

Appendix L. Derivation of Trophic Level Ratios

L.1 Introduction and Purpose

The goal of this data analysis is to calculate ratios of fish tissue mercury concentrations between fish trophic levels. These ratios were used in deriving protective wildlife targets (Appendix K). The ratios are meant to represent conditions in inland surface waters, enclosed bays or estuaries, which is the geographic scope of the Provisions.

L.2 Methods

The data used to derive the ratios was downloaded from the Water Board's California Environmental Data Exchange Network (CEDEN, www.ceden.org). Total mercury and total methylmercury data from fish tissue samples dated January 1, 2000 to September 30, 2012 were compiled. Total mercury and total methylmercury were assumed to be equivalent in fish tissue, so no conversion between the two forms was made.

The data from any species that were not finfish (e.g.: mussels, clams) were removed from the data set. Sampling stations with primarily marine fish or estuarine fish were separated from freshwater sampling stations. The 'estuarine' data set was compiled from data from water bodies that are considered enclosed bays or estuaries according to State Water Resource Control Board (Appendix 1 of State Water Board 2005). Data from fish from open ocean waters were not used. Data were grouped by the size of the fish sampled to match the fish size classifications used in the wildlife analysis (150 – 500 mm, 150 - 350 mm, and <150 mm, Appendix K). Anadromous fish species were removed since they spend a portion of their lives out at sea and the resulting mercury concentration in their tissues does not represent local conditions. The fish sampled were categorized as either trophic level 3 or trophic level 4 by the fish size and species, according to Table L-1 and Table L-2.

Individual ratios were calculated by sampling station. Ratios were calculated only for the sampling stations that met the following minimum quality control criteria: (1) the data set contained at least two fish species per trophic level and (2) had a sample size greater than 5 fish sampled per trophic level. These criteria were used to create the data sets for 150-500 mm fish for each sampling station. The data sets for 150-350 mm fish for each sampling station were created using the data set for 150 -500 mm fish, but omitting data for fish larger than 350 mm. Therefore, the data sets for 150-350 mm fish are smaller and some did not meet the quality control criteria. The number of fish in each data set is shown in Table L3 and Table L-4.

Table L-1. Fish Species used in the Fresh Water Data Analysis

Freshwater Fish Trophic Levels*	
Trophic Level 3	Trophic Level 4
Black Bullhead (<i>Ameiurus melas</i>)	Black Crappie (<i>Pomoxis nigromaculatus</i>)
Bluegill (<i>Lepomis macrochirus</i>)	Channel Catfish (<i>Ictalurus punctatus</i>) > 200mm
Brown Bullhead (<i>Ictalurus nebulosus</i>)	Largemouth Bass (<i>Micropterus salmoides</i>)
Common Carp (<i>Cyprinus carpio</i>)	Sacramento Pikeminnow (<i>Ptychocheilus grandis</i>)
Hitch (<i>Lavinia exilicauda</i>)	Smallmouth Bass (<i>Micropterus dolomieu</i>)
Goldfish (<i>Carassius auratus</i>)	Spotted Bass (<i>Micropterus punctulatus</i>)
Pumpkinseed (<i>Lepomis gibbosus</i>)	White Catfish (<i>Ictalurus catus</i>) > 200mm
Rainbow Trout (<i>Oncorhynchus mykiss</i>)**	
Redear Sunfish (<i>Lepomis microlophus</i>)	
Sacramento Sucker (<i>Catostomus occidentalis</i>)	
Tule Perch (<i>Hysterothorax traskii</i>)	
White Catfish (<i>Ictalurus catus</i>) 150-200mm	

* From Appendix B of *Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury* (Central Valley Water Board 2010) and *Inland fishes of California* (Moyle 2002).

**The only sampling station in Table L-3 with data on rainbow trout is Big Bear Lake.

Table L-2. Fish Species used in the Estuarine Data Analysis.

