Appendix N. Potential Impacts on Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Use

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Potential Impacts on Wildlife, Amphibians, Plants, and Ecosystems from Increased Glyphosate and Other Chemical Use

Executive Summary

Increased Glyphosate and Other Herbicide Use on Glyphosate-Tolerant Crops

The adoption of glyphosate-tolerant (GT) crops has caused a shift in herbicide use; generally glyphosate use has increased while use of other herbicides has declined resulting in a reduction in total herbicide use for several years after adoption of GT crops (i.e., corn, soybeans, and cotton). Several reviews concerning genetically engineered crops and herbicide use have supported this conclusion (Brimner et al., 2005; Fernandez-Cornejo, 2006; Gianessi and Reigner, 2006; Kleter et. al., 2007; Sankula, 2006; Johnson et al., 2008) and are discussed in appendix J. Similaryly, data presented in supplemental tables by Benbrook (2009) indicated increasing use (i.e., lbs per acre) of glyphosate on GT corn and soybeans from 1996 to 2008, without much change in use of other herbicides on those crops (Benbrook, 2009, supplemental table 15).

All data sources have strengths and weaknesses that must be considered in drawing conclusions from them. This technical report will review published information relevant to the environmental risks of glyphosate useage, evaluated against risks from other herbicides commonly used on conventional alfalfa. GT alfalfa cultivation practices are almost identical to those for conventional alfalfa except for the use of glyphosate post-emergence.

Herbicides Associated With Alfalfa Farming

Herbicides related to alfalfa farming can be divided into two major groups. One group includes herbicides that do not kill alfalfa (e.g., 2,4-DB, benefin, bromonoxynil, clethodim, diuron, S-ethyl dipropyl(thiocarbamate) (EPTC), hexazinone, imazamox, imazethapyr, metribuzin, norfluzaon, paraquat, pronamide, sethoxydim, terbacil, and trifluralin), and are, therefore, used to control weeds during the growing season. The other group includes herbicides that kill alfalfa (e.g., 2,4-D, dicamba, clopyralid, and picloram), which are used soley for stand removal. Adoption of GT alfalfa allows a decrease in the number of herbicides used to control weeds in alfalfa because glyphosate is a broad spectrum herbicide, killing all types of weeds including grasses and broad-leaved weeds.

Relying on glyphosate as the only weed removal herbicide, however, may increase the number of glyphosate-resistant weeds; for more information on this subject, refer to the technical reports *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G) and *Effects of Glyphosate-Resistant Weeds in Non-Agricultural Ecosystems* (appendix H). With an increase in glyphosate resistant weeds due to the adoption of GT alfalfa, and increased reliance on glyphoste, there may be a corresponding increase in the use of other herbicides in addition to glyphosate for control of weeds in GT alfalfa fields. Glyphosate is the herbicide most often used for alfalfa stand removal every 2-7 years. For GT alfalfa, stand removal would require

herbicides other than glyphosate. Overall, however, herbicide shifts due to stand removal, which occurs only once every 2-7 years, would be smaller in magnitude than herbicide shifts due to weed control on a yearly basis.

Glyphosate Use and Chemical Fate in the Environment

Glyphosate is a systemic, broad spectrum, post-emergence herbicide widely used on agricultural commodities (food uses) and nonagriculture sites. According to the U.S. Environmental Protection Agency (EPA), glyphosate's environmental fate database is considered complete (U.S. EPA, 1993a, 2006a). Glyphosate absorbs directly through plant leaves and rapidly spreads throughout the plant. The use of surfactants in the herbicide formulation enables greater glyphosate penetration into the leaves. Glyphosate is as a potent and specific inhibitor of the enzyme, 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS). This enzyme is located in the shikimate metabolic pathway and is essential for the biosynthesis of aromatic amino acids and other aromatic compounds in algae, higher plants, bacteria, fungi, and apicomplexian parasites. The shikimate pathway is absent in mammals and other animals; it is unique to plants and to some microorganisms (Giesy et al., 2000).

Glyphosate adsorbs strongly to soil and is not expected to move vertically below the six inch soil layer; residues are expected to be immobile in soil (U.S. EPA, 1993a, 2006a). In the environment, glyphosate is primarily degraded by soil microbes, with its major degradate being aminomethyl phosphonic acid (AMPA), which further degrades in the soil to carbon dioxide. The half-life of glyphosate in soil laboratory studies is 2 days (U.S. EPA, 1993a, 2006a). In agricultural soils, the disappearance time for 50 percent of the parent chemical (DT50) ranges from 1.7 to 197.3 days, but is typically less than 60 days depending upon edaphic and climatic conditions (Giesy et al., 2000). Due to glyphosate and AMPA's strong adsorptive characteristics, they are not likely to leach to groundwater from the soil; however, monitoring data by United State Geological Survey (USGS) demonstrate low amounts of glyphosate and AMPA in groundwater, especially in heavy agricultural regions. Further discussions of measured environmental concentrations of glyphosate are presented below.

Glyphosate and its metabolite sorbed to soil particles might erode into surface waters during storm events. Soil erosion in perennial alfalfa fields, however, is uncommon due to heavy vegetative cover and the deep root systems during the life of the stand. Once in surface waters, glyphosate and AMPA are not readily broken down by water or sunlight. Bacteria and other microorganisms in surface water and sediment, however, do break down both chemicals rapidly and completely (U.S. EPA, 1993a, 2006a).

Glyphosate Occurrence in the Environment

In a USGS monitoring study of surface water, groundwater, and soil conducted from 2001 to 2006, the metabolite AMPA was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). The sample collections were from several USGS studies including: the National Stream Quality Accounting Network Program, the National Water-Quality Assessment Program, and the Toxic Substances Hydrology Program. Additionally, glyphosate and its metabolite AMPA were found in surface water more frequently than in groundwater. Higher

occurrences of glyphosate and AMPA were found in samples of ground and surface waters taken from areas close to agricultural lands with recent applications of glyphosate and a recent rain event. Glyphosate also was found in rainwater; however, this was due to glyphosate's association with particulate matter (dust) and not to its existence as vapor. Soil samples indicate "trace levels" of glyphosate and AMPA may persist from year to year (Scribner et al., 2007), although that finding seems inconsistent with available environmental fate and transformation data. For an in depth discussion of soil, water, and air environmental levels of glyphosate, refer to the technical report *Effects of Changes in Farming Practices on Water, Soil and Air Due to Use of Glyphosate-Tolerant Alfalfa* (appendix J).

Glyphosate Residue on Crops and Livestock

Studies with a variety of plants indicate that uptake of glyphosate or AMPA from soil is limited (U.S. EPA, 2006c). For the most part, the ratio of glyphosate to AMPA is 9 to 1, but can approach 1 to 1 in some cases (e.g., soybeans and carrots). Much of the residue data for crops reflects a detectable residue of parent glyphosate (0.05 - 0.15 part per million (ppm)) along with residues below the level of detection (<0.05 ppm) of AMPA (U.S. EPA, 2006c). EPA determined that, based on toxicological considerations, AMPA need not be regulated and should be dropped from the residue tolerance expression (U.S. EPA, 2006c).

Metabolism studies submitted for genetically engineered GT canola and GT corn have indicated that metabolism of glyphosate in GT plants is essentially the same as that in non-GT plants (U.S. EPA, 2006c). During a confined crop rotational study, residues of glyphosate were undetected 30 days after treatment (U.S. EPA, 2006c). Glyphosate is used on a large variety of crops, but only a limited number of uses leave residues in the edible parts of the crops; per Monsanto, GT alfalfa is not to be grown for human food (e.g., alfalfa sprouts).

GT alfalfa is to be used as forage by many livestock. Studies with lactating goats, laying hens, rats, rabbits, and cows fed a mixture of glyphosate and AMPA indicate rapid elimination primarily by excretion in urine and feces (U.S. EPA, 1993a, 2006). Residues in eggs, milk, and livestock tissues are minimal to below detection and consist of glyphosate and its metabolite (U.S. EPA, 1993a, 2006c). Additionally, studies with livestock show that there is very little transfer of residues from feed to animal tissues and no bioaccumulation of residue occurs (U.S. EPA, 2006c). Controlled experimental studies with rats indicate that glyphosate is rapidly eliminated from the body as the parent compound, with very limited metabolism to AMPA. The half-life for glyphosate was 7.2 hours for males and 4.2 hours for females (U.S. EPA, 1993a).

Glyphosate Herbicide Use on GT Alfalfa

Glyphosate is among the most widely used pesticides by volume in the United States. The only products approved and that have a subsequent proposed maximum application rate for GT alfalfa are the following Monsanto glyphosate herbicide products: Honcho®, Honcho Plus ®, Roundup Original MAX ®, Roundup WeatherMAX ®, and Roundup Ultra MAX II ®. Glyphosate products can be formulated to have different concentrations of glyphosate acid per gallon of product. To improve handling, performance, and concentration, the glyphosate acid is formulated as a salt compound. The term acid equivalent (a.e.) refers to the weight of the

glyphosate acid, which is herbicidally active, while the term active ingredient (a.i.) is the weight of the glyphosate acid plus the salt. The Honcho ® and Honcho Plus ® products contain 41 percent of the isopropylamine salt of glyphosate, or 480 grams/Liter, which is equivalent to 356 g/L (3 lbs/gallon or 0.75 lbs/quart) of the glyphosate acid equivalent (a.e.). The maximum use rate for *noncrop* applications is 7.95 lbs a.e. per acre year; assuming 4 applications in one year, 1.99 lbs a.e./acre per application would be required to achieve that limit. The maximum use rate for *crops* is 6.0 lbs a.e./acre/yr. Assuming 4 applications in one year, 1.5 lbs a.e./acre per application would be required. Note that on use labels, Monsanto states 1.55 lbs a.e./acre is the maximum single application use rate for crops.

Modeled Glyphosate Residues

Exposure of aquatic species to glyphosate was estimated using GENEEC Version 2.1 as the Tier I simulation model. Both application rates noted above were evaluated: 4 applications of 1.99 lbs a.e./acre at 30-day intervals and 4 applications of 1.5 lbs a.e./acre at 30-day intervals. For the highest application rate, the peak concentration of glyphosate in a pond receiving runoff from a drainage basin treated 100 percent with glyphosate was estimated to be 15.66 µg/L (ppb) for Honcho®. Exposure to terrestrial species was estimated using Tier 1 TREX (Terrestrial Residue EXposure) simulation model (Version 1.2.3) based on the maximum proposed application rate (i.e., 1.99 lb a.e./acre with 4 applications), re-application interval (i.e., 30-day internval), and the default foliar dissipation half-life of 35 days. Peak estimated environmental concentrations (EECs), or residues, on various terrestrial food sources ranged from 61 to 968 mg/kg diet (see table N-1).

Table N-1. Dietary-based Peak Estimated Environmental Concentrations (EECs) Upper Bound Kenaga Values from TREX model (Assumptions and Values Differ from U.S. EPA 1993a)

Food source	Estimate concentration glyphosate (ppm)
Short Grass	968.42
Tall Grass	443.86
Broadleaf plants/Small Insects	544.74
Fruits/pods/seeds/Large insects	60.53

Glyphosate Toxicity and Risk to the Environment

The EPA toxicological and ecotoxicology and fate databases on glyphosate are considered adequate and complete (U.S. EPA, 1993a, 2006a). To estimate risk, peak EEC values were compared with acute dietary toxicity values for birds and mammals (tables N-7 and N-11) to calculate Risk Quotients (i.e., RQ = EEC/dietary toxicity value). The RQs were compared with EPA levels of concern (LOC) for non-endangered wildlife (i.e., RQ is of concern if > 1.0) and for endangered species (i.e., RQ for endangered species is of concern if > 0.1). Based on those data, glyphosate is considered to be a toxicologically and ecologically low-risk herbicide (Cerdeira and Duke, 2006). Given the data available on glyphosate use on GT alfalfa, chemical fate, and toxicity, and after a Tier 1 “high-end use case” scenario screening of hazard quotients, as explained below, we conclude that glyphosate is not expected to pose a risk to the following categories of wildlife:

- acute or chronic risk to birds

- acute or chronic risk to mammals
- acute or chronic risk to terrestrial invertebrates
- acute or chronic risk to aquatic invertebrates
- acute or chronic risk to fish

Glyphosate used on GT alfalfa might pose a risk to terrestrial and aquatic plants, however. Most plant species, when exposed to glyphosate, experience high levels of toxicity. Higher plants that use the shikimate pathway to produce aromatic amino acids will experience toxic effects as they metabolize glyphosate. These toxic effects could include the inability to photosynthesize, complete respiration, or synthesize nucleic acids. Although the effects can be slow to progress, any of these toxic effects could result in plant death. Spray drift is one of the pathways of concern for nontarget plants; however, if aerial applications are minimized, the risk to nontarget plants should be reduced. Standard toxicity studies as well as drift studies are available for several species of nontarget terrestrial plants (USDA, 2003) and are presented below. AMPA, the primary degradation product of glyphosate, seems to be equally or less toxic than glyphosate; therefore, a separate risk assessment was not performed.

Glyphosate Bird Toxicity and Risk

Glyphosate is practically nontoxic to birds and has not been found to cause reproductive effects (U.S. EPA, 1993a, 2006a). Toxicity in birds was assessed using single-dose, dietary, and reproductive toxicity studies, primarily with mallard ducks and bobwhite quail. In general, one-time gavage administration experiments did not identify an LD_{50} (dose required to kill 50 percent of a population of test animals) at the highest doses tested (e.g., 2,000 to 3,850 milligrams acid equivalents per kilogram body weight (mg a.e./kg); U.S. EPA, 1993a; Giesy et al., 2000). Results of longer term (5- to 8-day) dietary studies using bobwhite quail and mallard ducks similarly indicated that glyphosate is practically nontoxic to birds, with no-observed-adverse-effect levels (NOAELs) of 4,640 mg a.e./kg diet (= 4,640 ppm in diet), the highest dietary concentration tested (U.S. EPA, 1993a, 2006a; Giesy et al., 2000). Reproductive studies did not indicate any effects after glyphosate treatment in mallard ducks or bobwhite quail. The no-observed-effect concentration (NOEC) for reproduction for both the mallard and bobwhite quail was the highest concentration tested, 1000 mg a.e./kg diet (U.S. EPA, 1993a, 2006a). Studies with glyphosate tested as its isopropylamine (IPA) salt were not reported for review.

None of the RQs estimated from peak EECs exceeded a LOC with the exception of the RQ for the birds with a diet of broad leaf plants and small insects (birds do not consume grasses per se), for which the acute dietary NOEC was 1000 mg a.e./kg (= ppm) diet, yielding an RQ of 0.12 (i.e., RQ = 545 ppm/4640 ppm). This RQ is of some concern for endangered species. Because the EECs estimated above are based on worst-case/high-end-use scenarios, the RQ of 0.54 is considered a minimal risk to threatened and endangered species.

Glyphosate Mammal Toxicity and Risk

Wild mammal toxicity testing is not required by EPA for ecological risk assessments. In most cases, the rodent and rabbit toxicity values obtained from studies conducted to support human health risk assessments substitute for wild mammal testing. All of the acute toxicity (2,000 to 6,000 mg/kg gavage oral and 4-day dietary administration) study results in rodents indicaited glyphosate is slightly toxic to practically nontoxic and a non-sensitizer. In terms of subchronic and chronic toxicity in rodents, one of the more consistent effects of exposure to glyphosate is loss of body weight. Glyphosate is a Group E carcinogen, which means no evidence of carcinogenicity. Additionally, glyphosate is not a mutagen. Glyphosate was not found to cause reproductive or developmental effects. Glyphosate produced an acute oral LD_{50} of 5,700 mg a.e./kg/day in the goat (Rowe, 1987b as cited in Giesy et al., 2000), with the product Roundup® having a LD_{50} of 4,860 mg of Roundup® product/kg/day. A full summary of mammalian toxicity of glyphosate is provided in another technical report for this Environmental Impact Statement (EIS) entitled, *Health and Safety Risks from Increased Glyphosate and Other Chemical Use on Humans (Exclusive of Field Workers)* (appendix M). None of the dietary RQs for mammals estimated from peak EECs exceeded a LOC.

Glyphosate Terrestrial Invertebrate Toxicity

Honeybees are the preferred species to assess nontarget arthropod toxicity by EPA. The LD_{50} for glyphosate is >100 µg/honeybee (U.S. EPA, 1993a, 2006a), which is considered Practically Non-Toxic according to EPA standards. Furthermore, formulations of glyphosate that are approved for use on GT alfalfa have LD_{50} values that range from >100 to >326 µg/honeybee, which is also considered Practically Non-Toxic by EPA standards (Giesy et al., 2000; Monsanto, 2005, 2006, 2007b, 2007d).

Glyphosate Terrestrial Plant Toxicity

Glyphosate is toxic to plants; however, it is much less toxic to germinating plants than it is to the foliage of growing plants. The NOEC for seed germination in both monocots and dicots is 4.5 lbs a.e./acre application rate (USDA, 2003). The highest reported NOEC for growth in a vegetative vigor study was 0.56 lb a.e./acre (USDA, 2003), which is well below the recommended maximum single application rate of 1.55 lb a.e./acre. In a vegetative vigor study (U.S. EPA, 2006a), the most sensitive dicot was oilseed rape, displaying phototoxicity when exposed at > 0.038 lb a.e./acre; the most sensitive monocot was winter wheat where dry weight was affected at > 0.049 lb a.e./acre.

Glyphosate Soil Invertebrates and Microorganism Toxicity

Acute toxicity tests were not conducted on invertebrates and microorganisms since the life-cycles for these organisms are short. Soil microbes readily metabolize glyphosate into AMPA and other metabolites (USDA, 2003). Many microorganisms produce aromatic amino acids through the shikimate pathway, similar to plants. Since glyphosate inhibits this pathway, it could be expected that glyphosate would be toxic to these microorganisms. Field studies have shown changes in soil microbial communities in response to GT crops with applications of glyphosate;

however, the changes have not been conclusively linked to significant adverse effects to the soil communities or to plant health or yield.

Earthworm toxicity was evaluated over 14 days for glyphosate and for formulations of glyphosate that are approved for use on GT alfalfa. Glyphosate had a no mortality level of 3750 mg/kg soil and a NOEC of 118.7 mg kg/soil; the formulated products had LD_{50} values ranging from > 5000 to > 10000 mg/kg dry soil (Giesy et al., 2000; Monsanto, 2005, 2006, 2007b, 2007d).

Glyphosate Aquatic Plant Toxicity

For algae, USDA ® reported results of 26 tests on 19 species with various glyphosate herbicide formulations; the reported EC_{50} values (the concentration of a compound that produces a 50 percent effect level, e.g., 50 percent reduced growth) for glyphosate in algae ranged from 0.85 to 590 milligrams product per liter (mg/L) (USDA, 2003). In chronic tests of other aquatic plants, the EC_{50} for glyphosate ranged from 1.6 to 25.5 mg product/L (USDA, 2003).

U.S. EPA (2004) Office of Pesticide Programs categories for acute toxicity for aquatic organisms based on LC_{50} or EC_{50} (mg/L) data is as follows: <0.1 very highly toxic; 0.1 to 1 highly toxic; >1-10 moderately toxic; >10-100 slightly toxic; >100 practically nontoxic. Glyphosate therefore is considered highly to moderately toxic to some aquatic plant species while practically nontoxic to others.

Glyphosate Amphibian Toxicity

Glyphosate is slightly toxic to amphibians; however, some formulations of glyphosate with the surfactant polyethoxylated tallowamine (POEA) are very toxic to amphibians. The LC_{50} for tadpoles exposed to glyphosate alone ranged from > 343 to 466 mg a.e./L for the IPA salt and 78 to 180 mg a.e./L for the acid (Giesy et al., 2000). Formulated products were more toxic in the acute tadpole tests (LC_{50} values from 0.8 to 3.2 mg a.e./L). POEA is a non-ionic surfactant used in many herbicide formulations to increase the ability of active ingredients to penetrate leaf cuticles. POEA has been found to be more toxic to amphibians and other aquatic animals than the herbicide itself by more than an order of magnitude (Lajmanovich, 2003; Mann and Bidwell, 1999; Relyea, 2005a, 2005b; Relyea and Jones, 2009).

A recent effects determination by EPA on the effect of glyphosate use on the California red-legged frog (*Rana aurora draytonii*) (CRLF) found no toxic effects at the maximum single application rate for glyphosate products labeled for GT alfalfa (1.55 lb a.e./acre) (U.S. EPA, 2008).

None of the glyphosate formulations that contain surfactants are approved for use over water. Some without surfactants are approved for use over water.

Glyphosate Aquatic Invertebrate Toxicity

As for amphibians and some salmonid fish, glyphosate is slightly toxic to aquatic invertebrates. Glyphosate-based herbicide formulations that also contain surfactants can be very toxic to aquatic invertebrates. Several acute and lifecycle toxicity tests have been performed on a variety of freshwater aquatic invertebrates for glyphosate and various glyphosate-based herbicide formulations. The most sensitive species to glyphosate was the midge larva *Chironomus plumosus*, with a 48-hour LC_{50} of 55 ppm (mg a.e./L) (Folmar et al., 1979 as cited in U.S. EPA, 1993a, 2006a), which is classified as slightly toxic by EPA. The 48-hour LC_{50} for *Daphnia magna* ranged from 780 mg a.e./L (U.S. EPA, 1993a, 2006a) to 930 mg/L (tested as IPA salt), with a NOEC of 560 mg a.e./L (Giesy et al., 2000), which is considered Practically Non-Toxic according to EPA standards.

The most sensitive species to glyphosate herbicide end-use formulations was *Daphnia magna*, with a 48-hour EC_{50} of 9.7 Roundup® product/L (Folmar et al., 1979, as cited in Giesy et al., 2000), which is roughly equivalent to 3 mg a.e./L assuming 1.0 mg of RU contains 0.31 mg glyphosate a.e. (USDA, 2003); 48-hour EC_{50} values for other formulations ranged up to 160 mg/L (USDA, 2003; Monsanto, 2005, 2006, 2007b, 2007d). The NOEC of a Roundup® formulation to *D. magna*, on the other hand, was 3.2 mg RU/L, or about 1 mg a.e./L assuming 0.31 mg a.e./1 mg RU (Giesy et al., 2000). The tests, therefore, indicated that herbicide formulations of glyphosate were more toxic to *Daphnia magna* than technical glyphosate by more than an order of magnitude. Toxicity values (96-hour EC_{50} or LC_{50}) for *Gammarus pseudolimnaeus* ranged from 42 mg RU/L to 200 mg RU/L, with a NOEC of 4.4 mg RU/L (Giesy et al., 2000).

Glyphosate Fish Toxicity

A large number of studies have been performed using a variety of freshwater fish species to determine the acute toxicity of glyphosate. According to EPA's (2004) Office of Pesticide Programs toxicity classification system, overall, the tests indicate that glyphosate is moderately toxic to fish. The most sensitive species to glyphosate is rainbow trout (fry), with a 96-hour LC_{50} of 7.9 parts per million (ppm) (USDA, 2003). Published 96-hour LC_{50} values for rainbow trout exposed to glyphosate range from 7.9 to 25,657 mg/L (USDA, 2003). This large range is most likely indicative of varying study conditions. Reported 96-hour LC_{50} values for sockeye salmon were 8.1 mg/L for fingerlings and 8.7 mg/L for fry. For Coho salmon, 96-hour LC_{50} values ranged from 12.8 mg a.e./L (fry) to 36 mg a.e./L (glyphosate tested as acid) (USDA, 2003). Fathead minnow underwent a full life-cycle toxicity study, and the Maximum Allowable Toxicant Concentration (MATC) was calculated to be greater than 25.7 mg/L glyphosate (whether a.i. or a.e. not specified; U.S. EPA, 1993a). A 21-day chronic study in rainbow trout identified a NOEC of 52 mg a.e./L (Giesy et al., 2000), whereas a study with Roundup® identified a NOEC of 2.4 mg RU/L (or 0.74 mg a.e./L) for rainbow trout.

Many studies have also been performed using a variety of species of freshwater fish to determine the acute toxicity of glyphosate formulations approved for use on GT alfalfa. Glyphosate formulations appear to be slightly more toxic than glyphosate alone. The most sensitive species to the formulations considered was rainbow trout, with a 96-hour LC_{50} of 3.13 mg/L when treated with formulations similar to Roundup UltraMAX II ® and Roundup WeatherMAX ® (RU, a.e., or a.i. not specified; Monsanto, 2004, 2005). The 96-hour LC_{50} for rainbow trout

treated with glyphosate herbicide formulations ranged from 4.2 to 52 mg RU/L (or 1.3 to 16 mg a.e./L; Giesy et al., 2000). Sockeye salmon was observed to have a 96-hour LC_{50} of 26.7 mg RU/L (equivalent to 8.3 mg a.e./L), and Coho salmon was observed to have a 96-hour LC_{50} ranging from 13 to 42 mg RU/L (equivalent to 4 to 13 mg a.e./L; Giesy et al., 2000).

Glyphosate Marine Organism Toxicity

The only saltwater and marine species that have been tested for toxicity of glyphosate and glyphosate herbicide formulations for GT alfalfa are invertebrates. The most sensitive marine species to glyphosate was the small zooplankton species *Acartia tonsa*, with a 48-hour LC_{50} of 35.3 mg a.e./L or 49.3 mg a.e. as an IPA salt (Tsui and Chu, 2003). Grass shrimp were reported to have a 96-hour LC_{50} of 281 ppm (U.S. EPA, 1993a). The 48-hour level that produced toxic effects in 50 percent of the population (TL_{50}) for Atlantic oyster was determined to be > 10 mg/L (U.S. EPA, 1993a). The 48-hour TL_{50} for fiddler crab was determined to be 935 ppm (U.S. EPA, 1993a). Those test results suggest that glyphosate is slightly toxic (*Acartia tonsa*) to practically non-toxic (grass shrimp and fiddler crab) (U.S. EPA, 2004a criteria). In contrast, the full Roundup ® formulation was found to be moderately toxic to the *Acartia tonsa*, with a 48-hour LC_{50} of 1.77 mg/L.

Other Herbicides Used on GT Alfalfa Chemical Fate in the Environment

This report was not an exhaustive examination of the chemical fate of the 20 pesticides used on GT alfalfa. Each pesticide's EPA Reregistration Eligibility Decision and Material Safety Data Sheet (MSDS) were used as sources. The 20 other pesticides used on alfalfa have varying chemical fates. In general, most of these pesticides were more persistent in the environment and had higher mobility in soils than glyphosate, making them more apt to continually contaminate surrounding water systems. A few were even considered compounds that could bioaccumulate (e.g., clopyralid, EPTC, norfluzaon, sethoxydim, and trifluralin).

Environmental Impact of GT Alfalfa Herbicides Compared to Glyphosate

The most sensitive toxicity endpoints that were publicly available for all ecological receptors were used for the Environmental Impact Quotient (EIQ) assessment (Kovach et al., 1992 and updated annually). According to this assessment, all of the common alfalfa herbicides pose a higher risk to the environment than glyphosate, excluding EPTC. Thus, use of other, more toxic herbicides could either decrease or increase in alfalfa production with increased adoption and planting of GT alfalfa, depending on several factors such as the exact adoption rate of GT alfalfa. Overall, glyphosate use in agriculture is increasing (Benbrook, 2009), and glyphosate is more environmentally benign than many other herbicides used on non-GT crops.

