

APPENDIX 2: UPDATED TOXICITY DATABASES

Appendix 2 Table 1.1: Updated aluminum acute toxicity database

Species	Common name	Method ^a	pH	Hardness (mg/L as CaCO ₃)	Acute value (µg total Al/L)	Normalized acute value (µg total Al/L)	SMAV	Reference	Slope?
<i>Acroneuria</i> sp.	stonefly	S,M	7.46	47.4	> 22,600	> 23,628	> 23,628	Call 1984	
<i>Asellus aquaticus</i>	isopod	S,U	6.75	50	4,370	4,370	4,370	Martin and Holdich 1986	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.42	50	1,900	1,900		McCauley et al. 1986	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.86	50	1,500	1,500		McCauley et al. 1986	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	8.13	50	2,560	2,560		McCauley et al. 1986	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.5	26	720	1,241		ENSR 1992a	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.6	46	1,880	2,015		ENSR 1992a	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.8	96	2,450	1,423		ENSR 1992a	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	8.1	194	> 99,600	> 32,206		ENSR 1992a	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.6	98.5	2,880	1,638	2,466	Soucek et al. 2001	
<i>Ceriodaphnia</i> sp.	cladoceran	S,M	7.36	47.4	2,300	2,405		Call 1984	
<i>Ceriodaphnia</i> sp.	cladoceran	S,M	7.68	47.4	3,690	3,858	3,046	Call 1984	
<i>Crangonyx pseudogracilis</i>	amphipod	S,U	6.75	50	9,190	9,190	9,190	Martin and Holdich 1986	
<i>Cyclops viridis</i>	copepod	S,U	6.9	--	> 27000*	--	--	Storey et al. 1992	
<i>Daphnia magna</i>	cladoceran	S,M	7.05	220	38,200	11,124		Kimball, manuscript	Y
<i>Daphnia magna</i>	cladoceran	S,M	7.61	45.4	> 25,300	> 27,417		Brooke et al. 1985	
<i>Daphnia magna</i>	cladoceran	S,U	7	45.3	3,900	4,234	10,890	Biesinger and Christensen 1972	Y
<i>Dugesia tigrina</i>	flatworm	S,M	7.48	47.4	> 16,600	> 17,355	> 17,355	Brooke et al. 1985	
<i>Gammarus pulex</i>	amphipod	S,U	6.9	--	> 2700*	--	--	Storey et al. 1992	
<i>Gammarus pseudolimnaeus</i>	amphipod	S,M	7.53	47.4	22,000	23,000	23,000	Call 1984	
<i>Physa</i> sp.	snail	S,M	7.46	47.4	55,500	58,024		Call 1984	
<i>Physa</i> sp.	snail	S,M	6.59	47.4	> 23,400	> 24,464		Call 1984	
<i>Physa</i> sp.	snail	S,M	7.55	47.4	30,600	31,991		Call 1984	
<i>Physa</i> sp.	snail	S,M	8.17	47.4	> 24,700	> 25,823	> 32,907	Call 1984	
<i>Tanytarsus dissimilis</i>	midge	S,U	7.1-6.8	17.43	> 79,900	> 192,155	> 192,155	Lamb and Bailey 1981	
<i>Tubifex tubifex</i>	worm	R,U	7.6	245	50,230	13,373	13,373	Khargarot 1991	
<i>Hybognathus amarus</i>	Rio Grande silvery minnow	S,M	8.1	140	> 59,100	> 25,075	> 25,075	Buhl 2002	
<i>Ictalurus punctatus</i>	channel catfish	S,M	7.54	47.4	> 47,900	> 50,078	> 50,078	Call 1984	
<i>Lepomis cyanellus</i>	green sunfish	S,M	7.55	47.4	> 50,000	> 52,274	> 52,274	Call 1984	
<i>Micropterus dolomieu</i>	smallmouth bass	S,M	7.5	12.45	> 1,000	> 3,183	> 3,183	Kane and Rabeni 1987	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,U	7	1	3,800	98,745		Tomsen et.al 1988	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	R,U	7	150	71,000	28,442		Tomsen et.al 1988	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	S,M	6.59	47.4	7,400	7,736		Call 1984	
<i>Oncorhynchus mykiss</i>	rainbow trout	S,M	7.31	47.4	14,600	15,264		Call 1984	
<i>Oncorhynchus mykiss</i>	rainbow trout	S,M	7.46	47.4	8,600	8,991		Call 1984	
<i>Oncorhynchus mykiss</i>	rainbow trout	S,M	8.17	47.4	> 24,700	> 25,823		Call 1984	

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Species	Common name	Method ^a	pH	Hardness (mg/L as CaCO ₃)	Acute value (µg total Al/L)	Normalized acute value (µg total Al/L)	SMAV	Reference	Slope?
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	7.6	25	> 8,000	> 14,248		Gundersen et al. 1994	
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	7.6	45	> 8,000	> 8,734		Gundersen et al. 1994	
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	7.6	85	> 8,000	> 5,143		Gundersen et al. 1994	
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	7.6	125	> 8,000	> 3,730		Gundersen et al. 1994	
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	8.25	23.2	6,170	11,694		Gundersen et al. 1994	
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	8.25	35	6,170	8,304		Gundersen et al. 1994	
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	8.29	83.6	7,670	4,999		Gundersen et al. 1994	
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	8.29	115.8	6,930	3,444	10,835	Gundersen et al. 1994	
<i>Oncorhynchus tshawytscha</i>	chinook salmon	S,M	7	28	> 40,000	> 64,825	> 64,825	Peterson et al. 1974	
<i>Perca flavescens</i>	yellow perch	S,M	7.55	47.4	> 49,800	> 52,064	> 52,064	Call 1984	
<i>Pimephales promelas</i>	fathead minnow	S,M	8.1	140	> 59,100	> 25075*		Buhl 2002	
<i>Pimephales promelas</i>	fathead minnow	S,M	7.34	220	35,000	10,192		Kimball, mss.	Y
<i>Pimephales promelas</i>	fathead minnow	S,M	7.61	47.4	> 48,200	> 50,392		Call 1984	
<i>Pimephales promelas</i>	fathead minnow	S,M	8.05	47.4	> 49,800	> 52,064		Call 1984	
<i>Pimephales promelas</i>	fathead minnow	S,U	7.6	--	> 18,900	--		Boyd 1979	
<i>Pimephales promelas</i>	fathead minnow	S,M	7.8	26	1,160	2,000		ENSR 1992b	Y
<i>Pimephales promelas</i>	fathead minnow	S,M	7.6	46	8,180	8,768		ENSR 1992b	Y
<i>Pimephales promelas</i>	fathead minnow	S,M	8.1	96	20,300	11,792		ENSR 1992b	Y
<i>Pimephales promelas</i>	fathead minnow	S,M	8.1	194	44,800	14,486	13,461	ENSR 1992b	Y
<i>Salmo salar</i>	atlantic salmon	S,M	6.5	6.8	599	3,154	3,154	Hammilton and Haines 1995	
<i>Salvelinus fontinalis</i>	brook trout	F,M	6.5	--	3,600	--	--	Decker and Menendez 1974	

^a S=static, F=flow through, R=renewal, M=measured, U=unmeasured

^b Slope value 0.8327 was used to normalize toxicity values to a hardness of 50 mg/L of CaCO₂

Appendix 2 Table 1.2: Updated aluminum chronic toxicity database

Species	Common name	Test ^a	Durration	pH	Hardness (mg/L as CaCO ₃)	NOEC	LOEC	Chronic Value (ug total Al/L)	Normalized Chronic Value ^b	SMCV	reference
<i>Ceriodaphnia dubia</i>	cladoceran	LC	7d	7.3	50	1400	2600	1908	1908		McCouley et.al. 1986
<i>Ceriodaphnia dubia</i>	cladoceran	LC	7d	7.75	50	1100	2400	1624	1624*		McCouley et.al. 1986
<i>Ceriodaphnia dubia</i>	cladoceran	LC	8d	7.55	47.4	6250	12100	8696.3	9092	4165	Call 1984
<i>Daphnia magna</i>	cladoceran	LC	--	8.3	220	540	1020	742.2	216		Kimball manuscript
<i>Daphnia magna</i>	cladoceran	LC	28d	7.74	45.3	--	--	320 ^x	347		Biesinger and Christenson 1972
<i>Daphnia magna</i>	cladoceran	LC	28d	7.74	45.3	--	--	1400 ^y	1520*	274	Biesinger and Christenson 1972
<i>Micropterus dolomieu</i>	smallmouth bass	ELS	30d	7.3	12.8	0	250	< 250	< 777	777	Kane and Rabeni 1987
<i>Oncorhynchus mykiss</i>	rainbow trout	ELS	45d	8	82.4	52	520	164.44*	109*		Everhart et. al. 1973
<i>Oncorhynchus mykiss</i>	rainbow trout	ELS	45d	6.8	82.4	0	520	< 520*	< 343*		Everhart et. al. 1973
<i>Oncorhynchus mykiss</i>	rainbow trout	ELS	16d	7.94-8.10	103	--	--	3910 ^{z*}	2142*		Gunderson et.al. 1994
<i>Oncorhynchus mykiss</i>	rainbow trout	ELS	16d	7.97-8.14	20.3	--	--	1940 ^{c*}	4109*	757*	Gunderson et.al. 1994
<i>Pimephales promelas</i>	fathead minnow	ELS	--	7.24-8.15	220	2300	4700	3288	957	957	Kimball manuscript
<i>Salmo salar</i>	atlantic salmon	ELS	30d	6.5	8.6	4700	200	< 200*	< 866*		Hamilton and Haines 1995
<i>Salmo salar</i>	atlantic salmon	ELS	21d	7.4	5.9	350	>350	> 350*	> 2075*	1341*	Poleo and Hytterod 2003
<i>Salvelinus fontinalis</i>	brook trout	ELS	60d	6.5	7.5	88	169	122	587		Cleveland et. al. 1989
<i>Salvelinus fontinalis</i>	brook trout	ELS	60d	7.2	12.5	303.9	>303.9	> 303.9	964		Cleveland 1991
<i>Salvelinus fontinalis</i>	brook trout	ELS	60d	6.5	7.5	169	350	243.21	1180		Cleveland manuscript
<i>Salvelinus fontinalis</i>	brook trout	ELS	60d	6.5	12.5	57	88	70.82	225		Cleveland manuscript
<i>Salvelinus fontinalis</i>	brook trout	ELS	60d	7.81	0.567	0	300	< 300*	< 11795	624	Hunn et.al. 1987
<i>Tanytarsus dissimilis</i>	midge	LC	55d	6.8	17.43	10000	80000	28284	68021	68021	Lamb and Bailey 1981

^aELS=early life-stage, LC=life cycle

^x EC₁₆ for reduced reproduction

^y 21 day LC₅₀

^z 16 day LC₅₀

* value/species not used to derive chronic criteria

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Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Actinonaias pectorosa</i>	pheasantshell mussel	25.0	8.00	9.2448	0.25	4.57	3.76	3.76	10.38	Augsburger et al. 2003
<i>Actinonaias pectorosa</i>	pheasantshell mussel	25.0	8.00	9.2448	0.92	17.07	14.06	14.05		Augsburger et al. 2003
<i>Actinonaias pectorosa</i>	pheasantshell mussel	25.0	7.90	9.2448	0.74	--	17.06	14.15		Keller et al. 2000 (unpublished)
<i>Actinonaias</i> sp.	mussel	25.0	7.95	9.2448	0.83	--	17.09	15.55		Keller et al. 2000 (unpublished)
<i>Skwala americana</i>	stonefly	13.8	7.76	9.6021	2.06	145.27	119.63	77.18	77.10	Thurston et al. 1984
<i>Skwala americana</i>	stonefly	13.1	7.81	9.6254	2.00	132.73	109.31	77.03		Thurston et al. 1984
<i>Caecidotea racovitzai</i>	isopod	4.0	8.00	9.9384	4.95	434.47	357.80	357.60	165.94	Arthur et al. 1987
<i>Caecidotea racovitzai</i>	isopod	22.0	7.80	9.3379	5.09	180.72	148.83	103.02		Arthur et al. 1987
<i>Caecidotea racovitzai</i>	isopod	11.9	7.81	9.6655	2.94	213.72	176.01	124.02		Thurston et al. 1983a, as in EPA 1999
<i>Baetis rhodani</i>	mayfly	13.1	8.15	9.6254	8.20	253.20	208.52	277.70	94.19	Khatami et al. 1998
<i>Baetis rhodani</i>	mayfly	13.1	8.15	9.6254	8.20	253.20	208.52	277.70		Khatami et al. 1998
<i>Baetis rhodani</i>	mayfly	13.1	8.15	9.6254	0.32	9.88	8.14	10.84		Khatami et al. 1998
<i>Callibaetis skokianus</i>	mayfly	10.8	7.70	9.7026	3.15	320.02	263.55	153.36	164.08	Arthur et al. 1987
<i>Callibaetis skokianus</i>	mayfly	13.3	7.90	9.6187	4.82	257.02	211.66	175.56		Arthur et al. 1987
<i>Callibaetis</i> sp.	mayfly	11.9	7.81	9.6655	1.80	130.85	107.76	75.93	75.93	Thurston et al. 1984
<i>Ceriodaphnia acanthina</i>	cladoceran	24.0	7.60	9.2756	0.70	33.68	27.73	13.68	13.68	Mount 1982
<i>Ceriodaphnia dubia</i>	cladoceran	25.0	8.00	9.2448	1.54	28.60	23.55	23.54	22.17	Bailey et al. 2001
<i>Ceriodaphnia dubia</i>	cladoceran	25.0	8.00	9.2448	1.36	25.26	20.80	20.79		Bailey et al. 2001
<i>Ceriodaphnia dubia</i>	cladoceran	25.0	8.00	9.2448	1.22	22.66	18.66	18.65		Bailey et al. 2001
<i>Ceriodaphnia dubia</i>	cladoceran	25.0	8.00	9.2448	1.01	18.76	15.45	15.44		Bailey et al. 2001
<i>Ceriodaphnia dubia</i>	cladoceran	25.0	8.00	9.2448	1.54	28.60	23.55	23.54		Bailey et al. 2001
<i>Ceriodaphnia dubia</i>	cladoceran	25.0	8.00	9.2448	1.22	22.66	18.66	18.65		Bailey et al. 2001
<i>Ceriodaphnia dubia</i>	cladoceran	25.0	8.00	9.2448	1.36	25.26	20.80	20.79		Bailey et al. 2001
<i>Ceriodaphnia dubia</i>	cladoceran	25.0	8.00	9.2448	1.01	18.76	15.45	15.44		Bailey et al. 2001
<i>Ceriodaphnia dubia</i>	cladoceran	23.0	7.85	9.3067	1.56	--	46.21	34.98		Sarda 1994
<i>Ceriodaphnia dubia</i>	cladoceran	23.0	7.85	9.3067	1.84	--	54.50	41.26		Sarda 1994
<i>Crangonyx pseudogracillis</i>	amphipod	24.9	8.00	9.2479	1.63	30.48	25.10	25.08	83.19	Arthur et al. 1987
<i>Crangonyx pseudogracillis</i>	amphipod	4.0	8.00	9.9384	2.76	242.25	199.50	199.39		Arthur et al. 1987
<i>Crangonyx pseudogracillis</i>	amphipod	13.3	8.00	9.6187	3.29	140.03	115.32	115.25		Arthur et al. 1987
<i>Crangonyx pseudogracillis</i>	amphipod	13.0	8.20	9.6287	3.56	99.09	81.60	119.73		Arthur et al. 1987
<i>Crangonyx pseudogracillis</i>	amphipod	12.1	8.00	9.6588	5.63	262.25	215.97	215.85		Arthur et al. 1987
<i>Crangonyx pseudogracillis</i>	amphipod	12.0	7.50	9.6621	0.36	--	52.65	22.24		Prenter et al. 2004
<i>Crangonyx</i> sp.	amphipod	12.0	7.68	9.6621	2.05	198.79	163.71	92.10	92.10	Diamond et al. 1993
<i>Daphnia magna</i>	cladoceran	19.6	7.68	9.4137	1.17	64.65	53.24	29.95	35.24	Diamond et al. 1993
<i>Daphnia magna</i>	cladoceran	19.7	8.34	9.4105	4.94	63.05	51.92	100.02		Reinbold and Pescitelli 1982a
<i>Daphnia magna</i>	cladoceran	25.0	8.20	9.2448	2.08	25.14	20.71	30.38		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	22.0	7.95	9.3379	2.45	62.30	51.30	46.68		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	19.6	8.07	9.4137	2.69	62.04	51.09	58.33		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	20.9	8.09	9.3725	2.50	50.41	41.51	49.25		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	22.0	8.15	9.3379	2.77	45.46	37.44	49.86		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	22.8	8.04	9.3129	2.38	46.99	38.70	41.73		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	20.1	7.51	9.3978	0.75	58.67	48.32	20.72		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	20.1	7.53	9.3978	0.90	67.28	55.41	24.49		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	20.6	7.40	9.3819	0.53	51.37	42.31	15.48		Russo et. al 1985, as in EPA 1999
<i>Daphnia magna</i>	cladoceran	20.3	7.50	9.3914	0.67	52.85	43.52	18.39		Russo et. al 1985, as in EPA 1999
<i>Daphnia pulicaria</i>	cladoceran	14.0	8.10	9.5955	1.16	37.46	30.85	37.31	37.31	DeGraeve et al. 1980
<i>Dendrocoelom lacteum</i>	flatworm	18.0	8.20	9.4649	1.40	27.17	22.37	32.82	32.82	Stammer 1953, as in EPA 1999
<i>Ephemera grandis</i>	mayfly	12.8	7.84	9.6354	4.96	314.59	259.07	192.64	189.16	Thurston et al. 1984

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Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Ephemera grandis</i>	mayfly	12.0	7.85	9.6621	5.88	387.39	319.03	241.54		Thurston et al. 1984
<i>Ephemera grandis</i>	mayfly	13.2	7.84	9.6220	3.86	237.53	195.62	145.46		Thurston et al. 1984
<i>Erythronna najas</i>	damsel	25.0	7.52	9.2448	10.42	563.40	463.98	202.02	308.62	Beketov 2002
<i>Erythronna najas</i>	damsel	25.0	8.70	9.2448	37.80	170.34	140.28	534.71		Beketov 2002
<i>Erythronna najas</i>	damsel	25.0	9.14	9.2448	22.14	50.33	41.44	323.90		Beketov 2002
<i>Erythronna najas</i>	damsel	25.0	7.43	9.2448	12.45	825.30	679.66	259.28		Beketov 2002
<i>Fusconaia masoni</i>	Atlantic pigtoe mussel	25.0	7.60	9.2448	0.07	3.29	2.71	1.34	1.34	Black 2001
<i>Gammarus pulex</i>	amphipod	12.0	7.50	9.6621	1.54	--	225.82	95.40	95.40	Prenter et al. 2004
<i>Helisoma trivolvis</i>	snail	22.0	7.90	9.3379	2.04	57.95	47.73	39.58	60.84	Arthur et al. 1987
<i>Helisoma trivolvis</i>	snail	12.9	8.20	9.6320	2.76	77.39	63.73	93.52		Arthur et al. 1987
<i>Hyalella azteca</i>	amphipod	23.0	7.85	9.3067	2.08	--	61.61	46.64	51.34	Sarda 1994
<i>Hyalella azteca</i>	amphipod	23.0	7.85	9.3067	2.52	--	74.64	56.51		Sarda 1994
<i>Lampsilis cardium</i>	plain pocketbook mussel	20.5	8.20	9.3851	1.86	30.37	25.01	36.69	22.14	Newton et al. 2003
<i>Lampsilis cardium</i>	plain pocketbook mussel	21.2	8.20	9.3630	1.94	30.11	24.79	36.38		Newton et al. 2003
<i>Lampsilis cardium</i>	plain pocketbook mussel	21.3	8.10	9.3599	0.80	15.38	12.67	15.32		Newton et al. 2003
<i>Lampsilis cardium</i>	plain pocketbook mussel	21.0	7.90	9.3693	0.56	17.20	14.16	11.75		Newton et al. 2003
<i>Lampsilis fasciola</i>	wavy-rayed lampmussel	12.6	7.83	9.6420	0.32	21.10	17.38	12.69	9.55	Mummert et al. 2003
<i>Lampsilis fasciola</i>	wavy-rayed lampmussel	12.6	7.83	9.6420	0.24	16.10	13.26	9.68		Mummert et al. 2003
<i>Lampsilis fasciola</i>	wavy-rayed lampmussel	12.6	7.83	9.6420	0.23	15.40	12.68	9.26		Mummert et al. 2003
<i>Lampsilis fasciola</i>	wavy-rayed lampmussel	12.6	7.83	9.6420	0.25	16.50	13.59	9.92		Mummert et al. 2003
<i>Lampsilis fasciola</i>	wavy-rayed lampmussel	20.6	7.96	9.3819	0.54	14.90	12.27	11.38		Mummert et al. 2003
<i>Lampsilis fasciola</i>	wavy-rayed lampmussel	20.6	7.96	9.3819	0.28	7.74	6.37	5.91		Mummert et al. 2003
<i>Lampsilis siliquoidea</i>	fatmucket mussel	24.0	8.30	9.2756	0.09	0.95	0.78	1.39	2.43	Myers-Kinzie 1998
<i>Lampsilis siliquoidea</i>	fatmucket mussel	24.0	8.30	9.2756	0.28	2.90	2.39	4.26		Myers-Kinzie 1998
<i>Lasmigona subviridis</i>	green floater mussel	24.0	7.70	9.2756	0.13	5.20	4.28	2.49	2.82	Black 2001
<i>Lasmigona subviridis</i>	green floater mussel	24.0	7.70	9.2756	0.13	5.20	4.28	2.49		Black 2001
<i>Lasmigona subviridis</i>	green floater mussel	25.0	8.00	9.2448	0.24	4.38	3.61	3.61		Black 2001
<i>Lestes sponsa</i>	dragonfly	25.0	7.54	9.2448	7.30	377.27	310.69	139.48	139.48	Beketov 2002
<i>Medionidus conradicus</i>	cumberland moccasinshell mussel	25.0	8.00	9.2448	0.29	5.44	4.48	4.47	4.47	Augsburger et al. 2003
<i>Musculium transversum</i>	finger nail clam	5.4	8.20	9.8889	0.93	46.36	38.18	56.02	35.65	Arthur et al. 1987
<i>Musculium transversum</i>	finger nail clam	20.5	8.60	9.3851	1.10	7.81	6.43	20.38		Arthur et al. 1987
<i>Musculium transversum</i>	finger nail clam	14.6	8.10	9.5757	1.29	39.86	32.83	39.70		Arthur et al. 1987
<i>Orconectes immunis</i>	crayfish	17.1	7.90	9.4940	14.72	592.65	488.07	404.82	770.46	Arthur et al. 1987
<i>Orconectes immunis</i>	crayfish	4.6	8.20	9.9171	22.84	1213.54	999.38	1,466.35		Arthur et al. 1988
<i>Orconectes nais</i>	crayfish	26.5	8.30	9.1990	3.15	28.12	23.15	41.27	41.27	Evans 1979, as in EPA 1999
<i>Phylarctus quaeris</i>	crayfish	21.9	7.80	9.3410	10.07	360.05	296.51	205.25	282.09	Arthur et al. 1987
<i>Phylarctus quaeris</i>	crayfish	13.3	7.80	9.6187	10.17	680.08	560.07	387.70		Arthur et al. 1987
<i>Physa gyrina</i>	snail	4.0	8.00	9.9384	1.59	139.56	114.93	114.87	74.48	Arthur et al. 1987
<i>Physa gyrina</i>	snail	24.9	8.00	9.2479	1.71	31.97	26.33	26.32		Arthur et al. 1987
<i>Physa gyrina</i>	snail	13.3	8.00	9.6187	1.78	75.76	62.39	62.36		Arthur et al. 1987
<i>Physa gyrina</i>	snail	5.5	8.20	9.8854	2.09	103.37	85.13	124.90		Arthur et al. 1987
<i>Physa gyrina</i>	snail	12.8	8.00	9.6354	2.16	95.44	78.60	78.56		Arthur et al. 1987
<i>Physa gyrina</i>	snail	12.1	8.10	9.6588	2.49	92.64	76.29	92.27		Arthur et al. 1987
<i>Procamberus clarkii</i>	crayfish	20.0	7.68	9.4010	1.21	64.85	53.41	30.05	30.05	Diamond et al. 1993
<i>Pyganodon grandis</i>	giant floater mussel	25.0	7.50	9.2448	0.20	11.16	9.19	3.88	4.70	Scheller 1997
<i>Pyganodon grandis</i>	giant floater mussel	25.0	7.70	9.2448	0.33	11.89	9.79	5.70		Scheller 1997
<i>Simocephalus vetulus</i>	cladoceran	20.4	8.10	9.3883	1.27	25.93	21.36	25.83	38.13	Arthur et al. 1987