Estuarine Fish Trophic Levels*	
Trophic Level 3	Trophic Level 4
Black Perch (<i>Embiotoca jacksoni</i>)	Barred Sand Bass (<i>Paralabrax nebulifer</i>)
Chub Mackerel (<i>Scomber japonicas</i>)	Kelp Bass (<i>Paralabrax clathratus</i>)
Opaleye (<i>Girella nigricans</i>)	Spotted Sand Bass (<i>Paralabrax maculatofasciatus</i>)
Pile Perch (<i>Rhacochilus vacca</i>)	Yellowfin Croaker (<i>Umbrina roncadore</i>)
Rainbow Surfperch (<i>Hypsurus caryi</i>)	
Striped Mullet (<i>Mugil cephalus</i>)	
Shiner Surfperch (<i>Cymatogaster aggregata</i>)	

*From Appendix A of *Contaminants in Fish from the California Coast, 2009-2010* (Davis et al. 2012) and FishBase (www.fishbase.org).

The average mercury concentration in each trophic level (trophic level 3 and trophic level 4) was calculated for each size classification. These average mercury concentrations were used to calculate ratios for each sampling station (Table L-3, Table L-4) by dividing the average mercury concentrations in trophic level 3 fish by the average mercury concentration in trophic level 4 fish at each sampling station. Then, the statewide ratios (Table L-5) were calculated as the geometric means of the individual ratios from each sampling station.

The available data enable calculation of ratios for different types of sport fish (ratios of mercury in TL3 fish to TL4 fish). However there was insufficient data in CEDEN to calculate ratios for the mercury concentrations in prey fish to sport fish (trophic level 3 fish <150 mm compared to trophic level 4 fish 150-500mm), using the minimum criterion of including only sampling stations with at least two different species.

In the freshwater data, all mercury concentration data were above the analytical reporting limit. Six of the results were “detected but not quantifiable (DNQ)”. For the DNQ samples, the estimated mercury concentration reported in CEDEN was used. In the estuarine data set, there were two results of “non-detect (ND)”. For the ND samples, half the minimum detection limit (MDL) was used as the resulting mercury concentration.

L.3 Results

L.3.1 Freshwater Ratios

Data from 34 sampling stations met the criteria of samples from fish 150 - 500 mm from two species per trophic level and at least five fish per trophic level. The sampling stations were predominately located in or near the Sacramento- San Joaquin River Delta with a few scattered throughout the state (Figure L-1). Sampling stations included sloughs, rivers, and lakes (Table L-6). Most of the samples were collected in 2005 - 2007. Two stations have samples from 2004 or 2011 as well. The average mercury concentrations at each sampling station and the trophic level ratios comparing the mercury concentrations in trophic level 3 fish to trophic level 4 fish are reported in Table L-3.

L.3.2 Estuarine Ratios

Overall data were very limited for estuarine sampling stations. Data from only three sampling stations met the criteria of samples from fish 150 -500 mm from two species per trophic level and at least five fish per trophic level. The average mercury concentrations at each sampling station and the trophic level ratios comparing the mercury concentrations in trophic level 3 fish to trophic level 4 fish are reported in Table L-4.

L.3.3 Statewide Ratios

The statewide trophic level ratios, calculated from all sampling stations combined (the freshwater and estuarine sampling stations) are shown in Table L-5. The statewide ratios were similar to freshwater ratios, since there were so few sampling stations with estuarine data. The estuarine ratios had little weight in the statewide ratios, and did not change the final outcome of the ratios (the first two significant digits of the ratios did not change).

