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Supporting Material

A Methodology for Ecosystem-Scale Modeling of Selenium

(Ecosystem-Scale Modeling of Selenium)

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ECOSYSTEM-SCALE SELENIUM MODELING: DATA AND REFERENCES

Compilation and Calculation of K_ds and TTFs

Ratios derived here employ dry weight (dw) for media (particulate material and tissue). Datasets are temporally and spatially matched from 52 field studies that included water-column Se concentrations and particulate Se concentrations (Supplemental Table A). The K_ds typical of a variety of ecosystems (e.g., ponds, rivers, estuaries) are given. If a range was reported, a median is listed; if a series of data was reported, a mean is listed.

A compilation of experimental data for invertebrate physiological parameters allowed calculation of kinetic TTFs for invertebrates (particulate to invertebrate) (Supplemental Table B). Additional calculated TTFs from denoted field studies are shown in Supplemental Table C. A compilation of experimental data for fish physiological parameters allowed calculation of kinetic TTFs for fish (invertebrate to fish) (Supplemental Table D). Additional calculated TTFs from denoted field studies (invertebrate to fish except where noted as fish to fish) are shown in Supplemental Table D.

Detailed Data Sets for Field Case Studies Used in Validation

Datasets (in dw) are temporally and spatially matched from 29 field locations (Supplement Tables E and F). Food webs focus on particulate material, invertebrates, and fish (Supplemental Table E) or birds (Supplement Table F). Predicted and observed Se concentrations for invertebrates, fish (whole-body or muscle), and bird eggs are shown. Data collection at most field case studies included all these media phases. Case studies that were not complete still

yielded useful information in either validation of prey or predator Se concentrations. Sites illustrated are those exposed to selenium contamination. However, in three study area investigations (Kesterson Reservoir, McLeod River/Luscar Creek watershed, and the San Joaquin River), sites identified as reference sites are included.

Modeled invertebrate and fish species are identified under food webs (Supplemental Tables E and F). Bioaccumulation data for invertebrates (in dw) from field studies for comparison with biodynamic predictions were available for crustaceans (amphipods, copepods, generic zooplankton, *Daphnia*, crayfish); aquatic insects (mayfly, caddisfly, crane fly, stonefly, damselfly, corixid, chironomid); and freshwater and marine clams (*C. fluminea*; *C. amurensis*, respectively). Bioaccumulation data for fish (in dw) were available for freshwater minnow, sunfish, trout, sucker, catfish, sculpin, perch, silversides; shad; killifish, livebearers (sailfin molly and mosquitofish) and saltwater sturgeon, sargo, talapia, croaker, corvina, topsmelt, halibut, goby, turbot, perch, mullet, and anchovy. Bioaccumulation data for birds were included for coot, stilt, avocet, killdeer, gadwall, teal, mallard, grebe, dipper, sandpiper, scoter, scaup, gull, skimmer, rail, tern, egret, and heron (See main text Tables 3 and 4 and Supplemental Tables B, C, and D for more detailed information on species).

Prediction starts with an observed particulate Se concentration and uses a species-specific $TTF_{\text{invertebrate}}$ (see main text Tables 3 and 4 for details) to predict an invertebrate Se concentration (Supplemental Tables E and F). The type of particulate material that was collected varied among different case studies. Where data were available from multiple types of particulates, concentrations were averaged. In a few cases professional judgment was employed to eliminate unrepresentative particulate data (e.g. to avoid what were obviously sandy sediments or an obvious error in data reduction). Invertebrate Se concentrations are predicted using a subset of

$TTF_{\text{invertebrate}}$ shown in main text Table 3: amphipod, 0.9; zooplankton, 1.5; crayfish, 1.6; aquatic insects, 2.8; brine shrimp, 4.2; brine fly, 1.65; freshwater clam, 2.8; and marine clam 6.25.

Where applicable to a specific species (i.e. for piscivores), an additional factor of 1.1 is applied to an invertebrate Se concentration to represent an interim transfer step of invertebrate to fish for a fish-eating bird or forage fish to predator fish. For the San Francisco Bay-Delta Estuary, an additional factor of 1.35 is applied to represent a food web from particulate material to copepod to mysid to striped bass. In a few cases, data for Se concentrations in diet were used to validate both fish and bird food webs, if, for example, a complete temporally matched data set was not available (e.g., Blackfoot River watershed, southeast Idaho).

Fish Se concentrations are predicted using a TTF_{fish} of 1.1 (see main text Table 3) applied to the predicted invertebrate Se concentrations (Supplemental Table E). If data are available for more than one invertebrate food web, multiple fish concentrations are predicted. Ranges of fish Se concentrations and means of invertebrate and fish species for a site location are given for comparison. As noted in Supplemental Table E, individual identified species-specific food web Se concentrations or grand means of observed invertebrate and fish Se concentrations were used to derive correlations of observed to predicted Se concentrations (see main text Figures 3 and 4).

Bird egg Se concentrations are predicted using a 1.8 TTF_{bird} applied to the predicted invertebrate Se concentration (Supplemental Table E). In complex food webs that consider birds consuming fish, an additional step applying a TTF_{fish} of 1.1 is used.

Sites are noted in Supplemental Tables E and F (e.g., Belews Lake, Kesterson Reservoir) where Se exposure caused die-offs and deformities in fish or high rates of embryonic terata in birds (Skorupa, 1998; Ohlendorf, 2002). Conditions at these sites showed extensive ecosystem exposure and, at sites affecting birds, effects of general Se toxicity or poisoning (e.g.,

emaciation, no nesting, dead adult birds). In modeling, these sites show predicted Se concentrations in tissue of predators above observed Se concentrations. Food avoidance by birds is a documented phenomenon in the laboratory (Heinz and Sanderson, 1990) and at contaminated sites such as Kesterson Reservoir (Ohlendorf, 1996; Ohlendorf et al., 1988). Heinz and Sanderson (1990) state that at 10 to 20 $\mu\text{g/g}$, Se-treated diets were avoided by mallards. Heinz and Fitzgerald (1993) state that high dietary concentrations of Se make birds sick, leading to reduced feeding, and ultimately to severe emaciation and death. Food avoidance by fish in laboratory experiments takes place in about the same range (13-14 $\mu\text{g/g}$) (Hodson et al., 1980; Finley, 1985).

WILDLIFE SELENIUM CRITERIA: EXAMPLE CALCULATION

A reference dose (RfD) for Se can be derived from experimental feeding studies for adult mallards in which effects from maternally ingested Se were measured (Heinz, 1989; Sample et al. (1996)). The measured reproductive endpoint is avian egg hatchability. The example equation

$$\text{RfD} = (4 \mu\text{g/g ww food as selenomethionine}) (0.1 \text{ kg food/day}) \div 1 \text{ kg BW ww} \quad (1)$$

uses a No Observable Effect Level (NOEL) of 4 $\mu\text{g/g}$ (laboratory chow at 10% moisture enriched with selenomethionine), an ingestion rate of 100 g/day, and a Body Weight (BW) of 1 kg. This ingestion rate is 10% of BW because a 1-kg mallard was tested. The derived RfD is 0.400 mg/kg-day or 400 $\mu\text{g/kg-day}$. The USEPA derived an avian tissue residue value (TRV) for Se by combining three endpoints (growth, reproduction, and mortality) for two test species ingesting invertebrates and sediment from terrestrial food webs (USEPA, 2007). The derived avian wildlife TRV for Se is 290 $\mu\text{g/kg-d}$ [highest NOEL lower than lowest bounded Lowest

Observable Effect Level (LOEL) for reproduction, growth or survival], with a geometric mean of NOEL values of 606 $\mu\text{g}/\text{kg}\text{-day}$.

