diet Concentration Calculated from Assumed Egg Concentration
From Bioaccumulation Model v 4.3

Comparison of Shorebird & Mallard Models to Relate Egg to Diet Concentration for Shorebirds								
Egg Concentration	Estimate for Diet Concentration Shorebird Model	Estimate for Diet Concentration Mallard Model	Estimates for Water Concentrations (µg/L) Brine Shrimp Model					
			Grosell		BAF		MS-TF	
(mg/kg)	(mg/kg)	(mg/kg)	Shorebird	Mallard	Shorebird	Mallard	Shorebird	Mallard
3.0	1.5	0.9	0.6	0.4	0.7	0.4	0.7	0.4
4.7	2.3	1.6	0.9	0.6	1.1	0.7	1.1	0.8
6.4	3.1	2.3	1.2	0.9	1.4	1.0	1.5	1.1
9.5	4.6	3.4	1.8	1.4	2.1	1.6	2.2	1.6
13	6.0	4.5	2.4	1.8	2.7	2.0	2.8	2.1
15	7.0	5.2	2.8	2.0	3.2	2.3	3.3	2.4
17	7.9	5.8	3.2	2.3	3.6	2.6	3.7	2.7

Comparison of Gull Transfer Factor & Mallard Models to Relate Egg to Diet Concentration for Gulls								
Egg Concentration	Estimate for Diet Concentration		Estimates for Water Concentrations (µg/L) Brine Shrimp Model					
	Gull Transfer Factor (GTF)	Mallard Model	Grosell		BAF		MS-TF	
(mg/kg)	(mg/kg)	(mg/kg)	GTF	Mallard	GTF	Mallard	GTF	Mallard
3.0	4.3	0.9	0.5	0.1	0.6	0.1	0.7	0.1
4.7	6.8	1.6	0.9	0.2	1.0	0.2	1.0	0.3
6.4	9.2	2.3	1.2	0.3	1.4	0.3	1.4	0.4
9.5	14	3.4	1.8	0.4	2.0	0.5	2.1	0.5
13	18	4.5	2.3	0.6	2.7	0.7	2.8	0.7
15	21	5.2	2.7	0.7	3.1	0.8	3.2	0.8
17	24	5.8	3.1	0.7	3.5	0.9	3.7	0.9

NOTE:
Used default values prescribed by Science Panel for bird diet mix (100 percent brine shrimp for gulls, 100 percent brine fly larvae for shorebirds with 5 percent sediment)
Geometric means for samples collected as part of this research program: shorebird eggs - 2.7 mg/kg, gull eggs - 2.9 mg/kg, gull diet - 4.2

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TABLE 7-5

Water and Diet Concentration Calculated from Assumed Egg Concentration

From Bioaccumulation Model v 4.3

Egg Concentration (mg/kg)	Estimate for Diet Concentration (mg/kg)	Estimate for Water Concentration (µg/L)
Shorebirds		
6.4	3.1	1.5
9.5	4.6	2.2
12.5	6.0	2.8
14.5	7.0	3.3
16.5	7.9	3.7
Gulls		
6.4	9.2	1.4
9.5	13.7	2.1
12.5	18.0	2.8
14.5	20.9	3.2
16.5	23.8	3.7

NOTE:

Assumes the use of Shorebird Model for shorebirds, Gull Transfer Factor Model for gulls and MS-TF Brine Shrimp Model for both species.

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