1.0 Introduction

1.1 Glyphosate-Tolerant Alfalfa Background

Alfalfa is one of the most important livestock forage crops in the United States, particularly for dairy cows. Across the country, farmers grow more than 20 million acres of alfalfa (USDA,

2008). Alfalfa is an important animal feed because of its high protein and low fiber content. Alfalfa ranks fourth on the list of most widely grown crops, behind corn, soybeans, and wheat, and it is the third most valuable crop to agriculture. Because it is widespread and typically grown as a perennial crop, alfalfa also serves as important habitat for wildlife (Hubbard, 2008).

Due to the agricultural importance of alfalfa, Monsanto Company scientists have modified its genome to make a strain that is resistant to the broad-spectrum herbicide, glyphosate. Monsanto scientists incorporated the gene sequence from a native soil microorganism, *Agrobacterium tumefaciens*, into the alfalfa genome to make a strain of alfalfa that can survive applications of glyphosate. Glyphosate is the active ingredient in Roundup®, an herbicide produced by Monsanto. In June 2005, the USDA approved the use of Roundup Ready® alfalfa. This GT alfalfa is the only commercially available genetically engineered alfalfa on the market. Monsanto produced GT alfalfa in partnership with the largest alfalfa seed company, Forage Genetics International (FGI). The transgene responsible for glyphosate tolerance was first introduced in soybeans in 1996, and has been commercialized in several other crops (e.g., corn, canola, and cotton). Alfalfa is the first perennial GT crop that was approved for commercial planting in the United States.

GT alfalfa will be used primarily by dairy farmers, because they prefer to feed their cows pure alfalfa, free of weeds and grasses thatdilute the protein content of the forage, whereas beef cattle producers and horse owners typically feed their animals an alfalfa-grass mixed hay (Putnam, 2005). Monsanto and Forage Genetics International (2004) reported that the majority of alfalfa acreage in the United States is planted to pure stands (40 percent), 35 percent is planted with a cover (nurse) crop, and 25 percent is planted with grasses or with another companion crop.

Herbicide usage in alfalfa varies with growing region and age of the alfalfa planting. In general herbicides are applied early in stand establishment when alfalfa seedlings are unable to compete with more vigourous weeds. Once an alfalfa field is established it may continue to be productive for several years without additional herbicide application. Approximately 74 percent of alfalfa hay acreage was located in the North Central region of the United States where weeds are less of a problem than in the Western region. Only 8.1 percent of the North Central alfalfa fields were sprayed with herbicides while 50 percent of alfalfa fields in the West, which constitute only one quarter of the alfalfa fields nationwide, were herbicide-treated (Hower et al., 1999). USDA-NASS (1999, p. 9) reported that only 7 percent of alfalfa acreage for hay was sprayed with herbicides in 1998. Hower et al. (1999) reported that from 1988 to 1992, before the introduction of any GT alfalfa, only 16.6 percent of alfalfa acreage grown for hay nationwide was treated with herbicides.

1.2 Glyphosate and Other Herbicides Related to GT Alfalfa Cultivation

As mentioned above, glyphosate was first introduced as an herbicide under the trade name of Roundup® by Monsanto in 1974. Before the introduction of GT crops, glyphosate was used in noncrop situations, during preplanting, or with particular application equipment to avoid contact with the crop due to its toxicity to most species of plants (Duke, 1988; Duke et al., 2003; Franz et al., 1997). Glyphosate is a systemic, post-emergence herbicide widely used on agricultural commodities (food uses) and nonagriculture sites. It is a very effective nonselective herbicide

(Cerdeira and Duke, 2006). Glyphosate inhibits amino acid metabolism in plants in what is known as the shikimate acid pathway (Pesticide Action Network, 1996). More specifically, it is a potent and specific inhibitor of the enzyme 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS) in plants. This enzyme is the sixth enzyme on the shikimate pathway, and it is essential for the biosynthesis of aromatic amino acids and other aromatic compounds in algae, higher plants, bacteria, fungi, and apicomplexian parasites (U.S. EPA, 1993a, 2006a). The shikimate pathway is absent in mammals. "Glyphosate is particularly effective because most plants metabolically degrade it very slowly or not at all, and it translocates well to metabolically active tissues such as meristems" (Cerdeira and Duke, 2006).

Cultivation practices for GT alfalfa are essentially the same as for conventional alfalfa, except that GT alfalfa can tolerate an in-crop glyphosate treatment. Herbicides related to alfalfa farming can be divided into two major groups. One group includes herbicides that do not kill alfalfa (e.g., 2,4-DB, benefin, bromonoxynil, clethodim, diuron, *S*-ethyl dipropyl (thiocarbamate) (EPTC), hexazinone, imazamox, imazethapyr, metribuzin, norfluzaon, paraquat, pronamide, sethoxydim, terbacil, and trifluralin), and are, therefore, used to control weeds during the growing season. The other group includes herbicides that kill alfalfa (e.g., 2,4-D, dicamba, clopyralid, and picloram), which are used for stand removal. Glyphosate is the herbicide most often used for alfalfa stand removal every 2-7 years in conventional alfalfa. For GT alfalfa, stand removal would require herbicides other than glyphosate. Overall, herbicide shifts due to stand removal, which occurs only once every 2-7 years, would be smaller in magnitude than herbicide shifts due to weed control on a yearly basis.

1.3 Glyphosate Resistant Weeds and GT Alfalfa Cultivation

Weeds can develop resistance to herbicides for the following reasons: frequent exposure to a particular herbicide, the spread of naturally resistant weed seeds, and the outcrossing of herbicide-tolerant genes from genetically altered plants to weedy relatives. Certain weeds have become resistant to glyphosate due to the over reliance on glyphosate to control weeds ; however, none have developed due to outcrossing from GT crops. Further details on glyphosate resistant weeds; refer to technical reports *Effects of Glyphosate-Resistant Weeds in Agricultural Systems* (appendix G) and *Effects of Glyphosate-Resistant Weeds in Nonagricultural Ecosystems* (appendix H).

Proper crop and weed management practices should be followed to reduce the risk of glyphosate-resistant weed development. Increased exposure to one herbicide, namely glyphosate, offers the potential for some weeds to develop glyphosate resistance. Diversifying weed control tactics can delay the development of herbicide resistance and aid in controlling herbicide-resistant weeds, thus, preserving the herbicide efficacy. Using herbicides with different modes of action also will decrease the chance of plants developing resistance to a single herbicide. GT crops should be rotated with non-GT crops to reduce heavy reliance on glyphosate, thus, decreasing the risk of weeds developing resistance to glyphosate.

The Herbicide Resistance Action Committee (HRAC) is a consortium of agrochemical manufacturers that provides information about resistance cases and strategies for management (HRAC, 2002). The EPA and the Pest Management Regulatory Agency of Canada (PMRA)

have worked closely with the HRAC and the Weed Science Society of America (WSSA) to address herbicide resistance. The EPA and PMRA have developed voluntary resistance management guidelines encouraging rotation of herbicides based on mode of action for all agricultural pesticide use (Canada PMRA, 1999; U.S. EPA, 2001).

In the event of glyphosate resistant weeds, the management practices suggested are to use the following less-resistance-prone herbicides: paraquat/diquat, MSMA, phenoxy herbicide (e.g., 2,4-D, MCPA, trichlopyr, dicamba), tubulin inhibitors (e.g., benefin, fluchloralin, pendimethalin, ethanlfluralin, trifluralin), triazine (amitrole, atrazine, cyanazine, simazine, trietazine, metribuzin), bromoxynil, s-ethyl dipropylthiocarbamate (EPTC), imazamox, imazethapyr, sethoxydim, clethodim, glufosinate, and/or rare protox herbicides (acifluorfen). A list of glyphosate-tolerant weeds and suggested herbicides for their control are presented in appendix N-4 of this technical report; however, the list is not exhaustive due to new weeds regularly being registered or discovered. These herbicides are more toxic and persistent in the environment than glyphosate, thus, they may exert a greater environmental impact; however, weed management is plant specific. In some cases of a multiple herbicide resistance, the preferred weed management practice is deep tillage. Currently, glyphosate resistant weeds have taken over two million acres of farmland in the United States (Hubbard, 2008). The most problematic glyphosate resistant weeds in the United States include pigweed (waterhemp), horseweed (marestail), common and giant ragweed, and ryegrass (Hubbard, 2008).

1.4 Methodology

In efforts to assess the potential impacts on wildlife, amphibians, plants, and ecosystems from increased glyphosate and other chemical use due to the deregulation of GT alfalfa by USDA in 2005, a Tier 1 ecological risk assessment was conducted for glyphosate use on GT alfalfa. In the preparation of this risk assessment, literature searches for data on environmental fate, transport, and toxicity of glyphosate were conducted using the literature search strategy presented in appendix N-2 of this technical report. . Primary sources of data were obtained from the following three documents: the EPA 1993 Reregistration Eligibility Decision (RED) document on glyphosate (U.S. EPA, 1993a); the EPA 2006 Glyphosate New Use (bent-grass): Environmental Fate and Effects Risk Assessment (U.S. EPA, 2006a), the EPA Glyphosate Human Health Risk Assessment for Proposed Use on Indian Mulberry and Amended Use on Pea, Dry. (U.S. EPA, 2006c); the USDA, Forest Service 2003 human health and ecological risk assessment on glyphosate (USDA, 2003); and an ecotoxicological risk assessment for Roundup® herbicide by John P Giesy and colleagues in 2000 (Giesy et al., 2000). Additional information was used from a risk assessment on the use of glyphosate by Monsanto (Carr and Honegger, 2008; Honegger et al., 2008; Mortensen et al., 2008; Priester et al., 2007, 2008)

This ecological risk assessment presented is not a comprehensive summary of all of the available information and does not cite all of the available literature. As USDA determined in 2003, an all inclusive and detailed review of each ecotoxicological study would tend to obscure rather than inform. Therefore this document relies on the information that is likely to impact the risk assessment.

The application rate of glyphosate on GT alfalfa was determined by reviewing all the glyphosate herbicide formulations that report the maximum daily and yearly use rate on GT alfalfa. These formulations are all Monsanto Company products, as GT alfalfa is also a Monsanto product. It can be expected that other formulations for glyphosate herbicide could and may be used on GT alfalfa; however, to develop a conservative quantitative risk assessment, the maximum use rate of 1.99 lb a.i./acre for a single use, with minimum reapplication within 7 days and not to exceed 7.95 lb a.e./acre in a year, the value for maximum recommended for noncrops, was used. The legal maximum single use rate for glyphosate on GT alfalfa is 1.55 lb a.e./acre, with minimum reapplication within 7 days and not to exceed 6 lb a.e./acre in a year. Thus, the risk assessment conducted is a particularly conservative one.

2.0 Chemical Description and Commercial Formulations of Glyphosate Herbicides

Glyphosate is a substituted glycine, the simplest amino acid. The glyphosate molecule has a methylphosphono group bonded to the nitrogen atom of the amino group of glycine as denoted in figure N-1 below.

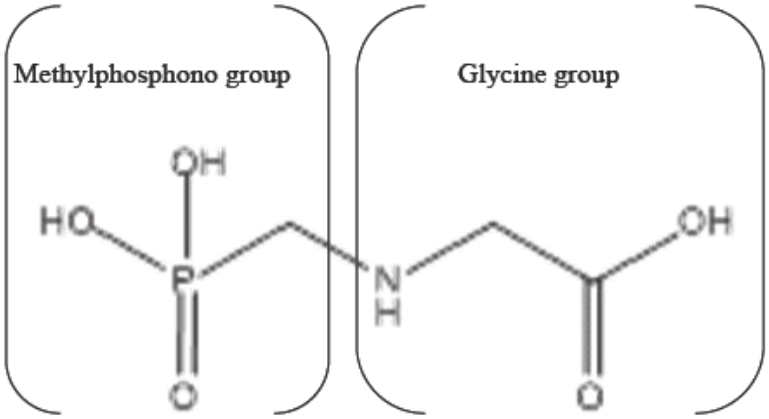

Figure N-1: Glyphosate molecular structure

Physical and chemical properties of glyphosate are in table N-2 below.

Table N-2. Physical and Chemical Properties of Glyphosate

Property	Value	Source
Common Name	Glyphosate	U.S. EPA, 1993a
Chemical Name	*N*-(phosphonomethyl)glycine	U.S. EPA, 1993a
Chemical Abstract Registry Number (CAS)	1071-83-6	U.S. EPA, 1993a
Smiles notation	OC(=O)CNCP(O)(O)=O	EPI Suite
PC Code	417300	U.S. EPA, 1993a
Molecular Weight g	169.07	USDA, 2003
Density at 25°C	1.7	U.S. EPA, 1993a
Solubility in water at 25°C	12,000 mg/L	U.S. EPA, 1993a
pKa	0.8 first phosphonic acid 2.3 carboxylate 6.0 second phosphonic acid 11.0 amine	
Vapor Pressure at 25°C, Pa	1.3×10^{-7}	U.S. EPA, 1993a
Henry's Law Constant (Pa m^3/mol)	2.1×10^{-9}	U.S. EPA, 1993a

Glyphosate salts serve as the source of *N*-(phosphonomethyl) glycine. Several salts of glyphosate with different counter cations are currently marketed. Each salt has a different "glyphosate equivalent", which is defined as the ratio of the molecular weight of *N*-(phosphonomethyl)-glycine to the molecular weight of the salt. The glyphosate herbicides approved for use on GT alfalfa are listed in table N-3. GT alfalfa could tolerate other herbicide

formulations with glyphosate; however, the five products listed below are the herbicides approved for use on GT alfalfa.

Table N-3. End-Use Products Approved for Use on GT Alfalfa

Product Name	% Salt	Glyphosate salt CAS No.	USEPA PC Code	Surfactant	Manufacturer
Honcho®	41	Isopropylamine CAS: 38641-94-0	103601	Alkyl Tallow Ethoxylated Amines CAS 61791-26-2	Monsanto, 2007a
Honcho Plus®	41	Isopropylamine CAS: 38641-94-0	103601	Trade Secret	Monsanto, 2007c
Roundup Original MAX®	48.7	Potassium CAS: 70901-12-1	103613	Trade Secret	Monsanto, 2007e
Roundup WeatherMAX®	48.8	Potassium CAS: 70901-12-1	103613	Trade Secret	Monsanto, 2007f
Roundup Ultra MAX II®	48.8	Potassium CAS: 70901-12-1	103613	Trade Secret	Monsanto, 2004

2.1 Application Rate Specific to GT Alfalfa

The Honcho® and Honcho Plus® products contain 41 percent of the isopropylamine salt of glyphosate, or 480 grams/Liter of the salt, which is equivalent to 356 g/L (3 lbs/U.S. gallon or 0.75 lbs/quart) of the glyphosate acid equivalent (a.e.). The product is to be applied as over-the-top (spot treatment; broadcast ground application) for pre-plant, pre-emergence, and post-emergence uses. For crop uses, the combined total treatments should not exceed 8 quarts per acre per year (/acre/yr), or 6.0 lbs a.e./acre/yr. For noncrop uses, the combined total of all treatments should not exceed 10.6 quarts per year, or 7.95 lbs a.e./acre/yr. For the risk assessment, to be conservative, the maximum total application rate of 7.95 glyphosate a.e. per acre per year (2.65 gal of product/acre/yr) was assumed. To achieve that total maximum application rate, four single applications of 1.99 lbs glyphosate a.e./acre were assumed with a minimum reapplication interval of 7 days. In actuality, for use on GT alfalfa, the maximum label rate for a single application of glyphosate is 1.55 lbs glyphosate a.e./acre, and the maximum total application rate for the year is 6.0 lbs glyphosate a.e./acre.

The Roundup Ready Original MAX®, Roundup WeatherMAX®, and Roundup Ultra MAX II® products contain 48.8 percent of the phosphate salt of glyphosate, equivalent to 4.5 lbs of glyphosate acid equivalents per gallon (1.125 lb a.e./quart or 540 g glyphosate a.e./L). The product is to be applied over-the-top (spot treatment; broadcast ground application) for pre-plant, pre-emergence, and post-emergence uses. The maximum total application rate is 7.32 glyphosate acid equivalents per acre per year (2.4 gal of product per acre or 9.6 quarts of product per acre), with a single use maximum application of 1.90 lbs glyphosate a.e./acre. The minimum reapplication interval is 7 days. The maximum label rate for a single application of glyphosate to GT alfalfa is 1.55 lbs glyphosate a.e./acre, and the maximum total application rate for the year is 6.0 lbs glyphosate a.e./acre.

2.2 Residue of Glyphosate on Crops and Livestock

Studies with a variety of plants indicate that uptake of glyphosate or AMPA from soil is limited. Foliar-applied glyphosate is readily absorbed and translocated throughout the trees or vines to

the fruit of apples, coffee, dwarf citrus (calamondin), pears, and grapes (U.S. EPA, 2006c). Nonetheless, residues on fruit consumed by wildlife were estimated to be ≤ 35 ppm (mg/kg fruit, U.S. EPA, 2006c). The tolerances set for residues of glyphosate on fruits consumed by humans are 0.5 ppm or less.

There are over 85 tolerances established for residues of glyphosate and its metabolite, AMPA, in or on a wide variety of crops and crop groups consumed by humans as well as in animal feed and animal tissues (see 40 CFR 180.364, 40 CFR 185.3500, and 40 CFR 186.3500). EPA has conducted a human health risk assessment for human dietary consumption of glyphosate assuming the worst case, that 100 percent of all possible commodities or acreage was treated and that residues in those commodities were at the tolerance levels. EPA concluded that chronic dietary risk posed by glyphosate residues in foods is minimal for humans. Further analysis of human health dietary risks are discussed in the technical report, *Health and Safety Risks from Increased Glyphosate and Other Chemical Use on Humans (Exclusive Of Field Workers)* (appendix L).

For the most part, the ratio of glyphosate to AMPA in plants is 9 to 1 but can approach 1 to 1 in a few cases (e.g., soybeans and carrots). Nonetheless, much of the residue data for crops reflects a low level of the parent glyphosate compound plus AMPA (0.05 - 0.15 ppm) or residues below the level of detection (<0.05 ppm; U.S. EPA, 2006c). EPA determined that, based on toxicological considerations, AMPA need not be regulated and should be dropped from the tolerance expression (U.S. EPA, 2006c). It should be noted that humans will not be directly consuming GT alfalfa.

Metabolism studies submitted for genetically engineered GT canola and GT corn have indicated that metabolism in GT plants is essentially the same as that in normal plants (U.S. EPA, 2006c). During a confined crop rotational study the residues of glyphosate were undetected 30 days after treatment (U.S. EPA, 2006c, MRIDs 41543201 and 41543202). The qualitative nature of glyphosate residue in plants is adequately understood (U.S. EPA, 2006c).

Monsanto in Brussels (M-A Reding) conducted metabolism studies with lactating goats, laying hens, and cows fed a mixture of glyphosate and AMPA. Test groups of animals were fed a daily diet of a 9:1 mixture of glyphosate to AMPA at total combined dietary levels of 40, 120, and 400 mg/kg diet for 28 days. Those doses represent 1x, 3x, and 10x the maximum expected residue level of glyphosate and AMPA in the diet of those groups. The results indicated no detectable transfer at the 1x dose level, the glyphosate residues were less than the detection limit (<0.05 mg/kg) in all animal tissues and less than the detection limit (0.025 mg/kg) in milk and eggs. The studies indicated rapid and essentially complete elimination of dietary glyphosate and AMPA, primarily by excretion in urine and feces (Monsanto M-A Reding; U.S. EPA, 1993a, 2006b). Thus, transfer of glyphosate and AMPA to milk, eggs, and livestock tissues appear to be negligible and there clearly is no bioaccumulation (U.S. EPA, 1993a, 2006).

Those conclusions are consistent with experimentally controlled metabolism studies conducted with rats. In a single and repeated oral dose metabolism study in rats using radiolabeled ^{14}C-glyphosate, only 30 to 36 percent of the glyphosate was absorbed from the gastrointestinal tract and over 97.5 percent of the administered dose was excreted in the feces and urine as the parent

compound (U.S. EPA, 1993a). The only metabolite found, AMPA, was excreted in both urine and feces (0.2–0.3 percent of the administered dose excreted in urine and 0.2–0.4 percent excreted in feces). Less than 1 percent of the absorbed dose remained in the rats. Repeated dosing did not change the pattern of uptake, distribution, or excretion. Less than one percent of the absorbed dose remained in tissues and organs in all tests, primarily in bone tissue (U.S. EPA, 1993a). A second study using intraperitoneal injections of radiolabeled glyphosate (1150 mg glyphosate a.e./kg) found that very little glyphosate reaches bone marrow, that it is rapidly eliminated from bone marrow, and that it is even more rapidly eliminated from blood plasma (U.S. EPA, 1993a). The half-life for glyphosate (radioactivity) in the bone marrow was 7.l6 hours for males and 4.2 hours for females (U.S. EPA, 1993a, MRID 00132685). The half-life of glyphosate in blood plasma was approximately 1 hour, indicating rapid elimination overall.

3.0 Glyphosate and Alfalfa Herbicide Fate in the Environment and Occurrence

3.1 Glyphosate Fate

The environmental fate assessment is based on the EPA 1993 RED document on glyphosate (U.S. EPA, 1993a); the EPA 2006 Glyphosate New Use (bent-grass): Environmental Fate and Effects Risk Assessment (U.S. EPA, 2006a); U.S. Forest Service 2003 human health and ecological risk assessment on glyphosate (USDA, 2003); an ecotoxicological risk assessment for Roundup® herbicide by John P Giesy and colleagues in 2000 (Giesy et al., 2000), and recent relevant open literature studies related to the behavior of glyphosate in the environment. Glyphosate has a low vapor pressure and Henry's law constant; thus, it has a low potential to volatilize from soil and water. Glyphosate is hydrophilic, with a low *n*-octanol-water partition coefficient; therefore, it has low potential to bioaccumulate in animals. It has a high solubility in water and does not undergo hydrolysis or photolysis. Glyphosate residues can end up in the soil after application due to translocation from plant shoots to roots, and then exudation from roots to the soil (Laitinen et al., 2007). However, due to glyphosate's strong adsorptive quality to soil, it is not expected to contaminate groundwater (Borgaard and Gimsing, 2008); although, runoff water could contain particulates with adsorbed glyphosate. The chemical fate properties of glyphosate are presented in table N-4 below.

Table N-4. Chemical Fate Properties of Glyphosate

Property	Value	Source
Common Name	Glyphosate	U.S. EPA, 2006a, 1993a
Chemical Name	*N*-(phosphonomethyl) glycine	
Log Kow	-3	
Hydrolysis	Stable ≥30 days at pH 3, 6, and 9 at 5 and 35°C	
Photolysis	Does not absorb light energy pH 5, 7, and 9	
Metabolism in soil, half life	1.85 – 2.06 day	
Metabolism water-sediment system, half life	Aerobic: 7 days Anaerobic: 8.1 – 199 days	
Soil Mobility, $K_{ads\ Freundlich}$	9.4 – 700 mL/g	
Soil water partition coefficient $K_{d\ (adsorption)}$	62 Drummer silty clay loam 90 Ray silt 70 Spinks sandy loam 22 Lintonia sandy loam 175 Cattail swamp sediment	
Soil adsorption K_{oc}	2100 (500 – 2600) (L/kg) 2600 – 4900 (L/kg) 8 to >500,000 (L/kg) 54 (L/kg)	USDA, 2003
Metabolite	aminomethyl phosphonic acid (AMPA)	U.S. EPA, 2006a, 1993a
Field dissipation (application rate: 7.95 lb ae/acre, 10.7 lb ai/acre), half life	13.9 days (median) 2.6 days in Texas 140.6 days Iowa	
Aquatic field dissipation, half life	7.5 days and 120 days	
Bioaccumulation in fish	0.38X edible tissue 0.63X nonedible tissue 0.52X whole fish	

In soil, sediment, or natural water, microbes degrade glyphosate quickly and the major metabolite is aminomethyl phosphonic acid (AMPA) which is further degraded to CO_2, although at a slower rate than the parent glyphosate (U.S. EPA, 2006a, 1993a). Figure N-2 presents the chemical structure of AMPA.

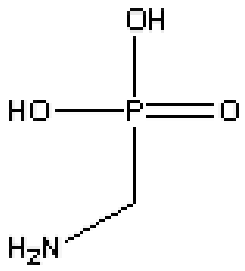

Figure N-2: Chemical structure of AMPA

In the environmentally significant pH range of 5 to 9, the first phosphonic and carboxylate protons are fully dissociated. The dissociation of the second phosphonic proton increases above a pH of 6, but the amine proton is unlikely to dissociate in the environment.

The molecule of glyphosate can be envisioned as a ligand that binds via the oxygen atoms. These molecular characteristics of glyphosate have major implications in its mode of herbicide action and in the sorption behavior of glyphosate on soils.

Studies cited in the EPA 1993 RED document (U.S. EPA, 1993a) reported that half-lives in field studies (including soils) conducted in the coldest climates (i.e., Minnesota, New York, and Iowa) were the longest and ranged from about 29 days up to about 140 days, indicating that glyphosate residues in the field are somewhat more persistent in cooler climates as opposed to milder ones (Georgia, California, Arizona, Ohio, and Texas). Also, glyphosate was shown to remain predominantly in the top 0-6 inch soil layer at all field sites in one study.

3.2 Alfalfa Other Herbicide Comparative Fate Data

Sixteen herbicides are used on alfalfa and four are used to remove GT alfalfa fields. Table N-5 below has compiled environmental fate data on these twenty herbicides for the herbicides respective EPA RED documents, MSDSs, or PAN Pesticides Database. In general most of the 20 herbicides aremore persistent in the soil and more apt to bioaccumulate, when compared to glyphosate. In section 5.2 a comparison of the environmental impact of these herbicides via an indicator known as the EIQ is made.

