Appendices to Glyphosate

Human Health and Ecological Risk Assessment

FINAL REPORT

Submitted to:
Paul Mistretta, COR
USDA/Forest Service, Southern Region
1720 Peachtree RD, NW
Atlanta, Georgia 30309

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Submitted by:
Patrick R. Durkin
Syracuse Environmental Research Associates, Inc.
8125 Solomon Seal
Manlius, New York 13104

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LIST OF APPENDICES

Appendix 1: Selected Toxicity Data from Material Safety Data Sheets

Note: The order and color coding of the formulations is consistent with that of Tables 4 and 5 of the current Forest Service risk assessment.

A1 Table 1: Mammalian Toxicity Data from MSDSs

Formulation Name	Oral LD_{50} (mg/kg bw)	Dermal LD_{50} (mg/kg bw)	Inhalation. LC_{50} (mg/L)	Eye Irritation	Skin Irritation
Accord XRT	>5000	>5000	>5.23		
Imitator Plus	>5000	>5000			
KGro Grass and Weed Killer					
DuraMax	>5000	>5000	>5.63	Corneal	Slight
Durango DMA (GF-1280)	>5000	>5000	>5.63	Corneal	Slight
RapidFire	>5000	>5000	>5.63	Corneal	Slight
Accord XRT II	>5000	>5000	>5.63	Corneal	Slight
Glyfos Aquatic	>5000	>4000	>4.24	May cause	May cause
Glyfos X-TRA	>5000	>2000	>2.86	May cause	May cause
GlyphoMate 41 or Pronto	>2000	>2000	>2.05	Mild	None
AquaNeat	>5000	>5000	>4.24	Minimal	Non-irritating
Foresters' Non Selective	>5000	>5000	>2.08	Minimal	Non-irritating
Aqua Star	>5000	>5000	>2.5	Moderate	Mild
Buccaneer	>5000	>5000	2.6	Moderate	Non-irritating
Buccaneer Plus	>5000	>5000		Moderate	Slight
Cornerstone	>5000	>5000	2.6	Moderate	Non-irritating
Cornerstone Plus	>5000	>5000	1.6	Moderate	Slight
Credit Extra	>5000	>5000	>2.10	Moderate	Slight
Credit Systemic Extra	>5000	>5000	>2.05	Moderate	Slight
Eliminator **[need label]**	>5000	>5000	2.6	Moderate	Non-irritating
Gly-4 Plus	>5000	>2000	>4.86	Moderate	
Glyphogan	>5000	>5000	>2.6	Moderate	Non-irritating
Gly Star Plus	>5000	>5000	>2.5	Moderate	Mild
Glyphosate 41 Plus or GLY- 4 Plus	>5000	>2000	>4.86	Moderate	Slight
Honcho (a.k.a. Roundup Original)	>5000	>5000	2.6	Moderate	Non-irritating
Honcho Plus	>5000	>5000	1.6	Moderate	Slight
Mirage	>5000	>5000	1.6	Moderate	Slight
Razor	>5000	>5000	>2.05	Moderate	Slight
Razor Pro	>5000	>5000	>2.05	Moderate	Slight
Roundup Original Max	>5000	>5000		Moderate	Moderate
Roundup Pro Concentrate	>5000	>5000		Moderate	Slight
Roundup ProMax	>5000	>5000		Moderate	Slight
Roundup UltraDry	3700	>5000		Moderate	Slight
Roundup UltraMax	>5000	>5000	>2.01	Moderate	Slight

Appendix 1: Selected Toxicity Data from Material Safety Data Sheets *(continued)*

A1 Table 1: Mammalian Toxicity Data from MSDSs

Formulation Name	Oral LD_{50} (mg/kg bw)	Dermal LD_{50} (mg/kg bw)	Inhalation. LC_{50} (mg/L)	Eye Irritation	Skin Irritation
Roundup WeatherMax	>5000	>5000	>1.2	Moderate	Moderate
RT 3	>5000	>5000	>1.2	Moderate	Moderate
Accord	>5000	>5000	>1.3	Non-irritating	Non-irritating
AquaMaster (a.k.a. Export and Rodeo)	>5000	>5000	>4.24	Non-irritating	Essentially Non-irritating
Glyphosate VMF	>5000	>5000	>1.3	Non-irritating	Non-irritating
Rattler	>5000	>5000	>3.18	Non-irritating	Slight
Helosate Plus	5000	5000	3.28	**Severe**	
Accord Concentrate	>5000	>5000	>6.37	Slight	Slight
Accord SP (a.k.a. Glyphosate Plus)	>5000	>5000	>5.00	Slight	Non-irritating
Diamondback	>5000	>5000		Slight	Non-irritating
Durango (GF-1279)	>5000	>5000	>5.23	Slight	Non-irritating
Glyphomax Plus	>5000	>5000	>5.0	Slight	Non-irritating
Glyphomax XRT	>5000	>5000	>5.23	Slight	Non-irritating
Glypro	>5000	>5000	>6.37	Slight	Non-irritating
Ranger Pro	5108	>5000	2.9	Slight	Non-irritating
Rodeo	>5000	>5000	>6.37	Slight	Non-irritating
Roundup Pro	5108	>5000	2.9	Slight	Non-irritating
Roundup ProDry	3,794	>5000	>2.6	Slight	Slight
Hi-yield Killzall				Yes	Yes

Appendix 1: Selected Toxicity Data from Material Safety Data Sheets *(continued)*

A1 Table 2: Aquatic Toxicity Information from MSDS

Formulation Name	Bluegill LC_{50} (mg/L)	Rainbow Trout LC_{50} (mg/L)	Daphnia LC_{50} (mg/L)	Most Sensitive Aquatic LC_{50} (mg/L)	Notes on MSDS	Notes on Aquatic Data
Accord	>1000	>1000	930			Bluegill: Griffen and Thompson 1981, MRID 78662, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Trout: Thompson and Griffen 1981, MRID 78661, in EPA 1993c give >1000 mg/L for a 62.4% formulation.
Accord Concentrate		>2500	918			All values are identical to MSDS for Rodeo. Trout: The LC50 for Rodeo is 430.1 mg a.e./L MRID 40579301/1985. This would correspond to 1417.6 mg form/L. Daphnia: Cannot identify study. 918 mg/L is higher than technical grade glyphosate.
Accord SP (a.k.a. Glyphomax Plus)		60		10		Trout: 60 mg formulation/L would correspond to about 26 mg a.e./L. Cannot identify study. Conversely, this 60 mg/L is in the range of unformulated glyphosate as well as the a.e. LC_{50} for 80WDG (a.k.a. Glygran WDG) formulation (an IPA salt, granular?).
Accord XRT		>1000	930	10	Toxicity data based on IPA salt	Trout: Thompson and Griffen 1981, MRID 78661, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Daphnia: The LC50 of 930 mg./L is consistent with unformulated glyphosate. This formulation is identical to Durango and Glyphomax XRT (Fonseca 2010a).
Accord XRT II				0.1		
Aqua Star	5.8	8.2				The bluegill is 5.8 mg formulation/L from Forbis et al. 1982a. Trout: 8.2 mg form/L from Forbis et al. 1982b. The data from Bringolf et al. (2007) indicates that this formulation does not contain a POEA surfactant.
AquaMaster (a.k.a. Export and Rodeo)	>1000	>1000	930			Bluegill: Griffen and Thompson 1981, MRID 78662, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Trout: Thompson and Griffen 1981, MRID 78661, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Daphnia: The LC50 of 930 mg./L is consistent with unformulated glyphosate.
AquaNeat	120 a.e.	86 a.e.	780 a.e.			Bluegill: From McAllister and Forbes 1978a not correcting for purity of the acid. Trout: From Thompson and McAllister 1978, MRID 136339. Daphnia: From McAllister and Forbes 1978b not correcting for purity of acid.
Buccaneer	5.8	8.2	11		Aquatic data on similar formulation.	The bluegill is 5.8 mg formulation/L from Forbis et al. 1982a. Trout: 8.2 mg form/L from Forbis et al. 1982b. Daphnia: May be 10.5 mg form/L for a 30% a.e. formulation from Drottar and Krueger 2000c

Appendix 1: Selected Toxicity Data from Material Safety Data Sheets *(continued)*

A1 Table 2: Aquatic Toxicity Information from MSDS

Formulation Name	Bluegill LC_{50} (mg/L)	Rainbow Trout LC_{50} (mg/L)	Daphnia LC_{50} (mg/L)	Most Sensitive Aquatic LC_{50} (mg/L)	Notes on MSDS	Notes on Aquatic Data
Buccaneer Plus	24	42	160		Aquatic data on product or similar formulation or components.	Bluegill: Morrill 1973 gives an LC50 of >24 mg/L for acid. Trout: 42 mg form/L would correspond to about 12.7 mg a.e./L. Cannot identify. Daphnia: May be from Swarbrick and Shillabeer 1999b, 164.3 mg form/L for a 27.25% formulation.
Cornerstone	5.8	8.2	11		Mammalian: product or components. Aquatic: similar or components	The bluegill is 5.8 mg formulation/L from Forbis et al. 1982a. Trout: 8.2 mg form/L from Forbis et al. 1982b. Daphnia: May be 10.5 mg form/L for a 30% a.e. formulation from Drottar and Krueger 2000c
Cornerstone Plus	24	42	160		Aquatic data on product or similar formulation.	Bluegill: Morrill 1973 gives an LC50 of >24 mg/L for acid. Trout: 42 mg form/L would correspond to about 12.7 mg a.e./L. Cannot identify. Daphnia: May be from Swarbrick and Shillabeer 1999b, 164.3 mg form/L for a 27.25% formulation.
Credit Extra	120 a.e.	86 a.e.	780 a.e.		Aquatic: Data on a.e. ***May contain ethoxylated tallowamines.***	Bluegill: From McAllister and Forbes 1978a not correcting for purity of the acid. Trout: From Thompson and McAllister 1978, MRID 136339. Daphnia: From McAllister and Forbes 1978b not correcting for purity of acid.
Credit Systemic Extra	120 a.e.	86 a.e.	780 a.e.		Aquatic: Data on a.e. ***May contain ethoxylated tallowamines***.	Bluegill: From McAllister and Forbes 1978a not correcting for purity of the acid. Trout: From Thompson and McAllister 1978, MRID 136339. Daphnia: From McAllister and Forbes 1978b not correcting for purity of acid.
Diamondback	>1000	>1000	930			Bluegill: Griffen and Thompson 1981, MRID 78662, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Trout: Thompson and Griffen 1981, MRID 78661, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Daphnia: The LC50 of 930 mg./L is consistent with unformulated glyphosate.
DuraMax				0.1		
Durango (GF-1279)				10	Aquatic: Based largely or completely on a.e.	This formulation is identical to Accord XRT and Glyphomax XRT (Fonseca 2010a).
Durango DMA (GF-1280)				0.1		
Eliminator **[need label]**	8.2	11	11		Aquatic: Similar products	Bluegill: Cannot identify. EPA 1993c cites a trout LC50 of 8.2 mg/L for Roundup 41.8% Daphnia: May be 10.5 mg form/L for a 30% a.e. formulation from Drottar and Krueger 2000c Trout: This appears to be MRID 70895, 11 mg formulation/L for a 41% IPA formulation

Appendix 1: Selected Toxicity Data from Material Safety Data Sheets *(continued)*

A1 Table 2: Aquatic Toxicity Information from MSDS

Formulation Name	Bluegill LC_{50} (mg/L)	Rainbow Trout LC_{50} (mg/L)	Daphnia LC_{50} (mg/L)	Most Sensitive Aquatic LC_{50} (mg/L)	Notes on MSDS	Notes on Aquatic Data
Foresters' Non Selective	120 a.e.	86 a.e.	780 a.e.			Bluegill: From McAllister and Forbes 1978a not correcting for purity of the acid. Trout: From Thompson and McAllister 1978, MRID 136339. Daphnia: From McAllister and Forbes 1978b not correcting for purity of acid.
Gly-4 Plus	11.9 a.e.	18.6 a.e.			Based on a.e.?	Bluegill: Cannot associate 11.9 mg/L with a study. Trout: Cannot associate 18.6 a.e./L with a study.
Glyfos Aquatic	>1000 a.i.	>1000 a.i.	930 a.i.		Based on IPA salt	Bluegill: Griffen and Thompson 1981, MRID 78662, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Trout: Thompson and Griffen 1981, MRID 78661, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Daphnia: The LC50 of 930 a.i./L corresponds to about 688 mg a.e./L. This is close to unformulated glyphosate.
Glyfos X-TRA	11.9	18.6	21.6		Aquatic: Appears to indicate that toxicity is in units of formulation.	Bluegill: 11.9 mg form/L would correspond to about 3.6 mg a.e./L. An LC50 of 3.7 mg a.e./L is given in Appendix J, MRID 162296/1979 Trout: 18.6 mg form/L would correspond to about 5.6 mg/L.. This is in the range of formulation studies - e.g., 5.5 mg a.e./L for a 36% a.i. formulation. Daphnia: Cannot identify study. In the range of Roundup formulations if value is a.e.
Glyphogan	5.8	8.2	12.9			The bluegill is 5.8 mg formulation/L from Forbis et al. 1982a. Trout: 8.2 mg form/L from Forbis et al. 1982b. Daphnia: Cannot identify formulation LC50 of 12.9 mg/L. This would correspond to about 3.9 mg a.e./L. This is in the range of Roundup formulations.
GlyphoMate 41 or Pronto					No aquatic data in MSDS	
Glyphomax Plus **[need label]**		109	105	>100		Trout: Cannot identify. 109 mg form/L would correspond to 33 mg a.e./L. This is less than LC50s of unformulated glyphosate. Daphnia: Cannot identify 105 mg form/L with a study. This would correspond to about 32 mg a.e./L.. This is below the LC50 for unformulated glyphosate but is in the range of less toxic surfactant formulations -- i.e., MRID 78657, >21.7 mg a.e./L.
Glyphomax XRT				10 to 100	Aquatic: Based largely or completely on a.e.	This formulation is identical to Accord XRT and Durango (Fonseca 2010a).
Gly Star Plus	5.8	8.2			MSDS states a.e. units.	The MSDS is not correct in indicating that the units of the toxicity values apply to glyphosate acid. The bluegill is 5.8 mg formulation/L from Forbis et al. 1982a. Trout: 8.2 mg form/L from Forbis et al. 1982b.

Appendix 1: Selected Toxicity Data from Material Safety Data Sheets *(continued)*

A1 Table 2: Aquatic Toxicity Information from MSDS

Formulation Name	Bluegill LC_{50} (mg/L)	Rainbow Trout LC_{50} (mg/L)	Daphnia LC_{50} (mg/L)	Most Sensitive Aquatic LC_{50} (mg/L)	Notes on MSDS	Notes on Aquatic Data
Glyphosate VMF	>1000	>1000	930		MSDS does not specify a.e. or formulation. Give data on Rodeo.	Bluegill: Griffen and Thompson 1981, MRID 78662, in EPA 1993c give >1000 mg/L for a 62.4% formulation. Trout: Thompson and Griffen 1981, MRID 78661, in EPA 1993c give >1000 mg/L for a 62.4% formulation.
Glyphosate 41 Plus or GLY- 4 Plus	11.9 a.e.	18.6 a.e.			Aquatic appears to be on a.e.	Bluegill: Cannot associate 11.9 mg/L with a study. Trout: Cannot associate 18.6 a.e./L with a study.
Glypro		>2500	918	>100		All values are identical to MSDS for Rodeo. Trout: The LC50 for Rodeo is 430.1 mg a.e./L MRID 40579301/1985. This would correspond to 1417.6 mg form/L. Daphnia: Cannot identify study. 918 mg/L is higher than technical grade glyphosate.
Helosate Plus	5.6 a.e.	2.3 a.e.	3 a.e.			Bluegill: Cannot associate 5.6 mg/L with a study but this is in the range of Roundup formulations, Trout: Cannot associate 2.3 mg a.e./L with a specific study but this is in the range of Roundup formulations. Daphnia: Cannot associated 3 mg a.e./L with a specific study but this is in the range or Roundup formulations.
Hi-yield Killzall					No detailed information on MSDS.	
Honcho (a.k.a. Roundup Original)	5.8	8.2	11		Aquatic: similar products and on components.	The bluegill is 5.8 mg formulation/L from Forbis et al. 1982a. Trout: 8.2 mg form/L from Forbis et al. 1982b. Daphnia: May be 10.5 mg form/L for a 30% a.e. formulation from Drottar and Krueger 2000c
Honcho Plus	24	42	160		Aquatic: product, similar products and on components.	Bluegill: Morrill 1973 gives an LC50 of >24 mg/L for acid. Trout: 42 mg form/L would correspond to about 12.7 mg a.e./L. Cannot identify. Daphnia: May be from Swarbrick and Shillabeer 1999b, 164.3 mg form/L for a 27.25% formulation.
Imitator Plus					No detailed information on MSDS.	
KGro Grass and Weed Killer					Cannot locate MSDS	
Mirage	8.2	37	24		**More detailed ecotox on MSDS**	Bluegill: Cannot identify. EPA 1993c cites a trout LC50 of 8.2 mg/L for Roundup 41.8%. Trout: 37 mg form/L would correspond to about 11.2 mg a.e./L. Cannot identify study. Daphnia: Cannot identify formulation study with 24 mg/L. Corresponds to about 7.3 mg a.e./L.. This is somewhat above the range for Roundup formulations.

Appendix 1: Selected Toxicity Data from Material Safety Data Sheets *(continued)*

A1 Table 2: Aquatic Toxicity Information from MSDS

Formulation Name	Bluegill LC_{50} (mg/L)	Rainbow Trout LC_{50} (mg/L)	Daphnia LC_{50} (mg/L)	Most Sensitive Aquatic LC_{50} (mg/L)	Notes on MSDS	Notes on Aquatic Data
Ranger Pro	7.3	5.4	11		Aquatic: Product and components.	Bluegill 7.3 mg/L is formulation LC50 from Drottar and Krueger 2000 for a 41% formulation. Daphnia: May be 10.5 mg form/L for a 30% a.e. formulation from Drottar and Krueger 2000c Trout: Cannot identify specific study but data are consistent with formulation toxicity.
RapidFire				0.1		
Rattler					Acute oral on mouse not rat. No ecotox on MSDS	
Razor	86 a.e.	120 a.e.	780 a.e.			Bluegill: From McAllister and Forbes 1978a not correcting for purity of the acid. Trout: From Thompson and McAllister 1978, MRID 136339. Daphnia: From McAllister and Forbes 1978b not correcting for purity of acid.
Razor Pro	120 a.e.	86 a.e.	780 a.e.		Aquatic: The MSDS does not specify formulation or a.e.	Bluegill: From McAllister and Forbes 1978a not correcting for purity of the acid. Trout: From Thompson and McAllister 1978, MRID 136339. Daphnia: From McAllister and Forbes 1978b not correcting for purity of acid.
Rodeo		>2500	918	>100		Trout: The LC_{50} for Rodeo is 430.1 mg a.e./L MRID 40579301/1985. This would correspond to 1417.6 mg form/L. Daphnia: Cannot identify study. 918 mg/L is higher than technical grade glyphosate.
Roundup Original Max	5.2		8		Aquatic: similar products and components	Bluegill: Cannot identify study with toxicity value of 5.2 mg/L.. Daphnia: Cannot identify study with toxicity value of 8 mg/L.. For a K formulation, this would be equivalent to about 3.2 mg a.e./L. This is consistent with MRID 45365004, an IPA formulation.
Roundup Pro	7.3	5.4	11		Aquatic: similar products and components	Bluegill 7.3 mg/L is formulation LC50 from Drottar and Krueger 2000a for a 41% formulation. Daphnia: May be 10.5 mg form/L for a 30% a.e. formulation from Drottar and Krueger 2000c Trout: Cannot identify specific study but data are consistent with formulation toxicity.
Roundup Pro Concentrate	7.3	5.4	11		Aquatic: similar products and components	Bluegill 7.3 mg/L is formulation LC50 from Drottar and Krueger 2000a for a 41% formulation. Daphnia: May be 10.5 mg form/L for a 30% a.e. formulation from Drottar and Krueger 2000c Trout: Cannot identify specific study but data are consistent with formulation toxicity.

Appendix 1: Selected Toxicity Data from Material Safety Data Sheets *(continued)*

A1 Table 2: Aquatic Toxicity Information from MSDS

Formulation Name	Bluegill LC_{50} (mg/L)	Rainbow Trout LC_{50} (mg/L)	Daphnia LC_{50} (mg/L)	Most Sensitive Aquatic LC_{50} (mg/L)	Notes on MSDS	Notes on Aquatic Data
Roundup ProDry		3	29.1		Aquatic: similar products and components	Trout: Cannot be identified but it is clearly a formulation. This may be a rounding of MRID 45767101 for a 66% a.i. ammonium formulation (MON78568) with an LC50 of 1.9 mg a.e./L.. Daphnia: Cannot identify. The only reasonably close study is MRID 45777401 which reports an EC50 of 28.8 mg a.e./L.
Roundup ProMax	5.2		8		Aquatic: similar products and components	Bluegill: Cannot identify study with toxicity value of 5.2 mg/L. Daphnia: Cannot identify study with toxicity value of 8 mg/L.. For a K formulation, this would be equivalent to about 3.2 mg a.e./L. This is consistent with MRID 45365004, an IPA formulation.
Roundup UltraDry					The oral LD50 is for female rats. Aquatic: No studies conducted.	
Roundup UltraMax	7.3	5.4	11		Aquatic: similar products and components	Bluegill 7.3 mg/L is formulation LC50 from Drottar and Krueger 2000 for a 41% formulation. Daphnia: May be 10.5 mg form/L for a 30% a.e. formulation from Drottar and Krueger 2000c Trout: Cannot identify specific study but data are consistent with formulation toxicity.
Roundup WeatherMax	3.13		8		Aquatic: similar products and components	Bluegill: Cannot identify 3.13 mg/L. Assuming formulation units, this would correspond to 1.5 mg a.i./L or 1.23 a.e./L. Daphnia: Cannot identify study with toxicity value of 8 mg/L.. For a K formulation, this would be equivalent to about 3.2 mg a.e./L. This is consistent with MRID 45365004, an IPA formulation.
RT 3	3.13		8		Similar formulation	Bluegill: Cannot identify 3.13 mg/L. Assuming formulation units, this would correspond to 1.5 mg a.i./L or 1.23 a.e./L. Daphnia: Cannot identify study with toxicity value of 8 mg/L.. For a K formulation, this would be equivalent to about 3.2 mg a.e./L. This is consistent with MRID 45365004, an IPA formulation.

Appendix 2: Toxicity to Mammals

A2 Table 1: Glyphosate Technical/Acid, Acute Oral/Gavage Toxicity

Species	Exposure	Response	Reference[1]
Rat (*Rattus norvegicus*)	Acid, 96%	LD_{50}: >4800 mg a.e./kg bw No mortalities.	MRID 43728003 [2]
Rat (*Rattus norvegicus*)	Acid, 95%	LD_{50}: >4750 mg a.e./kg bw No mortalities.	MRID 45058306 [2]
Rat (*Rattus norvegicus*)	Acid, 97.2%	LD_{50}: >4860 mg a.e./kg bw No mortalities.	MRID 46760505 [2]
Rat (*Rattus norvegicus*)	Acid, 88%	LD_{50}: >4400 mg a.e./kg bw No mortalities.	MRID 44320604 [2]
Rat (*Rattus norvegicus*)	Acid, 95%	LD_{50}: >4750 mg a.e./kg bw No mortalities.	MRID 46998805 [2]
Rat (*Rattus norvegicus*)	Acid, 76%	LD_{50}: >3800 mg a.e./kg bw No mortalities.	MRID 41400601 [2]
Rat (*Rattus norvegicus*)	Acid, 96%	LD_{50}: > 1920 mg a.e./kg bw No mortalities.	MRID 44142104 [2]
Rat (*Rattus norvegicus*)	Acid, 95.4%	LD_{50}: > 4770 mg a.e./kg bw No mortalities.	MRID 46816107 [2]
Rats	Glyphosate IPA	Reported 72 hour LD_{50}: 5957 mg a.i./kg bw or ≈4400 mg a.e./kg bw Data below are from Baba et al. 1989, Table 1.	Baba et al. 1989
Rats	Glyphosate IPA	LD_{50}: >5000 mg/kg bw	Smith and Oehme 1992 [3]
Rats	Technical grade	LD_{50}: 4873 mg/kg bw	Babaunmi et al. 1978
Mice	Technical grade	LD_{50}: 1568 mg/kg bw	Babaunmi et al. 1978

Baba et al. 1989, Table 1.

Dose mg a.i./kg bw	Mortality	Number
3986	0	7
4784	1	7
5740	3	7
6880	5	7
8226	7	7

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 1: Glyphosate Technical/Acid, Acute Oral/Gavage Toxicity

Species	Exposure	Response	Reference[1]
Deer mice	Glyphosate IPA	LD_{50}: >6000 mg/kg bw	McComb et al. 2008
Rabbit	Technical grade	LD_{50}: 3800 mg/kg bw	Smith and Oehme 1992[3]
Goat, female	Glyphosate technical, 98.7%	LD_{50}: 3500 mg/kg bw	WHO 1994 summarizing USDA study
Goat, female	Glyphosate IPA, 65% in water	LD_{50}: 5700 mg/kg bw	WHO 1994 summarizing USDA study
Rat	Technical grade	LD_{50}: >5000 mg/kg bw Same value reported for 3 different studies.	WHO 1994

[1] Studies with only MRID designations are taken from Table 4.31 of U.S. EPA/OPP 2008a and/or Table J-25 of Appendix J of U.S. EPA/OPP 2008a.

[2] MRID is not referenced in Appendix L of U.S. EPA/OPP 2008a or in Attachment 1 of the current Forest Service risk assessment

[3] All of the studies summarized by Smith and Oehme 1992 are unpublished studies that had been submitted to WHO by Monsanto (rats and mice).

A2 Table 2: Glyphosate Formulations, Acute Oral/Gavage Toxicity

Species	Agent	Response	Reference[1]
Rat (*Rattus norvegicus*)	HM-2028, 11.4% a.i.	LD_{50}: 357 mg a.e./kg bw	MRID 46714802 [2]
Rat (*Rattus norvegicus*)	MON 20033, 63% a.i. This is identified as EPA Reg. No. 524-435 (EZ-Ject Capsuls) in Table 5.5 of U.S. EPA/OPP 2008a.	LD_{50}: 3150 mg a.e./kg bw (5000 mg formulation/ kg bw)	MRID 41142304 [2]
Rat (*Rattus norvegicus*)	MON 77063, 65.4% a.i. This is identified as EPA Reg. No. 524-504 (Roundup Ultradry) in Table 5.5 of U.S. EPA/OPP 2008a.	LD_{50}: 2599 mg a.e./kg bw (5827 mg formulation/ kg bw)	MRID 44615502
Rat (*Rattus norvegicus*)	This is identified as EPA Reg. No. 62719-323 (Glyphomax) in Table 5.5 of U.S. EPA/OPP 2008a. IPA salt, 22.9% a.i.	LD_{50}: 724 mg a.e./kg bw (3803 mg formulation/kg bw)	MRID 44918601
Rat (*Rattus norvegicus*)	MON 20047, 18.4% a.i. [This is identified as EPA Reg. No. 524-400, which is Roundup Rainfast (25.1% IPA or 18.6% a.e.), in Table 5.5 of U.S. EPA/OPP 2008a.]	LD_{50}: 460 – 690 mg a.e./kg bw (3750 mg formulation/kg bw) [4] Note: The 690 mg a.e./kg bw appears to be calculated from the formulation toxicity value. The source of the lower bound of 460 mg a.e./kg bw is not clear.	MRID 41305404[3]
Rat (*Rattus norvegicus*)	ClearOut 41 (41% IPA salt), 30.3% a.i. [3]	L D_{50}: >606 mg a.e./kg bw (limit test)	MRID 44883104
Rat (*Rattus norvegicus*)	Clearout 62 (62% glyphosate IPA), 62% a.i.	L D_{50}: >1240 mg a.e./kg bw (limit test)	MRID 45657801
Rat (*Rattus norvegicus*)	GF-1667 (62.1% glyphosate dimethyl ammonium salt), 49% a.i. [3] Dow formulation.	LD_{50}: >2450 mg a.e./kg bw	MRID 46730705

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 2: Glyphosate Formulations, Acute Oral/Gavage Toxicity			
Species	**Agent**	**Response**	**Reference[1]**
Rat (*Rattus norvegicus*)	GF-1280 (50.8% glyphosate dimethylammonium), 40.1% a.i. Note: GF-1280 typically contains 50.2% of the DMA salt of glyphosate.	LD_{50}: >2005 mg a.e./kg bw **Note: This is the basis for the LD_{50} of >5000 mg/kg bw on the MSDSs for Accord XRT II, Duramax, Durango DMA. Back calculating for formulation, the LD_{50} would be >5334 mg formulation/kg bw.**	MRID 46775603
Rat (*Rattus norvegicus*)	HM-0548 5905-LTE mixture of ammonium salt (19.68%) and IPA (13.36%), 25% a.e.?	LD_{50}: >1250 mg a.e./kg bw	MRID 47236803 [2]
Rat (*Rattus norvegicus*)	MON 60696 (70.1% monoammonium salt), 54% a.i. [3]	LD_{50}: > 2700 mg a.e./kg bw	MRID 43049302
Rat (*Rattus norvegicus*)	MON 78634 (71.8% ammonium salt), 65.2% a.i. [3]	LD_{50}: >1304 mg a.e./kg bw	MRID 46087001 [2]
Rat (*Rattus norvegicus*)	Nufarm RUP0532 (41% Glyphosate as IPA and ammonium salts), 30.3% a.i. [3]	LD_{50}: >1515 mg a.e./kg bw	MRID 45386802
Rat (*Rattus norvegicus*)	56077-LL -Phoss-8, 80% a.i. Note: Not in Attachment 1 – i.e., probably not an IPA formulation.	LD_{50}: >4000 mg a.e./kg bw	MRID 45044402
Rat (*Rattus norvegicus*)	Roundup L&G Ready to Use (glyphosate IPA), 0.85% a.i.	LD_{50}: >40 mg a.e./kg bw	MRID 41395601
Rat (*Rattus norvegicus*)	Spray–Charlie (44% GLY41 (524-475 with 41% IPA), 15.2% a.i.?	LD_{50}: >70 mg a.e./kg bw	MRID 45929403 [2]
Rat (*Rattus norvegicus*)	Dual Salt Fully Loaded (glyphosate IPA and NH4 Salt)	LD_{50}: >1800 mg a.e./kg bw	MRID 45615104
Rat (*Rattus norvegicus*)	Glyphosate Acid 7.10 g/kg SL Formulation, 0.71%	LD_{50}: >35.5 mg a.e./kg bw	MRID 43746804 [2]
Rat (*Rattus norvegicus*)	EH-1384 (6.75% glyphosate IPA)	LD_{50}: >100 mg a.e./kg bw	MRID 45328903 [2]
Rat (*Rattus norvegicus*)	EH-1386 (50.0% glyphosate IPA	LD_{50}: >740 mg a.e./kg bw	MRID 45387703 [2]
Rat (*Rattus norvegicus*), Fischer 344	GF-772 (40.2% IPA salt)	LD_{50}: >1490 mg a.e./kg bw	MRID 45871303
Rat (*Rattus norvegicus*)	GF-887 (54.2% glyphosate IPA)	LD_{50}: >2005 mg a.e./kg bw	MRID 45819303 [2]
Rat (*Rattus norvegicus*)	Glyphos (41% IPA) Note: The 41% IPA composition is consistent with Glyphos X-TRA, a formulation with a surfactant.	LD_{50}: >1515 mg a.e./kg bw	MRID 43530002
Rat (*Rattus norvegicus*)	Glygran WDG glyphosate 80 WDG, 80%	LD_{50}: >1600 mg a.e./kg bw	MRID 44125603 [2]

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 2: Glyphosate Formulations, Acute Oral/Gavage Toxicity			
Species	**Agent**	**Response**	**Reference[1]**
Rat (*Rattus norvegicus*)	Glyphosate, 62% NOS	LD_{50}: >3100 mg a.e./kg bw	MRID 45101503
Rat (*Rattus norvegicus*)	Glyphosate Unloaded (52.9% IPA), 39.2% a.i.? `[Note: Study title in Attachment 1 indicates 53.8% unloaded formulation.]`	LD_{50}: >1960 mg a.e./kg bw	MRID 46783403
Rat (*Rattus norvegicus*)	Glyphosate 360g/l SL, 27.25% a.i.	LD_{50}: >1363 mg a.e./kg bw	MRID 44953503 [2]
Rat (*Rattus norvegicus*)	Glyphosate 500 SL-M (36.7% Glyphosate Potassium)	LD_{50}: >1835 mg a.e./kg bw	MRID 45830201 [2]
Rat (*Rattus norvegicus*)	Glyphosate Acid 7.10 g/kg SL Formulation	LD_{50}: >36.5 mg a.e./kg bw	MRID 44497001 [2]
Rat (*Rattus norvegicus*)	Glyphosate acid formulation 500 g/kg WP	LD_{50}: >2465 mg a.e./kg bw	MRID 44317201 [2]
Rat (*Rattus norvegicus*)	Glyphosate IPA , 30.9% (NAF-545)	LD_{50}: >1545 mg a.e./kg bw	MRID 44863801
Rat (*Rattus norvegicus*)	Glyphosate premix (62.2%) Note: This is included in Attachment 1 (MRID listing for IPA)	LD_{50}: >3110 mg a.e./kg bw	MRID 44949802
Rat (*Rattus norvegicus*)	Glyphosate SL (600), 42.6 a.i. (NOS)	LD_{50}: >2130 mg a.e./kg bw	MRID 46006803 [2]
Rat (*Rattus norvegicus*)	HM-0548 5905-LTE Mixture of ammonium salt (19.68%) and IPA (13.36%)	LD_{50}: >1250 mg a.e./kg bw	MRID 47236803 [2]
Rat (*Rattus norvegicus*)	HM-2028 (Glyphosate: 11.4%)	LD_{50}: 357 mg a.e./kg bw `Note: This is the lowest reported` LD_{50}.	MRID 46714802 [2]
Rat (*Rattus norvegicus*)	LI6130 (13 41% Glyphosate Full Load: 40.6% IPA)	LD_{50}: >215 mg a.e./kg bw	MRID 46862303
Rat (*Rattus norvegicus*)	LI6167-11, 40.5% IPA ("Half load") `Note: Specified as EZJECT in Attachment 1.`	LD_{50}: >1500 mg a.e./kg bw	MRID 46862103
Rat (*Rattus norvegicus*)	MON 65005 (41% IPA), 30.3% a.e.	LD_{50}: >1515 mg a.e./kg bw	MRID 43020902
Rat (*Rattus norvegicus*)	MON 77945, 44.6% a.e. `Note: Not in Attachment 1 – i.e., probably not an IPA formulation.`	LD_{50}: >2330 mg a.e./kg bw	MRID 44715402
Rat (*Rattus norvegicus*)	MON 78063, 37.7% a.e. IPA? `Note: This is in Attachment 1 – i.e., probably an IPA formulation.`	LD_{50}: >1885 mg a.e./kg bw	MRID 44872702
Rat (*Rattus norvegicus*)	MON 78293, 39.3% a.e., IPA? `Note: This is in Attachment 1 – i.e., probably an IPA formulation.`	LD_{50}: >1965 mg a.e./kg bw	MRID 44809002
Rat (*Rattus norvegicus*)	Mon 79186 (2.02% glyphosate IPA), 1.5% a.e.	LD_{50}: >75 mg a.e./kg bw	MRID 46473802

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 2: Glyphosate Formulations, Acute Oral/Gavage Toxicity

Species	Agent	Response	Reference[1]
Rat (*Rattus norvegicus*)	MON 79188, 4.42 a.e. IPA? Note: This is in Attachment 1 – i.e., probably an IPA formulation.	LD_{50}: >221 mg a.e./kg bw	MRID 46078502
Rat (*Rattus norvegicus*)	Nufarm NUP 3G 02 (450 g/L glyphosate as IPA salt), 45% a.e.	LD_{50}: >2250 mg a.e./kg bw	MRID 46009104
Rat (*Rattus norvegicus*)	NUP-07010 (Glyphosate, a.e., 41.72%) IPA? Note: This is in Attachment 1 – i.e., probably an IPA formulation.	LD_{50}: >2086 mg a.e./kg bw	MRID 47298403
Rat (*Rattus norvegicus*)	NUP3a99 (41% glyphosate IPA), 30.3% a.e.	LD_{50}: >1515 mg a.e./kg bw	MRID 44872602
Rat (*Rattus norvegicus*)	NUP3b99 (53.8% glyphosate IPA)	LD_{50}: >1990 mg a.e./kg bw	MRID 44873302
Rat (*Rattus norvegicus*)	NUP5a99 (62% glyphosate MUP) IPA? Note: This is in Attachment 1 – i.e., probably an IPA formulation.	LD_{50}: >3100 mg a.e./kg bw	MRID 45293503
Rats	Roundup (41% a.i., 15% surfactant) See doses/responses in column 3	Reported 72 hour LD_{50}: 5337 mg formulation/kg bw 1619 mg a.e./kg bw Data below are from Baba et al. 1989, Table 1.	Baba et al. 1989
Rats	Roundup (360 g/L, 18% surfactant)	LD_{50}: 2300 mg formulation/kg bw	Dellegrave et al. 2002
Mouse	Roundup	LD_{50}: >5000 mg/kg bw Unit for exposure not specified.	WHO 1994
Rat	Roundup	LD_{50}: >5000 mg/kg bw Unit for exposure not specified.	WHO 1994
Goat, female	Roundup	LD_{50}: 4860 mg/kg bw Unit for exposure not specified.	WHO 1994

Dose	Mortality	Number
3123	0	7
3749	1	7
4498	2	7
5398	4	7
6476	6	7
7771	7	7

[1] Studies with only MRID designations are taken from Table 4.32 of U.S. EPA/OPP 2008a. Some additional information (e.g., formulation code or strain of rats) from Attachment 1.