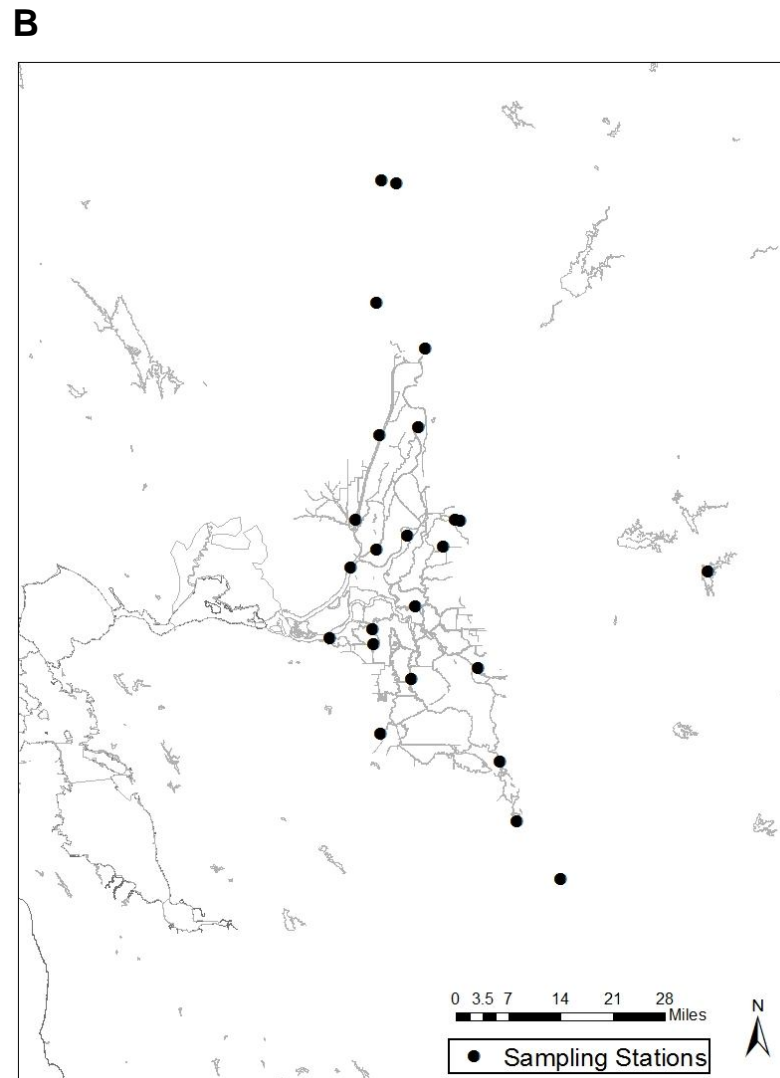
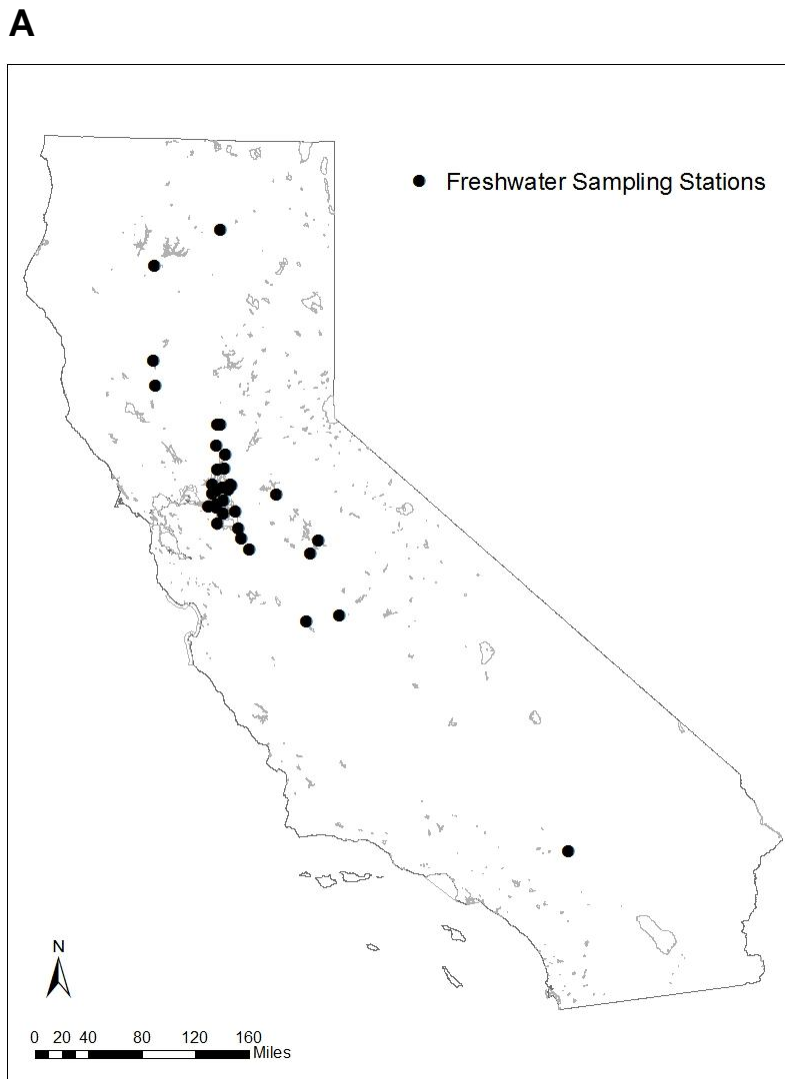


Figure L-1 . Overall distribution of sample stations used for the freshwater data analysis (A) and the cluster of freshwater sampling sites in or near the Sacramento-San Joaquin Delta (B).