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility K_{ads}, Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
Glyphosate	N-phosphonomethyl glycine	Stable at pH 3, 5, 6, 7, and 9	Aqueous Photolysis Stable in pH 5, 7 and 9 Soil Photolysis Stable	Aerobic Kickapoo Sandy Loam = 1.85 days Dupo Silt Loam = 2.06 days	Aerobic 7 days in silty clay loam sediment Anaerobic 8.1 days in silty clay loam sediment	62 - 175	22 - 175	8 - >50,000	Aerobic Soil, Aerobic & Anaerobic Aquatic Aminomethyl phosphonic acid (AMPA)	13.9 days when applied at 7.95 lb a.e./acre, 10.7 lb a.i./acre	0.38X = edible tissue 0.63X = nonedible tissue 0.52X = whole fish	7.5 days (water) and 120 days (sediment)
2,4-D	2,4-dichlorophenoxy acetic acid	Stable at pH 5, 7, and 9	Aqueous Photolysis 12.9 calendar days or 7.57 days of constant light in pH 5 Soil Photolysis 68 days	Aerobic 6.2 days	Aerobic 15 days Anaerobic 41-333 days	0.17-0.52	-	59-117 mL/g	Aerobic Soil and Aquatic 2,4-dichlorophenol, 4-chlorophenol, 4-chlorophenoxyacetic acid, and chlorohydroquinone Anaerobic Aquatic 2,4-DCP, 4-chlorophenol, 2-chlorophenol, CO_2, 2,4-DCA, and 4-chlorophenol	1.1-42.5 days	-	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
2,4-DB/ 2,4-DB-DMAS	4-(2,4-dichloro phenoxy) Butyric Acid/Di methyla mine 4-(2,4-dichloro phenoxy) Butyrate	Stable at pH 5, 7, and 9	Aqueous Photolysis 6.3 days at pH5, 17.2 days at pH 7, and 6.9 days at pH 9	Aerobic 24.5 days in mineral soils Anaerobic Stable	6.3 to 17.2 days	0.755-3.27 mg/L Very mobile to moderately mobile in mineral soils	1.5 mL/g	154 (EPA) ; 370 at pH 7.9	2,4-D (2,4-dichlorophen oxyacetic acid)	2 - 6.7 days	Ionic -not expected to bioaccumulate; 280 mL/g (MSDS)	Stable up to 50 days in distilled water
Dicamba	3,6-dichloro -o-anisic acid	Stable at all pH levels	Aqueous Photolysis Slow Soil photolysis Slow	Aerobic 6 days Anaerobic 141 days	Degrades more rapidly in aquatic systems with sediment	-	-	2 g/mL	DCSA	-	-	-
Benefin/ Benfluralin	[N-butyl-n-ethyl-alpha-alpha-alpha-tri-fluoro-2,6-dinitro-p-toluidine]	Stable at pH 5, 7 and 9	Aqueous Photolysis 5.5 to 9 hours Soil photolysis 12.5 days	Aerobic 20-86 days Anaerobic 12 days	Anaerobic 38 hours	Low Mobility	-	9,840 – 11,660 L/kg	2,6 dinitro-4-trifluoromethyl-phenol (6% of parent in soil)	22-79 days CA lettuce 79 days (spray incorp) GA peanuts 62 days (spray incorp) CA turf 22 days (granular broadcast)	Fish: 1580 mL/g - bioaccumulative	-

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility K_{ads}, Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
Bromoxynil/ Bromoxynil phenol/ Bromoxynil octanoate	3,5-dibromo-4-hydroxybenzonitrile	34.1 days at pH 5, 11.5 days at pH 7 and 1.7 days at pH 9, phenol stable at pH 5, 7 and 9	Aqueous photolysis 4.6 days at pH 5 Soil photolysis 2.6 days	Aerobic 2 days Anaerobic 3.7 days	Aerobic <12 hours	Mobile in unaged columns of sand, sandy loam and loam soils; Not mobile in aged soil columns and aquatic sediment	7.0 mL/g	1003 mL/g	Hydrolysis bromoxynil (phenol) and 3,5-dibromo-dihydroxy-cyclohexadienylnitrile Aqueous Photolysis 4-cyano-2-bromophenyl octanoate, bromoxynil (phenol) and phenyl carbamate Aerobic Soil Metabolism CO_2 and Bromoxynil (phenol) Anaerobic Aquatic Metabolism 4-Hydroxybenzonitrile and Bromoxynil (phenol) Aerobic Aquatic Metabolism bromoxynil (phenol), p-hydroxybenzonitrile; 3-bromo-4-hydroxybenz	1-14 days CA = 14 days NC = 1 day	Bluegill Sunfish 63X – ed ble tissue 400X – inedible tissue 230X – whole fish	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility K_{ads}, Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
									onitrile, and 3,5-dibromo-4-hydroxybenzoic acid.			
Clethodim Data Source = PAN Pesticides Database	2-(1-(((3-chloro-2-propenyl)oxy)imino)propyl)	10 days	-	Aerobic 3 days Anaerobic 10 days	-	-	-	10.00	-	-	-	- -
Clopyralid	3,6-Dicholor-2-pyridine carboxylic acid	-	Aqueous photolysis 261 days Soil photolysis >12 years	Aerobic 71 days	-	Very high potential	-	-	-	-	BCF < 100	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	Stable at pH 5, 7, and 9	Aqueous photolysis 43 days Soil photolysis 173 days	Aerobic 372 days Anaerobic 1000 days	Aerobic 33 days Anaerobic 5 days	-	7.9-28	468-1666	Hydrolysis 3,4-dichloroaniline (3,4-DCA) Aqueous Photolysis CO_2 and 13 minor polar products Soil Metabolism N'-(3,4-dichlorophenyl)-N-methylurea (DCPMU), demethylated DCPMU (DCPU), dichloroaniline (DCA), and 3,3',4,4'-tetrachlorobenzene (TCAB) Aerobic Aqueous Metabolism N'-(3-chlorophenyl)-N,N-dimethylurea (MCPDMU), DCPMU and CPMU Anaerobic Aqueous Metabolism MCPDMU, PDMU and MCPMU	73-139 days FL = 73 days MS = 139 days CA = 133 days	-	- 115-177 days

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
EPTC	S-Ethyl di propyl thiocarbamate.	Stable	Stable	Aerobic 10.3 to 36.9 days (nonlinear); 36.5 to 74.9 days (ln-transformed) bi-phasic 1st phase: 12.7 to 27.7 days 2nd phase: 73.0 to 127 days Anaerobic 31 to 127 days	-	-	0.77 to 2.99	136 to 264	EPTC-Sulfoxide and dipropylamine.	2 to 18.8 days; mean 8.6 days	Bluegill Sunfish 97X – Viscera 34X - Fillet	- -
Hexazinone	3-cyclohexyl-6-(dimethylamino)-1-methyl-Striazine-2,4-(1H,3H)-dione	Stable at pH 5, 7, and 9	Aqueous Photolysis Stable Soil Photolysis 82 days	Aerobic Sterile 1440 days Aerobic nonsterile 216 days	Anaerobic Sterile >1500 days Anaerobic nonsterile 230 days Aerobic Sterile and nonsterile >2 months	Mobile	0.24-10.8	-	Soil Photolysis 3-cyclohexyl-6-(methylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione and CO_2 Aerobic Soil 3-hydroxy-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,-3H)-dione and 3-	DE & MS = 123-154 days	Low	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
									(ketocyclohexyl)-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione <u>Anaerobic Aquatic</u> 3-hydroxyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione, 3-(ketocyclohexyl)-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione <u>and</u> 3-cyclohexyl-1-methyl-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione <u>Aerobic Aquatic</u> [3-(4-ketocyclohexyl)-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione;			

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
									3-(2-hydroxycyclohexyl)-6-(dimethylamino-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione; 3-(cyclohexyl-6-(methylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione <u>and</u> 3-(cyclohexyl-1-methyl-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione			
Imazamox Data Source = Pesticide Fact Sheet	2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-y]-5-(methoxymethyl)-3-pyridine carboxylic acid	Stable at pH 5, 7, and 9	<u>Aqueous Photolysis</u> 6.8 days <u>Soil Photolysis</u> slow	-	-	Immobile or moderately mobile	-	-	-	15-130 days	-	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
Imazethapyr Data Source = New York State Department of Environ. Conservation	(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridine carboxylic acid	Stable	Aqueous Photolysis 46 hours Soil Photolysis 33 months	Aerobic Metabolism 33 – 37 months Anaerobic Metabolism >2 months	-	0.45 - 0.82	-	97 – 283	5-ethyl-3-pryidine carboxylic acid	2 – 4 months	-	-
Metribuzin	4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one	Stable at pH 5, 7, and 9 at 25ºC in darkness	Aqueous Photolysis = 4.3 hours in pH 6.6 @ 25ºC Soil Photolysis = 2.5 days at temperatures up to 31ºC	Aerobic 106 days Anaerobic 112 days	-	Unaged Soil 0.02-0.25 Aged Soil 0.13-0.51	-	-	Aqueous Photolysis deaminated metr buzin (DA) Soil Photolysis deaminated metr buzin (DA), pentylidene metr buzin and hexylidene metr buzin Aerobic Soil deaminated, diketo metr buzin (DADK), diketo metr buzin (DK),	Watsonville (CA) = 128 days Fresno (CA) = 40 days ME, MI & CA = 58-107 days	-	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility K_{ads}, Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
									deaminated metr buzin (DA), 2-methyl-DADK, 4-methyl-DADK, <u>and</u> 3-amino-DA <u>Anaerobic Soil</u> DADK, DA, DK, <u>and</u> 2-methyl-DADK.			
Norfluzaon	4-chloro-5-(methyl amino)-2-(, , -trifluoro-*m*-tolyl)-3-(2*H*)-pyridazinone	Stable at pH 5, 7, and 9	<u>Aqueous Photolysis</u> 2-3 days <u>Soil Photolysis</u> 12-15 days	<u>Aerobic</u> 130 days @ 22ºC	<u>Aerobic</u> 6-8 months <u>Anaerobic</u> 8 months	0.14-7.11 – mobile in soils with low organic content, clay content and cation exchange capacities (CECs)	-	-	<u>Aqueous Photolysis</u> desmethyl norflurazon, deschloroflurazon <u>and</u> dimers of norflurazon <u>Soil Photolysis, Aerobic Soil and Anaerobic Aquatic metabolism</u> desmethyl norflurazon	-	<u>Bluegill Sunfish</u> 6-8X - Fillet 16-28X - Whole Fish 30-59X – Viscera, Low	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility K_{ads}, Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
Paraquat Dichloride	1,1'-dimethyl-4,4'-bipyridinium dichloride	Stable at pH 5, 7, and 9	Aqueous Photolysis Stable for 32 days @ 25ºC Soil Photolysis Stable for 85 weeks when exposed to sunlight	Aerobic Stable in Sandy Loam @ 20 ± 2º C for 180 days. Anaerobic Stable for 60 days	Aerobic <2 weeks	Immobile in silty clay loam, loam, loamy sand, and sand soils	68-50,000 mL/g	-	No Metabolites detected	Loamy sand soil (soybeans) = Decreased from 1.1 mg/kg to 0.76 mg/kg at 86 days and remained stable at 0.42-0.50 mg/kg from 296-657 days post-treatment	-	-
Picloram/ Picloram Acid	4-amino-3,5,6-trichloro-2-pyridine carboxylic acid	Stable to hydrolysis in acidic, neutral and basic media	Aqueous Photolysis 2.6 days @ 25ºC Soil Photolysis Stable when irradiated	Aerobic 167-513 days Anaerobic Stable after 300 days	Anaerobic Stable after 300 days	<1 for soils with organic matter (OM) content as high as 4.2%	-	13#	Aerobic Soil CO_2, 4-amino-3,5-dichloro-2-pyridinol and 4-amino-2,3,5-trichloro pyridine	SC (2.0 lb ai/A) = detectable 840 days post-application NC (2.0 lb ai/A) = detected in all samples beyond 8 weeks MT (1 b ai/A) = detectable 790 days post-application WA (1 lb ai/A) = detectable 9 months post-application	-	

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
Pronamide	3,5-dichloro-N-(1,1-dimethyl-2-propynyl)benzamide	Stable	Soil Photolysis Stable Aqueous Photolysis Stable	Aerobic 13 months Anaerobic >13 months	-	Mobile	-	-	-	-	-	-
Sethoxydim	[2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]3-hydroxy-2-cyclohexen-1-one	8.7 days at pH 5, 155 days at pH 7, and 284 days at pH 9	Soil Photolysis 1 hour Aqueous Photolysis 5.23 days	Aerobic <1 day Anaerobic >60 days	Aerobic 0.7-1.0 days Anaerobic 39.9 days	<1.00 Mobile to very mobile in sterile (autoclaved) sand, sandy loam, sandy clay loam, silt loam, and clay loam soils	-	-	Hydrolysis 6-(2-(ethylthio)propyl)-4-oxo-2-propyl-4,5,6,7-tetrahydrobenzoxazole Aqueous Photolysis 2-(1-aminobutylidene)-5-(2-(ethylthio)-propyl)-cyclohex-1,3-dione Soil Photolysis, Aerobic and Anaerobic Soil 2-(1-ethoxyiminobutyl)-5-(2-(ethylsulfinyl)propyl)-3-hydroxycyclohex-2-enone	Residues: 32 days	7X - edible fish 25X - nonedible fish 21X - whole fish	Residues: 1-9 days

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
Terbacil	3-tert-butyl-5-chloro-6-methyl uracil	Stable at pH 5, 7 and 9 @ 25ºC	Aqueous Photolysis 29-54 days Soil Photolysis 122 days	Aerobic 653 days @ 25ºC Anaerobic 235 days @ 25ºC	-	0.39 to 1.3 ml/g Very mobile in soil	-	44 to 61 ml/g	Photolysis 5-chloro-6-methyluracil, 3-tert-butyl-6-methyluracil, and 6-chloro-2,3-dihydro-3,3, 7-trimethyl-5H oxazolo (3,2-a)-pyrimidine-5-one, tert-butyl-5-acetyl-5-hydroxyhydantoin (Compound II), 3-tert-butyl-5-hydroxyhydantoin (Compound III), and 5-chloro-6-methyl-(3',5')-5'-chloro-6'-methyl-5',6'-dihydro-6',2-anhydro-3'-tertbutyluracilyluracil (Compound VI) Aerobic Soil CO_2, t-butylurea and 3-tert-butyl-6-methyluracil Anaerobic Soil t-butylurea and 3-tert-butyl-5-chloro-6-hydroxymethyluracil	204-252 days DE (5 lb a.i./A) = 212 days IL (5 lb a.i./A) = 204 days CA (5 lb a.i./A) = 252 days	Not expected to bioaccumulate in fish tissues	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
Trilfluralin	α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine	-	Aqueous Photolysis 8.93 hours at pH 7 Soil Photolysis 41 days	Aerobic Sandy Loam = 189 days Clay Loam = 201 days Loam Soils = 116 days Anaerobic 25-59 days @ 22ºC	-	54.8-155.6	-	-	Aqueous Photolysis 2-ethyl-7-nitro-5-trifluoromethylbenzimidazole, 5-trifluoromethyl3-nitro-1,2-benzene diamine and 2-ethyl-7-nitro-1-propyl-5-trifluoromethylbenzimidazole Soil Photolysis 2,6-dinitro-N-propyl-4-trifluoromethylbenzenamine, and 2-ethyl-7nitro-5-trifluoromethylbenzimidazole-3-oxide Aerobic Soil α,α,α-trifluoro-2,6-dinitro-N-propyl-p-toluidine; α,α,α-trifluoro-5-nitro-4-propyl-	15-149 days	Bluegill Sunfish 2041X - ed ble tissue 9586X - nonedible tissue 5674X - whole fish	- -

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
									toluene- 3,4-diamine; 2-ethyl-7-nitro-1-propyl-5-(trifluoromethyl)benzimidazole-3-oxide; 2-ethyl-7-nitro-1-propyl-5-(trifluoromethyl)benzimidazole; 2-ethyl-7-nitro-5-(trifluoromethyl)benzimidazole; α,α,α-trifluoro-2,6-dinitro-p-cresol <u>and</u> 2,2'azoxybis(α,α,α -trifluoro-6-nitro-N-propyl-p-toluidine <u>Anaerobic Soil</u> α,α,α-trifluoro-5-nitro-N4,N4-dipropyl-toluene- 3,4-diamine; 7-amino-2-ethyl-1-propyl-5-(trifluoromethyl)benzimidazole, <u>and</u> α,α,α-			

Table N-5. Glyphosate and Other Commercial Herbicides – Comparative Environmental Fate Properties

	Environmental Fate Properties											
Herbicide	**Chem. Name**	**Hydrolysis**	**Photolysis ($t_{1/2}$)**	**Soil Metabolism ($t_{1/2}$)**	**Aquatic Metabolism ($t_{1/2}$)**	**Soil Mobility $K_{ads,}$ Freundlich**	**Soil water Part. coeff. (K_d)**	**Soil Adsorp. (K_{oc})**	**Metabolites**	**Terrestrial Field Dissip. ($t_{1/2}$)**	**Bioaccumulation**	**Aqua. Field. Dissip. ($t_{1/2}$)**
									trifluoro-N4,N4-dipropyltoluene-3,4,5-triamine			

3.2.1 Hydrolysis Alfalfa Herbicide Comparison Data

Most herbicides (2,4-D, 2,4-DB, benefin, clethodim, dicamba, diuron, EPTC, hexazinone, metribuzin, norfluzaon, imazethapyr, picloram, picloram, sethoxydim, and terbacil) were stable to hydrolysis, including glyphosate. Bromoxynil was unstable at higher pHs (U.S. EPA, 1998a); sethoxydim was slightly unstable at lower pHs with a 9 day half-life at pH 5 (U.S. EPA, 2005c). Four herbicides (imazamox, clopyralid, imazethapyr, and pronamide) had missing hydrolysis data. Details are in table N-5.

3.2.2 Photolysis Alfalfa Herbicide Comparison Data

3.2.2.1 Aqueous

Seven herbicides were stable (>30 days: clopyralid, dicamba, diuron, EPTC, hexazinone, paraquat, and terbacil) to aqueous photolysis, including glyphosate. Six herbicides (2,4-D, 2,4-DB, bromonoxynil, imazamox, norfluzaon, and picloram) were stable for 1 to 30 days in water. At least five herbicides (benefin, metribuzin, imazethapyr, sethoxydim, and trifluralin) were unstable and underwent photolysis in less than 48 hours. Three herbicides (clethodim, imazethapyr, and pronamide) had missing data. Details are in table N-5.

3.2.2.2 Soil

Many herbicides were stable (>30 days; 2,4-D, 2,4-DB, clopyralid, dicamba, diuron, EPTC, hexazinone, imazamox, imazethapyr, paraquat, picloram, pronamide, terbacil, and trifluralin) to soil photolysis, including glyphosate. Two herbicides (benefin and norfluzaon) were stable for 7 to 30 days in soil to photolysis. At least three of the herbicides (bromonoxynil, metribuzin, and sethoxydim) underwent photolysis in less than 7 days. Three herbicides (metribuzin, clethodim, and imazethapyr) had missing data. Details are in table N-5.

3.2.3 Soil Metabolism Alfalfa Herbicide Comparison Data

3.2.3.1 Aerobic Soil

Many herbicides had greater than 30 day half-lives in aerobic (benefin, clopyralid, diuron, EPTC, hexazinone, imazamox, imazethapyr, metribuzin, norfluzaon, paraquat, picloram, pronamide, terbacil, and trifluralin) soils. Six herbicides had a short half-life of <30 days in aerobic soil metabolism studies, including glyphosate (2,4-D, 2,4-DB, bromoxynil, clethodim, dicamba, and sethoxydim). All herbicide had aerobic soil metabolism data.

3.2.3.2 Anaerobic Soil

Many herbicides were stable in anaerobic soils (2,4-DB, dicamba, diuron, EPTC, hexazinone, imazamox, imazethapyr, metribuzin, paraquat, picloram, pronamide, sethoxydim, terbacil, and trifluralin) with greater than 30 day half lives and three herbicides (benefin, bromoxynil, and clethodim) with a short half life (<30 days) in anaerobic soil. Three anaerobic soil metabolism data (2,4-D, clopyralid, and glyphosate) were missing. Details are in table N-5.

3.2.4 Aquatic Metabolism Alfalfa Herbicide Comparison Data

3.2.4.1 Aerobic

Many herbicides had missing data concerning aquatic metabolism for aerobic (benefin, clethodim, clopyralid, dicamba, EPTC, imazamox, imazethapyr, metribuzin, picloram, pronamide, terbacil, and trifluralin) systems. Some had greater than 30 day half-lives in aerobic (diuron, hexazinone, norfluzaon) water tests. Three herbicides had a short half-life of <7 days in aerobic soil metabolism studies (bromoxynil, glyphosate, and sethoxydim). Four aerobic water metabolism studies on herbicides had a range of 1 week to a month half-lives (2,4-D, 2,4-DB, and paraquat). Details are in table N-5.

3.2.4.2 Anaerobic

Many herbicides had missing data concerning anaerobic aquatic metabolism for anaerobic (bromoxynil, clethodim, clopyralid, dicamba, EPTC, imazamox, imazethapyr, metribuzin, paraquat, terbacil, and trifluralin). Some had greater than 30 day half-lives in anaerobic (diuron, hexazinone, norfluzaon, picloram, and sethoxydim) water tests. Two herbicides (benefin and glyphosate) had a short half-life of >7 days in anaerobic soil. Two anaerobic water studies had a range of 1 week to a month half-lives (2,4-D and 2,4-DB). Details are in table N-5.

3.2.5 Soil Mobility Alfalfa Herbicide Comparison Data

Thirteen herbicides had a very low adsorption coefficient <1, suggesting they are highly mobile in the soil (bromoxynil, clopyralid, hexazinone, imazethapyr, metribuzin, picloram, pronamide, sethoxydim, and terbacil). One herbicide had soil adsorption coefficient between 1 and 50 (norfluzaon). Four herbicides including glyphosate had limited or low mobility (>50 soil adsorption coefficient; benefin, imazamox, paraquat, and trifluralin), four herbicide had missing data on soil mobility (clethodim, dicamba, diuron, and EPTC). Details are in table N-5.

3.2.6 Soil Water Partition Coefficient (K_d) Alfalfa Herbicide Comparison Data

Most of the soil water partition coefficient (K_d) for herbicides used in alfalfa were missing (benefin, clethodim, clopyralid, dicamba, imazamox, imazethapyr, metribuzin, norfluzaon, picloram, pronamide, sethoxydim, and terbacil). Three herbicides had >10 coefficients (diuron glyphosate, and paraquat), five had moderate to mobile soil water partition coefficients of 0-10 (2,4-D, 2,4-DB, bromoxynil, EPTC, and hexazinone). The K_d value is simply a ratio of the sorbed phase concentration to the solution phase concentration at equilibrium and based more on surface area than organic matter; thus, lower numbers mean a higher affinity for the aqueous phase rather than suspended particulate matter. Details are in table N-5.

3.2.7 Soil Adsorption Coefficient (K_{oc}) Alfalfa Herbicide Comparison Data

The K_{oc} is the partition coefficient of the herbicide in the organic fraction of the soil. The higher the value the more likely the compound is bound tightly to carbon rich soil. Only two herbicides had a lower than 10 partition coefficient, dicamba and hexazinone. Ten herbicides had >10 partition coefficients (2,4-D, 2,4-DB, benefin, bromoxynil, clethodim, diuron, EPTC, glyphosate,

imazethapyr, picloram, and terbacil), whereas seven had missing data (clopyralid, imazamox, metribuzin, norfluzaon, paraquat, pronamide, and sethoxydim). Details are in table N-5.

3.2.8 Terrestrial Field Dissipation Studies (half-life) Alfalfa Herbicide Comparison Data

Thirteen herbicides were detected in the soil at least 30 days after application (2,4-D, 2,4-DB, benefin, bromoxynil, diuron, hexazinone, imazamox, imazethapyr, metribuzin, paraquat, picloram, sethoxydim, and terbacil); four herbicides were detected in less than 30 days (bromoxynil, EPTC, glyphosate [except in Iowa study: 140 days], and trifluralin), with five herbicides missing data (clethodim, clopyralid, dicamba, norfluzaon, and pronamide). Details are in table N-5.

3.2.9 Bioaccumulation

Five herbicides were found to have the potential to bioaccumulate (clopyralid, EPTC, norfluzaon, sethoxydim, and trifluralin). Whereas five herbicides are not expected to bioaccumulate (<1; 2,4-D, 2,4-DB, glyphosate, hexazinone, and terbacil), eleven did not have data (benefin, bromoxynil, clethodim, dicamba, diuron, imazamox, imazethapyr, metribuzin, paraquat, picloram, and pronamide). Details are in table N-5.

3.2.9.1 Aquatic Field Dissipation Studies (half-life) Alfalfa Herbicide Comparison Data

Four of the twenty herbicides used on alfalfa had aquatic field dissipation studies the half lives were as follows: sethoxydim 1-9 days; glyphosate 7.5 days in water and 120 days in sediment; 2,4-D was stable up to 50 days; and diuron 115 to 177 days. Details are in table N-5.

3.3 Glyphosate and Metabolite Occurrence

In a USDA monitoring study conducted on surface water, groundwater, and soil from 2001 to 2006, the metabolite AMPA was observed more frequently than the parent compound glyphosate (Scribner et al., 2007). The sample collections were from several USGS studies including: the National Stream Quality Accounting Network Program; the National Water-Quality Assessment Program; and the Toxic Substances Hydrology Program. Groundwater samples had measured concentrations of glyphosate, ranging from < 0.01 to 4.7 µg/L (68 detections out of 873 samples), and AMPA, ranging from <0.01 to 2.6 µg/L (133 detections out of 873 samples). In surface water the range of glyphosate detected was <0.01 to 427 µg/L (489 detections out of 1262 samples), and the range of AMPA detected was 0.38 to 29 µg/L (489 detections out of 1262 samples).

In all of the samples, the maximum detections were from an agricultural ditch basin (Leary Weber ditch of the White River Basin in Indiana). In rainwater collected from the Indiana Leary Weber Ditch Basin, measured concentrations of glyphosate ranged from 0.02 to 1.1 µg/L and AMPA ranged from 0.02 to 0.47 µg/L in 12 of the 14 samples. Glyphosate detections in precipitation are more likely due to glyphosate associated with dust particles being washed down with rain than to glyphosate dissolved in rain). Soil samples from Indiana Leary Weber Ditch Basin indicate glyphosate and AMPA may persist from year to year with a glyphosate maximum concentration of 476 µg/L (119 detections out of 193 samples) and an AMPA maximum

concentration of 956 μg/L (154 detections out of 193 samples) (Scribner et al., 2007); however, the detection of these large quantities may have coincided with a recent rain event and application. "The potential persistence of glyphosate in soils warrants further studies given the potential increase of use due to GT alfalfa" (Scribner et al., 2007).

3.4 Summary of Findings

Glyphosate has a low potential to leach to groundwater from the soil due to its rapid microbial degradation and strong soil binding properties (Giesy et al., 2000). In direct soil application field dissipation studies glyphosate and AMPA were found in the top 6 inches, also indicative of a nonleaching chemical. Glyphosate is applied to the foliage and direct soil contact is not expected unless a spill or recent rain event moves the glyphosate from the leaves to the soil. Due to glyphosate's strong adsorptive qualities to soil groundwater contamination is not expected, as noted with no more than 4.7 μg/L detected by USGS survey study (Scribner et al., 2007). Evaporation is not a major route of dissipation, nor will glyphosate degrade due to hydrolysis or photolysis; microbial degradation is the primary route of dissipation of glyphosate from most ecosystems regardless of the soil and climatic conditions (Giesy et al., 2000). Glyphosate exposure is also possible due to runoff after a rain soon after application, spray drift, inadvertent direct overspray, or wind transport of soil particulates loaded with adsorbed glyphosate. Glyphosate is not expected to bioaccumulate.

The twenty other pesticides used on alfalfa have varying chemical fates. In general most were more persistent and had higher mobility in soils, making them more apt to continually contaminate surrounding water systems. Few were even considered compounds that could bioaccumulate (e.g., clopyralid, EPTC, norfluzaon, sethoxydim, and trifluralin). In section 5.2 further environmental impacts of these herbicides in comparison to glyphosate will be discussed.

4.0 Ecotoxicity of Glyphosate and Glyphosate Commercial Formulations and AMPA

The terrestrial ecosystems potentially at risk include the treated area and areas immediately adjacent to the treated area that might receive drift or runoff (recent rain event after application), and might include other cultivated fields, fence rows and hedgerows, meadows, fallow fields or grasslands, woodlands, riparian habitats, or other uncultivated areas. For EPA Tier 1 assessment purposes, risk is assessed to terrestrial animals or plants assumed to occur exclusively adjacent to the treated area.

Aquatic ecosystems potentially at risk include water bodies adjacent to, or downstream from, the treated field and might include impounded bodies such as ponds, lakes and reservoirs, or flowing waterways such as streams or rivers. The proposed use sites may be located either near freshwater or saltwater habitats. For uses in coastal areas, an aquatic habitat also includes marine ecosystems including estuaries. For EPA Tier 1 assessment purposes, risk is assessed to aquatic animals and plants assumed to occur in small, static ponds receiving runoff and drift from treated areas. Table N-6 list examples of representative species for the plant and animal taxonomic groups that could potentially be affected by runoff and/or drift.