Appendix 2 Table 2.1: Updated ammonia acute toxicity database

Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Simocephalus vetulus</i>	cladoceran	17.0	8.30	9.4972	2.29	38.35	31.58	56.29		Arthur et al. 1987
<i>Stenelmis sexlineata</i>	beetle	25.0	8.70	9.2448	8.00	36.05	29.69	113.17	113.17	Hazel et al. 1979, as in EPA 1999
<i>Sympetrum flaveolum</i>	dragonfly	25.0	6.96	9.2448	1.72	333.13	274.34	61.73	100.50	Beketov 2002
<i>Sympetrum flaveolum</i>	dragonfly	25.0	7.44	9.2448	3.41	220.98	181.98	70.42		Beketov 2002
<i>Sympetrum flaveolum</i>	dragonfly	25.0	8.22	9.2448	6.11	70.81	58.31	88.95		Beketov 2002
<i>Sympetrum flaveolum</i>	dragonfly	25.0	7.42	9.2448	12.56	851.69	701.39	263.82		Beketov 2002
<i>Tubifex tubifex</i>	tubificid worm	12.0	8.20	9.6621	2.70	80.95	66.67	97.82	97.82	Stammer 1953, as in EPA 1999
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.10	9.2448	0.64	9.56	7.87	9.52	8.43	Augspurger et al. 2003
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.00	9.2448	1.36	25.21	20.76	20.75		Augspurger et al. 2003
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.00	9.2448	0.72	13.36	11.00	10.99		Black 2001
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.00	9.2448	0.16	3.05	2.51	2.51		Black 2001
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.00	9.2448	0.22	4.04	3.33	3.32		Black 2001
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.00	9.2448	0.19	3.50	2.88	2.88		Black 2001
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.30	9.2448	2.02	19.76	16.28	29.01		Black 2001
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.20	9.2448	0.85	10.24	8.43	12.37		Black 2001
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.20	9.2448	0.75	9.13	7.51	11.03		Black 2001
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	8.35	9.2448	0.45	--	3.97	7.80		Keller et al. 2000 (unpublished)
<i>Utterbackia imbecellis</i>	paper pondshell mussel	25.0	7.90	9.2448	0.49	--	11.35	9.42		Keller et al. 2000 (unpublished)
<i>Villosa iris</i>	rainbow mussel	22.0	8.10	9.3379	0.36	6.63	5.46	6.60	6.45	Goudreau et al. 1993
<i>Villosa iris</i>	rainbow mussel	12.5	7.30	9.6454	0.17	36.80	30.31	9.71		Mummert et al. 2003
<i>Villosa iris</i>	rainbow mussel	12.5	7.30	9.6454	0.13	29.60	24.38	7.81		Mummert et al. 2003
<i>Villosa iris</i>	rainbow mussel	12.5	7.30	9.6454	0.10	22.80	18.78	6.02		Mummert et al. 2003
<i>Villosa iris</i>	rainbow mussel	12.5	7.30	9.6454	0.09	20.60	16.96	5.44		Mummert et al. 2003
<i>Villosa iris</i>	rainbow mussel	20.6	7.41	9.3819	0.35	33.40	27.51	10.20		Mummert et al. 2003
<i>Villosa iris</i>	rainbow mussel	20.6	7.41	9.3819	0.19	18.20	14.99	5.56		Mummert et al. 2003
<i>Villosa iris</i>	rainbow mussel	20.6	7.41	9.3819	0.13	12.50	10.29	3.82		Mummert et al. 2003
<i>Villosa iris</i>	rainbow mussel	20.6	7.41	9.3819	0.12	11.40	9.39	3.48		Mummert et al. 2003
<i>Villosa iris</i>	rainbow mussel	20.0	7.90	9.4010	0.10	3.11	2.56	2.12		Scheller 1997
<i>Villosa iris</i>	rainbow mussel	25.0	8.20	9.2448	0.96	11.63	9.58	14.06		Scheller 1997
<i>Villosa iris</i>	rainbow mussel	25.0	8.20	9.2448	0.87	10.51	8.65	12.70		Scheller 1997
<i>Villosa iris</i>	rainbow mussel	25.0	8.10	9.2448	0.48	7.22	5.95	7.20		Scheller 1997
<i>Acipenser brevirostrum</i>	shortnose sturgeon	17.9	7.05	9.4681	0.58	--	152.48	37.15	37.15	Fontenot et al. 1998
<i>Campostoma anomalum</i>	central stoneroller	25.7	7.80	9.2234	1.72	47.32	38.97	26.97	26.97	Swigert and Spacie 1983
<i>Catostomus commersoni</i>	white sucker	3.6	7.80	9.9526	0.76	108.76	89.57	62.00	45.82	Arthur et al. 1987
<i>Catostomus commersoni</i>	white sucker	12.6	8.20	9.6420	1.73	49.60	40.85	59.94		Arthur et al. 1987
<i>Catostomus commersoni</i>	white sucker	11.3	8.10	9.6857	1.87	73.90	60.86	73.60		Arthur et al. 1987
<i>Catostomus commersoni</i>	white sucker	15.3	8.20	9.5526	2.22	52.22	43.01	63.10		Arthur et al. 1987
<i>Catostomus commersoni</i>	white sucker	15.0	8.16	9.5625	1.40	36.77	30.28	41.11		Reinbold and Pescitelli 1982b, as in EPA 1999
<i>Catostomus commersoni</i>	white sucker	15.4	8.14	9.5494	1.35	36.00	29.65	38.73		Reinbold and Pescitelli 1982b, as in EPA 1999
<i>Catostomus commersoni</i>	white sucker	22.5	7.80	9.3222	0.79	27.08	22.30	15.44		Swigert and Spacie 1983
<i>Catostomus platyrhynchus</i>	mountain sucker	11.7	7.73	9.6722	0.71	62.69	51.62	31.62	31.71	Thurston and Meyn 1984, as in EPA 1999
<i>Catostomus platyrhynchus</i>	mountain sucker	12.0	7.67	9.6621	0.82	81.25	66.91	37.02		Thurston and Meyn 1984, as in EPA 1999
<i>Catostomus platyrhynchus</i>	mountain sucker	13.2	7.69	9.6220	0.67	57.79	47.59	27.23		Thurston and Meyn 1984, as in EPA 1999
<i>Chasmistes brevirostris</i>	shortnose sucker	20.0	8.00	9.4010	1.06	--	27.74	27.73	19.61	Sakai et al. 1999
<i>Chasmistes brevirostris</i>	shortnose sucker	20.0	8.00	9.4010	0.53	--	13.87	13.86		Sakai et al. 1999
<i>Cottus bardi</i>	mottled sculpin	12.4	8.02	9.6487	1.39	60.51	49.83	51.73	51.73	Thurston and Russo 1981
<i>Cyprinodon sp.</i>	minnow	12.0	7.68	9.6621	1.42	137.70	113.40	63.79	63.79	Diamond et al. 1993
<i>Cyprinus carpio</i>	common carp	28.0	7.72	9.1537	1.74	--	48.97	29.48	30.32	Hasan and Macintosh 1986

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Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Cyprinus carpio</i>	common carp	28.0	7.72	9.1537	1.84	--	51.78	31.18		Hasan and Macintosh 1986
<i>Deltistes luxatus</i>	lost river sucker	20.0	8.00	9.4010	0.48	--	12.56	12.56	16.01	Sakai et al. 1999
<i>Deltistes luxatus</i>	lost river sucker	20.0	8.00	9.4010	0.78	--	20.42	20.40		Sakai et al. 1999
<i>Etheostoma spectabile</i>	orangethroat darter	21.0	8.04	9.3693	0.90	20.11	16.56	17.86	18.14	Hazel et al. 1979, as in EPA 1999
<i>Etheostoma spectabile</i>	orangethroat darter	22.0	8.40	9.3379	1.07	10.34	8.52	18.44		Hazel et al. 1979, as in EPA 1999
<i>Gambusia affinis</i>	mosquitofish	26.8	7.25	9.1914	0.72	63.64	52.41	15.80	15.25	Sangli and Kanabur 2001
<i>Gambusia affinis</i>	mosquitofish	26.8	7.25	9.1914	0.70	61.87	50.95	15.36		Sangli and Kanabur 2001
<i>Gambusia affinis</i>	mosquitofish	26.8	7.25	9.1914	0.69	60.98	50.22	15.14		Sangli and Kanabur 2001
<i>Gambusia affinis</i>	mosquitofish	26.8	7.25	9.1914	0.67	59.22	48.77	14.70		Sangli and Kanabur 2001
<i>Hybognathus amarus</i>	Rio grande silvery minnow	25.0	8.10	9.2448	1.12	--	16.75	20.26	20.26	Buhl 2002
<i>Ictalurus punctatus</i>	channel catfish	3.5	8.00	9.9562	0.50	45.70	37.64	37.61	35.81	Arthur et al. 1987
<i>Ictalurus punctatus</i>	channel catfish	14.6	8.10	9.5757	0.98	30.28	24.94	30.16		Arthur et al. 1987
<i>Ictalurus punctatus</i>	channel catfish	19.6	7.80	9.4137	1.29	54.29	44.71	30.95		Arthur et al. 1987
<i>Ictalurus punctatus</i>	channel catfish	17.0	8.10	9.4972	1.91	49.58	40.83	49.38		Arthur et al. 1987
<i>Ictalurus punctatus</i>	channel catfish	26.0	8.00	9.2142	2.26	39.27	32.34	32.32		Arthur et al. 1987
<i>Ictalurus punctatus</i>	channel catfish	22.0	8.70	9.3379	2.40	12.83	10.56	40.26		Colt and Tchobanoglous 1976, as in EPA 1999
<i>Ictalurus punctatus</i>	channel catfish	26.0	8.70	9.2142	2.90	12.38	10.19	38.85		Colt and Tchobanoglous 1976, as in EPA 1999
<i>Ictalurus punctatus</i>	channel catfish	30.0	8.70	9.0939	3.80	13.21	10.88	41.47		Colt and Tchobanoglous 1976, as in EPA 1999
<i>Ictalurus punctatus</i>	channel catfish	28.0	8.40	9.1537	1.95	13.01	10.71	23.19		Colt and Tchobanoglous 1978
<i>Ictalurus punctatus</i>	channel catfish	23.8	7.98	9.2818	1.76	37.02	30.49	29.35		Reinbold and Pescitelli 1982c, as in EPA 1999
<i>Ictalurus punctatus</i>	channel catfish	23.8	7.94	9.2818	1.75	40.20	33.10	29.57		Reinbold and Pescitelli 1982c, as in EPA 1999
<i>Ictalurus punctatus</i>	channel catfish	22.0	8.09	9.3379	2.10	39.26	32.33	38.36		Roseboom and Richey 1977, as in EPA 1999
<i>Ictalurus punctatus</i>	channel catfish	28.0	8.08	9.1537	4.20	53.96	44.44	51.72		Roseboom and Richey 1977, as in EPA 1999
<i>Ictalurus punctatus</i>	channel catfish	25.7	7.80	9.2234	1.45	39.89	32.85	22.74		Swigert and Spacie 1983
<i>Ictalurus punctatus</i>	channel catfish	23.0	8.00	9.3067	1.82	38.69	31.87	31.85		Tomasso et al. 1980
<i>Ictalurus punctatus</i>	channel catfish	23.0	7.00	9.3067	1.39	283.01	233.07	54.26		Tomasso et al. 1980
<i>Ictalurus punctatus</i>	channel catfish	23.0	9.00	9.3067	1.49	4.51	3.71	23.57		Tomasso et al. 1980
<i>Ictalurus punctatus</i>	channel catfish	23.0	7.00	9.3067	1.79	364.46	300.14	69.88		Tomasso et al. 1980
<i>Lepomis cyanellus</i>	green sunfish	12.3	7.84	9.6521	0.61	40.18	33.09	24.61	30.31	Jude 1973, as in EPA 1999
<i>Lepomis cyanellus</i>	green sunfish	22.4	6.61	9.3254	0.61	315.86	260.12	46.87		McCormick et al. 1984
<i>Lepomis cyanellus</i>	green sunfish	22.4	7.20	9.3254	1.29	173.07	142.53	40.55		McCormick et al. 1984
<i>Lepomis cyanellus</i>	green sunfish	22.4	7.72	9.3254	1.63	67.21	55.35	33.32		McCormick et al. 1984
<i>Lepomis cyanellus</i>	green sunfish	22.4	8.69	9.3254	2.10	11.17	9.20	34.44		McCormick et al. 1984
<i>Lepomis cyanellus</i>	green sunfish	26.2	8.28	9.2081	1.08	10.23	8.43	14.45		Reinbold and Pescitelli 1982a
<i>Lepomis gibbosus</i>	pumpkinseed	12.0	7.77	9.6621	0.14	11.06	9.11	5.98	18.05	Jude 1973, as in EPA 1999
<i>Lepomis gibbosus</i>	pumpkinseed	14.5	7.77	9.5790	0.78	51.02	42.02	27.59		Thurston 1981, as in EPA 1999
<i>Lepomis gibbosus</i>	pumpkinseed	14.0	7.77	9.5955	0.86	58.40	48.09	31.58		Thurston 1981, as in EPA 1999
<i>Lepomis gibbosus</i>	pumpkinseed	15.7	7.71	9.5395	0.61	41.81	34.43	20.38		Thurston 1981, as in EPA 1999
<i>Lepomis machrochirus</i>	bluegill	20.0	7.68	9.4010	1.00	53.60	44.14	24.83	24.16	Diamond et al. 1993
<i>Lepomis machrochirus</i>	bluegill	12.0	7.68	9.6621	0.65	63.03	51.91	29.20		Diamond et al. 1993
<i>Lepomis machrochirus</i>	bluegill	18.5	8.11	9.4488	0.89	20.31	16.73	20.62		Emery and Welch 1969
<i>Lepomis machrochirus</i>	bluegill	18.5	8.24	9.4488	2.97	51.01	42.01	66.62		Emery and Welch 1969
<i>Lepomis machrochirus</i>	bluegill	18.5	8.75	9.4488	2.57	15.42	12.70	52.95		Emery and Welch 1969
<i>Lepomis machrochirus</i>	bluegill	22.0	8.10	9.3379	1.06	19.39	15.97	19.31		Mayes et al. 1986
<i>Lepomis machrochirus</i>	bluegill	22.0	8.07	9.3379	0.55	10.74	8.85	10.10		Roseboom and Richey 1977, as in EPA 1999
<i>Lepomis machrochirus</i>	bluegill	22.0	8.00	9.3379	0.68	15.48	12.75	12.74		Roseboom and Richey 1977, as in EPA 1999
<i>Lepomis machrochirus</i>	bluegill	22.0	7.93	9.3379	1.10	29.24	24.08	21.11		Roseboom and Richey 1977, as in EPA 1999
<i>Lepomis machrochirus</i>	bluegill	28.0	8.20	9.1537	1.80	17.98	14.81	21.72		Roseboom and Richey 1977, as in EPA 1999

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Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Lepomis machrochirus</i>	bluegill	21.7	7.60	9.3473	0.94	53.47	44.03	21.72		Smith et al. 1984
<i>Lepomis machrochirus</i>	bluegill	24.2	7.80	9.2695	1.35	41.14	33.88	23.45		Swigert and Spacie 1983
<i>Lepomis machrochirus</i>	bluegill	26.5	7.60	9.1990	1.75	71.26	58.69	28.95		Swigert and Spacie 1983
<i>Lepomis machrochirus</i>	bluegill	26.6	7.80	9.1960	1.76	45.56	37.52	25.97		Swigert and Spacie 1983
<i>Micropterus dolomieu</i>	smallmouth bass	22.3	6.53	9.3285	0.69	437.06	359.93	62.67	36.90	Broderius et al. 1985
<i>Micropterus dolomieu</i>	smallmouth bass	22.3	7.16	9.3285	1.00	148.40	122.21	33.26		Broderius et al. 1985
<i>Micropterus dolomieu</i>	smallmouth bass	22.3	7.74	9.3285	1.20	47.72	39.30	24.49		Broderius et al. 1985
<i>Micropterus dolomieu</i>	smallmouth bass	22.3	7.74	9.3285	1.78	70.79	58.30	36.33		Broderius et al. 1985
<i>Micropterus salmoides</i>	largemouth bass	22.0	7.96	9.3379	1.00	24.87	20.48	18.99	20.03	Roseboom and Richey 1977, as in EPA 1999
<i>Micropterus salmoides</i>	largemouth bass	28.0	8.04	9.1537	1.70	23.79	19.59	21.12		Roseboom and Richey 1977, as in EPA 1999
<i>Morone americana</i>	white perch	16.0	6.00	9.5297	0.15	508.11	418.44	63.94	30.89	Stevenson 1977
<i>Morone americana</i>	white perch	16.0	8.00	9.5297	0.52	18.13	14.93	14.92		Stevenson 1977
<i>Morone chrysops</i>	white bass	19.7	7.02	9.4105	0.63	--	155.45	36.84	19.16	Ashe et al. 1996
<i>Morone chrysops</i>	white bass	18.7	8.60	9.4424	0.40	--	3.18	10.09		Harcke and Daniels 1999
<i>Morone chrysops</i>	white bass	25.0	7.00	9.2448	0.46	--	81.29	18.93		Weirich et al. 1993
<i>Notemigonus chrysoleucas</i>	golden shiner	24.5	7.50	9.2602	0.72	42.17	34.73	14.67	14.67	Swigert and Spacie 1983
<i>Cyprinella lutrensis</i>	red shiner	24.0	8.30	9.2756	2.83	29.59	24.37	43.43	45.65	Hazel et al. 1979, as in EPA 1999
<i>Cyprinella lutrensis</i>	red shiner	24.0	9.10	9.2756	3.16	7.90	6.50	47.99		Hazel et al. 1979, as in EPA 1999
<i>Cyprinella spilopterus</i>	spotfin shiner	26.5	7.95	9.1990	1.20	22.49	18.52	16.85	19.51	Rosage et al. 1979
<i>Cyprinella spilopterus</i>	spotfin shiner	26.5	8.15	9.1990	1.62	19.76	16.27	21.67		Rosage et al. 1979
<i>Cyprinella spilopterus</i>	spotfin shiner	25.7	7.90	9.2234	1.35	29.78	24.52	20.34		Swigert and Spacie 1983
<i>Cyprinella whipplei</i>	steelcolor shiner	25.7	7.90	9.2234	1.25	27.57	22.71	18.83	18.83	Swigert and Spacie 1983
<i>Oncorhynchus aquabonita</i>	golden trout	13.2	8.60	9.6220	0.76	8.70	7.16	22.71	22.71	Thurston and Russo 1981
<i>Oncorhynchus clarki</i>	cutthroat trout	13.1	7.81	9.6254	0.80	53.09	43.72	30.81	25.80	Thurston et al. 1978
<i>Oncorhynchus clarki</i>	cutthroat trout	12.8	7.80	9.6354	0.66	45.84	37.75	26.13		Thurston et al. 1978
<i>Oncorhynchus clarki</i>	cutthroat trout	12.4	7.80	9.6487	0.62	44.38	36.55	25.30		Thurston et al. 1978
<i>Oncorhynchus clarki</i>	cutthroat trout	12.2	7.78	9.6554	0.52	39.55	32.57	21.76		Thurston et al. 1978
<i>Oncorhynchus gorboscha</i>	pink salmon	4.3	6.40	9.9277	0.08	279.86	230.47	38.33	42.07	Rice and Bailey 1980
<i>Oncorhynchus gorboscha</i>	pink salmon	4.3	6.40	9.9277	0.10	337.18	277.68	46.18		Rice and Bailey 1980
<i>Oncorhynchus kisutch</i>	coho salmon	15.0	7.00	9.5625	0.27	99.60	82.02	19.10	16.97	Robinson-Wilson and Seim 1975
<i>Oncorhynchus kisutch</i>	coho salmon	15.0	7.00	9.5625	0.28	102.53	84.43	19.66		Robinson-Wilson and Seim 1975
<i>Oncorhynchus kisutch</i>	coho salmon	15.0	7.50	9.5625	0.55	64.06	52.76	22.29		Robinson-Wilson and Seim 1975
<i>Oncorhynchus kisutch</i>	coho salmon	15.0	7.50	9.5625	0.53	61.50	50.65	21.40		Robinson-Wilson and Seim 1975
<i>Oncorhynchus kisutch</i>	coho salmon	15.0	8.00	9.5625	0.17	6.45	5.31	5.31		Robinson-Wilson and Seim 1975
<i>Oncorhynchus kisutch</i>	coho salmon	15.0	8.00	9.5625	0.70	26.26	21.63	21.62		Robinson-Wilson and Seim 1975
<i>Oncorhynchus kisutch</i>	coho salmon	15.0	8.50	9.5625	0.88	11.04	9.09	23.86		Robinson-Wilson and Seim 1975
<i>Oncorhynchus kisutch</i>	coho salmon	17.2	8.10	9.4907	0.55	14.07	11.59	14.02		Robinson-Wilson and Seim 1975
<i>Oncorhynchus mykiss</i>	rainbow trout	3.6	7.70	9.9526	0.26	46.77	38.52	22.41	19.94	Arthur et al. 1987
<i>Oncorhynchus mykiss</i>	rainbow trout	16.2	7.90	9.5232	0.43	18.49	15.23	12.63		Arthur et al. 1987
<i>Oncorhynchus mykiss</i>	rainbow trout	11.3	7.90	9.6857	0.59	36.61	30.15	25.01		Arthur et al. 1987
<i>Oncorhynchus mykiss</i>	rainbow trout	9.8	7.70	9.7365	0.61	66.96	55.15	32.09		Arthur et al. 1987
<i>Oncorhynchus mykiss</i>	rainbow trout	18.7	8.30	9.4424	1.04	15.48	12.75	22.72		Arthur et al. 1987
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.95	9.7297	0.70	42.67	35.14	31.97		Broderius and Smith 1979
<i>Oncorhynchus mykiss</i>	rainbow trout	14.5	7.40	9.5790	0.49	73.87	60.83	22.25		Calamari et al. 1981
<i>Oncorhynchus mykiss</i>	rainbow trout	14.5	7.40	9.5790	0.16	24.32	20.03	7.33		Calamari et al. 1981
<i>Oncorhynchus mykiss</i>	rainbow trout	14.5	7.40	9.5790	0.44	66.88	55.07	20.15		Calamari et al. 1981
<i>Oncorhynchus mykiss</i>	rainbow trout	14.0	8.10	9.5955	0.77	24.87	20.48	24.77		DeGraeve et al. 1980
<i>Oncorhynchus mykiss</i>	rainbow trout	15.0	7.50	9.5625	0.40	46.59	38.37	16.21		Holt & Malcolm 1979

Appendix 2 Table 2.1: Updated ammonia acute toxicity database

Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Oncorhynchus mykiss</i>	rainbow trout	14.1	7.86	9.5922	0.77	42.44	34.95	26.94		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.8	7.84	9.6021	0.68	40.18	33.09	24.60		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.9	8.10	9.5988	0.68	22.03	18.14	21.94		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.6	8.12	9.6087	0.66	21.06	17.34	21.80		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.8	7.94	9.6354	0.64	32.17	26.49	23.66		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.5	7.98	9.6454	0.69	32.81	27.02	26.01		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.4	7.89	9.6487	0.76	44.60	36.73	29.91		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.5	7.94	9.6454	0.92	47.66	39.25	35.05		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.1	7.85	9.6254	0.64	38.55	31.75	24.04		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	11.9	7.90	9.6655	0.46	27.50	22.65	18.79		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.90	9.6287	0.83	45.43	37.41	31.03		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.90	9.6287	0.80	43.41	35.75	29.65		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	9.8	7.66	9.7365	0.26	31.51	25.95	14.12		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.64	9.7297	0.31	38.67	31.85	16.77		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.7	7.90	9.6387	0.44	24.32	20.03	16.61		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.4	7.90	9.6154	0.45	23.60	19.44	16.12		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.91	9.6287	0.48	25.49	20.99	17.73		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.1	7.91	9.6254	0.29	15.40	12.68	10.71		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.8	7.88	9.6354	0.23	13.44	11.07	8.85		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.9	7.88	9.6320	0.34	19.32	15.91	12.72		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.9	7.87	9.6320	0.35	20.41	16.81	13.19		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.5	7.95	9.6454	0.47	23.98	19.75	17.97		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.87	9.6287	0.44	25.68	21.15	16.61		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.9	7.87	9.6320	0.39	23.05	18.99	14.91		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.4	7.88	9.6154	0.43	23.59	19.43	15.53		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.1	7.87	9.6254	0.40	23.17	19.08	14.98		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.4	7.86	9.6154	0.50	28.79	23.71	18.28		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.86	9.6287	0.42	25.14	20.70	15.96		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.8	8.08	9.6354	0.76	27.99	23.05	26.82		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.7	7.86	9.6387	0.57	34.93	28.77	22.18		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.5	7.85	9.6454	0.57	36.15	29.77	22.54		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.1	7.85	9.6254	0.67	40.79	33.59	25.44		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.2	8.06	9.6220	1.09	40.85	33.64	37.68		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.3	7.85	9.6521	0.64	41.28	33.99	25.74		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.4	7.79	9.6487	0.70	50.97	41.97	28.55		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	14.1	7.86	9.5922	0.77	42.44	34.95	26.94		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.8	7.84	9.6021	0.68	40.18	33.09	24.60		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.4	7.80	9.6487	0.81	58.13	47.87	33.14		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.1	7.85	9.6254	0.63	38.31	31.55	23.89		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.1	7.87	9.6588	0.62	38.62	31.80	24.97		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	11.4	7.71	9.6823	0.41	38.88	32.02	18.95		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	11.5	7.71	9.6789	0.39	36.70	30.22	17.89		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.84	9.6287	0.75	46.98	38.69	28.77		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.5	7.83	9.6120	0.66	40.74	33.55	24.50		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.3	7.80	9.6187	0.76	51.02	42.02	29.09		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.8	7.44	9.6354	0.25	39.45	32.49	12.57		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.2	7.84	9.6554	0.45	29.80	24.54	18.25		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.2	7.87	9.6554	0.39	24.31	20.02	15.72		Thurston and Russo 1983