If a Se RfD of 400 $\mu\text{g}/\text{kg}\text{-day}$ is assumed for modeling of effects to birds, then allowable C_{food} for various species of birds can be calculated. Note that uncertainty factors could be applied to adjust the selected RfD downward for a margin of safety as is recommended in 1) a Canadian protocol for wildlife protection [Canadian Council of Ministers of the Environment (CCME), 1999]; and 2) the derivation of fish consumption advisories for humans (USEPA, 2000a). In an example deriving a wildlife criterion for lesser scaup, a bird of similar body weight to mallard of 1 kilogram, the ingestion rate is increased to 0.2 kg (20% of BW) and 0.3 kg (30% of BW) food/d based on increased feeding rates for wild birds. If 10% moisture is assumed in ingested food (similar to laboratory chow), then the calculated allowable C_{food} is 2.0 $\mu\text{g}/\text{g}$ ww and 2.2 $\mu\text{g}/\text{g}$ dw at the lower feeding rate and 1.3 $\mu\text{g}/\text{g}$ ww and 1.5 $\mu\text{g}/\text{g}$ dw at the higher feeding rate. If the hypothetical ingested food is fish with a 75% moist content, then the allowable C_{food} is 2.0 $\mu\text{g}/\text{g}$ ww and 8.0 $\mu\text{g}/\text{g}$ dw at the lower feeding rate and 1.3 $\mu\text{g}/\text{g}$ ww and 5.3 $\mu\text{g}/\text{g}$ dw at the higher feeding rate. In an example derivation for a smaller bird species, if a belted kingfisher weighs 0.148 kg, ingests 50 g fish/d (34% of BW) with a moisture content of 75%, then the allowable C_{food} is

$$(400 \mu\text{g Se}/\text{kg BW}\text{-day}) (0.148 \text{ kg}) \div 12.5 \text{ g dw food}/\text{day} = 4.74 \mu\text{g}/\text{g dw} \quad (2)$$

Thus, to successfully calculate allowable C_{food} , both the % BW ingested and the % moisture in food need to be specified. For watershed evaluation, the allowable C_{food} is used as a dietary target and compared to 1) existing Se concentrations in dietary items of biologically appropriate food webs; or 2) predicted concentrations as a result of food web modeling. Equations can be added to consider mixtures of food (see main text Table 6).

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Supplemental Table A. Water-column Se concentrations, particulate Se concentrations (dw), and calculated K_d s from field studies. If a range was reported, a median is listed; if a series of data was reported, a mean is listed. [a] see example in text; b) means of K_d s, water-column Se, and algae Se]

K_d	Ecosystem	Water-column Se ($\mu\text{g/L}$)	Particulate Se ($\mu\text{g/g dw}$)	Reference
107	San Diego Creek, California	14.4	1.54	Presser and Luoma, 2009
110	Alamo River, California	6.35	0.7	LeBlanc and Schroeder, 2008
122	Fording River, British Columbia, Canada	18	2.2	Harding et al., 2005
146	San Joaquin River, California	11	1.6	Saiki et al., 1993
255	San Diego Creek constructed pond, California	20.4	5.2	Presser and Luoma, 2009
256	New River, California	3.9	1.0	LeBlanc and Schroeder, 2008
269	Tulare Basin, evaporation ponds, California (range 109-500)	2.2-49	0.45-19.4	Moore et al., 1990
272	Upper Newport Bay, California (range 101-776)	0.29-3.5	0.17-0.39	Presser and Luoma, 2009
276	Mud Slough, California	13	3.6	Saiki et al. 1993
340	Benton Lake (pool 2), Montana	10.4	3.5	Zhang and Moore, 1996
346	Luscar Creek, Alberta Canada (range 220-514) ^a	10.7	3.7	Casey, 2005
355	Kesterson Reservoir (SLD/pond 2), California (range 200-500)	330	55-165	Presser and Piper, 1998
359	Salt Slough, California	9.0	3.2	Saiki et al. 1993
494	Sage Creek, Idaho	7.7	3.8	Greater Yellowstone Coalition, 2005; 2006
500	Benton Lake, Montana, pool 5	0.74	0.35	Zhang and Moore, 1996
512	Benton Lake, Montana, pool 1 channel	20.3	10.4	Zhang and Moore, 1996
591	Elk River, British Columbia, Canada	2.2	1.3	McDonald and Stosher, 1998
611	Lower Great Lakes, Lake Ontario	0.18	0.11	Ware, 2008
625	East Allen Reservoir, Wyoming	4.8	3.0	Birkner, 1978
657	Crow Creek at Toner, Idaho	3.5	2.3	Greater Yellowstone Coalition, 2005; 2006
667	Meeboer Lake, Wyoming	0.3	0.2	Birkner, 1978
750	Diamond Lake, Wyoming	0.3	0.225	Birkner, 1978
762	Chevron Marsh (constructed), California (range 214-1241)	5-9.8	2.1-6.7	Hansen and others, 1998
767	Miller's Lake, Colorado	6.0	4.6	Birkner, 1978
784	San Diego Creek constructed marsh, California	2.0	1.6	Presser and Luoma, 2009
818	Mac Mesa Reservoir, Colorado	2.2	1.8	Birkner, 1978
968	Sweitzer Lake, Colorado	9.4	9.1	Birkner, 1978
968	Desert Reservoir, Colorado	12.5	12.1	Birkner, 1978
1,104	Mud River at Spurlock, West Virginia	6.25	6.9	USGS, 2008
1,196	Salton Sea, California	0.92	1.1	California Resources Agency, 2006
1,224	Twin Buttes Reservoir, Wyoming	7.6	9.3	Birkner, 1978
1,312	Galett Lake, Wyoming	0.8	1.05	Birkner, 1978
1,341	Angus Creek, Idaho	0.82	1.1	Greater Yellowstone Coalition, 2005; 2006;