Table N-6. Taxonomic Groups and Test Species Evaluated for Ecological Effects in Screening-Level Risk Assessments

Taxonomic Group	Example(s) of Representative Species
Birds [a]	Mallard duck (*Anas platyrhynchos*) Bobwhite quail (*Colinus virginianus*)
Mammals	Laboratory rat (*Rattus norvegicus*)
Freshwater fish [b]	Bluegill sunfish (*Lepomis macrochirus*) Rainbow trout (*Oncorhynchus mykiss*)
Freshwater invertebrates	Water flea (*Daphnia magna*)
Estuarine/marine fish	Sheepshead minnow (*Cyprinodon variegatus*)
Estuarine/marine invertebrates	Eastern oyster (*Crassostrea virginica*) Mysid shrimp (*Americamysis bahia*)
Terrestrial plants	Monocot and dicot
Insects	Honeybee
Aquatic plants	Bluegreen alga Green alga Saltwater diatom Duckweed (*Lemna gibba*)

[a] Birds are considered surrogates for amphibians (terrestrial phase) and reptiles when no data are available.
[b] Freshwater fish may be surrogates for amphibians (aquatic phase) when no data are available.

Within each of these very broad taxonomic groups, an acute and/or chronic endpoint is selected from the available test data. A complete discussion of all toxicity data available for this risk assessment and the resulting measures of effect selected for each taxonomic group are discussed below.

All available data from the EPA RED document on glyphosate (1993) and new use risk assessment for bent grass (2006); Giesy and colleagues (2000) risk assessment on glyphosate; USDA (2003) risk assessment on glyphosate for the Forest Service; and public literature on the toxicity of glyphosate to plants and animals were used in this risk assessment. Not all taxonomic groups are surveyed because of EPA registration of pesticide study guideline limitations.

Instead, some animals are used as surrogates for other groups based on the similarity of their physiology and habitat. Therefore, extrapolation to other taxonomic groups may constitute a source of uncertainty in the ecological risk assessment.

4.1 Avian Toxicity

Several acute toxicity tests were conducted on birds for glyphosate and its formulations, as well as were several chronic toxicity tests on glyphosate. No data were available on chronic bird toxicity to glyphosate herbicide formulations. A few toxicity tests were also performed for the glyphosate metabolite AMPA. The toxicity study results are discussed in sections 4.1.1 through 4.1.4.

4.1.1 Acute Avian Toxicity to Glyphosate

Acute toxicity in birds was assessed using single-dose, multiple-dose, dietary, and reproductive toxicity studies. The EPA preferred test species are the mallard duck (a waterfowl) and bobwhite quail (an upland game bird). The results of acute glyphosate toxicity tests in birds are provided in table N-7 below. In acute lethality studies, LD_{50} values (i.e., the dose required to kill 50 percent of the test animals) for bobwhite quail exceeded the highest doses tested (single administration LD_{50} > 2000 mg/kg and daily administration for 8 days LD_{50} > 6300 mg/kg body weight). In 8-day dietary tests, LC_{50} values (the concentration of chemical in the diet required to kill 50 percent of test animals) exceeded the highest dietary concentrations tested (i.e., LC_{50} > 4640 ppm diet for mallard duck and bobwhite quail). Thus, even though LD_{50} and LC_{50} values were not determined, glyphosate can be no more than slightly toxic to birds by EPA criteria (U.S. EPA, 1993a, 2004a). No toxicity studies were found testing glyphosate as the IPA salt.

Table N-7. Acute Avian Toxicity to Glyphosate

Study Type (% a.i.)	Species	Results	Endpoint	Reference
Glyphosate				
Acute, Oral, SingleDose,(83%)	Bobwhite quail	LD_{50} = >2000 mg/kg	Death, range and time frame exposure time not reported	U.S. EPA, 1993a
8-day, Dietary (98.5%)	Bobwhite quail	LC_{50} = >4640 ppm	Reproductive Impairment, range and time frame exposure time not reported	U.S. EPA, 1993a
8-day, Subacute toxicity	Bobwhite quail	LC_{50} = > 6300 mg/kg	Death	USDA, 2003
Reproductive (83%)	Bobwhite quail	No effects up to 1000 ppm	Reproductive Impairment	U.S. EPA, 1993a
8-day, Dietary (98.5%)	Mallard duck	LC_{50} = >4640 ppm	Reproductive Impairment, range and time frame exposure time not reported	U.S. EPA, 1993a
8-day, Subacute toxicity	Mallard duck	LC_{50} = > 6300 mg/kg	Death	USDA, 2003
Reproductive (90.4%)	Mallard duck	No effects up to 30 ppm	Reproductive Impairment	U.S. EPA, 1993a
Reproductive (83%)	Mallard duck	No effects up to 1000 ppm	Reproductive Impairment	U.S. EPA, 1993a
Glyphosate tested as acid				

Table N-7. Acute Avian Toxicity to Glyphosate

Study Type (% a.i.)	Species	Results	Endpoint	Reference
Acute, Oral, Single dose	Bobwhite quail	LC_{50} = > 3851 mg a.e./kg bw	Death	Giesy et al., 2000
8-day, Dietary	Bobwhite quail	LC_{50} = > 4640 mg a.e./kg diet	Death	Giesy et al., 2000
8-day, Dietary	Mallard duck	LC_{50} = > 4640 mg a.e./kg diet	Death	Giesy et al., 2000

4.1.2 Acute Avian Toxicity to Glyphosate Herbicide Formulations

The formulations of glyphosate (Honcho® Herbicide, Honcho Plus® Herbicide, Roundup Original MAX® Herbicide, and Roundup WeatherMAX® Herbicide) also could be no more than slightly toxic to birds. The results of acute glyphosate toxicity tests in birds are listed in table N-8. The LD_{50} values exceeded the highest doses tested while the LC_{50} values exceeded the highest dietary concentrations tested in experiments with bobwhite quail, mallard ducks, and even the zebra finch (a passerine songbird). .

Table N-8. Acute Bird Toxicity to Glyphosate Herbicide Formulations

Study Type (% a.i.)	Species	Results	Endpoint	Reference
Acute, Single-Dose, (Roundup Original MAX® Herbicide)	Bobwhite quail	LD_{50} > 2,250 mg product /kg bw	Death	Monsanto, 2006
Acute, Single-Dose, I (Roundup Original MAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])	Bobwhite quail	LD_{50} > 3,851 mg a.e./kg bw	Death	Monsanto, 2006
Acute, Single-Dose, (Roundup WeatherMAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])	Bobwhite quail	LD_{50} > 3,851 mg a.e./kg bw	Death	Monsanto, 2005
5-day, Dietary (Roundup Original MAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])	Bobwhite quail	LC_{50} > 4,640 mg a.e./kg diet	Death	Monsanto, 2006
5-day, Dietary (Roundup WeatherMAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])	Bobwhite quail	LC_{50} > 4,640 mg a.e./kg diet NOEL = 4640 mg a.e./kg diet	Death	Monsanto, 2005
5-day, Dietary (Honcho® Herbicide)	Bobwhite quail	LC_{50} > 5,620 mg product/kg	Death	USDA, 2003
5-day, Dietary (Honcho® Herbicide)	Bobwhite quail	LC_{50} > 5,620 mg product/kg diet	Death	Monsanto, 2007b
5-day, Dietary (Honcho ® Plus Herbicide)	Bobwhite quail	LC_{50} > 5,620 mg product /kg diet	Death	Monsanto, 2007d
8-day, Dietary (Roundup)	Bobwhite quail	LC_{50} > 5,620 product mg product/kg diet	Death	Giesy et al., 2000

Table N-8. Acute Bird Toxicity to Glyphosate Herbicide Formulations

Study Type (% a.i.)	Species	Results	Endpoint	Reference
5-day, Dietary (Roundup Original MAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])	Mallard duck	LC_{50} > 4,640 mg/kg diet	Death	Monsanto, 2007b
5-day, Dietary (Roundup WeatherMAX® Herbicide [N-(phosphonomethyl)glycine; [glyphosate]])	Mallard duck	LC_{50} > 4,640 mg a.e./kg diet NOEL = 4640 mg a.e./kg diet	Death	Monsanto, 2005
5-day, Dietary (Honcho® Herbicide)	Mallard duck	LC_{50} > 5620 mg product/kg	Death	USDA, 2003
5-day, Dietary (Honcho® Herbicide)	Mallard duck	LC_{50} > 5,620 mg product/kg diet	Death	Monsanto, 2007b
5-day, Dietary (Honcho® Plus Herbicide)	Mallard duck	LC_{50} = 5,620 mg product/kg diet	Death	Monsanto, 2007d
8-day, Dietary (Roundup®)	Mallard duck	LC_{50} > 5620 mg product /kg diet	Death	Giesy et al., 2000
5-day, Dietary (Roundup®)	Zebra Finch	LC_{50} > 8064 mg product /kg diet	Death	Giesy et al., 2000

4.1.3 Acute Avian Toxicity to AMPA

AMPA administered orally as a single dose to the Bobwhite quail produced LD_{50} values of >2250 mg AMPA/kg (see table N-9). AMPA administered in the diet for 8 days to Mallard ducks and Bobwhite quail, resultant LC_{50} values were >5620 mg AMPA/kg. The no observed effect concentration (NOEC) for both species was 5620 mg AMPA/kg.

Table N-9. Acute Avian Toxicity to AMPA

Study Type (%a.i.)	Species	Results	Endpoint	Reference
Oral – single dose	Bobwhite quail	LC_{50} >2250 mg/kg	Death	Giesy et al., 2000
8 day - Dietary	Bobwhite quail	LC_{50} >5620 mg/kg	Death	Giesy et al., 2000
8 day - Dietary	Mallard duck	LC_{50} >5620 mg/kg	Death	Giesy et al., 2000

4.1.4 Chronic Avian Toxicity

Chronic effect levels of glyphosate (tested as acid) were deduced from long-term (16-17 wk) dietary studies. The NOEC for both the mallard and Bobwhite quail was 1000 mg a.e./kg diet (see table N-10).

Table N-10. Chronic Avian Toxicity to Glyphosate

Study Type (%a.i.)	Species	Results	Endpoint	Reference
17-wk, Dietary	Bobwhite quail	NOEC = 1000 mg a.e./kg diet	Reproductive Effects	Giesy et al., 2000
16-wk, Dietary	Mallard duck	NOEC = 1000 mg a.e./kg diet	Reproductive Effects	Giesy et al., 2000

4.1.5 Chronic Avian Toxicity to Glyphosate Herbicide Formulations

No data are available on chronic bird toxicity to commercial glyphosate herbicide formulations.

4.2 Mammal Toxicity

Several acute toxicity tests were conducted on mammals for glyphosate and its formulations, as well as several chronic toxicity tests on glyphosate. Further details on mammalian toxicity are addressed in the technical reports with this EIS, *Health and Safety Risks from Increased Glyphosate and Other Chemical Use on Humans (Exclusive of Field Workers)* (appendix L) and *Health and Safety Risks to Field Workers* (appendix M). No studies were found addressing the chronic toxicity of commercial formulations of glyphosate to terrestrial mammals. The toxicity study results are discussed in sections 4.2.1 through 4.2.4.

4.2.1 Acute Mammal Toxicity to Glyphosate

Acute toxicity in terrestrial mammals was assessed using 21-day subacute oral studies. More in depth discussion of mammalian toxicity can be found in another technical report for this EIS entitled, *Health and Safety Risks from Increased Glyphosate and Other Chemical Use on Humans (Exclusive of Field Workers)* (appendix L). All of the acute toxicity (2,000 to 6,000 mg/kg and acute oral intraperitoneal) studies in rodents for glyphosate are slightly toxic to practically nontoxic, and a non-sensitizer. The results of the acute glyphosate toxicity studies in terrestrial mammals including goat, rabbit, and rat, and are summarized in table N-11 below. Acute oral LD_{50}s for mammals range from 2,047 to > 5,000 mg a.e./kg/ day (d) for glyphosate. Glyphosate tested as IPA salt produced an acute oral LD_{50} of 5,700 mg a.e./kg/d in the goat. No studies were reviewed with glyphosate tested as an acid.

Table N-11. Acute Mammalian Toxicity to Glyphosate

Study Type (% a.i.)	Species	Results	Endpoint	Reference
Glyphosate				
Acute, Oral	Rat	LD_{50} = 2,047 mg a.e./kg/d	Death	Giesy et al., 2000
Acute, Oral	Rat	LD_{50} = > 5,000 mg a.e./kg/d	Death	Giesy et al., 2000
Acute, Oral	Goat	LD_{50} = 3,500 mg a.e./kg/d	Death	Giesy et al., 2000
21-day, Oral	Rabbit	NOAEL = 175 mg a.e./kg/d	Maternal toxicity: mortality, diarrhea, soft stools, and nasal discharge	Giesy et al., 2000 U.S. EPA, 1993a
Glyphosate tested as IPA salt				
Acute, Oral (tested as IPA salt)	Goat	LD_{50} = 5,700 mg a.e./kg/d	Death	Giesy et al., 2000

4.2.2 Acute Mammalian Toxicity to Glyphosate Herbicide Formulations

In glyphosate herbicide formulations, the acute oral LD_{50} was 4,860 mg product/kg body weight/day. The NOAEL for the hopping mouse was 16,000 mg product/kg diet (16,000 ppm product in diet). Assuming a food ingestion rate of 10 to 15 percent of body weight per day for a

hopping mouse (U.S. EPA, 1993a), the NOAEL would be greater than 1,600 to 2,400 mg/kg body weight/day. The results are presented in table N-12 below. Comparing the LD_{50} values for the goat for the Roundup® formulation (table N-11) and glyphosate alone, the latter appears to be more toxic. The same is true for the rat, with the LD_{50} for glyphosate being lower than that for Roundup® (table N-11).

Table N-12. Acute Mammalian Toxicity to Glyphosate Herbicide Formulations

Study Type (% a.i.)	Species	Results	Endpoint	Reference
Acute, Oral (Roundup®)	Goat	LD_{50} = 4,860 mg product /kg/d NML[b] = 2,100 mg product/kg/d	Death	Giesy et al., 2000
4-day, Dietary (Roundup®)	Hopping Mouse	NOAEL = > 16,000 mg product/kg diet	NOAEL[a]	Giesy et al., 2000
4-day, Dietary (Roundup®)	Hopping Mouse	NOAEL = > 16,000 mg product/kg diet	NOAEL[a]	Giesy et al., 2000

[a] NOAEL: No Observable Adverse Effect Level
[b] NML: No mortality level

4.2.3 Chronic Mammalian Toxicity to Glyphosate

Chronic effect levels of glyphosate (tested as an acid) were estimated from long-term (13-52 weeks) dietary studies in the rat, mouse, and dog models. In terms of subchronic and chronic toxicity in rodents, one of the more consistent effects of exposure to glyphosate is loss of body weight. Toxicity varied significantly both within and across species. Across species, the NOAEL in mammals ranged from 30 mg a.e./kg/day to > 12,500 mg a.e./kg/day. Within species, the rat showed the most extreme variation (NOAEL ranged from 30 mg a.e./kg/day to > 12,500 mg a.e./kg diet), followed by the mouse (NOAEL ranged from 507 to 1,890 mg a.e./kg/day). Only one study using a dog model was reviewed and therefore variability cannot be assessed. A 3-generation reproduction study was conducted with male and female Sprague-Dawley rats which were administered 0, 3, 10, or 30 mg/kg/day of glyphosate continuously in the diet. The only effect observed was an increased incidence of focal tubular dilation of the kidney (both unilateral and bilateral combined) in the high-dose male F_{3b} pups. Therefore, the NOEL for systemic and reproductive toxicity is 30 mg/kg/day (U.S. EPA, 1993a). A second reproductive study was conducted. In the 2-generation rat reproduction study, the offspring and parental NOAELs were 500 mg/kg/day based on decreased pup body weight during lactation (offspring) and soft stools, decreased body weight and food consumption (parents) at the LOAEL of 1500 mg/kg/day. The reproductive NOAEL was >1500 mg/kg/day. The focal tubular dilation of the kidneys was not observed at the 1500 mg/kg/day level in the subsequent 2-generation rat reproduction study. Therefore, EPA concluded that the effect seen in the three generation study was a spurious rather than glyphosate-related effect. Therefore, the NOAELs for parental, reproductive or offspring toxicity were 30 mg/kg/day. The toxicity results are presented in table N-13.

Table N-13. Chronic Mammalian Toxicity to Glyphosate

Study Type (%a.i.)	Species	Results	Endpoint	Reference
13-wk, Dietary	Rat	NOAEL = 205 mg a.e./kg/day	NOAEL	Giesy et al., 2000

Table N-13. Chronic Mammalian Toxicity to Glyphosate

Study Type (%a.i.)	Species	Results	Endpoint	Reference
13-wk, Dietary	Rat	NOAEL = 1,267 mg a.e./kg/day	NOAEL	Giesy et al., 2000
13-wk, Dietary	Rat	NOAEL = > 12,500 mg a.e./kg diet	NOAEL	Giesy et al., 2000
24-mon, Dietary	Rat	NOAEL = 410 mg a.e./kg/day	NOAEL	Giesy et al., 2000
Chronic, Dietary	Rat	NOAEL = > 31 mg a.e./kg/day	NOAEL	Giesy et al., 2000
2 generations, Dietary	Rat	NOAEL = 500 mg a.e./kg/day	NOAEL: decreased body weight gain during lactation	Giesy et al., 2000 U.S. EPA, 1993a, 2006c
3 generations, Dietary	Rat	NOAEL = > 30 mg a.e./kg/day	NOAEL: increased incidence of focal tubular dilation of the kidney (both unilateral and bilateral combined) in the high-dose male F3b pups	Giesy et al., 2000 U.S. EPA, 1993a, 2006c
13-wk, Dietary	Mouse	NOAEL = 507 mg a.e./kg/day	NOAEL	Giesy et al., 2000
13-wk, Dietary	Mouse	NOAEL = 1,890 mg a.e./kg/day	NOAEL	Giesy et al., 2000
24-mon, Dietary	Mouse	NOAEL = 814 mg a.e./kg/day	NOAEL	Giesy et al., 2000
52 wk, Oral (capsule)	Dog	NOAEL = > 500 mg a.e./kg/day	NOAEL	Giesy et al., 2000

4.2.4 Chronic Mammalian Toxicity to Glyphosate Herbicide Formulations

No studies were found addressing the chronic toxicity of commercial formulations of glyphosate to terrestrial mammals.

4.3 Terrestrial Invertebrate Toxicity

Several acute toxicity tests were conducted on terrestrial invertebrates for glyphosate and its formulations. No studies were found addressing the chronic toxicity of glyphosate and its commercial formulations on terrestrial invertebrates. The toxicity study results are discussed in sections 4.3.1 through 4.3.4.

4.3.1 Acute Terrestrial Invertebrate Toxicity to Glyphosate

Acute toxicity in nontarget arthropods was assessed using contact, oral, and dietary studies. The preferred EPA test species for nontarget arthropods is the honeybee. Studies may also use spiders, butterflies, or other terrestrial arthropods (USDA, 2003). All reviewed studies reported a LD_{50} for glyphosate of > 100 µg/honeybee. No studies were reviewed that tested glyphosate as an acid or IPA salt. The study results are presented in table N-14 below.

Table N-14. Acute Terrestrial Invertebrate Toxicity to Glyphosate

Study Type (%a.i.)	Species	Results	Endpoint	Reference
Acute, Diet	Honeybee	LD_{50}= 100; 2-day; range not reported	Death	Giesy et al., 2000
Acute, Contact	Honeybee	LD_{50} = > 100; 2-day; range not reported	Death	Giesy et al., 2000
Acute, Oral	Honeybee	LD_{50} = > 100 µg/bee	Death	U.S. EPA, 1993a
Acute, Contact	Honeybee	LD_{50} = > 100 µg/bee	Death	U.S. EPA, 1993a
Acute, Oral (36% MON2139)	Honeybee	LD_{50} = > 100 µg/bee	Death	U.S. EPA, 1993a
Acute, Contact (36% MON2139)	Honeybee	LD_{50} = > 100 µg/bee	Death	U.S. EPA, 1993a

4.3.2 Acute Terrestrial Invertebrate Toxicity to Glyphosate Herbicide Formulations

The formulations of glyphosate (Honcho® Herbicide, Honcho Plus® Herbicide, Roundup Original MAX® Herbicide, and Roundup WeatherMAX® Herbicide) produced LD_{50} values between 100 and 326 µg/honeybee. Nontarget arthropods appeared most sensitive to Roundup WeatherMAX® and least sensitive to Honcho® products. The study results are presented in table N-15 below.

Table N-15. Acute Terrestrial Invertebrate Toxicity to Glyphosate Herbicide Formulations

Study Type (% a.i.)	Species	Results	Endpoint	Reference
Acute, Diet (Roundup®)	Honeybee	LD_{50} = > 100 µg/bee	Death	Giesy et al., 2000
Acute, Contact (Roundup®)	Honeybee	LD_{50} = > 100 µg/bee	Death	Giesy et al., 2000
48-hr, Oral (Roundup WeatherMAX® Herbicide)	Honeybee	LD_{50} > 238.8 µg/bee	Death	Monsanto, 2005
48-hr, Contact (Roundup WeatherMAX® Herbicide)	Honeybee	LD_{50} > 250 µg/bee	Death	Monsanto, 2005
48-hr, Contact (Roundup Original MAX® Herbicide)	Honeybee	LD_{50} > 273 µg/bee	Death	Monsanto, 2006
48-hr, Oral toxicity (Roundup Original MAX® Herbicide)	Honeybee	LD_{50} > 281 µg/bee	Death	Monsanto, 2006
48-hr, Oral/Contact (Honcho® Herbicide)	Honeybee	LD_{50} > 326 µg/bee	Death	Monsanto, 2007b
48-hr, Oral/Contact (Honcho® Plus Herbicide)	Honeybee	LD_{50} > 326 µg/bee	Death	Monsanto, 2007d

4.3.3 Chronic Terrestrial Invertebrate Toxicity to Glyphosate and Glyphosate Herbicide Formulations

No studies were found addressing the chronic toxicity of glyphosate and commercial formulations of glyphosate to terrestrial invertebrates.

4.4 Plant Toxicity

Several acute toxicity tests were conducted on plants for exposure to glyphosate, as well as were several chronic toxicity tests on glyphosate and its formulations. Glyphosate is a broad-spectrum herbicide and will affect many types of nontarget plants if applied to the foliage. Therefore, a

detailed risk assessment on the impact of foliar application of glyphosate in the treated area was not conducted. No studies were found addressing the acute toxicity of commercial formulations of glyphosate to plants. The toxicity study results are discussed in sections 4.4.1 through 4.4.4.

4.4.1 Acute Plant Toxicity to Glyphosate

Glyphosate is estimated to be equally toxic to both terrestrial and aquatic plants (USDA, 2003). EPA has evaluated glyphosate's toxicity to aquatic plants based on studies submitted for the registration of the chemical and additional studies are also available (USDA, 2003). Table N-16 highlights glyphosate's acute toxicity levels for 26 tests on 19 aquatic plant species. EC_{50} values (concentration that causes an effect in 50 percent of the test animals) for glyphosate in algae are as low as 0.85 mg/L (USDA, 2003), indicating high toxicity. Aquatic macrophyte sensitivity to glyphosate is similar to that of algae (USDA, 2003). Note that USDA (2003) did not clearly distinguish whether a.i. indicated a.e. or not.

Table N-16. Acute Nontarget Aquatic Plants Toxicity to Glyphosate

Study Type (% a.i.)	Species	Result	Endpoint	Reference
Aquatic Plant Growth (96.6%)	*Selenastrum capricornutum*	EC_{50} = 12.5 mg/L, 4-day	Not reported	U.S. EPA, 1993a
Aquatic Plant Growth (96.6%)	*Navicula pelliculosa*	EC_{50} = 39.9 mg/L, 4-day	Not reported	U.S. EPA, 1993
Aquatic Plant Growth (96.6%)	*Skeletonema costatum*	EC_{50} = 0.85 mg/L, 4-day	Not reported	U.S. EPA, 1993a
Aquatic Plant Growth (96.6%)	*Anabaena flosaquae*	EC_{50} = 11.7 mg/L, 4-day	Not reported	U.S. EPA, 1993
Aquatic Plant Growth (96.6%)	*Lemna gibba*	EC_{50} = 21.5 mg/L, 7-day	Not reported	U.S. EPA, 1993a
Aquatic Plant Growth (96.7%)	*Chlorella fusca*	EC_{50}= 377 mg/L, 1 generation cycle (24-hours), range not reported	Not reported	USDA, 2003
Aquatic Plant Growth (96.7%)	*Chlorella pyrenoidosa*	EC_{50} = 590 mg/L, 4-day	Not reported	USDA, 2003
Aquatic Plant Growth (96.7%)	*Chlorococcum hypnosporum*	EC_{50} = 68 mg/L, 4-day	Not reported	USDA, 2003
Aquatic Plant Growth (96.6%)	*Zygnema cylindricum*	EC_{50} = 88 mg/L, 4-day	Not reported	USDA, 2003
Aquatic Plant Growth (96.6%)	*Anabaena flosaquae*	EC_{50} = 304 mg/L, 4-day	Not reported	USDA, 2003
Aquatic Plant Growth (96.6%)	*Cyclotella meneghiana*	73% inhibition at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Nitzschia sp.*	77% inhibition at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Scenedesmus quadricauda*	3% inhibition at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Selenastrum capricornutum*	18% inhibition at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Microcystis aeruginosa*	-41% inhibition[a] at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Microcystis aeruginosa*	16% inhibition at 2.8 mg/L	Inhibition of carbon fixation after 24	USDA, 2003

Table N-16. Acute Nontarget Aquatic Plants Toxicity to Glyphosate

Study Type (% a.i.)	Species	Result	Endpoint	Reference
			hours	
Aquatic Plant Growth (96.6%)	*Oscillatoria sp.*	-12% inhibition[a] at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Pseudoanabaena sp.*	12% inhibition at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Anabaena inaequalis*	11% inhibition at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Aphanizomenon flos-aquae*	74% inhibition at 2.8 mg/L	Inhibition of carbon fixation after 24 hours	USDA, 2003
Aquatic Plant Growth (96.6%)	*Lemna minor*	No inhibition at 2.8 mg/L	Inhibition of carbon fixation over 5 days	USDA, 2003
Aquatic Plant Growth (96.6%)	*Scenedesmus quadricauda*	Growth simulation at 0.2 mg/L; stimulation of photosynthesis at 0.2 mg/L; stimulation of chlorophyll-a synthesis at 0.02 mg/L; at ≥ 20 mg/L complete inhibition of algal growth, photosynthesis, and chlorophyll-a synthesis	Algal growth, photosynthesis, and chlorophyll-a synthesis	USDA, 2003
Aquatic Plant Growth (96.6%)	*Scenedesmus acutus*	NOEC = 2 mg/L LOEC = 4 mg/L EC_{50} = 10.2 mg/L, 96-hour, no range reported	Not reported	USDA, 2003
Aquatic Plant Growth (96.6%)	*Scenedesmus quadricauda*	NOEC = 3.2 mg/L LOEC = 4.08 mg/L EC_{50} = 9.08 mg/L, 96-hour, no range reported	Not reported	USDA, 2003
Aquatic Plant Growth (96.6%)	*Scenedesmus acutus*	NOEC = 3.2 mg/L LOEC = 4.08 mg/L EC_{50} = 9.08 mg/L, 96-hour, no range reported	Not reported	USDA, 2003
Aquatic Plant Growth (96.6%)	*Scenedesmus quadricauda*	NOEC = 1.25 mg/L LOEC = 2.5 mg/L EC_{50} = 9.09 mg/L, 96-hour, no range reported	Not reported	USDA, 2003

a.e.= glyphosate acid equivalent
[a] Negative values indicate stimulation
[b] Derived from an acute EC_{50}/chronic NOEC ratio of 20

4.4.2 Acute Plant Toxicity to Glyphosate Herbicide Formulations

No studies were found addressing the acute toxicity of commercial formulations of glyphosate to plants.