Table L-3. Freshwater Average Mercury Concentrations by Trophic Level (TL) Category and Ratios

Station Name	Number of fish				Average Mercury Conc. (mg/kg)				Ratios				
	TL4 150 - 500mm	TL4 150 - 350mm	TL3 150 - 500mm	TL3 150 - 350mm	TL4 150 - 500mm	TL4 150 - 350mm	TL3 150 - 500mm	TL3 150 - 350mm	TL4/TL3 150 - 350mm	TL4/ TL3 150 - 500mm	TL4 150 -500mm / TL3 150- 350mm	TL4 150 -500mm / TL4 150- 350mm	TL3 150 -500mm / TL3 150- 350mm
(New) Hogan Reservoir	27	12	14	14	0.49	0.44	0.20	0.20	2.14	2.43	2.43	1.13	1.00
Beaver Slough (SF Mokelumne R.)	19	11	8	8	0.18	0.16	0.10	0.10	1.59	1.80	1.80	1.13	1.00
Big Bear Lake	29	9	34	21	0.19	0.04	0.03	0.04	1.07	5.97	4.85	4.53	0.81
Big Break – Delta waterways	31	21	24	18	0.22	0.19	0.11	0.07	2.85	2.04	3.25	1.14	1.59
Calaveras R. off Deep Water	19	15	10	10	0.14	0.11	0.05	0.05	2.11	2.82	2.82	1.33	1.00
Cosumnes R. at River Mile (RM) 1	35	21	14	11	1.26	1.39	0.57	0.63	2.20	2.21	1.98	0.90	0.89
Cosumnes R. u/s I-5	29	17	35	21	0.83	0.85	0.25	0.22	3.96	3.34	3.87	0.98	1.16
East Park Reservoir Southeast	21	9	14	8	0.22	0.21	0.14	0.08	2.76	1.56	4.00	1.07	1.89
Feather R.: Nicolaus	23	21	27	21	0.34	0.28	0.19	0.20	1.42	1.82	1.74	1.22	0.95
Frank's Tract - Delta waterways	29	15	24	24	0.16	0.13	0.07	0.07	1.79	2.17	2.17	1.21	1.00
Georgiana Slough	17	16	8	5	0.29	0.26	0.22	0.18	1.45	1.32	1.61	1.11	1.22
Italian Slough	20	15	17	16	0.22	0.21	0.08	0.08	2.64	2.80	2.71	1.03	0.97
Lake Britton	22	22	8	4	0.13	0.13	0.18	0.09	1.42	0.75	1.42	1.00	1.90
Lake McClure at Bagby	12	12	7	3	0.69	0.69	0.18	0.19	3.54	3.79	3.54	1.00	0.94
Mendota Pool/Mendota Slough	14	5	23	15	0.17	0.14	0.09	0.08	1.69	1.98	2.18	1.29	1.10
Merced R.: Hatfield State Park	17	9	16	8	0.29	0.21	0.19	0.09	2.19	1.48	3.08	1.40	2.08
Middle R.: Bullfrog	43	29	31	29	0.28	0.24	0.12	0.12	2.02	2.42	2.38	1.18	0.98
Prospect Slough (mid-Prospect)	62	58	22	11	0.28	0.28	0.22	0.21	1.35	1.27	1.35	1.00	1.06
Sacramento R.: W.Sac. RM59	17	13	13	9	0.49	0.39	0.18	0.14	2.73	2.64	3.36	1.23	1.27
Sacramento R.: Rio Vista	51	39	40	27	0.35	0.28	0.18	0.15	1.91	1.92	2.43	1.27	1.27
Sacramento R.: RM44	59	31	28	11	0.51	0.36	0.17	0.09	3.99	2.94	5.73	1.44	1.95
Sacramento R.: Veterans Bridge	27	12	16	7	0.53	0.29	0.14	0.07	4.01	3.66	7.27	1.81	1.99
Sacramento R.: Near Verona	16	13	14	7	0.37	0.36	0.21	0.17	2.07	1.81	2.18	1.05	1.20
San Joaquin R.: Hwy 99	11	7	11	11	0.10	0.09	0.04	0.04	2.17	2.40	2.40	1.11	1.00
San Joaquin R.: Mossdale	18	12	10	10	0.26	0.23	0.13	0.13	1.75	1.97	1.97	1.13	1.00
San Joaquin R.: Potato Slough	29	14	32	27	0.27	0.23	0.13	0.11	2.06	2.04	2.41	1.17	1.18
San Joaquin R.: Vernalis	45	33	22	8	0.43	0.40	0.26	0.13	3.04	1.64	3.30	1.08	2.01
San Joaquin R.: Laird Park	15	8	12	8	0.27	0.31	0.18	0.13	2.48	1.51	2.18	0.88	1.44
Sand Mound Slough	18	12	10	10	0.18	0.16	0.06	0.06	2.87	3.18	3.18	1.11	1.00
Steamboat Slough	22	17	12	7	0.50	0.41	0.26	0.18	2.26	1.94	2.78	1.23	1.43
Stony Gorge Reservoir: Dam	12	3	14	9	0.19	0.24	0.15	0.12	2.05	1.31	1.63	0.80	1.25
Sutter Bypass Below Kirkville Rd.	12	7	8	5	0.38	0.32	0.12	0.11	2.85	3.11	3.42	1.20	1.10
Toe Drain (Propsect Slough)	60	38	15	5	0.39	0.33	0.25	0.27	1.24	1.56	1.47	1.18	0.94
Whiskeytown Lake at Brandy Ck.	14	13	11	9	0.10	0.08	0.07	0.08	1.02	1.29	1.19	1.16	0.92