K _d	Ecosystem	Water-column Se (µg/L)	Particulate Se (µg/g dw)	Reference
				Presser et al., 2004
1,388	Lower Great Lakes, Hamilton Harbor	0.67	0.93	Ware, 2008
1,436	Tulare Basin, evaporation ponds, California ^b	8.8	11.8	Fan et al., 2002
1,498	Big Canyon Wash (sites 1 and 2), California	21.5	32.2	Presser and Luoma, 2009
1,579	Cobb Lake, Colorado	3.8	6.0	Birkner, 1978
1,619	Timber Lake, Colorado	2.1	1.3	Birkner, 1978
1,717	Larimer HWY 9 pond, Colorado	15.9	27.3	Birkner, 1978
1,759	Great Salt Lake, Utah	0.54	0.95	Marden, 2008
1,800	Upper Mud River Reservoir at Palermo, West Virginia	3.7	6.7	USGS, 2008
1,818	Crow Creek above Sage Creek, Idaho	0.99	1.8	Greater Yellowstone Coalition, 2005; 2006
1,941	Wellington State Pond, Colorado	1.7	3.3	Birkner, 1978
1,943	Thompson Creek, Idaho	1.75	3.4	GEI Consultants Inc., 2008
2,143	Highline Reservoir, Colorado	4.2	9.0	Birkner, 1978
2,250	Deer Creek, Idaho	1.6	3.6	Greater Yellowstone Coalition, 2005; 2006
2,798	Belews Lake, North Carolina	10.9	30.5	Cumbie, 1984; Lemly, 1985
2,902	Kesterson Reservoir (pond 8), California	41	119	Saiki and Lowe, 1987
3,044	Hyco Reservoir, North Carolina	6 -17	27	Bowie et al., 1996
3,150	Big Canyon Wash (site 3) California	24	75.6	Presser and Luoma, 2009
3,556	Kesterson Reservoir (pond 11), California	9.0	32	Saiki and Lowe, 1987
4,000	Delaware River (tidal freshwater), Delaware	0.17-0.35	0.6-1.5	Riedel and Sanders, 1998
6,500	Great Marsh, Delaware	0.01-0.06	0.3-0.7	Velinsky and Cutter, 1991
7,817	San Francisco Bay, California (1998-1999)	0.114	0.823	Cutter and Cutter 2004; Doblin et al., 2006
9,456	Salton Sea estuary, Alamo River	0.92	8.7	LeBlanc and Schroeder, 2008
11,956	Salton Sea estuary, Whitewater River	0.92	11	LeBlanc and Schroeder, 2008
13,788	Outer San Francisco Bay, California (1998-1999)	0.088	1.20	Cutter and Cutter 2004; Doblin et al., 2006
15,000	Xiamen Bay, Fujian Province, China	0.08	1.2	Liu et al., 1987
17,391	Salton Sea estuary, New River, California	0.92	16	LeBlanc and Schroeder, 2008
21,500	San Francisco Bay (1986;1995-96) (range 3,000-40,000)	0.05-0.4	suspended 0.3-8	Presser and Luoma, 2006
18,942	Lower Newport Bay, California (range 6,933-42,715)	0.07-0.15	1.05-2.98	Presser and Luoma, 2009

Supplemental Table B. Experimental data for invertebrate physiological parameters and calculated kinetic TTFs for invertebrates (particulate to invertebrate in dw). [a] assumed IR; b) chosen from Fowler and Benayoun, 1976; Zhang et al., 1990; and Okazaki and Panietz, 1981; c) calculated from 23 day half-life [efflux (d) = 0.69/half-life (d)], Reinfelder et al., 1997; d) calculated from 52 day half-life; e) calculated from 70 day half-life; f) calculated from 10 day half-life.]

Marine Environments					
Species	AE	IR	ke	TTF (AE X IR/ke)	Reference
copepod (<i>Acartia tonsa</i>)	0.97	0.42 ^a	0.13	3.1	Fisher and Reinfelder, 1991
copepod (<i>Temora longicornis</i>)	0.55	0.42	0.155	2.0	Wang and Fisher, 1998
copepod (<i>A. tonsa</i> ; <i>T. longicornis</i>)	0.8	0.42 ^a	0.19	1.8	Wang et al., 1996b
copepod (<i>Oithona</i> ; <i>Limnoithona</i> ; <i>Tortanus</i> ; <i>Acartia</i> ; <i>T. longicornis</i>)	0.50	0.42	0.155	1.35	Schlekat et al., 2004
mysid (<i>Neomysis mercedis</i>)	0.61-0.73	0.45	0.25	1.1-1.3	Schlekat et al., 2004
amphipod (<i>Leptocheirus plumulosus</i>)	0.45	0.20	0.15	0.6	Schlekat et al., 2004
clam (<i>Corbula amurensis</i>)	0.45-0.80	0.25	0.025	4.5-8.0	Schlekat et al., 2002
clam (<i>C. amurensis</i>)	0.36-0.54	0.25	0.025	3.6-5.4	Lee et al., 2006
clam (<i>Corbicula fluminea</i>) (also freshwater)	0.29-0.81	0.05	0.010	1.45-4.05	Lee et al., 2006
clam (<i>Macoma balthica</i>)	0.22-0.86	0.25	0.012 ^b	11.2 (using mean AE)	Luoma et al., 1992
clam (<i>M. balthica</i>)	0.54 (mean)	0.25	0.030 ^c	4.5	Luoma et al., 1992
clam (<i>Puditapes philippinarum</i>)	0.52-0.70	0.25 ^a	0.013 ^d	10-13.5	Zhang et al., 1990
clam (<i>Mercenaria mercenaria</i>)	0.92	0.25 ^a	0.010 ^e	23	Reinfelder et al., 1997
oyster (<i>Crassostrea virginica</i>)	0.45-0.70	0.25 ^a	0.069 ^f	1.6-2.5	Reinfelder et al., 1997
oyster (<i>Crassostrea rivularis</i>)	0.55	0.45			Ke and Wang, 2001
oyster (<i>Saccostrea glomerata</i>)	0.45	0.32			Ke and Wang, 2001
mussel (<i>Mytilus edulis</i>)	0.31	0.27	0.022	3.8	Wang et al., 1996a
mussel (<i>M. edulis</i>)	0.72	0.27	0.022	8.8	Reinfelder et al., 1997
barnacle (<i>Balanus amphitrite</i>)	0.63-0.79	0.40	0.014	18-22.6	Wang et al., 1999
barnacle (<i>Elminius modestus</i>)	0.34-0.74	0.40	0.0137	9.9-21.6	Rainbow and Wang, 2001
Freshwater Environments					
Species	AE	IR	ke	TTF (AE X IR/ke)	Reference
zebra mussel (<i>Dreissena polymorpha</i>)	0.28-0.46	0.42	0.026	4.5-7.4	Roditi and Fisher, 1999
clam (<i>Corbicula fluminea</i>) (also marine)	0.29-0.81	0.05	0.010	1.45-4.05	Lee et al., 2006

Supplemental Table C. Calculated TTFs from field studies for invertebrates (particulate to invertebrate in dw).

Freshwater Environments		
Invertebrate	Field TTF	Reference
mayfly (Baetidae; Heptageniidae; Ephemerellidae)	2.7	Casey, 2005
caddisfly (Rhyacophilidae; Hydropsychidae)	3.2	Casey, 2005
crane fly (Tipulidae)	2.3	Casey, 2005
stonefly (Perlodidae/Perlidae; Chloroperlidae)	2.6	Casey, 2005
aquatic insect (composite)	3.2	Harding et al, 2005
damselfly (Coenagrionidae)	2.6	Birkner, 1978
midge (<i>Chironomus</i> sp.)	2.7	Birkner, 1978; Saiki et al., 1993
waterboatman (<i>Cenocorixa</i> sp.)	2.14	Birkner, 1978
crayfish (<i>Procambarus clarki</i> ; Astacidae; <i>Orconectes</i> sp.)	1.5	Birkner, 1978; Saiki et al., 1993
<i>Daphnia</i> (<i>Daphnia magna</i>)	1.9	Besser et al., 1989
amphipod (<i>Hyalella azteca</i> ; <i>Gammarus fasciatus</i> ; <i>Corophium</i> spp.)	0.94	Birkner, 1978; Saiki et al., 1993
zooplankton (composite)	1.5	Saiki et al., 1993
Saline or Marine Environments		
Invertebrate	Field TTF	Reference
euphausiid (<i>Meganyctiphanes norvegica</i>)	1.3	Fowler and Benayoun 1976
brine shrimp adult (<i>Artemia franciscana</i>)	4.2	Marden, 2008
brine shrimp nauplius	2.6	Marden, 2008
brine shrimp cysts	2.2	Marden, 2008
brine fly adult (<i>Ephydra gracilis</i>)	1.8	Cavitt, 2007; Wurtzbach, 2007
brine fly larvae	1.5	Cavitt, 2007; Wurtzbach, 2007

Supplemental Table D. Calculated kinetic or field TTFs for fish (invertebrate to fish in dw except where noted as fish to fish in dw). [a] rotifer to larval fish microcosm; b) with assumptions; c) experimental microcosm.]