4.4.3 Acute Plant Toxicity to AMPA

Table N-17 shows the acute plant toxicity of AMPA. The EC_{50} was established to be 90 mg/L while the NOEC was 7.9 mg/L.

Table N-17. Aquatic Plants Toxicity to AMPA

Study Type	Species	Result	Endpoint	Reference
3-day Acute Toxicity	*Scenedesmus subspicatus*	NOEC = 7.9 mg/L; EC_{50} = 90 mg/L	Not reported	Giesy et al., 2000

4.4.4 Chronic Plant Toxicity to Glyphosate

Table N-18 shows the chronic toxicity of glyphosate on three nontarget aquatic plant species. A Tier II terrestrial seedling emergence study indicated <25 percent effects at a rate of 4.0 lbs ai/acre (U.S. EPA, 2006a). In a Tier II vegetative vigor test on terrestrial plants, found that oil rape seed was the most sensitive dicot species, with phytotoxicity as the most sensitive effect; the EC_{25} was 0.074 lb ai/acre and NOAEL of 0.038 lb ai/acre. The most sensitive monocot species was winter wheat, with dry weight as the most sensitive effect, the EC_{25} was 0.159 lb ai/acre and NOAEL of 0.049 lb ai/acre (U.S. EPA, 2006a). EC_{50} values for glyphosate are as low as 1.6 mg a.i./L (USDA, 2003).

In concentration ranges of 0.002 mg/L to 0.3 mg/L, glyphosate is used as a phosphorus nutrient source for some algae since glyphosate stimulates algal growth at these concentrations (USDA, 2003).

Table N-18. Chronic Nontarget Aquatic Plants Toxicity to Glyphosate

Study Type	Species	Result	Endpoint	Reference
Chronic	*Myriophyllum*	EC_{50} = 1.6 mg a.e./L NOEC = 0.08 [b] mg/L; 14-day, no range reported	Growth Inhibition (change in root length)	Giesy et al., 2000
Chronic	*Lemna gibba*	EC_{50} = 10 mg a.e./L 7-day, no range reported	Growth Inhibition	Giesy et al., 2000
Chronic	*Lemna gibba*	EC_{50} = 25.5 mg a.e./L NOEC = 16.6 mg/L; 14-day, no range reported	Growth Inhibition	Giesy et al., 2000

[b] Derived from an acute EC_{50}/chronic NOEC ratio of 20

4.5 Soil Invertebrates and Microorganisms Toxicity

The results of toxicity studies in soil invertebrates and microorganisms from exposure to glyphosate and its formulations are discussed in sections 4.5.1 through 4.5.4 below.

4.5.1 Soil Invertebrates Toxicity to Glyphosate

The results of glyphosate toxicity studies in invertebrates are provided in table N-19. The sensitivity of the earthworm to glyphosate was tested in two 14-day dietary studies using glyphosate IPA salt. The NOEC was determined to be 118.7 mg/kg soil in one study, and the No mortality level was found to be 3,750 mg/kg soil in a second study.

Table N-19. Soil Invertebrates Toxicity to Glyphosate

Study Type (% a.i.)	Species	Results	Endpoint	Reference
14-day, Dietary	Earthworm	NOEC = 118.7 mg/kg soil	NOEC[a]	Giesy et al., 2000
14-day, Dietary	Earthworm	NML = 3750 mg/kg soil	NML[b]	Giesy et al., 2000

[a] NOEC: No Observed Effect Concentration
[b] NML: No Mortality Level

4.5.2 Soil Invertebrates Toxicity to Glyphosate Herbicide Formulations

The sensitivity of the earthworm to Honcho® Herbicide, Honcho Plus® Herbicide, Roundup Original MAX® Herbicide, and Roundup WeatherMAX® was tested in 14-day dietary and acute toxicity studies. The acute toxicity values are provided in table N-20. The NOEC for earthworms was determined to be 500 mg/kg soil in one study, and the NML was found to be 5,000 mg/kg soil in a second study.

Table N-20. Soil Invertebrate Toxicity to Glyphosate Herbicide Formulations

Study Type (% a.i.)	Species	Results	Endpoint	Reference
14-day, Dietary (Roundup®)	Earthworm	NOEC = 500 mg/kg soil	NOEC	Giesy et al., 2000
14-day, Acute toxicity (Honcho® Herbicide)	Earthworm	LC_{50} > 5,000 mg/kg dry soil	Death	Monsanto, 2007b
14-day, Acute toxicity (Honcho® Plus Herbicide)	Earthworm	LC_{50} > 5,000 mg/kg dry soil	Death	Monsanto, 2007d
14-day, Dietary (Roundup®)	Earthworm	NML = 5000 mg/kg soil	NML	Giesy et al., 2000
14-day, Acute toxicity (Roundup Original MAX® Herbicide)	Earthworm	LC_{50} > 10,000 mg/kg dry soil	Death	Monsanto, 2006
14-day, Acute toxicity (Roundup WeatherMAX® Herbicide)	Earthworm	LC_{50} > 10,000 mg/kg dry soil	Death	Monsanto, 2005

4.5.3 Soil Microorganism Toxicity to Glyphosate

Soil microbes readily metabolize glyphosate into AMPA and other metabolites (USDA, 2003). Microorganisms produce aromatic amino acids through the shikimate pathway, similar to plants. Since glyphosate inhibits this pathway, it could be expected that glyphosate would be toxic to microorganisms. However, field studies show that glyphosate has little effect on soil microorganisms, and, in some cases, field studies have shown an increase in microbial activity (USDA, 2003).

Studies have tested the effects of glyphosate and glyphosate formulations on soil microbes' ability for nitrification, denitrification, dehydrogenase activity, nitrogen fixation, urea hydrolysis, immobilization of ammonium, ammonification, and degradation of cellulose, starch, protein, and leaf litter. *In vitro* studies were excluded from this report due to challenges associated with extrapolating the results of *in vitro* environments to natural soil ecosystems.

The results of chronic glyphosate acid toxicity studies in soil microbes are provided in table N-21. Microbial activities including degradation of leaf litter, cellulose, starch, and protein showed the least sensitivity to glyphosate, while ammonification, denitrification, nitrification, and nitrogen fixation were more sensitive. However, one 3-day nitrification study produced no observable adverse effects up to a concentration of 76.7 mg a.e./kg. Alfalfa is a legume that

forms a symbiotic relationship with the nitrogen-fixing bacterium, *Sinorhizobium meliloti*. The result is the conversion of atmospheric nitrogen to fixed nitrogen in the soil, resulting in a net increase in available nitrogen to the soil. GT alfalfa does not alter the symbiotic association with *S. meliloti* and does not negatively affect the availability of nitrogen in the soil.

Table N-21. Soil Microorganism Toxicity to Glyphosate

Study Type (% a.i.)	Species	Result[a]	Endpoint[b]	Reference
7-day, Ammonification	Soil Microorganism	NOAEC = 10 mg a.e./kg	NOAEC	Giesy et al., 2000
7, 14-day, Denitrification	Soil Microorganism	NOAEC = 10 mg a.e./kg	NOAEC	Giesy et al., 2000
14-day, Nitrification	Soil Microorganism	NOAEC = < 10 mg a.e./kg	NOAEC	Giesy et al., 2000
21-day, Nitrification	Soil Microorganism	NOAEC = 10 mg a.e./kg	NOAEC	Giesy et al., 2000
3-day, Nitrification	Soil Microorganism	NOAEC = < 76.7 mg a.e./kg	NOAEC	Giesy et al., 2000
7-day, Nitrogen fixation	Soil Microorganism	NOAEC = 12.7 mg a.e./kg	NOAEC	Giesy et al., 2000
84-day, Degradation of cellulose, starch, protein	Soil Microorganism	NOAEC = 25 mg a.e./kg	NOAEC	Giesy et al., 2000
84-day, Degradation of leaf litter	Soil Microorganism	NOAEC = 25 mg a.e./kg	NOAEC	Giesy et al., 2000

[a] a.e, glyphosate acid equivalents
[b] NOAEC unless specified. Effects may have been observed at higher levels, but they were not judged to be adverse (e.g., stimulatory effects).

4.5.4 Soil Microorganism Toxicity to Glyphosate Herbicide Formulations

The results of chronic toxicity studies of Roundup® in soil microbes are provided in table N-22. The NOAEC endpoint was determined for various microbial activities, including dehydrogenase activity, immobilization of ammonium, nitrification, nitrogen fixation, urea hydrolysis, and nitrogen and carbon transformation. Microbial response to Roundup® varied significantly. For example, the NOAEC for microbial nitrification ranged from 5 mg a.e./kg to 230 mg a.e./kg, and the NOAEC for urea hydrolysis ranged from 5 mg a.e./kg (1-day study) to 50 mg a.e./kg (42-day study).

Table N-22. Soil Microorganism Toxicity to Glyphosate Herbicide Formulations

Study Type (% a.i)	Species	Results	Endpoint[a]	Reference
28-day, Dehydrogenase activity (Roundup®)	Soil Microorganism	NOAEC = 24 mg a.e./kg	NOAEC	Giesy et al., 2000
42-day, Immobilization of ammonium (Roundup®)	Soil Microorganism	NOAEC = 50 mg a.e./kg	NOAEC	Giesy et al., 2000
7-21-day, Nitrification (Roundup®)	Soil Microorganism	NOAEC = 5.0 mg a.e./kg	NOAEC	Giesy et al., 2000
25-day, Nitrification (Roundup®)	Soil Microorganism	NOAEC = 21.4 mg a.e./kg	NOAEC	Giesy et al., 2000
28-day, Nitrification (Roundup®)	Soil Microorganism	NOAEC = 24 mg a.e./kg	NOAEC	Giesy et al., 2000

Table N-22. Soil Microorganism Toxicity to Glyphosate Herbicide Formulations

Study Type (% a.i)	Species	Results	Endpoint[a]	Reference
42-day, Nitrification (Roundup®)	Soil Microorganism	NOAEC = 50 mg a.e./kg	NOAEC	Giesy et al., 2000
3-day, Nitrification (Roundup®)	Soil Microorganism	NOAEC = 230 mg a.e./kg	NOAEC	Giesy et al., 2000
7-day, Nitrogen fixation (Roundup®)	Soil Microorganism	NOAEC = 12.7 mg a.e./kg	NOAEC	Giesy et al., 2000
1-day, Urea hydrolysis (Roundup®)	Soil Microorganism	NOAEC = 5.0 mg a.e./kg	NOAEC	Giesy et al., 2000
Urea hydrolysis, test duration not reported (Roundup®)	Soil Microorganism	NOAEC = 11.5 mg a.e./kg	NOAEC	Giesy et al., 2000
42-day, Urea hydrolysis (Roundup®)	Soil Microorganism	NOAEC = 50 mg a.e./kg	NOAEC	Giesy et al., 2000
28-day, Nitrogen and carbon transformation (Roundup Original MAX® Herbicide)	Soil Microorganism	29.5 kg/ha	<25% effect on nitrogen or carbon transformation processes in soil	Monsanto, 2006
28-day, Nitrogen and carbon transformation (Roundup WeatherMAX® Herbicide)	Soil Microorganism	40 L/ha	<25% effect on nitrogen or carbon transformation processes in soil	Monsanto, 2005

[a] NOAEC unless specified. Effects may have been observed at higher levels, but they were not judged to be adverse (e.g., stimulatory effects).

4.5.5 Effects of GT Crops and Glyphosate Herbicide Formulations on Soil Microbial Communities

As noted in section 4.5.3 above, soil microorganisms play several important roles in plant health and soil quality (Powell and Swanton, 2008; Johal and Huber, 2009; Bohm et al., 2009). The effects of glyphosate on soil microbial communities and interactions between those communities and GT plants have been investigated in several laboratory experiments and field trials, as summarized below. These studies have examined potential effects of GT plants and glyphosate on soil microbial communities in general, on soil microbes that can cause plant diseases, disease antagonism and resistance, nutrient availability and uptake, and nitrogen fixation. Although the research to date generally has focused on GT soybean, corn, and cotton; someof the findings may be relevant to GT alfalfa. Overall, none of the current research shows definitive improvements or decrements in soil microbe community function with use of GT crops or glyphosate.

Modifications of soil microbial communities by GT crops have been demonstrated in some studies. For example, Locke et al. (2008) compared soils in fields planted with GT and conventional corn and cotton crops under limited tillage management over a 5-year field trial. Analysis of soil microbial communities based on total fatty acid methyl ester analysis indicated that GT crops treated with glyphosate produced a significant effect on soil microbial communities; whether the changes were of ecological or agricultural significance, however, cannot be evaluated by that endpoint. In their 10-year field trial of GT and non-GT corn or soybean that received glyphosate, no herbicide, or an alternative herbicide (atrazine), Kremer

and Means (2009) found that GT soybeans, even when not sprayed with glyphosate, showed reduced root nodule number and mass compared with conventional soybeans.

Modifications of soil microbial communities by glyphosate applications also have been demonstrated, although the significance of those alterations remains debated. Johal and Huber (2009) conducted a review of the literature to investigate mechanisms by which glyphosate can affect soil microbes and can affect plants both directly and indirectly. They cited studies that describe the re-emergence of 34 pathogen-related crop diseases in glyphosate weed control programs and concluded that glyphosate may stimulate pathogenic soil organisms, including *Fusarium*, *Gaeumannomyces*, *Phyophthora*, *Pythium*, and *Zylella*. = .

Some studies have suggested a link between glyphosate application to GT crops and development of plant diseases, particularly blights cause by the fungus *Fusarium*, but consensus on cause and effect is lacking. Powell and Swanton (2008) reviewed studies that examined the effects of glyphosate on diseases associated with *Fusarium*, and cited greenhouse studies that have shown *Fusarium* growth to be stimulated by glyphosate. In their review of the literature, however, they found no direct evidence of glyphosate effects on either *Fusarium* abundance or *Fusarium*-related disease in field studies. Fernandez et al. (2005) examined crop production factors (e.g., tillage, herbicide application) associated with levels of *Fusarium* head blight (FHB) in spring wheat crops over a 4-year period in eastern Saskatchewan. Although glyphosate application was positively associated with the percentage of *Fusarium*-damaged kernels, Fernandez et al. (2005) could not establish a cause-and-effect relationship. Powell and Swanton (2008) concluded that field studies inferring a relationship between glyphosate and plant disease have not demonstrated a causal link, and experimental studies provide varying results, perhaps because they are not representative of realistic field conditions, especially concerning ecological interactions occurring among microorganisms.

More recently, Kremer and Means (2009) reported the results of a 10-year field research program in which plots of GT and non-GT corn or soybean received glyphosate, no herbicide, or an alternative herbicide (atrazine). The investigators consistently found higher rates of *Fusarium* colonization of roots of GT plants, especially where glyphosate was applied. Colonization on glyphosate-treated GT soybean was generally two to five times higher than colonization on soybean receiving no herbicide or the alternative herbicide. Kremer and Means (2009) found similar results for corn: glyphosate-treated GT plants had colonization rates 3 to 10 times higher than GT plants treated with the alternative herbicide. Kremer and Means (2009) also analyzed root-associated soil for fluorescent *Pseudomonad* spp. (i.e., bacteria that produce beneficial metabolites including antibiotics and antifungal chemicals) and Mn transforming (i.e., oxidizing or reducing) microorganisms. Their analysis of pseudomonads indicated that pseudomonads were always higher in non-GT soybean rhizospheres, and they may be reduced in GT-soybean due to their sensitivity to glyphosate.

Some investigators have examined the possible effects of both GT plants and glyphosate application, alone and in combination, on soil characteristics. Bohm et al. (2009) conducted a field experiment in Brazil in which GT and non-GT soybean crops received glyphosate, an alternative herbicide (imazethapyr), or no herbicide. The highest grain yields were obtained from GT crops treated with glyphosate, which was consistent with earlier studies (e.g. Delannay

et al., 1995; Elmore et al., 2001; Norsworthy, 2004 cited in Bohm, 2009) that reported soybean yields to be unaffected by glyphosate application. Glyphosate-treated GT soybean showed significantly lower nitrogen fixation and nodule weights than hand-weeded GT soybean. Hand-weeded non-GT soybeans showed intermediate values of nitrogen fixation and nodule weights. Total CO_2 evolution from the soil was significantly greater from plots treated with either glyphosate or imazethaphyr than from untreated plots.

Locke et al. (2008) found beneficial effects of GT corn on soil nutrients in their 5-year field trial that compared GT and conventional corn and cotton crops under limited tillage weed management (no herbicides). Where GT corn was grown, the soil maintained greater organic carbon and nitrogen compared with non-GT corn fields. These differences did not occur between GT and non-GT cotton crops or where cotton was rotated with corn.

Kremer and Means (2009) presented findings from a 10-year field research program in which plots of GT and non-GT corn or soybean received glyphosate, no herbicide, or an alternative herbicide (atrazine). Analysis of Mn-transforming microbes indicated that glyphosate treatment increased proportions of Mn-oxidizing microbes, which might reduce the bioavailability of Mn to plants. The Mn-oxidizing bacterial isolates included *Agrobacterium* spp. which typically produce biofilms on the rhizosphere in which Mn-oxidation and immobilization may occur (Toner et al., 2005 cited by Kremer and Means, 2009).

Taken together, the available research indicates that microbial communities associated with GT crops and glyphosate-treated GT crops may differ from microbial communities associated with conventional crops. Some data suggest stimulation of disease-causing *Fusarium* spp.; reduction in disease antagonizing *pseudomonad spp*.; and reduction in the availability and plant uptake of the soil nutrient Mn. One study indicated a reduction in nitrogen fixation in glyphosate-treated GT soybean compared with hand-weeded GT soybean. Researchers have identified specific organisms and physiological and biochemical processes that might account for the observed associations (Bohm et al., 2009; Johal and Huber, 2009). However, as noted by Powell and Swanton (2008), there remains limited evidence of a causative link between glyphosate and elevated levels of crop disease, and Bohm et al. (2009) noted that reduced nitrogen fixation did not affect grain yield. Because the interactions between herbicides, plants, and microbial communities are varied and complex, they are difficult to generalize and may vary on a case-by-case basis (Powell and Swanton, 2008).

4.6 Amphibian Toxicity

The results of toxicity studies in amphibians from exposure to glyphosate and its formulations are discussed in sections 4.6.1 through 4.6.2 below.

4.6.1 Amphibian Toxicity to Glyphosate

Amphibians use a wide range of aquatic habitats for their breeding sites and could be exposed to glyphosate in surface water. This would most likely occur as a result of heavy rainfall after a recent application and subsequent dissipation into stream sediment (Lajmanovich, 2003). Giesy et al. (2000) summarized acute (2- and 4-day) toxicity tests for tadpoles exposed to technical grade glyphosate. The tadpoles showed greater sensitivity to glyphosate tested as an acid; LC_{50}

values ranged from 78 to 121 mg a.e./L for glyphosate tested as acid and 343-466 mg a.e./L for glyphosate tested as IPA salt. The study results are presented in table N-23 below.

Table N-23. Toxicity of Glyphosate to Amphibians

Study Type	Lifestage (Species)	Results	Endpoint	Reference
Glyphosate tested as IPA salt				
2-day, Acute toxicity	Tadpole (*Litoria moorei*)	LC_{50} = > 343 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity	Tadpole (*Heleioporus eyrei*)	LC_{50} = > 373 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity	Tadpole (*Limnodynastes dorsalis)*	LC_{50} = > 400 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity	Tadpole (*Crinia insignifera*)	LC_{50} = > 466 mg a.e./L	Death	Mann and Bidwell, 1999
Glyphosate tested as acid				
2-day, Acute toxicity	Newly emerged tadpole (*C. insignifera*)	LC_{50} = 83.6 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity	Tadpole (*L. moorei*)	LC_{50} = 81.2 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity	Tadpole (*L. moorei*)	LC_{50} = 121 mg a.e./L	Death	Mann and Bidwell, 1999
4-day, Acute toxicity	Adult tadpole (*C. insignifera*)	LC_{50} = 78 mg a.e./L NOEC = 45 mg a.e./L	Death	Bidwell and Gorrie, 1995
4-day, Acute toxicity	Adult tadpole (*L. moorei*)	LC_{50} = > 180 mg a.e./L NOEC = 180 mg a.e./L	Death	Bidwell and Gorrie, 1995
4-day, Acute toxicity	Tadpole (*L. moorei*)	LC_{50} = 111 mg a.e./L	Death	Bidwell and Gorrie, 1995

[a] Data as reported in Giesy et al. 2000; original source is noted in the table.
Note: mg a.e./L = mg glyphosate acid equivalent per liter.

4.6.2 Amphibian Toxicity to Glyphosate Herbicide Formulations

In their 2000 ecological risk assessment for Roundup®, Giesy et al. (2000) summarized 2-day and 4-day acute toxicity studies for tadpoles and adults of five species (*Crinia insignifera*, the sign-bearing froglet, *Heleioporus eyrei*, an Australian moaning frog, *Limnodynastes dorsalis*, a bullfrog, *Litoria moorei*, an Australian ground-dwelling treefrog, and *Xenopus laevis*, the African clawed frog). Assuming that 1 mg of Roundup® (RU) includes 0.31 mg acid equivalents (a.e.) of glyphosate, Giesy et al. (2000) found that LC_{50} values for the five species ranged from 8.1 mg RU/L (or 2.5 mg a.e./L) for *L. moorei* to 175 mg RU/L (54 mg a.e./L) for *H. eyre*. In general, adults demonstrated higher tolerances to Roundup® than tadpoles, with the exception of one study performed with newly hatched *C. insignifera* tadpoles (LC_{50} values of 144 mg RU/L or 45 mg a.e./L). These results are provided in table N-24 below.

The frog tadpoles exhibited greater sensitivity to Roundup® formulations (LC_{50} values of 8.1–75 mg RU/L or 2.5–54 mg a.e./L) than to glyphosate tested as an acid or IPA salt (LC_{50} 78 to 466 mg a.e./L). This could be due to the surfactant (POEA) used in the Roundup® agricultural formulations, which has been found to be more toxic to amphibians and other aquatic animals than the herbicide itself (Giesy et al., 2000; Lajmanovich, 2003).

Table N-24. Glyphosate Herbicide Formulations Toxicity to Amphibians

Study Type	Lifestage & Group (Species)	Results	Endpoint	Reference[a]
4-day, Acute toxicity (Roundup®)	Larval salamander (*Ambystoma gracile*)	LC_{50} = 2.8 mg a.e./L	Death	Reylea and Jones, 2009
4-day, Acute toxicity (Roundup®)	Larval salamander (*A. maculatum*)	LC_{50} = 2.8 mg a.e./L	Death	Reylea and Jones, 2009
4-day, Acute toxicity (Roundup®)	Larval salamander (*A. laterale*)	LC_{50} = 3.2 mg a.e./L	Death	Reylea and Jones, 2009
16-day, Acute toxicity (Roundup®)	Tadpole toad (*Bufo americanus*)	LC_{50} = 2.52 mg a.i./L = 1.97 a.e./L	Death	Reylea, 2005b
4-day, Acute toxicity (Roundup®)	Tadpole toad (*B. americanus*)	LC_{50} = 1.6 mg a.e./L	Death	Reylea and Jones, 2009
4-day, Acute toxicity (Roundup®)	Tadpole toad (*B. boreas*)	LC_{50} = 2.0 mg a.e./L	Death	Reylea and Jones, 2009
2-day, Acute toxicity (Roundup®)	Tadpole froglet *(Crinia insignifera)*	LC_{50} = 10 mg RU/L = 3.1 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity (Roundup®)	Tadpole froglet (*C. insignifera*)	LC_{50} = < 54.9 mg a.e./L	Death	Bidwell and Gorrie, 1995
4-day, Acute toxicity (Roundup®)	Adult froglet (*C. insignifera*)	LC_{50} = 96.8 mg RU/L ≈ 30 mg a.e./L NOEC = 54 mg RU/L ≈ 17 mg a.e./L	Death	Bidwell and Gorrie, 1995
2-day, Acute toxicity (Roundup®)	Adult froglet (*C. insignifera*)	LC_{50} = 137 mg RU/L ≈ 42.5 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity (Roundup®)	Newly hatched froglet tadpole (*C. insignifera*)	LC_{50} = 144 mg RU/L ≈ 45 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity (Roundup®)	Tadpole treefrog (*Hyla eyrei*)	LC_{50} = 17.5 mg RU/L ≈ 5.4 mg a.e./L	Death	Mann and Bidwell, 1999
16-day, Acute toxicity (Roundup®)	Tadpole treefrog (*H. versicolor*)	LC_{50} = 1.35 mg a.i./L = 1.05 mg a.e./L	Death	Reylea, 2005b
4-day, Acute toxicity (Roundup®)	Tadpole treefrog (*H. versicolor*)	LC_{50} = 1.7 mg a.e./L	Death	Reylea and Jones, 2009
2-day, Acute toxicity (Roundup®)	Tadpole bullfrog (*Limnodynastes dorsalis*)	LC_{50} = 8.3 mg RU/L ≈ 2.6 mg a.e./L	Death	Mann and Bidwell, 1999
2-day, Acute toxicity (Roundup®)	Tadpole treefrog (*Litoria moorei*)	LC_{50} = 8.1 mg RU/L ≈ 2.5 mg a.e./L NOEC = 1.6[b] mg RU/L ≈ 0.50 mg a.e./L	Death	Mann and Bidwell, 1999
4-day, Acute toxicity (Roundup®)	Tadpole treefrog (*L. moorei*)	LC_{50} = 18.7 mg RU/L ≈ 5.8 mg a.e./L NOEC = 55 mg RU/L ≈ 17 mg a.e./L	Death	Bidwell and Gorrie, 1995

The frog tadpoles exhibited greater sensitivity to Roundup® formulations (LC_{50} values of 8.1–75 mg RU/L or 2.5–54 mg a.e./L) than to glyphosate tested as an acid or IPA salt (LC_{50} 78 to 466 mg a.e./L). This could be due to the surfactant (POEA) used in the Roundup® agricultural formulations, which has been found to be more toxic to amphibians and other aquatic animals than the herbicide itself (Giesy et al., 2000; Lajmanovich, 2003).