[2] MRID is not referenced in Appendix L of U.S. EPA/OPP 2008a or in Attachment 1 of the current Forest Service risk assessment

[3] Although listed as a.i., it appears that acid equivalents rather than the a.i. is reported in U.S. EPA/OPP 2008a, Table 4.32. Most other entries do not appear to do this.

[4] The toxicity value of 3750 mg/kg is given in Table 4.25 of U.S. EPA/OPP 2008a. The acid equivalent values are given in Table J-26 of Appendix J of U.S. EPA/OPP 2008a.

A2 Table 3: Glyphosate Reproductive and Developmental			
Species	**Exposure**	**Response**	**Reference**[1]
Reproduction			
Rat (*Rattus norvegicus*)	2-generation reproduction study, dietary exposure, glyphosate 97.67% a.i. Dietary concentrations of 0, 2000, 10,000 or 30,000 ppm. Estimated Daily Doses: 0, 100, 500 or 1500 mg/kg/day	U.S. EPA/OPP 1993b, p. 9. NOAEL: 10,000 ppm (500 mg/kg bw/day). LOAEL: 30,000 ppm (1500 mg/kg bw/day). Decreased food consumptions and soft stools in F_0 and F_1 males and females during pre-mating period. Decreased body weight gain in F1a, F2a and F2b male and female pups during lactation. This study is also summarized in U.S. EPA/OPP 2008a consistent with the above summary.	Reyna 1990 MRID 41621501
CD Rats/30 per sex per group	Glyphosate acid (98.7%) Concentrations: 0, 2000, 10000, 30000 ppm (97.7%) in the diet. Multi-generation (NOS)	Decreased body weight in parents and pups and equivocal decrease in average litter size at 30000 ppm. No effects at lower doses. NOAEL for systemic and reproductive effects: 10000 ppm (equivalent to 740 mg/kg/day). LOAEL for reproductive effects: 30000 ppm (equivalent to 2268 mg/kg/day).	Farmer et al. 2000a
Charles River CD Rats/12 M, 24F	Glyphosate acid Dietary exposure equivalent to 0, 3, 10, or 30 mg/kg bw/day 3-generation reproduction study	An increase in unilateral focal tubular dilation of the kidney in the male F3b pups (7/10 in treated animals compared with 2/10 in concurrent controls) of dams treated with 30 mg/kg/day. No compound-related effects were observed on fetal, pup, and adult survival; mean parental and pup body weight and food consumption; and mating, pregnancy, fertility, and gestation length. Note: Using the Fisher Exact test, 7/10 is significantly greater than 2/10 with a p-value of 0.0349.	Schroeder and Hogan 1981 MRID No. 0081674, 00105995 as summarized by U.S. EPA/ORD 1990.

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 3: Glyphosate Reproductive and Developmental			
Species	**Exposure**	**Response**	**Reference**[1]
Developmental			
Rats, Wistar, 210-230 g, 8 per group	Glyphosate acid (reagent grade) in water. 0, or 1% w/v (10,000 mg/L) from Day to Day 21 of gestation. See Table 1. Average water consumption in glyphosate group of 0.02579 L/day for a dose of 257.9 mg. For a mean bw of 0.22 kg with a terminal body weight gain of 0.053 kg[0.22 kg + 0.053 kg/2 = 0.2465 kg], the dose is about 1046 mg/kg bw [257.9 mg /0.2465 kg].	Maternal: Decrease in water and food consumption as well as absolute liver weight and body weight gain. Increases in liver peroxidation – i.e., oxidative stress. Fetal/Offspring: No effects on body weight or liver weight.	Beuret et al. 2005 Open literature
Rats, Wistar, 210-230g	Reagent grade glyphosate in drinking water at 5000 ppm and 10,000 ppm (w/v) from Day 1 to Day 21 of pregnancy as well as a food and water restricted control group	Doses based on reported water consumption and body weights were about 455 mg/kg bw and 1000 mg/kg bw. Significant decreases in adult food and water consumption. Significant decreases in adult body weight. No change in fetal body weights. Changes in biochemical parameters but no reports of fetal toxicity or abnormality.	Daruich et al. 2001 Open literature
Rats/Wistar/F/24 per dose	Glyphosate acid 0, 250, 500 or 1000 mg/kg/day by gavage on Days 7-16 of gestation	No signs of maternal or developmental toxicity.	Moxon 1996a MRID 44320615
Rabbits/New Zealand White/F/20	0, 100, 175, and 300 mg/kg/day by gavage on Days 8-20 of gestation	Maternal toxicity – observed at 175 and 300 mg/kg/day – diarrhea, reduced fecal output, reduced food intake and body weight. Fetal toxicity – observed at 300 mg/kg/day – reduced body weight and delayed ossification. No effects on survival and no signs of teratogenicity.	Moxon 1996b MRID 44320616

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 3: Glyphosate Reproductive and Developmental			
Species	**Exposure**	**Response**	**Reference**[1]
Rabbit (*Oryctolagus cuniculus*) Rabbits/Dutch Belted/F/16 per dose	Glyphosate acid 0, 75, 175, or 350 mg/kg/day by gavage on Days 6-27 of gestation.	Maternal toxicity – 175 mg/kg/day – diarrhea. 350 mg/kg/day – diarrhea and nasal discharge. Some animals in both controls and dosed groups died from causes unrelated to glyphosate treatment. No developmental effects. U.S. EPA Summary[1]: *Maternal NOAEL = 175 mg/kg/day LOAEL = 350 mg/kg/day based on mortality, diarrhea, soft stools, and nasal discharge.* *Developmental NOAEL = 350 mg/kg/day (HDT) LOAEL = not established.*	MRID 46363 Rodwell et al. 1980b
Rat (*Rattus norvegicus*)	Glyphosate acid 0, 300, 1000, or 3500 mg/kg/day by gavage	Breathing difficulty, reduced activity, diarrhea, stomach hemorrhages, weight gain deficits, altered physical appearance, and mortality during treatment in high-dose dams; unossified sternebrae in fetuses from high-dose dams. U.S. EPA Summary[1]: *Maternal NOAEL = 1000 mg/kg/day LOAEL = 3500 mg/kg/day based on inactivity, mortality, stomach hemorrhages and reduced body weight gain.* *Developmental NOAEL = 1000 mg/kg/day LOAEL = 3500 mg/kg/day based on increased incidence in the number of fetuses and litters with unossified sternebrae and decreased fetal body weight.*	MRID 46362 Rodwell et al. 1980a

A2 Table 3: Glyphosate Reproductive and Developmental			
Species	**Exposure**	**Response**	**Reference**[1]
Rats/CD/ females/ 25/dose group	0, 300, 1000, or 3500 mg/kg/day glyphosate (98.7% pure) by gavage on days 6-19 of gestation	At 3500 mg/kg/day, severe maternal toxicity, including decreased weight gain and mortality in 6/25 animals was accompanied by decreases in fetal weights, viability, and ossification of sternebrae. NOEL = 1000 mg/kg/day for maternal and developmental toxicity	Farmer et al. 2000b
Rats, Wistar	**Roundup (Brazilian formulation),** 360 g/L glyphosate, 36% w/s with 18% w/v POEA surfactant. Salt of glyphosate not specified. Gavage: 0, 500, 750 or 1000 mg/kg glyphosate from day 6 to 15	1000 mg/kg bw/day: high maternal mortality. Dose-related increase in skeletal malformations. – i.e., growth retardation. NOEL for malformations not defined. No effects on implantation, resorptions, or fetuses/dam.	Dallegrave et al. 2003
Rats, Wister	**Roundup (Brazilian formulation),** 360 g/L glyphosate, 36% w/v with 18% w/v POEA surfactant. Salt of glyphosate not specified. Gavage: 0,50, 150 or 450 mg/kg glyphosate during gestation (21 to 23 days) as well as 21 days post-partum (lactation). Note: Doses appear to be expressed as acid equivalents.	No signs of maternal toxicity. Vaginal canal opening was significantly delayed for all dose levels relative to controls. The delay, however, was not dose-related. Increase in abnormal sperm at 50 mg/kg but not dose-related. Decrease in number of sperm in matured offspring at 50 and 450 mg/kg bw. Decrease in testosterone at puberty in 450 mg/kg bw group. The decrease appears to be dose-related (see Table 4 of paper). A NOEC for testosterone not defined.	Dallegrave et al. 2007 **See Section 3.1.9.1.2 for a more detailed discussion of this study.**

A2 Table 3: Glyphosate Reproductive and Developmental

Species	Exposure	Response	Reference[1]
Other Studies			
Rats, Wistar, newly weaned males	**Roundup Transorb**: Gavage doses of 0, 5, 50, or 250 mg/kg bw/day on post-natal Days 23 to 53 (i.e., 31 days). Doses appear to be expressed as mg a.e./kg bw/day.	Statistically reductions in serum testosterone accompanied by morphologic changes in testes. A NOEC for testosterone not defined. The decreases in testosterone are significant ($p<0.001$) at all doses. The tubule diameters are significantly increased ($p<0.05$) at all doses. Dose (mg/kg bw/day) / Testosterone (ng/dL) / Tubule Diameter[a] 0 / 154.5 / 94 5 / 108.6 / 116.6 50 / 84.5 / 114.3 250 / 76.9 / 130.3 [a] Diameter of lumen of seminiferous tubules in µm.	Romano et al. 2010 **See Section 3.1.9.3. for a more detailed discussion of this study.**
Rabbits/ New Zealand white/ male/ 4/dose	Not clear if glyphosate or a glyphosate formulation was used. $1/10^{th}$ and $1/100^{th}$ of the LD_{50} orally in gelatin capsule for 6 weeks with an additional 6 week recovery period.	Decreased body weight, libido, ejaculate volume, sperm concentrations, semen initial fructose and semen osmolality. Increases in abnormal and dead sperm.	Yousef et al. 1995

[1]Studies with only MRID designations are taken from Table 4.33 of U.S. EPA/OPP 2008a. Italics indicates text from U.S. EPA/OPP 2008a. Additional details from U.S. EPA/OPP 1993b.

A2 Table 4: Glyphosate Subchronic and Chronic Toxicity			
Species	**Exposure**	**Response**	**Refer-ence**
Subchronic oral			
Rats/ F344/N 10/sex/ dose	Glyphosate, technical grade, 99% purity. Duration: 13 weeks Dietary Conc.: 0, 3125, 6250, 12500, 25000, 50000 ppm. Corresponding doses: Males: 0, 205, 410, 811, 1678, 3393 mg/kg/day Females: 0, 213, 421, 844, 1690, 3393 mg/kg/day	Decrease in body weight in males (20%) and females (5%) at the highest dose level. In males, small increases in relative liver, kidney, and testicle weights and a decrease in relative thymus weight. No significant organ weight changes in females. Hematologic changes (increased hematocrit, RBC) at the three higher dose levels and increased hemoglobin at the two higher dose levels in males. The hematologic effects are unremarkable and attributed to mild dehydration. Treatment related increases in alkaline phosphatase in both sexes at all time points suggestive of mild liver toxicity. In males at the two higher dose levels, a 20% decrease in sperm counts. In females, a longer estrous cycle at the highest dose. Salivary gland lesions in both sexes at all dose levels with increasing incidence and severity with increasing dose. The effect could be blocked by isoproterenal, indicating an adrenergic mechanism.	NTP 1992
Mice/ B6C3F1/ 10/sex/ dose	Duration: 13 weeks Dietary Conc.: 0, 3125, 6250, 12500, 25000, 50000 ppm.	Body weight depression at the two highest dose levels for both sexes. Increases in relative heart, kidney, liver, lung, thymus, and testis for male mice. No differences in food consumption between the dosed and control groups. No effects on sperm motility or estrous cycle length. Salivary gland lesions.	NTP 1992
Rats, Sprague-Dawley	Technical grade glyphosate Duration: 90 days Dietary Conc.: 0, 1000, 5000 or 20000 ppm Corresponding doses: Males: 0, 63, 317 and 1267 mg/kg/day Females: 0, 84, 404 or 1623 mg/kg/day	Serum: elevated phosphorus and potassium, all groups; elevated glucose, mid- and high-dose males; Histopathology: pancreatic lesions in high-dose males. NOEL: not established.	U.S. EPA/OPP 1993b, pp. 4 MRID 40559401
Mice, CD-1	Technical grade glyphosate Duration:3 months Dietary Dose Equivalents: 0, 250, 500 or 2500 mg/kg/day	High Dose: Decreased body weights relative to controls in males (24%) and females (18%). NOEL: 500 mg/kg bw	U.S. EPA/OPP 1993b, pp. 4 MRID 00036803

A2 Table 4: Glyphosate Subchronic and Chronic Toxicity

Species	Exposure	Response	Refer-ence
Rats, Wistar, 280-310 g	**Glyphosate-Biocarb (Brazil). 360 g a.e./L with 18% POEA surfactant.** Gavage doses of 4.87, 48.7, or 487 mg/kg bw every other day for 75 days.	Based on Table 1 of the publication, these doses appear to be in units of formulation. Liver damage assayed by serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST),. Results from Tables 1 and 2 of the paper are given below. Dose (mg/kg bw) / ALT / AST 0 / 28.5 / 84.3 4.87 / 45.5 / 101.8 48.7 / 47.9 / 112.9 487 / 55 / 124.8 At the high dose, an increase in the number of Kupffer cells was noted. No pathology at lower levels.	Benedetti et al. 2004
Subchronic Dermal			
Rabbits, New Zealand	**Dermal** Duration: 21 days Doses: 10, 1000 or 5000 mg/kg/day, 6 hours/day, 5 days/week	High dose: Skin irritation, slight erythema and edema. Decreased food consumption in males. Decreased serum lactic acid dehydrogenase. NOEL: 1000 mg/kg bw	U.S. EPA/OPP 1993b, pp. 4 MRID 00036803
Chronic Oral			
Rats/ Sprague Dawley 60/sex/ group	Technical grade glyphosate Duration: 24 months Dietary Conc.: 0, 2000, 8000, or 20,000 ppm Corresponding doses: Males: 0, 89, 362, or 940 mg/kg/day Females: 0, 113, 45, or 1183 mg/kg/day	Significant decrease in body weight gain in high-dose females (day 51-month 20); significant increases in cataracts and lens abnormalities in high-dose males; significant decrease in urinary tract pH in high-dose males; increased relative liver weights; significantly increased incidence of inflammation of the gastric mucosa in mid-dose females. Increased incidence of pancreatic islet cell adenomas (low-dose males) and C-cell adenomas in the thyroid of mid- and high-dose males and females; slight increase in hepatocellular adenomas in males. Increased tumor incidences were not judged by U.S. EPA/OPP to be treatment related. NOAEL of 8000 ppm based on decreased body weight data.	U.S. EPA/OPP 1993b, pp. 5-6 MRID 41643801

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 4: Glyphosate Subchronic and Chronic Toxicity

Species	Exposure	Response	Refer-ence
Rats/ Sprague Dawley	Technical grade glyphosate Duration: 26 months Dietary Conc.: 0, 0, 30, 100 or 300 ppm Corresponding doses: Males: 0, 3.05, 10.3 and 31.39 mg/kg/day Females: 0, 3.37, 11.22 and 34,.02 mg/kg/day	No toxic effects in either sex in any of the dosed groups. Tumors: High Dose Females: thyroid C-cells carcinomas High Dose Males: increase in Leydig cell testicular tumors. *Carcinogenicity Peer Review Committee concluded that these neoplasms were treatment-unrelated and, therefore, glyphosate was not carcinogenic in this study.*	U.S. EPA/OPP 1993b, pp. 6 MRID 00093879 This is the basis for the AID (WHO 2004)
Mice, CD-1	Technical grade glyphosate Duration: 18 months Dietary Conc.: 0, 0,1000, ,5000 or 30000 ppm Corresponding doses: 150, 750 and 4500 mg/kg/day	Lower mean body weights (as much as 11% at week 102) among high-dose males; elevated mean absolute and relative weights of testes in high-dose males. Histopathological changes included hepatic centrilobular hypertrophy and necrosis of hepatocytes in high-dose males and chronic interstitial necrosis and proximal tubule epithelial cell basophilia and hypertrophy of the kidneys in high-dose females. Sporadic occurrence (not dose related) of lymphoreticular tumors in treated females and renal tubular adenomas in males. *HED Carcinogenicity Peer Review Committee concluded(along with the pathologists and biometricians) that the occurrence of these adenomas was spontaneous rather than compound induced.* The NOAEL for non-neoplastic chronic effects from this study is 5000 ppm, which corresponds to a dose of 750 mg/kg/day.	U.S. EPA/OPP 1993b, pp. 7 MRIDs 00130406 and 00150564
Dogs, Beagle	Technical grade glyphosate Duration: 1 year Gelatin capsules Daily Doses: 0, 20, 100 or 500 mg/kg/day	No toxic effects in any animals at any doses	U.S. EPA/OPP 1993b, p. 6 MRID 00153374

A2 Table 5: Surfactant Toxicity Studies

Species	Exposure	Response	Reference[1]
Acute Toxicity			
Rats	POEA 72 hours. Doses of 482, 578, 694, 833, and 1000 mg/kg bw.	Reported LD50: 661 mg/kg bw Data below are from Baba et al. 1989, Table 1. Dose / Mortality / Numb 482 / 0 / 7 578 / 2 / 7 694 / 4 / 7 833 / 6 / 7 1000 / 7 / 7	Baba et al. 1989
Rats	Roundup surfactant	LD_{50}: 1200 mg/kg bw	Williams et al. 2000 (citing unpublished data)
Rats	LI 700	Male: >5,000 mg/kg bw Female: >5,000 mg/kg bw	Lapurga 1996
Subchronic Studies			
Rats, Sprague-Dawley	1 month dietary exposure at 0, 800, 2000, and 5000 ppm (mg/kg diet).	800 ppm: No effects noted 2000 ppm: Decrease weight gain in males. Sigs of irritation of the gastrointestinal tract in females characterized as: *Prominent enlarged lymphoid aggregates in the colon.* 5000 ppm: Decrease weight gain in males and females.	Williams et al. 2000 (citing unpublished data by Ogrowsky 1989)
Rats, Sprague-Dawley	3 month dietary exposure at 0, 500, 1500, and 4500 ppm (mg/kg diet). Williams et al. (2000) indicate that 500 ppm corresponded to a dose of ≈36 mg/kg bw/day [a food consumption factor of 0.072 g food/kg bw]	500 ppm: No effects reported. 1500 ppm: Intestinal irritation. 4500 ppm: Decrease weight gain, food consumption, and intestinal irritation in males and females. Changes (NOS) in hematology and serum chemistry.	Williams et al. 2000 (citing unpublished data by Stout 1989)
Dogs, beagles	14 week study Exposure via gelatin capsules at daily doses of 0, 30, 60, and 90 mg/kg bw during last 10 weeks of study. Lower doses (NOS) used during first 4 weeks of study due to intestinal irritation.	30 and 60 mg/kg bw/day: Slight (NOS) decrease in body weights in females which *…were not always dose related*. Also, *slight reductions in serum calcium and protein.* 90 mg/kg bw/day: Decreased body weight.	Williams et al. 2000 (citing unpublished data by Filmore 1973)

A2 Table 5: Surfactant Toxicity Studies			
Species	**Exposure**	**Response**	**Reference[1]**
Developmental Studies			
Rats/CD/ females/ 25/dose group	POEA: 0, 15, 100, or 300 mg/kg/day by gavage on days 6-15 of gestation	No developmental toxicity at any doses. At 100 mg/kg/day, slight maternal toxicity – i.e., decreased food consumption and mild clinical signs. At 300 mg/kg/day, mortality as well as decreases in food consumption and body weight gain. NOEL = 15 mg/kg/day for maternal toxicity	Farmer et al. 2000b This is presented in an abstract only. This study is also summarized in Williams et al. (2000) and attributed to Holson (1990), an unpublished report.
Rats/CD/ females/ 25/dose group	Phosphate ester neutralized POEA: 0, 15, 50, or 150 mg/kg/day phosphate ester neutralized POEA by gavage on days 6-15 of gestation	No developmental toxicity. At 150 mg/kg/day, mortality as well as decreases in food consumption and body weight gain. NOEL = 50 mg/kg/day for maternal toxicity	Farmer et al. 2000b
Reproduction Studies			
Rats, CD (Sprague-Dawley), groups of 20 males and 20 females, parental (P) animals 10 weeks old at start.	**MON 0818** Two-generation Reproduction Study involving dietary exposures to 0, 100, 300, or 1000 ppm. Parental generation dosed for at least 70 days prior to mating. Based on measured food consumption, the daily doses in units of mg/kg bw/day are: Males: F0: 5.5, 16.6, 56.1. F1: 5.0, 14.9, 52.8 Females: F0: 6.7, 19.5, 66.6 F1: 6.9, 18.9, 64.9 10 weeks prior to mating 69-73% a.i.	No adverse effects in parental organisms at any dose level. Reproductive NOAEL: 300 ppm Reproductive LOAEL: 1000 ppm. LOAEL described in U.S. EPA/OPP (2009c) based on *…on litter loss, increase mean number of unaccounted-for implantation sites and decreased mean number of pups born, live litter size and postnatal survival from birth to LD 4 (F1). … At 1000 ppm, 3 F0 dams w/ small litters (2-4 pups/litter), and some of these pups died before PND 4; effect not repeated in F2 litters.* Study assayed for blood testosterone and thyroid hormone concentrations as well as sperm motility and morphology and effects on estrous cycle. No effects noted	MRID 47097401, Knapp 2006, as summarized in U.S. EPA/OPP (2009c) See Section 3.1.9.2.2 for discussion.

A2 Table 6: Case Reports of Human Poisoning

Number of individuals, formulation, [Location]	Average Dose	Symptoms, Outcome, and post mortem pathology	Reference
1 [Taiwan]	400 mL of a Chinese formulation containing 41% glyphosate and a surfactant	A 51 year old female in a suicide attempt with a glyphosate formulation containing a surfactant. Cause of death given as cardiopulmonary failure	Chang and Chang 2009
50, Roundup [Japan]	181±201 mL	Esophageal injury observed in 68% of patients; gastric injury in 72%; and duodenal injury in 16%. One patient died on the second hospital day due to refractory shock and aspiration pneumonia.	Chang et al. 1999
2,186 [Taiwan]	Highly variable – i.e., from about 5 mL to 950 mL of formulations	Severe or fatal outcomes more likely in older individuals and in individuals with median exposures of 150 mL vs median exposures of 75 mL. Table 3 of publication summarizes other epidemiology studies.	Chen et al. 2009
2, Roundup [New Zealand]	200-250 ml [fatal]	Vomiting and acidosis. Both individuals died. Ulcerated oropharynx, congested lungs and airway mucosa, petechial submucosal hemorrhages and gastric funduc, acute pulmonary edema, and acute tubular necrosis of the lungs in on individual. Edema of the bronchi and lungs in the other individual.	Dickson et al. 1988
2, glyphosate [Spain]	NS [fatal]	Concentrations in blood (1.64-892.27 ppm) and gastric content (0.08-11.06 ppm)	Garcia-Repetto et al. 1998
1 [Taiwan]	Glyphosate/ surfactant mixture (NOS), about 100 mL	89 year old male, pancreatitis, severe respiratory distress, abdominal pain and bleeding. Individual survived but was hospitalized for over 30 days.	Hsiao et al. 2008
53, Roundup [Taiwan]	258±347 mL (range 15-2000 mL)	Blood WBC counts significantly higher and hospital stays significantly longer in patients with laryngeal injury ($p<0.005$); laryngeal injury strongly correlated with aspiration pneumonitis ($X^2=4.449$, $p<0.05$)	Hung et al. 1997
1, Roundup [U.S.]	N.S.	A self report of "nervous system and immune system problems" that "no doctor has been able to accurately diagnose and treat... "	Jensen 1989
1, Roundup [Japan]	N.S.	Foam and fluid in the trachea and bronchi. Death attributed to aspiration of the formulation into the lungs	Kageura et al. 1988
N.S., Roundup and others, [France]	N.S.	Estimated lethal dose of about 1 g/kg.	Kammerer 1995

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 6: Case Reports of Human Poisoning

Number of individuals, formulation, [Location]	Average Dose	Symptoms, Outcome, and post mortem pathology	Reference
131, GlySH (glyphosate-surfactant herbicide), [Taiwan]	330±42 mL [fatal]	11 fatalities (mortality rate of 8.4%); most common presentations included sore throat, nausea (with or without vomiting) and fever; most common laboratory abnormalities included leukocytosis (68%), decreased bicarbonate (48.1%); acidosis (35.8%), elevated AST (33.6%), hypoxemia (28.4%), and elevated BUN (17.1%).	Lee et al. 2000
58 [Taiwan]	Presumably glyphosate /surfactant formulations	17/58 died (29%). Most prominent organ damage in lungs and kidney.	Lee et al. 2008
1, Chun-Dou-Dou (41% isopropylamine salt of glyphosate, 15% polyoxy-ethylene-amine) [China]	~150 mL	Cardiogenic shock with accelerated idio-ventricular rhythm	Lin et al. 1999
4, Roundup [New Zealand]	50 -1,000 ml [non-fatal] 200-250 ml [fatal]	Abdominal pain, diarrhea and vomiting. Decreased urinary output. Estimates of non-fatal doses: 85 g for 27 year old male, 18-36 g for 15 year old female, "up to 1 liter" for a 38 year old male. About 72-91 g for a 43 year old woman.	Menkes et al. 1991
2 [South Korea]	Ingestion of 200 or 300 mL of Roundup formulations	Renal failure and cardiovascular effects. Both individuals survived following hemodialysis.	Moon et al. 2006
15 [Japan]	No details provided	Death in only one individual. No details of symptoms.	Nagami et al. 2005
1, Roundup, [Israel]	NS [non fatal]	Shortness of breath, irritative cough, dizziness, throat discomfort, episodes of hemoptysis, temperature of 38.40 °C (101.12°F), mild to moderate respiratory distress, diffuse rales and crackles heard over the lungs. 42-year-old, male mechanic.	Pushnoy et al. 1998
1 [USA]	About 240 mL of Roundup	Renal failure and hypoxia. Survived following hemodialysis.	Sampogna and Cunard 2007
56, Roundup [Japan]	104 ml [non-fatal] 206 ml [fatal]	Hypovolemic shock. Sore throat, abdominal pain, and vomiting. Pulmonary edema (3 cases) and severe pneumonia (2 cases). Oliguria, anuria, and hypotension in all fatal cases. Increases serum amylase and WBC count, some with increased bilirubin and LDH activity, probably attributable to hemolysis.	Sawada et al. 1988
2 [Australia]	Roundup formulations, 500 to 1,000 mL	Renal failure with severe abdominal pain, pulmonary edema, and metabolic acidosis. Both individuals died despite hemodialysis.	Stella and Ryan 2004

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 6: Case Reports of Human Poisoning

Number of individuals, formulation, [Location]	Average Dose	Symptoms, Outcome, and post mortem pathology	Reference
93, Roundup [Taiwan]	184±70 mL (range 85-200 mL) [fatal]; however, ingestion of much higher amounts (500 mL) only resulted in mild to moderate signs and symptoms	Mild: mainly GIT symptoms (nausea, vomiting, diarrhea, abdominal pain, mouth and throat pain) that resolved in 24 hours Moderate: GII symptoms lasting longer than 24 hours, GIT hemorrhage, endoscopically verified oesophagitis or gastritis, oral ulceration, hypotension responsive to IV fluids, pulmonary dysfunction not requiring intubation, acid-base disturbance, evidence of transient hepatic or neal damage, or temporary oliguira. Severe: pulmonary dysfunction requiring intubation, renal failure requiring dialysis, hypotension requiring treatment with pressor amines, cardiac arrest, coma, repeated seizures, or death.	Talbot et al. 1991
1, Roundup [New Zealand]	200-250 ml [fatal]	Hypotension, metabolic acidosis, and vomiting, and hyperkalemia. Death due to respiratory and cardiac arrest. Pulmonary edema and acute renal tubular necrosis.	Temple and Smith 1992
92, Roundup [Taiwan]	120 ml (range of 5-500 ml) [non-fatal] 263 ml (range of 150-500 ml) [fatal]	Irritation and pain in the throat and mouth, some with oral mucosal ulceration. Gastritis, esophagitis, and mucosal edema. Vomiting and diarrhea. Abdominal or epigastric pain. Diffuse pulmonary damage, non-cardiogenic pulmonary edema. Intensive therapy failed to reverse hypoxemia in fatal cases. Oliguria or anuria in 10 patients, perhaps related to hypotension. Metabolic acidosis. Mild temperature elevations in 7 patients.	Tominack et al. 1991
1 [China]	Glyphosate-surfactant formulation, 6 mL, **intramus-cular** injection.	Swelling and injection site pain. Recovery within 4 days.	Weng et al. 2008
83 [France]	NS	34 cases were associated with Roundup. 40 individuals evidenced no signs of toxicity. 3 individuals died. The most frequent clinical signs involved gastrointestinal irritation.	Weppelman 1994
1 [Taiwan]	Glyphosate-surfactant formulation, 250 mL, **intravenous** injection.	22 year old male, individual survived with alkaline dieresis supportive (blood transfusion) care. Recovery within 4 days. **Note: The estimated dose seems dubious given the reported route of administration.**	Wu et al. 2006
74, Glyphosate (NOS) [Taiwan]	NS	Glyphosate was among the 28 substances (1.27%) most frequently involved in pediatric poisoning exposures reported to NPC Taiwan 1985-1993. Details regarding the signs and symptoms of poisoning are not provided.	Yang et al. 1997

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 7: *In vitro* studies relating to endocrine function

Test System	Exposure	Effect	Reference
Equine testicular microsomes	Roundup Bioforce (480 g IPA/L, 360 g a.e./L, Belgium formulation from Monsanto), pH≈5.8. Concentrations of about 0.1% to 10% formulation (about 1000 mg/L to 100,000 mg/L) or 360 to 36,000 mg a.e./L.	Possible low concentration stimulation in P450 aromatase activity based on graph. Concentration related decrease in P450 aromatase activity above 5,000 mg formulation/L (0.5%). Similar pattern in both pH adjusted and non-adjusted assays. IC50s of about 25,000 to 40,000 mg formulation/L (9000 to 14,400 mg a.e./L).	Benachour et al.2007b Fig. 5B of paper
Human embryonic 293 cells	Glyphosate (reagent grade), ≈100 to 10,000 mg a.e./L for 24 hours	Slight stimulation of P450 aromatase up to about 1000 mg/L. Dose related decrease at higher concentrations. IC_{50} ≈ 8,000 mg/L.	Benachour et al.2007b Figure 4A of paper
Human embryonic 293 cells, serum free media	Roundup Bioforce (480 g IPA/L, 360 g a.e./L), pH≈5.8. ≈100 to 2000 mg formulation/L (≈36 to 720 mg a.e./L)	Decrease in P450 aromatase of about 70% of controls but the decrease was not concentration related.	Benachour et al.2007b Figure 4A of paper
Human placental microsomes	Roundup Bioforce (480 g IPA/L, 360 g a.e./L), pH≈5.8. Concentrations of about 0.1% to 10% formulation (about 1000 mg/L to 100,000 mg/L) or 360 to 36,000 mg a.e./L.	A slight stimulation in P450 aromatase activity up to about 3000 mg formulation/L followed by a concentration related decrease in P450 aromatase activity. Similar in both pH adjusted and non-adjusted assays. IC_{50}s of about 30,000 to 40,000 mg formulation/L (≈10,800 to 14,400 mg a.e./L).	Benachour et al.2007b Fig. 5A of paper
Human placental microsomes	Glyphosate, ≈0.01% to 2% (100 mg a.e./L to 20,000 mg a.e./L) for 15 minutes at 25°C and 37°C (body temperature)	Modest decrease in P450 aromatase activity above 5,000 mg a.e/L (1800 mg a.e./L).	Benachour et al.2007b Fig. 7B of paper