Appendix 2 Table 2.1: Updated ammonia acute toxicity database

Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Oncorhynchus mykiss</i>	rainbow trout	11.9	7.90	9.6655	0.46	27.50	22.65	18.79		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	14.5	7.50	9.5790	0.24	29.39	24.20	10.22		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.2	7.82	9.6220	0.64	40.89	33.67	24.15		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.3	7.75	9.6521	0.51	41.21	33.94	21.52		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.9	7.84	9.6320	0.62	39.22	32.30	24.01		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.90	9.6287	0.83	45.43	37.41	31.03		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.9	7.70	9.5988	0.43	34.65	28.54	16.60		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.90	9.6287	0.80	43.41	35.75	29.65		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.87	9.6287	0.71	41.68	34.32	26.95		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	9.7	7.80	9.7400	0.33	28.72	23.65	16.37		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	14.3	7.65	9.5856	0.40	35.23	29.02	15.53		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	14.0	7.67	9.5955	0.39	33.15	27.30	15.11		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	14.4	7.62	9.5823	0.38	34.75	28.62	14.58		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.1	7.64	9.6254	0.36	35.56	29.28	15.42		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.6	7.66	9.6087	0.38	34.33	28.27	15.38		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.2	7.65	9.6220	0.37	34.78	28.64	15.33		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.4	7.69	9.6154	0.39	33.40	27.51	15.74		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.9	7.60	9.6320	0.28	30.53	25.14	12.40		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	11.8	7.75	9.6688	0.46	38.28	31.53	19.99		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.8	7.66	9.6354	0.43	41.25	33.97	18.48		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.60	9.6287	0.27	28.90	23.80	11.74		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.9	7.63	9.6320	0.31	31.15	25.65	13.29		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	12.7	7.59	9.6387	0.35	39.62	32.62	15.84		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.0	7.68	9.6287	0.45	40.26	33.15	18.65		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	13.6	7.77	9.6087	0.55	38.63	31.81	20.89		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.2	7.86	9.7229	0.58	42.88	35.31	27.23		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.88	9.7297	0.48	34.73	28.60	22.87		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.7	7.69	9.7060	0.30	31.11	25.62	14.66		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.4	7.74	9.7161	0.33	31.28	25.76	16.05		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.76	9.7297	0.29	27.24	22.44	14.47		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	9.8	7.66	9.7365	0.26	31.51	25.95	14.12		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.64	9.7297	0.31	38.67	31.85	16.77		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.4	7.69	9.7161	0.20	21.55	17.75	10.15		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	10.7	7.69	9.7060	0.23	24.51	20.18	11.55		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	9.8	7.64	9.7365	0.25	31.35	25.82	13.59		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	9.8	7.65	9.7365	0.19	23.63	19.46	10.41		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	7.9	7.62	9.8017	0.16	24.93	20.53	10.46		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	16.1	7.85	9.5265	0.86	41.50	34.17	25.87		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	16.7	7.88	9.5069	0.80	34.73	28.60	22.87		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	19.0	7.91	9.4328	0.90	30.79	25.36	21.42		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	19.1	7.91	9.4296	0.94	32.11	26.44	22.34		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	19.2	7.96	9.4264	0.93	28.18	23.21	21.52		Thurston and Russo 1983
<i>Oncorhynchus mykiss</i>	rainbow trout	9.7	7.86	9.7400	0.50	38.42	31.64	24.40		Thurston et al. 1981
<i>Oncorhynchus mykiss</i>	rainbow trout	8.1	7.74	9.7948	0.30	33.88	27.90	17.39		Thurston et al. 1981
<i>Oncorhynchus mykiss</i>	rainbow trout	7.9	7.62	9.8017	0.16	24.93	20.53	10.46		Thurston et al. 1981
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.40	135.00	111.18	31.63		Wicks and Randall 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.54	185.00	152.35	43.34		Wicks and Randall 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.42	143.00	117.76	33.50		Wicks and Randall 2002

Appendix 2 Table 2.1: Updated ammonia acute toxicity database

Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.52	177.00	145.76	41.47		Wicks and Randall 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.39	132.00	108.71	30.92		Wicks and Randall 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.41	139.00	114.47	32.56		Wicks and Randall 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.41	138.00	113.65	32.33		Wicks and Randall 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.42	141.00	116.12	33.03		Wicks and Randall 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	10.0	7.20	9.7297	0.51	174.00	143.29	40.76		Wicks and Randall 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	16.6	6.97	9.5102	0.72	251.36	207.00	46.97		Wicks et al. 2002
<i>Oncorhynchus mykiss</i>	rainbow trout	16.6	6.97	9.5102	0.11	39.32	32.38	7.35		Wicks et al. 2002
<i>Oncorhynchus tshawytscha</i>	chinook salmon	13.5	7.87	9.6120	0.40	22.43	18.47	14.50	17.34	Thurston and Meyn 1984, as in EPA 1999
<i>Oncorhynchus tshawytscha</i>	chinook salmon	12.2	7.82	9.6554	0.48	33.06	27.23	19.53		Thurston and Meyn 1984, as in EPA 1999
<i>Oncorhynchus tshawytscha</i>	chinook salmon	12.3	7.84	9.6521	0.46	30.04	24.74	18.39		Thurston and Meyn 1984, as in EPA 1999
<i>Pimephales promelas</i>	fathead minnow	12.1	8.10	9.6588	1.83	68.09	56.07	67.81	41.89	Arthur et al. 1987
<i>Pimephales promelas</i>	fathead minnow	17.1	8.00	9.4940	1.97	63.41	52.22	52.19		Arthur et al. 1987
<i>Pimephales promelas</i>	fathead minnow	3.4	7.90	9.9597	2.41	278.95	229.72	190.54		Arthur et al. 1987
<i>Pimephales promelas</i>	fathead minnow	26.1	8.10	9.2112	2.55	35.49	29.23	35.35		Arthur et al. 1987
<i>Pimephales promelas</i>	fathead minnow	14.0	8.10	9.5955	1.59	51.35	42.29	51.14		DeGraeve et al. 1980
<i>Pimephales promelas</i>	fathead minnow	19.6	7.68	9.4137	0.25	13.79	11.36	6.39		Diamond et al. 1993
<i>Pimephales promelas</i>	fathead minnow	22.0	8.10	9.3379	1.50	27.44	22.60	27.33		Mayes et al. 1986
<i>Pimephales promelas</i>	fathead minnow	25.9	7.78	9.2173	1.75	49.65	40.89	27.32		Swigert and Spacie 1983
<i>Pimephales promelas</i>	fathead minnow	25.6	7.80	9.2265	1.87	51.79	42.65	29.53		Swigert and Spacie 1983
<i>Pimephales promelas</i>	fathead minnow	16.3	7.91	9.5200	1.50	62.60	51.55	43.55		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.1	7.89	9.6254	1.10	60.91	50.16	40.85		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.6	7.64	9.6087	0.75	70.92	58.40	30.74		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.5	7.68	9.6120	0.91	78.56	64.69	36.40		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	22.1	8.03	9.3347	2.73	57.80	47.60	50.35		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	22.0	8.06	9.3379	2.59	51.70	42.58	47.69		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.9	7.67	9.5988	0.83	71.45	58.84	32.55		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.0	8.05	9.6287	2.33	90.65	74.65	82.04		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.6	8.05	9.6087	2.17	80.73	66.48	73.06		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	19.1	7.94	9.4296	1.61	51.32	42.26	37.75		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	19.0	7.76	9.4328	1.27	61.06	50.28	32.44		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.4	7.66	9.6154	0.78	70.71	58.23	31.68		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	15.8	7.87	9.5363	1.51	71.53	58.91	46.25		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	22.0	7.83	9.3379	1.85	61.42	50.58	36.94		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	18.9	7.91	9.4360	1.73	59.82	49.26	41.62		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	14.3	7.77	9.5856	1.22	81.00	66.71	43.80		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	14.1	7.77	9.5922	1.31	88.29	72.71	47.74		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	22.4	8.04	9.3254	2.16	43.83	36.09	38.92		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	21.4	8.08	9.3567	2.73	54.36	44.76	52.10		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	21.4	8.16	9.3567	3.44	57.55	47.39	64.35		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	21.7	7.88	9.3473	2.04	61.87	50.95	40.74		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	12.9	7.68	9.6320	1.23	111.36	91.71	51.60		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	12.3	7.74	9.6521	1.10	90.94	74.89	46.67		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.2	7.63	9.6220	1.10	109.10	89.85	46.53		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	11.7	7.62	9.6722	0.98	111.84	92.10	46.93		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.6	7.93	9.6087	1.37	66.75	54.97	48.19		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	12.6	7.77	9.6420	1.45	109.44	90.13	59.18		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	12.5	7.83	9.6454	1.12	74.33	61.22	44.71		Thurston et al. 1983

Appendix 2 Table 2.1: Updated ammonia acute toxicity database

Species	Common name	Temperature (°C)	pH	pK	Acute value (mg NH ₃ /L)	Acute value (mg TA/L)	TA-N (mg/L)	TA-N pH8 (AV _{t,8})	SMAV (TA-N pH8 mg/L)	Reference
<i>Pimephales promelas</i>	fathead minnow	12.9	7.76	9.6320	1.73	130.57	107.53	69.38		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	21.7	7.84	9.3473	2.03	67.31	55.43	41.22		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	16.0	7.90	9.5297	0.95	41.54	34.21	28.37		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	15.5	7.92	9.5461	1.18	51.06	42.05	36.19		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	13.1	7.76	9.6254	1.09	81.03	66.73	43.05		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	12.8	7.74	9.6354	0.80	63.35	52.17	32.51		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	15.9	7.91	9.5330	1.34	57.59	47.43	40.07		Thurston et al. 1983
<i>Pimephales promelas</i>	fathead minnow	25.0	8.12	9.2448	1.01		14.47	18.19		Buhl 2002
<i>Poecilia reticulata</i>	guppy	25.0	7.22	9.2448	1.47	157.12	129.40	37.66	33.15	Rubin and Elmaraghy 1976, 1977
<i>Poecilia reticulata</i>	guppy	25.0	7.45	9.2448	1.59	100.73	82.95	32.56		Rubin and Elmaraghy 1976, 1977
<i>Poecilia reticulata</i>	guppy	25.0	7.45	9.2448	1.45	91.86	75.65	29.69		Rubin and Elmaraghy 1976, 1977
<i>Prosopium williamsoni</i>	mountain whitefish	12.3	7.80	9.6521	0.36	25.82	21.27	14.72	12.11	Thurston and Meyn 1984, as in EPA 1999
<i>Prosopium williamsoni</i>	mountain whitefish	12.1	7.68	9.6588	0.14	13.76	11.33	6.38		Thurston and Meyn 1984, as in EPA 1999
<i>Prosopium williamsoni</i>	mountain whitefish	12.4	7.84	9.6487	0.47	30.92	25.47	18.94		Thurston and Meyn 1984, as in EPA 1999
<i>Rana pipiens</i>	northern leopard frog	20.0	7.68	9.4010	1.44	77.18	63.56	35.76	25.97	Diamond et al. 1993
<i>Rana pipiens</i>	northern leopard frog	12.0	7.68	9.6621	0.42	40.73	33.54	18.87		Diamond et al. 1993
<i>Salmo trutta</i>	brown trout	13.2	7.85	9.6220	0.60	35.92	29.58	22.39	23.74	Thurston and Meyn 1984, as in EPA 1999
<i>Salmo trutta</i>	brown trout	13.8	7.86	9.6021	0.70	39.41	32.46	25.02		Thurston and Meyn 1984, as in EPA 1999
<i>Salmo trutta</i>	brown trout	14.2	7.82	9.5889	0.68	40.44	33.30	23.89		Thurston and Meyn 1984, as in EPA 1999
<i>Salvelinus fontinalis</i>	brook trout	13.8	7.83	9.6021	1.05	63.18	52.03	38.00	36.39	Thurston and Meyn 1984, as in EPA 1999
<i>Salvelinus fontinalis</i>	brook trout	13.6	7.86	9.6087	0.96	54.90	45.21	34.86		Thurston and Meyn 1984, as in EPA 1999
<i>Sander vitreum</i>	walleye	19.0	8.30	9.4328	0.51	7.43	6.12	10.91	25.89	Arthur et al. 1987
<i>Sander vitreum</i>	walleye	3.7	7.90	9.9490	0.52	58.74	48.37	40.12		Arthur et al. 1987
<i>Sander vitreum</i>	walleye	11.1	7.70	9.6924	1.10	109.20	89.93	52.33		Arthur et al. 1987
<i>Sander vitreum</i>	walleye	21.5	8.10	9.3536	1.04	19.69	16.21	19.61		Mayes et al. 1986

Appendix 2 Table 2.2: Updated ammonia chronic toxicity database

Species	Common name	Effect	Temperature			TA-N EC20	TA-N	TA-N EC20 @	TA-N EC20 @	TA-N EC20 @	TA-N EC20 @	SMCV	SMCV @	Reference
			(°C)	pH	pK	@ test pH & Temp (mg N/L)	EC20 @ pH=8 (mg N/L)	pH=8 & 25°C (mg N/L)	pH=8 & 25°C (mg N/L)	pH=8 & 25°C (mg N/L)	@ pH8 & 25°C for > or < (mg N/L)	@ pH8	pH8 25°C	
<i>Musculium transversum</i>	finger nail clam	42d juvenile, survival	23.50	8.15	9.2911	5.82	7.30	6.63				2.62	2.25	Anderson et al. 1978
<i>Musculium transversum</i>	finger nail clam	42d juvenile, survival	21.80	7.80	9.3441	1.23	0.94	0.77						Sparks and Sandusky 1981
<i>Ceriodaphnia acanthina</i>	cladoceran	LC reproduction	24.50	7.15	9.2602	44.90	19.77	19.14				19.77	19.14	Mount 1982
<i>Ceriodaphnia dubia</i>	cladoceran	7d LC reproduction	26.00	8.57	9.2142	5.80	14.60	15.57				13.03	13.46	Willingham 1987
<i>Ceriodaphnia dubia</i>	cladoceran	7d LC reproduction	25.00	7.80	9.2448	15.20	11.63	11.63						Nimmo et al. 1989
<i>Daphnia magna</i>	cladoceran	21d LC reproduction	19.80	8.45	9.4073	7.37	15.14	10.83				17.14	12.38	Gersich et al. 1985
<i>Daphnia magna</i>	cladoceran	21d LC reproduction	20.10	7.92	9.3978	21.70	19.41	14.15						Reinbold and Pescitelli 1982a
<i>Hyalella azteca</i>	amphipod	10wk LC reproduction	25.00	7.94	9.2448	<1.58	1.45	<1.45	1.45				<1.45	Borgmann 1994
<i>Pimephales promelas</i>	fathead minnow	LC hatch	24.20	8.00	9.2695	1.97	1.97	1.87				3.09	3.03	Thurston et al. 1986
<i>Pimephales promelas</i>	fathead minnow	30d ELS biomass	25.10	7.82	9.2418	3.73	2.93	2.95						Swigert and Spacie 1983
<i>Pimephales promelas</i>	fathead minnow	28d ELS survival	24.80	8.00	9.2510	5.12	5.12	5.06						Mayes et al. 1986
<i>Catostomus commersoni</i>	white sucker	30d ELS biomass	18.60	8.32	9.4456	>2.9	4.79	>4.79	3.17				>4.79	Reinbold and Pescitelli 1982a
<i>Esox lucius</i>	northern pike	52d ELS hatching success	9.00	7.60	9.7639	43.20	26.47	9.43				12.33	4.39	Harrahy et al. 2004
<i>Esox lucius</i>	northern pike	52d larval mortality	9.00	7.60	9.7639	20.56	12.60	4.49						Harrahy et al. 2004
<i>Esox lucius</i>	northern pike	52d weight of survivors	9.00	7.60	9.7639	13.21	8.25	2.94						Harrahy et al. 2004
<i>Esox lucius</i>	northern pike	52d biomass	9.00	7.60	9.7639	13.44	8.40	2.99						Harrahy et al. 2004
<i>Ictalurus punctatus</i>	channel catfish	30d ELS biomass	26.90	7.76	9.1869	11.50	8.39	9.48				8.85	9.65	Swigert and Spacie 1983
<i>Ictalurus punctatus</i>	channel catfish	30d ELS weight	25.80	7.80	9.2203	12.20	9.34	9.83						Reinbold and Pescitelli 1982a
<i>Ictalurus punctatus</i>	channel catfish	30d juvenile survival	27.90	8.35	9.1567	≤5.02 - ≤5.71	9.32	≤8.7 - ≤9.9	11.23					Colt and Tchobanoglous 1978
<i>Oncorhynchus clarki</i>	cutthroat trout	29d juvenile survival	12.65	8.00	9.6404	<19.7	19.72	<19.7	8.89					- Thurston et al. 1978
<i>Oncorhynchus mykiss</i>	rainbow trout	5yr LC	9.00	7.70	9.7639	>8.0	5.45	>5.4	1.94					- Thurston et al. 1984b
<i>Oncorhynchus mykiss</i>	rainbow trout	42d ELS survival	11.00	7.50	9.6958	<33.6	18.75	<18.7	7.60					Burkhalter and Kaya 1977
<i>Oncorhynchus mykiss</i>	rainbow trout	73d ELS survival	14.90	7.52	9.5658	<2.55	1.45	<1.44	0.76					Solbe and Shurben 1989
<i>Oncorhynchus mykiss</i>	rainbow trout	72d ELS survival	14.50	7.40	9.5790	2.60	1.34	0.68						Calamari et al 1977, 1981
<i>Oncorhynchus nerka</i>	sockeye salmon	62d embryo hatch	10.00	8.42	9.7297	<2.13	4.16	<4.16	1.58				<4.16	Rankin 1979
<i>Lepomis cyanellus</i>	green sunfish	30d ELS survival	25.40	8.16	9.2326	5.84	7.44	7.64				6.03	5.54	Reinbold and Pescitelli 1982a
<i>Lepomis cyanellus</i>	green sunfish	30d ELS biomass	22.00	7.90	9.3379	5.61	4.88	4.03						McCormick et al. 1983
<i>Lepomis macrochirus</i>	bluegill	30d ELS biomass	22.50	7.76	9.3222	1.85	1.35	1.15				1.35	1.15	Smith et al. 1984
<i>Micropterus dolomeiu</i>	smallmouth bass	32d ELS biomass	22.30	6.60	9.3285	9.61	3.57	3.00				4.56	3.83	Broderius et al. 1985
<i>Micropterus dolomeiu</i>	smallmouth bass	32d ELS biomass	22.30	7.25	9.3285	8.62	4.01	3.37						Broderius et al. 1985
<i>Micropterus dolomeiu</i>	smallmouth bass	32d ELS biomass	22.30	7.83	9.3285	8.18	6.50	5.46						Broderius et al. 1985
<i>Micropterus dolomeiu</i>	smallmouth bass	32d ELS biomass	22.30	8.68	9.3285	1.54	4.66	3.92						Broderius et al. 1985
<i>Salvelinus namayacush</i>	lake trout	growth	11.60	8.02	9.6756	9.13	9.40	3.96				9.40	3.96	Beamish and Tandler 1990
<i>Lasmigona subviridis</i>	green floater mussel	survival	22.00	8.00	9.3379	0.56	0.56	0.46				0.56	0.46	Black 2001

^aELS=early life-stage, PLC=partial life cycle, LC=life cycle

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Acroneuria lycorias</i>	stonefly	S,U	--	44.0	40.0	8,300		9,407.86	9,407.86	Warnick and Bell 1969	
<i>Actinonaias pectorosa</i> (juvenile)	FW mussel	S,M,T	CuSO ₄	96.0	--	24		12.66	16.48	Keller unpublished	
<i>Actinonaias pectorosa</i> (juvenile)	FW mussel	S,M,T	CuSO ₄	68.0	--	<29		<21.45		Keller unpublished	
<i>Actinonaias pectorosa</i> (juvenile)	FW mussel	S,M,T	CuSO ₄	87.0	--	70		40.68		Keller unpublished	
<i>Amnicola</i> sp.	FW mussel	S,M	--	50.0	--	9,300		9300*	900.00	Rehwoldt et al. 1973	
<i>Amnicola</i> sp.	FW mussel	S,M	--	50.0	--	900		900.00		Rehwoldt et al. 1973	
<i>Asellus aquaticus</i>	isopod	S,U	--	50.0	--	9,210		9,210.00	9,210.00	Martin and Holdich 1986	
<i>Bosmina longirostris</i>	cladoceran	R,U	CuSO ₄	33.8	--	1.4		2.05	2.05	Koivisto et al. 1992	
<i>Cameloma decism</i>	snail	F,M,T	CuSO ₄	44.9	42.7	2,000		2,222.41	1,859.40	Arthur and Leonard 1970	
<i>Cameloma decism</i>	snail	F,M,T	CuSO ₄	44.9	42.7	1,400		1,555.69		Arthur and Leonard 1970	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	26.04	25.0	28.87	7.74	Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	17.71	17.0	19.63		Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	31.25	30.0	34.65		Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	25.00	24.0	27.72		Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	29.17	28.0	32.34		Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	33.33	32.0	36.96		Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	23.96	23.0	26.56		Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	20.83	20.0	23.10		Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	45.0	39.7	19.79	19.0	21.94		Belanger et al. 1988	Y
<i>Ceriodaphnia dubia</i>	cladoceran	R,M	--	97.6	74.2	28.0		14.54		Belanger and Cherry 1990	Y
<i>Ceriodaphnia dubia</i>	cladoceran	R,M	--	97.6	74.2	31.0		16.09		Belanger and Cherry 1990	Y
<i>Ceriodaphnia dubia</i>	cladoceran	R,M	--	113.6	121.9	76.0		34.00		Belanger and Cherry 1990	Y
<i>Ceriodaphnia dubia</i>	cladoceran	R,M	--	113.6	121.9	91.0		40.71		Belanger and Cherry 1990	Y
<i>Ceriodaphnia dubia</i>	cladoceran	R,M	--	182.0	144.3	84.0		23.68		Belanger and Cherry 1990	Y
<i>Ceriodaphnia dubia</i>	cladoceran	R,M	--	182.0	144.3	93.0		26.21		Belanger and Cherry 1990	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	52.0	55.0	19		18.28		Carlson et al. 1986	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	36.0	36.5	20		27.60		Carlson et al. 1986	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuSO ₄	57.1	--	13.4		11.76		Oris et al. 1991	Y
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	Cu(NO ₃) ₂	290.0	--	9.5		1.70		Schubauer-Berigan et al. 1993	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	Cu(NO ₃) ₂	290.0	--	28		5.00		Schubauer-Berigan et al. 1993	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	Cu(NO ₃) ₂	290.0	--	200		35.71		Schubauer-Berigan et al. 1993	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	Cu(NO ₃) ₂	175.0	--	12		3.52		Banks et al. 2003	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	CuCl ₂	182.0	120.0	16.35	15.7	4.61		Gensemer et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	CuCl ₂	390.0	120.0	23.13	22.2	3.09		Gensemer et al. 2002	

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	CuCl ₂	584.0	120.0	22.29	21.4	2.00		Geneser et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	CuCl ₂	786.0	120.0	26.77	25.7	1.80		Geneser et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=6.5)	30.0	1.67	1.6	1.89		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=7.5)	30.0	2.29	2.2	2.60		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=6.5)	30.0	9.90	9.5	11.22		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=6.5)	30.0	2.19	2.1	2.48		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=7.5)	30.0	2.92	2.8	3.31		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=8.1)	60.0	6.77	6.5	7.67		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=8.4)	125.0	16.67	16.0	18.89		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=7.8)	30.0	2.85	2.7	3.24		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=8.1)	30.0	3.76	3.6	4.26		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,D	--	44.0 (pH=8.4)	30.0	7.03	6.8	7.97		Hyne et al. 2005	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	178.0 (Ca:Mg=4:0)	115.0	10.5		3.02		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	178.0 (Ca:Mg=3:1)	117.0	17.47		5.03		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	180.0 (Ca:Mg=1:1)	111.0	16.16		4.60		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	178.0 (Ca:Mg=4:0)	117.0	7.92		2.28		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	180.0 (Ca:Mg=3:1)	117.0	12.94		3.69		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	180.0 (Ca:Mg=1:1)	117.0	14.49		4.13		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	180.0 (Ca:Mg=4:0)	117.0	7.88		2.25		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	182.0 (Ca:Mg=3:1)	117.0	9.14		2.58		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuCl ₂	180.0 (Ca:Mg=1:1)	118.0	7.89		2.25		Naddy et al. 2002	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuSO ₄	80.0 (70-90)	53.0 (48-58)	3.7		2.33		Diamond 1997	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuSO ₄	80.0 (70-90)	53.0 (48-58)	7.8		4.92		Diamond 1997	
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuSO ₄	80.0	53.0	8.4		5.30		Diamond 1997	