Geometric Mean					0.29	0.24	0.14	0.12	2.12	2.09	2.54	1.19	1.20
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Table L-4. Estuarine Average Mercury Concentrations by Trophic Level (TL) Category and Ratios

Estuarine Station Name	Number of fish*				Average Mercury Conc. (mg/kg)				Ratios				
	TL4 150 - 500mm	TL4 150 - 350mm	TL3 150 - 500mm	TL3 150 - 350mm	TL4 150 - 500mm	TL4 150 - 350mm	TL3 150 - 500mm	TL3 150 - 350mm	TL4/TL3 150 - 350mm	TL4/ TL3 150 - 500mm	TL4 150 - 500mm / TL3 150- 350mm	TL4 150 - 500mm / TL4 150- 350mm	TL3 150 - 500mm / TL3 150- 350mm
Mission Bay 9170 CFCP	41 (8)	30 (6)	35 (7)	20 (4)	0.14	0.11	0.02	0.03	3.66	6.66	4.47	1.22	0.67
San Diego Bay	57(11)	49 (9)	43 (7)	43 (7)	0.14	0.12	0.10	0.10	1.23	1.45	1.45	1.17	1.00
San Diego Bay/Zuniga Jetty	13 (3)	13 (3)	32 (7)	32 (7)	0.15	0.15	0.09	0.09	1.72	1.70	1.70	0.99	1.00
Geometric Mean					0.14	0.13	0.06	0.06	1.98	2.54	2.22	1.12	0.88

* number of fish including composited fish (number of samples where each composite sample is counted as one sample)

Table L-5.Statewide Trophic Level (TL) Ratios

TL4/TL3 150 - 350mm	TL4/TL3 150 - 500mm	TL4 150 - 500mm / TL3 150-350mm	TL4 150 - 500mm / TL4 150-350mm	TL3 150 - 500mm / TL3 150-350mm
2.11	2.12	2.51	1.18	1.17

Table L-6. Freshwater Water Body Types

Waterbody Type	Number of Stations
Slough, Delta Waterways, Sutter Bypass	11
River	17
Reservoir/Lake	7

L.4 Conclusions

Given the limited data, the estuarine ratios may be a poor representation of bioaccumulation in estuarine conditions. Even the freshwater ratios were limited, since they were predominately from California's Central Valley. Thus the resulting ratios may not be accurate for other areas of California outside the Central Valley. Within the Central Valley the ratio of mercury concentration in trophic level 4 fish compared to trophic level 3 fish (TL3/TL4) was about 2, which matches well with most locations since the ratios for individual sampling stations did not deviate much from this ratio. The ratios derived in this appendix were used in Appendix K to derive the wildlife targets for California.

References

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