A2 Table 7: *In vitro* studies relating to endocrine function

Test System	Exposure	Effect	Reference
Human placental microsomes	Roundup Bioforce (480 g IPA/L, 360 g a.e./L), pH≈5.8. Concentrations of about 0.01% to 2% formulation (about 100 mg/L to 20,000 mg/L) or 36 to 7,200 mg a.e./L for 15 minutes at 25°C and 37°C (body temperature)	37°C A slight stimulation in P450 aromatase activity is apparent at concentrations below about 0.1% (1000 mg formulation/L or 360 mg a.e./l). At higher concentrations, a clear concentration related decrease in P450 aromatase activity that appears to be exponential. IC50 of ≈0.5% (5000 mg formulation/L or 1800 mg a.e./L) 25°C No remarkable inhibition in P450 aromatase activity at concentration less than 10,000 mg formulation/L.	Benachour et al.2007b Fig. 7A of paper
Inhibition of dihydrotestosterone binding (AR receptor) and estradiol 17β (ERα and ERβ receptors) in HepG2 cells	Technical grade glyphosate, ≈0.05 to 0.3% (500 to 3000 mg/L)	No remarkable anti-estrogenic activity. Substantial but non-concentration dependant inhibition of androgen receptor.	Gasnier et al. 2009 See Figure 5 of publication.
Inhibition of dihydrotestosterone binding (AR receptor) and estradiol 17β (ERα and ER β receptors) in HepG2 cells	Roundup Express (7.2 g/L) [R7.2]	IC_{50} values for inhibition of binding as glyphosate (a.e.) equivalents Receptor / µM / mg/L ERα / 86.5 / 14.6 ERβ / 104.8 / 17.7 AR / 32.8 / 5.55 µM concentrations from Table 2 of paper. Mg/L concentrations calculated using a MW of 169.07 and rounded to 3 significant digits.	Gasnier et al. 2009 See Figure 5 and Table 2 of publication.
Inhibition of dihydrotestosterone binding (AR receptor) and estradiol 17β (ERα and ERβ receptors) in HepG2 cells	Bioforce (360 g/L) [R360]	IC_{50} values for inhibition of binding as glyphosate (a.e.) equivalents Receptor / µM / mg/L ERα / 3087.5 / 552 ERβ / 3406.9 / 576 AR / 660.1 / 112 µM concentrations from Table 2 of paper. Mg/L concentrations calculated using a MW of 169.07 and rounded to 3 significant digits.	Gasnier et al. 2009

A2 Table 7: *In vitro* studies relating to endocrine function

Test System	Exposure	Effect	Reference
Inhibition of dihydrotestosterone binding (AR receptor) and estradiol 17β (ERα and ERβ receptors) in HepG2 cells	Grands Travaux (400 g/L) [R400]	IC_{50} values for inhibition of binding as glyphosate (a.e.) equivalents Receptor / µM / mg/L ERα / 14.2 / 2.40 ERβ / 7.1 / 1.20 AR / 2.13 / 0.36 µM concentrations from Table 2 of paper. Mg/L concentrations calculated using a MW of 169.07 and rounded to 3 significant digits.	Gasnier et al. 2009
Inhibition of dihydrotestosterone binding (AR receptor) and estradiol 17β (ERα and ERβ receptors) in HepG2 cells	Grands Travaux Plus (450 g/L) [R450]	IC_{50} values for inhibition of binding as glyphosate (a.e.) equivalents Receptor / µM / mg/L ERα / 53.2 / 8.99 ERβ / No estimate provided. AR / 40 / 6.8 Note: The values for AR is listed in Table 2 of the paper as 53.2 µM, identical to the value given for the ERα receptor. Based on Figure 5 of the paper, the value in Table 2 appears to be in error. The correct IC_{50} looks like about 0.0015% or 40 µM (6.8 mg/L). µM concentrations from Table 2 of paper. Mg/L concentrations calculated using a MW of 169.07 and rounded to 3 significant digits.	Gasnier et al. 2009
MCF-7 human breast cancer cells, assay for changes in regulation of 1550 genes on commercial RZPD microarray chips.	15% *home use formulation* (NOS but presumably 15% IPA) as stock. Dilutions of 0.0001% to 0.1% (equiv. to about 0.111 to 111 mg a.e./L). 18 hour exposure.	Changes in regulation of ≈44% (680/1550) of genes. Increase of over a factor of 2 in ≈1.4% (21/1550) and decreases by over a factor of 2 in ≈0.5% (8/1550). Real time polymerase chain reaction assays confirmed activity in 3/7 of the 29 genes identified in the microarray analysis.	Hokanson et al. 2007
MCF-7 human breast cancer cells	Roundup, 1 to 10 mg/L, units not clear.	Non-estrogenic induction of cell proliferation	Lin and Garry 2000
MCF-7 human breast cancer cells	Glyphosate IPA, 0.228 to 2.28 mg/L	Non-estrogenic induction of cell proliferation	Lin and Garry 2000
Transcriptional activity of rtER (estrogen receptor) from trout in yeast system	Glyphosate (NOS), 10^{-8} to 10^{-4}M (≈1.7 µg/L to 16 mg/L)	No impact on rtER binding beyond basal levels (14-18%). See Figure 1A in paper.	Petit et al. 1997

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 7: *In vitro* studies relating to endocrine function

Test System	Exposure	Effect	Reference
Human placental JEG3	Glyphosate (NOS), 100 mg/L to ≈ 8,000 mg/L	No significant effect on either P450 aromatase activity or P450 aromatase mRNA.	Richard et al. 2005 See Fig. 3 of publication.
Human placental JEG3	Roundup (360 a.e./L, Monsanto, Belgium) 100 mg formulation/L to ≈ 800 mg formulation/L for 18 hours (36 to 288 mg a.e./L).	Concentration related decrease P450 aromatase activity between 100 mg/L (≈15% decrease) and 400 mg/L (≈55% decrease). Decrease in P450 aromatase mRNA at 200 mg/L (≈20% decrease) and 600 mg/L (≈35% decrease). At 1 hours, P450 aromatase activity evidenced non-concentration related stimulation (≈140% of control).	Richard et al. 2005 See Fig. 3 of publication.
Mouse Leydig tumor cell line	Glyphosate (NOS) up to 100 mg/L	No effects on steroid production.	Walsh et al. 2000
Mouse Leydig tumor cell line	Roundup (180 g/L, NOS), 10 to 100 mg/L Units are not clear but appear to be formulation.	IC_{50} of 24.4 mg/L for inhibition of progesterone production (disruption of StAR protein). No inhibition in protein synthesis (cytotoxicity) at up to 50 mg/L. (See Fig. 1 H in paper).	Walsh et al. 2000

A2 Table 8: *In vitro* studies on cellular/genetic toxicity

Formulation	Organism/ Cell/Test System	Exposure Level	Assay/Nature of Exposure	Effects	Reference
Glyphosate, POAE, and several glyphosate formulations	Three human cell lines: umbilical vein cord endothelial cells, embryonic kidney, and placental cells	Formulation dilutions of about 0.001% to 2%.	Cytotoxicity	POEA much more toxic than formulations. Glyphosate and AMPA much less toxic.	Benachour and Seralini 2009
Glyphosate, NOS	Mouse cell line	0.1 to 1000 µM	Cell growth	IC_{50} 34 µM (≈5.7 mg/L)	Bertheussen et al. 1997
Roundup, 360 g/L, 41% glyphosate (NOS)	Neo-tropical fish, Prochilodus lineatus	10 mg/L for up to 96 hours	Micronucleus and Comet assays	Chromosomal damage	Cavalcante et al. 2008
Roundup, 480 g/L, 36 a.e.% glyphosate (NOS)	Goldfish, Carassius auratus	5, 10, and 15 mg/L	Micronucleus and Comet assays	Chromosomal damage	Cavas and Konen 2007
Roundup	Tadpole (Rana catesbeiana)	1.69, 6.75, or 27 mg/L	Alkaline SCG assay.	No significant increase ($p>0.05$) in DNA damage, compared with control at 1.69 mg/L; significant increases in DNA damage at 6.75 mg/L ($p<0.05$) and 27 mg/L ($p<0.001$), compared with controls	Clements et al. 1997
Glyphosate	Vicia faba	35, 70, 105, 140, 350, 700, 1050, 1400 µg/g soil	frequency of micronucleated cells	no genotoxicity	De Marco et al. 1992
Glyphosate and four glyphosate formulations used in Belgium	Liver HepG2 cell cultures	Concentrations of up to 3%	Comet assay and cell viability	Formulation much more toxic than glyphosate. Effects at culture concentrations are low as 05 ppm for formulations	Gasnier et al. 2009

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 8: *In vitro* studies on cellular/genetic toxicity

Formulation	Organism/ Cell/Test System	Exposure Level	Assay/Nature of Exposure	Effects	Reference
Roundup (480g/l) and surfactant	Mice	Roundup: 50.0, 100.0, or 200.0 mg/kg	Intra-abdominal injection with erythrocyte micronuclei (MN) assay	No increase in polychromatic micronuclei.	Grisolia 2002 [1]
Roundup (480g/l) and surfactant	*Tilapia rendalli*	Roundup: 42, 85 and 170 mg/kg	Intra-abdominal injection with erythrocyte micronuclei (MN) assay	Significant increase in erythrocyte micronuclei (MN) at all doses.	Grisolia 2002 [1]
Pondmaster	*Drosophila melanogaster* larvae	0.1 ppm in food from larvae through pupation (up to 4 days)	sex-linked recessive lethal (SLRL) assay	0.24% of vials with spermatocytes broods with lethal mutations ($p<0.001$)	Kale et al. 1995 See Section 3.1.10.1. for a more detailed discussion
Roundup	*Drosophila melanogaster* larvae	1 ppm in food from larvae through pupation (up to 4 days)	sex-linked recessive lethal (SLRL) assay	0.26% of vials with spermatocytes broods with lethal mutations ($p<0.001$)	Kale et al. 1995 See Section 3.1.10.1. for a more detailed discussion
Glyphosate, 96% purity	*Drosophila melanogaster* larvae	Eggs through pupation at 0.1 mM to 10 mM – i.e., 16.9 to 1,690 mg/L	somatic mutation and recombination test	Concentration related increase in the incidence of small single wing spot mutations. Other mutations inconclusive or negative.	Kaya et al. 2000 See Section 3.1.10.1. for a more detailed discussion
Glyphosate, analytical grade, >98% pure	Bovine	17-70 µM	lymphocyte cultures	statistically significant increase of structural aberrations, sister chromatid exchanges, and G6PD activity	Lioi et al. 1998a
Glyphosate, analytical grade, >98% pure	human	5.0, 8.5, 17.0, or 51.0 µM	lymphocyte cultures	dose-related increase in the percent of aberrant cells and an increase of number of SCE/cell.	Lioi et al. 1998b
Glyphosate, analytical grade	Human Hep-2 cells	3, 4.5, 6, and 7.5 mM	Comet assay	Significant increase in tail moment	Manas et al. 2009a

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 8: *In vitro* studies on cellular/genetic toxicity

Formulation	Organism/ Cell/Test System	Exposure Level	Assay/Nature of Exposure	Effects	Reference
Glyphosate, analytical grade	Human lymphocytes	3, 4.5, 6, and 7.5 mM	Chromosomal aberrations	No effect	Manas et al. 2009a
Glyphosate, analytical grade	Mice	0, 50, 100, and 200 mg/kg bw by i.p. injection, 2 doses one day apart.	Micronucleus assay	Statistically significant increase in high dose group.	Manas et al. 2009a
Several glyphosate formulations	Sea urchin embryos	0.1 to 10 mM are reported. Not clear how these molar concentrations were derived	Embryo cell cycle progression	Interference with normal development – i.e., embryo toxicity. Authors extrapolate to inhalation exposures in humans	Marc et al. 2004b
Glyphosate and Roundup formulation	Sea urchin embryos	8 mM glyphosate and 0.2% Roundup	*In vitro* fertilized eggs.	Delay in hatching. Authors extrapolate to inhalation exposures in humans	Marc et al. 2005
Technical grade, 98%	Human lymphocytes	3.5 to 580 mg/L	Comet assay	No dose-dependent effects.	Mladinic et al. 2009a
Technical grade, 98%	Human lymphocytes	0.5 to 580 mg/L	Cytome/ fluorescence in situ hybridization assay	Effects on DNA only at high concentrations.	Mladinic et al. 2009b
Roundup	Erythrocytes of *Caiman latirostris* (alligator)	50 to 1750 µg/egg	Comet assay and micronucleus test	Damage at 500 µg/egg or higher	Poletta et al. 2009
Glyphosate	PZ-HPV-7, human prostate epithelial cell line	1 µM (≈0.169 mg/L)	expression of urokinase and its receptor, uPAR	No effect	Potti and Sehgal 2005
Roundup Ultra Max	PZ-HPV-7, human prostate epithelial cell line	1 µM (≈0.169 mg a.e./L)	expression of urokinase (uPA) and its receptor, uPAR	uPA induction by a factor of about 2.	Potti and Sehgal 2005

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 8: *In vitro* studies on cellular/genetic toxicity

Formulation	Organism/ Cell/Test System	Exposure Level	Assay/Nature of Exposure	Effects	Reference
Roundup, 41% IPA	Mice bone marrow cells	*In vivo* i.p. doses of 25 and 50 mg a.e./kg bw	chromosomal aberrations (CAs) and micronuclei (MN)	Glyphosate treatment significantly increases CAs and MN after i.p. doses of 25 and 50 mg/kg bw	Prasad et al. 2009
Glyphosate	*Allium cepa* (onion bulbs)	1440, 2880 µg/L	Allium anaphase-telophase assay	no effect	Rank et al. 1993
Roundup	*Allium cepa* (onion bulbs)	1440, 2880 µg/L	Allium anaphase-telophase assay	statistically significant increase in chromosome aberrations	Rank et al. 1993
Roundup	*Salmonella typhimurium*	360, 720, 1081, 1440 µg/plate	plate incorporation assay in the absence or presence of Aroclor induced S9 mix	slight but significant number of revertants at 360 µg/plate for TA98 (without S9) and at 720 µg/plate for TA100 (with S9)	Rank et al. 1993
Roundup	Mouse	133, 200 mg/kg bw	mice bone marrow micronucleus assay	no chromosome breaks	Rank et al. 1993
62% glyphosate formulation NOS (Belgium)	Bovine lymphocytes	0, 28, 56, 140, 280, 560 and 1120 µM.	chromosomal aberrations (CAs) sister chromatid exchanges (SCE)	SCE induction at 56 to 1122 µM.	Sivikova and Dianovsky 2006
Roundup	human	0.25, 2.5, 25 mg/mL	SCE in human lymphocytes in vitro	statistically significant increase ($p<0.001$) in SCE at 0.25 and 2.5 mg/mL; no lymphocyte growth at highest dose	Vigfusson and Vyse 1980

A2 Table 9: Field Studies

Exposure	Response	Reference
Glyphosate (NOS), 0.75 lbs/acre, aerial application. Less than 7 year post cutting clear cut. Comparable are used as control.	No marked changes in diversity and evenness of small-mammal communities over two year post-application observation period. Transient increase in *Microtus oregoni* associated with increase in grasses.	Anthony and Morrison 1985
Roundup, 2.25 kg/ha (2 lb/acre) applied aerially to field to suppress angiosperms competing with conifer regeneration.	Herbicide treatment had no effect on captures of most small mammal species over a one year observation period [Masked shrew, deer mouse, pygmy shrew, short-tailed shrew, southern bog lemming, or meadow jumping mouse]. Southern Red-backed voles were more numerous in control than in treated sites. This effect was attributed to defoliation of overhead cover.	D'Anieri et al. 1987
Glyphosate (NOS), 1 kg/ha (0.89 lb/acre) in clearcut area.	Substantial decrease utilization by mountain hare one year after spraying. A lesser decrease, not statistically significant, after 2 years.	Hjeljord et al. 1988
Roundup, 4 L/ha (1.4 kg/ha or 1.25 lb/acre), pre-harvest treatment of pasture.	No significant effects on the consumption of treated hay by sheep.	Jones and Forbes 1984
Roundup, 2.52 kg/ha (2.25 lb/acre) on pasture	Cattle preferred grazing on treated pasture over first 5-7 days post-treatment. There was an aversion to the treated area 15-21 days post treatment. Reasons for the preference and aversion were not apparent.	Kisseberth et al. 1986
Townsend chipmunk (n=8) dosed with gyphosate at 50 mg/kg (glyphosate IPA) and fitted with radio-transmitter. Movement and survival compared to control animals (n=10)	No effect on range of movement within release area. Mortality in treated animals less than controls although the difference is not statistically significant.	McComb et al. 2008
Glyphosate (NOS), 3.3 kg/ha (2.9 lb/acre).	Levels in wildlife monitored over a 55 day period. No residues exceeded 2 mg/kg in viscera and 0.5 mg/kg in whole body [shrews, deer mice, wood rats, squirrel, voles, and chipmunks]. Body residues were consistently less than residues on vegetation.	Newton et al. 1984

A2 Table 9: Field Studies		
Exposure	**Response**	**Reference**
Glyphosate (NOS), 1.2 kg/ha (1.1 lb/acre) aerial or 1.1 kg/ha (1 lb/acre) manual, 54 ha clearcut and surrounding old growth forest.	**No effect on body size and apparent reproductive capacity** [assayed as number of placental scars and foeti] of deer mice. Deer mice were more abundant in untreated clearcut probably due to changes in food abundance and quality secondary to changes in vegetation.	Ritchie et al. 1987
Roundup, aerial application at 4.7 L a.i./42.1 L water/ha. [1.7 kg/ha or 1.5 lb/acre] on 4-5 year old clearcuts in North Maine.	Decrease in available browse plants on 2-year post-treatment clearcuts. Moose used treated areas less than untreated areas.	Santillo 1994
Roundup, aerial application at 4.7 L a.i./42.1 L water/ha. [≈1.7 kg/ha or 1.5 lb/acre] on 4-5 year old clearcuts in North Maine.	Fewer small herbivorous mammals at 1-3 years post-treatment. No effect on carnivorous mammals. Effects attributable to changes in cover, food resources, and microclimate.	Santillo et al. 1989a,b
Roundup, aerial application to 2-year clearcut at 3.0 kg/ha (2.7 lb/acre).	Little difference in recruitment of voles between control and treated areas. Decline in deer mice during first post-spray summer and winter only. Population of deer mice increased in subsequent years. Significantly ($p<0.05$) better survival of female voles on treated sites.	Sullivan 1990
Roundup aerially applied at a rate of 2.2 to 3.0 kg/ha of active ingredient (2 to 2.7 lb a.i./acre or 1.5 to 2 lb a.e./acre).	No adverse affect on reproduction, survival. or growth of deer mice and Oregon voles in a coastal forest one decade after application. Little change noted in species richness or diversity of small mammal communities.	Sullivan et al. 1997
Vision, aerial application of 2.14 kg a.i./ha (1.4 lb a.e./acre) during August 17-28, 1987; one treated site was retreated in 1988 due to poor application. Study area included 8 sites in the sub-boreal spruce forest in British Columbia.	No adverse effect on herbaceous species diversity or on small mammal communities.	Sullivan et al. 1998a

Appendix 2: Toxicity to Mammals *(continued)*

A2 Table 9: Field Studies

Exposure	Response	Reference
Roundup, 1.5 kg/ha a.i. (1 lb a.e./acre) to total orchard floor on two contiguous treatment blocks in British Columbia in July and September 1983, May, July, and September 1984 and 1985.	Vole populations consistently reduced in response to treatment, with average abundance ranging from 2.8 to 28.0 times higher on control plots, compared with treated plots. Voles declined to or near extirpation in all orchards during the winter of 1985-1986. No differences in the abundance of deer mice or northwestern chipmunks after treatment. The average abundance of deer mice ranged from 1.3 to 11.1 times higher and that of chipmunks ranged from 1.8 to 13.3 time higher on treated blocks, compared with control blocks. The large numbers of deer mice and chipmunks on treated blocks were composed mainly of resident animals.	Sullivan et al. 1998b
Roundup, applied aerially at 1.65 kg a.e./ha (1.5 lb a.e./acre) to six clearcuts harvested between 1983 and 1985. Deciduous tree cover dominated the clearcuts and was approximately 1-2 m high.	No direct observations of deer populations. Inferences based on changed in vegetation. Glyphosate application initially decreased the abundance of leaves of deciduous trees and shrubs used as food in summer by white-tailed deer. Over a longer period of time, forb abundance increased.	Vreeland et al. 1998

Appendix 3: Toxicity to Birds

A3 Table 1: Acute Oral/Gavage Toxicity to Birds

Species	Exposure	Response	Reference[1]
Bobwhite quail *(Colinus virginianus)*	Glyphosate acid	LD_{50}: >1912 mg a.e./kg bw NOAEL: 1912 mg a.e./kg bw	MRID 44320626
Bobwhite quail *(Colinus virginianus)*	Glyphosate monoammonium salt, 68.5% a.i. (MON 14420 formulation)	LD_{50}: 1131 (925-1541) mg a.e./kg bw or 1651mg formulation/kg bw NOAEL: 333 mg a.e./kg bw	MRID 45777402
Bobwhite quail *(Colinus virginianus)*	Glyphosate, NOS	LD_{50}: >3196.3 mg a.e./kg bw	MRID 108204 [2]
Bobwhite quail *(Colinus virginianus)*	Glyphosate, NOS, 83% a.i.	LD_{50}: >2000 mg a.i./kg bw	U.S. EPA/OPP 1993c, Study ID MCOGLY04

[1] Studies with only MRID designations are taken from Table 4.28 of U.S. EPA/OPP 2008a and/or from Table J-21, Appendix J of U.S. EPA/OPP 2008a.

[2] Full citation not provided in U.S. EPA/OPP 2008a or in Attachment I (list of MRID studies from U.S. EPA) of the current Forest Service risk assessment.

A3 Table 2: Acute Dietary Toxicity to Birds

Species	Exposure	Response	Reference[1]
Bobwhite quail (*Colinus virginianus*)	Glyphosate acid, 95.6%	LC_{50}: >4971.2 ppm a.e. NOAEC: 4971.2 ppm a.e.	MRID 44320628
Mallard duck (*Anas platyrhynchos*)	Glyphosate acid, 95.6%	LC_{50}: >4971.2 ppm a.e. NOAEC: 4971.2 ppm a.e.	MRID 44320627[2]
Bobwhite quail (*Colinus virginianus*)	Glyphosate isopropylamine salt, 31.32% a.i. (**MON65005**). This appears to be Roundup PRO.	LC_{50}: > 1760 ppm a.e. NOAEC: 1760 ppm a.e.	MRID 44465702
Mallard duck (*Anas platyrhynchos*)	Glyphosate isopropylamine salt, 31.32% a.i. (**MON65005**) . This appears to be Roundup PRO.	LC_{50}: > 1760 ppm a.e. NOAEC: 1760 ppm a.e.	MRID 44465701
Mallard duck (*Anas platyrhynchos*)	Glyphosate, NOS, 98.5%	LC_{50}: >4570.4 ppm a.e. NOAEC: 4570.4 ppm a.e.	MRIDs 108107 & 37765/1973 [2]
Bobwhite quail (*Colinus virginianus*)	Glyphosate, NOS, 98.5%	LC_{50}: >4570 ppm a.e. NOAEC: 4570 ppm a.e.	MRID 76492 /1973

[1] Studies with only MRID designations are taken from Table 4.28 of U.S. EPA/OPP 2008a.

[2] Full citation not provided in U.S. EPA/OPP 2008a or in Attachment I (list of MRID studies from U.S. EPA) of the current Forest Service risk assessment.

A3 Table 3: Reproductive and Subchronic Toxicity to Birds			
Species	**Exposure**	**Response**	**Reference**[1]
Reproduction			
Bobwhite quail (*Colinus virginianus*)	Glyphosate, 83%	NOAEC: 830 ppm LOAEL: not determined	MRID 108207
Mallard duck (*Anas platyrhynchos*)	Glyphosate, 94.4%	NOAEC: 27 ppm LOAEC: not determined	MRID 36328 and 113457
Mallard duck (*Anas platyrhynchos*)	Glyphosate, 83%	NOAEC: 830 ppm LOAEL: not determined	MRID 111953
Other subchronic			
Mallard duck, (*Anas platyrhynchos*) males (6/dose)	Roundup: (360 g/L a.e., 480 g/L IPA salt. 0, 5 and 100 mg/kg bw for 15 days. Doses in paper are in units of formulation. The a.e. equivalent doses are 0, 1.8, and 36 mg a.e./kg bw.	A 13% decrease in relative testes weight. Not statistically significant. Significant ($p<0.05$) decrease in plasma testosterone relative to controls at both doses. About 90% less than controls. See Fig 1 in paper. Slight but significant histologic changes in testes and epididymis. Changes in androgen receptor expression in testes. U.S. EPA/OPP 2008a, p. 111: *Further studies would be needed to determine whether or not these observed effects would affect avian reproduction.*	Oliveira et. al. 2007
Zebra finches	Roundup at 2500 (n=6) and 5000 ppm (n=5) in diet. Not clear if this is formulation or a.i. or a.e.	2500 ppm: No mortality, loss of body weight, or decrease in food consumption. 5000 ppm: 4/5 died within 3 days with a 28% loss of body weight. The fifth bird died on day 7 with a 63% loss of body weight. Food consumption data not reported but authors suggest that the birds may have died from starvation.	Evans and Batty 1986

A3 Table 3: Reproductive and Subchronic Toxicity to Birds

Species	Exposure	Response	Reference[1]
Broiler chickens, controls weighed about 235 g over the course of the 21 day study in the 608 ppm a.i. group. Based on U.S. EPA/ORD 1993 (Eq. 3-3), food consumption rate of about 22.3 g or 9.5% of body weight.	Roundup (IPA salt, NOS) Dietary concentrations of 0, 60.8, 608, or 6080 ppm a.i. for 21 days. Concentrations correspond to 0, 45, 450, 4500 ppm a.e.	Reduced body weight at highest concentration – i.e., about 45% of controls by the end of the study. Elevated levels of calcium and magnesium in tibiotarsus bones by Day 21. Authors suggest that very high concentrations of glyphosate could act as a chelating agent. NOAEL 608 ppm a.i. or 450 ppm a.e. Based consumption factor of 0.095, this would correspond to a dose of about 43 mg a.e./kg bw.	Kubena et al. 1981

[1]Studies with only MRID designations are taken from Table 4.30 of U.S. EPA/OPP 2008a.

A3 Table 4: Acute Toxicity of AMPA Degradate

Species	Exposure	Response	Reference[1]
Bobwhite quail *(Colinus virginianus)*	Gavage, AMPA 87.8%	LD_{50}: >1976 mg/kg bw NOAEL: 1185 mg/kg bw	MRID 43334709
Bobwhite quail *(Colinus virginianus)*	Acute Dietary, AMPA, 87.8%	LC_{50}: >4934 ppm NOAEC: 4934 ppm	MRID 43334710
Mallard duck (*Anas platyrhynchos*)	Acute Dietary, AMPA, 87.8%	LC_{50}: >4934 ppm NOAEC: 4934 ppm	MRID 43334711

[1]Studies with only MRID designations are taken from Table 4.29 of U.S. EPA/OPP 2008a.

A3 Table 5: Field Studies

Application	Observations	Reference
Roundup, 1.4 kg a.i./ha [1.25 lb a.i./acre or 0.95 lb a.e./acre] by hand held controlled drop band applicators in a six year old spruce plantation (North Wales)	An initial decrease in Calluna and increased amount of bare ground. After 2 years, no difference in the abundance of *Vaccinium* and *Empetrum* species. Black grouse evidenced a preference for treated areas, probably because of increased accessibility or fruiting quality.	Cayford 1988
Comparison of glyphosate (NOS) hand spray with mechanical vegetation management in a confer forest area of British Columbia. Application rates not specified.	Increases in total bird populations in both areas. Nesting success in open cup nesting species significantly lower in herbicide treated areas (8%) relative to manually treated areas (46%). Less diverse bird populations in herbicide vs mechanically treated areas. At least some differences attributed to differences in vegetation.	Easton and Martin 1998
Rodeo, 5.8 kg a.i./ha [5.2 lb a.i./acre of 3.8 lb a.e./acre], aerially applied to a designated pool of 24 cattail-dominated wetlands in N. Dakota at 50, 70, or 90% coverages in 1990 and 1991to assess the influence of habitat changes on birds.	Positive correlation between the Black Terns and selected duck species and open water and dead cattails; positive correlation between blackbird numbers and live cattails; positive correlation between the numbers of Black Terns and the numbers of Mallards, Blue-winged Teals, Redheads, and Yellow-headed Blackbird, which suggests some common habitat requirements among these species. Investigators conclude that cattail management programs designed to specifically enhance duck use and decrease Red-winged Blackbird numbers may be benefit Black Terns.	Linz and Blixt 1997
Rodeo, 5.8 kg a.i./ha [5.2 lb a.i./acre of 3.8 lb a.e./acre] with a surfactant and drift retardant over a wetland areas.	An increase or no significant change in the usage of treated wetlands by black terns over a two year observation period. The increased usage was associated with an increase in open water and newly formed mats of dead emergent vegetation.	Linz et al. 1994
Rodeo, 5.8 kg a.i./ha [5.2 lb a.i./acre of 3.8 lb a.e./acre] with a surfactant and drift retardant over a wetland areas.	Increase in duck populations associated with increase in open water habitat.	Linz et al. 1996a
Rodeo, 5.8 kg a.i./ha [5.2 lb a.i./acre of 3.8 lb a.e./acre], aerially applied to a designated pool of 23 cattail-dominated wetlands in N. Dakota at 50, 70, or 90% coverages in 1990 and 1991 to assess the effects of herbicide treatments on the densities of territorial male Red-wing Blackbirds, Yellow-headed Blackbirds, and Marsh Wrens.	Two years after treatment, the densities of all three species of birds were greater in the control plots than in the treated plots. There was a positive correlation between the percent coverage of live emergent vegetation (mostly cattails) and the numbers of blackbirds and wrens. The results suggest that the numbers of the wetland dwelling birds were limited by the alteration of the cattail density, due to herbicide treatment. The investigators recommend staggering vegetation management treatments on large wetland complexes in order to help diversify the stages of cattail regeneration.	Linz et al. 1996b

A3 Table 5: Field Studies

Application	Observations	Reference
Rodeo, aerially applied to a designated pool of 17 cattail-dominated wetlands in N. Dakota at 50, 70, or 90% coverages in 1990 and 1991 to assess the effects of herbicide treatments on the densities of American Coots and Soras (waterfowl). Application rate: 5.8 L/ha, 0.48 kg a.e./L x 5.8 L/ha ≈ 2.8 kg/ha ≈ 2.5 lb a.e./acre	American Coot densities were lower in the control wetlands than in the glyphosate treated wetlands 1 year ($p=0.04$) and 2 years ($p=0.09$) after treatment. There was a positive correlation between the numbers of American Coots and the coverages of water and dead vegetation; however, there was a negative correlation between the numbers of American Coots and live vegetation ($p<0.1$). One year after treatment, Soras were more numerous in the control wetlands ($p=0.08$) than in the treated wetlands, but by 2 years after treatment, the numbers of Soras were similar among treatments. There was a positive correlation between the numbers of Soras and the coverage of live vegetation.	Linz et al. 1997
Glyphosate (NOS), 2.3 kg/ha aerial over clearcut (2 lb a.e./acre).	Heavy defoliation of ferns, birch, raspberry, maple, and other taxa. No difference in abundance of breeding birds in first-post spray season. A decrease in abundance of breeding birds was noted in the second post-spray season. Changes in bird density were associated with changes in vegetation.	MacKinnon and Freedman 1993
Rodeo, 2.8 L/ha [0.48 kg a.e./L x 2.8 L/ha ≈ 1.3 kg a.e./ha ≈ 1.2 lb a.e./acre] in wetlands to control cattails.	Effective control of cattails. Breeding ducks and over-water duck nest densities greater on treated areas because of increase wetland openings.	Solberg and Higgins 1993

Appendix 4: Toxicity to Terrestrial Invertebrates

A4 Table 1: Glyphosate Acid or Salts – Acute Toxicity

Salt/Acid	Species	Exposure	Response	Reference [1]
Acid	Honey bee (*Apis mellifera*)	Oral, 98.5% a.i.	48 hr LD_{50}: >100 µg/bee	MRID 26489
Acid	Honey bee (*Apis mellifera*)	Contact, 98.5% a.i.	48 hr LD_{50}: >100 µg/bee	MRID 26489
Glyphosate, NOS	Brown garden snail, *Helix aspersa*	Oral, 4,994 mg/kg in diet	No mortality. Other endpoints not assessed.	Schuytema et al. 1994
Glyphosate, NOS	Western bigeyed bug, *Geocoris pallens*	Leaves at rates equivalent to 6.7 kg/ha (6 lb/ac)	LD_{50}: 0.28 kg/ha (0.24 lb/ac) Duration of exposure not clear. Nature of exposure appears to be a combination of contact and oral.	Yokoyama et al. 1984

[1] Studies designated only with an MRID number are taken from Table 4.32 of U.S. EPA/OPP 2008a.