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Ceriodaphnia dubia</i>	cladoceran	S,M,T	CuSO ₄	(70-90) 80.0	(48-58) 53.0	7.1		4.48		Diamond 1997	
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	CuSO ₄	(70-90) 90.0	(48-58) 65	11		6.18*		Bright 1995	
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	CuSO ₄	90.0	65	36.6		20.57*		Bright 1995	
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	CuSO ₄	90.0	65	19.1		10.74*		Bright 1995	
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	CuSO ₄	90.0	65	36.4		20.46*		Bright 1995	
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	CuSO ₄	90.0	65	11.7		6.58*		Bright 1995	
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	CuSO ₄	90.0	65	12.3		6.91*		Bright 1995	
<i>Ceriodaphnia reticulata</i>	cladoceran	S,U	--	240.0	--	23		4.94	9.65	Elnabarawy et al. 1986	
<i>Ceriodaphnia reticulata</i>	cladoceran	S,U	--	45.0	44.0	17		18.85		Mount and Norberg 1984	
<i>Chironomus decorus</i>	midge	S,M	--	44.0	--	739		837.64	837.64	Kosalwat and Knight	
<i>Chironomus plumosus</i>	midge	S,U	CuSO ₄	(40-48) 80.0	--	200		126.17	124.86	Fargasova 2003	
<i>Chironomus</i> sp.	midge	S,M	--	50.0	--	30		30.00	30.00	Rehwoldt et al. 1973	
<i>Chironomus tentans</i> 2nd instar	midge	F,T,M	CuCl ₂	77.2	--	773		504.82	452.70	Nebeker et al. 1984a	
<i>Chironomus tentans</i> 3rd instar	midge	F,T,M	CuCl ₂	77.2	--	1,446		944.34		Nebeker et al. 1984a	
<i>Chironomus tentans</i> 1st instar	midge	F,T,M	CuCl ₂	77.2	--	298		194.61		Nebeker et al. 1984a	
<i>Chironomus tentans</i> 4th instar	midge	F,T,M	CuCl ₂	77.2	--	1,690		1,103.68*		Nebeker et al. 1984a	
<i>Chydorus sphaericus</i>	cladoceran	R,U	CuSO ₄	33.8	--	3.3		4.84	4.84	Koivisto et al. 1992	
<i>Corbicula manilensis</i>	freshwater clam	F,M,T	CuCl ₂	17.0	5.4	>2,600		>7484.64	>7,484.6	Harrison et al. 1984	
<i>Crangonyx pseudogracilis</i>	amphipod	S,U	--	50.0	--	1,290		1,290.00	1,290.00	Martin and Holdich 1986	
<i>Daphnia galeata</i>	cladoceran	R,U	CuSO ₄	33.8	--	4.1		6.02	6.02	Koivisto et al. 1992	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	170.0	115.0	41.2		12.42	14.93	Baird et al. 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	(160-180) 170.0	115.0	10.5		3.16		Baird et al. 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	(160-180) 170.0	115.0	20.6		6.21		Baird et al. 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	(160-180) 170.0	115.0	17.3		5.21		Baird et al. 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	(160-180) 170.0	115.0	70.7		21.31		Baird et al. 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	(160-180) 170.0	115.0	31.3		9.43		Baird et al. 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M	--	100.0	--	31.8		16.12		Borgman and Ralph 1983	Y
<i>Daphnia magna</i>	cladoceran	S,M,I	--	100.0	--	35.6		18.05		Borgman and Charlton 1984	Y
<i>Daphnia magna</i>	cladoceran	S,M	CuCl ₂	52.0	45.0	26		25.02		Chapman et al. manuscript	Y
<i>Daphnia magna</i>	cladoceran	S,M	CuCl ₂	105.0	79.0	30		14.50		Chapman et al. manuscript	Y
<i>Daphnia magna</i>	cladoceran	S,M	CuCl ₂	106.0	82.0	38		18.19		Chapman et al. manuscript	Y
<i>Daphnia magna</i>	cladoceran	S,M	CuCl ₂	207.0	166.0	69		17.14		Chapman et al. manuscript	Y
<i>Daphnia magna</i>	cladoceran	S,M	Cu oxide	143.0	--	26		9.28		Lewis 1983	Y

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	7.9	60.0	2		12.20		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	11.1	56.0	2		8.74		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	22.2	56.0	10		22.16		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	50.7	56.0	11.1		10.95		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	7.1	24.0	2		13.55		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	7.1	52.0	2.8		18.97		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	7.1	56.0	4.8		32.51		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	20.6	18.0	2		4.77		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	20.6	60.0	7.4		17.65		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuSO ₄	20.6	64.0	6.5		15.50		Long et al. 2004	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	7.4	7.1	3.42		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	17.1	16.4	7.89		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	41.6	39.9	19.21		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	19.5	18.7	9.00		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	19.7	18.9	9.10		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	41.4	39.7	19.11		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	47.9	46	22.14		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	59.6	57.2	27.54		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,D	CuSO ₄	109.9	12.5	70.6	67.8	32.64		Meador 1991	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	31		9.34		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	38		11.45		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	35		10.55		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	58		17.48		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	37		11.15		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	51		15.37		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	39		11.75		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	50		15.07		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	52		15.67		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	31		9.34		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	30		9.04		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	46		13.86		Lazorchak and Waller 1993	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	--	(160-180)	(110-120)						
<i>Daphnia magna</i>	cladoceran	S,M,T	--	170.0	115.0	63		18.99		Lazorchak and Waller 1993	Y

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃) (160-180)	Alkalinity (mg/L) (110-120)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	39.0	--	9.1		11.61		Nebeker et al. 1986a	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	39.0	--	11.7		14.93		Nebeker et al. 1986a	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	38.0	--	6.6		8.64		Nebeker et al. 1986a	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	38.0	--	9.9		12.96		Nebeker et al. 1986a	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	39.0	--	11.7		14.93		Nebeker et al. 1986a	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	39.0	--	6.7		8.55		Nebeker et al. 1986a	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	26.0	--	9.1		17.27		Nebeker et al. 1986a	Y
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	27.0	--	5.2		9.51		Nebeker et al. 1986a	Y
<i>Daphnia magna</i>	cladoceran	S,M,T,D	--	360.0	--	304	100.0	43.91		De Schampelaere et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T,D	--	(pH=7.59, DOC=1.5) 120.0	--	350	276.0	148.40		De Schampelaere et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T,D	--	(pH=7.65, DOC=3.6) 200.0	--	115	92.6	29.55		De Schampelaere et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T,D	--	(pH=6.77, DOC=1.86) 200.0	--	266	210.0	68.36		De Schampelaere et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T,D	--	(pH=8.39, DOC=4.65) 60.0	--	429	388.0	358.80		De Schampelaere et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T,D	--	(pH=7.74, DOC=4.0) 80.0	--	168	157.0	105.99		De Schampelaere et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T,D	--	(pH=8.46, DOC=3.1) 40.0	--	395	380.0	491.56		De Schampelaere et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	176.0	114.0	16.35		4.76		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=4:0) 176.0	111.0	20.97		6.11		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=3:1) 180.0	111.0	57.28		16.32		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=1:1) 180.0	117.0	21.55		6.14		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=4:0) 182.0	117.0	31.77		8.96		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=3:1) 180.0	118.0	42.68		12.16		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=1:1) 90.0	56.0	12.2		6.86		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=4:0) 90.0	59.0	16.93		9.52		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=3:1) 92.0	59.0	11.99		6.60		Naddy et al. 2002	
<i>Daphnia magna</i>	cladoceran	S,M,T	CuCl ₂	(Ca:Mg=1:1) 250.0	--	6.5		1.34*		Dave 1984	
<i>Daphnia magna</i>	cladoceran	R,U	CuSO ₄	33.8	--	11.5		16.88*		Koivisto et al. 1992	Y
<i>Daphnia magna</i>	cladoceran	S,U	--	240.0	--	41		8.81*		Elnabarawy et al. 1986	Y

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Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Daphnia magna</i>	cladoceran	S,U	--	45.0	44.0	54		59.87*		Mount and Norberg 1984	Y
<i>Daphnia magna</i>	cladoceran	S,U	CuCl ₂	45.3	--	9.8		10.80*		Biesinger and Christensen 1972	Y
<i>Daphnia magna</i>	cladoceran	S,U	CuSO ₄	226.0	--	200		45.60*		Cabejszek and Stasiak 1960	Y
<i>Daphnia magna</i>	cladoceran	S,U	CuSO ₄	45.0	--	10		11.09*		Cairns et al. 1978	Y
<i>Daphnia magna</i>	cladoceran	S,U	CuCl ₂	99.0	--	85		43.52*		Adema and Degroot-Van Ziji 1972	Y
<i>Daphnia magna</i>	cladoceran	S,U	CuCl ₂	99.0	--	50		25.60*		Adema and Degroot-Van Ziji 1972	Y
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	57.5	115	23.00		20.06	14.64	Winner 1985	
				(HA=0mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	57.5	115	28.80		25.11		Winner 1985	
				(HA=0mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	57.5	115	39.30		34.27		Winner 1985	
				(HA=0.75mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	57.5	115	40.30		35.14		Winner 1985	
				(HA=0.75mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	57.5	115	63.40		55.28		Winner 1985	
				(HA=1.5mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	57.5	115	71.20		62.09		Winner 1985	
				(HA=1.5mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	115.0	115	23.30		10.30		Winner 1985	
				(HA=0mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	115.0	115	32.70		14.46		Winner 1985	
				(HA=0mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	115.0	115	45.00		19.89		Winner 1985	
				(HA=0.75mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	115.0	115	27.20		12.02		Winner 1985	
				(HA=0.75mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	115.0	115	50.30		22.24		Winner 1985	
				(HA=1.5mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	115.0	115	52.80		23.34		Winner 1985	
				(HA=1.5mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	230.0	115	10.00		2.24		Winner 1985	
				(HA=0mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	230.0	115	17.10		3.83		Winner 1985	
				(HA=0mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	230.0	115	26.40		5.92		Winner 1985	
				(HA=0.15mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	230.0	115	31.40		7.04		Winner 1985	
				(HA=0.15mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	230.0	115	30.50		6.83		Winner 1985	
				(HA=0.75mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	230.0	115	45.60		10.22		Winner 1985	
				(HA=0.75mg/L)							
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	230.0	115	64.00		14.34		Winner 1985	

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Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Daphnia pulex</i>	cladoceran	S,M,T	CuSO ₄	(HA=1.5mg/L) 230.0	115	66.20		14.84		Winner 1985	
<i>Daphnia pulex</i>	cladoceran	S,U	CuSO ₄	(HA=1.5mg/L) 45.0	--	10		11.09*		Cairns et al. 1978	Y
<i>Daphnia pulex</i>	cladoceran	S,U	--	240.0	--	31		6.66*		Elnabarawy et al. 1986	Y
<i>Daphnia pulex</i>	cladoceran	S,U	--	45.0	44.0	53		58.77*		Mount and Norberg 1984	
<i>Daphnia pulex</i>	cladoceran	R,U	CuSO ₄	33.8	--	3.4		4.99*		Koivisto et al. 1992	Y
<i>Daphnia pulex</i>	cladoceran	S,U	CuCl ₂	85.0	--	18		10.70*		Roux et al. 1993	Y
<i>Daphnia pulex</i>	cladoceran	S,U	CuCl ₂	(80-90) 85.0	--	24		14.27*		Roux et al. 1993	Y
<i>Daphnia pulex</i>	cladoceran	S,U	CuCl ₂	(80-90) 85.0	--	22		13.08*		Roux et al. 1993	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	48.0	42.0	11.4		11.87	8.98	Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	48.0	42.0	9.06		9.43		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	48.0	44.0	7.24		7.54		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	44.0	42.0	10.8		12.24		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	45.0	--	9.3		10.31		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	95.0	--	17.8		9.49		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	95.0	--	25.2		13.43		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	145.0	--	23.7		8.35		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	145.0	--	25.1		8.84		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	245.0	--	27.3		5.75		Lind et al. manuscript	Y
<i>Daphnia pulicaria</i>	cladoceran	S,M,T	--	245.0	--	25.1		5.29		Lind et al. manuscript	Y
<i>Ephemerella subvaria</i>	mayfly	S,U	CuSO ₄	44.0	40.0	320		362.71	362.71	Warnick and Bell	
<i>Ephoron virgo</i>	mayfly	S,M,T	CuCl ₂	210.0	--	79		19.35	19.35	Van der Geest et al. 2000	
<i>Ephoron virgo</i>	mayfly	S,M,T	CuCl ₂	210.0	--	93		22.78		Van der Geest et al. 2000	
<i>Gammarus</i> sp.	amphipod	R,M,T	CuCl ₂	176.0	118.0	181		52.72	39.00	Naddy et al. 2002	
<i>Gammarus</i> sp.	amphipod	R,M,T	CuCl ₂	(Ca:Mg=4:0) 176.0	118.0	103		30.00		Naddy et al. 2002	
<i>Gammarus</i> sp.	amphipod	R,M,T	CuCl ₂	(Ca:Mg=3:1) 182.0	116.0	133		37.49		Naddy et al. 2002	
<i>Gammarus pseudolimnaeus</i> (1-3d)	amphipod	F,M,T	CuSO ₄	(Ca:Mg=1:1) 44.9	42.7	19		21.11	22.72	Arthur and Leonard 1970	
<i>Gammarus pseudolimnaeus</i> (1-3d)	amphipod	F,M,T	CuSO ₄	44.9	42.7	22		24.45		Arthur and Leonard 1970	
<i>Gammarus pulex</i>	amphipod	R,U	CuCl ₂	104.0	--	21		10.24	15.22	Stephenson 1983	
<i>Gammarus pulex</i>	amphipod	R,U	CuCl ₂	249.0	--	109		22.60		Stephenson 1983	
<i>Gyraulus circumstriatus</i>	snail	S,U	CuSO ₄	100.0	--	108		54.75	54.75	Wurtz and Bridges 1961	
<i>Hyalella azteca</i>	amphipod	S,M,T	Cu(NO ₃) ₂	290.0	--	17		3.04	16.35	Schubauer-Berigan et al. 1993	
<i>Hyalella azteca</i>	amphipod	S,M,T	Cu(NO ₃) ₂	(280-300) 290.0	--	24	(pH=6-6.5)	4.29		Schubauer-Berigan et al. 1993	
<i>Hyalella azteca</i>	amphipod	S,M,T	Cu(NO ₃) ₂	(280-300) 290.0	--	87	(pH=7-7.5)	15.53		Schubauer-Berigan et al. 1993	
<i>Hyalella azteca</i>	amphipod	S,M,T	Cu(NO ₃) ₂	(280-300) 290.0	--	87	(pH=8-8.5)	15.53		Schubauer-Berigan et al. 1993	

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<i>Hyalella azteca</i>	amphipod	S,M,T	CuSO ₄	20.5	--	24.3		58.23		Welsh 1996	
<i>Hyalella azteca</i>	amphipod	S,M,T	CuSO ₄	20.5	--	23.8		57.03		Welsh 1996	
<i>Hyalella azteca</i>	amphipod	S,M,T	CuSO ₄	20.6	--	8.2		19.55		Welsh 1996	
<i>Hyalella azteca</i>	amphipod	S,M,T	CuSO ₄	20.6	--	10		23.85		Welsh 1996	
<i>Juga plicifera</i>	snail	F,M,T	CuCl ₂	21.0	26.0	15		35.10	35.10	Nebeker et al. 1986b	
<i>Lampsilis teres</i>	yellow sandshell	S,M,T	CuSO ₄	40.0	--	36		44.80	44.80	Keller unpublished	
<i>Lampsilis claibornensis</i>	freshwater mussel	S,M,T	CuSO ₄	80.0	--	75		47.32	49.75	Keller unpublished	
<i>Lampsilis claibornensis</i>	freshwater mussel	S,M,T	CuSO ₄	40.0	--	65		80.89		Keller unpublished	
<i>Lampsilis claibornensis</i>	freshwater mussel	S,M,T	CuSO ₄	80.0	--	51		32.17		Keller unpublished	
<i>Limnodrilus hoffmeisteri</i>	worm	S,U	CuSO ₄	100.0	--	102		51.71	51.71	Wurtz and Bridges 1961	
<i>Lithoglyphus virens</i>	snail	F,M,T	CuCl ₂	21.0	26.0	8		18.72	18.72	Nebeker et al. 1986b	
<i>Lophopodella carteri</i>	bryozoan	S,U	--	204.5	--	140		35.21	35.21	Pardue and Wood 1980	
<i>Lumbriculus variegatus</i>	worm	S,M,T	Cu(NO ₃) ₂	290.0	--	130		23.21	46.40	Schubauer-Berigan et al. 1993	
<i>Lumbriculus variegatus</i>	worm	S,M,T	Cu(NO ₃) ₂	290.0	--	270	(pH=6-6.5)	48.21		Schubauer-Berigan et al. 1993	
<i>Lumbriculus variegatus</i>	worm	S,M,T	Cu(NO ₃) ₂	290.0	--	500	(pH=7-7.5)	89.28		Schubauer-Berigan et al. 1993	
<i>Lumbriculus variegatus</i>	worm	S,U	CuSO ₄	30.0	--	150	(pH=8-8.5)	247.47*		Bailey and Liu 1980	
<i>Lumbriculus variegatus</i>	worm	S,U	CuSO ₄	100.0	--	102		51.71*		Wurts and Bridges 1961	
<i>Orconectes rusticus</i>	crayfish	F,M,T	CuSO ₄	111.8	--	3,000		1,363.30	1,363.30	Hubschman 1967	
<i>Pectinatella magnifica</i>	bryozoan	S,U	--	204.5	--	510		128.27	128.27	Pardue and Wood 1980	
<i>Physella gyrina</i>	snail	S,U	CuSO ₄	90.0	65	48.5		27.26	27.26	Bright 1995	
<i>Physa heterostropha</i>	snail	S,U	CuSO ₄	100.0	--	69		34.98	34.98	Wurtz and Bridges 1961	
<i>Physa integra</i>	snail	F,M,T	CuSO ₄	44.9	42.7	41		45.56	43.28	Arthur and Leonard 1970	
<i>Physa integra</i>	snail	F,M,T	CuSO ₄	44.9	42.7	37		41.11		Arthur and Leonard 1970	
<i>Procambarus clarkii</i> (larva)	crayfish	F,M,T	CuCl ₂	17.0	13.0	720		2,072.67	2,072.67	Rice and Harrison 1983	
<i>Scapholeberis</i> sp.	cladoceran	S,M,T	CuCl ₂	52.0	--	18		17.32	17.32	Carlson et al. 1986	
<i>Simocephalus vetulus</i>	cladoceran	S,U	--	45.0	44.0	57		63.20	63.20	Mount and Norberg 1984	
<i>Tropocyclops prasinus mexicanus</i> (adults and copepodids V)	copepod	S,U	CuSO ₄	10.0	15	29		140.43	140.43	Lalande and Pinel-Allouï 1986	
<i>Tubifex tubifex</i>	worm	R,U	CuSO ₄	245.0	400.0	158		33.28	33.28	Khengarot 1991	Y
<i>Tubifex tubifex</i>	worm	S,M	CuSO ₄	128.0	--	90		35.82		Reynoldson et al. 1996	Y
<i>Trichoptera</i> Spp.	stonefly	S,M	--	50.0	--	6200		6,200.00	6,200.00	Rehwoldt et al. 1973	
<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	CuSO ₄	39.0	--	86		109.71	41.83	Keller and Zam 1991	
<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	CuSO ₄	90.0	--	199		111.86		Keller and Zam 1991	
<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	Cu(NO ₃) ₂	92.0	77.0	76		41.81		Keller unpublished	
<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	Cu(NO ₃) ₂	86.0	78.0	85		49.95		Keller unpublished	
<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	Cu(NO ₃) ₂	90.0	78.0	41		23.05		Keller unpublished	

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<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	CuSO ₄	90.0	99.0	79		44.41		Keller unpublished	
<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	CuSO ₄	90.0	99.0	72		40.47		Keller unpublished	
<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	CuSO ₄	86.0	59.0	38		22.33		Keller unpublished	
<i>Utterbackia imbecilis</i>	freshwater mussel	S,M,T	CuSO ₄	186.0	180.0	60		16.56		Keller unpublished	
<i>Villosa vibex</i>	S. rainbow mussel	S,M,T	CuSO ₄	49.0	--	56		57.12	45.15	Keller unpublished	Y
<i>Villosa vibex</i>	S. rainbow mussel	S,M,T	CuSO ₄	184.0	180.0	119		33.19		Keller unpublished	Y
<i>Villosa villosa</i>	freshwater mussel	S,M,T	CuSO ₄	40.0	--	20		24.89	24.89	Keller unpublished	
<i>Zygoptera</i> sp.	damsel fly	S,M	--	50.0	--	4,600		4,600.00	4,600.00	Rehwoldt et al. 1973	
<i>Acrochilus alutaceus</i>	chiselmouth	F,M,T	CuCl ₂	54.0	43.0	143		132.61	132.61	Andros and Garton 1980	
<i>Anguilla rostrata</i>	american eel	S,M	--	55.0	--	6,000		5,464.90	5,747.51	Rehwoldt et al. 1972	
<i>Anguilla rostrata</i>	american eel	S,M	Cu(NO ₃) ₂	53.0	--	6,400		6,044.74		Rehwoldt et al. 1971	
<i>Anguilla rostrata</i>	american eel	S,U	CuSO ₄	43.8	--	3,200		3641.9*		Hinton and Eversole 1979	
<i>Anguilla rostrata</i>	american eel	S,U	CuSO ₄	43.8	--	2,540		2890.8*		Hinton and Eversole 1979	
<i>Bufo boreas</i>	boreal toad	S,M,T	CuSO ₄	167.0	115.0	120		36.80	36.80	Dwyer et al. 1999	
<i>Camptostoma anomalum</i>	stoneroller	F,M,T	CuSO ₄	200.0	154.5	290		74.53	74.53	Geckler et al. 1976	
<i>Carassius auratus</i>	goldfish	F,M,T	CuSO ₄	52.0	--	300		288.69	288.69	Tsai and McKee 1978,1980	
<i>Carassius auratus</i>	goldfish	S,U	CuSO ₄	20.0	--	36		88.37*		Pickering and Henderson 1966	
<i>Catostomus latipinnis</i>	flannelmouth sucker	S,U	CuSO ₄	144.0	103.0	175		62.06	62.06	Hamilton and Buhl 1997	
<i>Cyprinus carpio</i>	carp	S,M	Cu(NO ₃) ₂	53.0	--	810		765.04	746.62	Rehwoldt et al. 1971	
<i>Cyprinus carpio</i>	carp	S,M	--	55.0	--	800		728.65		Rehwoldt et al. 1972	
<i>Cyprinus carpio</i>	carp	S,U	CuSO ₄	166.0	--	117.5		36.25*		Deshmukh and Marathe 1980	
<i>Cyprinus carpio</i>	carp	S,U	CuSO ₄	166.0	--	530		163.50*		Deshmukh and Marathe 1980	
<i>Cyprinus carpio</i>	carp	R,U	CuSO ₄	19.0	29.0	63		162.63*		Khengarot et al. 1983	
<i>Danio rerio</i>	zebrafish	F,M,D	CuSO ₄	362.5	227.5	155.21	149.0	22.27	22.27	Fogels and Sprague 1977	
<i>Etheostoma caeruleum</i>	rainbow darter	F,M,T	CuSO ₄	200.0	154.5	320		82.24	82.24	Geckler et al. 1976	
<i>Etheostoma flabellare</i>	fantail darter	S,M,T	CuSO ₄	170.0	--	330		99.45	107.94	Lydy and Wissing 1988	
<i>Etheostoma flabellare</i>	fantail darter	S,M,T	CuSO ₄	170.0	--	341		102.77		Lydy and Wissing 1988	
<i>Etheostoma flabellare</i>	fantail darter	S,M,T	CuSO ₄	170.0	--	373		112.41		Lydy and Wissing 1988	
<i>Etheostoma flabellare</i>	fantail darter	S,M,T	CuSO ₄	170.0	--	392		118.14		Lydy and Wissing 1988	
<i>Etheostoma lepidum</i>	greenthroat darter	S,M,T	CuSO ₄	167.0	115.0	260		79.74	79.74	Dwyer et al. 1999	
<i>Etheostoma nigrum</i>	Johnny darter	S,M,T	CuSO ₄	170.0	--	493		148.57	159.55	Lydy and Wissing 1988	
<i>Etheostoma nigrum</i>	Johnny darter	S,M,T	CuSO ₄	170.0	--	483		145.56		Lydy and Wissing 1988	
<i>Etheostoma nigrum</i>	Johnny darter	S,M,T	CuSO ₄	170.0	--	602		181.42		Lydy and Wissing 1988	
<i>Etheostoma nigrum</i>	Johnny darter	S,M,T	CuSO ₄	170.0	--	548		165.15		Lydy and Wissing 1988	
<i>Etheostoma rubrum</i>	fountain darter	S,M,T	CuSO ₄	167.0	115.0	60		18.40	18.40	Dwyer et al. 1999	