Table N-24. Glyphosate Herbicide Formulations Toxicity to Amphibians

Study Type	Lifestage & Group (Species)	Results	Endpoint	Reference[a]
2-day, Acute toxicity (Roundup®)	Tadpole treefrog (*L. moorei*)	LC_{50} = 32.2 mg RU/L ≈ 10 mg a.e./L	Death	Bidwell and Gorrie, 1995
4-day, Acute toxicity (Roundup®)	Adult treefrog (*L. moorei*)	LC_{50} > 165 mg RU/L > 51 mg a.e./L NOEC = 165 mg RU/L ≈ 51 mg a.e./L	Death	Bidwell and Gorrie, 1995
4-day, Acute toxicity (Roundup®)	Larval newt (*Notophthalamus viridescens*)	LC_{50} = 2.7 mg a.e./L	Death	Reylea and Jones, 2009
4-day, Acute toxicity (Roundup®)	Tadpole treefrog (*Pseudacris crucifer)*	LC_{50} = 0.8 mg a.e./L	Death	Reylea and Jones, 2009
4-day, Acute toxicity (Roundup®)	Tadpole Cascades frog (*Rana cascadae*)	LC_{50} = 1.7 mg a.e./L	Death	Reylea and Jones, 2009
16-day, Acute toxicity (Roundup®)	Tadpole American bull-Frog (*R. catesbeiana*)	LC_{50} = 2.07 mg a.i./L = 1.61 mg a.e./L	Death	Reylea, 2005b
4-day, Acute toxicity (Roundup®)	Tadpole American bull-Frog (*R. catesbeiana*)	LC_{50} = 0.8 mg a.e./L	Death	Reylea and Jones, 2009
16-day, Acute toxicity (Roundup®)	Tadpole green frog (*R. clamitans*)	LC_{50} = 2.17 mg a.i./L = 1.69 mg a.e./L	Death	Reylea, 2005b
4-day, Acute toxicity (Roundup®)	Tadpole green frog (*R. clamitans*)	LC_{50} = 1.4 mg a.e./L	Death	Reylea and Jones, 2009
16-day, Acute toxicity (Roundup®)	Tadpole leopard frog (*R. pipiens*)	LC_{50} = 2.46 mg a.i./L or = 1.92 mg a.e./L	Death	Reylea, 2005b
4-day, Acute toxicity (Roundup®)	Tadpole leopard frog (*R. pipiens*)	LC_{50} = 1.5 mg a.e./L	Death	Reylea and Jones, 2009
16-day, Acute toxicity (Roundup®)	Tadpole wood frog (R. sylvatica)	LC_{50} = 1.32 mg a.i./L (no predator) = 1.03 a.e./L LC_{50} = 0.55 mg a.i./L (caged predator) = 0.43 a.e./L	Death	Reylea, 2005b
4-day, Acute toxicity (Roundup®)	Tadpole wood frog (*R. sylvatica*)	LC_{50} = 1.9 mg a.e./L	Death	Reylea and Jones, 2009
4-day, Acute toxicity (Roundup®)	Embryo African clawed frog *(Xenopus laevis*)	LC_{50} = 72 mg RU/L ≈ 22 mg a.e./L	Death	Perkins, 1997

[a] Data as reported in Giesy et al. 2000 (except for Reylea 2005b and Reylea and Jones 2009); original source is noted in the table.
[b] Derived from raw data; not reported by reference authors.
Note: RU = Roundup formulation; a.i. = active ingredient; a.e. = acid equivalent

Roundup® formulations are toxic to amphibians; however most experiments simulating outdoor conditions have used direct overspray, which is not permitted, and highest recommended application rates. Relyea (2005a) examined tadpoles of three species of North American anurans

(leopard frog *Rana pipiens*, the American toad *Bufo americanus*, and the treefrog *Hyla versicolor*) in outdoor pond mesocosms that contained different types of soil and directly applied Roundup® (specified as 25.5 percent glyphosate) as an overspray. Relyea applied the manufacturer's recommended rate (as listed on the Roundup® container) of 1.6 mL a.i./m^2 which resulted in a glyphosate concentration of 3.8 mg of a.i./L, or approximately 3 mg a.e./L in the water. Relyea noted that this application rate represented a worst-case scenario and that the highest concentration of glyphosate in nature that had been recorded was 2.6 mg a.e./L. After three weeks, Roundup® had killed 96–100 percent of the tadpoles across all three species. Relyea (2005a) also exposed juveniles (post-metamorphic) of the same three species of anurans to a direct overspray of Roundup® in laboratory containers to simulate the impact of amphibians receiving a direct terrestrial overspray in an agricultural field. The same application rate (1.6 mL a.i./m^2) resulted in 68–86 percent mortality of the juveniles. Relyea (2005b) expanded the investigation to evaluate longer exposures (i.e., 16 days) to Roundup® for six species of anurans (New World true frogs *Rana sylvatica*, *R. pipiens*, *R. clamitans*, *R. catesbeiana*, the toad *B. americanus*, and the treefrog *H. versicolor*) with and without chemical cues emitted by predatory newts (*Notophthalmus viridescens*). $LC50_{16\text{-}d}$ estimates varied from 0.55 to 2.52 mg of active ingredient [a.i.] per liter [L] (or 0.41 to 1.9 mg a.e./L), indicating moderate to high toxicity (see table N-24 for acute toxicity LC_{50} values). In one of the six species tested (*R. sylvatica*), the addition of chemical cues from predatory newts made Roundup® twice as lethal, suggesting a synergistic interaction between predatory stress and Roundup® in that case.

In a similar study to Relyea (2005a), Bernal et al. (2009) assessed the effects of a glyphosate formulation (Glyphos-Cosmo-Flux, which is used to control coca in Columbia) overspray on frog habitat under field conditions. Tadpoles of the frog species *Rhinella granulosa*, *R. marina*, *Hypsiboas crepitans*, and *Scinax ruber* were placed in outdoor microcosms. The bottoms of the microcosms were covered with a 1.2-inch layer of local soil, and they were filled to a depth of 6 inches (above the sediment) with local spring water. The tadpoles were sprayed with the glyphosate mixture at concentrations greater and less than the normal Columbian field application rate (3.23 lbs glyphosate a.e./acre). The results indicated that, under realistic worst-case exposure conditions, the mixture of Glyphos and Cosmo-Flux to control coca exerts a low toxicity to aquatic and terrestrial stages of anurans and that risks to those organisms under field conditions are small.

Relyea and Jones (2009) conducted tests of concentrations of Roundup Original Max® estimated to kill 50 percent of a population after 4 days ($LC50_{96\text{-}h}$) on a variety of amphibian species from both eastern and western North America. Tests were conducted on tadpoles of nine species of anurans from three families (Ranidae: *R. pipiens*, *R. clamitans*, *R. sylvatica*, *R. catesbeiana*, *R. cascadae*; Bufonidae: *B. americanus*, *B. boreas*; and Hylidae: *H. versicolor*, *Pseudacris crucifer*) and larvae of four species of salamanders from two families (Ambystomatidae: *Ambystoma gracile*, *A. maculatum*, *A. laterale*; and Salamandridae: *Notophthalmus viridescens*). For the nine species of anurans, $LC50_{96\text{-}h}$ values for the tadpoles ranged from 0.8 to 2.0 mg a.e./L with relatively little variation in sensitivity among the species or families (see table N-24 for acute toxicity LC_{50} values). The larval lifestage of four species of salamanders were less sensitive than the anuran tadpoles, with $LC50_{96\text{-}h}$ values ranging from 2.7 to 3.2 mg a.e./L with no substantial differences among the species of salamanders.

4.6.3 California Red Legged Frog Toxicity to Glyphosate, Glyphosate Salts, and Glyphosate Formulations

EPA (2008) evaluated the potential direct and indirect effects on the California red-legged frog (*Rana aurora draytonii*) (CRLF) and its designated critical habitat from the use of glyphosate and its salts on agricultural and nonagricultural sites. Use of glyphosate on alfalfa was one of the uses for which risk was assessed. Since CRLFs exist in both aquatic and terrestrial habitats, exposure to glyphosate was assessed separately for the two habitats and for the CRLF and its prey in each habitat. The highest aquatic exposure to both glyphosate and its formulations is expected to result from uses with direct aquatic applications (U.S. EPA, 2008).
EPA (2008) concluded that the use of glyphosate "may affect and is likely to adversely affect" the CRLF. Additionally, EPA determined that there is the potential for modification of CRLF designated critical habitat from the use of glyphosate. However, the results indicate no toxic effects at the maximum single application rate for glyphosate products labeled for GT alfalfa (1.55 lb a.e./acre). EPA (2008) concluded:

> "There are no direct effects on the aquatic-phase CRLF for any of the terrestrial or aquatic uses. The terrestrial-phase CRLF eating broadleaf plants, small insects and small herbivorous mammals on a dietary-basis may be at risk to direct effects following chronic exposure to glyphosate at application rates of 7.5 lb a.e./A [acre] and above (forestry, areas with impervious surfaces and rights-of-way). In addition, terrestrial phase amphibians may be at risk following acute exposure to one particular formulation (Registration No. 524-424), at application rates of 1.1 lbs formulation/A and above (ornamental lawns and turf and industrial outdoor uses). Indirect effects to the aquatic-phase CRLF, based on reduction in the prey base may occur with aquatic nonvascular plants with aquatic weed management uses at an application rate of 3.75 lb a.e./A. Indirect effects to the terrestrial-phase CRLF, based on reduction in the prey base may occur with small insects at any registered rate, large insects at an application rate of 7.95 lb a.e./A (forestry uses), terrestrial phase amphibians following chronic exposure at application rates of 7.5 lb a.e./A and above and following acute exposure to one formulation at application rates of 1.1 lbs formulation/A and above and mammals following chronic exposure at application rates of 3.84 lbs a.e./A and above (i.e., many crops, forestry, rights-of-way and areas with impervious surfaces).
>
> Indirect effects to both the aquatic- and terrestrial-phase CRLF, based on habitat effects may occur with aquatic nonvascular plants following aquatic weed management use and with aquatic emergent plants and terrestrial plants exposed via spray drift with aerial application at rates of 3.75 lbs /A and above and with ground applications at a rate of 7.95 lbs/A."

Note that in all cases, the application rate is more than double the maximum single use (ground or aerial) application for GT alfalfa (1.55 lbs a.e./acre). The formulation that may have indirect toxic effects for CRLF is a formulation for ornamental planting and lawn/turf grasses, not for GT alfalfa uses.

4.7 Aquatic Invertebrate Toxicity

Several acute and chronic toxicity tests were conducted on aquatic invertebrates for exposure to glyphosate and its formulations. A study was also conducted on the toxic effects of the metabolite AMPA on aquatic invertebrates. The toxicity study results are discussed in sections 4.7.1 through 4.7.4.

4.7.1 Acute Aquatic Invertebrate Toxicity to Glyphosate

The acute toxicity of glyphosate to aquatic invertebrates is summarized in table N-25. The most sensitive species to glyphosate (96.7 percent a.i.) was the midge (larval stage) *Chironomus plumosus* with a 48-hour EC_{50} of 55 ppm (U.S. EPA, 1993a). The 48-hour EC_{50} for the water flea *Daphnia magna* ranged from 780 mg/L (tested as an acid) to 930 mg/L (tested as the IPA salt), with a NOEC value of 560 mg/L (Giesy et al., 2000).

The most sensitive marine animal species to glyphosate was the copepod (zooplankton) *Acartia tonsa*, which is abundant in warm coastal and estuary water (48-hr LC50 values for glyphosate acid, POEA, and Roundup® of 35.3, 0.57, and 1.77 mg a.e./L) (Tsiu and Chu, 2003).

Table N-25. Acute Aquatic Invertebrate Toxicity to Glyphosate

Study Type (% a.i.)	Species	Result	Endpoint	Reference
Acute (96.7%)	*Chironomus plumosus*	LC_{50} (95% CL) = 55 ppm (31-97), 48-hour	Death	U.S. EPA, 1993a
Acute	*Chironomus plumosus*	EC_{50} (95% CL) = 55 ppm (31-97), 48-hour	Not reported	USDA, 2003
Acute (83%)	*Daphnia magna*	LC_{50} = 780 ppm, 48-hour, range not reported	Death	U.S. EPA, 1993a[a]
Tested as acid:				
Acute	*Ceriodaphnia dubia*	LC_{50} (95% CI) = 147 mg/L (141-153), 48-hour	Death	Tsui and Chu, 2003
Acute	*Daphnia magna*	Toxicity Value[b] = 780 mg/L, 48-hour range not reported NOEC = 560 mg/L	Not reported	Giesy et al., 2000[a]
Acute	*Pseudosuccinea columella*	Toxicity Value[b] = 98.9 mg/L, range and time frame exposure time not reported	Not reported	Giesy et al., 2000
Tested as IPA salt:				
Acute	*Chironomus plumosis*	Toxicity Value[b] = 55 mg/L, 48-hour, range not reported	Not reported	Giesy et al., 2000
Acute	*Chironomus riparius*	Toxicity Value[b] = 5600 mg/L, 48-hour, range not reported	Not reported	Giesy et al., 2000
Acute; Sediment/water test	*Chironomus tetans*	Toxicity Value[b] = >530 mg/L, 10 day, range not reported NOEC = 265 mg/L	Not reported	Giesy et al., 2000
Acute	*Ceriodaphnia*	LC_{50} (95% CI) = 415	Death	Tsui and Chu,2003

Table N-25. Acute Aquatic Invertebrate Toxicity to Glyphosate

Study Type (% a.i.)	Species	Result	Endpoint	Reference
	dubia	mg/L (339-508), 48-hour		
Acute	*Daphnia magna*	Toxicity Value[b] = 930 mg/L, 48-hour, range not reported NOEC = 320 mg/L	Not reported	Giesy et al., 2000
Acute; Sediment/water test	*Hyalella azteca*	Toxicity Value[a] = >530 mg/L, 10 day, range not reported NOEC = 265 mg/L	Not reported	Giesy et al., 2000

4.7.2 Acute Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulations

The acute toxicity of glyphosate formulations to aquatic invertebrates is summarized in table N-26. The most sensitive species to glyphosate formulations was *Daphnia magna* with a 48-hour EC_{50} ranging from 3.0 ppm to 160 mg/L (USDA, 2003; Monsanto, 2005, 2006, 2007b, 2007d). As evidenced by these data, glyphosate formulations may be several orders of magnitude more toxic to *Daphnia magna* than technical glyphosate. The 48-hour EC_{50} for *Chironomus plumosus* was 58.1 ppm (Giesy et al., 2000). Toxicity values (96-hour EC_{50} or LC_{50}) for *Gammarus pseudolimnaeus* ranged from 42 mg/L to 200 mg RU/L, with a NOEC value of 4.4 mg RU /L (Giesy et al., 2000; USDA, 2003), where RU represents the total Roundup® formulation with glyphosate, surfactant(s), and other inert compounds (e.g., water). Assuming that there are approximately 0.31 acid equivalents (a.e.) of glyphosate per unit RU (Giesy et al., 2000), the 96-hour EC_{50} or LC_{50} values would be 13 to 62 mg a.e./L and the NOEC would be 1.4 mg a.e./L.

Table N-26. Acute Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulation

Study Type	Formulation	Species	Result	Endpoint	Reference
Acute Toxicity	Roundup®	Fourth instar *Anopheles quadrimaculatus* larvae	LC_{50} (95% CL) = 673.43 ppm (572.57-770.17), 24-hour	Death	USDA, 2003
Acute Toxicity	Roundup®	*Chironomus plumosus*	Toxicity Value[a] = 58.1 mg/L[b], 48-hour, range not reported	Not reported	Giesy et al., 2000
Acute Toxicity	Roundup®	*Ceriodaphnia dubia*	LC_{50} (95% CL) =5.39 mg/L (4.81-6.05), 48-hour	Death	Tsui and Chu, 2003
Acute Toxicity	Roundup®	Fourth instar *Culex salinarius* larvae	LC_{50} (95% CL) = 1563.69 ppm (1262.00-2214.54), 24-hour	Death	USDA, 2003
Acute Toxicity	Roundup®	*Daphnia magna*	EC_{50} (95% CL) = 3.0 ppm (2.6-3.4), 48-hour	Not reported	USDA, 2003
Acute Toxicity, Static	Roundup Original MAX®	*Daphnia magna*	EC_{50} = 8.0 mg/L[c], 48-hour	Not reported	Monsanto, 2006
Acute Toxicity, Static	Roundup WeatherMAX®	*Daphnia magna*	EC_{50} = 8.0 mg/L[c], 48-hour	Not reported	Monsanto, 2005

Table N-26. Acute Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulation

Study Type	Formulation	Species	Result	Endpoint	Reference
Acute Toxicity, Static	Roundup UltraMAX® II	*Daphnia magna*	EC_{50} = 8.0 mg/L[c], 48-hour	Not reported	Monsanto, 2003
Acute Toxicity	Roundup®	*Daphnia magna*	EC_{50} = 9.7 mg/L[b], 48-hour NOEC = 1.9 mg/L[d]	Not reported	Giesy et al., 2000
Acute Toxicity, Static	Honcho®	*Daphnia magna*	EC_{50} =11.0 mg/L[c], 48-hour	Not reported	Monsanto, 2007b
Acute Toxicity	Roundup®	*Daphnia magna*	Toxicity Value[a] = 12.9 mg/L[b]; 48-hour NOEC = 4.6 mg/L	Not reported	Giesy et al., 2000
Acute Toxicity	Roundup®	*Daphnia magna*	Toxicity Value[a] = 24 mg/L; 48-hour NOEC=7.8 mg/L	Not reported	Giesy et al., 2000
Acute Toxicity, Static	Honcho® Plus	*Daphnia magna*	EC_{50} =160 mg/L, 48-hour	Not reported	Monsanto, 2007d
Acute Toxicity	Roundup®	*Daphnia pulex*	EC_{50} (95% CL) = 3.2 ppm (3.0-3.4), 48-hour	Not reported	USDA, 2003
Acute Toxicity	Roundup®	*Daphnia pulex*	EC_{50} (95% CL) = 7.9 ppm (7.2-8.6), 48-hour	Not reported	USDA, 2003
Acute Toxicity	Roundup®	*Daphnia pulex*	Toxicity Value[a] = 19 mg/L, 48-hour	Not reported	Giesy et al., 2000
Acute Toxicity	Roundup®	*Daphnia pulex*	Toxicity Value[a] = 25.5 mg/L, 96-hour	Not reported	Giesy et al., 2000
Acute Toxicity	Roundup®	*Daphnia* sp.	LC_{50} =5.3 ppm, 48-hour	Death	USDA, 2003
Acute Toxicity	Roundup®	*Daphnia* sp.	LC_{50} (95% CL) = 192 ppm (181-205), 48-hour	Death	USDA, 2003
Acute Toxicity	Roundup®	*Gammarus pseudolimnaeus*	Toxicity Value[a] = 42 mg/L; 48-hour NOEC = 4.4 mg/L	Not reported	Giesy et al., 2000
Acute Toxicity	Roundup®	*Gammarus pseudolimnaeus*	LC_{50} (95% CL) = 62 ppm (40-98), 48-hour; LC_{50} (95% CL) = 43 ppm (28-66), 96-hour	Death	USDA, 2003
Acute Toxicity	Roundup®	*Gammarus pseudolimnaeus*	Toxicity Value[a] = 138.7 mg/L[b]; 96-hour	Not reported	Giesy et al., 2000
Acute Toxicity	Roundup®	*Gammarus pseudolimnaeus*	Toxicity Value[a] =200 mg/L[b]; 48-hour	Not reported	Giesy et al., 2000
Acute Toxicity	Roundup®	*Nitocra spinipes*	LC_{50} (95% CL) = 22 ppm (17-29), 96-hour	Death	USDA, 2003
Acute Toxicity	Roundup®	*Orconectes nais*	Toxicity Value[a] =7 mg/L, 96-hour	Not reported	Giesy et al., 2000
Acute Toxicity	Roundup®	*Proambarus*	LC_{50} = 96, 597 ppm, 48-hour LC_{50} = 64,002 ppm, 96-hour	Death	USDA, 2003
Acute	Roundup®	*Procambarus clarkia*	LC_{50} (95% CL) =	Death	USDA, 2003

Table N-26. Acute Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulation

Study Type	Formulation	Species	Result	Endpoint	Reference
Toxicity			47.31 ppm (41.06-51.69); 96-hour		
Acute Toxicity	Roundup®	*Pseudosuccinea columella*	Delayed effect on growth and development, egg-laying capacity and hatching; 3 generations; 0.1-10 mg/L	Not reported	USDA, 2003
Acute Toxicity	Roundup®	Fourth instar *Psurophora columbiae* larvae	LC_{50} (95% CL) = 940.84 ppm (823.08-1067.12), 24-hour	Death	USDA, 2003
Acute Toxicity	Roundup®	*Scapholeberis kingi*	Toxicity Value[a] = 61 mg/L, 3-hour, range not reported	Not reported	Giesy et al., 2000

[a] Values were not specified as EC_{50} or LC_{50}.
[b] Value from data sources corrected to mg roundup/L
[c] Values are derived from a similar formulation
[d] Derived from an acute EC_{50}/acute NOEC ratio of 5

4.7.3 Acute Aquatic Invertebrate Toxicity to AMPA

The acute toxicity of AMPA to *Daphnia magna* is shown below in table N-27. The NOEC was 320 mg AMPA/L while the EC_{50}/LC_{50} was observed to be 690 mg/L.

Table N-27. Acute Aquatic Invertebrate Toxicity to AMPA

Study Type (% a.i.)	Species	Result	Endpoint	References
2 day – Acute	*Daphnia magna*	NOEC = 320 mg AMPA/L; LC_{50} = 690 mg AMPA/L	Not reported	Giesy et al., 2000

4.7.4 Chronic Aquatic Invertebrate Toxicity to Glyphosate

Several studies are available addressing the chronic toxicity of glyphosate to freshwater invertebrates (table N-28). An MATC of between 50 and 96 mg/L was determined for *Daphnia magna* in a flow-through study of their reproductive success with glyphosate (99.7 percent a.i.) (U.S. EPA, 1993a). Additionally, two separate 21-day flow-through studies using *D. magna* reported NOECs of 50 and 100 mg a.e./L for glyphosate (Giesy et al., 2000). A MATC of between 50 and 96 mg a.i./L (or 38 to 72 mg a.e./L) was calculated based on results for *Daphnia magna* in a flow-through study with glyphosate only (U.S. EPA, 1993a, 2006a) A 4-week study in *Pseudosuccinea columella* observed increased protein concentrations of snails reared in 1.0 mg/L glyphosate compared to those reared in 0.1 mg/L (USDA, 2003). Another 4-week developmental study in *Pseudosuccinea columella* with glyphosate (93 percent a.i.) observed an increased quantity of free amino acid pool (USDA, 2003).

Table N-28. Chronic Aquatic Invertebrate Toxicity to Glyphosate

Study Type (% a.i.)	Species	Result	Endpoint	References
Chronic, flow-through (99.7%)	*Daphnia magna*	MATC = > 50 - <96 mg/L, time frame exposure time not reported	Reduced reproductive capacity	U.S. EPA,1993a

Table N-28. Chronic Aquatic Invertebrate Toxicity to Glyphosate

Study Type (% a.i.)	Species	Result	Endpoint	References
	Pseudosuccinea columella	Increased protein concentration of snails reared in 1.0 mg/L compared to those reared in 0.1 mg/L; exact mechanism for response not determined; 4 weeks	Biochemical alteration	USDA, 2003
Developmental (93%)	*Pseudosuccinea columella*	Increased quantity of free amino acid pool; 4 weeks	Not reported	USDA, 2003
Tested as acid:				
Chronic, flow-through	*Daphnia magna*	NOEC = 50 mg a.e./L, 21-day, range not reported	Not reported	Giesy et al., 2000
Chronic, static	*Daphnia magna*	NOEC = 100 mg a.e./L, 21-day, range not reported	Not reported	Giesy et al., 2000

4.7.5 Chronic Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulations

The chronic toxicity of glyphosate formulations to aquatic invertebrates is summarized in table N-29. A 21-day study identified a NOEC of 3.2 mg/L for *Daphnia magna* (Giesy, et al., 2000). In accordance with acute toxicity observations, formulations of glyphosate were more toxic to *Daphnia magna* then technical glyphosate. A chronic toxicity study in *Tubifex tubifex* identified a NOEC of greater than 89 mg/L (Giesy, et al., 2000).

Table N-29. Chronic Aquatic Invertebrate Toxicity to Glyphosate Herbicide Formulation

Study Type	Formulation	Species	Result	Reference
Chronic toxicity	Roundup®	*Daphnia magna*	NOEC= 3.2 mg/L, 21 days	Giesy, et al., 2000
Chronic toxicity	Roundup®	*Tubifex tubifex*	NOEC= >89 mg/L	Giesy, et al., 2000

4.8 Fish Toxicity

Several acute and chronic toxicity tests were conducted on fish for exposure to glyphosate and its formulations. The toxicity study results are discussed in sections 4.8.1 through 4.8.5.

4.8.1 Acute Fish Toxicity to Glyphosate

A large number of studies have been performed in a variety of species of fish to determine the acute toxicity of glyphosate. The acute toxicity of glyphosate to freshwater fish is summarized in table N-30. Studies conducted on saltwater/estuarine fish were not reported. The most sensitive species to glyphosate is rainbow trout (fry), with a 96-hour LC_{50} of 7.9 mg/L (USDA, 2003). The 96-hour LC_{50} of glyphosate to rainbow trout ranges from 7.9 mg/L (percent active ingredient [a.i.] not specified) to 25,657 mg/L (38 percent a.i.) (USDA, 2003). This large range is most likely indicative of different study conditions. Sockeye salmon was observed to have an 96-hour LC_{50} ranging from 8.1 mg/L (fingerling) to 8.7 mg/L (fry), and Coho salmon was observed to have an 96-hour LC_{50} ranging from 12.8 mg/L (fry) to 36 mg/L (glyphosate tested as an acid) (USDA, 2003).

For bluegill sunfish, a 96-hour Toxic Limit $(TL)_{50}$ of > 24 mg/L was reported for a dynamic study with glyphosate (96.5 percent a.i.) (USDA, 2003). Reported 96-hour LC_{50} values ranged

from 120 mg/L to >1000 mg/L (tested as IPA salt) (USDA, 2003; Giesy et al., 2000). The 96-hour LC_{50} value for channel catfish was 130 mg/L (tested as IPA salt) (Giesy et al., 2000). The 96-hour LC_{50} for fathead minnow ranged from 84.9 mg/L (87.3 percent a.i.) to > 648 mg/L (tested as the IPA salt) (U.S. EPA, 1993a; Giesy et al., 2000). Salmonids are more sensitive to glyphosate than other species of fish.