A4 Table 2: Glyphosate Formulations – Acute Toxicity

Formulation, % a.i.	Species	Exposure	Response	Reference [1]
MON78568, monoammonium salt, 65.6%, a.e.	Honey bee (*Apis mellifera*)	Oral	48 hr LD_{50}: >100 µg/bee NOAEL: 100 µg/bee	MRID 45767104
MON78568, monoammonium salt, 64.9%	Predatory mite (Typhlodromus pyri)	Contact	7-day LD_{50}: 1200 (839-1786) g a.e./ha NOAEL: < 76.23 µg/bee g a.e./ha	MRID 45767105
MON78568, monoammonium salt, 65.6%, a.e.	Honey bee (*Apis mellifera*)	Contact	48 hr LD_{50}: >76.23 µg/bee NOAEL: < 76.23 µg/bee	MRID 45767104
MON 78568, monoammonium salt, 64.9% w/w a.e.	Predatory mite (*Typhlodromus pyri*)	Contact, 14 - 21 days	NOAEL: 216 or <119 (no dose-response) (<0.11 lb/A)	MRID 45767106
MON 78568, monoammonium salt, 64.9% w/w a.e.	Earthworm (*Eisenia fetida*)	Contact	NOAEL: 6560 ppm	MRID 45767109 [2]
MON78568 monoammonium salt, 64.9% w/w a.e.	Parasitic wasp (*Aphidius rhopalosiphi*)	Contact	48 hr - 13 days LD_{50}: >108 (N.R.) g a.e./ha (>0.096 lb/A)	MRID 45767107
MON78568 monoammonium salt, 64.9% w/w a.e.	Parasitic wasp (*Aphidius rhopalosiphi*)	Contact	48 hr - 13 days LD50 (C): >4320 (N.R.) g/ha (>3.86 lb/A) NOAEL: 4320 g/ha	MRID 45767107

Appendix 4: Toxicity to Terrestrial Invertebrates *(continued)*

A4 Table 2: Glyphosate Formulations – Acute Toxicity

Formulation, % a.i.	Species	Exposure	Response	Reference [1]
MON78568 monoammonium salt, 64.9% w/w a.e.	Parasitic wasp (*Aphidius rhopalosiphi*)	Contact	48 hr - 13 days LD_{50}: >4320 (N.R.) g a.e./ha (>3.86 lb/A) NOAEL: 4320 g/ha	MRID 45767108
MON78568 monoammonium salt, 64.9% w/w a.e.	Lacewing (*Chrysoperla carnia*)	Contact	Up to 10 days LD_{50}: >4320 (N.R.) g/ha (>3.86 lb/A) NOAEC: 4320 g/ha	MRID 45767110
(MON 2139, IPA salt, 36% a.i.	Honey bee (*Apis mellifera*)	Oral	48 hr LD_{50}: >100 µg/bee	MRID 26489
(MON 2139, IPA salt, 36% a.i.	Honey bee (*Apis mellifera*)	Contact	48 hr LD_{50}: >100 µg/bee	MRID 26489
MON65005, IPA, 31.32% a.i.	Honey bee (*Apis mellifera*)	Contact	48 hr LD_{50}: >31.3 (N.A.) µg a.e./bee NOAEL: 319 µg a.e./bee `The entry above may have a typo.`	MRID 44465703
MON 77360, IPA, 30%	Honey bee (*Apis mellifera*)	Contact	NOAEL: 30 µg a.e./bee	Palmer and Krueger 2001a MRID 45370301
MON 77360, IPA, 30%	Honey bee (*Apis mellifera*)	Oral	48 hr LD_{50}: >30 µg a.e./bee NOAEL: 15 µg a.e./bee	Palmer and Krueger 2001b MRID 45370301

[1] Studies designated only with an MRID number are taken from Table 4.35 of U.S. EPA/OPP 2008a.
[2] MRID is not referenced in Appendix L of U.S. EPA/OPP 2008a or in Attachment 1 of the current Forest Service risk assessment

A4 Table 3: Field or Field Simulation Studies

Application	Observations	Reference
Roundup, 1 ml applied in drilled holes around root collar of treated pine trees. Untreated trees served as controls.	Increased attack success as well as egg and larval development of mountain pine beetle (MPB). Corresponding increases observed in MPB predators and parasites.	Bergvinson and Borden 1991
Roundup, applied in drilled holes around root collar at doses ranging from about 0.006 to 0.6 g/tree.	Increased predation by woodpeckers on mountain pine beetles (MPB) over a 1 year observation period.	Bergvinson and Borden 1992
Accord (with Li 700 surfactant) used with 2,4-D and triclopyr in R.O.W. maintenance over a 2 year period	No adverse effects on butterfly populations when compared to mechanical R.O.W. maintenance.	Bramble 1997
Glyphosate (NOA) at 1.57 kg/ha (1.4 lb/ac)	No evidence of direct toxic effects. Decrease in large carabid populations lasting for about 28 days. This could be associated with decrease in canopy cover.	Brust 1990
Glyphosate (NOS), 3.4 kg a.i/ha.	Effects on soil invertebrates were secondary to effects on alfalfa density.	Byers and Bierlein 1984
Glyphosate added to small pots to simulate agricultural use. Cannot calculate soil concentrations.	No adverse effects (survival and growth) on four species of earthworm.	Dalby et al. 1995

Appendix 4: Toxicity to Terrestrial Invertebrates *(continued)*

A4 Table 3: Field or Field Simulation Studies

Application	Observations	Reference
Roundup, 6 L/ha (about 2.1 kg/ha)	Assays for the degradation of leaf litter by isopods. There was an increased decomposition of birch and a decreased decomposition of black cherry. Possible signs of toxicity in isopods but not statistically significant.	Eijsackers 1992
Glyphosate (NOS) applied to litter.	Concentrations of 5,000 to 10,000 ppm in litter caused a significant decrease in litter decomposition.	Fletcher and Freedman 1986
Glyphosate (Roundup Biactive) formulation (Australia) applied at rates of 10.8 to 14.4 kg/ha (≈9.6 to 12.8 lb/acre.	No significant impact on abundance or community composition of invertebrates after 4 months.	Lindsay and French 2004
Glyphosate (NOS) at 0.9 L a.i/ha. Cannot determine application rate.	No apparent adverse effects on populations of Collembola.	Lins et al. 2007
Roundup, aerial application at 4.7 L a.i./42.1 L water/ha. [1.7 kg/ha] on 4-5 year old clearcuts in North Maine.	Total shrub, forbs, and grass cover was diminished 1-3 years post treatment. Decrease in species richness of shrubs and forbs on treated clearcuts. Decrease in numbers of invertebrates. Effects attributable to changes in cover, food resources, and microclimate.	Santillo et al. 1989a,b
Glyphosate (NOS), 0.7, 1.4, and 2.8 g/ha, sprayed twice weekly on to culture dishes.	Earthworms evidenced decreased growth over 100 day exposure period with an uneven dose-effect relationship. Mortality observed in some worms after about 80 days.	Springett and Gray 1992
Glycel 41% S.L. (glyphosate 41%). Appears to an Indian formulation. Salt not specified, soil concentrations of 2 mg/kg at "1x". Concentrations appear to be in a.i. but this is not clear.	*Eisenia fetida*: Soil concentrations of 2 ppm and 8 ppm results in a general concentration related decrease in reproduction over a 28 day period but the decreases were not statistically significant.	Yasmin and D'Souza 2007
Glyphosate (NOS), 1.1 and 6.7 kg/ha, on cotton leaves	Bioassay using Western bigeyed bug, *Geocoris pallens*. Females exposed to glyphosate laid slightly more viable eggs than matched controls. A slight dose/response related improvement in survival is also apparent over a 192 day observation period.	Yokoyama and Pritchard 1984

Appendix 5: Toxicity to Terrestrial Plants

A5 Table 1: Glyphosate – Vegetative Vigor

Form	Species	Exposure	Response	Reference [1]
Monocots				
Glyphosate IPA, 96.6% a.i.	Oat (*Avena sativa*)	Foliar spray, 21 day observation	EC_{25}: 0.4 lb a.e./acre NOAEC/EC_{05}: 0.14 lb a.e./acre Slope: 2.3	Chetram and Lucash 1994 MRID 43088701
Glyphosate IPA, 96.6% a.i.	Corn (*Zea mays*)	Foliar spray, 21 day observation	EC_{25}: 0.43 lb a.e./acre NOAEC/EC_{05}: 0.07 lb a.e./acre Slope: 3.7	
Glyphosate IPA, 96.6% a.i.	Onion (*Allium cepa*)	Foliar spray, 21 day observation	EC_{25}: 0.83 lb a.e./acre NOAEC/EC_{05}: 0.56 lb a.e./acre Slope: 2.4	
Glyphosate IPA, 96.6% a.i.	Ryegrass (*Lolium perenne*)	Foliar spray, 21 day observation	EC_{25}: 0.98 lb a.e./acre NOAEC/EC_{05}: 0.56 lb a.e./acre Slope: 4.9	
Dicots				
Glyphosate IPA, 96.6% a.i.	Tomato (*Lycopersicon esculentum*)	Foliar spray, 21 day observation	EC_{25}: 0.11 lb a.e./acre NOAEC/EC_{05}: 0.035 lb a.e./acre Slope: 3.4	Chetram and Lucash 1994 MRID 43088701
Glyphosate IPA, 96.6% a.i.	Cucumber (*Cucumis sativus*)	Foliar spray, 21 day observation	EC_{25}: 0.46 lb a.e./acre NOAEC/EC_{05}: 0.14 lb a.e./acre Slope: 2.6	
Glyphosate IPA, 96.6% a.i.	Lettuce (*Lactuca sativa*)	Foliar spray, 21 day observation	EC_{25}: 0.4 lb a.e./acre NOAEC/EC_{05}: 0.14 lb a.e./acre Slope: N/A	
Glyphosate IPA, 96.6% a.i.	Cabbage (*Brassica oleracea*)	Foliar spray, 21 day observation	EC_{25}: 0.3 lb a.e./acre NOAEC/EC_{05}: 0.28 lb a.e./acre Slope: N/A	
Glyphosate IPA, 96.6% a.i.	Soybean (*Glycine max*)	Foliar spray, 21 day observation	EC_{25}: 0.42 lb a.e./acre NOAEC/EC_{05}: 0.28 lb a.e./acre Slope: N/A	
Glyphosate IPA, 96.6% a.i.	Radish (*Rhaphanus sativus*)	Foliar spray, 21 day observation	EC_{25}: 0.14 lb a.e./acre NOAEC/EC_{05}: 0.035 lb a.e./acre Slope: N/A	

[1] This study was reviewed in the previous Forest Service risk assessment but the above toxicity tabulation is taken from Table 4.36 of U.S. EPA/OPP 2008a.

A5 Table 2: Glyphosate Formulations – Tier 2 Vegetative Vigor				
Formulation	**Species**	**Exposure**	**Response**	**Reference [1]**
Monocots				
80WDG, 75% a.i.	Onion (*Allium cepa*)	Foliar, 27 day obs. period	EC_{25}: 0.28 lb a.e./acre NOAEC/EC_5: 0.14 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 75% a.i.	Sorghum (*Sorghum bicolor*)	Foliar, 27 day obs. period	EC_{25}: 0.16 lb a.e./acre NOAEC/EC_5: 0.07 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 75% a.i.	Wheat (*Triticum aestivum*)	Foliar, 27 day obs. period	EC_{25}: 0.22 lb a.e./acre NOAEC/EC_5: 0.1 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 75% a.i.	Corn (*Zea mays*)	Foliar, 27 day obs. period	EC_{25}: 0.35 lb a.e./acre NOAEC/EC_5: 0.18 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 48.3% a.i.	Corn (*Zea mays*)	Foliar, 4 week obs. period	EC_{25}: 0.227 lb a.e./acre NOAEC/EC_5: 0.148 lb a.e./acre	Everett et al. 1996b; MRID 44320636
80WDG, 48.3% a.i.	Purple nutsedge (*Cyperus rotundus*)	Foliar, 4 week obs. period	EC_{25}: 0.805 lb a.e./acre NOAEC/EC_5: 0.445 lb a.e./acre	
80WDG, 48.3% a.i.	Wheat (*Triticum aestivum*)	Foliar, 4 week obs. period	EC_{25}: 0.176 lb a.e./acre NOAEC/EC_5: 0.049 lb a.e./acre	
80WDG, 48.3% a.i.	Oat (*Avena sativa*)	Foliar, 4 week obs. period	EC_{25}: 0.201 lb a.e./acre NOAEC/EC_5: 0.148 lb a.e./acre	
Dicots				
80WDG, 75% a.i.	Garden pea (*Pisum sativum*)	Foliar, 27 day obs. period	EC_{25}: 0.89 lb a.e./acre NOAEC/EC_5: 0.45 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 75% a.i.	Sugar beet (*Beta vulgaris*)	Foliar, 27 day obs. period	EC_{25}: 0.21 lb a.e./acre NOAEC/EC_5: 0.12 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 75% a.i.	Sunflower (*Helianthus annus*)	Foliar, 27 day obs. period	EC_{25}: 0.16 lb a.e./acre NOAEC/EC_5: 0.08 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 75% a.i.	Radish (*Rhaphanus sativus*)	Foliar, 27 day obs. period	EC_{25}: 0.09 lb a.e./acre NOAEC/EC_5: 0.02 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 75% a.i.	Soybean (*Glycine max*)	Foliar, 27 day obs. period	EC_{25}: 0.32 lb a.e./acre NOAEC/EC_5: 0.12 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 75% a.i.	Cucumber (*Cucumis sativus*)	Foliar, 27 day obs. period	EC_{25}: 0.45 lb a.e./acre NOAEC/EC_5: 0.16 lb a.e./acre	MRIDs 44125715 and 45045101
80WDG, 48.3% a.i.	Sugar beet (*Beta vulgaris*)	Foliar, 4 week obs. period	EC_{25}: 0.277 lb a.e./acre NOAEC/EC_5: 0.148 lb a.e./acre	Everett et al. 1996b; MRID 44320636
80WDG, 48.3% a.i.	Radish (*Rhaphanus sativus*)	Foliar, 4 week obs. period	EC_{25}: 0.235 lb a.e./acre NOAEC/EC_5: 0.148 lb a.e./acre	

A5 Table 2: Glyphosate Formulations – Tier 2 Vegetative Vigor				
Formulation	**Species**	**Exposure**	**Response**	**Reference [1]**
80WDG, 48.3% a.i.	Soybean (*Glycine max*)	Foliar, 4 week obs. period	EC_{25}: 0.126 lb a.e./acre NOAEC/EC_5: 0.049 lb a.e./acre	Everett et al. 1996b; MRID 44320636
80WDG, 48.3% a.i.	Lettuce (*Lactuca sativa*)	Foliar, 4 week obs. period	EC_{25}: 0.217 lb a.e./acre NOAEC/EC_5: 0.148 lb a.e./acre	
80WDG, 48.3% a.i.	Cucumber (*Cucumis sativus*)	Foliar, 4 week obs. period	EC_{25}: 0.074 lb a.e./acre NOAEC/EC_5: 0.049 lb a.e./acre	
80WDG, 48.3% a.i.	Rape (*Brassica compestris*)	Foliar, 4 week obs. period	EC_{25}: 0.098 lb a.e./acre NOAEC/EC_5: 0.049 lb a.e./acre	
80WDG, 48.3% a.i.	Okra (*Hibiscus esculentus*)	Foliar, 4 week obs. period	EC_{25}: 0.172 lb a.e./acre NOAEC/EC_5: 0.049 lb a.e./acre	

[1] Studies designated only with an MRID number are taken from Table 4.37 of U.S. EPA/OPP 2008a. Studies cited with standard author/year reference were also reviewed in the previous Forest Service risk assessment (SERA 2003).

A5 Table 3: Glyphosate Formulations – Tier 1 Seedling Emergence				
Formulation	**Species**	**Exposure**	**Response**	**Reference [1]**
Monocots				
80WDG, 75% a.i.	crop monocots	Soil, 29 day obs. period	EC_{25}: >4.5 lb a.e./acre NOAEC/EC_{05}: 3.6 lb a.e./acre	Willard 1996; MRID 44125712
CP-70139, IPA, 50% a.i.	Oat (*Avena sativa*), Rice (*Oryza sativa*), Sorghum (*Sorghum bicolor*), Barnyard grass (*Echinochloa crusgalli*)	Soil, 14 day obs. period	14 D EC_{25}: >5 lb a.e./acre	Bohn 1987; MRID 40159301
80WDG, 48.3% a.i.	crop monocots	Soil, 4 week obs. period	NOAEC/EC_{05}: 4 lb a.e./acre	Everett et al. 1996a ; MRID 44320635
Dicots				
80WDG, 75% a.i.	crop dicots	Soil, 29 day obs. period	EC_{25}: >4.5 lb a.e./acre NOAEC/EC_{05}: 3.6 lb a.e./acre	Willard 1996; MRID 44125712
CP-70139, IPA, 50% a.i.	Soybean, Sugar beet, Buckwheat, Cocklebur, Crabgrass, *Panicum* grass, Downy brome, Velvetleaf, Smartweed, Morning glory, Lambsquarter, Hemp	Soil, 14 day obs. period	14-day EC_{25}: >5 lb a.e./acre	Bohn 1987; MRID 40159301
80WDG, 48.3% a.i.	crop dicots	Soil, 4 week obs. period	NOAEC/EC_{05}: 4 lb a.e./acre	Everett et al. 1996a ; MRID 44320635

[1] Studies designated only with an MRID number are taken from Table 4.37 of U.S. EPA/OPP 2008a. Studies cited with standard author/year reference were also reviewed in the previous Forest Service risk assessment (SERA 2003).

Appendix 5: Toxicity to Terrestrial Plants *(continued)*

A5 Table 4: Other Toxicity Studies			
Species	**Exposure**	**Response**	**Reference**
Bellis perennis, Daisy	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 14.26 (13.22-16.02) g a.i./ha Most sensitive species in study. Equivalent to 0.0094 lb a.e./acre	Boutin et al. 2004
Centaurea cyanus, Bachelor's button	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 29.18 (23.32 - 37.34) g a.i./ha	Boutin et al. 2004
Inula helenium, Elecampane	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 43.46 (38.42 - 51.36) g a.i./ha Least sensitive species in study. Equivalent to 0.029 lb a.e./acre	Boutin et al. 2004
Rudbeckia hirta, Blackeyed Susan	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 24.70 (15.86-29.98) g a.i./ha	Boutin et al. 2004
Solidago canadensis, goldenrod	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 24.06 (17.44-31.38) g a.i./ha	Boutin et al. 2004
Leonorus cardiaca, motherwort	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 35.82 (27.84 - 48.34) g a.i./ha	Boutin et al. 2004
Mentha spicata, Spearmint	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 17.94 (15.64 -21.12) g a.i./ha	Boutin et al. 2004
Nepeta cataria, Catnip	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 39.74 (32.28 - 48.46) g a.i./ha	Boutin et al. 2004
Prunella vulgaris, common selfheal	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 28.00 (22.10 - 33.34) g a.i./ha	Boutin et al. 2004
Polygonum convolvulus, black bindweed	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 15.76 (14.34 - 17.30) g a.i./ha	Boutin et al. 2004
Rumex crispus, curly dock	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 27.50 (24.92 - 29.92) g a.i./ha	Boutin et al. 2004
Anagallis arvensis, Scarlet pimpernel	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 17.52 (15.06 - 26.40) g a.i./ha	Boutin et al. 2004
Digitalis purpurea, Common Foxglove	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 64.66 (61.04 - 69.22) g a.i./ha	Boutin et al. 2004
Sinapis arvensis, wild mustard	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 19.28 (16.28 - 26.04) g a.i./ha	Boutin et al. 2004
Papaver rhoeas, corn poppy	Roundup Bio (IPA, 360 g a.e./L). foliar 3 week observation period.	EC_{50}: 18.52 (13.12 - 25.12) g a.i./ha	Boutin et al. 2004

A5 Table 5: Field Studies

Application	Observations	Reference
Glyphosate (NOS), 0.75 lbs/acre, aerial application. Less than 7 year post cutting clear cut. Comparable are uses as control.	**Vegetation:** Mortality in only about 5% of shrubs (primarily salmonberry and thimpleberry). Defoliation in about 50% of shrubs one year post-spray with increase in herbaceous (grass) cover.	Anthony and Morrison 1985
Roundup at 2.5 to 5 kg a.e./ha, two sites in British Columbia	Either no significant differences in plant community or an increase in diversity and species richness after 10 to 12 years.	Baoteng et al. 2000
Roundup WeatherMax, drift simulation, 0.84 kg/ha (drift simulation of 12.5% of typical application rate.	Initial decrease in nitrate assimilation and nitrogen fixation with rapid recovery.	Bellaloui et al. 2009
Roundup, 1 ml applied in drilled holes around root collar of treated pine trees. Untreated trees served as controls.	Increased attack success as well as egg and larval development of mountain pine beetle (MPB). Corresponding increases observed in MPB predators and parasites.	Bergvinson and Borden 1991
Glyphosate applied at simulated drift rates (4, 14, 43, or 143 g/ha) via CO2 pressurized backpack sprayer to grapevines (Vitis vinifera)	Leaf area was reduced only by the highest application rate.	Bhatti et al. 1997
Roundup, 1.7 kg a.e./ha, in summer of 1985 using a spray system mounted on a crawler-tractor. Site Description: Central Georgia, herbaceous and woody species. 0.6-0.8 ha. Woody plants removed prior to treatment. Loblolly pine seedlings planted in 1982.	Observations made in 1992-1993. No significant differences in species richness for any plant groups [Arborescents, nonarborescents, legume and non-legume forbs, grasses, and woody vines]. No effect on plant species diversity. The only effect compared to controls was a reduction in nonarborescent species Vaccinium stamineum and all Vaccinium species combined.	Boyd et al. 1995
Herbicidal glyphosate spray formulated as the isopropylamine salt applied at the rate of 1.4 kg a.i./ha by tractor mounted sprayer to silty clay loam soil from 1980 to 1983.	No pesticide residues detected in the soil 17 months after the last experimental treatment; no deleterious effects on crop productivity; and no differences noted in microbial processes in soils sampled in April 1992	Bromilow et al. 1996
Roundup, applications of 3 kg a.i./ha to ponderosa pine plantations over a period of 7 to 13 years.	No substantial effect on soil microorganisms based on basal respiration, metabolic quotient, total bacteria, or mineralizable nitrogen.	Busse et al., 2001
Roundup, 2 lbs/acre by tractor mounted pump and hand-held sprayer in pine release.	Significant increase (38%) in mortality of pine seedlings after 1 year. Increased mortality also apparent after 5 years. There was, however, an increase in the number of free-to-grow survivors after 5 years.	Cain 1991

Appendix 5: Toxicity to Terrestrial Plants *(continued)*

A5 Table 5: Field Studies		
Application	**Observations**	**Reference**
Glyphosate applied at 2.2.kg a.i./ha via spray application to 0.75x40 m strips of crested wheatgrass (height: 20-30 cm) in June 1989 and same application repeated in May 1991(height of wheatgrass 10-15 cm) in Swift Current Saskatchewan.	Glyphosate residues in treated foliage decreased to <50 mg/kg within 2 weeks of application. The major route of dissipation appeared to be washoff by rainfall. AMPA residues were generally about one order of magnitude less than the corresponding glyphosate residues.	Cessna and Waddington 1995
Roundup, 0.54-3.23 kg a.i./ha	At 0.54 kg/ha, a decrease in soil fungi and bacteria after 2 months. No effect after 6 months. At 3.23 kg/ha, no effect on soil fungi and bacteria after 10-14 months.	Chakravarty and Chatarpaul 1990
Drift simulation at 0.863 g/ha (≈0.8 lb/acre) to rice	Reduction in plant height and yield.	Hensley 2009
Rodeo repeated applications via hand sprayer to control smooth cordgrass in July 1997 and July 1998. Application rates on mudflat plots during 1997 ranged from 59.5 to 67.4 L/ha, while rates during 1998 ranged from 31.5 to 34.3 L/ha. Application rates for Spartina plots ranged from 34.1 to 39.3 L/ha in 1997 and from 39.5 to 43.0 L/ha in 1998	Glyphosate concentrations in sediment from mudflat plots decreased 88-96% by day 1 after treatment in 1997 to 1 year after the second Rodeo application. Glyphosate concentrations in Spartina plots increased 231-591% from 1997 to 1999 because Spartina rhizomes did not readily metabolize or exude the compound. Comparison between the results of the study and toxicity values for marine biota suggests that under worst-case conditions, detrimental effects to aquatic biota are highly unlikely to result from repeated application of Rodeo to control Spartina	Kilbride and Paveglio 2001
Glyphosate (NOS), 0.75-1.0 kg/ha.	Reduction of plant coverage by brush species by about 60%. Vegetation recovered after 3 years. No effect on plant species diversity. A substantial increase in the number of Norway spruce over 50 cm in height on treated vs untreated plots.	Lund-Hoie and Gronvold 1987
Glyphosate (NOS), 2.3 kg/ha aerial over clearcut.	Heavy defoliation of ferns, birch, raspberry, maple, and other taxa.	MacKinnon and Freedman 1993
Glyphosate (NOS), 2.2 kg/ha. Tractor-mounted team sprayer.	Bioassay of drift using five species of plants in pots. Plants were placed in greenhouse after spraying. Most species evidenced no effect when placed 4 meters downwind and no plants exposed to glyphosate drift evidenced a decrease in yield at the end of the season.	Marrs et al. 1991
Glyphosate (NOS), 2.6 kg/ha.	Initial glyphosate residues of 17 ppm in loam and 3.8 ppm in silt. No effect on soil nitrification or denitrification.	Mueller et al. 1981

Appendix 5: Toxicity to Terrestrial Plants *(continued)*

A5 Table 5: Field Studies		
Application	**Observations**	**Reference**
Glyphosate (NOS), 0.8-3.0 kg/ha,	Three dose levels assayed at five different application times during the year to 13 species of wood ornamentals. The most sensitive species, damaged at all times and exposure levels, were ajuga, azalea, and variegated liriope. Other species, such as juniper, evidenced only minor and transient damage.	Neal and Skroch 1985
Glyphosate (NOS), 0.1 g/m2 in lysimeters (30 cm x 45 cm). [1 kg/ha]	Death of vegetation in lysimeters associated with increased leaching of nitrates and cations from soil. Reestablishment of vegetation over 28 month observation period retarded leaching.	Ogner 1987a,b
Glyphosate (NOS), 2.2 kg/ha applied to 20 randomly selected larkspur plants. Direct application by single cone nozzle on CO2-pressurized backpack. Each plant was sprayed to wetness and analyzed for alkaloid concentration.	No effect on the absolute amount of toxic alkaloids, compared with controls. Nonetheless, gyphosate treatment did not decrease the larkspur toxicity. Consequently, the risk of poisoning (to cattle) remains until the plants desiccate. The investigators did not examine how the herbicide used in the study affected larkspur palatability.	Ralphs et al. 1998
Roundup, aerial application to conifer forest at 1.7 kg a.i./ha.	No significant impact on numbers of bacteria, fungi, and actinomycetes in litter or soil. In laboratory bioassays, no effects are rates up to 100 times field application rates.	Stratton and Stewart 1992.
Roundup, applied aerially in August 1991 to six clearcuts harvested between 1983 and 1985. Deciduous tree cover dominated the clearcuts and was approximately 1-2 m high.	Abundance of leaves of deciduous trees was greater on untreated sites (38 vs 11%) 1 year after treatment, but the difference was less (18 vs 12%) 7-10 years after treatment. A similar pattern was observed for deciduous shrubs. The abundance of forbs was similar (13-14%) 1 year after treatment but great on tread sties (29 vs 15%) 7-10 year after treatment. Grasses and ferns were less abundant than other forage classes. Overall, glyphosate application initially decreased the abundance of leaves of deciduous trees and shrubs used as food in summer by white-tailed deer.	Vreeland et al. 1998
Roundup, aerial application at 4 kg/ha on farmland planted for hay in previous 5 years.	No effect on any microbial soil variables tested: biomass, substrate-induced respiration, basal respiration, bacterial:fungal ratio.	Wardle and Parkinson 1991
Glyphosate (NOS), 5 kg/ha directly incorporated into soil of barley or weed plots.	No direct effect on basal soil respiration, microbial activity, or microbial biomass. Transient decrease in biomass on some plots secondary to toxic effects on weeds.	Wardle and Parkinson 1992

Appendix 6: Toxicity to Fish

All concentrations are in mg a.e./L unless otherwise specified.
MRID studies taken from U.S. EPA/OPP 2008a unless otherwise specified.

A6 Table 1: Glyphosate Salts - Acute LC_{50}s

Salt	Species	Exposure	Response	Reference
Technical, 95.6 %	Bluegill sunfish	96 hours	LC_{50}: 43 (30.6 - 53.5) mg/L NOAEC: 30.6 mg/L	MRID 44320630
Technical, 83%	Bluegill sunfish	96 hours	U.S. EPA/OPP 2008a LC_{50}: 99.6 (92.1 - 107.9) mg/L NOAEC: 83 mg/L EPA DER LC_{50}: 120 (111-130) mg material/L The apparent discrepancy reflects the correction made by U.S. EPA/OPP 2008a for purity of the material. The 120 mg/L value is used in several MSDSs.	McAllister and Forbes 1978a MRID 108205
Technical grade. Note: The U.S. EPA/OPP 2008a identifies the test material as glyphosate IPA with a purity of 96.7%. This is not consistent with the Folmar 1979 paper.	Bluegill sunfish	96 hours	Folmar paper LC_{50}: 140 (110-160) mg/L, pH 6.5 LC_{50}: 220 (170-280) mg/L, pH 9.5 U.S. EPA/OPP 2008a LC_{50}: 100.2 (78.7 – 114.5) mg/L, pH 6.5	Folmar et al. 1979 [MRID 162296] [2]
Technical, 96.7%	Bluegill sunfish	96 hours	EPA DER LC_{50}: >24 mg/L Supplemental	Morrill 1973 MRID 108112
Technical, 83%	Rainbow trout	96 hours	U.S. EPA/OPP 2008a LC_{50}: 71.4 (58.1-84.8) mg/L NOAEC: 34.9 mg/L Note: These toxicity values are given as 86 (70 – 106) mg/L in U.S. EPA/OPP 1993c. The above values from the EPA 2008a are corrected for compound purity.	Thompson and McAllister 1978; MRID 136339

A6 Table 1: Glyphosate Salts - Acute LC_{50}s

Salt	Species	Exposure	Response	Reference
Technical grade.	Rainbow trout	96 hours	Folmar paper LC_{50}: 140 (120-170) mg/L, pH 6.5 LC_{50}: 240 (200-290) mg/L, pH 9.5 U.S. EPA/OPP (2008a) LC_{50}: 100.2 (85.9 – 121.6) mg/L NOAEC: Not reported	Folmar et al. 1979 [MRID 162296] [2]
Acid, 95.6 %	Rainbow trout	96 hours	LC_{50}: 128.1 (95.6 - 172.1) mg/L Dark coloration at 53.6 mg/L NOAEC: 30.6 mg/L	MRID 44320629 [1]
Technical grade.	Fathead minnow	96 hours	Folmar paper LC_{50}: 97 (79-120) mg/L U.S. EPA/OPP (2008a) LC_{50}: 69.4 (56.5 - 85.9) mg/L NOAEC: Not reported	Folmar et al. 1979 [MRID 162296] [2]
Technical grade.	Channel catfish	96 hours	Folmar paper LC_{50}: 130 (110-160) mg/L U.S. EPA/OPP (2008a) LC_{50}: 93 (78.7 - 114.5) mg/L NOAEC: Not reported	Folmar et al. 1979 [MRID 162296] [2]
Glyphosate (62%)	Carp	96 hours, static renewal	LC_{50}: 620 mg a.e./L This may be a formulation.	Neskovic et al. 1996
Glyphosate technical from Monsanto	Coho salmon	96 hours, static	Water Type / pH / 96 h-LC_{50} (mg a.e./L): Soft (city) / 6.3 / 27 Soft (creek) / 7.2 / 36 Reconstituted / 7.8 / 112 Well / 7.8 / 111 Lake / 8.2 / 174	Wan et al. 1989
Glyphosate technical from Monsanto	Chum salmon (*Oncorhynchus keta*)	96 hours, static	Water Type / pH / 96 h-LC_{50} (mg a.e./L): Soft (city) / 6.3 / 10 Soft (creek) / 7.2 / 22 Reconstituted / 7.8 / 99 Well / 7.8 / N/A Lake / 8.2 / 148	Wan et al. 1989
Glyphosate technical from Monsanto	Chinook salmon (*Oncorhynchus tshawytscha*)	96 hours, static	Water Type / pH / 96 h-LC_{50} (mg a.e./L): Soft (city) / 6.3 / 19 Soft (creek) / 7.2 / 30 Reconstituted / 7.8 / 102 Well / 7.8 / 108 Lake / 8.2 / 211	Wan et al. 1989

A6 Table 1: Glyphosate Salts - Acute LC_{50}s

Salt	Species	Exposure	Response			Reference
Glyphosate technical from Monsanto	Pink salmon (*Oncorhynchus gorbuscha*)	96 hours, static	Water Type	pH	96 h-LC_{50} (mg a.e./L)	Wan et al. 1989
			Soft (city)	6.3	14	
			Soft (creek)	7.2	23	
			Reconstituted	7.8	94	
			Well	7.8	102	
			Lake	8.2	190	
Glyphosate technical from Monsanto	Rainbow trout	96 hours, static	Water Type	pH	96 h-LC_{50} (mg a.e./L)	Wan et al. 1989
			Soft (city)	6.3	10	
			Soft (creek)	7.2	22	
			Reconstituted	7.8	99	
			Well	7.8	93	
			Lake	8.2	197	

[1] Additional details from U.S. EPA/OPP 2008a, Appendix J

[2] Note on Folmar et al. 1979: U.S. EPA/OPP 2008a summarizes several data points from Folmar et al. 1979 as 00162296/1979. For glyphosate, the EPA report states that purity of the test material was 96.7% and that bioassays were conducted with the IPA salt. The 96.7% purity is not reported in Folmar et al. 1979 and the publication indicates that the IPA salt was used only in the assays for avoidance, reproduction and invertebrate drift. Consequently, the entries for the Folmar study present both the data given in the publication and the data from U.S. EPA/OPP 2008a. The toxicity values for glyphosate IPA reported in U.S. EPA/OPP 2008a from Folmar et al 1979 cannot be identified. Folmar indicates that the IPA salt was used only for the reproduction assay in trout.