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Etheostoma spectabile</i>	orange throat darter	F,M,T	CuSO ₄	200.0	154.5	850		218.44	218.44	Geckler et al. 1976	
<i>Fundulus diaphanus</i>	banded killifish	S,M	--	53.0	--	860		812.26	788.32	Rehboldt et al. 1971	
<i>Fundulus diaphanus</i>	banded killifish	S,M	--	55.0	--	840		765.09		Rehboldt et al. 1972	
<i>Gambusia affinis</i> (female)	mosquitofish	S,U	Cu(NO ₃) ₂	33.3	--	93		138.63	795.54	Joski and Rege 1980	Y
<i>Gambusia affinis</i> (female)	mosquitofish	S,U	CuSO ₄	33.3	--	200		298.13		Joski and Rege 1980	Y
<i>Gambusia affinis</i> (male)	mosquitofish	S,U	--	50.0	--	3,500		3,500.00		Kallanagoudar and Patil 1997	Y
<i>Gambusia affinis</i> (male)	mosquitofish	S,U	--	150.0	--	5,000		1,703.51		Kallanagoudar and Patil 1997	Y
<i>Gambusia affinis</i> (male)	mosquitofish	S,U	--	300.0	--	6,000		1,036.30		Kallanagoudar and Patil 1997	Y
<i>Gambusia affinis</i> (female)	mosquitofish	S,U	--	50.0	--	2,500		2,500.00		Kallanagoudar and Patil 1997	Y
<i>Gambusia affinis</i> (female)	mosquitofish	S,U	--	150.0	--	2,900		988.03		Kallanagoudar and Patil 1997	Y
<i>Gambusia affinis</i> (female)	mosquitofish	S,U	--	300.0	--	5,000		863.58		Kallanagoudar and Patil 1997	Y
<i>Gambusia affinis</i> (fry)	mosquitofish	S,U	--	50.0	--	900		900.00		Kallanagoudar and Patil 1997	Y
<i>Gambusia affinis</i> (fry)	mosquitofish	S,U	--	150.0	--	1,400		476.98		Kallanagoudar and Patil 1997	Y
<i>Gambusia affinis</i> (fry)	mosquitofish	S,U	--	300.0	--	2,000		345.43		Kallanagoudar and Patil 1997	Y
<i>Gila elegans</i>	bonytail	S,M,T	CuSO ₄	173.0	115.0	200		59.25	59.25	Dwyer et al. 1995	
<i>Gila elegans</i>	bonytail	S,U	CuSO ₄	199.0	--	364		94.01*		Buhl and Hamilton 1996	
<i>Gila elegans</i>	bonytail	S,U	CuSO ₄	199.0	--	231		59.66*		Buhl and Hamilton 1996	
<i>Hypognathus amarus</i>	rio grande silvery minnow	R,M,T	CuSO ₄	147.5	128.0	250		86.59	86.59	Buhl 2002	
<i>Ictalurus nebulosus</i>	brown bullhead	F,M	CuSO ₄	202.0	--	170		43.26	66.22	Brungs et al. 1973	
<i>Ictalurus nebulosus</i>	brown bullhead	F,M	CuSO ₄	202.0	--	190		48.35		Brungs et al. 1973	
<i>Ictalurus nebulosus</i>	brown bullhead	F,M,T	CuSO ₄	200.0	154.5	540		138.78		Geckler et al. 1976	
<i>Ictalurus punctatus</i> (fingerlings)	channel catfish	S,U	CuSO ₄	16.0	16.0	54		164.97	249.80	Straus and Tucker 1993	Y
<i>Ictalurus punctatus</i> (fingerlings)	channel catfish	S,U	CuSO ₄	16.0	16.0	55		168.02		Straus and Tucker 1993	Y
<i>Ictalurus punctatus</i> (fingerlings)	channel catfish	S,U	CuSO ₄	83.0	76.0	762		463.69		Straus and Tucker 1993	Y
<i>Ictalurus punctatus</i> (fingerlings)	channel catfish	S,U	CuSO ₄	83.0	76.0	700		425.96		Straus and Tucker 1993	Y
<i>Ictalurus punctatus</i> (fingerlings)	channel catfish	S,U	CuSO ₄	161.0	127.0	768		244.12		Straus and Tucker 1993	Y
<i>Ictalurus punctatus</i> (fingerlings)	channel catfish	S,U	CuSO ₄	161.0	127.0	1,139		362.05		Straus and Tucker 1993	Y
<i>Ictalurus punctatus</i> (fingerlings)	channel catfish	S,U	CuSO ₄	287.0	239.0	1,041		187.78		Straus and Tucker 1993	Y
<i>Ictalurus punctatus</i> (fingerlings)	channel catfish	S,U	CuSO ₄	287.0	239.0	925		166.85		Straus and Tucker 1993	Y
<i>Jodanella floridae</i>	flagfish	F,M,D	CuSO ₄	362.5	227.5	1,323	1270.0	189.81	189.81	Fogel and Sprague 1977	
<i>Lepomis gibbosus</i>	pumpkinseed	F,M,T	CuSO ₄	125.0	--	1,240		505.13	619.00	Spear, 1977;Anderson and Spear 1980b	
<i>Lepomis gibbosus</i>	pumpkinseed	F,M,T	CuSO ₄	125.0	--	1,300		529.57		Spear, 1977;Anderson and Spear 1980b	
<i>Lepomis gibbosus</i>	pumpkinseed	F,M,T	CuSO ₄	125.0	--	1,670		680.29		Spear, 1977;Anderson and Spear 1980b	
<i>Lepomis gibbosus</i>	pumpkinseed	F,M,T	CuSO ₄	125.0	--	1,940		790.28		Spear, 1977;Anderson and Spear 1980b	
<i>Lepomis gibbosus</i>	pumpkinseed	F,M,T	CuSO ₄	125.0	--	1,240		505.13		Spear, 1977;Anderson and Spear 1980b	
<i>Lepomis gibbosus</i>	pumpkinseed	F,M,T	CuSO ₄	125.0	--	1,660		676.22		Spear, 1977;Anderson and Spear 1980b	

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Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Lepomis gibbosus</i>	pumpkinseed	F,M,T	CuSO ₄	125.0	--	1,740		708.81		Spear, 1977;Anderson and Spear 1980b	
<i>Lepomis gibbosus</i>	pumpkinseed	S,M,T	Cu(NO ₃) ₂	53.0	--	2,400		2266.78*		Rehwoldt et al. 1971	
<i>Lepomis gibbosus</i>	pumpkinseed	S,M,T	Cu(NO ₃) ₂	55.0	--	2,700		2459.21*		Rehwoldt et al. 1972	
<i>Lepomis macrochirus</i>	bluegill	F,M,T	--	31.2	--	340		539.78	1,394.46	Bailey et al. 1985	Y
<i>Lepomis macrochirus</i>	bluegill	F,M,T	--	31.2	--	550		873.18		Bailey et al. 1985	Y
<i>Lepomis macrochirus</i>	bluegill	R,M,D	CuCl ₂	85.0	--	2,292	2200	1,362.35		Blaylock et al. 1985	Y
<i>Lepomis macrochirus</i>	bluegill	F,M,D	CuCl ₂	85.0	--	1,354	1300	805.02		Blaylock et al. 1985	Y
<i>Lepomis macrochirus</i>	bluegill	FT,M	CuCl ₂	26.0	--	1,000		1,898.21		Cairns et al. 1981	Y
				(21.2-28.8)							
<i>Lepomis macrochirus</i>	bluegill	F,M,T	CuSO ₄	200.0	154.5	8,300		2,133.04		Geckler et al. 1976	Y
<i>Lepomis macrochirus</i>	bluegill	F,M,T	CuSO ₄	200.0	154.5	10,000		2,569.93		Geckler et al. 1976	Y
<i>Lepomis macrochirus</i>	bluegill	F,M,T	CuSO ₄	35.0	--	2,400		3,404.32		O'Hara 1971	Y
<i>Lepomis macrochirus</i>	bluegill	F,M,T	CuCl ₂	40.2	28.0	900		1,114.55		Thompson et al. 1980	Y
				(21.2-59.2)	(23.2-32.8)						
<i>Lepomis macrochirus</i>	bluegill	F,M,T	CuCl ₂	40.2	28.0	1,100		1,362.23		Thompson et al. 1980	Y
				(21.2-59.2)	(23.2-32.8)						
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	43.0	--	770		892.67*		Academy of Natural Sciences 1960	Y
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	43.0	--	1,250		1449.13*		Academy of Natural Sciences 1960;	Y
			CuCl ₂		--					Patrick et al. 1968;Cairns and	
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	20.0	--	660		1620.19*		Pickering and Henderson 1966	Y
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	360.0	--	10,200		1473.43*		Pickering and Henderson 1966	Y
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	20.0	--	200		490.97*		Tarzwel and Henderson 1960	Y
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	400.0	--	10,000		1302.81*		Tarzwel and Henderson 1960	Y
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	52.0	--	400		384.92*		Inglis and Davis 1972	
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	209.0	--	680		167.38*		Inglis and Davis 1972	
<i>Lepomis macrochirus</i>	bluegill	S,U	CuSO ₄	365.0	--	1,020		145.36*		Inglis and Davis 1972	
<i>Morone americana</i>	whtie perch	S,M,T	Cu(NO ₃) ₂	53.0	--	6,200		5,855.84	5,842.52	Rehwoldt et al. 1971	
<i>Morone americana</i>	whtie perch	S,M,T	Cu(NO ₃) ₂	55.0	--	6,400		5,829.23		Rehwoldt et al. 1972	
<i>Morone saxatilis</i> (larva)	striped bass	S,U	Cupric chloride	34.5	--	50		71.93	95.34	Hughes 1973	Y
<i>Morone saxatilis</i> (fingerling)	striped bass	S,U	Cupric chloride	34.5	--	50		71.93		Hughes 1973	Y
<i>Morone saxatilis</i> (larva)	striped bass	S,U	CuSO ₄	34.5	--	100		143.86		Hughes 1973	Y
<i>Morone saxatilis</i> (fingerling)	striped bass	S,U	CuSO ₄	34.5	--	150		215.79		Hughes 1973	Y
<i>Morone saxatilis</i>	striped bass	S,U	--	285.0	262.0	270		49.04		Palawski et al. 1985	Y
<i>Morone saxatilis</i>	striped bass	S,M,T	Cu(NO ₃) ₂	53.0	--	4,300		4061.31*		Rehwoldt et al. 1971	
<i>Morone saxatilis</i>	striped bass	S,U	CuSO ₄	35.0	--	620		879.45*		Wellborn 1969	
<i>Nais</i> sp.		S,M	--	50.0	--	90		90.00	90.00	Rehwoldt et al. 1973	
<i>Notemigonus crysoleucas</i>	golden shiner	F,M,T	CuCl ₂	72.2	--	84,600		59,017.19	59,017.19	Hartwell et al. 1989	
<i>Notropis chrysocephalus</i>	striped shiner	F,M,T	CuSO ₄	200.0	154.5	790		203.02	314.86	Geckler et al. 1976	
<i>Notropis chrysocephalus</i>	striped shiner	F,M,T	CuSO ₄	200.0	154.5	1,900		488.29		Geckler et al. 1976	
<i>Oncorhynchus apache</i>	apache trout	S,M,T	CuSO ₄	169.0	115.0	70		21.22	21.22	Dwyer et al. 1995	

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<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	205.0	178.0	367.0		92.06	65.19	Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	69.9	174.0	186.0		133.94		Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	18.0	183.0	36.8		100.16		Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	204.0	44.9	232.0		58.48		Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	83.0	70.0	162.0		98.58		Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	31.4	78.3	73.6		116.12		Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	160.0	26.0	91.0		29.10		Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	74.3	22.7	44.4		30.12		Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki</i>	cutthroat	F,M	CuCl ₂	26.4	20.1	15.7		29.36		Chakoumakos et al. 1979	Y
<i>Oncorhynchus clarki henshawi</i>	cutthroat	S,M,T	CuSO ₄	169.0	115.0	80		24.25*		Dwyer et al. 1995	
<i>Oncorhynchus clarki henshawi</i>	cutthroat	S,M,T	CuSO ₄	169.0	115.0	60		18.19*		Dwyer et al. 1995	
<i>Oncorhynchus gorbusha</i> (alevin, pink salmon newly hatched)		F,M,T	CuSO ₄	83.1	--	143		86.92	82.22	Servizi and Martins 1978	
<i>Oncorhynchus gorbusha</i> (alevin)	pink salmon	F,M,T	CuSO ₄	83.1	--	87		52.88		Servizi and Martins 1978	
<i>Oncorhynchus gorbusha</i> (fry)	pink salmon	F,M,T	CuSO ₄	83.1	--	199		120.95		Servizi and Martins 1978	
<i>Oncorhynchus kisutch</i>	coho	R,M	--	33.0	--	164		246.44	115.58	Buckley 1983	
<i>Oncorhynchus kisutch</i> (parr)	coho	F,M	CuCl ₂	23.0	--	32.62		69.83		Chapman 1975	
<i>Oncorhynchus kisutch</i> (adult)	coho	F,M	CuCl ₂	23.0	--	42.9		91.83		Chapman 1975	
<i>Oncorhynchus kisutch</i> (adult)	coho	F,M,T	CuCl ₂	20.0	--	46		112.92		Chapman and Stevens 1978	
<i>Oncorhynchus kisutch</i> (yearling)	coho	S,M,T	CuCl ₂	93.9	--	74		39.91*		Lorz and McPherson 1976	
<i>Oncorhynchus kisutch</i> (yearling)	coho	S,M,T	CuCl ₂	(89-99) 93.9	--	70		37.76*		Lorz and McPherson 1976	
<i>Oncorhynchus kisutch</i> (smolt)	coho	S,M,T	CuCl ₂	(89-99) 93.9	--	60		32.36*		Lorz and McPherson 1976	
<i>Oncorhynchus kisutch</i> (alevin)	coho	S,U	CuSO ₄	41.3	30.9	21		25.33*		Buhl and Hamilton 1990b	
<i>Oncorhynchus kisutch</i> (alevin)	coho	S,U	CuSO ₄	41.3	30.9	19.3		23.28*		Buhl and Hamilton 1990b	
<i>Oncorhynchus kisutch</i> (0.41g)	coho	S,U	CuSO ₄	41.3	30.9	15.1		18.21*		Buhl and Hamilton 1990b	
<i>Oncorhynchus kisutch</i> (0.47g)	coho	S,U	CuSO ₄	41.3	30.9	23.9		28.82*		Buhl and Hamilton 1990b	
<i>Oncorhynchus kisutch</i> (0.87g)	coho	S,U	CuSO ₄	41.3	30.9	31.9		38.47*		Buhl and Hamilton 1990b	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T,D	CuCl ₂	44.1	--	46.7	40.0	52.82	27.70	Cacela et al. 1996	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T,D	CuCl ₂	44.6	--	24.2	19.0	27.07		Cacela et al. 1996	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	36.1	--	19.6	18.0	26.97		Cacela et al. 1996	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	36.2	--	12.9	12.0	17.70		Cacela et al. 1996	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	20.4	--	5.9	5.7	14.21		Cacela et al. 1996	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	45.2	--	37.8	35.0	41.73		Cacela et al. 1996	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	45.4	--	25.1	18.0	27.59		Cacela et al. 1996	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	41.9	--	17.2	17.0	20.45		Cacela et al. 1996	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	--	290.0	--	890	854.4	158.91		Calamari and Marchetti 1973	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	169.0		44.75		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	85.3		22.59		Chakoumakos et al. 1979	Y

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<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	83.3		22.06		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	103.0		27.27		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	274.0		72.55		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	128.0		33.89		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	221.0		58.52		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	165.0		43.69		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	197.0		52.16		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	514.0		136.10		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	194.0	174.0	243.0		64.34		Chakoumakos et al. 1979	Y
<i>Oncorhynchus mykiss</i> (alevin)	rainbow trout	F,M	CuCl ₂	23.0	--	28		59.94		Chapman 1975,1978	Y
<i>Oncorhynchus mykiss</i> (swim-up)	rainbow trout	F,M	CuCl ₂	23.0	--	17		36.39		Chapman 1975,1978	Y
<i>Oncorhynchus mykiss</i> (parr)	rainbow trout	F,M	CuCl ₂	23.0	--	18		38.53		Chapman 1975,1978	Y
<i>Oncorhynchus mykiss</i> (smolt)	rainbow trout	F,M	CuCl ₂	23.0	--	29		62.08		Chapman 1975,1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuCl ₂	42.0	--	57		67.62		Chapman 1975;	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	--	(28-59) 9.2	--	14		73.57		Chapman and Steven 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	--	90.0	--	190		106.80		Cusiman and Brakke 1986	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	214.0	--	101		24.29		Giles and Klaverkamp 1982	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	220.0	--	308		72.09		Hansen et al. 2000	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	105.0	--	93		44.94		Hansen et al. 2000	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	98.2	--	35.9		18.53		Hansen et al. 2000	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuCl ₂	104.0	--	54.4		26.54		Hansen et al. 2000	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	30.0	--	19.9		32.83		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	32.0	--	22.4		34.69		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	31.0	--	28.9		46.17		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	31.0	--	30		47.93		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	30.0	--	30		49.49		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	101.0	--	176		88.36		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	101.0	--	40		20.08		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	99.0	--	33.1		16.95		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	102.0	--	30.7		15.26		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	101.0	--	46.3		23.24		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	99.0	--	47.9		24.52		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	100.0	--	48.1		24.38		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	100.0	--	81.1		41.11		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	98.0	--	85.9		44.42		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	370.0	--	232		32.63		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	366.0	--	70		9.95		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	371.0	--	82.2		11.53		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	361.0	--	298		42.93		Howarth and Sprague 1978	Y

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	371.0	--	516		72.37		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	360.0	--	309		44.64		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	364.0	--	111		15.86		Howarth and Sprague 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T	--	120.0	126.0	80		33.92		Seim et al. 1984	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	125.0	--	200		81.47		Spear, 1977;Anderson and Spear 1980b	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	125.0	--	190		77.40		Spear, 1977;Anderson and Spear 1980b	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M	CuSO ₄	125.0	--	210		85.55		Spear, 1977;Anderson and Spear 1980b	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,D	CuCl ₂	42.0 (Ca:Mg=0.17)	44.0	3.54	3.4	4.20		Welsh et al. 2000	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,D	CuCl ₂	39.0 (Ca:Mg=4.75)	42.0	8.44	8.1	10.76		Welsh et al. 2000	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,D	CuCl ₂	90.0 (Ca:Mg=0.77)	98.0	17.92	17.2	10.07		Welsh et al. 2000	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,D	CuCl ₂	90.0 (Ca:Mg=5.16)	97.0	33.33	32.0	18.74		Welsh et al. 2000	
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T,D	CuSO ₄	362.5 (350-375)	227.5 (200-255)	106.25	102.0	15.24		Fogels and Sprague 1977	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	172.0 (Ca:Mg=4:0)	114.0	67.9		20.23		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	178.0 (Ca:Mg=3:1)	116.0	53.9		15.53		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	176.0 (Ca:Mg=1:1)	114.0	35.5		10.34		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	176.0 (Ca:Mg=1:3)	119.0	18.1		5.27		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	176.0 (Ca:Mg=4:0)	108.0	52.5		15.29		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	180.0 (Ca:Mg=3:1)	113.0	46.2		13.16		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	178.0 (Ca:Mg=1:1)	114.0	30.7		8.84		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	180.0 (Ca:Mg=1:3)	110.0	17.9		5.10		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	176.0 (Ca:Mg=1:4)	114.0	18.1		5.27		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	179.0 (Ca:Mg=4:0)	116.0	37.3		10.69		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	177.0 (Ca:Mg=3:1)	117.0	27.7		8.02		Naddy et al. 2002	
<i>Oncorhynchus mykiss</i>	rainbow trout	R,M,T	CuCl ₂	180.0 (Ca:Mg=1:1)	115.0	21.2		6.04		Naddy et al. 2002	

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Oncorhynchus mykiss</i> (fry)	rainbow trout	F,M,T	--	25.4	25.1	18		34.96		Marr et al. 1998	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	F,M,T	CuCl ₂	9.2	11.0	2.8		14.71		Cusimano et al. 1986	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	S,M,T	CuSO ₄	169.0	115.0	110		33.34*		Dwyer et al. 1995	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	S,M,T	CuSO ₄	169.0	115.0	50		15.16*		Dwyer et al. 1995	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	S,M,T	CuSO ₄	169.0	115.0	60		18.19*		Dwyer et al. 1995	Y
<i>Oncorhynchus mykiss</i> (alevin)	rainbow trout	S,U	CuSO ₄	41.3	--	36		43.42*		Buhl and Hamilton 1990b	Y
<i>Oncorhynchus mykiss</i> (0.6g)	rainbow trout	S,U	CuSO ₄	41.3	--	13.8		16.64*		Buhl and Hamilton 1990b	Y
<i>Oncorhynchus nerka</i>	sockeye	R,M,T	--	40.7	--	240		293.68	132.57	Davis and Shand 1978	
<i>Oncorhynchus nerka</i>	sockeye	R,M,T	--	40.7	--	103		126.04		Davis and Shand 1978	
<i>Oncorhynchus nerka</i>	sockeye	R,M,T	--	40.7	--	220		269.20		Davis and Shand 1978	
<i>Oncorhynchus nerka</i>	sockeye	R,M,T	--	40.7	--	210		256.97		Davis and Shand 1978	
<i>Oncorhynchus nerka</i>	sockeye	R,M,T	--	40.7	--	240		293.68		Davis and Shand 1978	
<i>Oncorhynchus nerka</i> (alevin, newly hatched)	sockeye	F,M,T	CuSO ₄	83.1	--	190		115.48		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (alevin)	sockeye	F,M,T	CuSO ₄	83.1	--	200		121.56		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (alevin)	sockeye	F,M,T	CuSO ₄	83.1	--	100		60.78		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (alevin)	sockeye	F,M,T	CuSO ₄	83.1	--	110		66.86		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (alevin)	sockeye	F,M,T	CuSO ₄	83.1	--	130		79.01		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (fry)	sockeye	F,M,T	CuSO ₄	83.1	--	150		91.17		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (smolt)	sockeye	F,M,T	CuSO ₄	83.1	--	210		127.64		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (smolt)	sockeye	F,M,T	CuSO ₄	83.1	--	170		103.33		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (smolt)	sockeye	F,M,T	CuSO ₄	83.1	--	190		115.48		Servizi and Martins 1978	
<i>Oncorhynchus nerka</i> (smolt)	sockeye	F,M,T	CuSO ₄	83.1	--	240		145.87		Servizi and Martins 1978	
<i>Oncorhynchus tshawytscha</i> (alevin)	chinook	F,M,T	CuCl ₂	23.0	--	26		55.66	33.23	Chapman 1975,1978	Y
<i>Oncorhynchus tshawytscha</i> (swim-up)	chinook	F,M,T	CuCl ₂	23.0	--	19		40.67		Chapman 1975,1978	Y
<i>Oncorhynchus tshawytscha</i> (parr)	chinook	F,M,T	CuCl ₂	23.0	--	38		81.34		Chapman 1975,1978	Y
<i>Oncorhynchus tshawytscha</i> (smolt)	chinook	F,M,T	CuCl ₂	23.0	--	26		55.66		Chapman 1975,1978	Y
<i>Oncorhynchus tshawytscha</i>	chinook	F,M	CuCl ₂	25.4	23.9	33.1		64.29		Chapman 1982	Y
<i>Oncorhynchus tshawytscha</i>	chinook	F,M,T	--	13.0	12.0	10		37.44		Chapman and McCrady 1977	Y
<i>Oncorhynchus tshawytscha</i>	chinook	F,M,T	--	46.0	35.0	22		23.87		Chapman and McCrady 1977	Y
<i>Oncorhynchus tshawytscha</i>	chinook	F,M,T	--	182.0	125.0	85		23.96		Chapman and McCrady 1977	Y
<i>Oncorhynchus tshawytscha</i>	chinook	F,M,T	--	359.0	243.0	130		18.83		Chapman and McCrady 1977	Y
<i>Oncorhynchus tshawytscha</i>	chinook	F,M	CuSO ₄	21.0	--	32		74.89		Finlayson and Verrue 1982	Y
<i>Oncorhynchus tshawytscha</i>	chinook	F,M,D	CuCl ₂	36.0	41.0	7.71	7.4	10.64		Welsh et al. 2000	
<i>Oncorhynchus tshawytscha</i>	chinook	F,M,D	CuCl ₂	35.0	41.0	13.02	12.5	18.47		Welsh et al. 2000	
<i>Oncorhynchus tshawytscha</i>	chinook	F,M,D	CuCl ₂	38.0	44.0	14.90	14.3	19.49		Welsh et al. 2000	
<i>Oncorhynchus tshawytscha</i>	chinook	F,M,D	CuCl ₂	36.0	43.0	19.06	18.3	26.30		Welsh et al. 2000	
<i>Oncorhynchus tshawytscha</i>	chinook	S,U	CuSO ₄	211.0	88.0	58		14.14*		Hamilton and Buhl 1990a	Y