Fish Species	Kinetic TTF	Field or lab TTF	Experimental Physiological Parameters	Reference
mangrove snapper (<i>Lutjanus argentimaculatus</i>)	1.1		ke 0.031; IR 5%; 69% AE	Xu and Wang, 2002
striped bass (juvenile) (<i>Morone saxatilis</i>)	0.89		ke 0.08; IR 17%; 42% AE	Baines et al., 2002
Chinese mudskipper (<i>Periophthalmus cantonensis</i>)	0.84		ke 0.019; IR 5%; 32% AE	Ni et al., 2005
smooth toadfish (<i>Tetractenos glaber</i>)	0.80		ke 0.015-0.032; assumed IR 7-10%; AE 24%	Alquezar et al., 2007
gilthead sea bream (<i>Sparus auratas</i>)	0.6		ke 0.13; assumed IR 10%; AE 77%	Mathews and Fisher. 2008
sea bass (from bream) (<i>Dicentrarchus labrax</i>)	1.1		ke 0.06; assumed IR 10%; AE 64%	Mathews and Fisher. 2008
fathead minnow ^a (<i>Pimephales promelas</i>)	1.0 ^b		ke 0.025; assumed IR 5%; AE 50%	Bennett et al., 1986
fathead minnow adult	0.71-1.8 ^b		ke 0.014; assumed IR 5%; AE 20-50%	Bertram and Brooks, 1986
bluegill (fry/juvenile) ^c (<i>Lepomis macrochirus</i>)	0.51 ^b		ke 0.035; AE 36% assumed IR 5%	Besser et al., 1993
bluegill (fry/juvenile)	0.61 ^b		ke 0.041; assumed IR 5% AE 50%	Cleveland et al., 1993
bluegill (juvenile)		1.15 (lab)		Lemly, 1993
bluegill		1.06		Saiki et al., 1993
white sturgeon (<i>Acipenser transmontanus</i>)		1.7		Presser and Luoma, 2006
white sturgeon		0.6-1.3 (mean 0.9)		Stewart et al., 2004
yellowfin goby (<i>Acanthogobius flavimanus</i>)		1.2		Stewart et al., 2004
starry flounder (<i>Platichthys stellatus</i>)		1.6		Stewart et al., 2004
leopard shark (<i>Triakis semifasciata</i>)		0.52		Stewart et al., 2004
striped bass		0.8		Stewart et al., 2004
western mosquitofish (<i>Gambusia affinis</i>)		range 0.71-1.8 (mean 1.2)		Saiki et al., 1993
western mosquitofish		1.3		Saiki et al., 2008
largemouth bass		range 0.95-1.1		Saiki et al., 1993

Fish Species	Kinetic TTF	Field or lab TTF	Experimental Physiological Parameters	Reference
(<i>Micropterus salmoides</i>)		(mean 1.0)		
sailfin molly (<i>Poecilia latipinna</i>)		1.4		Saiki et al., 2008
rainbow trout (<i>Oncorhynchus mykiss</i>)		range 0.71-1.1 (mean 0.91)		Casey, 2005
rainbow trout		1.04		Greater Yellowstone Coalition, 2005; 2006; Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
cutthroat trout (<i>Oncorhynchus clarkii</i>)		1.0		McDonald and Stosher, 1998
cutthroat trout from dace		range 0.87-0.99 (mean 0.93)		Greater Yellowstone Coalition, 2005; 2006; Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
cutthroat trout from sculpin		range 0.95-1.0 (mean 0.98)		Greater Yellowstone Coalition, 2005; 2006; Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
cutthroat trout		range 0.97-1.53 (mean 1.25)		Greater Yellowstone Coalition, 2005; 2006; Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
brook trout (<i>Salvelinus fontinalis</i>)		0.77		Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
brown trout (<i>Salmo trutta</i>)		range 1.18-1.45 (mean 1.32)		Greater Yellowstone Coalition, 2005; 2006; Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
mottled sculpin (<i>Cottus bairdi</i>)		range 1.23-1.66 (mean 1.45)		Greater Yellowstone Coalition, 2005; 2006; Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
longnose dace (<i>Rhinichthys cataractae</i>)		range 1.41-1.65 (mean 1.53)		Greater Yellowstone Coalition, 2005; 2006; Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
chub (<i>Gila</i> sp.) (Utah chub is common in Idaho)		range 1.03-1.38 (mean 1.21)		Greater Yellowstone Coalition, 2005; 2006; Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004
reidside shiner (<i>Richardsonius balteatus</i>)		1.5		Greater Yellowstone Coalition, 2005; 2006
mountain whitefish (<i>Prosopium williamsoni</i>)		1.31		Greater Yellowstone Coalition, 2005; 2006
sucker (<i>Catostomus</i> sp.) (Utah and mountain suckers are common in Idaho)		0.97		Greater Yellowstone Coalition, 2005; 2006

Supplemental Table E. Model validation for prediction of invertebrate and fish (whole-body or muscle) Se concentrations. Predicted and observed Se concentrations are shown. If data are available for more than one invertebrate food web, multiple fish concentrations are predicted. Ranges of fish Se concentrations and means of invertebrate and fish species for a site location are given for comparison. As noted below, individual identified species-specific food web Se concentrations or grand means of observed invertebrate and fish Se concentrations were used to derive correlations of observed to predicted Se concentrations (see main text Figures 3 and 4). Additional details of data interpretation are described in the main text. [ND = no data available; ** = die-offs and potential food avoidance by fish; mt whitefish = mountain whitefish; wt mosquitofish = western mosquitofish; CA killifish = California killifish; CA halibut = California halibut; spt sand bass = spotted and bass]

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish (wb or muscle)}	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
Belews Lake** (main reservoir, 1975-1984) North Carolina (Cumbie, 1984; Lemly, 1985) (converted from ww except suspended)	suspended particulate>insect>sunfish, bass	30.5	1.5 2.8 2.8	45.8 85.4 85.4	51 zoo- +phytoplankton 93 insect 54 mollusk 53 crustacean 70 annelid	1.1	94 for insectivores (16 fish species extirpated)	70 bluegill, redear sunfish, warmouth, pumpkinseed 81 largemouth bass (mean 72) (16 species extirpated)
Cienega de Santa Clara, Colorado River Delta (Garcia-Hernandez et al., 2000; 2001)	bed sediment>adult brine shrimp, crayfish>fish	1.6	4.2 1.6	6.7 2.6	5.0 brine shrimp 3.5 crayfish	1.1 1.1	7.4 2.9 (mean 5.2)	8.6 sailfin molly 1.7 largemouth bass 2.1 striped mullet 2.5 common carp (mean 3.7)
Elk Valley, Alexander Creek, British Columbia, Canada (Orr et al., 2006)	sediment, algae>insect>trout	2.7	2.8	7.6	9.6 mayfly 4.5 stonefly 3.4 caddisfly (mean 5.8)	1.1	8.4	4.9 cutthroat trout
Elk Valley, Barns Lake wetland, British Columbia, Canada (Orr et al., 2006)	algae>insect>trout	4.4	2.8	12.3	11.1 mayfly 5.9 crane fly (mean 8.5) 8.2 beetle	ND	ND	
Elk Valley, Elk River (below Michel Creek), British Columbia, Canada (McDonald and Strosher, 1998)	attached algae>benthic invertebrate>trout	1.3	2.8	3.6	4.3 benthic	1.1	4.0	5.3 cutthroat trout 4.2 mt whitefish 4.1 bull trout (mean 4.5)
Elk Valley, Fording River (above Swift Creek), British Columbia, Canada (McDonald and Strosher, 1998)	attached algae>benthic invertebrate>trout	1.6	2.8	4.5	10.7 benthic	1.1	5.0	9.1 cutthroat trout
Elk Valley, Fording River	sediment>insect>trout	8.8	2.8	24.6	18.4 mayfly	1.1	27.1	38.5 cutthroat trout