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

Formulation	Species	Exposure	Response	Reference/Year
Roundup	Bluegill sunfish	96 hours static	LC_{50}: 4.4 mg a.e./L	Abdelghani et al. 1997
Roundup	Channel catfish	96 hours static	LC_{50}: 4.9 mg a.e./L	Abdelghani et al. 1997
Spanish glyphosate formulation, 54.9% a.i. NOS	Rainbow trout	96 hours	LC_{50}: 4,291 mg a.i./L NOEC: 823.5 mg a.i./L Ratio: 5.2	Anton et al. 1994
Spanish glyphosate formulations (3) (NOS)	Goldfish (*Carassius auratus*)	96 hours, three different formulations with differing concentration of a.i.	% a.i. in formulation: 36%; LC_{50} (mg a.i./L): 9217; NOEC (mg a.i./L): 2880 % a.i. in formulation: 38%; LC_{50} (mg a.i./L): ; NOEC (mg a.i./L): 9500 % a.i. in formulation: 54.9%; LC_{50} (mg a.i./L): 4183; NOEC (mg a.i./L): 3431 Note: This appears to be a formulation without a surfactant but this is not explicitly stated in the study.	Anton et al. 1994
Rodeo, 53.8% a.i., IPA	Fathead minnow	96 hour static renewal	NOEC: 1000 mg/L formulation or ≈400 mg a.e./L	Beyers 1995
Rodeo, 53.8% a.i., IPA	Rainbow trout	96 hour static renewal	NOEC: 1000 mg/L formulation or ≈400 mg a.e./L	Beyers 1995
GF-1279, Glyphosate IPA, 53.6%.	Zebra fish (*Danio rerio*)	96 hours, static	LC_{50}: 11.26 mg formulation/L or ≈ 6 mg a.e./L NOEC (mortality): 5.6 mg formulation/L or ≈ 3 mg a.e./L	Bidinotto 2005a
MON 77360 formulation, 30% a.e., 41% isopropylamine glyphosate	Bluegill sunfish	96 hours, static	LC_{50}: 7.3 (4.4-10) mg/L MON 77360/L LC_{50}: 2.2 (1.3-3) mg a.e./L based on 30% a.e. No mortality at 4.4 mg form/L or 1.3 mg a.e./L. The formulation LC_{50} is cited on MSDSs for Ranger Pro, Roundup Pro, Roundup Pro Concentrate, and Roundup UltraMax.	Drottar and Krueger 2000 MRID 45365002
Glyphosate IPA, 30%	Bluegill sunfish	96 hours	LC_{50}: 5.0 (3.8-6.6) mg a.e./L	Folmar et al. 1979 MRID 162296 [3]
Roundup with POEA surfactant	Channel catfish	96 hours	Life Stage: Sac fry; LC_{50} (mg a.e./L): 4.3 Life Stage: Swim-up fry; LC_{50} (mg a.e./L): 3.3 Life Stage: Fingerlings; LC_{50} (mg a.e./L): 13	Folmar et al. 1979, Table 3 MRID 162296 [3]

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

Formulation	Species	Exposure	Response	Reference/Year
Roundup with POEA surfactant	Rainbow trout	96 hours	Life Stage / LC_{50} (mg a.e./L): Eggs 16; Sac fry 3.4; Swim-up fry 2.4; Fingerlings, 1 g 1.3; Fingerlings, 2 g 8.3	Folmar et al. 1979, Table 3[3]
Roundup with POEA surfactant	Rainbow trout	96 hours	pH / LC_{50} (mg a.e./L): 6.5 7.6; 7.5 1.6; 8.5 1.4; 9.5 1.4	Folmar et al. 1979, Table 6[3]
Roundup with POEA surfactant	Bluegill sunfish	96 hours	pH / LC_{50} (mg a.e/L): 6.5 4.2; 7.5 2.4; 8.5 2.4; 9.5 1.8	Folmar et al. 1979, Table 6[3]
Roundup with POEA surfactant	Rainbow trout, sac fry	96 hours	LC_{50}: 3.4 (5.2 - 7.3) mg a.e./L Working Note: U.S. EPA/OPP 2008a cites this as MRID 162296 add reports an LC50 of 3.4 (5.2 - 7.3) mg a.e./L. This appears to be typographical error.	Folmar et al. 1979, Table 3[3]
Roundup with POEA surfactant	Channel catfish	96 hours	LC_{50}: 13 (11-16) mg a.e./L	Folmar et al. 1979[3]
Roundup with POEA surfactant	Fathead minnow	96 hours	LC_{50}: 2.3 (1.9-2.8) mg a.e./L	Folmar et al. 1979[3] MRID 162296
Roundup with POEA surfactant	Rainbow trout	96 hours	LC_{50}: 8.3 (7.0-9.9) mg a.e./L	Folmar et al. 1979, Table 1[3]
Roundup, 31% a.i. The DER specifies 41.83% a.i. and 31.01% a.e.	Bluegill sunfish	96 hours	U.S. EPA/OPP 2008a LC_{50}: 1.8 (1.4 - 2.6) mg a.e./L NOAEC: 0.7 Note: The above values are correctly converted using 31.01% a.e. EPA DER 96-hr LC_{50}: 5.8 (4.4-8.3) mg formulation/L.	Forbis et al. 1982a MRID 124760/1982

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

Formulation	Species	Exposure	Response	Reference/Year
Roundup, 31% a.i. The DER specifies 41.8% a.i. This is the standard value for the original Roundup.	Rainbow trout	96 hours	U.S. EPA/OPP 2008a LC_{50}: 2.5 (2.0 - 3.1) mg a.e./L NOAEC: 1.8 mg a.e./L Note: The above values are correctly converted using 31.01% a.e. EPA DER LC_{50}: 8.2 (6.4 – 9.0) mg form/L.	Forbis et al. 1982b MRID 124761/1982
Roundup 356 g/L glyphosate IPA MON 02139 MON 02139 is 41% a.i.	Rainbow trout	96-hours, with aeration. pH varied from 4.8 to 6.2.	96-hr LC_{50}s Lab: 54.8 mg form./L Field: 52 mg form./L 96-hr LC_{50}s Lab: 16.6 mg e.g./L Field: 15.8 mg a.e./L	Hildebrand et al. 1982
GF-1280 (50.2%, DMA)	Rainbow trout	48 hours, static	LC_{50}: 11 (10-12) mg form/L LC_{50}: ≈4.3 (4.0-4.8) mg a.e./L NOEC (sublethal effects): 7.5 mg formulation/L or ≈3.0 mg a.e./L.	Hughes 2006a
Vision, 356 g a.e./L with 10% or 15% MON 0818 surfactant	Rainbow trout	96 hour static	LC_{50} (10% surf.): 75 ppm LC_{50} (15% surf.): 27 ppm Above appear to be in units of formulation but this is not clear.	Janz et al. 1991
Roundup (IPA, 48% a.e.)	Nile tilapia (*Oreochromis niloticus*), 1.7 g (young) or 17 g (adult)	96 hours, static without renewal	Adult LC_{50}: 36.8 ppm Young LC_{50}: 16.6 ppm Units are not clear	Jiraungkoorskul et al. 2002
Roundup, 360 g/L	Silver catfish (*Rhamdia quelen*), fingerlings	96 hours at 2, 4, 8, 16, and 32 mg a.i./L	LC_{50}: 7.3 (6.5 – 8.2) mg a.i./L Assuming authors considered IPA as the a.i. LC_{50}: 5.3 (4.8 – 6.1) mg a.e./L	Kreutz et al. 2008
Roundup (IPA, 41% IPA, 35% a.e)	S.A. ray fin (*Prochilodus lineatus*), 16.3 g	96 hours, static	LC_{50}: 13.69 ppm formulation or 4.9 mg a.e./L	Langiano and Martinez 2008
Roundup, 41% 41.36% a.i. in EPA DER	Bluegill sunfish	96 hours	U.S. EPA/OPP 2008a LC_{50}: 4.3 (2.7 - 7.3) mg a.e./L NOAEC: 2.7 mg a.e./L EPA DER LC_{50}: 14 mg/L DER does not specify units as formulation, a.i., or a.e. If units are in formulation, the a.e. conversion would be 0.4136 x 0.79. LC_{50}: 4.5 mg a.e./L	Le Blanc et al. 1980 MRID 70897

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

Formulation	Species	Exposure	Response	Reference/Year
Roundup, 360 g/L NOS	Bleak	96 hours, static	LC_{50}: 16 (15-18) mg/L Units probably formulation but this is not clear in paper.	Linden et al. 1979
Roundup 30.5% w/w glyphosate	Lee Koh (*Cyprinus carpio*)	96-hours	LC_{50}: 3.1 ppm a.e. NOEC: 0.5 ppm a.e.	Liong et al. 1988
Roundup 30.5% w/w glyphosate	Tilapia (*Oreochromis niloticus*)	96-hours	LC_{50}: 2.3 ppm a.e. 0.55 ppm a.e.: erratic swimming NOEC: 0.31 ppm a.e.	Liong et al. 1988
360 g/L SL, 28% Formulation designated as YF11357 This appears to be a Syngenta product registered in the Netherlands.	Bluegill sunfish	96 hours, static	DER Summary Limit assay. LC_{50}: >183.7 mg form/L >52 mg a.e./L NOAEC: 52 mg a.e./L for sublethal effects	Magor and Shillabeer 2000 MRID 45374002 These data are not cited in any of the MSDSs for the formulations covered in this risk assessment. This study is not cited in U.S. EPA/OPP 2008a.
Rodeo, no surfactant	Rainbow trout	96 hours, static	LC_{50}: 580 (460-730) mg a.i./L LC_{50}: 429 mg a.e./L	Mitchell et al. 1987a
Rodeo, X-77 surfactant ≈0.6%	Rainbow trout	96 hours, static	LC_{50}: 130 (120-160) mg a.i./L LC_{50}: 96 mg a.e./L	Mitchell et al. 1987a
Roundup	Chinook salmon	96 hours, static	LC_{50}: 9.6 mg a.i./L LC_{50}: 7.1 mg a.e./L	Mitchell et al. 1987a
Roundup	Coho salmon	96 hours, static	LC_{50}: 11 mg a.i./L LC_{50}: 8.1 mg a.e./L	Mitchell et al. 1987a
Roundup	Rainbow trout	96 hours, static	pH / LC_{50} (mg/L) / a.i / a.e 6.1 / 12 / 8.9 7.6 / 11 / 8.1 7.7 / 7.4 / 5.5	Mitchell et al. 1987a
Vision (356 g/L glyphosate acid with surfactant)	Rainbow trout	96 hours, static	LC_{50}: 10.42 (9.37-11.67) mg a.e./L Clear that units are in a.e.	Morgan and Kiceniuk 1992
Roundup, 30% a.i.	Rainbow trout	96 hours	LC_{50}: 1 (0.8 -1.2) mg a.e./L 3.17 mg formulation/L	MRID 40098001 /1986[1]
Glyphosate IPA (NOS), 30%	Bluegill sunfish	96 hours	LC_{50}: 3 (2.4 -3.7) mg a.e./L	MRID 40098001 /1986[1]
Roundup, 36%	Chinook salmon	96 hours	LC_{50}: 7.1 (5.9 - 9.7) mg a.e./L NOAEC: <1.3 mg a.e./L	MRID 40579201 /1986
Roundup, 36%	Chinook salmon	96 hours	LC_{50}: 8.2 (4.2 – 13.4) mg a.e./L NOAEC: 3.42 mg/L	MRID 40579202 /1986
Roundup, 36%	Rainbow trout	96 hours	LC_{50}: 5.5 - 9.2 (4.2 - 13) mg a.e./L NOAEC: 4.2 mg a.e./L	MRID 40579203 /1986

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s				
Formulation	**Species**	**Exposure**	**Response**	**Reference/Year**
Glyphosate IPA (Rodeo/X-77), 41%	Rainbow trout	96 hours	LC_{50}: 96.4 (89.0 - 118.7) mg a.e./L NOAEC: 37.5 mg a.e./L	MRID 40579301 /1985 This appears to be identical to Mitchell et al. 1987a
Glyphosate IPA (Rodeo/X-77), 41%	Rainbow trout	96 hours	LC_{50}: 430.1 (341 - 541) mg a.e./L NOAEC: 157 mg a.e./L	MRID 40579301 /1985 This appears to be identical to Mitchell et al. 1987a
Glyphosate IPA (Rodeo/X-77), 41%	Coho salmon	96 hours	LC_{50}: 148.3 (89.0 - 274.4) mg a.e./L NOAEC: 88.5 mg a.e./L	MRID 40579302 /1985
Glyphosate IPA (Rodeo/X-77), 41%	Chinook salmon	96 hours	LC_{50}: 103.8 (89.0 - 148.3) mg a.e./L NOAEC: 47.5 mg a.e./L	MRID 40579303 /1985
Glyphosate IPA (Rodeo/X-77)	Chinook salmon	96 hours	LC_{50}: 180.2 (133.5 - 240.3) mg a.e./L NOAEC: 74.8 mg a.e./L	MRID 40579305 /1987
Glyphosate IPA (Rodeo/X-77), 41%	Rainbow trout	96 hours	LC_{50}: 134 (75 - 240) mg a.e./L NOAEC: 43 mg a.e./L	MRID 40579306 /1987
Glyphosate(80WDG), 79%	Fathead minnow	96 hours	LC_{50}: 54.3 (47.3 - 79.1) mg a.e./L NOAEC: 28.7 mg a.e./L	MRID 44125704 /1996
Glyphosate(80WDG), 79%	Rainbow trout	96 hours	LC_{50}: 62.1 (48.2 - 80.0) mg a.e./L NOAEC: 28.7 mg a.e./L	MRID 44125705 /1996
Glyphosate IPA (MON65005)	Rainbow trout	96 hours	LC_{50}: 2.5 (1.9 - 3.1) mg a.e./L NOAEC: 1.9 mg a.e./L	MRID 44538202
Glyphosate IPA (MON65005)	Bluegill sunfish	96 hours	LC_{50}: 2.4 (2.0 - 3.5) mg a.e./L NOAEC: 1.2 mg a.e./L	MRID 44538203
Glyphosate IPA, 46% (MON77945 Manufacturing concentrate)	Rainbow trout	96 hours	LC_{50}: >977 mg form./L NOAEC: 591 mg a.e./L	MRID 44715409 /1998
Glyphosate IPA, 10%, with Geronol CF/AR	Rainbow trout	96 hours	LC_{50}: > 450 mg a.e./L or >1000 mg form./L NOAEC: 1000 mg form./L	MRID 44738201 /1996 **Note: This may be the source for several >1000 mg/L notes in MSDSs.**
Glyphosate IPA, 36% (Roundup Biactive)	Rainbow trout	96 hours	LC_{50}: >1000 (N.A.) mg form./L NOAEC: 800 mg a.e./L?	MRID 44738201 /1996
Glyphosate IPA, 36%, with Geronol CF/AR	Rainbow trout	96 hours	LC_{50}: >1000 mg form./L NOAEC: 1000 mg form./L	MRID 44738201 /1996 **Note: This may be the source for several >1000 mg/L notes in MSDSs.**

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s				
Formulation	**Species**	**Exposure**	**Response**	**Reference/Year**
Glyphosate IPA, 45% with Geronol CF/AR surfactant	Rainbow trout	96 hours	LC_{50}: > 450 (N.A.) mg a.e./L or >1000 mg formulation/L NOAEC: 1000 mg formulation/L	MRID 44738201 /1996
Glyphosate IPA (MON 77360), 30% a.i.	Rainbow trout	96 hours	LC_{50}: 1.6 (1.3 - 2.1) mg a.e./L NOAEC: 1.3 mg a.e./L	MRID 45365003
Glyphosate monoammonium salt (MON78568), 66%	Rainbow trout	96 hours	LC_{50}: 1.9 (1.04 - 2.31) mg a.e./L NOAEC: 1.04 mg a.e./L	MRID 45767101
Roundup, 41%	Channel catfish	96 hours	LC_{50}: 4.9 (2.9 - 8.0) mg a.e./L NOAEC: 2.9 mg a.e./L	MRID 70894/1980
Glyphosate IPA(MON 2139, Roundup), 41%	Rainbow trout	96 hours	LC_{50}: 3.4 (2.7 - 4.3) mg a.e./L NOAEC: 2.7 mg a.e./L	MRID 70895
Roundup, 41% a.i.	Fathead minnow	96 hours	LC_{50}: 2.9 (1.7 - 4.9) mg a.e./L NOAEC: 1.7 mg a.e./L	MRID 70896/1980
Glyphosate IPA, 41% (Roundup with 15 % "W")	Rainbow trout	96 hours	LC_{50}: 45.2 (30.1 - 96.4) mg a.e./L NOAEC: 30.1 mg a.e./L	MRID 78655/1980
Glyphosate IPA (Roundup with 15 % "W"), 41%	Bluegill sunfish	96 hours	LC_{50}: >30 (30 - 96.4.) mg a.e./L NOAEC: 30 mg a.e./L	MRID 78656
Glyphosate IPA, 41% (Roundup with 15.3 % "AA")	Rainbow trout	96 hours	LC_{50}: 36.6 (17.1 - 54.9) mg a.e./L	MRID 78658/1980
Glyphosate IPA (No surfactant), 62%	Rainbow trout	96 hours	LC_{50}: >461.8 mg a.e./L	MRID 78661/1980
Glyphosate IPA (No surfactant), 62%	Bluegill sunfish	96 hours	LC_{50}: >461.8 mg a.e./L	MRID 78662 /1981
Glyphosate IPA with X-77 surfactant Note: Based on the MRID number and the bibliography in Supplement 1, this study used MON-0139. This appears to be a 62% a.i. solution.	Rainbow trout	96 hours	LC_{50}: 9.4 (7.0 - 12.4) mg a.e./L NOAEC: 7 mg a.e./L	MRID 78664/1980
Glyphosate IPA with 0.5% "X-77" Note: Based on the MRID number and the bibliography in Supplement 1, this study used MON-0139. This appears to be a 62% a.i. solution.	Bluegill sunfish	96 hours	LC_{50}: 32.4 (24.2-62.4) mg a.e./L NOAEC: 7.1 mg a.e./L Slope:4.2	MRID 78665/1980
Rival (granular 75%, salt not specified) a formulation sold in Portugal	Mosquito fish (*Gambusia yucatana*)	96 hours, static	LC_{50}: ≈17.8 ppm formulation or 13.3 mg a.i./L Ratio: LC_{50}/LC_{10} = 1.8 No inhibition of AChE.	Rendon-von Osten et al. 2005

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

Formulation	Species	Exposure	Response	Reference/Year
Roundup, 30.5% a.e.	Sockeye salmon (*Oncorhynchus nerka*)	96 hours, static	LC_{50}: 8.1 mg a.e./L, 3.8 g fry LC_{50}: 8.4 mg a.e./L, 3.7 g fry LC_{50}: 8.7 mg a.e./L, 0.25 g fry	Servizi et al. 1987
Roundup, 30.5% a.e.	Coho salmon fry	96 hours, static	LC_{50}: 1.8 mg a.e./L, 3.4 g fry	Servizi et al. 1987 citing EPA data
Roundup, 30.5% a.e.	Rainbow trout fry	96 hours, static	LC_{50}: 8.6 mg a.e./L, 3.4 g fry LC_{50}: 7.8 mg a.e./L, 3.9 g fry	Servizi et al. 1987 citing EPA data
360 g/L SL, 27% a.i. DER gives formulation synonym YF11357. This appears to be an IPA salt. 27.25%	Rainbow trout	96 hours	U.S. EPA/OPP 2008a LC_{50}: 224.5 (160.1 - 280.0) mg a.e./L or 824 mg formulation/L NOAEC: 160 mg a.e./L EPA DER LC_{50}: 824 mg formulation/L NOEC mortality: 587.2 mg form/L NOEC sublethal effects: 183.5 mg form/L In the DER, the LC_{50} is given as 224.5 mg a.i./L rather than 224.5 mg a.e./L.	Swarbrick and Shillabeer 1999a MRID 45374001 /1999
Vision 356 g a.e./L with surfactants	Rainbow trout	96-hours	Surfactant concentrations of 7.5%, 10%, or 15%. 96-hr LC_{50}s 7.5%:100 ppm 10%: 75 ppm 15%: 27 ppm	U.S. EPA/OPP 2008a, Appendix J, p. 13. Cited as Reference E05182. Not otherwise referenced.
MON 8709, 41% glyphosate IPA (30.5% a.e.) with 10% MON 0818, 49% water and inerts (NOS)	Chinook salmon (*Oncorhynchus tshawytscha*)	96 hours, static Results from Table 4 (mg formulation/L) in paper given first in column 4 followed by conversion to mg a.e./L.	Water Type / pH / 96 h-LC_{50} (mg form./L) Soft (city) 6.3 67 Soft (creek) 7.2 62 Reconstituted 7.8 28 Well 7.8 45 Lake 8.2 33 Converted to a.e below, rounding to nearest mg: Water Type / pH / 96 h-LC_{50} (mg a.e./L) Soft (city) 6.3 20 Soft (creek) 7.2 19 Reconstituted 7.8 9 Well 7.8 14 Lake 8.2 10	Wan et al. 1989

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

Formulation	Species	Exposure	Response	Reference/Year
MON 8709, 41% glyphosate IPA (30.5% a.e.) with 10% MON 0818, 49% water and inerts (NOS)	Chum salmon (*Oncorhynchus keta*)	96 hours, static Results from Table 4 (mg formulation/L) in paper given first in column 4 followed by conversion to mg a.e./L.	Water Type / pH / 96 h-LC_{50} (mg a.e./L) Soft (city) 6.3 36 Soft (creek) 7.2 58 Reconstituted 7.8 34 Well 7.8 N/A Lake 8.2 23 Converted to a.e below, rounding to nearest mg: Water Type / pH / 96 h-LC_{50} (mg a.e./L) Soft (city) 6.3 11 Soft (creek) 7.2 18 Reconstituted 7.8 10 Well 7.8 N/A Lake 8.2 7	Wan et al. 1989
MON 8709, 41% glyphosate IPA (30.5% a.e.) with 10% MON 0818, 49% water and inerts (NOS)	Coho salmon	96 hours, static Results from Table 4 (mg formulation/L) in paper given first in column 4 followed by conversion to mg a.e./L.	Water Type / pH / 96 h-LC_{50} (mg form./L) Soft (city) 6.3 55 Soft (creek) 7.2 51 Reconstituted 7.8 34 Well 7.8 44 Lake 8.2 25 Converted to a.e below, rounding to nearest mg: Water Type / pH / 96 h-LC_{50} (mg a.e./L) Soft (city) 6.3 17 Soft (creek) 7.2 16 Reconstituted 7.8 10 Well 7.8 13 Lake 8.2 7.6	Wan et al. 1989

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

Formulation	Species	Exposure	Response	Reference/Year
MON 8709, 41% glyphosate IPA (30.5% a.e.) with 10% MON 0818, 49% water and inerts (NOS)	Pink salmon (*Oncorhynchus gorbuscha*)	96 hours, static Results from Table 4 (mg formulation/L) in paper given first in column 4 followed by conversion to mg a.e./L.	Water Type / pH / 96 h-LC_{50} (mg form../L) Soft (city) 6.3 48 Soft (creek) 7.2 46 Reconstituted 7.8 26 Well 7.8 34 Lake 8.2 24 Converted to a.e below, rounding to nearest mg: Water Type / pH / 96 h-LC_{50} (mg a.e./L) Soft (city) 6.3 15 Soft (creek) 7.2 14 Reconstituted 7.8 8 Well 7.8 10 Lake 8.2 7 X	Wan et al. 1989
MON 8709, 41% glyphosate IPA (30.5% a.e.) with 10% MON 0818, 49% water and inerts (NOS)	Rainbow trout	96 hours, static Results from Table 4 (mg formulation/L) in paper given first in column 4 followed by conversion to mg a.e./L.	Water Type / pH / 96 h-LC_{50} (mg form../L) Soft (city) 6.3 48 Soft (creek) 7.2 31 Reconstituted 7.8 34 Well 7.8 29 Lake 8.2 17 Converted to a.e below, rounding to nearest mg: Water Type / pH / 96 h-LC_{50} (mg a.e./L) Soft (city) 6.3 15 Soft (creek) 7.2 9 Reconstituted 7.8 10 Well 7.8 9 Lake 8.2 5	Wan et al. 1989

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

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<tr><td>Roundup (Vision), 41% glyphosate IPA (30.5% a.e.) with 15% MON 0818, 44% water and inerts (NOS)</td><td>Chinook salmon (Oncorhynchus tshawytscha)</td><td>96 hours, static

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<tr><td>Lake</td><td>8.2</td><td>3</td></tr>
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A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

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<tr><td>Soft (city)</td><td>6.3</td><td>10</td></tr>
<tr><td>Soft (creek)</td><td>7.2</td><td>9</td></tr>
<tr><td>Reconstituted</td><td>7.8</td><td>5</td></tr>
<tr><td>Well</td><td>7.8</td><td>6</td></tr>
<tr><td>Lake</td><td>8.2</td><td>4</td></tr>
</table>
</td><td>Wan et al. 1989</td></tr>
</table>

A6 Table 2: Glyphosate Formulations - Acute LC_{50}s

<table>
<tr><th>Formulation</th><th>Species</th><th>Exposure</th><th>Response</th><th>Reference/Year</th></tr>
<tr><td>Roundup (Vision), 41% glyphosate IPA (30.5% a.e.) with 15% MON 0818, 44% water and inerts (NOS)</td><td>Rainbow trout</td><td>96 hours, static

Results from Table 4 (mg formulation/L) in paper given first in column 4 followed by conversion to mg a.e./L.</td><td>
<table>
<tr><th>Water Type</th><th>pH</th><th>96 h-LC_{50} (mg form./L)</th></tr>
<tr><td>Soft (city)</td><td>6.3</td><td>33</td></tr>
<tr><td>Soft (creek)</td><td>7.2</td><td>15</td></tr>
<tr><td>Reconstituted</td><td>7.8</td><td>18</td></tr>
<tr><td>Well</td><td>7.8</td><td>18</td></tr>
<tr><td>Lake</td><td>8.2</td><td>14</td></tr>
</table>
Converted to a.e below, rounding to nearest mg:
<table>
<tr><th>Water Type</th><th>pH</th><th>96 h-LC_{50} (mg a.e./L)</th></tr>
<tr><td>Soft (city)</td><td>6.3</td><td>10</td></tr>
<tr><td>Soft (creek)</td><td>7.2</td><td>5</td></tr>
<tr><td>Reconstituted</td><td>7.8</td><td>5</td></tr>
<tr><td>Well</td><td>7.8</td><td>5</td></tr>
<tr><td>Lake</td><td>8.2</td><td>4</td></tr>
</table>
</td><td>Wan et al. 1989</td></tr>
</table>

[1] Summarized in Table 4.5 of U.S. EPA/OPP 2008a. The MRID number is not fully referenced and is not in Attachment 1 of the current Forest Service risk assessment.

[2] Summarized in Appendix J of U.S. EPA/OPP 2008a. The MRID number is not fully referenced and is not in Attachment 1 of the current Forest Service risk assessment.

[3] Folmar et al. (1979) report the Roundup formulation as "360.32 g/L active ingredient". The Roundup formulation in 1979 contained 480 g/L of the IPA salt (a.i.) and 356 g/L of the glyphosate acid equivalents. The U.S. EPA/OPP 2008a interpreted the LC_{50} values for Roundup as being reported in units of mg a.i./L and interprets the a.i./L as the IPA salt. While this follow current nomenclature, a review of Folmar et al. (1979) study by the Forest Service judges that the units for Roundup LC50s are reported in Folmar et al. (1979) in units of mg a.e./L and not units of mg a.i./L. Thus, the values summarized in this appendix are taken directly from Folmar et al. (1979). Thus, the LC_{50}s reported in U.S. EPA/OPP (2008a) for Folmar et al. (1979) are lower than the LC_{50} values summarized in this appendix by a factor of 0.74, the conversion factor for going from a.i. to a.e.

A6 Table 3: Other Acute Toxicity Studies

Agent	Species	Exposure	Response	Reference
Roundup, NOS	South American catfish (*Rhamdia quelen*)	16.6%, 33.3%, and 50% of nominal LC_{50} of 7.3 mg formulation/L for 96 hours	Concentration related decrease in cortisol levels. Units for exposure are not clear but appear to be formulation. LOAEL: ≈1.2 mg formulation/L or ≈0.4 mg a.e./L assuming a 30% w/w formulation. Decrease may be dose-related but the differences among the three doses are not substantial. See Fig. 1 of publication.	Cericato et al. 2008
Roundup, NOS	South American catfish (*Rhamdia quelen*)	16.6%of nominal LC_{50} of 7.3 mg/L for 96 hours	Cortisol levels similar to control fish. Units for exposure are not clear but appear to be formulation. The reason(s) for the differences with the above study are not apparent.	Cericato et al. 2009
Roundup, 48% a.e.	Silver catfish (*Rhamdia quelen*)	0, 0.2, and 0.4 mg a.e./L for 96 hours	Decrease in brain AChE at all concentrations. No significant inhibition of muscle AChE. As above, various biochemical changes indicative of stress response.	Glusczak et al. 2006
Roundup, 48% a.e.	South American ray fin (*Leporinus obtusidens*)	0, 3, 6, 10, and 20 mg a.e./L for 96 hours	Decrease in brain AChE at all concentrations. No significant inhibition of muscle AChE. Also changes in liver biochemical parameters and hematology which may be related to stress.	Glusczak et al. 2006
Roundup 356 g/L glyphosate IPA MON 02139	Rainbow trout (*O. mykiss*)	0.1 to 50 ppm. Units appear to be formulation but this is not clear from publication.	NOAEC for avoidance reaction: 30 ppm formulation? If units are in formulation, the a.e. equivalent is about 12 ppm a.e.	Hildebrand et al. 1982 [1]
Glyphosate, 95%	Flagfish (*Jordanella floridae*), 8 days old	2 hours pulse exposure with 96 hours obs. Period	Comparison of fed and fasted fish based on LC_{20}s Fed: LC_{20}: 29.6 (17.8-90.3) mg a.e./L Fasted: LC_{20}: 2.94 (0.30- 8.83) mg a.e./L NOTE: No mortality in fed or fasted 2-day old or 4-day old fish at 30 mg a.e./L	Holdway and Dixon 1988
Vision, 356 g a.e./L with 15% MON 0818 surfactant	Coho salmon	4-hour exposures in closed system respirometer to 1.35, 2.7, 13.5, and 21.6 mg/L.	Hematocrit significantly increased over controls at lowest (3.75 and 60 ppm) concentrations ($p<0.05$) but expected to decrease as a result of stress; no significant increases in plasma lactate or plasma glucose. Authors interpret data as indicating that a stress threshold was not reached for Vision-10% surfactant at concentrations up to 80% of the 96-hour LC_{50} (75 ppm).	Janz et al. 1991

Appendix : Toxicity to fish *(continued)*

Agent	Species	Exposure	Response	Reference
Roundup (IPA, 48% a.e.)	Nile tilapia (*Oreochromis niloticus*) 17 g (adult)	96 hours at 36 ppm (LC_{50}) Units are not clear. Static with renewal.	Histological damage to gills and kidney.	Jiraungkoorskul et al. 2002
Roundup (IPA, 41% IPA, 35% a.e)	S.A. ray fin (*Prochilodus lineatus*), 16.3 g	96 hours, static, 7.5 and 10 mg form/L, equiv. to 2.6 and 3.5 mg a.e./L	2.6 mg a.e./L: Transient histopathological changes in the liver – apparent at 24 but not 96 hours. 3.5 mg a.e./L: Increase in plasma glucose but no change in cortisol. Increase in hepatic catalase. Histopathological change in the liver. Sublethal responses generally consistent with stress response.	Langiano and Martinez 2008
Roundup (NOS, Ukraine)	Goldfish (*Carassius auratus*), 50-70 grams	0, 2.5, 5, 10, or 20 mg/L. Units appear to be in formulation	Suppression of activities of enzymes associated with oxidative stress. Several biochemical endpoints examined. Responses are statistically significant but do not display a clear dose-response relationship. This is not discussed by authors.	Lushchak et al. 2009
Roundup	Coho salmon smots	Flow-through concentrations 0, 0.029, 0.289, and 2.88 mg a.e./L for 10 days. Authors are clear that a.e. units are used.	No effect on growth as well as several sublethal parameters at exposure concentrations up to 2.78 ppm. No affect on seawater adaptation: plasma sodium values not significantly different from control.	Mitchell et al. 1987b
Vision with 10% surfactant	Rainbow trout	96 hours, static	NOEC: 18.75 mg a.e./L LOEC: 37.5 mg a.e./L at 24 hours, erratic swimming and labored respiration. Units of a.e. inferred from discussion of measured concentrations.	Morgan et al. 1991
Vision with 15% surfactant	Rainbow trout	96 hours, static	NOEC: 6.75 mg a.e./L LOEC: 13.5 mg a.e./L at 24 hours, erratic swimming and rapid respiration. Units of a.e. inferred from discussion of measured concentrations.	Morgan et al. 1991
Glyphosate technical, 62%	Carp, *Cyprinus carpio*	14 days 0, 2.5, 5, and 10 mg/L	2.5 mg/L: significant changes in GOT and GPT activity in liver and kidney. 5 mg/L: histopathological change to gills. significant changes in GOT and GPT activity in liver and kidney. 10 mg/L: histopathological changes to gills and liver. No effect on histopathology in kidneys but an increase in GPT in serum.	Neskovic et al. 1996

Agent	Species	Exposure	Response	Reference
Vision 356 g a.e./L with either 10% or 15% surfactant (POEA). 7.5% surfactant tested in acute study	Rainbow trout (*O. mykiss*)		*Avoidance: 27 ppm (15%) & 75 ppm (10%)* *Other behavior* *6.75 ppm (15%) & 18.75 ppm (10%)* *Other behavior LOAEC:* *Erratic swimming & rapid respiration 13.5 ppm (15%); erratic swimming & labored respiration 37.5 ppm (10%)*	Schaffer and Sebetich 2004 [1] **Note: This citation is not correct in U.S. EPA/OPP 2008a. The correct study may be Morgan et al. 1991 as summarized above in this table.**
Roundup NOS	Carp (*Cyprinus carpio*)	1 hour to 205 mg a.e./L or 0.5 hour to 410 mg a.e./L	All fish died. Mitochondrial swelling and other ultrastructural changes in hepatocytes. Control fish (no treatment) were used. Note: In the absence of stressed controls, it is not clear that the changes in the dead fish were specifically due to glyphosate or secondary to mortality.	Szarek et al. 2000
Roundup 143 g/L	Rainbow trout (*O. mykiss*)	0, 0.01, 0.1, 1, 10, and 100 mg a.i./L (0, 0.0074, 0.074, 0.74, 7.4, and 74 mg a.e./L).	Avoidance response at two high concentrations. No avoidance response at the lower concentrations. 0.1 mg/L: Trout can sense but will not avoid. 0.01 mg/L: No sensory effects.	Tierney et al. 2007 [1]
Glyphosate (no surfactant)	Rainbow trout (*Oncorhynchus mykiss*), juvenile	1.25 mg a.e./L for 7 days	No change in plasma vitellogenin.	Xie et al. 2005
Glyphosate (assumed technical) and combinations with surfactants R-11 and TPA.	Rainbow trout (*O. mykiss*)	1.25 ppm glyphosate with surfactants, ≈0.625 mg/L for R-11 and 0.3 mg/L for TPA.	Increased concentrations of plasma vitellogenin but the increases were not statistically significant. It does not appear that the increases in vitellogenin can be attributed to glyphosate. See Section 4.1.3.1 for discussion.	Xie et al. 2005 [1]

[1] Summarized in U.S. EPA/OPP 2008a, Table 4.15 and Appendix J, Table J-8. Summaries modified with review of original publication unless otherwise specified in Section 5 of the current Forest Service risk assessment.

A6 Table 4: Surfactants Used in Glyphosate Formulations – Acute LC_{50}s

Surfactant	Species	Exposure	Response	Reference [1]
MON 0818	Rainbow trout	96 hours	LC_{50}: 2.0 (1.5-2.7) mg/L	Folmar et al. 1979, Table 2 MRID 162296 [2]
MON 0818	Rainbow trout	96 hours	LC_{50}: 7.4 (6.1-9.0) mg/L, pH 6.5 LC_{50}: 0.65 (0.54-0.78) mg/L, pH 9.5	Folmar et al. 1979, Table 6
MON 0818	Fathead minnow	96 hours	LC_{50}: 1.0 (1.2-1.7) mg/L Working Note: The above values are as reported in the Folmar et al. (1979) publication. Based on the 24-hour LC_{50} values, the central estimate of the LC_{50} appears to be a typographical error in the publication. The correct value appears to be 1.4 mg/L rather than 1.0 mg/L.	Folmar et al. 1979, Table 2 MRID 162296
MON 0818	Channel catfish	96 hours	LC_{50}: 13 (10.0-17.0) mg/L	Folmar et al. 1979, Table 2 MRID 162296
MON 0818	Bluegill sunfish	96 hours	LC_{50}: 3 (2.5-3.7) mg/L	Folmar et al. 1979, Table 2 MRID 162296
MON 0818	Bluegill sunfish	96 hours	LC_{50}: 1.3 (1.1-1.6) mg/L, pH 6.5 LC_{50}: 1.0 (0.72-1.4) mg/L, pH 9.5	Folmar et al. 1979, Table 6
MON 0818	Sockeye fry	96 hours	LC_{50}: 3.2 mg a.i./L	Servizi et al. 1987
MON 0818	Rainbow trout fry	96 hours	LC_{50}: 2.6 mg a.i./L	Servizi et al. 1987 reporting EPA data
MON 0818	Coho salmon fry	96 hours	LC_{50}: 3.5 mg a.i./L	Servizi et al. 1987 reporting EPA data
MON 0818	Coho salmon	96 hours, static	Water Type / pH / 96 h-LC_{50} (mg a.e./L): Soft (city) 6.3 4.6 Soft (creek) 7.2 3.2 Reconstituted 7.8 2.8 Well 7.8 2.9 Lake 8.2 1.8	Wan et al. 1989
MON 0818	Chum salmon (*Oncorhynchus keta*)	96 hours, static	Water Type / pH / 96 h-LC_{50} (mg a.e./L): Soft (city) 6.3 2.7 Soft (creek) 7.2 2.4 Reconstituted 7.8 2.6 Well 7.8 N/A Lake 8.2 1.4	Wan et al. 1989

A6 Table 4: Surfactants Used in Glyphosate Formulations – Acute LC_{50}s

Surfactant	Species	Exposure	Response			Reference [1]
MON 0818	Chinook salmon (*Oncorhynchus tshawytscha*)	96 hours, static	Water Type	pH	96 h-LC_{50} (mg a.e./L)	Wan et al. 1989
			Soft (city)	6.3	2.8	
			Soft (creek)	7.2	2.8	
			Reconstituted	7.8	2.7	
			Well	7.8	2.6	
			Lake	8.2	1.7	
MON 0818	Pink salmon (*Oncorhynchus gorbuscha*)	96 hours, static	Water Type	pH	96 h-LC_{50} (mg a.e./L)	Wan et al. 1989
			Soft (city)	6.3	4.5	
			Soft (creek)	7.2	2.8	
			Reconstituted	7.8	1.5	
			Well	7.8	2.6	
			Lake	8.2	1.4	
MON 0818	Rainbow trout	96 hours, static	Water Type	pH	96 h-LC_{50} (mg a.e./L)	Wan et al. 1989
			Soft (city)	6.3	2	
			Soft (creek)	7.2	2.5	
			Reconstituted	7.8	1.6	
			Well	7.8	2.6	
			Lake	8.2	1.7	

[1] All toxicity values given as mg/L of surfactant unless otherwise specified. Studies designated only with an MRID number are taken from Table 4.6 of U.S. EPA/OPP 2008a.