Table N-30. Acute Freshwater Fish Toxicity to Glyphosate

Study Type (% a.i. if provided)	Species	Result	Endpoint	Reference
Acute, Dynamic	Bluegill	TL_{50} = 24 ppm, 96-hour, range not reported	Not reported	USDA, 2003
Acute (96.5%)	Bluegill Sunfish	LC_{50} = > 24 mg/L, 48-hour, range not provided	Death	U.S. EPA, 1993a
Acute	Rainbow Trout	TL_{50} = 38 ppm, 96-hour, range not reported	Not reported	USDA, 2003
Acute	Rainbow Trout (fry)	LC_{50} = 50 ppm, 96-hour, range not reported	Death	USDA, 2003
Acute	Bluegill	TL_{50} = 78 ppm, 96-hour, range not reported	Not reported	USDA, 2003
Acute (87.3%)	Fathead Minnow	LC_{50} (95% CL) = 84.9 mg/L (72.9-99.3), 48-hour	Death	U.S. EPA, 1993a
Acute, Static (96.7%)	Fathead Minnow	LC_{50} (95% CL) = 97 mg/L (79-120), 48-hour	Death	U.S. EPA, 1993a
Acute, Pulse Exposure (95%)	Flagfish	LC_{20} = 29.6 ppm, 96-hour, range not reported	Death	USDA, 2003
Acute (83%)	Rainbow Trout	LC_{50} (95% CL) = 86 mg/L (70-106), 48-hour	Death	U.S. EPA, 1993a
Acute	Trout	LC_{50} = 86 ppm, 96-hour, range not reported	Death	USDA, 2003
Acute	Carp	LC_{50} = 115 ppm, 96-hour, range not reported	Death	USDA, 2003
Acute, Static	Carp	TL_{50}= 115 ppm TL_1 = 125 ppm TL_{99} = 105 ppm 96-hour, range not reported	Not reported	USDA, 2003
Acute, Static	Carp	TL_{50}= 119 ppm TL_1 = 146 ppm TL_{99} = 96.7 ppm 48-hour, range not reported	Not reported	USDA, 2003
Acute	Bluegill	LC_{50} = 120 ppm, 96-hour, range not reported	Death	USDA, 2003
Acute (83%)	Bluegill Sunfish	LC_{50} (95% CL) = 120 mg/L (111-130), 48-hour	Death	U.S. EPA, 1993a
Acute, Static (96.7%)	Channel Catfish	LC_{50} (95% CL) = 130 mg/L (110-160), 48-hour	Death	U.S. EPA, 1993a
Acute, Static (96.7%)	Bluegill Sunfish	LC_{50} (95% CL) = 140 mg/L (110-160), 48-hour	Death	U.S. EPA, 1993a
Acute, Static (96.7%)	Rainbow Trout	LC_{50} (95% CL) = 140 mg/L (120-170), 48-hour	Death	U.S. EPA, 1993a
Acute	Harlequin fish	LC_{50} = 168 ppm, 96-hour, range not reported	Death	USDA, 2003[c]
Acute, Semi-Static (62%)	Carp	LC_{50} = 620 ppm, 96-hour, range not reported	Death	USDA, 2003
Acute, Semi-Static (62%)	Carp	LC_{50} = 645 ppm, 48-hour, range not reported	Death	USDA, 2003
Acute, Static (54.9%)	Rainbow trout	LC_{50}= 7,620 mg/L, 96-hour, range not reported NOEC = 6,250 mg/L	Death	USDA, 2003

Table N-30. Acute Freshwater Fish Toxicity to Glyphosate

Study Type (% a.i. if provided)	Species	Result	Endpoint	Reference
Acute, Static (54.9%)	Goldfish	LC_{50}= 7,816 mg/L, 96-hour, range not reported NOEC = 1,500 mg/L	Death	USDA, 2003
Acute, Static (36%)	Rainbow trout	LC_{50} = 25,605 mg/L, 96-hour, range not reported NOEC = 8,000 mg/L	Death	USDA, 2003
Acute, Static (38%)	Rainbow Trout	LC_{50} = 25,657 mg/L, 96-hour, range not reported	Death	USDA, 2003
Tested as acid:				
Acute Toxicity	Chum salmon	LC_{50} =22 mg/L, 148 mg/L[a], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Rainbow trout	LC_{50} =22 mg/L, 197 mg/L[a], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Pink salmon	LC_{50} =23 mg/L, 190 mg/L[a], 96-hour	Death	Giesy et al., 2000
Acute	Bluegill sunfish	LC_{50} = >24 mg/L, 96-hour NOEC= 24 mg/L	Death	Giesy et al., 2000[b]
Acute Toxicity	Chinook salmon	LC_{50} =30 mg/L, 211 mg/L[a], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Flagfish	LC_{50} = >30 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Coho salmon	LC_{50} =36 mg/L, 174 mg/L[a], 96-hour	Death	Giesy et al., 2000
Acute	Bluegill sunfish	LC_{50} = 120 mg/L, 96-hour NOEC= 100 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Rainbow trout	LC_{50} = 86 mg/L, 96-hour NOEC = 42 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Harlequin fish	LC_{50} = 168 mg/L, 96-hour NOEC= <100	Death	Giesy et al., 2000[c]
Acute Toxicity	Rainbow trout	LC_{50} = >1000 mg/L, 96-hour NOEC = 1000 mg/L	Death	USDA, 2003
Tested as IPA salt:				
Acute	Fathead minnow	LC_{50} = 97 mg/L, 96-hour	Death	Giesy et al., 2000
Acute	Bluegill sunfish	LC_{50} = 140-220 mg/L, 96-hour	Death	Giesy et al., 2000
Acute	Bluegill sunfish	LC_{50} = >1000 mg/L, 96-hour NOEC = 560 mg/L	Death	Giesy et al., 2000
Acute	Channel catfish	LC_{50} = 130 mg/L, 96-hour	Death	Giesy et al., 2000
Acute	Rainbow trout	LC_{50} = 140-240 mg/L, 96-hour	Death	Giesy et al., 2000
Acute	Fathead minnow	LC_{50} = >648 mg/L, 96-hour NOEC = 648 mg/L	Death	Giesy et al., 2000
Acute	Plains minnow	LC_{50} = >648 mg/L, 96-hour NOEC = 648 mg/L	Death	Giesy et al., 2000
Acute	Bluegill sunfish	LC_{50} = >1000 mg/L, 96-hour NOEC = 560 mg/L	Death	Giesy et al., 2000
Acute	Rainbow trout	LC_{50} = >1000 mg/L, 96-hour NOEC = 1000 mg/L	Death	Giesy et al., 2000

[a] Values for soft (creek) and hard (lake) water, respectively
[b] Linden E. et al. (1979) as cited in USDA, 2003 and Bionomics (1973c) as cited in Giesy et al., 2000 are believed to reference identical studies, but this cannot be confirmed with available data. Therefore, both studies are listed.
[c] Monsanto Co. (1982a) as cited in USDA, 2003 and HRC (1977) as cited in Giesy et al., 2000 are believed to reference identical studies, but this cannot be confirmed with available data. Therefore, both studies are listed.

4.8.2 Acute Fish Toxicity to Glyphosate Herbicide Formulations

Many studies have also been performed in a variety of species of fish to determine the acute toxicity of glyphosate formulations. This ecotoxicity risk assessment was limited to glyphosate formulations suggested for use on GT alfalfa. The acute toxicity of glyphosate to freshwater fish is summarized in table N-31. Studies conducted on saltwater fish were not reported.

In general, the glyphosate formulations were more toxic to fish than technical glyphosate. The most sensitive species to the glyphosate formulations considered was rainbow trout with a 96-hour LC_{50} ranging from 3.13 mg/L to 52 mg/L; when treated with formulations similar to Roundup UltraMAX II® and Roundup WeatherMAX® (Monsanto, 2004, 2005, 2006, 2007b, 2007d; Giesy et al., 2000). Comparatively, the 96-hour LC_{50} for rainbow trout treated with glyphosate alone was 7.9 mg/L.

Comparable toxicity was observed for several salmonid species exposed to Roundup® and glyphosate (acid form) in soft creek water. Glyphosate is an order of magnitude less toxic to salmonids than Roundup® when exposure occurs in hard (lake) water. When treated with glyphosate formulations, sockeye salmon was observed to have an 96-hour LC_{50} of 26.7 mg/L, and Coho salmon was observed to have an 96-hour LC_{50} ranging from 13 mg/L to 42 mg/L (Giesy et al., 2000).

For bluegill sunfish, reported 96-hour LC_{50} values ranged from 5.2 mg/L to 34 mg/L (Monsanto, 2005, 2006, 2007b, 2007d; Giesy et al., 2000). The 96-hour LC_{50} value for channel catfish ranged from 10.6 mg/L (fry) to 42 mg/L (adult) (Giesy et al., 2000). The 96-hour LC_{50} for fathead minnow ranged from 7.4 mg/L to 23 mg/L. In bluegill sunfish, channel catfish, and fathead minnow, formulations of glyphosate are much more toxic than technical grade glyphosate (Giesy et al., 2000). The increased toxicity is due to the presence of a surfactant in glyphosate formulations.

Table N-31. Acute Freshwater Fish Toxicity to Glyphosate Herbicide Formulation

Study Type	Formulation	Species	Result	Endpoint	Reference
Acute Toxicity, Semi-static	Roundup WeatherMAX®	Rainbow Trout	LC_{50} = 3.13 mg/L[a], 96-hour	Death	Monsanto, 2005
Acute Toxicity, Semi-static	Roundup UltraMAX® II	Rainbow Trout	LC_{50} = 3.13 mg/L[a], 96-hour	Death	Monsanto, 2003
Acute Toxicity	Roundup®	Rainbow trout, fingerling	LC_{50} = 4.2 – 27 mg/L[b], 96-hour NOEC= 0.84[d]	Death	Giesy et al., 2000
Acute Toxicity, Static	Roundup Original MAX®	Bluegill sunfish	LC_{50} = 5.2 mg/L[a], 96-hour	Death	Monsanto, 2006
Acute Toxicity, Static	Roundup Original MAX®	Common carp	LC_{50} = 4.0 mg/L[a], 96-hour	Death	Monsanto, 2005
Acute Toxicity, Flow through	Honcho®	Bluegill sunfish	LC_{50} = 5.8 mg/L[a], 96-hour	Death	Monsanto, 2007b
Acute Toxicity	Roundup®	Bluegill Sunfish	LC_{50} = 5.8 mg/L, 96-hour NOEC = 2.2 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Fathead minnow	LC_{50} = 7.4 mg/L[b], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Carp	LC_{50} = 10 mg/L, 96-hour NOEC= 5.6 mg/L	Death	Giesy et al., 2000
Acute Toxicity, Flow through	Honcho®	Rainbow Trout	LC_{50} = 8.2 mg/L[a], 96-hour	Death	Monsanto 2007b

Table N-31. Acute Freshwater Fish Toxicity to Glyphosate Herbicide Formulation

Study Type	Formulation	Species	Result	Endpoint	Reference
Acute Toxicity	Roundup®	Rainbow Trout	LC_{50} = 8.2 mg/L, 96-hour NOEC = 6.4 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Channel catfish, fry	LC_{50} = 10.6 mg/L[b], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Tilapia	LC_{50} = 13 mg/L, time frame exposure time not reported	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Mosquito fish	LC_{50} = 15 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Carp	LC_{50} = 15 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Rainbow Trout	LC_{50} =15 mg/L, 14 mg/L[c], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Rainbow Trout, Natural Waters	LC_{50} = 15 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Bluegill Sunfish	LC_{50} = 16.1 mg/L[b], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Chum Salmon	LC_{50} = 19 mg/L, 11 mg/L[c], 96-hour	Death	Giesy et al., 2000
Acute Toxicity, Static	Honcho® Plus	Bluegill sunfish	LC_{50} = 24 mg/L, 96-hour	Death	Monsanto, 2007d
Acute Toxicity	Roundup®	Carp	LC_{50} = 26 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Chinook Salmon	LC_{50} = 27 mg/L, 17 mg/L[c], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Chinook Salmon	LC_{50} = 20 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Coho Salmon	LC_{50} = 22 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Rainbow Trout	LC_{50} = 22 mg/L, 96-hour NOEC = 8.0 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Fathead minnow	LC_{50} = 23 mg/L, 96-hour NOEC= 13.6 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Sockeye salmon	LC_{50} = 26.7 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Coho Salmon	LC_{50} = 27 mg/L, 13 mg/L[c], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Rainbow Trout	LC_{50} = 27 mg/L, 96-hour NOEC = 6.75 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Rainbow Trout	LC_{50} = 27 mg/L[b], 96-hour NOEC = 21.4 mg/L[b]	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Pink Salmon	LC_{50} =31 mg/L, 14 mg/L[c], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Rainbow Trout	LC_{50} = 33.6 mg/L[b], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Bluegill Sunfish	LC_{50} = 34 mg/L[b], 96-hour NOEC= 21 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Channel catfish	LC_{50} = 39 mg/L, 96-hour NOEC= 23 mg/L	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Channel catfish, adult	LC_{50} = 42.0 mg/L[b], 96-hour	Death	Giesy et al., 2000
Acute Toxicity	Roundup®	Coho Salmon, fry	LC_{50} = 42 mg/L, 96-hour	Death	Giesy et al., 2000
Acute Toxicity, Static	Honcho® Plus	Rainbow Trout	LC_{50} = 42 mg/L, 96-hour	Death	Monsanto, 2007d
Acute Toxicity	Roundup®	Rainbow Trout, Natural Waters	LC_{50} = 52 mg/L, 96-hour	Death	Giesy et al., 2000

[a] Values are derived from a similar formulation
[b] Value from data sources corrected to mg roundup/L

[c] Values for soft (creek) and hard (lake) water, respectively
[d] Derived from an acute LC_{50}/acute NOEC ratio of 5

4.8.3 Acute Fish Toxicity to AMPA

The acute fish toxicity of AMPA is summarized in table N-32 below. The 4-day LC_{50} value was established to be 520 mg AMPA/L while the NOEC was 33 mg AMPA/L.

Table N-32. Acute Fish Toxicity to AMPA

Study Type (% a.i. if provided)	Species	Result	Endpoint	Reference
4-day	Rainbow trout	NOEC = 33 mg AMPA/L; LC_{50} = 520 mg/L	Not reported	Giesy et al., 2000

4.8.4 Chronic Fish Toxicity to Glyphosate

The chronic toxicity of glyphosate to fathead minnow and rainbow trout is summarized in table N-33. Chronic toxicity values for saltwater fish were not reported. The MATC for fathead minnow was determined to be greater than 25.7 mg/L glyphosate (87.3 percent a.i.) (U.S. EPA, 1993a). This study was a full life-cycle toxicity study, and fish were able to reproduce normally at the identified MATC. A 21-day chronic study in rainbow trout identified a NOEC of 52 mg/L (Giesy et al., 2000).

Table N-33. Chronic Fish Toxicity to Glyphosate

Study Type (% a.i. if provided)	Species	Result	Endpoint	Reference
Chronic (87.3%), life-cycle	Fathead Minnow	MATC > 25.7 mg/L	Range and time frame exposure time not reported	U.S. EPA,1993
Tested as acid:				
Chronic	Fathead Minnow	NOEC = 26 mg a.e./L, 255-day, range not reported	Survival, growth, or reproduction	Giesy et al., 2000
Chronic, flow-through	Rainbow trout	NOEC = 52 mg a.e./L, 21-day, range not reported	Not Reported	Giesy et al., 2000

MATC= Maximum acceptable toxicant concentration

4.8.5 Chronic Fish Toxicity to Glyphosate Herbicide Formulations

A single study is available assessing the toxicity of glyphosate formulations to freshwater fish. A 21-day chronic toxicity study with Roundup® identified a NOEC of 2.4 mg/L for rainbow trout. Details of this study are presented in table N-34. Data addressing the toxicity of glyphosate formulations to saltwater fish was not reported.

Table N-34. Chronic Fish Toxicity to Glyphosate Herbicide Formulation

Study Type	Formulation	Species	Result	Reference
Chronic	Roundup®	Rainbow trout	NOEC = 2.4 mg/L, 21-day	Giesy et al., 2000

4.9 Saltwater and Marine Species Toxicity

Several acute toxicity tests were conducted on saltwater and marine organisms for exposure to glyphosate and its formulations. Per the EPA 1993 RED for glyphosate, "since there is such an extensive data set for this chemical, the Agency can determine that glyphosate demonstrates low toxicity to fish and oyster species, and therefore is waiving the marine fish and oyster acute toxicity studies on the formulated product". The toxicity study results are discussed in sections 4.9.1.1 through 4.9.3.1.

4.9.1 Acute Saltwater and Marine Species Toxicity to Glyphosate

The acute toxicity of glyphosate to marine and estuarine organisms is summarized in table N-35. The most sensitive marine species to glyphosate was *Acartia tonsa* with a 48-hour LC_{50} of 35.3 mg/L (tested as acid) (Tsui and Chu, 2003). The grass shrimp was reported to have a 96-hour LC_{50} of 281 mg/L (U.S. EPA, 1993a). The 48-hour TL_{50} for Atlantic Oyster was determined to be > 10 mg/L (U.S. EPA, 1993a). The 48-hour TL_{50} for Fiddler crab was determined to be 935 mg/L (U.S. EPA, 1993a).

Table N-35. Acute Saltwater and Marine Species Toxicity to Glyphosate

Study Type (% a.i. if provided)	Species	Result	Endpoint	Reference
Acute (96.7%)	Atlantic oyster	TL_{50} = > 10 mg/L, 48-hour, range not reported	Death	U.S. EPA, 1993a[a]
Acute (96.7%)	Grass shrimp	LC_{50} = 281 ppm (207-381), 96-hour	Death	U.S. EPA, 1993a[b]
Acute (96.7%)	Fiddler crab	LC_{50} = 934 ppm (555-1570), 96-hour	Death	U.S. EPA, 1993a[b]
Tested as acid:				
Acute	*Acartia tonsa*	LC_{50} (95% CI) = 35.3 mg/L (30.9-40.3); 48-hour	Death	Tsui and Chu, 2003
Acute	*Cassostrea virginica*, eggs	Toxicity Value[c] = >10 mg/L, 48-hour, range not reported NOEC = 10 mg/L	Not Reported	Giesy et al., 2000[a]
Acute	*Mysidopsis bahia*	Toxicity Value[c] = >1000 mg/L, 4 day, range not reported	Not Reported	Giesy et al., 2000
Acute	*Palaemonetes vulgaris*	Toxicity Value[c] = 281 mg/L, 4 day, range not reported NOEC = 210 mg/L	Not Reported	Giesy et al., 2000[b]
Acute	*Tripneustes esculentus*	Toxicity Value[c] = >1000 mg/L, 4 day, range not reported NOEC = 1000 mg/L	Not Reported	Giesy et al., 2000
Acute	*Uca pugilator*	Toxicity Value[c] = 934 mg/L, 4 day, range not reported NOEC = 650 mg/L	Not Reported	Giesy et al., 2000[b]
Tested as IPA salt:				
Acute	*Acartia tonsa*	LC_{50} (95% CI)= 49.3 mg/L (38.4-63.1); 48-hour	Death	Tsui and Chu, 2003

[a] Bentley, R. (1973b) as cited in U.S. EPA, 1993 and Bionomics (1973a) as cited in Giesy et al., 2000 are believed to reference identical studies, but this cannot be confirmed with available data. Therefore, both studies are listed.
[b] Bentley, R. (1973a) as cited in U.S. EPA, 1993 and Bionomics (1973b) as cited in Giesy et al., 2000 are believed to reference identical studies, but this cannot be confirmed with available data. Therefore, both studies are listed.
[c] Values were not specified as EC_{50} or LC_{50}.

4.9.2 Acute Saltwater and Marine Species Toxicity to Glyphosate Herbicide Toxicity

One study is available addressing the toxicity of Roundup® to *Acartia tonsa.* A 48-hour LC_{50} of 1.77 mg/L was determined for *Acartia tonsa* treated with Roundup®. This study is summarized in table N-36.

Table N-36. Acute Saltwater and Marine Species Toxicity to Glyphosate Herbicide Formulation

Study Type	Species	Result	Endpoint	Reference
Acute	*Acartia tonsa*	LC_{50} (95% CI) = 1.77 mg/L (1.33-2.34); 48-hour	Death	Tsui and Chu, 2003

4.9.3 Chronic Saltwater and Marine Species Toxicity to Glyphosate and Glyphosate Herbicide Toxicity

No studies were identified that investigated chronic toxicity in saltwater or marine species.

4.10 Risk Assessment and Characterization

Risk characterization integrates the results of the exposure and ecotoxicity data to evaluate the likelihood of adverse ecological effects. The means of this integration is called the quotient method. Risk quotients (RQs) are calculated by dividing exposure estimates by acute and chronic ecotoxicity values (RQ = Exposure/Toxicity).

RQs are then compared to the EPA LOCs presented in table N-37 below. These LOCs are used by the EPA Office of Pesticide Programs to analyze potential risk to nontarget organisms and the need to consider regulatory action. The criteria indicate that a pesticide used as directed has the potential to cause adverse effects on nontarget organisms. LOCs currently address the following risk presumption categories: (1) **acute** – potential for acute risk to nontarget organisms which may warrant regulatory action in addition to restricted use classification, (2) **acute restricted use** – the potential for acute risk to nontarget organisms, but may be mitigated through restricted use classification, (3) **acute endangered species** – endangered species may be adversely affected by use, (4) **chronic risk** – the potential for chronic risk may warrant regulatory action, endangered species may potentially be affected through chronic exposure, (5) **non-endangered plant risk** – potential for effects in nontarget plants, and (6) **endangered plant risk** – potential for effects in endangered plants. Currently, EPA does not perform assessments for chronic risk to plants, acute or chronic risks to nontarget insects, or chronic risk from granular/bait formulations to birds or mammals.

The ecotoxicity test values (measurement endpoints) used in the acute and chronic risk quotients are derived from required studies. Examples of ecotoxicity values derived from short-term laboratory studies that assess acute effects are: (1) LC_{50} (fish and birds), (2) LD_{50} (birds and mammals), (3) EC_{50} (aquatic plants and aquatic invertebrates), and (4) concentration that causes an effect in 25 percent of the test animals concentration (EC_{25}) (terrestrial plants). Examples of toxicity test effect levels derived from the results of long-term laboratory studies that assess chronic effects are: (1) lowest observed adverse effect concentration (LOAEC) (birds, fish, and aquatic invertebrates) and (2) no observed adverse effect concentration (NOAEC) (birds, fish and aquatic invertebrates). For birds and mammals, the NOAEC generally is used as the

ecotoxicity test value in assessing chronic effects, although other values may be used when justified. However, the NOAEC is used if the measurement endpoint is production of offspring or survival.

Table N-37. Risk Presumption Categories

Risk Presumption for Terrestrial Animals	**LOC**
Acute: Potential for acute risk for all nontarget organisms	>0.5
Acute Restricted Use: Potential for acute risk for all nontarget organisms, but may be mitigated through restricted use classification	>0.2
Acute Endangered Species: Endangered species may be adversely affected by use	>0.1
Chronic Risk: Potential for chronic risk may warrant regulatory action	>1
Risk Presumption for Aquatic Organisms	**LOC**
Acute: Potential for acute risk for all nontarget organisms	>0.5
Acute Restricted Use: Potential for acute risk for all nontarget organisms, but may be mitigated through restricted use classification	>0.1
Acute Endangered Species: Endangered species may be adversely affected by use	>0.05
Chronic Risk: Potential for chronic risk may warrant regulatory action	>1
Risk Presumption for Terrestrial and Aquatic Plants	**LOC**
Potential for risk for all non-endangered and endangered plants	>1

4.10.1 Exposure and Risk to Nontarget Terrestrial Animals

Exposure to nontarget terrestrial organisms was estimated using the Tier 1 T-REX (Terrestrial Residue Exposure) simulation model (version 1.2.3) based on the maximum proposed application rate, re-application interval, and the default foliar dissipation half-life of 35 days at a rate of 1.99 lb ai/acre, applied four times at 30 day intervals. Residues on various terrestrial food items ranged from 60.53 to 968.42 mg/kg diet (U.S. EPA, 2005).

4.10.1.1 Terrestrial Exposure Modeling and Risk Characterization

This spreadsheet-based model calculates the residues on avian and mammalian food items along with the dissipation rate of a chemical applied to foliar surfaces (for single or multiple applications) in order to estimate acute and reproductive risk quotients (U.S. EPA, 2005). The methods used by TREX to estimate risk from consumption of selected contaminated food items is described below. For this analysis, TREX calculates estimated environmental concentrations (EECs) and risk quotients based on both the upper bound and mean residue concentrations as presented by Hoerger and Kenaga (1972) and modified by Fletcher et al. (1994). Based on the estimated dietary residue concentrations from the upper bound and mean Kenaga values, TREX calculates the associated doses for various size classes of birds and mammals. Both the dietary concentration (mg/kg-dietary item) and the resulting estimated doses (mg/kg-bw) may be used for risk estimation. The EECs for terrestrial exposure were derived from the Kenaga nomograph based on a large set of field residue data. The EECs presented in table N-38 were calculated by the TREX Version 1.2.3 model.

Table N-38. Dietary-based EECs Upper Bound Kenaga Values from TREX model

Food source	Estimate concentration glyphosate (ppm)
Short Grass	968.42
Tall Grass	443.86
Broadleaf plants/Small Insects	544.74
Fruits/pods/seeds/Large insects	60.53

Acute avian risk is assessed both by comparing the acute oral LD_{50} with estimated daily doses calculated from residues on avian food items and by comparing the dietary LC_{50} with residues on avian food items. Calculations for oral dose risk quotients are based on a Northern bobwhite quail oral acute LD_{50} of >2000 mg glyphosate/kg body weight and are shown in table N-39. Calculations for acute dietary-based risk quotients are based on a bobwhite quail subacute dietary NOEL of 4640 mg/kg diet and are shown in table N-40. There were no statistically significant results in the bobwhite quail reproductive toxicity, indicating a chronic NOAEC of > 1000 mg/kg diet. These endpoints are not adjusted for body weight. Note that birds generally do not consume grasses, with the exception of geese, which generally weigh 1.4 kg or more.

Avian dose-based risk scenarios are calculated by dividing the consumption-weighted equivalent dose by the body weight-adjusted LD_{50}. The acute RQs for birds based on single-oral dose oral studies are summarized in table N-39. The RQ values in table N-39 cannot be compared with LOCs, because the LD_{50} was not reached at the highest doses tested. Doses at which an LD_{50} would be reached might be substantially higher than 2000 mg/kg body weight, and thus the RQs based on comparing the EEC values to the LD_{50} value would have been substantially less than shown in table N-39.

Table N-39. Avian Dose-Based RQs from TREX model

Dose-based RQs (Dose-based EEC/adjusted LD_{50})	Avian Acute RQs		
	20 g bird	100 g bird	1000 g bird
Short Grass	0.77	0.34	0.11
Tall Grass	0.35	0.16	0.05
Broadleaf plants/sm insects	0.43	0.19	0.06
Fruits/pods/seeds/lg insects	0.05	0.02	0.01

Avian dietary-based risk scenarios are calculated by dividing the dietary concentrations shown in table N-38 by the avian NOAEL of 4640 mg/kg diet. The RQs, shown in table N-40 below, can be compared with the LOC values presented in table N-37. The peak EECs resulted in no LOC exceedences, except for the birds whose diet consists of broad leaf plants and small insects. That exceedence is minor with a RQ of 0.12, which is slightly greater than the LOC (>0.1) for Acute Endangered Species. The RQs in table N-40 for short and tall grasses are less than the LOC for non-endangered species of 1.0. There are no endangered species of geese in the continental United States; hence, the LOC of 0.1 for Acute Endangered Species does not apply to short and tall grasses in the continental United States. The federally endangered Hawaiian goose occurs on the islands of Hawaii, and therefore might be affected by use. However, it should be noted the estimated EECs are based on a worst case scenario, and the RQ is close to 1.0. The difference is minor and considered a minimal risk.

Table N-40. Avian Dietary-Based RQs from TREX model

Dietary-based RQs (Dietary-based EEC/LC50 or NOAEC)	RQs	
	Acute	Chronic
Short Grass	0.21	0.97
Tall Grass	0.10	0.44
Broadleaf plants/Small Insects	0.12	0.54
Fruits/pods/seeds/Large insects	0.01	0.06

Consumption-weighted doses for mammals based on weight class at four applications of 1.99 lb a.e./acre with 35-day foliar half-life resulted in the risk quotients presented in tables N-41 and N-42. Calculations for both oral dose-based and dietary-based risk quotients were based on an acute laboratory rat LD_{50} value of > 4320 mg/kg body weight (bw) and a 2-generation chronic reproductive effect NOAEC of 175 mg/kg bw. For chronic oral dose-based RQ calculations, the NOAEC (3500 mg/kg diet) was converted to a NOAEL (175 mg/kg body weight) based on a standard FDA lab rat conversion (U.S. EPA, 2006a).