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish} (wb or muscle)	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
(oxbow), British Columbia, Canada (Orr et al., 2006)					33 caddisfly 28.4 chironomid (mean 26.6)			
Elk Valley, Fording River, British Columbia, Canada (Harding et al., 2005)	particulate>insect	2.2	2.8	6.2 (from below)	7.1 (mayfly, stonefly, caddisfly, crane fly)	ND	ND	See bird case studies
Elk Valley, Fording River, British Columbia, Canada (Kennedy et al., 2000)	particulate>insect >trout	2.2 (from above)	2.8	6.2	ND	1.1	6.8	12.5 cutthroat trout (6.7-41)
Elk Valley, Fording River, British Columbia, Canada (Orr et al., 2006)	sediment, algae> insect>trout	2.9	2.8	8.1	7.1 mayfly 6.9 stonefly 8.9 caddisfly (mean 7.6)	1.1	8.9	8.2 cutthroat trout
Elk Valley, Goddard Marsh, British Columbia, Canada (Orr et al., 2006)	sediment>insect>trout	26	2.8	72.8	42.6, 29.5 dragonfly 165.4 caddisfly 66.6 mayfly (mean 76)	ND	ND	
Elk Valley, Line Creek, British Columbia, Canada (Orr et al., 2006)	sediment, algae> insect>trout	2.15	2.8	6.0	7.3 mayfly 2.7 stonefly 5.4 caddisfly (mean 5.1)	1.1	6.6	7.0 cutthroat trout
Hyc0 Reservoir** (1986-1987) North Carolina (Bowie et al., 1996)	phytoplankton>insect> bluegill	27	2.8	76	70 benthic insects	1.1	84	50 1986 bluegill 70 1987 bluegill mean 60 (38-75% reductions in fish densities)
Illco Pond (1996), Kendrick Reclamation Project, Natrona County, Wyoming (Ramirez and Dickerson, 1999; See et al., 1992)	pondweed>insect	6.6	2.8	18.5	25 composite insect	1.1	20.4	23.4 common carp
Imperial National Wildlife Refuge, Lower Colorado River (Lusk, 1993; Martinez, 1994)	sediment, detritus, aufwuch>clam, crayfish	4.0	2.8 1.6	11.2 6.4	10.5 clam (<i>C. fluminea</i>) (6-26) 7.7 crayfish (2-36)	ND	ND	See bird case studies
Kesterson Reservoir** (1983), pond 2	sediment, algae, detritus>insect>	58	2.8	162	180 dragonfly, damselfly, chironomids	1.1	178	224 wt mosquitofish (other species)

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish (wb or muscle)}	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
(Saiki and Lowe, 1987)	mosquitofish							extirpated)
Kesterson Reservoir** (1983), pond11 (Saiki and Lowe, 1987)	sediment, algae, detritus>insect> mosquitofish	18	2.8	50	41 dragonfly, damselfly, chironomid			
Kesterson Reservoir** (1984), ponds 2, 7, and 11, (Schuler et al., 1990; Ohlendorf and Hothem, 1995)	sediment, diatom,algae> insect>	35.3	2.8	99	18.6 corixid (59-130) 98 damsel (50-160) 69 dragonfly (48-110) 59 beetle (12-110) 102 diptera l(76-180) (72 mean insect)	ND	ND	See bird case studies
Kesterson Reservoir** (1983), (Ohlendorf et al., 1986)	algae>zooplankton, insect> mosquitofish (all other species died)	43.5	1.5 2.8	65 122	85 net plankton 22 corixid 139 chironomid 122 dragonfly 175 damselfly (mean insect 114)	1.1 1.1	71.5 134 (mean 103)	170 wt mosquitofish (115-283) (other species extirpated)
Kesterson Reservoir area reference site (Volta Wasteway), California (Saiki and Lowe, 1987)	sediment>plankton, insect> mosquitofish	0.34	1.4 2.8	0.48 0.95	2.8 net plankton 1.7 damselfly	1.1 1.1	0.53 1.1 (mean 0.79)	1.4 wt mosquitofish
McClellan Lake area (Vulture Lake), northern Saskatchewan, Canada (Muscatello and Janz, 2009)	sediment, algae, net plankton (153 micron)>insect>fish	1.3	2.8	3.6	1.6 chironomid 3.1 caddisfly 1.6 dragonfly (mean 2.1) 0.86 leech 0.52 snail	1.1	4.0	1.3 northern pike 3.4 white sucker 4.2 stickleback 11 burbot (mean 5.0)
McLeod River/Luscar Creek watershed, Alberta, Canada (Casey, 2005)	sediment, biofilm, algae>insect > trout, whitefish	3.7	2.8	10.4	10.1 mayfly 11.8 caddisfly 8.4 craneffly 9.4 stonefly (mean insect 10)	1.1	11	8.9 rainbow trout 14.6 brook trout 8.2 bull trout 11.6 mt whitefish (mean 10.8)
McLeod River/Luscar Creek watershed reference site (Deerlick Creek), Alberta, Canada (Casey, 2005)	sediment, biofilm> insect > trout	0.6	2.8	1.7	6.2 mayfly 3.8 caddisfly 3.3 stonefly 2.4 craneffly (mean insect 3.9)	1.1	1.85	1.8 rainbow trout
Miller's Lake, Colorado (Birkner, 1978)	algae>insect, crayfish> fathead	4.6	2.8 1.6	12.9 7.4	18.8 chironomid 9.9 corixid	1.1 1.1	14.2 8.1	11 fathead minnow (8.7-16.6)