[2] The toxicity values given in U.S. EPA/OPP 2008a are different from those given in the above table for Folmar et al. 1978. The U.S. EPA/OPP 2008a transposes the values for trout and minnow and also transposes the values for catfish and bluegills. The values given in the above table are the values given in the Folmar et al. 1979 publication.

A6 Table 5: Surfactants Added to Glyphosate Field Solutions				
Material, purity	**Species**	**Exposure**	**Response**	**Reference**
Syndets (anionic surfactant)	Channel catfish	96 hours	LC_{50}: 2.3 mg/L	Abdelghani et al. 1997
Syndets (anionic surfactant)	Bluegill sunfish	96 hours	LC_{50}: 1.9 mg/L	Abdelghani et al. 1997
Activator 90	Bluegill sunfish	96 hours	LC_{50}: 1.4 mg/L	McLaren/Hart 1995[1]
Activator 90	Rainbow trout	96 hours	LC_{50}: 2.0 mg/L	McLaren/Hart 1995[1]
Entry II	Bluegill sunfish	96 hours	LC_{50}: 4.2 mg/L	McLaren/Hart 1995[1]
Entry II	Rainbow trout	96 hours	LC_{50}: 1.3 mg/L	McLaren/Hart 1995[1]
Frigate	Bluegill sunfish	96 hours	LC_{50}: 3.6 mg/L	McLaren/Hart 1995[1]
Frigate	Rainbow trout	96 hours	LC_{50}: 2.4 mg/L	McLaren/Hart 1995[1]
Induce	Bluegill sunfish	96 hours	LC_{50}: 5.6 mg/L	McLaren/Hart 1995[1]
Induce	Rainbow trout	96 hours	LC_{50}: 7.5 mg/L	McLaren/Hart 1995[1]
No Foam A	Bluegill sunfish	96 hours	LC_{50}: 3.4 mg/L	McLaren/Hart 1995[1]
No Foam A	Rainbow trout	96 hours	LC_{50}: 6.0 mg/L	McLaren/Hart 1995[1]
R-11	Bluegill sunfish	96 hours	LC_{50}: 4.2 mg/L	McLaren/Hart 1995[1]
R-11	Rainbow trout	96 hours	LC_{50}: 3.8 mg/L	McLaren/Hart 1995[1]
S. Spreader 200	Bluegill sunfish	96 hours	LC_{50}: 4.2 mg/L	McLaren/Hart 1995[1]
S. Spreader 200	Rainbow trout	96 hours	LC_{50}: 9.3 mg/L	McLaren/Hart 1995[1]
Widespread	Bluegill sunfish	96 hours	LC_{50}: 6.6 mg/L	McLaren/Hart 1995[1]
Widespread	Rainbow trout	96 hours	LC_{50}: 7.0 mg/L	McLaren/Hart 1995[1]
X-77	Bluegill sunfish	96 hours	LC_{50}: 4.3 mg/L	McLaren/Hart 1995[1]
X-77	Rainbow trout	96 hours	LC_{50}: 4.3 mg/L	McLaren/Hart 1995[1]
Liqua-Wet	Bluegill sunfish	96 hours	LC_{50}: 13.0 mg/L	McLaren/Hart 1995[1]
Liqua-Wet	Rainbow trout	96 hours	LC_{50}: 11.0 mg/L	McLaren/Hart 1995[1]
Passage	Bluegill sunfish	96 hours	LC_{50}: 52.0 mg/L	McLaren/Hart 1995[1]
Passage	Rainbow trout	96 hours	LC_{50}: 75.0 mg/L	McLaren/Hart 1995[1]

A6 Table 5: Surfactants Added to Glyphosate Field Solutions

Material, purity	Species	Exposure	Response	Reference
Spreader-Sticker	Bluegill sunfish	96 hours	LC_{50}: 36.0 mg/L	McLaren/Hart 1995[1]
Spreader-Sticker	Rainbow trout	96 hours	LC_{50}: 35.0 mg/L	McLaren/Hart 1995[1]
Agri-Dex	Bluegill sunfish	96 hours	LC_{50}: >1000 mg/L	McLaren/Hart 1995[1]
Agri-Dex	Rainbow trout	96 hours	LC_{50}: >1000 mg/L	McLaren/Hart 1995[1]
LI 700	Bluegill sunfish	96 hours	LC_{50}: 210 mg/L	McLaren/Hart 1995[1]
LI 700	Rainbow trout	96 hours	LC_{50}: 130 mg/L	McLaren/Hart 1995[1]
Geronol CF/AR (alkyl polyoxy ethylene phosphoric acid ester)	Zebra fish	96 hours	LC_{50}: >100 mg/L	MRID 44738201

[1]Except as otherwise indicated, these are unpublished studies by Monsanto summarized in McLaren/Hart 1995, p. 12-9.

A6 Table 6: Aminomethyl phosphonic acid (AMPA) degradate – Acute LC_{50}s

Material, purity	Species	Exposure	Response	Reference
AMPA, 94.38%	Rainbow trout	96 hours	LC_{50}: 499 (391 - 647) mg/L NOAEC: 174 mg/L Slope: 6.42	MRID 43334713 /1991

[1]All toxicity values given as mg/L of AMPA unless otherwise specified. Studies designated only with an MRID number are taken from Table 4.7 of U.S. EPA/OPP 2008a.

A6 Table 7: Glyphosate and Formulations – Chronic Toxicity				
Salt or Formulation	**Species**	**Exposure**	**Response**	**Reference**
Acid, technical grade	Fathead minnow	Life-cycle	NOEC: 25.7 mg/L LOEC: not determined	MRID 108171 /1975 From U.S. EPA/OPP 2008a, Appendix J, Table J-14.
Roundup (NOS)	African catfish (*Clarias gariepinus*)	70 days 0, 3.9, 5.2, 7.8, and 9.1 mg formulation/L static renewal	Increase in liver enzymes in plasma indicative of liver damage. Note: The composition of the formulation is not given. Assuming a 30% a.e., the concentrations correspond to ≈1.2, 1.6, 2.3, and 2.9 mg a.e./L.	Gabriel and George 2005
Roundup (IPA, 48% a.e.)	Nile tilapia (*Oreochromis niloticus*), 15-20 g bw, 8-10 cm 30 fish per exposure level	Duration: 3 months. 0, 5, or 15 ppm formulation 0, 2.4, 7.2 ppm a.e. Renewal every 72 hours Observations at 1, 2, 3, months of 6 fish per group.	No mortality or overt signs of toxicity in any groups. Less activity and modest reduction of growth in exposed fish. Dose-related and statistically significant decrease in plasma AST, ALT, and ALP enzyme activities. Pathology: Dose-related changes in gill, liver, and kidney consistent with tissue degeneration.	Jiraungkoorskul et al. 2003a [1] Jiraungkoorskul et al. 2003b contains a shorter summary of this study.
Glyphosate IPA salt (41%), WSC formulation from China	Topmouth gudgeon (*Pseudorasobora parva*)	65 Days 0, 1, 5, and 25 mg a.i./L [0, 0.74, 3.7, and 18.5 mg a.e./L]	No significant effect on gill ATP-ase activity. Inhibition of liver ATP-ase activity (maximum inhibition of 43%). The response is marginal, depending on the statistical method used. U.S. EPA/OPP 2008a: *Initial possible inhibition of liver esterase activity and then possible induction of enzyme activity. Not dose dependent.*	Li and Kole 2004 [1]

A6 Table 7: Glyphosate and Formulations – Chronic Toxicity				
Salt or Formulation	**Species**	**Exposure**	**Response**	**Reference**
Vision (356 g/L glyphosate acid with surfactant)	Rainbow trout	Two months: Flow-through exposures to mean measured concentrations of 0, 4.25, 8 and 45.75 µg a.e./L (ppb). p. 773 of paper indicates a.e. units clearly.	1 month: Increased frequency in wigwag (i.e., aggressive) behavior at highest concentration (42.5 µg/L). 2 months: Fish at lowest concentration (4.25 µg/L) performed significantly fewer wigwags. This effect was not seen at 42.5 µg/L. Other behaviors (lateral display and swim against mirror) not impacted. No significant changes in growth or pathology. Gill tissue normal. No significant effect on foraging. Author's discussion: The biological significance of change in wigwag behavior is not clear and the dose-response relationship is not consistent.	Morgan and Kiceniuk 1992 **Note: U.S. EPA/OPP classifies 45.75 µg/L as an LOEC and 8 µg/L as an NOEC. Given the effect at month 2 (decrease in wigwags) at 4.25 µg/L and the lack of a dose-response relationship, the significance of the behavioral effect is not clear.**

A6 Table 8: Field Studies

Species	Exposure	Response	Reference
Mixed populations in a river in Ireland	A 5 L/ha treatment with an unspecified formulation for weed control.	Anecdotal reports of improved populations of brown trout and salmon.	Caffrey 1996
Mixed	Roundup, 2.88 kg a.e./ha, ground application made by 5 men in dugout canoes using knapsack sprayers in Abiala creek, Nigeria to control hyacinth infestation.	Significant ($p<0.5$) increase in fish population after treatment.	Olaleye and Akinyemiju 1996
Rainbow trout	Roundup: 2.2 kg a.e./ha, 22 kg a.e./ha, and 220 kg a.e./ha	Trout: 100% survival; short period (15 minutes) of increased swimming activity during and shortly after application; no acute manifestations of physical discomfort such as coughing or loss of equilibrium. Indigenous cutthroat trout and caddis fly larvae in pools along the stream course did not show signs of stress during the period of spraying	Hildebrand et al. 1982
Grey mullet (*Mugil cephalus*) and mud carp (*Cirrhinus molitorellai*) fish species native to China	Applications of Roundup to emergent weeds in ponds in a nature preserve in Hong Kong. Cannot estimate application rate. Spray solution contained 7,200 mg a.e./L	No fish mortality based on survival of caged fish.	Tsui and Chu 2008

Appendix 7: Toxicity to Aquatic-Phase Amphibians

All concentrations are in mg a.e./L unless otherwise specified.
MRID studies taken from U.S. EPA/OPP 2008a unless otherwise specified.

A7 Table 1: Glyphosate and Salts - Acute Toxicity

Agent	Species	Exposure	Response	Reference[1]
ACID				
Glyphosate, 96%	Australian tree frog (*Crinia insignifera*), tadpole	96 hours	LC_{50}: 103.2 (43.2 - 172.8) mg a.e./L	MRID 43839601 /1995
Glyphosate, 96%	Australian tree frog (*Crinia insignifera*), adult	96 hours	LC_{50}: 75 (60.4-92.7) mg a.e./L	MRID 43839601 /1995
Glyphosate acid	*Litoria moorei*, tadpoles	48-hours	LC_{50}: 81.2 (76.7-85.9) mg a.e./L In deionized water	Mann and Bidwell 1999
Glyphosate acid	*Litoria moorei*, tadpoles	48-hours	LC_{50}: 121 (111-133) mg a.e./L In lake water	Mann and Bidwell 1999
Glyphosate acid	*Crinia insignifera*, adult	48-hours deionized water	LC_{50}: 83.6 (67.4-103.6) mg a.e./L	Mann and Bidwell 1999
SALTS				
IPA salt	Green Frog (*Rana clamitans*)	96 hours	LC_{50}: >17.9 mg a.e./L	Howe et al. 2004 MRID 46650501 /2001
Glyphosate IPA	*Lymnodynastes dorsalis*, tadpoles	48-hours, deionized water	> 400 mg a.e./L	Mann and Bidwell 1999
Glyphosate IPA	*Litoria moorei*, tadpoles	48-hours, deionized water	> 343 mg a.e./L	Mann and Bidwell 1999
Glyphosate IPA	*Crinia insignifera*, tadpole	48-hours, deionized water	> 466 mg a.e./L	Mann and Bidwell 1999

[1] Studies with only MRID designations are taken from Table 4.10 of U.S. EPA/OPP 2008a.

A7 Table 2: Glyphosate Formulations - Acute Toxicity				
Formulation	**Species**	**Exposure**	**Response**	**Reference**
Glyfos (48% IPA and 15% POEA) []	*Scinax nasicus* tadpoles, Gosner stages 25-26, prometamorphic	96 hours	LC_{50}: 2.64 (2.16-2.84) mg form./L or about 0.94 mg a.e./L Various malformations noted in surviving tadpoles: facial, ocular, and bent tails.	Lajmanovich et al. 2003
Glyphos (48% IPA with POEA) Note: This does not correspond to the Glyphos formulations in Table 2	South American Hylidae frog (*Scinax nasicus*), Gosner stage 18-24.	96 hours	Reported LC_{50} :2.64 (2.19-2.84) mg formulation/L Calc. LC_{50} values: 0.94 (0.77-1.0) mg a.e./L Dose-related increase in larval malformations in surviving organisms.	Lajmaovich et al. 2003
Glyfos AU with 3-7% POEA	Green Frog (*Rana clamitans*)	96 hours	LC_{50}: 8.9 (8.6-9.2) mg a.e./L or 28.6 mg formulation/L	Howe et al. 2004 MRID 46650501 /2001 study
Glyfos BIO with 3-7% POEA	Green Frog (*Rana clamitans*)	96 hours	LC_{50}: >17.9 mg a.e./L or >57.7 mg formulation/L	Howe et al. 2004 MRID 46650501 /2001 study
Glyphos with Cosmo-Flux	*Dendrosophus microcephalus*, Gosner stages 10-11	96 hours	LC_{50}: 1.2 mg a.e./L LC_1: N/A	Bernal et al. 2009a
Glyphos with Cosmo-Flux	*Rhillella typhollius*, Gosner stage 25	96 hours	LC_{50}: 1.5 mg a.e./L LC_1: N/A	Bernal et al. 2009a
Glyphos with Cosmo-Flux	*Scinax ruber*, Gosner stage 25	96 hours	LC_{50}: 1.6 (1.5-1.8) mg a.e./L Values rounded to significant 2 digits from Table 3. LC_1: 1.1 mg a.e./L $LC_{50} \div LC_1 = 1.5$	Bernal et al. 2009a
Glyphos with Cosmo-Flux	*Hypsiboas crepitans*, Gosner stages 10-11	96 hours	LC_{50}: 2.1 (1.8-2.3) mg a.e./L Values rounded to significant 2 digits from Table 3 in paper. LC_1: 0.98 mg a.e./L $LC_{50} \div LC_1 = 2.1$	Bernal et al. 2009a
Glyphos with Cosmo-Flux	*Rhinella granulosa*, Gosner stages 10-11	96 hours	LC_{50}: 2.4 (2.1-2.6) mg a.e./L Values rounded to significant 2 digits from Table 3 in paper. LC_1: 1.3 mg a.e./L $LC_{50} \div LC_1 = 1.8$	Bernal et al. 2009a
Glyphos with Cosmo-Flux	*Celltrolene prosobiepon*, Gosner stages 10-11	96 hours	LC_{50}: 2.4 mg a.e./L Values rounded to significant 2 digits from Table 3 in paper. LC_1: 1.1 mg a.e./L $LC_{50} \div LC_1 = 2.2$	Bernal et al. 2009a
Glyphos with Cosmo-Flux	*Rhinella marilla*, Gosner stages 10-11	96 hours	LC_{50}: 2.7 (2.5-3.0) mg a.e./L Values rounded to significant 2 digits from Table 3 in paper. LC_1: 1.6 mg a.e./L $LC_{50} \div LC_1 = 1.7$	Bernal et al. 2009a

A7 Table 2: Glyphosate Formulations - Acute Toxicity

Formulation	Species	Exposure	Response	Reference
Glyphos with Cosmo-Flux	*Engystomops pustulosus*, Gosner stages 10-11	96 hours	LC_{50}: 2.8 (2.5-3.1) mg a.e./L Values rounded to significant 2 digits from Table 3 in paper. LC_1: 1.5 mg a.e./L $LC_{50} \div LC_1 = 1.9$	Bernal et al. 2009a
Glyphosate IPA, 0.0205%, with Cosmo Flux surfactant	African clawed frog *(Xenopus laevis*) Larvae	96 hours	LC_{50}: 1.3 (0.92 - 1.8) mg a.e./L or 16 mg form./L NOAEL: 0.43 mg a.e./L	MRID 46873602 /2006
Glyphosate IPA, 10%, with Geronol CF/AR surfactant	Common froglet (*Ranidella signifera*), tadpole	96 hours	LC_{50}: >100 a.e. mg/L or >1000 mg formulation/L The highest concentration was an NOEC.	MRID 44738201/1996 in U.S. EPA/OPP 2008a
Glyphosate IPA, 36%, with Geronol CF/AR surfactant	Common froglet (*Ranidella signifera*), tadpole	96 hours	LC_{50}: >360 mg a.e. /L or >1000 mg formulation/L The highest concentration was an NOEC.	MRID 44738201/1996 in U.S. EPA/OPP 2008a
Glyphosate IPA, 45%, with Geronol CF/AR surfactant	Common froglet (*Ranidella signifera*). Tadpole	96 hours	LC_{50}: >450 mg a.e. /L or >1000 mg formulation/L The highest concentration was an NOEC.	MRID 44738201/1996 in U.S. EPA/OPP 2008a
Roundup Biactive with 10-20% surfactant NOS	Green frog (*Rana clamitans*)	96 hours	LC_{50}: >17.9 mg a.e./L or > 57.7 mg formulation/L	Howe et al. 2004 MRID 46650501 /2001 study
Roundup Biactive, 36%	Common froglet (*Ranidella signifera*), tadpole	96 hours	LC_{50}: >360 mg/L or >1000 mg formulation/L	Howe et al. 2004 MRID 46650501 /1996 study
Roundup Biactive, alkylpolysac-charide and POEA (MON 77920)	*Lymnodynastes dorsalis*, tadpole	48 hours	LC_{50}: >400 mg a.e./L	Mann and Bidwell 1999
Roundup Biactive, alkylpolysac-charide and POEA (MON 77920)	*Litoria moorei*, tadpole	48 hours	LC_{50}: 328 (296-263) mg a.e./L	Mann and Bidwell 1999
Roundup Biactive, alkylpolysac-charide and POEA (MON 77920)	*Heleiopo eyrei*, tadpole	48 hours	LC_{50}: >427 mg a.e./L	Mann and Bidwell 1999

A7 Table 2: Glyphosate Formulations - Acute Toxicity

Formulation	Species	Exposure	Response	Reference
Roundup Biactive, alkylpolysac-charide and POEA (MON 77920)	*Crinia insignifera*, tadpole	48 hours	LC_{50}: >494 mg a.e./L	Mann and Bidwell 1999
Rodeo (480 g a.e./L no surfactant)	African clawed frog (*Xenopus laevis*), embryos	96 hour static renewal, pH 7.6	LC_{50}: 7297 (7048-7542) mg a.e./L LC_5: 5516 mg a.e./L Ratio: 1.3 Slope: 13.5 No significant increase in malformations.	Perkins et al. 2000
Rodeo (480 g a.e./L no surfactant)	African clawed frog (*Xenopus laevis*), embryos	96-hours, pH 7.6 to 7.9	LC_{50}: 9870 mg a.e./L LC_5: 3580 mg a.e./L Ratio: 2.8 Slope: 3.7 No significant increase in malformations.	Perkins 1997
Rodeo, 480 g a.e./L)	African clawed frog (*Xenopus laevis*), embryos, Gosner Stg 8-10	96 hour static renewal	Assay Type / pH / 96-h LC_{50} mg ae/L: CCRD[a] / 6.5 / 4341.6 (4012.6-4758.6) / 8.0 / 645.2 (248.3-835.2) Factorial / 6.5 / 6419.0 (5083.4-9099.0) / 8.0 / 604.3 (322.9-812.1) [a] CCRD: Central composite rotatable design.	Edginton et al. 2004b
Roundup (356 g a.e./L with POEA surfactant)	African clawed frog (*Xenopus laevis*), embryos	96-hours	LC_{50}: 22 mg a.e./L LC_5: 6 mg a.e./L Ratio: 3.7 Slope: 2.8 No significant increase in malformations.	Perkins 1997
Glyphosate IPA (Roundup Original with 15% POEA)	Green Frog (*Rana clamitans*) Gosner Stg 25	96-hours	LC_{50}: 2 (1.9-2.2) mg a.e./L or 6.5 mg form./L	Howe et al. 2004 MRID 46650501 /2001 study
Roundup 360, 30.3 % a.i.	Australian tree frog (*Litoria moorei*)	96 hours	LC_{50}: 5.6 (4.4 - 7.1) mg a.e./L or 18.5 mg formulation/L	Howe et al. 2004 MRID 46650501 /1995 study
Roundup 360, 30.3%	Australian frog (*Crinia insignifera*), adult	48 hours	LC_{50}: 30.4 mg a.e./L or 100.2 mg formulation/L	Howe et al. 2004 MRID 46650501 /1995 study

A7 Table 2: Glyphosate Formulations - Acute Toxicity

Formulation	Species	Exposure	Response	Reference
Roundup 360, 30.3%	Australian frog (*Crinia insignifera*), tadpole	48 hours	LC_{50}: 38.2 (30.2 - 48.8) mg a.e./L or 125.9 mg formulation/L	Howe et al. 2004 MRID 46650501 /1996 study
Roundup Original Max (48.7% a.i. with a surfactant NOS)	13 species of amphibian larvae (see column 4)	96 hours	Species / LC_{50} (mg a.e./L): Wood frog 1.9; Leopard frog 1.5; Cascades frog 1.7; Green frog 1.4; American bullfrog 0.8; American toad 1.6; Western toad 2.0; Gray tree frog 1.7; Spring peeper 0.8; N.W. salamander 2.8; Spotted salamander 2.8; Blue-spotted salam. 3.2; Red-spotted salam. 2.7. Note: LC_{10} values also given in Table 2 of publication. For all but one species, the ratio of the LC_{50} to the LC_{10} is in the range of 1.2 to 1.6. The only exception is the Spring peeper for which the ratio is 8.	Relyea and Jones 2009
Roundup Original with 15% POEA	Leopard Frog (*Rana pipiens*)	96 hours	LC_{50}: 2.9 mg a.e./L or 9.2 mg formulation/L	Howe et al. 2004 MRID 46650501 /2000 study
Roundup Original with 15% POEA	American toad (*Bufo americanus*)	96 hours	LC_{50}: <4.0 mg a.e./L or < 12.9 mg formulation/L	Howe et al. 2004 MRID 46650501 /1994 study
Roundup Original with 15% POEA	Leopard Frog (*Rana pipiens*)	96 hours	LC_{50}: 6.5 (6.1-6.8) mg a.e./L or 20.9 mg formulation/L	Howe et al. 2004 MRID 46650501 /1994 study
Roundup Original with 15% POEA	Green frog (*Rana clamitans*)	96 hours	LC_{50}: 7.1 (6.6-7.6) or 22.8 mg formulation/L	Howe et al. 2004 MRID 46650501 /1994 study
Roundup Original with 15% POEA	American toad (*Bufo americanus*)	96 hours	LC_{50}: 8 mg a.e./L or 25.8 mg formulation/L	Howe et al. 2004 MRID 46650501 /1994 study

A7 Table 2: Glyphosate Formulations - Acute Toxicity

Formulation	Species	Exposure	Response	Reference
Roundup Original with 15% POEA	Wood Frog (*Rana sylvatica*)	96 hours	LC_{50}: > 8 mg a.e./L or 25.8 mg formulation/L	Howe et al. 2004 MRID 46650501 /1994 study
Roundup Transorb with 15% POEA	Green Frog (*Rana clamitans*)	96 hours	LC_{50}: 2.2 (2.12.4) mg a.e./L or 7.2 mg formulation/L	Howe et al. 2004 MRID 46650501 /2001 study
Roundup with 15% POEA	Wood Frog (*Rana sylvatica*)	96 hours	LC_{50}: 5.1 (4.9-5.4) mg a.e./L or 16.5 mg formulation/L	Howe et al. 2004 MRID 46650501 /1994 study
Roundup with POEA surfactant (MON 2139)	*Lymnodynastes dorsalis*, tadpole	48 hours	LC_{50}: 3.0 (2.8-3.2) mg a.e./L	Mann and Bidwell 1999
Roundup with POEA surfactant (MON 2139)	*Litoria moorei*, tadpole	48 hours	LC_{50}: 2.9 (2.6-3.2) mg a.e./L	Mann and Bidwell 1999
Roundup with POEA surfactant (MON 2139)	*Litoria moorei*, tadpole	48 hours	LC_{50}: 12.7 (9.0-18.0) mg a.e./L	Mann and Bidwell 1999
Roundup with POEA surfactant (MON 2139)	*Heleiopo eyrei*, tadpole	48 hours	LC_{50}: 8.6 (7.8-9.5) mg a.e./L	Mann and Bidwell 1999
Roundup with POEA surfactant (MON 2139)	*Crinia insignifera*, tadpole	48 hours	LC_{50}: 3.6 (3.3-4.1) mg a.e./L	Mann and Bidwell 1999
Roundup with POEA surfactant (MON 2139)	*Crinia insignifera*, metamorph	48 hours	LC_{50}: 51.8 (42.1-63.8) mg a.e./L	Mann and Bidwell 1999
Roundup with POEA surfactant (MON 2139)	*Crinia insignifera*, adult	48 hours	LC_{50}: 49.4 (40.5-60.2) mg a.e./L	Mann and Bidwell 1999
Roundup (356 g a.e./L with POEA	African clawed frog (*Xenopus laevis*), embryos	96 hour static renewal	LC_{50}: 9.3 (9.1-9.6) mg a.e./L LC_5: 7.7 mg a.e./L Ratio: 1.2 Slope: 18.9 No significant increase in malformations.	Perkins et al. 2000
Vision (356 mg a.e./L with MON 0818 15%)	*Rana clamitans*, Gosner stages 8-12	96 hours, Site 1	LC_{50}: 4.34 (3.05-6.02) mg a.e./L LC_{10}: 1.78 (0.99-2.86)mg a.e./L Ratio: 2.4	Wojtaszek et al. 2004

A7 Table 2: Glyphosate Formulations - Acute Toxicity

Formulation	Species	Exposure	Response	Reference
Vision (356 mg a.e./L with MON 0818 15%)	*Rana clamitans* Gosner stages 8-12	96 hours, Site 2	LC_{50}: 2.70 (2.06-3.67) mg a.e./L LC_{10}: 1.20 (0.84-1.60) mg a.e./L Ratio: 2.25	Wojtaszek et al. 2004
Vision (356 mg a.e./L with MON 0818 15%)	*Rana pipiens* Gosner stages 21-24	96 hours, Site 1	LC_{50}: 11.47 (9.50-14.5) mg a.e./L LC_{10}: 7.31 (3.83-9.54) mg a.e./L Ratio: 1.6	Wojtaszek et al. 2004
Vision (356 mg a.e./L with MON 0818 15%)	*Rana pipiens* Gosner stages 21-24	96 hours, Site 2	LC_{50}: 4.25 (2.45-7.10) mg a.e./L LC_{10}: 3.26 (1.66-3.61) mg a.e./L Ratio: 1.3	Wojtaszek et al. 2004
Vision, 356 g a.e./L, 15% IPA w/w, (15% POEA surfactant)	*Xenopus laevis*, African clawed frog Embryo (Em), Gosner 8 to 25; Larva (Lv). Gosner 25	96 hours	Stage / pH / 96-hour LC_{50} mg a.e./L Em / 6 / 15.6 (12.7 - 23.0) Em / 7.5 / 7.9 (7.2 - 8.7) Lv / 6 / 2.1 (2.0 -2.7) Lv / 7.5 / 0.88 (0.84 - 0.92) Growth inhibition in surviving frogs.	Edginton et al. 2004a
Vision, 356 g a.e./L, 15% IPA w/w, (15% POEA surfactant)	*Bufo americanus*, American toad Embryo (Em), Gosner 8 to Gosner 25; Larva (Lv). Gosner 25	96 hours	Stage / pH / 96-hour LC_{50} mg ae/L Em / 6 / 4.8 (4.0 - 5.7) Em / 7.5 / 6.4 (5.8 - 7.0) Lv / 6 / 2.9 (2.3 -10.5) Lv / 7.5 / 1.7 (1.5 - 1.9) No growth inhibition	Edginton et al. 2004a
Vision, 356 g a.e./L, 15% IPA w/w, (15% POEA surfactant)	*Rana clamitans*, Green frog Embryo (Em), Gosner 8 to Gosner 25; Larva (Lv). Gosner 25	96 hours	Stage / pH / 96-hour LC_{50} mg ae/L Em / 6 / 5.3 (3.9 - 9.2) Em / 7.5 / 4.1 (3.4 -6.4) Lv / 6 / 3.5 (3.0 - 4.6) Lv / 7.5 / 1.4(1.2-1.7) Growth inhibition in surviving frogs.	Edginton et al. 2004a
Vision, 356 g a.e./L, 15% IPA w/w, (15% POEA surfactant)	*Rana pipiens*, Leopard frog Embryo (Em), Gosner 8 to Gosner 25; Larva (Lv). Gosner 25	96 hours	Stage / pH / 96-hour LC_{50} mg ae/L Em / 6 / 15.1 (14.0-17.5) Em / 7.5 / 7.5 (7.0-9.0) Lv / 6 / 1.8 (1.5-2.2) Lv / 7.5 / 1.1(0.96-1.14) Growth inhibition in surviving frogs.	Edginton et al. 2004a
Vision, 356 g a.e./L, 15% IPA w/w, (15% POEA surfactant)	African clawed frog (*Xenopus laevis*), embryos, Gosner Stg 8-10	96 hour static renewal	Assay Type / pH / 96-h LC_{50} mg ae/L CCRD[a] / 6.5 / 11.8 (10.4-14.5) / 8.0 / 6.9 (6.3-7.6) Factorial / 6.5 / 13.9 (10.6-27.2) / 8.0 / 6.9 (5.9-7.9) [a] CCRD: Central composite rotatable design.	Edginton et al. 2004b

[1] Studies with only MRID designations are taken from Table 4.11 or Appendix J, Table J-6 of U.S. EPA/OPP 2008a. All formulations designated as Roundup contain the IPA salt unless otherwise specified.

A7 Table 3: Surfactants Used with Glyphosate – Acute LC_{50}s

Surfactant	Species	Exposure	Response [1]	Reference
POEA or MON 0818, 69-73%	Green Frog (*Rana clamitans*) Gosner Stg 25	96 hours	LC_{50}: 1.1 (1.0-1.1) mg surfactant/L.	Howe et al. 2004 MRID 46650501 /2001 study
POEA[2]	African clawed frog (*Xenopus laevis*), embryos	96 hour static renewal	LC_{50}: 6.8 (6.6-6.9) mg/L $LC_{5:}$ 5.8 (5.5-6.0) mg/L Ratio: 1.2 Slope: 23.8	Perkins et al. 2000
POEA[2]	African clawed frog (*Xenopus laevis*), embryos	96 hour static renewal	LC_{50}: 5 mg/L $LC_{5:}$ 2 mg/L Ratio: 2.5 Slope: 3.8	Perkins 1997
MON 0818	African clawed frog (*Xenopus laevis*), embryos, Gosner Stg 8-10	96 hour static renewal	Assay Type / pH / 96-h LC_{50} mg ae/L: CCRD[a] / 6.5 / 3.9 (3.4 - 4.8) CCRD[a] / 8.0 / 1.5 (1.2 - 1.8) Factorial / 6.5 / 3.0 (2.5 - 3.9) Factorial / 8.0 / 1.4 (1.1 – 1.7) [a] CCRD: Central composite rotatable design.	Edginton et al. 2004b

[1] All toxicity values given as mg/L of surfactant. Studies designated only with an MRID number are also summarized in Table 4.6 of U.S. EPA/OPP 2008a.

[2] The description of POEA in Perkins (1997, p.28) and Perkins et al. (2000) suggests that the author are referring to MON 0818 rather than to the POEA in MON 0818.

A7 Table 4: Other Acute Toxicity Studies

Agent	Species	Exposure	Response [1]	Reference
Vision (glyphosate IPA with contains POEA surfactant)	Green frog (*Rana pipiens*), Gosner stage 25 tadpoles	24 hour static renewal for 10 days. Acclimation at pH 6.8 but testing at pH 5.5 or 7.5. Concentration of 0.75 ppm or 1.5 ppm	0.75 mg a.e./L Substantial decrease in survival at pH 7.5 – 100% in controls vs 70% in exposed. A lesser effect (relative to controls) at pH 5.5 – 80% in controls and 70% in exposed. Substantially higher mortality at 1.5 mg a.e./L Units are clearly in mg a.e. (p. 825, column 1)	Chen et al. 2004
Roundup Original, 41% IPA	Bullfrog (*Lithobates catesbeiana*) tadpoles, Gosner stage 25	1 ppm of formulation ≈ 0.33 mg a.e./L	Adverse effect on cardiac function. No mortality.	Costa et al. 2008
Kleeraway Grass and Weed Killer RTU (IPA 0.75%, surfactant – ethoxylated tallowamine)	Western chorus frog (*Pseudacris triseriata*), tadpoles Gosner stage 25	Formulation proportions of 0.0001, 0.001, 0.01 and 0.1 for 24 hours. Note: 0.1 = 555 ppm a.e.	No survivors at three highest concentrations and only 45% survivors at the lowest concentration. **LOAEC (45% mortality): 0.55 mg/L a.e.**	Smith 2001
Kleeraway Grass and Weed Killer RTU (IPA 0.75%, surfactant – ethoxylated tallowamine)	Plains leopard frog (*Rana blairi*), tadpoles Gosner stage 25	Formulation proportions of 0.0001, 0.001, 0.01 and 0.1 for 24 hours. Note: 0.1 = 555 ppm a.e.	Different results in two trials with survival of all animals at 0.0001 (0.056 ppm a.e.) in first trial but complete mortality at 0.0001 and higher in the second trial. **LOAEC (100% mortality in second trial): 0.55 mg/L a.e.**	Smith 2001

[1] Summarized in U.S. EPA/OPP 2008a, Table 4.15 and Appendix J, Table J-8. Summaries modified with review of original publication unless otherwise specified in Section 5 of the current Forest Service risk assessment.