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Oncorhynchus tshawytscha</i>	chinook	S,U	CuSO ₄	211.0	88.0	54		13.17*		Hamilton and Buhl 1990a	Y
<i>Pimephales notatus</i>	bluntnose minnow	F,M,T	CuSO ₄	200.0	154.5	290		74.53	68.49	Geckler et al. 1976	
<i>Pimephales notatus</i>	bluntnose minnow	F,M,T	CuSO ₄	200.0	154.5	260		66.82		Geckler et al. 1976	
<i>Pimephales notatus</i>	bluntnose minnow	F,M,T	CuSO ₄	200.0	154.5	260		66.82		Geckler et al. 1976	
<i>Pimephales notatus</i>	bluntnose minnow	F,M,T	CuSO ₄	200.0	154.5	280		71.96		Geckler et al. 1976	
<i>Pimephales notatus</i>	bluntnose minnow	F,M,T	CuSO ₄	200.0	154.5	340		87.38		Geckler et al. 1976	
<i>Pimephales notatus</i>	bluntnose minnow	F,M	CuSO ₄	194.0	--	210		55.60		Horning and Neiheisel 1979	
<i>Pimephales notatus</i>	bluntnose minnow	F,M	CuSO ₄	194.0	--	220		58.25		Horning and Neiheisel 1979	
<i>Pimephales notatus</i>	bluntnose minnow	F,M	CuSO ₄	194.0	--	270		71.49		Horning and Neiheisel 1979	
<i>Pimephales promelas</i>	fathead minnow	F,M	--	200.0	--	790		203.02	80.66	Andrew 1976	Y
<i>Pimephales promelas</i>	fathead minnow	F,M	--	45.0	--	200		221.76		Andrew 1976	Y
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	47.0	--	31.75	27.9	33.71		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	243.2	--	117.48	105.7	24.92		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	255.7	--	48.26	40.1	9.75		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	47.0	--	73.03	64.3	77.53		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	45.0	--	59.06	49.0	65.43		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	45.0	--	78.74	67.7	87.23		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	45.5	--	22.23	18.7	24.36		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	49.0	--	6.99	6.2	7.12		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	45.0	--	22.23	20.5	24.63		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	43.0	--	107.32	93.4	124.31		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	45.0	--	81.28	72.3	90.04		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	45.5	--	241.3	195.5	264.44		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	45.0	--	133.35	109.4	147.73		Erickson et al. 1996	Y
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	44.0	--	93.98	78.0	106.43		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	44.0	--	67.95	45.5	76.95		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	22.5	--	4.76	4.4	10.40		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	24.0	--	13.97	12.4	28.66		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	23.0	--	29.85	26.9	63.84		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T,D	CuSO ₄	21.5	--	59.69	51.3	136.38		Erickson et al. 1996	
<i>Pimephales promelas</i>	fathead minnow	F,M,T	CuSO ₄	200.0	154.5	440		113.08		Geckler et al. 1976	Y
<i>Pimephales promelas</i>	fathead minnow	F,M,T	CuSO ₄	200.0	154.5	490		125.93		Geckler et al. 1976	Y
<i>Pimephales promelas</i>	fathead minnow	F,M	--	48.0	44.0	114		118.65		Lind et al. manuscript	Y
<i>Pimephales promelas</i>	fathead minnow	F,M	--	45.0	44.0	121		134.16		Lind et al. manuscript	Y
<i>Pimephales promelas</i>	fathead minnow	F,M	--	46.0	41.0	88.5		96.04		Lind et al. manuscript	Y
<i>Pimephales promelas</i>	fathead minnow	F,M	CuSO ₄	200.0	--	470		120.79		Mount 1968	Y
<i>Pimephales promelas</i>	fathead minnow	F,M	CuSO ₄	31.0	--	75		119.82		Mount and Stephan 1969	Y
<i>Pimephales promelas</i> (6 week fry)	fathead minnow	F,M,T	CuSO ₄	202.0	--	460		117.07		Pickering et al. 1977	Y
<i>Pimephales promelas</i> (6 mo. subadult)	fathead minnow	F,M,T	CuSO ₄	202.0	--	490		124.70		Pickering et al. 1977	Y
<i>Pimephales promelas</i>	fathead minnow	F,M	CuSO ₄	43.9	--	96		109.06		Spehar and Fiandt 1986	Y

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Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Pimephales promelas</i>	fathead minnow	R,M,T	CuSO ₄	147.5 (142-153)	128.0	393		136.12		Buhl 2002	Y
<i>Pimephales promelas</i>	fathead minnow	R,M,T	CuCl ₂	176.0 (Ca:Mg=3:1)	116.0	837		243.81		Naddy et al. 2002	
<i>Pimephales promelas</i>	fathead minnow	R,M,T	CuCl ₂	182.0 (Ca:Mg=1:1)	116.0	503		141.79		Naddy et al. 2002	
<i>Pimephales promelas</i>	fathead minnow	R,M,T	CuCl ₂	176.0 (Ca:Mg=4:0)	118.0	442		128.75		Naddy et al. 2002	
<i>Pimephales promelas</i>	fathead minnow	R,M,T	CuCl ₂	176.0 (Ca:Mg=3:1)	116.0	502		146.23		Naddy et al. 2002	
<i>Pimephales promelas</i>	fathead minnow	R,M,T	CuCl ₂	182.0 (Ca:Mg=1:1)	116.0	434		122.34		Naddy et al. 2002	
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuCl ₂	52.0	55.0	55		52.93*		Carlson et al. 1986	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuCl ₂	36.0	38.0	180		248.37*		Carlson et al. 1986	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	173.0	115.0	290		85.91*		Dwyer et al. 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	173.0	115.0	630		186.63*		Dwyer et al. 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	173.0	115.0	400		118.50*		Dwyer et al. 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	173.0	115.0	390		115.54*		Dwyer et al. 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	166.0	--	450		138.82*		Richards and Beitinger 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	159.0	--	297		95.57*		Richards and Beitinger 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	168.0	--	311		94.82*		Richards and Beitinger 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	167.0	--	513		157.32*		Richards and Beitinger 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,M,T	Cu(NO ₃) ₂	290.0 (280-300)	--	15 (pH=6-6.5)		2.68*		Schubauer-Berigan et al. 1993	
<i>Pimephales promelas</i>	fathead minnow	S,M,T	Cu(NO ₃) ₂	290.0 (280-300)	--	44 (pH=7-7.5)		7.86*		Schubauer-Berigan et al. 1993	
<i>Pimephales promelas</i>	fathead minnow	S,M,T	Cu(NO ₃) ₂	290.0 (280-300)	--	>200 (pH=8-8.5)		>35.71*		Schubauer-Berigan et al. 1993	
<i>Pimephales promelas</i>	fathead minnow	S,M,T	CuSO ₄	101.0	--	252		126.51*		Bennett et al. 1995	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	103.0	--	210		103.42*		Birge et al. 1983	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	103.0	--	310		152.67*		Birge et al. 1983	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	103.0	--	120		59.10*		Birge et al. 1983	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	262.4	--	390		76.82*		Birge et al. 1983	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	200.0	--	430		110.51*		Mount 1968	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	31.0	--	84		134.20*		Mount and Stephan 1969	
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	20.0	--	25		61.37*		Pickering and Henderson 1966	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	20.0	--	23		56.46*		Pickering and Henderson 1966	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	20.0	--	23		56.46*		Pickering and Henderson 1966	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	20.0	--	22		54.01*		Pickering and Henderson 1966	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	360.0	--	1760		254.24*		Pickering and Henderson 1966	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	360.0	--	1140		164.68*		Pickering and Henderson 1966	Y
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	20.0	--	50		122.74*		Tarzwel and Henderson 1960	Y

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Pimephales promelas</i>	fathead minnow	S,U	CuSO ₄	400.0	--	1,400		182.39*		Tarzwel and Henderson 1960	Y
<i>Plumatella emarginata</i>	bryozoan	S,U	--	204.5	--	140		35.21	35.21	Pardue and Wood 1980	
<i>Poecilia reticulata</i>	guppy	F,M,T	Cu(NO ₃) ₂	87.5	--	112		64.72	81.76	Black 1974; Chyoweth et al. 1976	Y
<i>Poecilia reticulata</i>	guppy	F,M,T	Cu(NO ₃) ₂	67.2	--	138		103.28		Black 1974; Chyoweth et al. 1976	Y
<i>Poecilia reticulata</i>	guppy	S,U	CuSO ₄	20.0	--	36		88.37*		Chynoweth et al. 1976	Y
<i>Poecilia reticulata</i>	guppy	S,U	CuSO ₄	230.0	--	1230		275.64*		Khangarot 1981	Y
<i>Poeciliopsis occidentalis</i>	gila topminnow	S,M,T	CuSO ₄	167.0	115.0	160		49.07	49.07	Dwyer et al. 1999	
<i>Ptychocheilus lucius</i>	Colorado pikeminnow	S,U	CuSO ₄	199.0	107.0	363		93.75	117.29	Buhl and Hamilton 1996	
<i>Ptychocheilus lucius</i>	Colorado pikeminnow	S,U	CuSO ₄	199.0	107.0	663		171.23		Buhl and Hamilton 1996	
<i>Ptychocheilus lucius</i>	Colorado pikeminnow	S,U	CuSO ₄	144.0	82.0	293		103.90		Hamilton and Buhl 1997	
<i>Ptychocheilus lucius</i>	Colorado pikeminnow	S,U	CuSO ₄	144.0	82.0	320		113.47		Hamilton and Buhl 1997	
<i>Ptychocheilus oregonensis</i>	northern pikeminnow	F,M,T	CuCl ₂	25.0 (20-30)	25.0 (20-30)	18		35.51	40.14	Andros and Garton 1980	Y
<i>Ptychocheilus oregonensis</i>	northern pikeminnow	F,M,T	CuCl ₂	25.0 (20-30)	25.0 (20-30)	23		45.37		Andros and Garton 1980	Y
<i>Ptychocheilus oregonensis</i>	northern pikeminnow	S,M,T	CuSO ₄	173.0	115.0	380		112.57*		Dwyer et al. 1995	Y
<i>Ptychocheilus oregonensis</i>	northern pikeminnow	S,M,T	CuSO ₄	173.0	115.0	480		142.20*		Dwyer et al. 1995	Y
<i>Rhinichthys atratulus</i>	blacknose dace	F,M,T	CuSO ₄	200.0	154.5	320		82.24	82.24	Geckler et al. 1976	
<i>Salmo salar</i>	atlantic salmon	F,M,T	CuSO ₄	20.0	--	48		117.83	114.58	Sprague 1964	
<i>Salmo salar</i>	atlantic salmon	F,M,T	--	14.0	--	32		111.43		Sprague and Ramsey 1965	
<i>Salmo salar</i>	atlantic salmon	S,M,T	--	8.9	--	125		675.24*		Wilson 1972	
<i>Salvelinus confluentus</i>	bull trout	F,M,T,D	CuCl ₂	214.0	--	228		54.83	39.47	Hansen et al. 2000	Y
<i>Salvelinus confluentus</i>	bull trout	F,M,T,D	CuCl ₂	220.0	--	207		48.45		Hansen et al. 2000	Y
<i>Salvelinus confluentus</i>	bull trout	F,M,T,D	CuCl ₂	105.0	--	66.6		32.19		Hansen et al. 2000	Y
<i>Salvelinus confluentus</i>	bull trout	F,M,T,D	CuCl ₂	98.2	--	50		25.80		Hansen et al. 2000	Y
<i>Salvelinus confluentus</i>	bull trout	F,M,T,D	CuCl ₂	104.0	--	89		43.42		Hansen et al. 2000	Y
<i>Salvelinus fontinalis</i>	brook trout	F,M	CuSO ₄	45.0	--	100		110.88	110.88	McKim and Benoit 1971	
<i>Scaphirhynchus platyrhynchus</i>	shovelnose sturgeon	S,M,T	CuSO ₄	167.0	115.0	160		49.07	49.07	Dwyer et al. 1999	
<i>Semotilus atromaculatus</i>	creek chub	F,M,T	CuSO ₄	200.0	154.5	310		79.67	79.67	Geckler et al. 1976	
<i>Thymallus arcticus</i> (alevin)	arctic grayling	S,U	CuSO ₄	41.3	30.9	67.5		81.41	23.52	Buhl and Hamilton 1990b	
<i>Thymallus arcticus</i> (alevin)	arctic grayling	S,U	CuSO ₄	41.3	30.9	23.9		28.82		Buhl and Hamilton 1990b	
<i>Thymallus arcticus</i> (alevin)	arctic grayling	S,U	CuSO ₄	41.3	30.9	131		157.99		Buhl and Hamilton 1990b	
<i>Thymallus arcticus</i> (fry)	arctic grayling	S,U	CuSO ₄	41.3	30.9	9.6		11.58		Buhl and Hamilton 1990b	
<i>Thymallus arcticus</i> (0.2g juvenile)	arctic grayling	S,U	CuSO ₄	41.3	30.9	2.7		3.26		Buhl and Hamilton 1990b	
<i>Thymallus arcticus</i> (0.34g juvenile)	arctic grayling	S,U	CuSO ₄	41.3	30.9	2.58		3.11		Buhl and Hamilton 1990b	
<i>Thymallus arcticus</i> (0.81g juvenile)	arctic grayling	S,U	CuSO ₄	41.3	30.9	49.3		59.46		Buhl and Hamilton 1990b	
<i>Thymallus arcticus</i> (0.85g juvenile)	arctic grayling	S,U	CuSO ₄	41.3	30.9	30		36.18		Buhl and Hamilton 1990b	
<i>Tilapia mossambica</i>	tilapia	S,U	CuSO ₄	115.0	--	1500		663.07	663.07	Qureshi and Saksena 1980	
<i>Xyrauchen texanus</i>	razorback sucker	S,M,T	CuSO ₄	173.0	115.0	220		65.17	81.02	Dwyer et al. 1995	
<i>Xyrauchen texanus</i>	razorback sucker	S,M,T	CuSO ₄	173.0	115.0	340		100.72		Dwyer et al. 1995	

Appendix 2 Table 3.1: Updated copper acute toxicity database

Species	Common name	Method ^a	Chemical ^b	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	Acute value (µg total Cu/L)	Acute value (µg dissolved Cu/L)	Normalized acute value ^b (µg total Cu/L)	SMAV	Reference	Slope?
<i>Xyrauchen texanus</i>	razorback sucker	S,U	CuSO ₄	199.0	107.0	404		104.34*		Buhl and Hamilton 1996	
<i>Xyrauchen texanus</i>	razorback sucker	S,U	CuSO ₄	199.0	107.0	331		85.48*		Buhl and Hamilton 1996	

^a S=static, F=flow through, R=renewal, M=measured, U=unmeasured, T=total, D=dissolved,

^b acute values normalized to hardness = 50 mg/L using the updated acute-hardness slope of 0.9801

* not used in SMAV calculation, see text for details

Appendix 2 Table 3.2: Updated copper chronic toxicity database

Species	Common name	Test ^a	Chemical	Hardness (mg/L as CaCO ₃)	Alkalinity (mg/L)	NOEC	LOEC	Chronic Value (µg total Cu/L)	Normalized Chronic value ^b (µg total Cu/L)	SMCV	Reference	Slope?
<i>Daphnia pulex</i>	cladoceran	LC (42d)	CuSO ₄	230.0 (HA=0.15mg/L)	--	--	--	12.25	4.98		Winner 1985	Y
<i>Daphnia pulex</i>	cladoceran	LC (42d)	CuSO ₄	230.0 (HA=0.75mg/L)	--	--	--	14.14	5.75		Winner 1985	
<i>Daphnia pulex</i>	cladoceran	LC (42d)	CuSO ₄	230.0 (HA=0.75mg/L)	--	--	--	24.49	9.96		Winner 1985	
<i>Catostomus commersonii</i>	white sucker	ELS	CuSO ₄	45.4	42.4	12.9	33.8	20.88	22.10	22.10	McKim et al. 1978	
<i>Esox lucius</i>	northern pike	ELS	CuSO ₄	45.4	42.4	34.9	104.4	60.36	63.90	63.90	McKim et al. 1978	
<i>Oncorhynchus mykiss</i>	rainbow trout	ELS	CuSO ₄	45.4	42.4	11.4	31.7	19.01	20.12	10.60	McKim et al. 1978	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	ELS	CuCl ₂	120.0	126	16	31	22.27	13.29		Seim et al. 1984	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	ELS	CuCl ₂	170.0	--	--	--	20.32	9.87		Besser et al. 2001	Y
<i>Oncorhynchus mykiss</i>	rainbow trout	ELS	CuCl ₂	25.0	27.7	2.2	4.6	3.18	4.79		Marr et al. 1996	Y
<i>Oncorhynchus tshawytscha</i>	chinook salmon	ELS	CuCl ₂	23.0	--	1.2	7.4	2.98	4.71	4.71	Chapman 1975, 1982	
<i>Pimephales notatus</i>	bluntnose minnow	LC	CuSO ₄	194.0	--	4.3	18	8.80	3.95	3.95	Horning and Neiheisel 1979	
<i>Pimephales promelas</i>	fathead minnow	LC	CuSO ₄	198.0	--	--	--	21.87	9.71	12.59	Mount 1968	Y
<i>Pimephales promelas</i>	fathead minnow	LC	CuSO ₄	30.0	--	--	--	13.97	18.88		Mount and Stephan 1969	Y
<i>Pimephales promelas</i>	fathead minnow	LC	CuSO ₄	202.0	--	24	37	29.80	13.08		Pickering et al. 1977	Y
<i>Pimephales promelas</i>	fathead minnow	ELS	--	45.0	--	--	--	18.53	19.72		Lind et al. Manuscript	Y
<i>Pimephales promelas</i>	fathead minnow	ELS	CuSO ₄	43.9	--	--	--	6.2	6.69		Spehar and Fiandt 1986	Y
<i>Salmo trutta</i>	brown trout	ELS	CuSO ₄	45.4	42.4	22	43.2	30.83	32.63	32.63	McKim et al. 1978	
<i>Salvelinus fontinalis</i>	brook trout	PLC	CuSO ₄	35.0	--	3	5	<3.9	<4.78	9.66	Sauter et al. 1976	
<i>Salvelinus fontinalis</i>	brook trout	LC	CuSO ₄	45.0	--	--	--	12.86	13.68		McKim and Benoit 1971	
<i>Salvelinus fontinalis</i>	brook trout	ELS	CuSO ₄	45.4	42.4	7.6	22.3	13.02	13.78		McKim et al. 1978	
<i>Salvelinus namaycush</i>	lake trout	ELS	CuSO ₄	45.4	42.4	22	42.3	30.51	32.29	32.29	McKim et al. 1978	

^aELS=early life-stage, PLC=partial life cycle, LC=life cycle

^b chronic values normalized to hardness = 50 mg/L using the updated chronic-hardness slope of 0.5897

Appendix 2 Table 4.1: Updated diazinon acute toxicity database

Species	Common name	Method ^a	pH	Acute value (µg total daizinon/L)	SMAV (ug/L)	Reference
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.6		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.35		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.35		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.25		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.33		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.35		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.59		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.43		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.35		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	--	0.36		Norberg-King 1987
<i>Ceriodaphnia dubia</i>	cladoceran	S,U	7.8	0.5		Ankley 1991
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.82	0.58		Bailey 1997
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.82	0.48		Bailey 1997
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.82	0.26		Bailey 1997
<i>Ceriodaphnia dubia</i>	cladoceran	R,M	8.3	0.47		CDFG 1992a
<i>Ceriodaphnia dubia</i>	cladoceran	R,M	8.5	0.507		CDFG 1992b
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	7.82	0.29		Bailey 1997
<i>Ceriodaphnia dubia</i>	cladoceran	S,M	8.35	0.45	0.40	Banks et al. 2003
<i>Chironomus tentans</i>	midge	S,M	7.55	30	30.00	Belden 2000
<i>Daphnia magna</i>	cladoceran	S,U	7.9	0.96		Vilkas 1976
<i>Daphnia magna</i>	cladoceran	S,U	--	0.86		Fernandez et al. 1995
<i>Daphnia magna</i>	cladoceran	S,U	--	1.5		Dorland 1980
<i>Daphnia magna</i>	cladoceran	S,U	7.8	0.8	1.00	Ankley 1991
<i>Daphnia pulex</i>	cladoceran	S,U	--	0.9		Cope 1965a
<i>Daphnia pulex</i>	cladoceran	S,U	7.6	0.9		Sanders and Cope 1966
<i>Daphnia pulex</i>	cladoceran	S,U	7.25	0.8		Mayer and Ellersieck 1986
<i>Daphnia pulex</i>	cladoceran	S,U	7.35	0.8		Johnson and Finley 1980
<i>Daphnia pulex</i>	cladoceran	S,U	7.8	0.65		Ankley 1991
<i>Daphnia pulex</i>	cladoceran	S,U	--	0.9	0.82	Cope 1965
<i>Gammarus fasciatus</i>	amphipod	S,U	7.35	0.2	0.20	Johnson and Finley 1980; Mayer and Ellersieck 1986
<i>Gammarus lacustris</i>	amphipod	S,U	--	200*	200*	Sanders 1969
<i>Girardia tigrina</i>	planaria	S,M	--	11,640		Phipps 1988
<i>Girardia tigrina</i>	planaria	S,M	--	630	2,708	Villar et.al. 1994

Appendix 2 Table 4.1: Updated diazinon acute toxicity database

Species	Common name	Method ^a	pH	Acute value (µg total daizonin/L)	SMAV (ug/L)	Reference
<i>Gyraulus altilis</i>	snail	S,U	6.8	11,000	11,000	Robertson and Mazzella 1989
<i>Lestes congener</i>	damselfly	S,U	7.4	50	50.00	Federle and Collins 1975
<i>Lumbriculus variegatus</i>	worm	S,M	--	9,980		Phipps 1988
<i>Lumbriculus variegatus</i>	worm	S,U	7.95	6,160	7,841	Ankley and Collyard 1995
<i>Physa paludosa</i>	snail	F,M	--	2,950		Call 1993
<i>Physa paludosa</i>	snail	F,M	--	3,270		Call 1993
<i>Physa paludosa</i>	snail	F,M	--	3,390	3,198	Call 1993
<i>Simocephalus serrulatus</i>	cladoceran	S,U	7.6	1.8		Sanders and Cope 1966
<i>Simocephalus serrulatus</i>	cladoceran	S,U	7.6	1.4		Sanders and Cope 1966
<i>Simocephalus serrulatus</i>	cladoceran	S,U	7.35	1.4		Johnson and Finley 1980
<i>Simocephalus serrulatus</i>	cladoceran	S,U	--	2		Cope 1965a
<i>Simocephalus serrulatus</i>	cladoceran	S,U	--	2	1.70	Cope 1965
<i>Pteronarcella californica</i>	stonefly	S,U	7.35	25	25	Johnson and Finley 1980; Mayer and Ellersieck 1986
<i>Brachydanio rerio</i>	zebrafish	R,M	--	8,000		Keizer 1991
<i>Brachydanio rerio</i>	zebrafish	R,M	7.6	7,304	7,644	Keizer 1993
<i>Carassius auratus</i>	goldfish	S,U	--	9,000	9,000	Beliles 1965
<i>Carassius carassius</i>	crucian carp	S,U	7.2	5,000	5,000	Bathe et al. 1975
<i>Clarias batrahus</i>	walking catfish	R,U	7.3	14,792	14,792	Tripathi et al. 1992
<i>Ictalurus melas</i>	black bullhead	S,U	7.2	8,000	8,000	Bathe et al. 1975
<i>Jordanella floridae</i>	flagfish	F,M	7.4	1,500		Allison and Hermanutz 1977
<i>Jordanella floridae</i>	flagfish	F,M	7.4	1,800	1,643	Allison and Hermanutz 1977
<i>Lepomis macrochirus</i>	bluegill	S,U	--	136		Beliles 1965
<i>Lepomis macrochirus</i>	bluegill	S,U	--	22		Cope 1965b
<i>Lepomis macrochirus</i>	bluegill	S,U	--	22		Ciba-Giegy 1976
<i>Lepomis macrochirus</i>	bluegill	S,U	--	120		Meier 1979, Dennis 1980
<i>Lepomis macrochirus</i>	bluegill	S,U	7.35	168		Johnson and Finley 1980; Mayer and Ellersieck 1986
<i>Lepomis macrochirus</i>	bluegill	F,M	7.4	480		Allison and Hermanutz 1977
<i>Lepomis macrochirus</i>	bluegill	F,M	7.4	440	115.86	Allison and Hermanutz 1977
<i>Oncorhynchus clarki</i>	cutthroat trout	S,U	7.35	1,700		Johnson and Finley 1980; Mayer and Ellersieck 1986
<i>Oncorhynchus clarki</i>	cutthroat trout	S,U	7.25	2,760	2,166	Myer and Ellersieck 1986
<i>Oncorhynchus mykiss</i>	rainbow trout	S,U	--	400		Beliles 1965
<i>Oncorhynchus mykiss</i>	rainbow trout	S,U	7.35	90		Johnson and Finley 1980; Mayer and Ellersieck 1986
<i>Oncorhynchus mykiss</i>	rainbow trout	S,U	--	90		Cope 1965b

Appendix 2 Table 4.1: Updated diazinon acute toxicity database

Species	Common name	Method ^a	pH	Acute value (µg total daizinon/L)	SMAV (ug/L)	Reference
<i>Oncorhynchus mykiss</i>	rainbow trout	S,U	--	3,200*		Bathe et al. 1975
<i>Oncorhynchus mykiss</i>	rainbow trout	R,U	8.2	>1,000		Beauvais et al. 2000
<i>Oncorhynchus mykiss</i>	rainbow trout	S,U	--	90		Ciba-Giegy 1976
<i>Oncorhynchus mykiss</i>	rainbow trout	S,U	--	1,350	455	Meier 1979, Dennis 1980
<i>Oreochromis mossambicus</i>	tilapia	S,U	6.2	161	161	Mustafa et al 1982
<i>Pimephales promelas</i>	fathead minnow	S,U	--	10,300		Meier 1979, Dennis 1980
<i>Pimephales promelas</i>	fathead minnow	S,M	7.6	4,300		Jarvinen and Tanner 1982
<i>Pimephales promelas</i>	fathead minnow	S,M	7.6	2,100		Jarvinen and Tanner 1982
<i>Pimephales promelas</i>	fathead minnow	F,M	7.6	6,900		Jarvinen and Tanner 1982
<i>Pimephales promelas</i>	fathead minnow	F,M	7.4	6,600		Allison and Hermanutz 1977
<i>Pimephales promelas</i>	fathead minnow	F,M	7.4	6,800		Allison and Hermanutz 1977
<i>Pimephales promelas</i>	fathead minnow	F,M	7.4	10,000		Allison and Hermanutz 1977
<i>Pimephales promelas</i>	fathead minnow	F,M	7.6	7,460		Unv of WI-Superior 1988
<i>Pimephales promelas</i>	fathead minnow	F,M	7.6	9,350	6,478	Unv of WI-Superior 1988
<i>Poecilia reticulata</i>	guppy	R,M	7.6	800		Keizer 1991
<i>Poecilia reticulata</i>	guppy	R,M	7.6	670	732	Keizer 1993
<i>Salvelinus fontinalis</i>	brook trout	F,M	7.4	800		Allison and Hermanutz 1977
<i>Salvelinus fontinalis</i>	brook trout	F,M	7.4	450		Allison and Hermanutz 1977
<i>Salvelinus fontinalis</i>	brook trout	F,M	7.4	1,050	723	Allison and Hermanutz 1977
<i>Salvelinus namaycush</i>	lake trout	S,U	7.35	602	602	Johnson and Finley 1980; Mayer and Ellersieck 1986