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish (wb or muscle)}	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
					(mean insect 14.4) 11.3 crayfish		(mean 11.2)	
Newport Bay (lower), California (Presser and Luoma, 2009)	particulate> copepod> pelagic fish	2.05	1.5	3.1	ND	1.1	3.4	3.9 CA killifish 2.6 topsmelt 1.5 CA halibut 1.6-2.3 goby 2.2 spt. sandbass 2.7 diamond turbot 2.0 staghorn sculpin 1.2 surfperch (mean 2.5)
Newport Bay (upper), California (Presser and Luoma, 2009)	particulate> mysid, clam>pelagic fish	1.5	0.9 2.8	1.4 4.2	4.8 amphipod 6.1 bivalve 2.9 clam 4.4 mussel (mean 4.5) 8.4 isopod 6.1 crab 6.2 snail	1.1 1.1	3.6 4.6 (mean 4.1)	3.4 topsmelt 3.3 diamond turbot 3.0 anchovy 4.0 CA halibut 5.5 striped mullet 5.8 CA killifish 4.0-5.1 goby 3.2 spt. sand bass 1.6 staghorn sculpin 1.8 surfperch (4.07 mean)
Rasmus Lee Lake** (1994), Kendrick Reclamation Project, Natrona County, Wyoming (Ramirez and Dickerson, 1999; See et al., 1992)	pondweed> insect>	30	2.8	84	93 composite insect	ND	ND	See bird case studies
Red Draw Reservoir, Big Spring, Texas (USEPA 2000b)	periphyton> snail, chironomid> silverside, minnow, killifish	3.1	2.8	8.7	12.4 chironomid 2.2 snail (up to 8.8)	1.1	9.6	11.8 inland silverside (7.0-18) 8.2 sheepshead minnow (5.9-16.3) 8.0 Gulf killifish (4.1-11.7) (mean 9.3)
Salton Sea, California (California Resources Agency, 2006)	sediment, algae> amphipod, corixid	1.1	0.9 2.8	0.99 3.1	1.6 amphipod 2.3 corixid	ND	ND	See bird case studies

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish} (wb or muscle)	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
Salton Sea, California (California Resources Agency, 2006)	sediment, algae> pileworm>fish		6.0 (site specific)	6.6	6.6 pileworm	1.1	7.3	8.1 largemouth bass 8.8 sargo 9-10 redbelly talapia 12 Gulf croaker 12 orangemouth corvina 3.2 channel catfish (mean 8.9)
San Diego Creek watershed (lower San Diego Creek), California (Presser and Luoma, 2009)	particulate> insect, crayfish, clam	2.8	2.8 1.6 2.8	7.8 4.5 7.8	7.5 corixid 5.8 crayfish 7.5 clam 4.9 snail	ND	ND	See bird case studies
San Diego Creek watershed (marsh A), California (Presser and Luoma, 2009)	particulate> insect	2.2	2.8	6.2	5.6 dragonfly 4.2 backswimmer (mean insect 4.9)	ND	ND	
San Diego Creek watershed (marsh B), California (Presser and Luoma, 2009)	particulate> zooplankton, insect, crayfish>fish	5.3	1.5 1.6 2.8	8.0 8.5 14.8	6.8 zooplankton 12.1 crayfish 11 chironomid 11.6 corixid 10.2 dragonfly (10.9 mean insect) 5.3 snail 7.6 freshwater clam	1.1 1.1 1.1	8.8 9.4 16.3 (mean 11.5)	13 mixed fish 10.1 wt mosquitofish 19 common carp (mean 14)
San Francisco Bay-Delta Estuary (1989–1997), California (Presser and Luoma, 2006)	particulate>clam> sturgeon	2.0	6.25	12.5	13.5 (maximum 20) (<i>C. amurensis</i> , in 1995-1997)	1.1	13.8	15 (2-50) white sturgeon in 1989-1990
San Francisco Bay-Delta Estuary (2000-2001), California (Presser and Luoma, 2006)	particulate> copepod>mysid> striped bass	1.0	1.3 and 1.35 (two-steps)	1.8	4.5 zooplankton 2.2 mysid 1.8 amphipod 1.7 isopod 2.2 shrimp	1.1 (from mysid)	2.0	2.0 striped bass
San Francisco Bay-Delta Estuary (2000-2001),	particulate>clam> sturgeon	1.0	6.25	6.2	10.8 (clam, <i>C. amurensis</i>)	1.1	6.8	8.0 white sturgeon

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish (wb or muscle)}	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
California (Presser and Luoma, 2006)								
San Joaquin River at Hills Ferry, California (Saiki et al., 1993)	particulate> amphipod, zooplankton, insect, crayfish >bluegill, bass	1.6	1.5 0.9 2.8 1.6	2.4 1.4 4.5 2.6 (mean 2.7)	4.3 zooplankton 2.8 amphipod 4.1 chironomid 1.9 crayfish (mean 3.3)	1.1	3.0 (based on mean of predicted invertebrates)	2.7 bluegill 2.4 largemouth bass (mean 2.6)
San Joaquin River reference site (at Durham), California (Saiki et al., 1993)	particulate> amphipod, zooplankton, insect, crayfish >bluegill, bass	0.61	1.5 0.9 2.8 1.6	0.92 0.55 1.7 0.98 (mean 1.04)	1.8 zooplankton 1.1 amphipod 1.6 chironomid 1.3 crayfish (1.45 mean)	1.1	1.1 based on mean)	1.9 bluegill 1.7 largemouth bass (mean 1.8)
San Joaquin River reference site (at Lander), California (Saiki et al., 1993)	particulate> amphipod, zooplankton, insect, crayfish >bluegill, bass	0.25	1.5 0.9 2.8 1.6	0.38 0.22 0.70 0.40 (0.42 mean)	1.3 zooplankton 1.3 amphipod 1.0 chironomid 0.74 crayfish (1.1 mean)	1.1	0.46 based on mean)	1.4 bluegill 1.8 largemouth bass (mean 1.6)
San Joaquin River tributary (Mud Slough) California (Saiki et al., 1993)	particulate> amphipod, zooplankton, insect, crayfish >bluegill, bass	3.6	1.5 0.9 2.8 1.6	5.4 3.2 10.1 5.8 (mean 6.1)	4.4 zooplankton 3.7 amphipod 6.9 chironomid 3.2 crayfish (mean 4.6)	1.1	6.7 (based on mean of predicted invertebrates)	4.3 bluegill 4.0 largemouth bass (mean 4.2)
San Joaquin River tributary (Salt Slough) California (Saiki et al., 1993)	particulate> amphipod, zooplankton, insect, crayfish >bluegill, bass	3.2	1.5 0.9 2.8 1.6	4.8 2.9 9.0 5.1 (mean 5.45)	5.4 zooplankton 3.3 amphipod 7.2 chironomid 4.4 crayfish (mean 5.1)	1.1	6.0 ((based on mean of predicted invertebrates)	5.0 bluegill 6.9 largemouth bass (mean 6.0)
Savage River watershed, Blacklick Run (atmospheric) western Maryland (Mason et al., 2000)	periphyton, bryophyte>crayfish insect>sculpin, dace>trout	0.78	1.6 2.8	1.25 2.2	0.89 crayfish 7.8 mayfly 6.2 caddisfly 1.3 cranefly 2.7 stonefly 2.3 dragonfly 2.4 dobsonfly (mean insect 3.8)	1.1 1.1	1.4 2.4 (mean 1.9)	2.0 mottled sculpin 1.3 longnose dace 1.4-1.7 brook trout (mean 1.6)
Savannah River (D-area Power Plant) (coal ash	sediment>insect> chubsucker	20.7	2.8	58	56.9 benthic	1.1	62.6	70.3 lake chubsucker