A7 Table 5: Subchronic and Chronic Toxicity

Agent	Species	Exposure	Response	Reference
Technical Grade				
Technical grade glyphosate IPA	Leopard Frog (*Rana pipiens*), Gosner stage 25 larvae	42 days static renewal to 1.8 mg a.e./L.	NOAEC: >1.8 mg a.e./L. This is the highest and only level tested.	Howe et al. 2004 MRID 46650501 /2004 study
Formulations				
Roundup (25.2% IPA with surfactant)	Six species of North American tadpoles, Gosner stage 25. See column 4.	16 days. 0, 0.1, 1, 5, 10, and 20 mg a.i./L or 0, 0.1, 1, 5, 10, and 20 mg a.i./L LC_{50} for wood frog with predation by newts was 0.55 mg a.i./L. NOEC for wood frog appears to be about 0.1 mg/L (see Fig. 2 in paper)	Species: 16 d LC_{50} (mg a.i./L) Bull frog: 2.07 Green frog: 2.17 Gray tree frog: 1.35 Leopard frog: 2.46 American toad: 2.52 Wood frog: 1.32	Relyea 2005a
Roundup, 50.2% IPA	*Rana cascadae* larvae	43 days Nominal concentrations of 1 ppm and 2 ppm as glyphosate.	Concentration related decrease in survival times – i.e., about 7 days at 2 ppm and 34 days at 1 ppm relative to control of about 52 days (see paper Fig.1). Earlier metamorphosis at 1 ppm relative to controls.	Cauble and Wagner 2005
Roundup Original and Transorb 15% POEA	Leopard Frog (*Rana pipiens*), Gosner stage 25 at start of study	42 days static renewal to 0.6 mg a.e./L or 1.8 mg a.e./L. Note: Concentrations were renewed only once each week over the six week duration of exposure.	LOAEC: 0.6 mg a.e./L LOAEL based on decreased survival and length at time to metamorphosis. Changes in thyroid hormone function as well as increase in intersex gonads. Roundup Transorb may be somewhat more toxic but differences do not appear to be substantial	Howe et al. 2004 MRID 46650501 /2004 study in U.S. EPA/OPP 2008a

A7 Table 5: Subchronic and Chronic Toxicity

Agent	Species	Exposure	Response	Reference
Surfactants				
POEA or MON 0818	Leopard Frog (*Rana pipiens*), Gosner stage 25 at start of study	42 days static renewal to 0.6 mg/L or 1.8 mg/L.	NOAEC: 0.6 mg/L LOAEC: 1.8 mg/L a.e./L Changes in thyroid hormone function as well as increase in intersex gonads.	Howe et al. 2004 MRID 46650501 /2004 study from U.S. EPA/OPP 2008a

A7 Table 6: Field or Field Simulation Studies

Exposure	Response	Reference
Glyphosate (NOS) applied aerially at rate of 1.3 kg/ha in 92 L/ha water to 40- to 60-year-old hardwood stands in Oregon during the slate summer	No direct effect ($p>0.14$) on the six sampled species of amphibians.	Cole et al. 1997
Small ponds on jack pine plantations following aerial sprays of Vision (41% IPA formulation) at rates of 1.44 or 1.8 kg a.e./acre or two applications, one at 1.44 and the other at 1.88 kg a.e./acre	Smaller post-hatch lengths and juvenile lengths from egg masses taken from glyphosate treated sites. Also an increase (1024%) in the frequency of post-hatch (Gosner stage 21) deformities when all Vision treatments were compared to eggs from ponds not treated with Vision. No dose-response relationship, however, for the three Vision treatments. No increases in pre-metamorphic (about Gosner Stage 34) or juvenile deformities. No data on concentration of glyphosate in ponds. Not clear that ponds were directly sprayed.	Glaser 1998
Rough-skinned newt (n=7) dosed with gyphosate at 50 mg/kg (glyphosate IPA) by intraperitoneal injection and fitted with radio-transmitter. Movement and survival compared to control animals (n=10)	No effect on range of movement within release area. Mortality in treated animals less than controls although the difference is not statistically significant.	McComb et al. 2008
Aquatic mesocosm Roundup with POEA surfactant. Nominal initial concentration of 3.5 mg a.i./L (2.6 mg a.e./L) with an observation period of 13 days	Generally poor survival in control and exposed frogs. Nonetheless, mortality in wood, leopard and green frogs exposed to Roundup was significantly greater than controls. See U.S. EPA/OPP 2008a, p. 102 for further discussion: *…relatively high mortality rate with control tadpole species was likely due to predation from spotted salamanders and predacious beetles…red-spotted salamanders were not affected*	Relyea 2005b
Aquatic mesocosm. Roundup (Weed and Grass Killer, 25.2% active ingredient plus POEA surfactant) at a simulated application rate of 1.6 mg a.i./m^2 – i.e., 16 kg a.i./ha or ≈14 lb a.i./acre – with an observation period of 20 days .	The nominal concentration in water was 3.8 mg a.i./L or about 2.8 mg a.e./L. Decreased survival in tree frog, toads, and leopard frogs with or without sand or loam sediment. Discussed by U.S. EPA/OPP 2008a, p. 103	Relyea 2005c

A7 Table 6: Field or Field Simulation Studies

Exposure	Response	Reference
Aquatic mesocosm: tadpoles of leopard frog, gray tree frog and the American toad with and without predators (red-spotted newt or Dytiscus beetles) Roundup, 13% a.i. glyphosate formulation with POEA surfactant for 23 days. Approximate glyphosate concentration of 1.3 mg/L.	Decrease in biomass and numbers of surviving tadpoles. No effect on newts. See U.S. EPA/OPP 2008a, p. 104: *The study design is not sufficient to determine whether the decreased survival/biomass associated with exposure to Roundup is due to glyphosate or to some other component of the formulated product. While the study authors speculate on the potential role of the surfactant, polyethoxylated tallowamine (POEA), in causing the observed effects on anuran larvae, the study does not test this potential relationship*.	Relyea et al. 2005
Glyphosate acid at 6.9 ppb (µg/L) with or without low concentrations of 4 other herbicides. Gray tree frogs, (*Hyla versicolor*) and leopard frogs (*Rana pipiens*)	No impact on mortality or growth from glyphosate alone or from a combined exposure to glyphosate with acetochlor, metolachlor, 2,4-D, and atrazine	Relyea 2009
Field study of 51 wetland areas in Ontario, Canada Roundup Original (glyphosate formulation with MON0818 surfactant). Areas over-sprayed, adjacent, or buffered in relation to the operational target spray blocks. Application rates varied from 1.07 to 1.92 kg a.e./ha (≈1 to 1.7 lb a.e./acre)	No significant effect on *in situ* leopard frog and green frog larvae. Average concentration in over-sprayed areas was 0.33 mg a.e./L. This study is discussed in U.S. EPA/OPP 2008a, p. 104.	Thompson et al. 2004
In situ enclosures in two forest wetland sites in Ontario. [See Table 2 of this appendix for acute lethality data]. Vision formulations applied at concentrations of 0.29 to 14.3 mg a.e./L	No effects on growth, mortality, or avoidance responses at 1.43 mg a.e./L.	Wojtaszek et al. 2004

Appendix 8: Toxicity to Aquatic Invertebrates

All concentrations are in mg a.e./L unless otherwise specified.

A8 Table 1: Glyphosate Acid or Salts – LC_{50}s

Salt/Acid	Species	Exposure	Response	Reference [1]
Acid	Mussel (*Lampsilis siliquoidea)*	48hours 96 hours	Larvae LC_{50}: >200 mg/L Juvenile LC_{50}: >200 mg/L	Bringolf et al. 2007
Glyphosate IPA	Mussel (*Lampsilis siliquoidea*)	48hours 96 hours	Larvae LC_{50}: 5.0 mg/L Juvenile LC_{50}:7.2 mg/L	Bringolf et al. 2007
Isopropanol amine only, no glyphosate	Mussel (*Lampsilis siliquoidea*)	48hours 96 hours	Larvae LC_{50}: 4.6 mg/L Juvenile LC_{50}:6.3 mg/L	Bringolf et al. 2007
Acid, 96.7%	Midge (*Chironomus plumosus*)	48-hours	Folmar paper LC_{50}: 55 (31-97) mg/L U.S. EPA/OPP 2008a LC_{50}: 53.2 (30.0 - 93.8) mg a.e./L [corrected for compound purity]	Folmar et al. 1979 MRID 162296[2]
Acid, 83%	*Daphnia magna*	48-hours	U.S. EPA/OPP 2008a EC50: 647.4 (577.7 - 725.4) mg a.e./L NOAEC: 464.8 mg a.e./L Note: The above values are corrected for compound purity. The following values are not. EPA DER Author's Results EC_{50}: 780 (696-874) mg a.e./L NOAEC: 560 mg a.e./L, no mortality. EPA Reanalysis (Probit) EC_{50}: 760 (741-780) mg a.e./L	McAllister and Forbes 1978b, MRID 00108172 This study is cited on several MSDSs.
Acid, 95.6%	*Daphnia magna*	48-hours	EC_{50}: 128.1 (95.6 - 172.1) mg a.e./L NOAEC: 95.6 mg a.e./L	MRID 44320631 /1995
Glyphosate, NOS	*Daphnia magna*	48 hours	LC_{50}: >2000 mg/L	Pereira et al. 2009

A8 Table 1: Glyphosate Acid or Salts – LC_{50}s				
Salt/Acid	Species	Exposure	Response	Reference [1]
Glyphosate acid	*Ceriodaphnia dubia*	48 hours	LC_{50}: 147 mg a.e./L	Tsui and Chu 2003
Glyphosate acid	Copepod *Acartai tonsa*	48 hours	LC_{50}: 35.3 mg a.e./L	Tsui and Chu 2003
Glyphosate IPA salt	*Ceriodaphnia dubia*	48 hours	LC_{50}: 415 mg a.e./L	Tsui and Chu 2003
Glyphosate IPA salt	Copepod *Acartai tonsa*	48 hours	LC_{50}: 49.3mg a.e./L	Tsui and Chu 2003

[1] Studies designated only with an MRID number are taken from Table 4.16 of U.S. EPA/OPP 2008a.
[2] Note on Folmar et al. 1979: U.S. EPA/OPP 2008a summarizes several data points from Folmar et al. 1979 as 00162296/1979. For glyphosate, the EPA report states that purity of the test material was 96.7%. The 96.7% purity is not reported in Folmar et al. 1979. Consequently, the entries for the Folmar study present both the data given in the publication and the data from U.S. EPA/OPP 2008a.

A8 Table 2: Glyphosate Formulations – LC_{50}s				
Formulation, % a.i.	**Species**	**Exposure**	**Response**	**Reference [1]**
Roundup (35.6% a.e. of the IPA salt) Note: The 35.6% value in paper may refer to 356 g/L (w/v).	Crawfish (*Procambarus* sp.)	48 hours	LC_{50}: 21,633 mg a.e./L	Abdelghani et al. 1997
RON-DO (48% IPA with 15% oxide-coco-amide-propyl dimethyl-amine surfactant)	*Daphnia magna*	48 hours	LC_{50}: 61.72 mg IPA/L LC_{50}: ≈46 mg a.e./L	Alberdi et al. 1996
RON-DO (48% IPA with 15% oxide-coco-amide-propyl dimethyl-amine surfactant)	*Daphnia spinulata*	48 hours	LC_{50}: 66.18 mg IPA/L LC_{50}: ≈49 mg a.e./L	Alberdi et al. 1996
Roundup Super Concentrate (NOS, see Table 1 of study)	Fairy Shrimp (*Thamnocephalus platyurus*)	48-hours Concentrations of 19.9, 199, 747, 1595, 4175, 19920, 199200 µg/L for 48 hours. Not clear if these concentrations apply to a.e., a.i., or formulation.	LC_{50}: 1243.38 µg /L Working Note: If the units apply to µg form/L and if the formulation was a 41% IPA salt of glyphosate, the LC50 would be about 0.377 mg a.e./L. This would be the lowest LC_{50} for an invertebrate. The paper, however, is not clear. See Section 4.1.3.3.2.2 for discussion.	Brausch et al. 2006
Aqua Star, 53.8% IPA (no surfactant)	Mussel (*Lampsilis siliquoidea*)	48hours 96 hours	Larvae LC_{50}: >148 mg a.e./L Juvenile LC_{50}:>148 mg a.e./L	Bringolf et al. 2007

A8 Table 2: Glyphosate Formulations – LC_{50}s

Formulation, % a.i.	Species	Exposure	Response	Reference [1]
Roundup Ultramax, 50.2% IPA	Mussel (*Lampsilis siliquoidea*)	48hours 96 hours	Larvae LC_{50}: 2.9 mg a.e./L Juvenile LC_{50}: 5.9 mg a.e./L	Bringolf et al. 2007
Rodeo (53.5% a.i.)	Midge (*Chironomus riparius*)	48 hours	LC_{50}: 5600 (4690-6690) mg a.i./L. Corresponds to ≈ 4140 (3470-4950) mg a.e./L	Buhl and Faerber 1989
Roundup, 18% IPA salt	Mussel (*Utterbackia imbecillis*), larvae	24 hours	LC_{50}: >18.3 mg a.i./L or 13.5 mg a.e./L.	Conners and Black 2004
Glyphosate IPA (MON 77360), 30% a.i. DER indicates a 30% a.e. formulation.	*Daphnia magna*	48-hours	U.S. EPA/OPP 2008a EC_{50}: 3.2 (2.9 - 3.7) mg a.e./L NOAEC: 0.8 mg a.e./L EPA DER EC_{50}: 10.5 (9.5-12.2) mg form./L	Drottar and Krueger 2000c MRID 45365004
Glyphosate IPA, 30.3%	Scud (*Gammarus pseudolimnaeus*)	96 hours	48 h LC_{50}: 62 (40-98) mg a.e./L 96 h LC_{50}: 43 (28 - 66) mg a.e./L	Folmar et al. 1979, Table 1[2]
Roundup, 30.3%, with POEA surfactant	*Daphnia magna*	48-hours	EC_{50}: 3.0 (2.6-3.4) mg a.e./L	Folmar et al. 1979, Table 1[2]
Roundup, 30.3%, with POEA surfactant	Midge (*Chironomus plumosus*)	48-hours	LC_{50}: 18 (9.4-32) mg a.e./L	Folmar et al. 1979, Table 1[2]
Roundup (41% a.i.)	*Daphnia pulex*	48 Hours	Effect of sediment on toxicity. LC_{50}: 7.9 (7.2-8.6) mg a.i./L with no sediment. Equivalent to ≈5.85 mg a.e./L. LC_{50}: 3.2 (3.0-3.4) mg a.i./L with sediment. Equivalent to ≈2.4 mg a.e./L.	Hartman and Martin 1984
Rodeo (53.5% a.i.)	Amphipod *Hyalella azteca*	96 hours	LC_{50}: 720 (399-1076) mg form/L LC_{50}: ≈ 385 mg a.e./L	Henry et al. 1994
Rodeo (53.5% a.i.)	*Daphnia magna*	48 hours	LC_{50}: 218 (150-287) mg form/L	Henry et al. 1994
Rodeo (53.5% a.i.)	Leech *Nephelopsis obscura*	96 hours	LC_{50}: 1,177 (941-1,415) mg form/L LC_{50}: ≈ 630 mg a.e./L	Henry et al. 1994
Rodeo (53.5% a.i.)	Midge *Chironomus riparius*	96 hours	LC_{50}: 1,216 (996-1566) mg form/L LC_{50}: ≈ 650 mg a.e./L	Henry et al. 1994

A8 Table 2: Glyphosate Formulations – LC_{50}s

Formulation, % a.i.	Species	Exposure	Response	Reference [1]
Roundup (1.5 lb/gal., Soluble Liquid)	Crawfish *Procambarus clarkii*	96 hours	LC_{50}: 47.3 (41.1-51.7) mg form/L Cannot convert to a.e.	Holck and Meek 1987
Roundup (1.5 lb/gal., Soluble Liquid, 20.5% a.i.?)	Mosquito, *Anopheles quadrimaculatus*	96 hours	LC_{50}: 673 (573-770) mg form/L Cannot convert to a.e.	Holck and Meek 1987
Roundup (1.5 lb/gal., Soluble Liquid)	Mosquito, *Psorophora columbiae*	96 hours	LC_{50}: 940.84 (823-1067) mg form/L Cannot convert to a.e.	Holck and Meek 1987
Roundup (1.5 lb/gal., Soluble Liquid)	Mosquito, *Culex salinarius*	96 hours	LC_{50}: 1563 (1262-2215) mg form/L Cannot convert to a.e.	Holck and Meek 1987
GF-1280 (50.2%, DMA)	*Daphnia magna*	48 hours, static	LC_{50}: 50 (37-79) mg form/L LC_{50}: ≈25 mg a.e./L	Hughes 2006c
Roundup, 41.36%	*Daphnia magna*	48-hours	U.S. EPA/OPP 2008a EC_{50}: 1.6 (1.4 - 1.9) mg a.e./L NOAEC: 0.6 mg a.e./L Slope: 5.4 EPA DER EC_{50}: 5.3 (4.4 - 6.3) mg form./L	LeBlanc et al. 1980b MRID 70893
Roundup, 360 g/L	Copepod, Harpacticoid	96 hours, static	LC_{50}: 22 (17-29) mg/L Units probably formulation. Cannot be certail.	Linden et al. 1979
Glyphosate IPA, 48% (MON 2139)	*Daphnia magna*	48-hours	EC_{50}: 68.3 (64.3 - 72.8.) mg a.e./L NOAEC: <21.3 mg a.e./L	MRID 108109 /1973
Roundup 31%	Scud (*Gammarus pseudolimnaeus*)	48-hours	LC_{50}: 13 (9.6 - 19.2) mg a.e./L NOAEC: 1.4 mg a.e./L Slope: 2.33	MRID 124762
Roundup 30.3%	Crayfish (*Orconectes nais*)	48-hours	LC_{50}: 5.2 (4.1 - 6.4) mg a.e./L	MRID 40098001
Glyphosate (80WDG formulation), 80%	*Daphnia magna*	48-hours	EC_{50}: >17.6 mg a.e./L	MRID 44125706 /1996
Glyphosate IPA (Roundup), 30.3 %	*Daphnia pulex*	48-hours	EC_{50}: 5.8 (5.3 - 6.4) mg a.e./L	MRID 44125714 /1984
Glyphosate IPA (MON65005)	*Daphnia magna*	48-hours	EC_{50}: 2.7 (2.3 - 3.1) mg a.e./L NOAEC: 1.3 mg a.e./L Slope: 6.2	MRID 44538201 /1998

A8 Table 2: Glyphosate Formulations – LC_{50}s

Formulation, % a.i.	Species	Exposure	Response	Reference [1]
Glyphosate IPA, 46% (MON77945 Manufacturing concentrate)	*Daphnia magna*	48-hours	EC_{50}: 833 (665 - 1253) mg a.e./L NOAEC: 204 mg a.e./L Slope: 3.7	MRID 44715410 /1998
Glyphosate IPA, 36%, with surfactant Geronol CF/AR	*Daphnia magna*	48-hours	EC_{50}: 220 (194 – 252) mg a.e./L or 610 (540 - 700) mg formulation/L NOAEC: 49 or 135 mg formulation/L	MRID 44738201
Glyphosate IPA, 10 % with surfactant Geronol CF/AR	*Daphnia magna*	48-hours	EC_{50}: 810 (700 - 940) mg a.e./L NOAEC: 400 mg a.e./L	MRID 44738201 /1996
Glyphosate IPA, 35% (Roundup Biactive), Rhone-Poulenc Surfactant	*Daphnia magna*	48-hours	EC_{50}: 150 (151 - 179) mg a.e./L NOAEC: 45 mg a.e./L	MRID 44738201 /1996
Glyphosate IPA, 35% with surfactant Geronol CF/AR	*Daphnia magna*	48-hours	EC_{50}: 610 (540 - 700) mg a.e./L NOAEC: 135 mg a.e./L	MRID 44738201 /1996
Glyphosate IPA, 45% with surfactant Geronol CF/AR	*Daphnia magna*	48-hours	EC_{50}: 365 (315 - 420) mg a.e./L NOAEC: 190 mg a.e./L	MRID 44738201 /1996
Glyphosate monoammonium salt (MON 14420), 68.5%	*Daphnia magna*	48-hours	EC_{50}: 28.8 (12.3 - 48.5) mg a.e./L NOAEC: 12.3 mg a.e./L	MRID 45777401 /1999
Glyphosate IPA (Roundup with "W" surfactant)	*Daphnia magna*	48-hours	EC_{50}: 21.7 (18.7 - 25.0) mg a.e./L	MRID 78657 /1980
Glyphosate, 41.2% (Roundup with "AA" surfactant), (MON 2139 NF-80-AA)	*Daphnia magna*	48-hours	EC_{50}: 94.5 (76.3 - 122.0) mg a.e./L NOAEC: 17.1 mg a.e./L Slope: 3.5	MRID 78660 /1980
Glyphosate IPA, 62.4%, no surfactant	*Daphnia magna*	48-hours	EC_{50}: 401.3 (347.7 - 470.5) mg a.e./L NOAEC: 147.8 mg a.e./L Slope: 7.6	MRID 78663
Glyphosate IPA (X-77 surfactant)	*Daphnia magna*	48-hours	EC_{50}: >39 mg a.e./L NOAEC: 21.8 mg a.e./L	MRID 78666 /1980

A8 Table 2: Glyphosate Formulations – LC_{50}s

Formulation, % a.i.	Species	Exposure	Response	Reference [1]
Spasor (a Portuguese formulation, 360 g a.e./L). Only MSDS is for Spasor Biactive, an IPA salt. 41% a.i.	*Daphnia magna*	48 hours, static	LC_{50}: 307 mg/L Unit are reported as a.i. LC_{50}: ≈227 mg a.e./L assuming IPA as a.i.	Pereira et al. 2009
GF-1279, Glyphosate IPA, 53.6%.	*Daphnia magna*	48 hours, static	LC_{50}: 35.53 mg formulation/L or ≈ 19 mg a.e./L NOEC (immobility): 13 mg formulation/L or ≈ 7 mg a.e./L	Sesso 2005a
360 g/L SL formulation DER does not specify the a.i. DER gives formulation synonym YF11357. This appears to be an IPA salt. 27.25%	*Daphnia magna*	48-hours	U.S. EPA/OPP 2008a EC_{50}: 44.8 (38.0 52.0) mg a.e./L or 164.3 formulation/L NOAEC: 26 mg a.e./L Slope: 7.6 EPA DER 164.3 (139.5 to 190.8) mg formulation/L 44.8 mg a.i./L Note: Converting the a.i. to a.e. (0.74), the LC_{50} is 33.1 mg a.e./L	Swarbrick and Shillabeer 1999b MRID 45374003
Roundup, 41% IPA salt	*Ceriodaphnia dubia*	48 hours	LC_{50}: 5.39 mg a.e./L	Tsui and Chu 2003
Roundup, 41% IPA salt	Copepod *Acartai tonsa*	48 hours	LC_{50}: 1.77 mg a.e./L	Tsui and Chu 2003
Rodeo	Amphipod *Hyalella azteca*	48 hours	LC_{50}: 225 mg a.e./L	Tsui and Chu 2004
Rodeo	*Ceriodaphnia dubia*	48 hours	LC_{50}: 415 mg a.e./L	Tsui and Chu 2004
Roundup (Monsanto)	Amphipod *Hyalella azteca*	48 hours	LC_{50}: 1.5 mg a.e./L	Tsui and Chu 2004
Roundup (Monsanto)	*Ceriodaphnia dubia*	48 hours	LC_{50}: 5.7 mg a.e./L	Tsui and Chu 2004
Roundup Biactive (Australia)	Amphipod *Hyalella azteca*	48 hours	LC_{50}: 120 mg a.e./L	Tsui and Chu 2004
Roundup Biactive (Australia)	*Ceriodaphnia dubia*	48 hours	LC_{50}: 81.5 mg a.e./L	Tsui and Chu 2004

A8 Table 2: Glyphosate Formulations – LC_{50}s

Formulation, % a.i.	Species	Exposure	Response	Reference [1]
U.S. formulation, 41% (NOS)	Rotifer, *Brachionus calyciflorus*	24 hours	LC_{50}: 28.0 mg/L Probably units of formulation. Assuming the IPA, LC_{50}: 7.3 mg a.e./L	Xi and Feng 2004 Ref 79406 in U.S. EPA/OPP 2008a

[1] Studies designated only with an MRID number are taken from Table 4.17 of U.S. EPA/OPP 2008a or Appendix J, Table J-11 of U.S. EPA/OPP 2008a. All Roundup formulations are IPA unless otherwise specified. Some additional details of materials obtained from the listing of U.S. EPA/OPP MRID studies in Attachment 1 of the current Forest Service risk assessment.

[2]Folmar et al. (1979) report the Roundup formulation as "360.32 g/L active ingredient". The Roundup formulation in 1979 contained 480 g/L of the IPA salt (a.i.) and 356 g/L of the glyphosate acid equivalents. The U.S. EPA/OPP 2008a interpreted the LC_{50} values for Roundup as being reported in units of mg a.i./L and interprets the a.i./L as the IPA salt. While this follow current nomenclature, a review of Folmar et al. (1979) study by the Forest Service judges that the units for Roundup LC50s are reported in Folmar et al. (1979) in units of mg a.e./L and not units of mg a.i./L. Thus, the values summarized in this appendix are taken directly from Folmar et al. (1979). Thus, the LC_{50}s reported in U.S. EPA/OPP (2008a) for Folmar et al. (1979) are lower than the LC_{50} values summarized in this appendix by a factor of 0.74, the conversion factor for going from a.i. to a.e.

A8 Table 3: Other Acute Toxicity Studies				
Agent	**Species**	**Exposure**	**Response**	**Reference**
Glyphosate acid and Roundup-like formulation (NOS)	Horsehair worms *(Chordodes nobilii*)	48 to 96 hours	LC_{50}: ≈1.76 mg a/e//L for formulated glyphosate. No substantial difference between a.e. and a *Roundup-like* formulation. LOAEC (infectivity): 0.1 mg a.e./L	Achiorno et al. 2008
Glyphosate acid	*Daphnia pulex*	10 or 100 mg a.e/L	Reduced grazing efficiency.	Bengtsson et al. 2004
Roundup (3 lb/gal)	Mayfly nymphs	0.1, 1.0, and 10 mg/L	Avoidance behavior only at 10 mg/L.	Folmar 1978
Various glyphosate formulations	Sea urchins *Sphaerechinus granularis*	Exposures to 0.1 to 10 mM glyphosate (16.7 mg a.e./L to 1,670 mg a.e./L) for up to 5 hours.	Disruption in normal egg development at concentrations of 167 mg a.e./L to 1,670 mg a.e./L depending on the formulation.	Marc et al. 2004b
U.S. formulation, 41% (NOS)	Rotifer, *Brachionus calyciflorus*	0, 2, 4, 6 and 8 mg/L for 3 days. Units appear to be in formulation. Assuming IPA: 0, 0.6 1.2, 1.8 and 2.5 mg a.e./L	Significant **increase** in growth rate (both sexual and asexual) at 1.2 mg a.e./L and higher. Also caused an increase in resting egg productions. Note: As with egg production in daphnids, an increase in resting eggs in rotifers could be viewed as an adverse effect.	Xi and Feng 2004 Ref 79406 in U.S. EPA/OPP 2008a
Roundup Biactive (336 g a.e./L)	*Daphnia carinata*	Exposure to 3 generations to 5 mg/L in combination with varying concentrations of cadmium	Antagonism of cadmium toxicity in first two generations. No effect on cadmium toxicity in third generation.	Zalizniak and Nugegoda 2006

A8 Table 4: Glyphosate, Formulations, and Surfactants – Chronic Toxicity				
Salt or Formulation	**Species**	**Exposure**	**Response**	**Reference**
Acid and Salts				
Glyphosate acid	Mussel (*Lampsilis siliquoidea*), juvenile	21 days	LC_{50}: >200 mg/L	Bringolf et al. 2007
Glyphosate IPA	Mussel (*Lampsilis siliquoidea*), juvenile	28 days	LC_{50}: 4.8 (3.0-7.6) mg/L	Bringolf et al. 2007
Glyphosate , 97%	Snail, *Pseudosuccinea columella*	0, 0.1, 1, and 10 mg/L for 4 weeks – i.e., egg to hatching and development	Significant ($p<0.05$) increases in glutamic oxaloacetic transaminase (GOT) and decrease in glutamic pyruvic transaminase (GPT) at all exposure levels. None of the changes are clearly concentration dependent. Enzyme changes could be associated with hepatic function.	Christian et al. 1993
Technical grade, 99.7%	*Daphnia magna*, 40 per dose. Mean measured concentrations of 0, 27, 50, 96, 186, and 365 mg a.i./L.	Life cycle, 21 days, flow-through.	U.S. EPA/OPP 2008a NOEC: 49.9 mg/L LOEC: 95.7 mg/L Reduced reproductive capacity . EPA DER NOEC: 50 mg/L	McKee et al. 1982 MRID 124763
Glyphosate acid, 97%	Snails *(Pseudosuccinea columella)*	0, 0.1, 1., and 10 mg a.e./L, static renewal for 3 generations. Exact period of exposure not specified but appears to be about 4 weeks.	Author Interpretation: delayed effect on growth and development, egg-laying capacity, and hatching. Note: For the most part, changes are not concentration-related. There does appear to be a stimulation in eggs production at 0.1 mg a.e./L in the third generation. The only clear adverse effect is a decrease (≈50%) in % egg hatching at 10 mg a.e./L.	Tate et al. 1997
Surfactant				
MON 0818	Mussel (*Lampsilis siliquoidea*) , juvenile	28 days	LC_{50}: 1.7 (1.0-2.7) mg/L	Bringolf et al. 2007
Formulations				
Aqua Star, 53.8% IPA (no surfactant)	Mussel (*Lampsilis siliquoidea*) , juvenile	28 days	LC_{50}: 43 (28.2-68.1) mg a.e./L	Bringolf et al. 2007

A8 Table 4: Glyphosate, Formulations, and Surfactants – Chronic Toxicity

Salt or Formulation	Species	Exposure	Response	Reference
Roundup (41% IPA salt)	*Daphnia pulex* (stable cultures)	Single treatment at initial concentrations of 0, 1, 2, and 4 mg a.i./L with a 9 week observation period. Two groups, one with suspended clay and the other without	*No suspended sediment* Decreases in number of organisms/mL and numbers of immature organisms at Week 1. No effects from Week 2 to Week 9. *With suspended sediment* Similar to above but the magnitude of the decreases was greater. See Table 1 in paper.	Hartman and Martin 1984
Roundup Ultramax, 50.2% IPA	Mussel (*Lampsilis siliquoidea*), juvenile	28 days	LC_{50}: 3.7 (1.2-11.7) mg a.e./L	Bringolf et al. 2007
Vision (glyphosate IPA with POEA surfactant)	*Sirnocephalus vetulus* (Cladoceran)	8 days 0, 0.75, or 1.5 mg a.e./L at pH 5.5 or pH 7.5.	Significant decrease in reproduction rates and cumulative reproduction at pH 7.5. Note: the lack of a significant effect at pH 5.5 could be due to the decrease in reproduction in controls secondary to pH stress.	Chen et al. 2004

A8 Table 5: Surfactants – LC_{50}s

Agent	Species	Exposure	Response	Reference [1]
MON 0818	Mussel (*Lampsilis siliquoidea*)	48hours 96 hours	Larvae LC_{50}: 0.5 mg/L Juvenile LC_{50}: 3.8 mg/L	Bringolf et al. 2007
MON 0818	*Daphnia magna*	96 hours	EC_{50}: 2.00 mg/L	Servizi et al. 1987
MON 0818	*Daphnia magna*	48 hours	LC_{50}: 2.9 mg/L	Wang et al. 2005
MON 0818	Midge (*Chironomus plumosus*)	48 hours	LC_{50}: 13 (7.1-24.0) mg/L	Folmar et al. 1979 MRID 162296
POEA	*Ceriodaphnia dubia*	48 hours	LC_{50}: 1.15 mg/L	Tsui and Chu 2003
POEA	Copepod *Acartai tonsa*	48 hours	LC_{50}: 0.57 mg/L	Tsui and Chu 2003
POEA with different oxide: tallowamine ratios	Fairy Shrimp, *Thamnocephalus platyurus*	48 hours	Oxide: Tallow Ratio / 48-h LC_{50} mg/L 5:1 — 0.00517 10:1 — 0.0027 15:1 — 0.00201	Brausch and Smith 2007
POEA with different oxide: tallowamine ratios	*Daphnia magna*	48 hours	Oxide: Tallow Ratio / 48-h LC_{50} mg/L 5:1 — 0.1764 10:1 — 0.097 15:1 — 0.849 Concentration related decrease in body mass in surviving animals	Brausch et al. 2007
Surfactant Geronol CF/AR (alkyl polyoxy ethylene phosphoric acid), Technical grade	*Daphnia magna*	48 hours	EC_{50}: 48 mg/L	MRID 44738201

[1] Studies designated only with an MRID number are taken from Table 4.18 of U.S. EPA/OPP 2008a.

A8 Table 6: Surfactants Added to Glyphosate Field Solutions

Agent	Species	Exposure	Response	Reference [1]
Activator 90	*Daphnia magna*	48 hours	EC_{50}: 2.0 mg/L	McLaren/Hart 1995[1]
Activator N.F.	Midge (*Chironomus riparius*)	48 hours	LC_{50}: 10.1 (6.6-13.3) mg/L	Buhl and Faerber 1989
Agri-Dex	*Daphnia magna*	48 hours	EC_{50}: >1000 mg/L	McLaren/Hart 1995[1]
Entry II	*Daphnia magna*	48 hours	EC_{50}: 2.0 mg/L	McLaren/Hart 1995[1]
Frigate	*Daphnia magna*	48 hours	EC_{50}: 11.0 mg/L	McLaren/Hart 1995[1]
Induce	*Daphnia magna*	48 hours	EC_{50}: 18.0 mg/L	McLaren/Hart 1995[1]
LI 700	*Daphnia magna*	48 hours	EC_{50}: 190 mg/L	McLaren/Hart 1995[1]
Liqua-Wet	*Daphnia magna*	48 hours	EC_{50}: 7.2 mg/L	McLaren/Hart 1995[1]
No Foam A	*Daphnia magna*	48 hours	EC_{50}: 7.3 mg/L	McLaren/Hart 1995[1]
Passage	*Daphnia magna*	48 hours	EC_{50}: 17 mg/L	McLaren/Hart 1995[1]
R-11	*Daphnia magna*	48 hours	EC_{50}: 19 mg/L	McLaren/Hart 1995[1]
S. Spreader 200	*Daphnia magna*	48 hours	EC_{50}: 24 mg/L	McLaren/Hart 1995[1]
Spreader-Sticker	*Daphnia magna*	48 hours	EC_{50}: 48 mg/L	McLaren/Hart 1995[1]
Syndets (anionic surfactant)	Crawfish (*Procambarus* sp.)	48 hours 96 hours	LC_{50}: 27.9 mg/L LC_{50}: 19.0 mg/L	Abdelghani et al. 1997
Widespread	*Daphnia magna*	48 hours	EC_{50}: 16 mg/L	McLaren/Hart 1995[1]
X-77	*Daphnia magna*	48 hours	EC_{50}: 2 mg/L	McLaren/Hart 1995[1]
X-77	Midge (*Chironomus riparius*)	48 hours	LC_{50}: 8.6 (6.3-12.4) mg/L	Buhl and Faerber 1989
X-77	Amphipod *Hyalella azteca*	96 hours	LC_{50}: 5.3 (4.3-6.7) mg/L	Henry et al. 1994
X-77	*Daphnia magna*	48 hours	LC_{50}: 2 (1.5-2.7) mg/L	Henry et al. 1994
X-77	Leech *Nephelopsis obscura*	96 hours	LC_{50}: 14.1 (10.7-19.0) mg/L	Henry et al. 1994
X-77	Midge *Chironomus riparius*	96 hours	LC_{50}: 10 (8.2-13.1) mg/L	Henry et al. 1994

[1] These are unpublished studies by Monsanto summarized in McLaren/Hart 1995, p. 12-9.