^a S=static, F=flow through, R=renewal, M=measured, U=unmeasured

* value not used in SMAV calculations or to derive acute criteria

Appendix 2 Table 4.2: Updated diazinon chronic toxicity database

Species	Common name	Test ^a	Duration	pH	NOEC	LOEC	Chronic value		SMCV Reference
							(µg total daizinon/L)		
<i>Brachionus calyciflorus</i>	rotifer	LC	48hr	7.5	8000	31000	15,748	15,748	Snell 1992
<i>Ceriodaphnia dubia</i>	cladocern	LC	7d	--	0.22	0.52	0.34	0.34	Norberg-King 1987
<i>Daphnia magna</i>	cladocern	LC	21d	7.9	0	0.15	< 0.15		Fernandez et al. 1995
<i>Daphnia magna</i>	cladocern	LC	21d	7.9	0.15	0.18	0.17		Fernandez et al. 1995
<i>Daphnia magna</i>	cladocern	LC	21d	(7.7-8.1)	0	0.05	< 0.05		Sanches et al. 2000
<i>Daphnia magna</i>	cladocern	LC	21d	8.1	0.17	0.32	0.23	0.12	Suprenant 1988
<i>Brachydanio rerio</i>	zebrafish	ELS	42d	7.4	200	--	> 200	>200	Bresh 1991
<i>Clarias batrachus</i>	walking catfish	PLC	40d	7.3	--	--	2,418.6 ^b	2,418.6	Tripathi et al. 1992
<i>Jordanella floridae</i>	flagfish	LC	--	--	0	14	< 14.00	<14.00	Allison 1977
<i>Lepomis macrochirus</i>	bluegill	M	84d	(8.5-9.0)	9.2	22	14.23	14.23	Giddings et al. 1996
<i>Pimephales promelas</i>	fathead minnow	PLC	247d	--	28	60.3	41.09		Allison and Hermanutz 1977
<i>Pimephales promelas</i>	fathead minnow	ELS	32d	(7.4-7.8)	50	90	67.08		Jarvinen and Tanner 1982
<i>Pimephales promelas</i>	fathead minnow	ELS	32d	--	16.5	37.8	24.97		Norberg-King 1987
<i>Pimephales promelas</i>	fathead minnow	ELS	34d	7.3	92	170	125.00	54.16	Suprenant 1988
<i>Salvelinus fontinalis</i>	brook trout	PLC	122d	--	0	0.8	< 0.80	<0.80	Allison and Hermanutz 1977

^aELS=early life-stage, PLC=partial life cycle, LC=life cycle, M = micocosm

^bLC₅₀ value

Appendix 2 Table 5.1: Updated zinc acute toxicity database

Species	Common name	Method ^a	Chemical	Hardness (mg/L as CaCO ₃)	Acute value (ug total Zn/L)	Adjusted acute value* (ug Zn/L)	SMAV Reference	Slope?
<i>Aeolosoma headleyi</i>	Worm	--	--	45	18,100	19,803	17,362 Cairns <i>et al.</i> 1978	
<i>Aeolosoma headleyi</i>	Worm	--	--	45	17,600	19,256	Cairns <i>et al.</i> 1978	
<i>Aeolosoma headleyi</i>	Worm	--	--	45	15,600	17,068	Cairns <i>et al.</i> 1978	
<i>Aeolosoma headleyi</i>	Worm	--	--	45	15,000	16,412	Cairns <i>et al.</i> 1978	
<i>Aeolosoma headleyi</i>	Worm	--	--	45	13,500	14,771	Cairns <i>et al.</i> 1978	
<i>Amnicola</i> sp. (adult)	Snail (adult)	S, M	--	50	14,000	14,000	16,817 Rehwoldt <i>et al.</i> 1973**	
<i>Amnicola</i> sp. (embryo)	Snail (embryo)	S, M	--	50	20,200	20,200	Rehwoldt <i>et al.</i> 1973**	
<i>Anodonta imbecilis</i>	Freshwater mussel	S,M,T	Zinc sulfate	39	268	331	296 Keller and Zam 1991	
<i>Anodonta imbecilis</i>	Freshwater mussel	S,M,T	Zinc sulfate	90	438	265	Keller and Zam 1991	
<i>Argia</i> sp.	Damselfly	S, U	Zinc sulfate	20	40,930	89,488	89,488 Wurtz and Bridges 1961**	
<i>Asellus aquaticus</i>	Isopod	S, U	--	50	18,200	18,200	18,200 Martin and Holdich 1986	
<i>Bryocamptus zschokkei</i> (nauplius)	Copepod	S,M,T	Zinc sulfate	100		509	Brown <i>et al.</i> 2005	
<i>Bryocamptus zschokkei</i> (copepodid)	Copepod	S,M,T	Zinc sulfate	100	920		343 Brown <i>et al.</i> 2005	
<i>Bryocamptus zschokkei</i> (adult)	Copepod	S,M,T	Zinc sulfate	100	620	1,145	Brown <i>et al.</i> 2005	
<i>Caecidotea bicrenata</i>	Isopod (3-7 mm)	F, M	Zinc sulfate	220	20,110	5,677	5,677 Bosnak and Morgan 1981**	
<i>Carcidotea communis</i>	Isopod	S, U	Zinc sulfate	20	12,734	27,841	11,614 Wurtz and Bridges 1961**	
<i>Carcidotea communis</i>	Isopod	S, U	Zinc sulfate	100	8,755	4,845	Wurtz and Bridges 1961**	
<i>Ceriodaphnia dubia</i>	Cladoceran	R, M	Zinc chloride	52	180	174	175 Carlson <i>et al.</i> 1986**	Y
<i>Ceriodaphnia dubia</i>	Cladoceran	S, M	Zinc bromide	190	500	160	Magliette <i>et al.</i> 1995	Y
<i>Ceriodaphnia dubia</i>	Cladoceran	S,M,D	--	44	413	461	Hyne <i>et al.</i> 2005	
<i>Ceriodaphnia dubia</i>	Cladoceran	S,M,D	--	44	200	223	Hyne <i>et al.</i> 2005	
<i>Ceriodaphnia dubia</i>	Cladoceran	S,M,D	--	44	539	601	Hyne <i>et al.</i> 2005	
<i>Ceriodaphnia dubia</i>	Cladoceran	S,M,D	--	44	518	578	Hyne <i>et al.</i> 2005	
<i>Ceriodaphnia dubia</i>	Cladoceran	S,M,D	--	44	155	173	Hyne <i>et al.</i> 2005	
<i>Ceriodaphnia dubia</i>	Cladoceran	S,M,D	--	374	390	70	Hyne <i>et al.</i> 2005	
<i>Ceriodaphnia dubia</i>	Cladoceran	S,M,D	--	44	70	78	Hyne <i>et al.</i> 2005	
<i>Ceriodaphnia dubia</i>	Cladoceran	S,M,D	--	374	160	29	Hyne <i>et al.</i> 2005	
<i>Ceriodaphnia reticulata</i>	Cladoceran	S, U	--	45	76	83	51 Mount and Norberg 1984	
<i>Ceriodaphnia reticulata</i>	Cladoceran	S, U	Zinc chloride	45	41	45	Carlson and Roush 1985**	
<i>Ceriodaphnia reticulata</i>	Cladoceran	S, M	Zinc chloride	45	32	35	Carlson and Roush 1985**	
<i>Chironomus</i> sp.	Midge	--	--	50	18,200	18,200	18,200 Rehwoldt <i>et al.</i> 1973	

Appendix 2 Table 5.1: Updated zinc acute toxicity database

Species	Common name	Method ^a	Chemical	Hardness (mg/L as CaCO ₃)	Acute value (ug total Zn/L)	Adjusted acute value* (ug Zn/L)	SMAV Reference	Slope?
<i>Chironomus plumosus</i>	Midge	S, U	Zinc sulfate	80	32,600	21,825	21,825 Fargasova 2003	
<i>Corbicula fluminea</i>	Asiatic clam (10-21 mm)	S, M	Zinc sulfate	64	6,040	4,892	4,892 Cherry <i>et al.</i> 1980; Rodgers <i>et al.</i> 1980**	
<i>Crangonyx pseudogracilis</i>	Amphipod	R,U	Zinc sulfate	50	19,800	19,800	19,800 Martin and Holdich 1986	
<i>Cypris</i> sp.	Ostracod	--	--	114	3,000	1,484	1,484 Qureshi <i>et al.</i> 1980	
<i>Daphnia magna</i>	Cladoceran	R, M	--	300	1,100	238	299 Berglund and Dave 1984***	Y
<i>Daphnia magna</i>	Cladoceran	S,M	Zinc sulfate	45	280	306	Cairns <i>et al.</i> 1978**	Y
<i>Daphnia magna</i>	Cladoceran	S,M	--	54	334	313	Chapman <i>et al.</i> Manuscript**	Y
<i>Daphnia magna</i>	Cladoceran	S,M	--	105	525	279	Chapman <i>et al.</i> Manuscript**	Y
<i>Daphnia magna</i>	Cladoceran	S,M	--	196	655	204	Chapman <i>et al.</i> Manuscript**	Y
<i>Daphnia magna</i>	Cladoceran	F,M	--	130	799	353	Attar and Maly 1982**	Y
<i>Daphnia magna</i>	Cladoceran	S,M	Zinc sulfate	46.1	259	278	Barata <i>et al.</i> 1998	Y
<i>Daphnia magna</i>	Cladoceran	S,M	Zinc sulfate	90.7	1,060	638	Barata <i>et al.</i> 1998	Y
<i>Daphnia magna</i>	Cladoceran	S,M	Zinc sulfate	179	962	324	Barata <i>et al.</i> 1998	Y
<i>Daphnia magna</i>	Cladoceran	S,M	Zinc sulfate	46.1	131	140	Barata <i>et al.</i> 1998	Y
<i>Daphnia magna</i>	Cladoceran	S,M	Zinc sulfate	90.7	457	275	Barata <i>et al.</i> 1998	Y
<i>Daphnia magna</i>	Cladoceran	S,M	Zinc sulfate	179	601	202	Barata <i>et al.</i> 1998	Y
<i>Daphnia magna</i>	Cladoceran	S,M	Zinc bromide	190	1,220	390	Magliette <i>et al.</i> 1995	Y
<i>Daphnia magna</i>	Cladoceran	S,M,T	--	170	1,831	644	Baird <i>et al.</i> 1991	
<i>Daphnia magna</i>	Cladoceran	S,M,T	--	170	756	266	Baird <i>et al.</i> 1991	
<i>Daphnia magna</i>	Cladoceran	S,M,T	--	170	745	262	Baird <i>et al.</i> 1991	
<i>Daphnia magna</i>	Cladoceran	S,M,T	--	170	862	303	Baird <i>et al.</i> 1991	
<i>Daphnia magna</i>	Cladoceran	S,M,T	--	170	986	347	Baird <i>et al.</i> 1991	
<i>Daphnia magna</i>	Cladoceran	S,M,T	--	170	798	281	Baird <i>et al.</i> 1991	
<i>Daphnia magna</i>	Cladoceran	S,U	Zinc chloride	45.3	100	109 ^T	Biesinger and Christensen 1972**	
<i>Daphnia magna</i>	Cladoceran	S,U	--	45	68	74 ^T	Mount and Norberg 1984	
<i>Daphnia pulex</i>	Cladoceran	S,M	--	45	500	547	253 Cairns <i>et al.</i> 1978**	
<i>Daphnia pulex</i>	Cladoceran	S,U	--	45	107	117	Mount and Norberg 1984	
<i>Drunella grandis</i>	Mayfly	S, M	zinc sulfate	50.6	>1,560	>1,544	>1,264 CEC 2005	
<i>Drunella grandis</i>	Mayfly	S, M	zinc sulfate	54.2	>3,050	>2,847	CEC 2005	
<i>Drunella grandis</i>	Mayfly	S, M	zinc sulfate	172	>2,190	>763	CEC 2005	
<i>Drunella grandis</i>	Mayfly	S, M	zinc sulfate	175	>3,050	>1,047	CEC 2005	
<i>Drunella grandis</i>	Mayfly	S, M	zinc sulfate	260.7	>3,270	>799	CEC 2005	
<i>Drunella grandis</i>	Mayfly	S, M	zinc sulfate	277.7	>6,290	>1,455	CEC 2005	
<i>Echinogammarus tibaldii</i>	Amphipod	--	--	240	25,900	6,788	6,788 Pantani <i>et al.</i> 1997	
<i>Gammarus italicus</i>	Amphipod	--	--	240	8,800	2,306	2,306 Pantani <i>et al.</i> 1997	
<i>Gammarus</i> sp.	Amphipod	S, M	--	50	8,100	8,100	8,100 Rehwoldt <i>et al.</i> 1973**	
<i>Girardia tigrina</i>	Flatworm	--	--	50	7,400	7,400	7,004 See <i>et al.</i> 1994	
<i>Girardia tigrina</i>	Flatworm	--	--	40	5,480	6,630	See 1976	
<i>Haplodiptomus viduus</i>	Copepod	S,M	Zinc sulfate	37.6	500	638	638 Sharma and Selverai 1994	
<i>Helisoma campanulatum</i>	Snail (adult)	S, U	Zinc sulfate	20	870	1,902	1,579 Wurtz 1962**	

(@12.8°C)

Appendix 2 Table 5.1: Updated zinc acute toxicity database

Species	Common name	Method ^a	Chemical	Hardness (mg/L as CaCO ₃)	Acute value (ug total Zn/L)	Adjusted acute value* (ug total Zn/L)	SMAV Reference	Slope?
<i>Helisoma campanulatum</i>	Snail (adult)	S, U	Zinc sulfate	20 (@22.8°C)	1,270	2,777	Wurtz 1962**	
<i>Helisoma campanulatum</i>	Snail (adult)	S, U	Zinc sulfate	100 (@12.8°C)	3,030	1,677	Wurtz 1962**	
<i>Helisoma campanulatum</i>	Snail (adult)	S, U	Zinc sulfate	100 (@22.8°C)	1,270	703	Wurtz 1962**	
<i>Hyalella azteca</i>	Amphipod	--	--	100	436	241	241 Eisenhauer <i>et al.</i> 1999	
<i>Isoperla</i> sp.	Stonefly	S,U	Zinc sulfate	182.2	>27,000	8,952	>8,952 CEC 2005	
<i>Lepidostoma</i> sp.	Caddisfly	S, M	Zinc sulfate	62.1	>19,100	>15,874	>15,054 CEC 2005	
<i>Lepidostoma</i> sp.	Caddisfly	S, M	Zinc sulfate	189.4	>38,800	>12,446	CEC 2005	
<i>Lepidostoma</i> sp.	Caddisfly	S, M	Zinc sulfate	308.8	>81,700	>17,266	CEC 2005	
<i>Limnodrilus hoffmeisteri</i>	Tubificid worm	S, U	Zinc sulfate	100	>2,274	>1,258	>1258 Wurtz and Bridges 1961**	
<i>Lirceus alabamiae</i>	Isopod (3-7 mm)	F, M	Zinc sulfate	152	8,375	3,242	3,242 Bosnak and Morgan 1981**	
<i>Lophopodella carteri</i>	Bryozoan	S, U	--	205 (190-220)	5,630	1,688	1,688 Perdue and Wood 1980**	
<i>Lumbricius variegatus</i>	Worm	S, U	Zinc chloride	30	6,300	9,744	9,744 Bailey and Liu 1980**	
<i>Mesocyclops hyalinus</i>	Copepod	S,M	Zinc sulfate	37.6	3,800	4,847	4,847 Sharma and Selverai 1994	
<i>Moina irrasa</i>	Cladoceran	--	--	5	77	553	667 Zou and Bu 1994**	
<i>Moina irrasa</i>	Cladoceran	--	--	5	153	1,089	Zou and Bu 1994**	
<i>Moina irrasa</i>	Cladoceran	--	--	5	205	1,466	Zou and Bu 1994**	
<i>Moina irrasa</i>	Cladoceran	--	--	5	50	357	Zou and Bu 1994**	
<i>Moina irrasa</i>	Cladoceran	--	--	5	93	663	Zou and Bu 1994**	
<i>Moina irrasa</i>	Cladoceran	--	--	5	59	423	Zou and Bu 1994**	
<i>Moina macrocopa</i>	Cladoceran	S,M	Zinc sulfate	37.6	120	153	153 Sharma and Selverai 1994	
<i>Nais</i> sp.	Worm	S, M	--	50	18,400	18,400	18,400 Rehwoldt <i>et al.</i> 1973**	
<i>Pectinatella magnifica</i>	Bryozoan	S, U	--	205 (190-220)	4,310	1,292	1,292 Perdue and Wood 1980**	
<i>Physa gyrina</i>	Snail (adult)	F, M	Zinc chloride	36	1,274	1,686	1,686 Nebeker <i>et al.</i> 1986**	
<i>Physa heterostropha</i>	Snail	S, U	Zinc chloride	45 (@20°C)	1,800	1,969	1,087 Cairns and Scheler 1958b; Academy of Natural Sciences 1960**	Y
<i>Physa heterostropha</i>	Snail	S, U	Zinc chloride	45 (@30°C)	1,000	1,094	Cairns and Scheler 1958b; Academy of Natural Sciences 1960**	Y
<i>Physa heterostropha</i>	Snail	S, U	Zinc chloride	170 (@20°C)	6,200	2,181	Cairns and Scheler 1958b; Academy of Natural Sciences 1960**	Y
<i>Physa heterostropha</i>	Snail	S, U	Zinc chloride	170 (@30°C)	7,100	2,498	Cairns and Scheler 1958b; Academy of Natural Sciences 1960**	Y
<i>Physa heterostropha</i>	Snail (adult)	S, U	Zinc sulfate	20	1,110	2,427	Wurtz and Bridges 1961; Wurtz 1962**	Y
<i>Physa heterostropha</i>	Snail (adult)	S, U	Zinc sulfate	100	3,160	1,749	Wurtz and Bridges 1961; Wurtz 1962**	Y
<i>Physa heterostropha</i>	Snail (young)	S, U	Zinc sulfate	20 (@10.6°C)	303	662	Wurtz 1962**	Y

Appendix 2 Table 5.1: Updated zinc acute toxicity database

Species	Common name	Method ^a	Chemical	Hardness (mg/L as CaCO ₃)	Acute value (ug total Zn/L)	Adjusted acute value* (ug total Zn/L)	SMAV Reference	Slope?
<i>Physa heterostropha</i>	Snail (young)	S, U	Zinc sulfate	20	434	949	Wurtz 1962**	Y
<i>Physa heterostropha</i>				(@12.8°C)				
<i>Physa heterostropha</i>	Snail (young)	S, U	Zinc sulfate	20	350	765	Wurtz 1962**	Y
				(@32.2°C)				
<i>Physa heterostropha</i>	Snail (young)	S, U	Zinc sulfate	100	434	240	Wurtz 1962**	Y
				(@10.6°C)				
<i>Physa heterostropha</i>	Snail (young)	S, U	Zinc sulfate	100	1,390	769	Wurtz 1962**	Y
				(@12.8°C)				
<i>Physa heterostropha</i>	Snail (young)	S, U	Zinc sulfate	100	1,110	614	Wurtz 1962**	Y
				(@32.2°C)				
<i>Plumatella emarginata</i>	Bryozoan	S, U	--	205	5,300	1,589	1,589 Perdue and Wood 1980**	
				(190-220)				
<i>Ranatra elongata</i>	Water scorpion	--	--	112.4	1,658	830	830 Shukla <i>et al.</i> 1983	
<i>Stenocypris malcomsoni</i>	Ostracod	S, M	Zinc sulfate	37.6	3,500	4,464	4,464 Sharma and Selverai 1994	
<i>Trichoptera</i>	Caddisfly	--	--	50	58,100	58,100	58,100 Rehwoldt <i>et al.</i> 1973	
<i>Tropocyclops prasinus</i>	Copepod	S, U	Zinc chloride	10	52	205	205 Lelande and Pinel-Alloul 1985	
<i>Tubifex tubifex</i>	Tubificid worm	--	--	224	130,000	36,137	9,612 Qureshi <i>et al.</i> 1980	Y
<i>Tubifex tubifex</i>	Tubificid worm	--	--	34.2	2,570	3,554	Brkovic-Popovic and Popovic 1977	Y
<i>Tubifex tubifex</i>	Tubificid worm	--	--	261	60,200	14,687	Brkovic-Popovic and Popovic 1977	Y
<i>Tubifex tubifex</i>	Tubificid worm	--	--	0.1	110	22,157	Brkovic-Popovic and Popovic 1977	Y
<i>Tubifex tubifex</i>	Tubificid worm	--	--	34.2	2,980	4,121	Brkovic-Popovic and Popovic 1977	Y
<i>Tubifex tubifex</i>	Tubificid worm	R, U	Zinc sulfate	245	17,780	4,578	Khangarot 1991	
<i>Zygoptera</i>	Damselfly	--	--	50	26,200	26,200	26,200 Rehwoldt <i>et al.</i> 1973	
<i>Agosia chrysogaster</i>	Longfin dace (juvenile)	R, M	Zinc sulfate	217	790	226	226 Lewis 1978**	
<i>Anguilla rostrata</i>	American eel	S, M	--	55	14,500	13,367	13,627 Rehwoldt <i>et al.</i> 1972**	
<i>Anguilla rostrata</i>	American eel	S, M	Zinc nitrate	53	14,600	13,892	Rehwoldt <i>et al.</i> 1973**	
<i>Carassius auratus</i>	Goldfish	S, U	Zinc sulfate	50	7,500	7,500	10,276 Cairns <i>et al.</i> 1978**	
<i>Carassius auratus</i>	Goldfish (1-2 g)	S, U	Zinc sulfate	20	6,440	14,080	Pickering and Henderson 1966**	
<i>Catostomus commersoni</i>	White sucker (17.7 g)	F, M	Zinc chloride	18	2,200	5,263	5,263 Duncam and Klaverkamp 1983**	
<i>Catostomus latipinnis</i>	Flannelmouth Sucker	--	--	144	1,480	600	600 Hamilton and Buhl 1997	
<i>Cottus bairdi</i>	Mottled Sculpin	F, M	--	48.6	156	160	182 Woodling <i>et al.</i> 2002	Y
<i>Cottus bairdi</i>	Mottled Sculpin	F, M	Zinc sulfate	154	439	168	Brinkman and Woodling 2005	Y
<i>Cottus bairdi</i>	Mottled Sculpin	F, M	Zinc sulfate	156	590	223	Brinkman and Woodling 2005	Y
<i>Cyprinus carpio</i>	Common carp (<20 cm)	S, M	Zinc nitrate	53	7,800	7,421	7,245 Rehwoldt <i>et al.</i> 1971**	
<i>Cyprinus carpio</i>	Common carp	S, M	--	55	7,800	7,190	Rehwoldt <i>et al.</i> 1972**	
<i>Cyprinus carpio</i>	Common carp (2.1 g)	R, U	Zinc sulfate	19	3,120	7,127	Khangarot <i>et al.</i> 1983**	
<i>Fundulus diaphanus</i>	Banded killifish (<20 cm)	S, M	Zinc nitrate	53	19,100	18,173	17,935 Rehwoldt <i>et al.</i> 1971**	
<i>Fundulus diaphanus</i>	Banded killifish	S, M	--	55	19,200	17,700	Rehwoldt <i>et al.</i> 1972**	
<i>Gambusia affinis (fries)</i>	Mosquitofish	S, U	--	50	50,000	50,000	32,370 Kallanagoudar and Patil 1997	
<i>Gambusia affinis (fries)</i>	Mosquitofish	S, U	--	150	80,000	31,316	Kallanagoudar and Patil 1997	
<i>Gambusia affinis (fries)</i>	Mosquitofish	S, U	--	300	100,000	21,662	Kallanagoudar and Patil 1997	