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish} (wb or muscle)	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
drainage swamp microcosms) South Carolina (Hopkins et al., 2004)								
Sweitzer Lake**, Colorado (Birkner, 1978)	particulate>zooplankton, insect, crayfish >killifish, minnow, mixed fry	9.1	1.5 2.8 1.6	13.6 25.5 14.6	42.5 plankton 45 damselfly 27 chironomid (mean insect 36) 20 crayfish	1.1 1.1 1.1	15 28 16.1 (mean 19.7)	32 plains killifish 26 mixed fry (mean 29) (progressive mortality of 7 species of stocked fish)
Thompson Creek downstream of Thompson Mine, Idaho (GEI Consultants, 2008)	sediment, detritus>insect>sculpin, trout	3.2	2.8	9.0	11.5 insect	1.1	9.9	15.6 slimy sculpin 13.8 cutthroat/ rainbow trout (mean 14.7)
Thompson Creek downstream of Thompson Mine, Idaho (GEI Consultants, 2008)	sediment, detritus>insect>sculpin, trout	6.3	2.8	17.6	13.9 insect	1.1	19.4	11.4 slimy sculpin 7.8 cutthroat/ rainbow trout (mean 9.6)
Thompson Creek downstream of Thompson Mine, Idaho (GEI Consultants, 2008)	sediment, detritus> insect>sculpin, trout	4.3	2.8	12.0	17.9 insect	1.1	13.2	18.9 slimy sculpin 14.0 cutthroat/ rainbow trout (mean 16.4)
Thompson Creek upstream of Thompson Mine, Idaho (GEI Consultants, 2008)	sediment, detritus> insect>sculpin, trout	1.8	2.8	5.0	7.2 insect	1.1	5.5	13.5 slimy sculpin 10.0 cutthroat/ rainbow trout (mean 11.8)
Thompson Creek upstream of Thompson Mine, Idaho (GEI Consultants, 2008)	sediment, detritus> insect>sculpin, trout	2.1	2.8	5.9	9.6 insect	1.1	6.5	10.9 slimy sculpin 7.8 cutthroat/ rainbow trout (mean 9.4)
Tulare Basin Pond** (Sam Andrews), San Joaquin Valley, California (Moore et al., 1990)	sediment, algae> adult brine shrimp, insect, brine fly larvae	4.4	4.2 2.8 1.5	18.5 12.3 6.6	20.6 brine shrimp 8.1 brine fly larvae 7.5 damselfly	ND	ND	See bird case studies
Tulare Basin Pond** (Westfarmers), San Joaquin Valley, California	sediment, algae>adult brine shrimp, brine fly larvae, insect,	5.45	4.2 1.5 2.8	22.9 8.2 15.3	25.5 brine shrimp 21.7 fly larvae 41.1 corixid	ND	ND	See bird case studies

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish} (wb or muscle)	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
(Moore et al., 1990)					80 damselfly (mean insect 61)			
Tulare Basin Pond** (Stone Land Company), California (Moore et al., 1990)	sediment, algae>adult brine shrimp, insect	0.75	4.2 2.8	3.2 2.1	3.4 brine shrimp 2.3 corixid	ND	ND	See bird case studies
Tulare Basin Pond** (Carmel Ranch) San Joaquin Valley, California (Moore et al., 1990)	sediment, algae>adult brine shrimp, insect, brine fly larvae	0.40	4.2 2.8 1.5	1.7 1.1 0.60	3.9 brine shrimp 4.4 brine fly larvae 2.5 corixid	ND	ND	See bird case studies
Twin Buttes Reservoir, Wyoming (Birkner, 1978)	sediment, algae>zooplankton, amphipod, insect> darter, killifish, fathead minnow, mixed fry	9.3	1.5 0.9 2.8	14 8.4 26.0	15.4 plankton 11 amphipod 16 corixid 18 damselfly 34 chironomid (mean insect 23)	1.1 1.1 1.1	15.4 9.2 28.6 (mean 17.7)	42 Iowa darter 22 plains killifish 34 fathead minnow 22 mixed fry (mean 30)
Uncompahgre River watershed, Arizona and Colorado Dry Creek, DRY1 (Butler et al., 1994)	sediment, algae> insect>sucker, dace, chub	2.45	2.8	6.9	NA	1.5	10.4	2.0 bluehead sucker 5.9 flannelmouth sucker 4.9 white sucker 9.7 speckled dace 8.1 roundtail chub (mean 6.1)
Uncompahgre River watershed, Arizona and Colorado Loutsenhizer Arroyo, LZA 1 (Butler et al., 1991; 1994; 1996)	sediment, algae>insect, crayfish> sucker, dace, sunfish	5.5	2.8 1.6	15.4 8.8	26 invertebrates (some insects) 14 crayfish	1.1 1.1	16.9 9.7 (mean 13.3)	9.0 bluehead sucker 17 flannelmouth sucker 28 speckled dace (18 mean) 37 green sunfish (all mean 22.8)
Upper Blackfoot River watershed, southeast Idaho (Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004)	sediment>insect > sculpin, dace	2.5	2.8	7.0	12.1 benthic (some crane fly)	1.1	7.7	7.7 mottled sculpin 9.3 longnose dace (mean 8.5)
Upper Blackfoot River watershed, southeast	sediment>insect> sculpin, dace>	2.5	2.8	7.0	12.1 benthic (some crane fly)	1.1 and	8.5	13.2 cutthroat trout 13.4 brook trout

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g dw)	TTF _{fish (wb or muscle)}	Predicted fish Se (wb or muscle) (µg/g dw)	Mean observed fish Se (wb or muscle) (µg/g dw)
Idaho (Hamilton and Buhl, 2004; 2005; Hamilton et al., 2004)	trout					1.1		(mean 13.3)
Upper Blackfoot River watershed, southeast Idaho (Greater Yellowstone Coalition 2005;2006)	attached algae>insect > sculpin, dace	4.1	2.8	11.4	7.8 (crane fly, caddisfly, dragonfly, mayfly, stonefly, shrimp)	1.1	12.5	11.4 mottled sculpin 15.6 longnose dace (mean 13.5)
Upper Blackfoot River watershed, southeast Idaho (Greater Yellowstone Coalition 2005; 2006)	attached algae>insect> sculpin, dace> trout	4.1	2.8	11.4	7.8 (crane fly, caddisfly, dragonfly, mayfly, stonefly, shrimp)	1.1 and 1.1	13.8	8.6 cutthroat trout 12.6 brown trout (mean 10.6)
Upper Mud Reservoir (left fork), West Virginia (USGS, 2008; West Virginia Department of Environmental Protection, 2009)	suspended material>insect, crayfish, clam	1.7	2.8 1.6 2.8	4.8 2.7 4.8	10.5 dragonfly 5.6 crayfish 17.5 clam 8.5 snail	ND	ND	
Upper Mud Reservoir above Palermo, (right fork) West Virginia [USGS, 2008; West Virginia Department of Environmental Protection (WVDEP), 2009]	suspended material>insect, crayfish, clam>bluegill, green sunfish, crappie	6.7	2.8 1.6 2.8	19.0 10.9 19	16.5 dragonfly 12.1 crayfish 30.7 clam 36.6 snail	1.1	20.9 12.0 29.7 (mean 20.9)	28 bluegill (USGS) 26 bluegill (WVDEP) 20 green sunfish 20.4 crappie (mean 22.1)

Supplemental Table F. Model validation for prediction of invertebrate and bird egg Se concentrations. Predicted and observed Se concentrations are shown. [ND = no data available; max = maximum]; ** = embryonic terata and potential food avoidance; blk-nk stilt = black-necked stilt; red-wg blackbird = red-winged blackbird]