A8 Table 7: AMPA – LC_{50}s

Agent	Species	Exposure	Response	Reference [1]
AMPA, 94.38%	*Daphnia magna*	48-hours	EC_{50}: 683 (553 - 1010) mg/L NOAEC: 320 mg/L	Burgess and Hicks 1994 MRID 43334715

[1] Studies designated only with an MRID number are taken from Table 4.19 of U.S. EPA/OPP 2008a.

A8 Table 8: Field Studies

Exposure	Response	Reference
Vision (glyphosate formulation with surfactant) applied to artificial streams at 0.0019 to 0.2874 mg/L. Cannot identify units (a.e., a.i., or formulation)	Increase in periphyton concentrations perhaps due to utilization of glyphosate and/or surfactant as a nutrient source.	Austin et al. 1991
Applications of Rodeo (with LI 700 nonionic surfactant) at 1 L/ha (≈0.4 lb a.e./acre assuming 4 lbs a.e./gallon)	In situ bioassays of *Daphnia magna* noted no significant differences in survival between treated and control areas.	Gardner and Grue 1996
Roundup, 2.0 kg a.i./ha by Microfil boom w/1.5 mm hayrack nozzles mounted on Bell helicopter. Applied to 11 spray blocks at various times over 4 days to watershed on west coast of Vancouver Island in September 1984	No undue disturbance of stream invertebrates; no increase in drift densities of most aquatic invertebrates; no significant increase in total invertebrate catches. The maximum concentration monitoring in stream water was 162 µg/L.	Kreutzweiser et al. 1989
In situ pond bioassays with Roundup (35.6% IPA) applications (overspray) of 2.2 kg/ha, 22 kg/ha, and 222 kg/ha into porous experimental cylinders.	No substantial increase in mortality of *Daphnia magna* over an 8-day observation period. Note: This study was designed to mimic an aerial spray. It is likely that the glyphosate was rapidly and substantially diluted by water flow through the test cylinders. Concentrations of glyphosate not reported.	Hildebrand et al. 1980
Roundup, simulated direct spraying of pond at application rate of 0.43 kg/ha or about 0.4 lbs/acre	No effects on zooplankton populations or water quality.	Perschbacher et al. 1997
Aquatic mesocosm Roundup with POEA surfactant. Nominal initial concentration of 3.5 mg a.i./L with an observation period of 13 days	No effect on predatory insects or snails. Dragonfly populations were reduced but the effect does not appear to be statistically significant (see Fig. 3 of publication).	Relyea 2005b
Rodeo (4.7 L/ha) and X-77 Spreader (1 L/ha) aerially applied to three mudflat sites in Willapa Bay, WA with invasive Spartina alterniflora in August 1992.	No direct or indirect short term (28 days post treatment) or long term (119 days post treatment) effects on mudflat benthic invertebrates.	Simenstad et al. 1996

A8 Table 8: Field Studies

Exposure	Response	Reference
Rodeo, 2.8 L/ha [1.3 kg/ha] in wetlands to control cattails.	Effective control of cattails. Decrease in aquatic invertebrates in treated areas. Could not determine if decrease in invertebrates was due to toxicity or habitat changes.	Solberg and Higgins 1993

Appendix 9: Toxicity to Aquatic Plants

Note: *Pseudokirchneriella subcapitata* is the newer designation for *Selenastrum capricornutum*. In the tables below, the designation used in the study is reported.

A9 Table 1: Glyphosate Acid and Salts

Salt	Species	Exposure	Response	Reference [1]
Algae				
Glyphosate acid, 95%	Green algae (*Selenastrum capricornutum*)	48 hours	EC_{50}: 270 mg./L EC_{10}: 92.5 mg./L Ratio: 2.9	Cedergreen and Streibig 2005
Glyphosate IPA	Green algae (*Chlorella fusca*)	24 hours	EC_{50}: 377 mg a.i./L EC_{50}: ≈280 mg a.e./L	Faust et al. 1994
Gyphosate acid, 95%	Green algae (*Scenedesmus obliquus*)	96 hours	EC_{50}: 55.85 mg/L Presumably a.e. because molar concentrations are also given.	Ma 2002
Gyphosate (technical 95%)	Green algae (*Chlorella pyrenoidosa*)	96 hours	EC_{50}: 3.53 mg/L Presumably a.e. because molar concentrations are also given.	Ma 2002, Ma et al. 2001
Gyphosate acid, 95%	Green algae (*Chlorella vulgaris*)	96 hours	EC_{50}: 4.7 mg/L Units presumably a.e. because molar concentrations are also given.	Ma et al. 2002
Glyphosate acid, 96.7%	Blue-green algae (*Anabaena flosaquae*)	96 hours	EC_{50}: 304 mg a.e./L	Maule and Wright 1984
Glyphosate acid, 96.7%	Green algae (*Chlorella pyrenoidosa*)	96 hours	EC_{50}: 590 mg a.e./L	Maule and Wright 1984
Glyphosate acid, 96.7%	Green algae (*Chlorococcum hypnosporum*)	96 hours	EC_{50}: 68 mg a.e./L	Maule and Wright 1984
Glyphosate acid, 96.7%	Green algae (*Zygnema cllindricum*)	96 hours	EC_{50}: 88 mg a.e./L	Maule and Wright 1984
Glyphosate acid, 96.6%	Green algae *(Selenastrum capricornutum*	4 days	EC_{50}: 12.1 (11.5 - 12.9) mg a.e./L Slope: 12	MRID 40236901
Glyphosate acid, 96.6%	Freshwater diatom (*Navicula pelliculosa*)	7 days	EC_{50}: 37.3 (34.8 - 41.5) mg a.e./L NOAEC: 5.87 mg a.e./L	MRID 40236902

A9 Table 1: Glyphosate Acid and Salts				
Salt	**Species**	**Exposure**	**Response**	**Reference [1]**
Glyphosate acid, 96.6%	Bluegreen algae (*Anabaena flos-aquae*)	4 days	EC_{50}: 11.4 (10.5 - 12.1) mg a.e./L Slope: 3.53	MRID 40236904
Glyphosate acid, 95.6%	Green algae *(Selenastrum capricornutum*	5 days	EC_{50}: 13.4 (9.6 - 19.1) mg a.e./L NOAEC: 9.6 mg a.e./L	MRID 44320637
Glyphosate acid, 95.6%	Bluegreen algae (*Anabaena flos-aquae*)	5 days	EC_{50}: 14.3 (9.3 - 25.8) mg a.e./L NOAEC: 11.5 mg a.e./L	MRID 44320639
Glyphosate acid, 95.6%	Freshwater diatom (*Navicula pelliculosa*)	5 days	EC_{50}: 16.3 (11.5 - 22.9) mg a.e./L NOAEC: 1.7 mg a.e./L	MRID 44320641
Glyphosate IPA, 99.5%	*Scenedesmus acutus*	96 hours	EC_{50}: 10.2 mg a.e./L NOEC: 2 mg a.e./L LOEC: 4 mg a.e./L Results clearly given as a.e. See Table 1 of paper.	Saenz et al. 1997
Glyphosate IPA, 99.5%	*Scenedesmus quadricauda*	96 hours	EC_{50}: 7.2 mg a.e. /L NOEC: 0.77 a.e. mg/L LOEC: 1.55 mg a.e./L Results clearly given as a.e. See Table 1 of paper.	Saenz et al. 1997
Glyphosate IPA salt	Diatom (*Selenastrum capricornutum*)	96 hours	EC_{50}: 5.89 mg/L	Tsui and Chu 2003
Glyphosate acid	Diatom (*Skeletonema costatum*)	96 hours	EC_{50}: 2.27 mg/L	Tsui and Chu 2003
Glyphosate acid	Green algae (*Selenastrum capricornutum*)	96 hours	EC_{50}: 24.7 mg/L	Tsui and Chu 2003
Glyphosate IPA salt	Green algae (*Selenastrum capricornutum*)	96 hours	EC_{50}: 41.0 mg/L	Tsui and Chu 2003
Glyphosate acid, 97.5%	Green algae (*Chlorella saccharophila*)	72 hours	EC_{50}: 40.6 (36.7–45.2) mg a.e./L	Vendrell et al. 2009
Glyphosate acid, 97.5%	Green algae (*Chlorella vulgaris*)	72 hours	EC_{50}: 41.7 (37.5–46.6) mg a.e./L	Vendrell et al. 2009
Glyphosate acid, 97.5%	Green algae (*Scenedesmus acutus*)	72 hours	EC_{50}: 24.5 (21.9–27.7)mg a.e./L	Vendrell et al. 2009

A9 Table 1: Glyphosate Acid and Salts				
Salt	**Species**	**Exposure**	**Response**	**Reference [1]**
Glyphosate acid, 97.5%	Green algae (*Scenedesmus subspicatus*)	72 hours	EC_{50}: 26.0 (23.5–28.9) mg a.e./L	Vendrell et al. 2009
Macrophytes				
Glyphosate acid	Eelgrass (*Zostera marina*), marine	3 days	100 µM (≈170 mg a.e./L), no significant adverse effects. Significant increase in relative growth rate at 10 µM (≈17 mg a.e./L).	Nielsen and Dahllof 2007
Glyphosate acid, 95%	*Lemna minor*	7 days	EC_{50}: 46.9 mg a.e./L EC_{10}: 3.78 mg a.e./L Ratio: 12	Cedergreen and Streibig 2005
Glyphosate acid	Watermilfoil (*Myriophyllum sibiricum*)	14 days	Most sensitive EC_{50} Root length: 1.56 (1.29-1.89) mg a.e./L	Perkins 1997
Glyphosate acid	*Lemna gibba*	14 days	Most sensitive EC_{50} Fresh weight: 9.98 (4.13-29.03) mg a.e./L	Perkins 1997
Glyphosate acid, 95% w/w	*Lemna gibba*	2 to 10 days	2-day IC_{50}: 33.1 (21.6-47.9) mg a.e./L 10-day IC_{50}: 20.5 (19.6-21.7) mg a.e./L Ratio of 10-d IC_{50} to IC_{10}: 4.5 Above are for growth rate. Other endpoints are give but are similar to those for growth rate.	Sobrero et al. 2007
Glyphosate acid, 95.6%	*Lemna gibba*	14 days	EC_{50}: 11.9 (9.4-14.9) mg a.e./L NOAEC: 1.3 mg a.e./L	MRID 44320638
Glyphosate acid, 96.6%	*Lemna gibba*	14 days	EC_{50}: 20.8 mg a.e./L NOAEC: <1.8 mg a.e./L	MRID 40236905
Glyphosate acid, 96.8%	*Lemna gibba*	7 days	EC_{50}: 23.2 (20.3-27.1) mg a.e./L NOAEC: 2.91 mg a.e./L	MRID 45773101
Glyphosate, IPA	*Lemna paucicostata*	7 days	Reported EC_{50}: 0.3875 mM EC_{50}: ≈ 42 mg a.i./L (31 mg a.e./L)	Michel et al. 2004
Glyphosate (NOS)	Giant salvinia (*Salvinia molesta*)	42 days	Substantial growth inhibition (≈85-90%) at concentrations of 4500 to 36,400 mg a.e./L.	Fairchild et al. 2002

[1] Studies designated only with an MRID number are taken from Table 4.21 of U.S. EPA/OPP 2008a.

A9 Table 2: Glyphosate Formulations				
Formulation, %a.i.	**Species**	**Exposure**	**Response**	**Reference**
Algae				
Glyphos (MON 14420), monoammonium, 68.5% [2]	Green algae (*Selenastrum capricornutum*)	72 hours	EC_{50}: 1.85 (1.3 - 2.3) mg a.e./L NOAEC: 0.61 mg a.e./L	MRID 45777403
MON 78568, Glyphosate monoammonium salt, 64.9%	Green algae (*Selenastrum capricornutum*)	72 hours	EC_{50}: 11.2 (10 - 12.6) mg a.e./L NOAEC: 1.58 mg a.e./L	MRID 45767102
Glyphosate IPA salt, 36%, with surfactant Geronol CF/AR	Green algae (*Selenastrum capricornutum*)	72 hours	EC_{50}: 97 (85 - 111) mg a.e./L NOAEC: 73 mg a.e./L	MRID 44738201
Glyphosate IPA salt, 36%, with surfactant Geronol CF/AR	Green algae (*Selenastrum capricornutum*)	72 hours	EC_{50}: 39 (33 - 45) mg a.e./L NOAEC: 16 mg a.e./L	MRID 44738201
Glyphos, 31% [2]	Freshwater diatom (*Navicula pelliculosa*)	96 hours	EC_{50}: 0.12 (0.11 – 0.13) mg a.e./L or 0.39 mg formulation/L NOAEC: 0.082 mg a.e./L Slope: 8.78	MRID 45666701
Glyphos, IPA, 31% [2]	Green algae (*Selenastrum capricornutum*)	96 hours	EC_{50}: 0.68 (0.57 - 0.81) mg a.e./L NOAEC: 0.43 mg a.e./L Slope: 4.47	MRID 45666702
Roundup, 360 g/L	Green algae (*Selenastrum capricornutum*)	48 hours	EC_{50}: 64.7 mg./L EC_{10}: 13.6 Ratio: 4.8 Units appear to be in formulation. Assuming ≈30% a.e., EC_{50}: 19 mg a.e./L EC_{10}: 4.1 mg a.e./L.	Cedergreen and Streibig 2005
Roundup, 41% IPA salt	Green algae (*Selenastrum capricornutum*)	96 hours	EC_{50}: 3.92 mg a.e./L	Tsui and Chu 2003
Roundup, 41% IPA salt	Diatom (*Selenastrum capricornutum*)	96 hours	EC_{50}: 1.85 mg a.e./L	Tsui and Chu 2003
Rodeo (no surfactant)	*Ankistrodesmus* sp.	96 hours	EC_{50}: 74 µg/mL Units appear to be in formulation. EC_{50}: ≈29 mg a.e./L	Gardner et al. 1997

A9 Table 2: Glyphosate Formulations

Formulation, %a.i.	Species	Exposure	Response	Reference
Roundup, NOS	4 species of green algae and 8 species of blue-green algae	24 hours at 2.848 mg/L. Units not clear.	Substantial (73-77%) inhibition of carbon fixation in two species of green algae and one species of blue-green algae. Simulation of carbon fixation in two species of blue-green algae. No significant effect on five species.	Peterson et al. 1994
Ron-do, 48% IPA and 15% oxide-coco-amide-propyl dimethyl amine surfactant	*Scenedesmus acutus*	96 hours	EC_{50}: 9.08 mg a.e./L NOEC: 3.2 mg a.e./L LOEC: 4.1 mg a.e./L Results clearly given as a.e. See Table 1 of paper.	Saenz et al. 1997 Note that there is little difference in toxicity between formulation and IPA salt.
Ron-do, 48% IPA and 15% oxide-coco-amide-propyl dimethyl amine surfactant	*Scenedesmus quadricauda*	96 hours	EC_{50}: 9.09 mg a.e. /L NOEC: 0.25 a.e. mg/L LOEC: 2.5 mg a.e./L Results clearly given as a.e. See Table 1 of paper.	Saenz et al. 1997 Note that there is little difference in toxicity between formulation and IPA salt.
Unspecified Monsanto formulation, 35.6% a.i. NOS	*Scenedesmus quadricauda*	0.02 to 200 mg/L. Duration not specified. Probably 4 days	No growth at 20 and 200 mg/L. Significant stimulation of growth at 0.02 mg/L. Significant inhibition of growth at 2 mg/L. No effect on growth at 0.2 mg/L	Wong 2000
GF-1279, Glyphosate IPA, 53.6%.	*Pseudokirchneriella subcapitata*	72 hours, static	EC_{50}: 9.72 mg formulation/L or ≈ 5.2 mg a.e./L NOEC: 3.2 mg formulation/L or ≈ 1.6 mg a.e./L	Sesso 2005b
GF-1280 (50.2%, DMA)	*Pseudokirchneriella subcapitata*	48 hours, static	EC_{50}: 1 (0.91-1.1) mg form/L or ≈ 0.40 (0.36-0.44) mg a.e./L NOEC: 0.5 mg form/L or ≈ 0.20 mg a.e./L	Hughes 2006b

A9 Table 2: Glyphosate Formulations

Formulation, %a.i.	Species	Exposure	Response	Reference
Roundup (NOS)	Mixed periphyton community	7.8 to 39 mg a.i./L for 7 days	Slight stimulation in chlorophyll at 7.8 mg/L. Statistically insignificant decreases at 15.6 mg a.i./L to 39 mg a.i./L. No significant changes in ratios of chlorophyll a or chlorophyll c to chlorophyll b.	Kish et al. 2006
Macrophytes				
Roundup	*Lemna minor*	48 hours	EC_{50}: >16.91 mg a.e./L NOAEC: 16.91mg a.e./L	Lockhart et al. 1989 MRID 44125713
Roundup, 360 g/L	*Lemna minor*	7 days	EC_{50}: 11.2 mg/L EC_{10}: 3.56 mg./L Ratio: 3.1 Above units appear to be in formulation. Assuming 30% a.e. w/w, EC50: 3.36 mg a.e./L	Cedergreen and Streibig 2005
Glyphos (Glyphosate IPA salt, 31%)[2]	*Lemna gibba*	7 days	EC_{50}: 7.7 (7.1 - 8.3) mg a.e./L or 25 mg formulation/L NOAEC: 0.29 mg a.e./L Slope: 4.76	MRID 45666704
Roundup	*Lemna minor*	7 days at 2.848 mg/L. Units not clear.	No effect on growth.	Peterson et al. 1994
Roundup Max, 70.7% a.e.	*Lemna gibba*	2 to 10 days	*Reported values:* 2-day IC_{50}: 9.2 (4.4-17.3) mg formulation/L 10-day IC_{50}: 11.6 mg formulation /L a.e. equivalent values: 2-day IC_{50}: 6.5 mg a.e./L 10-day IC_{50}: 8.2 mg a.e./ L	Sobrero et al. 2007[3]
Roundup	*Lemna minor*	14 days	EC_{50}: 2 mg a.i./L (1.48 mg a.e./L) in the absence of suspended clay. NOEC: 10 mg a.i./L (7.4 mg a.e./L) with suspended clay.	Hartman and Martin 1984 MRID 44125714
Glyphosate 41% (no other description)	Sago pondweed *(Potamogeton pectinatus)*	14 days	NOAEC: 10 mg/L. Units not specified as a.e., a.i., or formulation.	Hartman and Martin 1985
Rodeo (480 g a.e./L no surfactant)	Watermilfoil (*Myriophyllum sibiricum*)	14 days	Most sensitive EC_{50} Root length: 0.84 (0.77-0.91) mg a.e./L	Perkins 1997

A9 Table 2: Glyphosate Formulations

Formulation, %a.i.	Species	Exposure	Response	Reference
Roundup (356 g a.e./L with POEA surfactant)	Watermilfoil (*Myriophyllum sibiricum*)	14 days	Most sensitive EC_{50} Root length: 1.22 (0.86-1.73) mg a.e./L	Perkins 1997
Roundup (356 g a.e./L with POEA surfactant)	*Lemna gibba*	14 days	Most sensitive EC_{50} Plant number: 4.58 (3.44-6.10) mg a.e./L	Perkins 1997
Rodeo (480 g a.e./L no surfactant)	*Lemna gibba*	14 days	Most sensitive EC_{50} Plant number: 7.60 (5.79-9.98) mg a.e./L	Perkins 1997

[1] Studies designated only with an MRID number are taken from Table 4.22 of U.S. EPA/OPP 2008a. All Roundup formulations are IPA unless otherwise specified.

[2] As indicated in Table 2, Glyfos Aquatic formulation contains 53.8% IPA and Glyfos X-TRA contains 41% IPA. Thus, these formulations in Table 2 do not appear to correspond to the formulations summarized in the above table of this appendix. In particular, it is not clear which salt was used in MRID 45666701. This MRID is not in Appendix L of U.S. EPA/OPP 2008a but is in Attachment 1 of the current Forest Service risk assessment. Thus, the salt appears to be an IPA.

[3] Other endpoints are give but are similar to those for growth rate. Also note that the 2- and 10 day values are not typos. The reported 2-day IC_{50} is lower than the reported 10-day IC_{50}.

A9 Table 3: Surfactant Toxicity

Agent	Species	Exposure	Response	Reference
POEA	Green algae (*Selenastrum capricornutum*)	96 hours	EC_{50}: 3.92 mg/L	Tsui and Chu 2003
POEA	Diatom (*Skeletonema costatum*)	96 hours	EC_{50}: 3.35 mg/L	Tsui and Chu 2003
POEA	Green algae (*Selenastrum capricornutum*)	96 hours	EC_{50}: 4.1 (3.7-4.5) mg/L	Van Ginkel et al. 1993

A9 Table 4: Field or Field Simulation Studies

Exposure	Response	Reference
Rodeo (with LI 700 nonionic surfactant) at 1 L/ha (≈0.4 lb a.e./acre assuming 4 lbs a.e./gallon)	In situ bioassays of duckweed (NOS) noted no significant differences in survival between treated and control areas.	Gardner and Grue 1996
Roundup (35.6% a.e) using mixed periphytic algal cultures from two boreal ponds (Manitoba).	4-hour EC_{50} for growth inhibition of about 69.7 and 44.4 mg/L in the two ponds. Stimulation of photosynthesis at concentrations below 10 mg/L.	Goldsborough and Brown 1988
Roundup at 6 and 12 mg a.e./L in aquatic mesocosm	Increase in primary productivity at both concentrations but a decrease in the abundance of phytoplankton.	Perez et al. 2007
Roundup, simulated direct spraying of pond at application rate of 0.43 kg/ha or about 0.4 lbs/acre	No effects on plankton productivity or water quality.	Perschbacher et al. 1997
Rodeo applied to mixed phytoplankton culture collected from a lake (U.S.) Glyphosate concentrations of 0.125, 1.25, and 12.5 mg/L	A stimulation of primary productivity at all concentrations. The magnitude of the stimulation was not concentration-related – i.e., 161%, 168%, and 161% in the low, medium, and high concentrations. Authors note that stimulation could be associated with the nutritional value of glyphosate – i.e., nitrogen and phosphorous source – but this would not explain the lack of a concentration-response relationship.	Schaffer and Sebetich 2004
Roundup, 2 lb/acre, overspray of stream in Douglas fir plantation.	Variable effects on several species of diatoms colonizing glass slides placed in streams. Direct effects on diatoms cannot be ruled out but the authors note that the effects seen could have due to secondary changes in habitat.	Sullivan et al. 1981

Appendix 10: Gleams-Driver Simulations

Table 1: Effective Offsite Application Rate (lb/acre)

Site	Clay	Loam	Sand
Dry and Warm Location	0.000104	0	0
	(0 - 0.006)	(0 - 3.03E-05)	(0 - 5.90E-07)
Dry and Temperate	1.14E-07	0	0
Location	(0 - 0.00048)	(0 - 0)	(0 - 0)
Dry and Cold Location	0.00063	0	0
	(0.000068 - 0.0037)	(0 - 3.70E-07)	(0 - 0)
Average Rainfall and	0.0102	0.0006	3.80E-07
Warm Location	(0.00277 - 0.046)	(1.04E-05 - 0.0135)	(0 - 0.00245)
Average Rainfall and	0.0088	0.00062	6.30E-07
Temperate Location	(0.00233 - 0.048)	(2.17E-06 - 0.0119)	(0 - 0.0042)
Average Rainfall and Cool	0.0041	0.000071	0
Location	(0.00084 - 0.0159)	(1.15E-07 - 0.0021)	(0 - 0.000127)
Wet and Warm Location	0.0115	0.0005	1.35E-05
	(0.0034 - 0.065)	(0.000039 - 0.0044)	(0 - 0.00199)
Wet and Temperate	0.0054	0.000059	0
Location	(0.00138 - 0.0207)	(1.14E-07 - 0.00127)	(0 - 0.000068)
Wet and Cool Location	0.036	0.0058	0.00057
	(0.0141 - 0.089)	(0.00165 - 0.0228)	(9.50E-06 - 0.0082)
		Average of Central Values:	0.003147
		25th Percentile of Lower Bounds:	0
		Maximum Value:	0.089
		Summary of Values:	0.00315 (0 - 0.089)

Table 2: Concentration in Top 12 Inches of Soil (ppm)

Site	Clay	Loam	Sand
Dry and Warm Location	0.283	0.176	0.176
	(0.28 - 0.38)	(0.176 - 0.176)	(0.176 - 0.176)
Dry and Temperate	0.282	0.176	0.176
Location	(0.27 - 0.38)	(0.172 - 0.176)	(0.172 - 0.176)
Dry and Cold Location	0.263	0.176	0.176
	(0.253 - 0.33)	(0.171 - 0.176)	(0.171 - 0.176)
Average Rainfall and	0.264	0.176	0.176
Warm Location	(0.256 - 0.32)	(0.172 - 0.176)	(0.172 - 0.176)
Average Rainfall and	0.267	0.176	0.176
Temperate Location	(0.26 - 0.34)	(0.172 - 0.176)	(0.172 - 0.176)
Average Rainfall and Cool	0.266	0.176	0.176
Location	(0.257 - 0.277)	(0.172 - 0.176)	(0.172 - 0.176)
Wet and Warm Location	0.241	0.172	0.172
	(0.233 - 0.251)	(0.171 - 0.176)	(0.172 - 0.176)
Wet and Temperate	0.267	0.176	0.176
Location	(0.255 - 0.34)	(0.172 - 0.176)	(0.172 - 0.176)
Wet and Cool Location	0.243	0.172	0.172
	(0.233 - 0.255)	(0.171 - 0.176)	(0.172 - 0.176)
		Average of Central Values:	0.2047
		25th Percentile of Lower Bounds:	0.172
		Maximum Value:	0.38
		Summary of Values:	0.205 (0.172 - 0.38)

Table 3: Concentration in Top 60 Inches of Soil (ppm)

Site	Clay	Loam	Sand
Dry and Warm Location	0.057 (0.056 - 0.076)	0.035 (0.035 - 0.035)	0.035 (0.035 - 0.035)
Dry and Temperate Location	0.056 (0.054 - 0.077)	0.035 (0.034 - 0.035)	0.035 (0.034 - 0.035)
Dry and Cold Location	0.053 (0.051 - 0.067)	0.035 (0.034 - 0.035)	0.035 (0.034 - 0.035)
Average Rainfall and Warm Location	0.053 (0.051 - 0.064)	0.035 (0.034 - 0.035)	0.035 (0.034 - 0.035)
Average Rainfall and Temperate Location	0.053 (0.052 - 0.068)	0.035 (0.034 - 0.035)	0.035 (0.034 - 0.035)
Average Rainfall and Cool Location	0.053 (0.051 - 0.055)	0.035 (0.034 - 0.035)	0.035 (0.034 - 0.035)
Wet and Warm Location	0.048 (0.047 - 0.05)	0.034 (0.034 - 0.035)	0.034 (0.034 - 0.035)
Wet and Temperate Location	0.053 (0.051 - 0.069)	0.035 (0.034 - 0.035)	0.035 (0.034 - 0.035)
Wet and Cool Location	0.049 (0.047 - 0.051)	0.034 (0.034 - 0.035)	0.034 (0.034 - 0.035)
		Average of Central Values:	0.0408
		25th Percentile of Lower Bounds:	0.034
		Maximum Value:	0.077
		Summary of Values:	0.041 (0.034 - 0.077)

Table 4: Maximum Penetration into Soil Column (inches)

Site	Clay	Loam	Sand
Dry and Warm Location	8	4	4
	(4 - 8)	(4 - 8)	(4 - 8)
Dry and Temperate	4	4	4
Location	(4 - 8)	(4 - 8)	(4 - 8)
Dry and Cold Location	8	4	8
	(4 - 8)	(4 - 8)	(4 - 8)
Average Rainfall and	8	8	8
Warm Location	(8 - 8)	(8 - 12)	(8 - 12)
Average Rainfall and	8	8	8
Temperate Location	(8 - 8)	(4 - 12)	(8 - 12)
Average Rainfall and Cool	8	8	8
Location	(8 - 8)	(4 - 8)	(8 - 12)
Wet and Warm Location	8	8	8
	(8 - 8)	(8 - 12)	(8 - 18)
Wet and Temperate	8	8	8
Location	(8 - 8)	(4 - 8)	(8 - 12)
Wet and Cool Location	8	8	12
	(8 - 12)	(8 - 12)	(8 - 18)
		Average of Central Values:	7.26
		25th Percentile of Lower Bounds:	4
		Maximum Value:	18
		Summary of Values:	7.26 (4 - 18)

Table 5: Stream, Maximum Peak Concentration in Surface Water (ug/L or ppb)

Site	Clay	Loam	Sand
Dry and Warm Location	0.16	0	0
	(0 - 9.5)	(0 - 0.04)	(0 - 0.0007)
Dry and Temperate	0.00016	0	0
Location	(0 - 0.7)	(0 - 0)	(0 - 0)
Dry and Cold Location	0.9	0	0
	(0.11 - 4.2)	(0 - 0.0004)	(0 - 0)
Average Rainfall and	12	0.9	0.0005
Warm Location	(3.9 - 44)	(0.014 - 13.9)	(0 - 4)
Average Rainfall and	10.1	0.7	0.0008
Temperate Location	(2.04 - 52)	(0.003 - 23.7)	(0 - 4.3)
Average Rainfall and Cool	6.3	0.08	0
Location	(1.08 - 24.6)	(0.00014 - 2.07)	(0 - 0.19)
Wet and Warm Location	14.3	0.6	0.02
	(3.02 - 72)	(0.05 - 6)	(0 - 2.04)
Wet and Temperate	5.5	0.08	0
Location	(1 - 29.7)	(0.00013 - 1.45)	(0 - 0.07)
Wet and Cool Location	23.2	3.8	0.4
	(7.9 - 83)	(0.9 - 23.8)	(0.012 - 5.2)
		Average of Central Values:	2.93
		25th Percentile of Lower Bounds:	0
		Maximum Value:	83
		Summary of Values:	2.93 (0 - 83)

Table 6: Stream, Annual Average Concentration in Surface Water (ug/L or ppb)

Site	Clay	Loam	Sand
Dry and Warm Location	0.0025	0	0
	(0 - 0.1)	(0 - 0.0006)	(0 - 0.000009)
Dry and Temperate	2.2E-06	0	0
Location	(0 - 0.009)	(0 - 0)	(0 - 0)
Dry and Cold Location	0.016	0	0
	(0.0017 - 0.07)	(0 - 0.000007)	(0 - 0)
Average Rainfall and	0.3	0.011	0.000005
Warm Location	(0.09 - 1.39)	(0.00027 - 0.2)	(0 - 0.03)
Average Rainfall and	0.26	0.011	0.00001
Temperate Location	(0.08 - 1.19)	(0.00004 - 0.19)	(0 - 0.07)
Average Rainfall and Cool	0.14	0.0012	0
Location	(0.03 - 0.5)	(2.3E-06 - 0.029)	(0 - 0.002)
Wet and Warm Location	0.4	0.009	0.00018
	(0.14 - 1.81)	(0.001 - 0.09)	(0 - 0.024)
Wet and Temperate	0.15	0.0008	0
Location	(0.05 - 0.5)	(0.000004 - 0.019)	(0 - 0.001)
Wet and Cool Location	1	0.08	0.005
	(0.4 - 2.58)	(0.025 - 0.24)	(0.00016 - 0.05)
		Average of Central Values:	0.0884
		25th Percentile of Lower Bounds:	0
		Maximum Value:	2.58
		Summary of Values:	0.088 (0 - 2.58)

Table 7: Pond, Maximum Peak Concentration in Surface Water (ug/L or ppb)

Site	Clay	Loam	Sand
Dry and Warm Location	0.07	0	0
	(0 - 3.3)	(0 - 0.011)	(0 - 0.0004)
Dry and Temperate	0.00006	0	0
Location	(0 - 0.25)	(0 - 0)	(0 - 0)
Dry and Cold Location	0.5	0	0
	(0.04 - 2)	(0 - 0.00018)	(0 - 0)
Average Rainfall and	8	0.3	0.00017
Warm Location	(2.34 - 24.7)	(0.006 - 6.4)	(0 - 1.18)
Average Rainfall and	6.4	0.3	0.0003
Temperate Location	(2.08 - 28.8)	(0.001 - 5.6)	(0 - 1.77)
Average Rainfall and Cool	3.5	0.03	0
Location	(0.8 - 11.2)	(0.00004 - 1.35)	(0 - 0.07)
Wet and Warm Location	6.2	0.18	0.004
	(2.59 - 21.3)	(0.022 - 1.19)	(0 - 0.4)
Wet and Temperate	3.3	0.031	0
Location	(0.8 - 12.2)	(0.00006 - 0.6)	(0 - 0.009)
Wet and Cool Location	5.6	0.7	0.05
	(2.05 - 14.2)	(0.21 - 2.39)	(0.0014 - 0.7)
		Average of Central Values:	1.3
		25th Percentile of Lower Bounds:	0
		Maximum Value:	28.8
		Summary of Values:	1.3 (0 - 28.8)

Table 8: Pond, Annual Average Concentration in Surface Water (ug/L or ppb)

Site	Clay	Loam	Sand
Dry and Warm Location	0.009	0	0
	(0 - 0.4)	(0 - 0.0019)	(0 - 0.00004)
Dry and Temperate	0.000005	0	0
Location	(0 - 0.03)	(0 - 0)	(0 - 0)
Dry and Cold Location	0.06	0	0
	(0.006 - 0.26)	(0 - 0.000019)	(0 - 0)
Average Rainfall and	1.25	0.05	0.000024
Warm Location	(0.4 - 4.4)	(0.0009 - 0.6)	(0 - 0.14)
Average Rainfall and	1.01	0.04	0.00004
Temperate Location	(0.3 - 4.5)	(0.00017 - 0.7)	(0 - 0.25)
Average Rainfall and Cool	0.5	0.005	0
Location	(0.12 - 1.57)	(0.000008 - 0.12)	(0 - 0.008)
Wet and Warm Location	0.8	0.019	0.0004
	(0.3 - 2.37)	(0.0024 - 0.12)	(0 - 0.025)
Wet and Temperate	0.4	0.0025	0
Location	(0.12 - 1.26)	(0.000005 - 0.06)	(0 - 0.0012)
Wet and Cool Location	0.9	0.06	0.004
	(0.4 - 2.59)	(0.02 - 0.2)	(0.00017 - 0.04)
		Average of Central Values:	0.1893
		25th Percentile of Lower Bounds:	0
		Maximum Value:	4.5
		Summary of Values:	0.189 (0 - 4.5)