Appendix 2 Table 5.1: Updated zinc acute toxicity database

Species	Common name	Method ^a	Chemical	Hardness (mg/L as CaCO ₃)	Acute value (ug total Zn/L)	Adjusted acute value* (ug Zn/L)	SMAV Reference	Slope?
<i>Gambusia affinis (male)</i>	Mosquitofish	S,U	--	50	115,000	115,000 [†]	Kallanagoudar and Patil 1997	
<i>Gambusia affinis (male)</i>	Mosquitofish	S,U	--	150	140,000	54,804 [†]	Kallanagoudar and Patil 1997	
<i>Gambusia affinis (male)</i>	Mosquitofish	S,U	--	300	150,000	32,493 [†]	Kallanagoudar and Patil 1997	
<i>Gambusia affinis (female)</i>	Mosquitofish	S,U	--	50	90,000	90,000 [†]	Kallanagoudar and Patil 1997	
<i>Gambusia affinis (female)</i>	Mosquitofish	S,U	--	150	120,000	46,975 [†]	Kallanagoudar and Patil 1997	
<i>Gambusia affinis (female)</i>	Mosquitofish	S,U	--	300	140,000	30,326 [†]	Kallanagoudar and Patil 1997	
<i>Gila elegans</i>	Bonytail (larvae)	S,U	Zinc chloride	199	5,350	1,645	2,013 Buhl and Hamilton 1996	
<i>Gila elegans</i>	Bonytail (larvae)	S,U	Zinc chloride	199	8,010	2,463	Buhl and Hamilton 1996	
<i>Jordanella floridae</i>	Flagfish (juvenile)	F, M	Zinc sulfate	44	1,500	1,673	1,673 Spehar 1976 a,b**	
<i>Lepomis gibbosus</i>	Pumpkinseed (<20 cm)	S, M	Zinc nitrate	53	20,000	19,029	18,778 Rehwoldt <i>et al.</i> 1971**	
<i>Lepomis gibbosus</i>	Pumpkinseed	S, M	--	55	20,100	18,529	Rehwoldt <i>et al.</i> 1972**	
<i>Lepomis macrochirus</i>	Bluegill	F, M	Zinc sulfate	46	9,900	10,630	5,290 Cairns <i>et al.</i> 1971**	Y
<i>Lepomis macrochirus</i>	Bluegill	F, M	Zinc sulfate	46	12,100	12,993	Cairns <i>et al.</i> 1971**	Y
<i>Lepomis macrochirus</i>	Bluegill (0.96 g)	F, M	Zinc chloride	45	3,573	3,909	Cairns and Scheler 1959**	Y
<i>Lepomis macrochirus</i>	Bluegill (2.80 g)	F, M	Zinc chloride	45	3,453	3,778	Cairns and Scheler 1959**	Y
<i>Lepomis macrochirus</i>	Bluegill (54.26 g)	F, M	Zinc chloride	45	3,314	3,626	Cairns and Scheler 1959**	Y
<i>Lepomis macrochirus</i>	Bluegill	F,M,T	Zinc sulfate	40.2	3,600	4,337	Thompson <i>et al.</i> 1980	Y
<i>Lepomis macrochirus</i>	Bluegill	F,M,T	Zinc sulfate	40.2	3,000	3,614	Thompson <i>et al.</i> 1980	Y
<i>Lepomis macrochirus</i>	Bluegill (3.5-3.9 g)	S, U	Zinc chloride	45	4,200	4,595	Cairns and Scheler 1957, 1968; Academy of Natural Sciences 1960**	Y
<i>Lepomis macrochirus</i>	Bluegill (3.5-3.9 g)	S, U	Zinc chloride	45 (@18°C)	3,500	3,829	Cairns and Scheler 1957; Academy of Natural Sciences 1960**	Y
<i>Lepomis macrochirus</i>	Bluegill (3.5-3.9 g)	S, U	Zinc chloride	170 (@30°C)	12,900	4,538	Cairns and Scheler 1957; Academy of Natural Sciences 1960**	Y
<i>Lepomis macrochirus</i>	Bluegill (3.5-3.9 g)	S, U	Zinc chloride	170 (@18°C)	12,500	4,397	Cairns and Scheler 1957; Academy of Natural Sciences 1960**	Y
<i>Lepomis macrochirus</i>	Bluegill (2.5-3.9 g)	S, U	Zinc chloride	45 (@30°C)	8,020	8,775	Cairns and Scheler 1958a; Academy of Natural Sciences 1960**	Y
<i>Lepomis macrochirus</i>	Bluegill (1-2 g)	S, U	Zinc sulfate	20 (@15°C)	6,440	14,080	Pickering and Henderson 1966**	Y
<i>Lepomis macrochirus</i>	Bluegill (1-2 g)	S, U	Zinc sulfate	20 (@25°C)	5,460	11,938	Pickering and Henderson 1966**	Y
<i>Lepomis macrochirus</i>	Bluegill (1-2 g)	S, U	Zinc sulfate	20 (@25°C)	4,850	10,604	Pickering and Henderson 1966**	Y
<i>Lepomis macrochirus</i>	Bluegill (1-2 g)	S, U	Zinc sulfate	20 (@25°C)	5,820	12,725	Pickering and Henderson 1966**	Y
<i>Lepomis macrochirus</i>	Bluegill (1-2 g)	S, U	Zinc chloride	20 (@25°C)	5,370	11,741	Pickering and Henderson 1966**	Y
<i>Lepomis macrochirus</i>	Bluegill (1-2 g)	S, U	Zinc sulfate	360 (@25°C)	40,900	7,583	Pickering and Henderson 1966**	Y

Appendix 2 Table 5.1: Updated zinc acute toxicity database

Species	Common name	Method ^a	Chemical	Hardness (mg/L as CaCO ₃)	Acute value (ug total Zn/L)	Adjusted acute value* (ug Zn/L)	SMAV Reference	Slope?
<i>Morone americana</i>	White perch (<20 cm)	S, M	Zinc nitrate	53	14,300	13,606	13,439 Rehwoldt <i>et al.</i> 1971**	
<i>Morone americana</i>	White perch	S, M	--	55	14,400	13,275	Rehwoldt <i>et al.</i> 1972**	
<i>Morone saxatilis</i>	Striped bass (63 d old)	S, U	Zinc chloride	40	120	145	119 Palawski <i>et al.</i> 1985**	Y
<i>Morone saxatilis</i>	Striped bass (63 d old)	S, U	Zinc chloride	285	430	97	Palawski <i>et al.</i> 1985**	Y
<i>Notemigonus crysoleucas</i>	Golden shinner	S, U	Zinc sulfate	50	6,000	6,000	6,000 Cairns <i>et al.</i> 1969**	
<i>Oncorhynchus clarki</i>	Cutthroat trout	F, M	--	31.1	140	210	368 Brinkman and Hansen 2004	Y
<i>Oncorhynchus clarki</i>	Cutthroat trout	F, M	--	149.4	1,645	646	Brinkman and Hansen 2004	Y
<i>Oncorhynchus kisutch</i>	Coho salmon (yearling)	R, M	Zinc chloride	94	4,600	2,684 ^T	1,635 Lorz and McPherson 1976, 1977**	
<i>Oncorhynchus kisutch</i>	Coho salmon	F, M	Zinc chloride	25	905	1,635	Chapman and Stevens 1978**	
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	F, M	Zinc sulfate	330	7,210	1,440	582 Sinley <i>et al.</i> 1974**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	F, M	Zinc sulfate	25	430	777	Sinley <i>et al.</i> 1974**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (30.5 g)	F, M	Zinc sulfate	30	430	665	Goettl <i>et al.</i> 1974**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (22.6 g)	F, M	Zinc sulfate	30	810	1,253	Goettl <i>et al.</i> 1974**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (29.7 g)	F, M	Zinc sulfate	30	410	634	Goettl <i>et al.</i> 1974, 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (18.3 g)	F, M	Zinc sulfate	312	4,520	947	Goettl <i>et al.</i> 1974, 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (2.0 g)	F, M	Zinc sulfate	312	1,190	249	Goettl <i>et al.</i> 1974, 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (34.6 g)	F, M	Zinc sulfate	23	560	1,087	Goettl <i>et al.</i> 1974, 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (4.9 g)	F, M	Zinc sulfate	22	240	484	Goettl <i>et al.</i> 1974, 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (52.1 g)	F, M	Zinc sulfate	30	830	1,284	Goettl <i>et al.</i> 1974, 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (15.4 g)	F, M	Zinc sulfate	314	7,210	1,502	Goettl <i>et al.</i> 1974, 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (72 g)	F, M	Zinc sulfate	102	1,000	544	Goettl <i>et al.</i> 1974, 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	R, U	Zinc sulfate	5	280	1,999	McLeay 1976**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (alevin)	F, M	Zinc chloride	23	815	1,581	Chapman 1975, 1978b**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (swim-up alevin)	F, M	Zinc chloride	23	93	180	Chapman 1975, 1978b**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (parr)	F, M	Zinc chloride	23	136	264	Chapman 1975, 1978b**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (adult male)	F, M	Zinc chloride	83	1,755	1,139	Chapman and Stevens 1978**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	F, M	Zinc sulfate	46.8	370	391	Holcombe and Andrew 1978**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	F, M	Zinc sulfate	47	517	545	Holcombe and Andrew 1978**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	F, M	Zinc sulfate	44.4	756	837	Holcombe and Andrew 1978**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	F, M	Zinc sulfate	178	2,510	849	Holcombe and Andrew 1978**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	F, M	Zinc sulfate	179	2,960	996	Holcombe and Andrew 1978**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (juvenile)	F, M	Zinc sulfate	170	1,910	672	Holcombe and Andrew 1978**	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (fry)	F, M	Zinc chloride	9.2	66	280	Cusimano <i>et al.</i> 1986	Y
				(@pH=7.0)				
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	--	350	4,520	858	Goettl <i>et al.</i> 1972	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	--	350	1,190	226	Goettl <i>et al.</i> 1972	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	--	30	560	866	Goettl <i>et al.</i> 1972	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	--	30	240	371	Goettl <i>et al.</i> 1972	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	--	38	105	133	Davies 1980	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	--	38	186	235	Davies 1980	Y

Appendix 2 Table 5.1: Updated zinc acute toxicity database

Species	Common name	Method ^a	Chemical	Hardness (mg/L as CaCO ₃)	Acute value (ug total Zn/L)	Adjusted acute value* (ug Zn/L)	SMAV Reference	Slope?
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	--	33.2	125	177	Brinkman and Hansen 2004	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	--	145.4	588	236	Brinkman and Hansen 2004	Y
<i>Oncorhynchus mykiss</i>	Rainbow trout (fingerling)	S, M	Zinc sulfate	14	560	1,660	Spry and Wood 1984**	Y
<i>Oncorhynchus nerka</i>	Sockeye salmon (parr)	F, M	Zinc chloride	22	749	1,510	1,510 Chapman 1975, 1978b**	
<i>Oncorhynchus tshawytscha</i>	Chinook salmon (juvenile)	F, M	Zinc sulfate	21	84	176	449 Finlayson and Verrue 1982**	
<i>Oncorhynchus tshawytscha</i>	Chinook salmon (swim-up)	F, M	Zinc chloride	23	97	188	Chapman 1975, 1978b**	
<i>Oncorhynchus tshawytscha</i>	Chinook salmon (parr)	F, M	Zinc chloride	23	463	898	Chapman 1975, 1978b**	
<i>Oncorhynchus tshawytscha</i>	Chinook salmon (smolt)	F, M	Zinc chloride	23	701	1,360	Chapman 1975, 1978b**	
<i>Pimephales promelas</i>	Fathead minnow (embryo)	F, M	Zinc sulfate	186	1,820	593	3,808 Pickering and Vigor 1965**	
<i>Pimephales promelas</i>	Fathead minnow (embryo)	F, M	Zinc sulfate	(174-198) 186	1,850	603	Pickering and Vigor 1965**	
<i>Pimephales promelas</i>	Fathead minnow (fry)	F, M	Zinc sulfate	(174-198) 186	870	283	Pickering and Vigor 1965**	
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	63	12,500	10,262	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	54	13,800	12,922	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	97	18,500	10,507	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	103	25,000	13,489	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	212	29,000	8,449	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	208	35,500	10,513	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	54	13,700	12,829	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	63	6,200	5,090	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	100	12,500	6,917	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	99	12,500	6,977	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	186	19,000	6,190	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	195	13,600	4,255	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	54	4,700	4,401	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	49	5,100	5,189	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	98	8,100	4,560	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	102	9,900	5,386	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	193	8,200	2,588	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	F, M	Zinc sulfate	216	15,500	4,444	Mount 1966**	Y
<i>Pimephales promelas</i>	Fathead minnow (2-3 g)	F, M	Zinc sulfate	203	8,400	2,540	Brungs 1969**	Y
<i>Pimephales promelas</i>	Fathead minnow (2-3 g)	F, M	Zinc sulfate	203	10,000	3,023	Brungs 1969**	Y
<i>Pimephales promelas</i>	Fathead minnow (4 wk)	F, M	Zinc sulfate	46	600	644	Benoit and Holcombe 1978**	
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	S, M	Zinc sulfate	45	2,100	2,298	Judy and Davies 1979**	
<i>Pimephales promelas</i>	Fathead minnow (juvenile)	F, M	Zinc sulfate	220	2,610	737	Broderius and Smith 1979**	
<i>Pimephales promelas</i>	Fathead minnow (larva)	S, M	Zinc chloride	45	396	433	Carison and Roush 1985**	
<i>Pimephales promelas</i>	Fathead minnow (<24 hr)	S, M	Zinc chloride	52	551	533	Carison <i>et al.</i> 1986**	
<i>Pimephales promelas</i>	Fathead minnow (44.6 mm)	S, U	Zinc sulfate	166	7,630	2,739	Rachlin and Perimutter 1968**	
<i>Pimephales promelas</i>	Fathead minnow (2-3 g)	S, U	Zinc sulfate	203	12,000	3,628	Brungs 1969**	Y

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<i>Pimephales promelas</i>	Fathead minnow (2-3 g)	S, U	Zinc sulfate	203	13,000	3,930	Brungs 1969**	Y
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	S, U	Zinc sulfate	20	2,550	5,575	Pickering and Henderson 1966**	Y
				(@15°C)				
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	S, U	--	20	2,330	5,094	Pickering and Henderson 1966**	Y
				(@15°C)				
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	S, U	Zinc sulfate	20	770	1,683	Pickering and Henderson 1966**	Y
				(@25°C)	(780)			
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	S, U	Zinc sulfate	20	960	2,099	Pickering and Henderson 1966**	Y
				(@25°C)				
<i>Pimephales promelas</i>	Fathead minnow (1-2 g)	S, U	Zinc sulfate	360	33,400	6,192	Pickering and Henderson 1966**	Y
				(@25°C)				
<i>Poecilia reticulata</i>	Guppy (6 mo)	S, U	Zinc sulfate	20	1,270	2,777	5,926 Pickering and Henderson 1966**	Y
<i>Poecilia reticulata</i>	Guppy	S, U	Zinc sulfate	120	30,000	14,208	Cairns et al. 1969**	Y
<i>Poecilia reticulata</i>	Guppy (fry)	S, M	Zinc sulfate	30	1,740	2,691	Pierson 1981**	Y
<i>Poecilia reticulata</i>	Guppy (adult male)	S, M	Zinc sulfate	30	5,050	7,811	Pierson 1981**	Y
<i>Poecilia reticulata</i>	Guppy (adult female)	S, M	Zinc sulfate	30	6,400	9,899	Pierson 1981**	Y
<i>Poecilia reticulata</i>	Guppy (adult male)	S, U	Zinc sulfate	118	300,000	144,134	Sehgal and Saxena 1986**	
<i>Poecilia reticulata</i>	Guppy (adult female)	S, U	Zinc sulfate	118	278,000	133,564	Sehgal and Saxena 1986**	
<i>Ptychocheilus lusius</i>	Colorado pikeminnow (larvae)	S,U	Zinc chloride	199	3,340	1,027	2,211 Buhl and Hamilton 1996	
<i>Ptychocheilus lusius</i>	Colorado pikeminnow (juvenile)	S,U	Zinc chloride	199	8,620	2,651	Buhl and Hamilton 1996	
<i>Ptychocheilus lusius</i>	Colorado pikeminnow (larvae)	S,U	Zinc sulfate	144	9,800	3,972	Hamilton and Buhl 1997b	
<i>Ptychocheilus oregonensis</i>	Northern pikeminnow (juvenile)	F, M	Zinc chloride	25	3,498	6,321	6,495 Andros and Garton 1980**	
				(20-30)				
<i>Ptychocheilus oregonensis</i>	Northern pikeminnow (juvenile)	F, M	Zinc chloride	25	3,693	6,674	Andros and Garton 1980**	
				(20-30)				
<i>Salmo salar</i>	Atlantic salmon (parr)	F, M	Zinc sulfate	14	740	2,194	2,194 Carson and Carson 1972**	
<i>Salmo trutta</i>	Brown Trout	F, M	Zinc sulfate	206.7	2,267	675	647 Davies and Brinkman, 1999	Y
				(alk = 37.5)				
<i>Salmo trutta</i>	Brown Trout	F, M	Zinc sulfate	54.4	1,033	961	Davies and Brinkman, 1999	
				(alk = 37.4)				
<i>Salmo trutta</i>	Brown Trout	F, M	Zinc sulfate	54.0	690	646	Davies and Brinkman, 1999	Y
				(alk = 139.6)				
<i>Salmo trutta</i>	Brown Trout	F, M	Zinc sulfate	207.2	>2,660	>790	Davies and Brinkman, 1999	Y
				(alk = 141.4)				
<i>Salmo trutta</i>	Brown Trout	F, M	Zinc sulfate	51.9	871	844	Davies and Brinkman, 2000	Y
<i>Salmo trutta</i>	Brown Trout	F, M	Zinc sulfate	51.8	392	380	Davies and Brinkman, 2000	Y

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Species	Common name	Method ^a	Chemical	Hardness (mg/L as CaCO ₃)	Acute value (ug total Zn/L)	Adjusted acute value* (ug Zn/L)	SMAV Reference	Slope?
				(2 wk de-acli)				
<i>Salmo trutta</i>	Brown Trout (wild)	F, M	--	37.6	642	819	Davies and Brinkman, 1994	Y
<i>Salmo trutta</i>	Brown Trout	F, M	--	42.3	476	549	Davies <i>et al.</i> 2000	Y
<i>Salmo trutta</i>	Brown Trout	F, M	--	52.6	484	464	Davies <i>et al.</i> 2000	Y
<i>Salmo trutta</i>	Brown Trout	F, M	--	52.6	603	577	Davies <i>et al.</i> 2000	Y
<i>Salvelinus fontinalis</i>	Brook trout (juvenile)	F, M	Zinc sulfate	46.8	1,550	1,640	1,691 Holcombe & Andrew 1978**	Y
<i>Salvelinus fontinalis</i>	Brook trout (juvenile)	F, M	Zinc sulfate	47	2,120	2,235	Holcombe & Andrew 1978**	Y
<i>Salvelinus fontinalis</i>	Brook trout (juvenile)	F, M	Zinc sulfate	44.4	2,420	2,678	Holcombe & Andrew 1978**	Y
<i>Salvelinus fontinalis</i>	Brook trout (juvenile)	F, M	Zinc sulfate	178	6,140	2,077	Holcombe & Andrew 1978**	Y
<i>Salvelinus fontinalis</i>	Brook trout (juvenile)	F, M	Zinc sulfate	179	6,980	2,350	Holcombe & Andrew 1978**	Y
<i>Salvelinus fontinalis</i>	Brook trout (juvenile)	F, M	Zinc sulfate	170	4,980	1,752	Holcombe & Andrew 1978**	Y
<i>Salvelinus fontinalis</i>	Brook trout	F, M	--	52.6	738	707	Davies <i>et al.</i> 2000	Y
<i>Salvelinus fontinalis</i>	Brook trout	F, M	--	52.6	1,178	1,128	Davies <i>et al.</i> 2000	Y
<i>Tilapia mossambica</i>	Mozambique tilapia (18 g)	S, U	Zinc chloride	115	1,600	786	786 Qureshi and Saksena 1980**	
<i>Thymallus arcticus</i>	Arctic grayling (0.34g)	S, U	Zinc chloride	41.3	112	132	199 Buhl and Hamilton 1990	
<i>Thymallus arcticus</i>	Arctic grayling (0.2g)	S, U	Zinc chloride	41.3	142	167	Buhl and Hamilton 1990	
<i>Thymallus arcticus</i>	Arctic grayling (0.85g)	S, U	Zinc chloride	41.3	166	195	Buhl and Hamilton 1990	
<i>Thymallus arcticus</i>	Arctic grayling (0.97g)	S, U	Zinc chloride	41.3	168	198	Buhl and Hamilton 1990	
<i>Thymallus arcticus</i>	Arctic grayling (1.85g)	S, U	Zinc chloride	41.3	168	198	Buhl and Hamilton 1990	
<i>Thymallus arcticus</i>	Arctic grayling (fry)	S, U	Zinc chloride	41.3	315	371	Buhl and Hamilton 1990	
<i>Thymallus arcticus</i>	Arctic grayling (alevin)	S, U	Zinc chloride	41.3	1,580	1,860	Buhl and Hamilton 1990	
<i>Thymallus arcticus</i>	Arctic grayling (alevin)	S, U	Zinc chloride	41.3	2,920	3,438	Buhl and Hamilton 1990	
<i>Xenopus laevis</i>	Frog	S, M		100	34,500	19,091	19,091 Dawson <i>et al.</i> 1988***	
<i>Xiphophorus maculatus</i>	Southern platyfish (20.8)	S, U	Zinc sulfate	166	12,000	4,308	4,308 Rachlin and Perimutter 1968**	
<i>Xyrauchen texanus</i>	Razorback sucker (larvae)	S,U	Zinc chloride	199	4,100	1,261	1,651 Buhl and Hamilton 1996	
<i>Xyrauchen texanus</i>	Razorback sucker (juvenile)	S,U	Zinc chloride	199	2,920	898	Buhl and Hamilton 1996	
<i>Xyrauchen texanus</i>	Razorback sucker (larvae)	S,U	Zinc sulfate	144	9,800	3,972	Hamilton and Buhl 1997b	

* acute values adjusted to hardness = 50 mg/L with revised slope of 0.85

** as cited in U.S. EPA Zinc Document (1987)

*** as cited in U.S. EPA 1995 Updates (1996)

^a F = flow-through. S = static. R = renewal. M = measured. U = unmeasured. T = total. D = dissolved

[†] not used in SMAV calculation, see text for detail

Appendix 2 Table 5.2: Updated zinc chronic toxicity database

Species	Common name	Hardness (mg/L as CaCO ₃)	Chronic value (µg total Zn/L)	Normalized chronic value* (µg total Zn/L)	SMCV Reference
<i>Acroneuria lycorias</i>	Stonefly	50	32,000	32,000	32,000 Warrick and Bell 1969
<i>Bryocamptus zschokkei</i>	Copepod	100	380	210	210 Brown et al. 2005
<i>Clistoronia magnifica</i>	Caddisfly	31	>5243	>7,885	>7,885 Nebeker et al. 1984
<i>Daphnia magna</i>	Cladoceran	45	<140	<154	<51 Blesinger et al. 1986
<i>Daphnia magna</i>	Cladoceran	52	136	131	Chapman et al. Manuscript
<i>Daphnia magna</i>	Cladoceran	104	47	25	Chapman et al. Manuscript
<i>Daphnia magna</i>	Cladoceran	211	47	14	Chapman et al. Manuscript
<i>Drunella grandis</i>	Mayfly	50	>9,200	>9,200	>9,200 Nehring 1976
<i>Ephemera subvaria</i>	Mayfly	54	16,000	14,983	14,983 Warrick and Bell 1969
<i>Hydropsyche betteni</i>	Caddisfly	52	32,000	30,946	30,946 Warrick and Bell 1969
<i>Pteronarcys californica</i>	Stonefly	50	>13,900	>13,900	>13,900 Nehring 1976
<i>Tanytarsus</i> sp.	Midge	46.8	37	39	39 Anderson et al. 1980
<i>Cottus bairdi</i>	Mottled sculpin	46.3	21	22	47 Woodling et al. 2002
<i>Cottus bairdi</i>	Mottled sculpin	154	255	98	Brinkman and Woodling 2005
<i>Jordanella floridae</i>	Flagfish	44	36	41	41 Spehar 1976a,b
<i>Oncorhynchus clarkii</i>	Cutthroat trout	40.5	670	802	440 Nehring and Goettl 1974
<i>Oncorhynchus clarkii</i>	Cutthroat trout	31.1	134	201	Brinkman and Hansen 2004
<i>Oncorhynchus clarkii</i>	Cutthroat trout	149.4	1,343	528	Brinkman and Hansen 2004
<i>Oncorhynchus mykiss</i>	Rainbow trout	26	277	484	292 Sinley et al. 1974
<i>Oncorhynchus mykiss</i>	Rainbow trout	25	603	1,090*	Cairns et al. 1982
<i>Oncorhynchus mykiss</i>	Rainbow trout	33.2	74	105	Brinkman and Hansen 2004
<i>Oncorhynchus mykiss</i>	Rainbow trout	145.4	325	131	Brinkman and Hansen 2004
<i>Oncorhynchus nerka</i>	Sockeye salmon	34.5	242	332	332 Chapman 1978a
<i>Oncorhynchus tshawytscha</i>	Chinook salmon	25	371	671	671 Chapman 1975
<i>Pimephales promelas</i>	Fathead minnow	46	106	114	114 Benoit and Holcombe 1978
<i>Poecilia reticulata</i>	Guppy	30	<173	<268	<268 Pierson 1981
<i>Salmo trutta</i>	Brown trout	39	457	565	377 Davies and Brinkman 1994
<i>Salmo trutta</i>	Brown trout	52.6	234	224	Davies et al. 2000
<i>Salmo trutta</i>	Brown trout	52.6	327	313	Davies et al. 2000
<i>Salmo trutta</i>	Brown trout	28.5	640	1,034	Nehring and Goettl 1974
<i>Salmo trutta</i>	Brown trout	26.8	162	276	Davies and Brinkman 1999, 2002, 2003
<i>Salmo trutta</i>	Brown trout	48.1	196	203	Davies and Brinkman 1999, 2002, 2003
<i>Salmo trutta</i>	Brown trout	54.1	381	356	Davies and Brinkman 1999, 2002, 2003
<i>Salmo trutta</i>	Brown trout	153	1,306	503	Davies and Brinkman 1999, 2002, 2003
<i>Salvelinus fontinalis</i>	Brook trout	45.9	855	919	609 Holcombe et al. 1979
<i>Salvelinus fontinalis</i>	Brook trout	52.6	327	313	Davies et al. 2000
<i>Salvelinus fontinalis</i>	Brook trout	52.6	819	784	Davies et al. 2000

* not used in SMCV calculation, see text for details