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g, dw)	TTF _{bird egg}	Predicted bird egg Se (µg/g, dw)	Mean observed bird egg Se (µg/g, dw)
Converse County (uranium mine wastewater irrigates grasslands), Wyoming (Ramirez and Rogers, 2002)	soil>grass> grasshopper> blackbird	3.1 soil 12.7 grass			12.8 grasshopper (11-20)	1.8	23.0	17.4 red-wg blackbird (13.2-22)
Elk Valley, Fording River, British Columbia, Canada (Harding et al., 2005)	particulate>insect> dipper, sandpiper	2.2	2.8	6.2	7.1 (mayfly, stonefly, caddisfly, crane fly)	1.8	11.2	8.4 American dipper 7.3 spotted sandpiper
Goose Lake** (1994), Kendrick Reclamation Project, Natrona County, Wyoming (Ramirez and Dickerson. 1999; See et al., 1992)	pondweed>insect>avocet	37.6	2.8	105	52.6 (composite insect)	1.8	189	40.8-111 eared grebe (embryonic terata)
Great Salt Lake, Ogden/Antelope Islands, Utah (Cavitt, 2007; Wurtzbach, 2007)	seston>brine fly larvae> shorebirds	0.95	1.5	1.4	1.4 brine fly larvae 1.7 brine fly adults	1.8	2.5	2.7 American avocet and blk-nk stilt
Great Salt Lake, Utah (Marden, 2008; Conover, 2009)	seston>brine shrimp>gull	0.95	3.0	2.8	2.8 brine shrimp (4.0 adults; 2.4 nauplius; 2.1 cyst)	1.8	5.0	3.0 California gull
Imperial National Wildlife Refuge, Lower Colorado River (Lusk, 1993; Martinez, 1994)	particulate>crayfish, clam> bird	4.0	1.6 2.8	6.4 11.2	7.7 crayfish (2-36) 10.5 clam (<i>C. fluminea</i>) (6-26)	1.8	20.2 11.5	5.2 l. lesser nighthawk 8.7 green heron (developing eggs) 10.3; 8.6 green heron 9.9 pied-billed grebe 8.7 least bittern
Kesterson Reservoir** (1984) (ponds 2, 7, and 11), California (Schuler et al., 1990; Ohlendorf and Hothem, 1995)	particulate>insect> aquatic and terrestrial birds (grebes and coots not nesting)	35.3	2.8	99	98 damselfly 69 dragonfly 59 adult beetle 102 diptera larvae 19 corixid	1.8	178	25 blk-nk stilt (max 64) 16 American avocet (max 61) 33 killdeer (max 50) 21 gadwall (max 26) 14 cinnamon teal (max 37) 10 mallard (max 19) 15 western meadowlark (24) 6 tri-color blackbird (max 9.6)

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g, dw)	TTF _{bird egg}	Predicted bird egg Se (µg/g, dw)	Mean observed bird egg Se (µg/g, dw)
								4.4 cliff swallow (max 9) (embryonic terata)
Kesterson Reservoir** (1983), California (Ohlendorf et al., 1986)	algae, plants>insect>grebe, coot, duck, stilt (grebes and coots not nesting)	43.5	1.4 2.8	61 122	85 net plankton 22 corixid 139 chironomid 122 dragonfly 175 damselfly	1.8	220	81 eared grebe(72-110) 54 American coot (34-110) 9.9 duck (mallard, northern pintail, cinnamon teal, gadwall) (2.2-46) 32.7 blk-nk stilt (12-74) (embryonic terata)
Kesterson Reservoir area reference site (Volta Wildlife Area) (Ohlendorf et al., 1986)	plankton>insect>grebe, duck, stilt, avocet				2.0 net plankton 1.7 insects	1.8	3.6 3.1 (mean 3.4)	1.9 eared grebe 1.2 mallard 0.84 gadwall 1.6 blk-nk stilt 1.4 American avocet
Newport Bay (upper), California (Presser and Luoma, 2009)	particulate> copepod, amphipod>avocet, stilt, killdeer, rail	0.20 1.5	1.4	0.28 2.1		1.8	0.50 3.8	5.3 American avocet 5.1 blk-nk stilt 2.6 killdeer 3.7 clapper rail
Newport Bay (upper), California (Presser and Luoma, 2009)	particulate> copepod, amphipod>topsmelt>tern, skimmer, grebe	0.20 1.5	1.4 and 1.1 1.4 and 1.1 (two-steps)	0.31 2.3		1.8 1.8	0.56 4.2	4.4 least tern 3.1 black skimmer 5.8 pied-billed grebe
Rasmus Lee Lake** (1994), Kendrick Reclamation Project, Natrona County, Wyoming (Ramirez and Dickerson. 1999; See et al., 1992)	pondweed>insect>avocet	30	2.8	84	93 composite insect	1.8	167	85.9 American avocet (embryonic terata)
Salton Sea, California (California Resources Agency, 2006)	particulate>amphipod, insect, pileworm>bird	1.1	0.6 2.8 7.4	0.66 3.1 8.1	1.6 amphipod 2.3 corixid 6.6 pileworm	1.8	2.9 5.6 11.9	2.8 Caspian tern 3.6 white-faced ibis 5.3 snowy egret 6.0 black skimmer 6.3 great egret 6.7 night heron
Salton Sea, California (California Resources Agency, 2006)	particulate>insect>fish>bird	1.1	2.8 and 1.1 (two-steps)	3.4	8.1 largemouth bass 8.8 sargo 9-10 redbelly	1.8	6.1	2.8 caspian tern 3.6 white-faced ibis 5.3 snowy egret 6.0 black skimmer

Location	Food Web	Mean observed particulate Se (µg/g dw)	TTF _{invertebrate}	Predicted invertebrate Se (µg/g dw)	Mean observed invertebrate Se (µg/g, dw)	TTF _{bird egg}	Predicted bird egg Se (µg/g, dw)	Mean observed bird egg Se (µg/g, dw)
					talapia 12 Gulf croaker 12 orangemouth corvina 3.2 channel catfish			6.3 great egret 6.7 night heron
San Diego Creek watershed (lower San Diego Creek), California (Presser and Luoma, 2009)	particulate> insect, crayfish, clam> avocet, stilt, killdeer, grebe, coot	1.2	1.6 2.8 2.8	1.9 3.4	7.5 corixid 5.8 crayfish 4.9 snail 7.5 clam	1.8	3.4 6.1	2.8 American avocet 6.9 blk-nk stilt 9.5 killdeer 5.8 pied-billed grebe 5.2 American coot
Tulare Basin Pond** (Sumner Peck), California (Moore et al., 1990)	particulate>brine shrimp	6.0	2.8 4.2	16.8 25.2	54.2 brine shrimp 100 damselfly 250 fly larvae 25.7 beetle 43.9 corixid	1.8	45.4	60 American avocet 67 blk-nk stilt (embryonic terata)
Tulare Basin Pond** (Westfarmers), California (Moore et al., 1990)	particulate>brine shrimp> shorebird, grebe	5.45	2.8 4.2	15.3 22.9	25.5 brine shrimp 80 damselfly 21.7 fly larvae 41.1 corixid	1.8	41.2	20.8 American avocet 28 blk-nk stilt 74 eared grebe (embryonic terata)
Upper Blackfoot River watershed, southeast Idaho (Ratti et al., 2006)	sediment>insect> bird				7.8 (assumed from Greater Yellowstone Coalition data; see Supplemental Table E)	1.8	14	10.7 common snipe 8.6 American coot 8.1 killdeer 8.1 eared grebe 8.0 cinnamon teal 8.0 mountain bluebird 7.2 red-wg blackbird 7.2 yellow-headed blackbird 6.9 marsh wren 6.7 western grebe plus other species