Table N-41. Mammalian Dose-Based Risk Quotients (RQ) from TREX model

Dose-based RQs (Dose-based EEC/LD50 or NOAEL)	15 g mammal		35 g mammal		1000 g mammal	
	Acute	Chronic	Acute	Chronic	Acute	Chronic
Short Grass	0.10	2.40	0.08	2.05	0.04	1.10
Tall Grass	0.04	1.10	0.04	0.94	0.02	0.50
Broadleaf plants/small insects	0.05	1.35	0.05	1.15	0.03	0.62
Fruits/pods/large insects	0.01	0.15	0.01	0.13	0.00	0.07
Seeds (granivore)	0.00	0.03	0.00	0.03	0.00	0.02

Table N-42. Mammalian Dietary-Based Risk Quotients (RQ) from TREX model

Dietary-based RQs (Dietary-based EEC/LC50 or NOAEC)	Mammal RQs	
	Acute	Chronic
Short Grass	<0.1	0.28
Tall Grass	<0.1	0.13
Broadleaf plants/small insects	<0.1	0.16
Fruits/pods/seeds/large insects	<0.1	0.02

The RQs listed in table N-41 indicate some risk to small mammals that consume grass directly. However, small mammals cannot obtain sufficient energy to subsist on a diet of grasses. Shrews (approximately 15 to 19 grams) and deer mice (approximately 15 to 20 grams) consume either insects only or insects and seeds, respectively (U.S. EPA, 1993b). Voles (30 to 50 grams), the smallest herbivorous mammals, consume shoots rather than mature grasses, as well as seeds and insects. Voles might be at risk of death or other adverse effects from glyphosate spraying to agricultural fields; however, they are considered pests in those settings. Larger mammals are unlikely to have RQs that exceed LOC values. For example, muskrats which do consume mature grasses in the vicinity of surface waters, weigh approximately 1 kg, suggesting a marginal risk according to table N-41 (i.e., RQ of 1.1), but no risk according to table N-42. Other herbivores (e.g., deer) are substantially larger.

Risk to nontarget insects is expected to be low; the honey bee LD_{50} is very high >100 µg/honeybee; therefore, glyphosate is not considered a risk to honeybee and other nontarget arthropods.

4.10.2 Exposure and Risk to Aquatic Organisms

Exposure to aquatic species was estimated using GENEEC (GENeric Estimated Exposure Concentration) Version 2. 0 (U.S. EPA, 2001b) as the Tier I simulation model. GENEEC is a Tier 1 simulation model that estimates the peak value which occurs on the day of a single large rainstorm event as well as multiple day averages over periods of 4, 21, 60 and 90 days. The magnitude of the peak concentration is the result of how fast the chemical dissipates (degradation; partitioning) in the field. The multiple day average over periods of four to 90 days reflect the dissipation (such as degradation and partitioning) of the chemical that takes place in the water body. These peak and average concentrations are then compared with the appropriate toxicity tests for aquatic plants and animals.

The peak concentration of glyphosate in a pond receiving runoff from a drainage basin treated 100 percent with glyphosate would be 15.66 µg/L (ppb) for Honcho® at the highest application rate. This does not exceed any LOCs, and longer term exposures would be lower; therefore risk is presumed to be below thresholds of concern. The input parameters for and the results of this model are presented in the following section.

4.10.2.1 Aquatic Exposure Modeling

GENEEC Version 2.0 (U.S. EPA, 2001b) was used to estimate the EECs in surface water in order to assess exposure in aquatic ecosystems.

These estimated environmental concentrations were based on the labeled application rates for use on tolerant, gene modified alfalfa. It was assumed that glyphosate was applied in four sequential applications; at least 7 days apart to an annual total maximum of 7.98 lbs glyphosate equivalent per acre and that each single application is assumed to be 1.99 lbs glyphosate equivalents per acre.

Environmental fate input parameters were selected in accordance with EFED's "Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides, Version II" (February 28, 2002; http://www.epa.gov/oppefed1/models/water/input_guidance2_28_02.htm) and are presented below.

Environmental Fate Input Parameters:

- Solubility in water (mg/L): 12,000
- Soil Organic Carbon Partition Coefficient (K_d): 62[1]
- Aerobic soil metabolism half-life (days): 2[2]

[1] The values for K_d were the lowest values determined from a non-sandy soil, for Drummer silty clay loam (U.S. EPA, 1993)
[2] The value of aerobic soil metabolism half-life for glyphosate equivalents is based on data from U.S. EPA, 1993.

- Nonwetted ground high boom fine spray application with 0 ft no spray zone, and 0 in depth incorporation
- Aerobic aquatic metabolism half-life (days): 7[3]
- Photolytic half-life (days): 0
  Hydrolytic half-life (days): 0

4.10.2.2 Aquatic Risk Characterization

Risk presumptions and the corresponding acute and chronic RQs and LOCs are tabulated in tables N-43 and N-44. The values in these tables are based on results of submitted studies and data from peer-reviewed literature, as indicated by the notes following each table. None of the acute or chronic RQs for glyphosate exceeded LOCs for any of the most sensitive aquatic species tested.

Table N-43. Acute Risk Quotients for Glyphosate and Most Sensitive Species

Species	EEC (µg/L) [a]	Toxicity (µg/L)	Acute RQ	Acute LOCs Exceeded
Amphibians				
Crinia insignifera tadpoles	15.66	78,000 [b]	0.0002	None
Freshwater Fish				
Rainbow Trout	15.66	7,800[c]	0.002	None
Freshwater Invertebrates				
Chironomus plumosus	15.66	55,000[d]	0.0003	None
Marine and Estuarine Organisms				
Acartia tonsa	15.66	35,300[e]	0.0004	None
Freshwater Algae				
Skeletonema costatum	15.66	850 [d]	0.018	None

[a] GENEEC Version 2.0 (U.S. EPA, 2001)
[b] Giesy et al., 2000
[c] USDA, 2003
[d] U.S. EPA, 1993a
[e] Tsui and Chu, 2003

Table N-44. Chronic Risk Quotients for Glyphosate and Most Sensitive Species

Species	EEC (µg/L)[a]	Toxicity (µg/L) [b]	Acute RQ	Chronic LOC Exceeded?
Freshwater Fish				
Fathead Minnow	15.66	25,700	0.0006	None
Freshwater Invertebrates				
Daphnia magna	15.66	50,000	0.0003	None
Marine and Estuarine Organism				
Acartia tonsa	15.66	1,770 [e]	0.0011	None
Freshwater Algae				
Lemna gibba	15.66	16,600 [c]	0.0009	None

[a] GEENC Version 2.0 (U.S. EPA, 2001)
[b] U.S. EPA, 1993a
[c] Giesy et al., 2000
[e] Tsui and Chu, 2003

[3] The value of aerobic aquatic metabolism half-life for glyphosate equivalents is based on data from U.S. EPA, 1993.

4.11 Summary of Findings

In general, glyphosate has a low toxicity to terrestrial animals. Worst-case exposure scenarios indicate negligible risk to birds and mammals. Estimated RQs based on EECs for glyphosate on animal foods compared with available toxicity data do not exceed EPA LOC values with two exceptions that are considered minor. The RQ of 0.12 for birds is close to the LOC of 1.0 for endangered species and the RQ of 1.1 for grass-eating mammals is marginal for muskrat (a non-endangered species). Given the conservative nature of the exposure scenario, however, those comparisons do not indicate concern for impacts. Glyphosate is considered non-toxic to honey bees.

In aquatic ecosystems, certain surfactants in glyphosate formulations result in a higher toxicity to amphibians, aquatic invertebrates, and fish, than do glyphosate exposures alone. Formulations that contain surfactants, however, are not registered for use over water. The dose-response assessment for fish is substantially complicated by information indicating that some fish species such as salmonids are more sensitive to glyphosate than other species. Glyphosate appears to be about equally toxic to both algae and aquatic macrophytes.

For GT alfalfa use, exposure to glyphosate does not result in risk exceeding LOCs; however, the end use herbicide concentration could not be determined, and without an estimate of environmental concentrations, quantitative risk values cannot be calculated. The 2008 risk assessment published by EPA for the effects of glyphosate, its salts, and glyphosate herbicide formulations found indirect effects on the CRLF at application rates more than twice the application rate of glyphosate on GT alfalfa.

5.0 Alfalfa Other Pesticide Ecotoxicity Data

5.1 Alfalfa Pesticide Comparative Ecotoxicity

Tables N-45 through N-47 identify the most sensitive species of the freshwater, terrestrial, and marine taxonomic groups that could potentially be affected by the use of glyphosate and other herbicides.

5.2 Comparative Environmental Impact of Glyphosate and Other Herbicides Used on Alfalfa

Glyphosate is considered to be more environmentally and toxicologically benign than many of the herbicides that it replaces in GT crops (Brookes and Barfoot, 2006). Peterson and Hulting (2004) examined the ecological risks of glyphosate, anticipated for future use with GT spring wheat under development at that time, and 15 other herbicides used on conventional spring wheat populations in the northern U.S. Great Plains (MN, ND, SD, WY, and MT). The other herbicides were as follows: 2,4-D, bromoxynil, clodinafop, clopyralid, dicamba, fenoxaprop, flucarbazone, MCPA, metasulfuron, thifensulfuron, tralkoxydim, triallate, triasulfuron, tribenuron, and trifluaralin. A Tier 1 quantitative risk assessment method was used to evaluate the acute dietary risk to birds and wild mammals, the acute risk to aquatic vertebrates, aquatic invertebrates, and aquatic plants, and the effects on seedling emergence and vegetative vigor to nontarget terrestrial plants. Estimated groundwater exposures to the 16 herbicides (including glyphosate) were assessed. The assessment did not include chronic risks, risks to estuarine or marine animals, or risks to nontarget insect pollinators (Peterson and Hulting, 2004). The ecological risks for the 15 herbicides relative to glyphosate were highly variable, with glyphosate having less relative risk to nontarget terrestrial and aquatic plant life and groundwater than most other active ingredients. The study predicted that glyphosate use in GT crops will be less toxic to terrestrial and aquatic wildlife than several of the herbicides which it replaces (Peterson and Hulting, 2004).

The environmental impact of other herbicides used on alfalfa in comparison to glyphosate includes an assessment of pesticide active ingredient use, as well as the assessment of the specific pesticides used via an indicator known as the Environmental Impact Quotient (EIQ). This universal indicator, developed by Kovach et al. (1992 & updated annually), effectively integrates the various environmental impacts of individual pesticides into a single indicator value of impact; however, it does not take into account all environmental issues/impacts. This provides a balanced assessment of the impact of herbicides on the environment as it draws on key toxicity and environmental exposure data related to individual products (as applicable to impacts on farm workers, consumers and ecology), thus, providing a consistent but a fairly comprehensive measure of environmental impact as applied by Brookes and Barfoot in 2006 for genetically modified crop impact assessments.

Table N-45. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Amphibians[4]				
No data were available from the EPA RED documents or MSDS on the soil microorganism toxicity for the 20 herbicides used in alfalfa				
Freshwater Fish				
Glyphosate	Acute Toxicity – Cold Water Rainbow trout (*Oncorhynchus mykiss*)	48-hr LC_{50} = 140 mg/L (120-170, 95% CL)	Slightly nontoxic to Practically Non-Toxic to both cold water and warm water fish	U.S. EPA, 1993a MRID 00136339. Thompson, C.; Mcallister, W. (1978) Acute Toxicity of Technical Glyphosate (AB-78-165) to Rainbow Trout (Salmo gairdneri). (Unpublished study received Dec 5, 1978 under 524-308; prepared by Analytical Bio Chemistry Laboratories, Inc., submitted by Monsanto Co., Washington, DC; CDL:097661-B)
	Acute Toxicity – Warm Water Bluegill sunfish (*Lepomis macrochirus*)	48-hr LC_{50} = 140 mg/L (110-160, 95% CL)		U.S. EPA, 1993a MRID 00108205. McAllister, W.; Forbis, A. (1978) Acute Toxicity of Technical Glyphosate to Bluegill Sunfish (Lepomis macrochirus): Static Acute Bioassay Report. (Unpublished study received Jul 14, 1978 under 524-308; prepared by Analytical Bio Chemistry Laboratories, Inc., submitted by Monsanto Co., Washington, DC; CDL:234395-B)
	Chronic Toxicity to Freshwater Fish Fathead Minnow (*Pimephales promelas*, Rafinesque)	MATC > 25.7 mg/L	No effects at or below this level	U.S. EPA, 1993a MRID 00108171. EG & G, Bionomics (1975) Chronic Toxicity of Glyphosate to the Fathead Minnow (Pimephales promelas, Rafinesque). (Unpublished study received Dec 27, 1978 under 524-308; submitted by Monsanto Co., Washington, DC; CDL:097759-B)
2,4-D	Acute Toxicity to Freshwater Fish Bluegill sunfish *(Lepomis macrochirus)*	LC_{50} = 263 mg ae/L	Practically Non-Toxic	U.S. EPA, 2005a MRID 41158301. Alexander, H.; Mayes, M.; Gersich, F. (1983) The Acute Toxicity of (2,4-Dichlorophenoxy)acetic Acid to Representative Aquatic Organisms: Project Study ID: ES-DR-0002-2297-4. Unpublished study prepared by Dow Chemical U.S.A. 26 p.

[4] See also the 2008 risk assessment for the California Red Legged Frog published by EPA (http://www.epa.gov/espp/litstatus/effects/redleg-frog/index.html#glyphosate)

Table N-45. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Chronic Toxicity to Freshwater Fish Fathead Minnow (*Pimephales promelas* Rafinesque)	NOEC = 63.4 mg ae/L	NOEC based on length and larval survival from the early life stage studies	U.S. EPA, 2005 MRID 41737304. Mayes, M.; Gorzinski, S.; Potter, R.; et al. (1990) 2,4-Dichloro- phenoxyaceticAcid: Evaluation of the Toxicity to Early Life Stages of the Fathead Minnow, Pimephales promelas Rafinesque: Lab Project Number: ES-DR-0002-2297-10. Unpublished study pre- pared by The Dow Chemical Co. 48 p.
2,4-DB	Acute Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss*)	96-hr LC_{50} = 2.4 mg a.i./L	Moderately Toxic	U.S. EPA, 2005b MRID 00116622. Johnson, W.; Finley, M. (1980) Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates. By U.S. Fish and Wildlife Service, Columbia National Fisheries Research Laboratory. Washington, DC:USFWS. (Resource publication 137, pages 59, 60 only; published study; CDL:248614-Q).
Benefin	Acute Toxicity to Freshwater Fish Bluegill sunfish *(Lepomis macrochirus)*	96-hr LC_{50} = 3.17 ppb a.i.	Very Highly Toxic	U.S. EPA, 2004b MRID 00026955. Kehr, C.C.; West, H.C.; Hamelink, J.L.; et al. (1978) The Toxicity of Benefin in Bluegills (?~Lepomis Macrochirus~?): A Twenty- Eight Day Continuous Flow-Through Study: Study No. 2057-77. (Unpublished study received Jun 29, 1978 under 1471-71; submitted by Elanco Products Co., Div. of Eli Lilly and Co., Indiana- polis, Ind.; CDL:234214-C)
	Chronic Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss*)	NOAEL = 0.0019 ppm a.i. LOAEL = 0.005 ppm a.i.	May affect fish and larval length and survival	U.S. EPA, 2004b MRID 41613805. Cocke, P.; Gunnoe, M.; Koenig, G. (1990) The Toxicity of Benefin to Rainbow Trout (Salmo gairdneri) in a 49-Day Early Life-Stage Study: Lab Project Number: F00690. Unpublished study prepared by Lilly Research Laboratories. 88 p.
Bromoxynil	Acute Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss*)	LC_{50} = 2100 ppb a.i. (phenol)	Moderately Toxic	U.S. EPA, 1998a MRID 00155072. Surprenant, D. (1985) Acute Toxicity of Bromoxynil Phenol to Rainbow Trout (Salmo gairdneri): Study #565.0285.6110.103: Report #BW-85-10-1855. Unpublished study prepared by Springborn Bionomics, Inc. 15 p.

Table N-45. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Acute Toxicity to Freshwater Fish Bluegill sunfish *(Lepomis macrochirus)*	LC_{50} = 4000 ppb a.i. (phenol)	Moderately Toxic	U.S. EPA, 1998a MRID 43059601. Bettencourt, M. (1993) Bromoxynil Heptanoate-Acute Toxicity to Bluegill Sunfish (Lepomis macrochirus) Under Flow-Through Conditions: Lab Project Number: 93-10-5006: 10566.0693. 6303.105. Unpublished study prepared by Springborn Labs., Inc., Environmental Sciences Div. 72 p.
	Chronic Toxicity to Freshwater Fish Fathead Minnow (*Pimephales promelas)*	NOAEL = 18 ppb LOAEL = 39 ppb MATC = 26 ppb	Very Highly Toxic, decreased larval growth, survival and embryo hatching success	U.S. EPA, 1998a MRID 41928301. Sousa, J. (1991) Bromoxynil Octanoate: Toxicity to Fathead Minnow (Pimephales promelas) Embryos and Larvae: Final Report: Lab Project Number: 10566. 0990. 6167. 120: 91-4-3719. Unpublished study prepared by Springborn Laboratories, Inc. 68 p.
Clethodim	Acute Toxicity to Freshwater Fish Bluegill sunfish *(Lepomis macrochirus)*	96-hr LC_{50} >1000 mg/L	Practically Non-Toxic	MSDS, 2007
Clopyralid	No Data Available			
Diuron	Acute Toxicity to Freshwater Fish Cutthroat trout *(Oncerynchus clarki)*	96-hr LC_{50} = 0.71 ppm	Highly Toxic	U.S. EPA, 2003 MRID 40098001. Mayer, F.; Ellersieck, M. (1986) Manual of Acute Toxicity: Inter- pretation and Data Base for 410 Chemicals and 66 Species of Freshwater Animals. US Fish & Wildlife Service, Resource Publication 160. 579p.
	Chronic Toxicity to Freshwater Fish Fathead Minnow (*Pimephales promelas)*	NOEC = 0.026 ppm LOEC = 0.062 ppm	Affects survival	U.S. EPA, 2003 MRID 00141636. Call, D.; Brooke, L.; Kent, R. (1983) Toxicity, bioconcentration, and metabolism of five herbicides in freshwater fish. Prepared by Univ. of Wisconsin, Center for Lake Superior Environmental studies for the Environmental Protection Agency; available from the National Technical Information Service. 113 p.
EPTC	Acute Toxicity to Freshwater Fish	96-hr LC_{50} = 14-27 ppm	Slightly Toxic	U.S. EPA, 1999

Table N-45. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Hexazinone	Acute Toxicity to Freshwater Fish Fathead Minnow (*Pimephales promelas)*	LC_{50} = 274 ppm	Practically Non-Toxic	U.S. EPA, 1994 MRID 00104980. Sleight, B. (1973) Acute Toxicity of H-7759, MR-581 to Bluegill (*Lepomis macrochirus*), Rainbow Trout (*Salmo gairdneri*) and Fathead Minnow (*Pimephales promelas*). (Unpublished study received Dec 5, 1973 under 352-EX-85; prepared by Bionomics, Inc., submitted by E.I. du Pont de Nemours & Co., Inc., Wilmington, DE; CDL:223386-L)
	Chronic Toxicity to Freshwater Fish	NOEL = 17 mg/L LOEL = 35.5 mg/L MATC = 24.6 ppm	Fish length was affected	U.S. EPA, 1994 MRID 41406001. Pierson, K. (1990) Effects of IN A3674-207 on the Embryos and Larvae of Fathead Minnows (Pimephales promelas): Lab Project Number HLR 656-89: MR-8705-001. Unpublished study prepared by E. I. du Pont de Nemours and Co., Inc. 221 p.
Imazamox	Acute Toxicity to Freshwater Fish Bluegill sunfish *(Lepomis macrochirus)*	LC_{50} >119 mg/L	Practically Non-Toxic	U.S. EPA, 1997a. Imazamox – Pesticide Fact Sheet.
Imazethapyr	No Data Available			
Metribuzin	Acute Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss)*	LC_{50} = 76.77 ppm	Slightly Toxic	U.S. EPA, 1998b EPA Accession No. 255025
	Acute Toxicity to Freshwater Fish Bluegill sunfish *(Lepomis macrochirus)*	LC_{50} = 75.96 ppm	Slightly Toxic	
	Chronic Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss)*	NOEC = 3.0 ppm	Growth affected	U.S. EPA, 1998b MRID 42447801. Gagliano, G.; Roney, D. (1992) Early Life Stage Toxicity of Sencor Technical to the Rainbow Trout (*Oncorhynchus mykiss*) under Flow-through Conditions: Lab Project Number: 103249:SE842201. Unpublished study prepared by Miles, Inc. 87 p.
Norfluzaon	Acute Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss)*	LC_{50} = 8.1 ppm	Moderately Toxic	U.S. EPA, 1996a MRID 00087863. Stoll, R.E.; LeBlanc, G.A.; Sousa, J.V. (1981) Acute LC50 Toxicity Study in Rainbow Trout on Norflurazon: EG&G Bionomics No. BK-31-7-899; Sandoz Project T-1637. (Unpublished study received Dec. 18, 1981, under 11273-10; prepared in cooperation with EG&G Bionomics, submitted by Sandoz, Inc. Crop Protection, San Diego, Calif.; CDL:246433-A).

Table N-45. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Chronic Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss*)	NOEC = 0.77 ppm LOEC = 1.5 ppm MATC >0.77 <1.5 ppm	Survival and growth of larvae affected	U.S. EPA, 1996a MRID 00118048. LeBlanc, G. (1982) Early Life Stage Toxicity Study in the Rainbow Trout on Norflurazon: Report #BW-82-5-1165: Sandoz Project T-1733. (Unpublished study received Nov 15, 1982 under 11273-13; prepared by EG&G Bionomics, submitted by Sandoz, Inc., Crop Protection, San Diego, CA; CDL:248829-A).
Paraquat	Acute Toxicity to Freshwater Fish Bluegill sunfish *(Lepomis macrochirus)*	LC_{50} = 13 ppm	Slightly Toxic	U.S. EPA, 1997b MRID 40098001. Mayer Jr., F.; Ellersieck, M. (1986) - Manual of Acute Toxicity: Interpretation and Database for 410 Chemicals in 66 Species of Freshwater Animals. U.S. Department of Interior, Fish and Wildlife Service. Resource publication 160.
Picloram	Acute Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss*)	LC_{50} = 5.5 mg/L	Moderately Toxic	U.S. EPA, 1995 MRID 00112016. Batchelder, T. (1974) Acute Fish Toxicity of Picloram--(Dry Tordon Acid). (Unpublished study received Sep 10, 1976 under 464-541; submitted by Dow Chemical U.S.A., Midland, MI; CDL:226137-C)
Pronamide	Aquatic Toxicity	LC_{50} or EC_{50} = 0.1-1.0 mg/L	Highly Toxic	MSDS, 2006
Sethoxydim	No Data Available			
Terbacil	Acute Toxicity to Freshwater Fish Rainbow trout *(Oncorhynchus mykiss*)	96-hr LC_{50} = 46.2 ppm	Slightly Toxic	U.S. EPA, 1998c MRID 00390017
Trifluralin	Acute Toxicity to Freshwater Fish – Cold Water Rainbow trout *(Oncorhynchus mykiss*)	LC_{50} = 41 ppb	Very Highly Toxic	U.S. EPA, 1996c MRID 40094602. Johnson, W.; Finley, M. (1980) Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates: Resource Publication 137. U.S. Fish and Wildlife Service, Washington, D.C. 106 p.
	Acute Toxicity to Freshwater Fish – Warm Water Bluegill sunfish *(Lepomis macrochirus)*	LC_{50} = 58 ppb		
	Chronic Toxicity to Freshwater Fish – Early Life Stage Rainbow trout *(Oncorhynchus mykiss*)	NOEC = 1.14 ppb LOEC = 2.18 ppb MATC = 1.58 ppb	Larval fish length affected	U.S. EPA, 1996c MRID 41386202. Adams, E.; Cocke, P. and Gunnoe, M. (1990) The Toxicity of Trifluralin to Rainbow Trout (Salmo gairdneri) in a 48-Day Early Lifestage Study: Lab Project Number: FO2489. Unpublished study prepared by Lilly Research Laboratories. 86 p.

Table N-45. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Chronic Toxicity to Freshwater Fish – Life Cycle Fathead Minnow (*Pimephales promelas)*	NOEC = 1.9 ppb LOEC = 5.1 ppb MATC = 3.5 ppb	Not reported	U.S. EPA, 1996c MRID 05008271. 05008271 Macek, K.J.; Lindberg, M.A.; Sauter, S.; Buxton, K.S.; Costa, P.A. (1976) Toxicity of Four Pesticides to Water Fleas and Fathead Minnows. Duluth, Minn.: U.S. Environmental Protection Agency, Environmental Research Laboratory. (EPA report no. EPA-600/3-76-099; available from: NTIS, Springfield, VA; PB-262 912)
Aquatic Plants				
Glyphosate	Aquatic Plant Toxicity *Skeletonema costatum*	4-day EC_{50} = 0.85 mg/L	Not reported	U.S. EPA, 1993a.
2,4-D	Aquatic Plant Toxicity – Vascular Plants Duckweed (*Lemna gibbons*)	EC_{50} = 0.695 mg a.i./L NOEC = 0.0581 mg a.i./L	Vascular plants more than 2 orders of magnitude more sensitive than nonvascular plants	U.S. EPA, 2005a MRID 44295101. Hughes, J.; Williams, T.; Conder, L. (1997) Effect of 2,4-Dichlorophenoxyacetic Acid on the Growth and Reproduction of Lemna gibba G3: (Final Report): Lab Project Number: 10-05-1. Unpublished study prepared by Carolina Ecotox, Inc. 72 p.
	Aquatic Plant Toxicity – Nonvascular Plants Freshwater diatom (*Navicula pelliculosa*)	EC_{50} = 3.88 mg ae/L NOEC = 1.41 mg ae/L	Highly Toxic	U.S. EPA, 2005a MRID 43307902. Hughes, J.; Williams, T.; Conder, L. (1994) The Toxicity of 2,4-D to *Navicula pelliculosa*: Lab Project Number: 10/01/2. Unpublished study prepared by Carolina Ecotox, Inc. 55 p.
2,4-DB	Aquatic Plant Toxicity Green Algae (*Selenastrum capricornutum)*	LOAEL = 1100 ppb a.i.	Practically Non-Toxict	U.S. EPA, 2005b MRID 41407803. Giddings, J. (1990) 2,4-DB Amine-Toxicity to the Freshwater Green Alga Selenastrum capricornutum: Final Report: Lab Report # 90-1-3196; Study # 10566-0289-6129-430. Unpublished study prepared by Springborn Laboratories, Inc., Environmental Sciences Div. 29 p.
Benefin	Aquatic Plant Toxicity Green algae (formerly *Selenastrum capricorntum)* *Kirchneria subcapitata*	EC_{50} = 0.100 ppm	Very Highly Toxic	U.S. EPA, 2004b MRID 41613809. Cocke, P.; Koenig, G. (1990) Toxicity of Benefin to a Freshwater Green Alga (Selenastrum capricornutum) in a Static Test System: Lab Project Number: J00790. Unpublished study prepared by Lilly Research Laboratories. 43 p.

Table N-45. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Bromoxynil	Aquatic Plant Toxicity Freshwater diatom (*Navicula pelliculosa)*	EC_{50} = 51 ppb a.i. (Octanoate)	Toxic	U.S. EPA, 1998a MRID 41606001. Giddings, J. (1990) Bromoxynil Octanoate-Toxicity to the Freshwater Diatom Navicula pelliculosa: Lab Project Number: 90-8-3431:566.1089.6142.440. Unpublished study prepared by Springborn Laboratories, Inc. 50 p.
Clethodim	No Data Available			
Clopyralid	No Data Available			
Diuron	Aquatic Plant Toxicity – Nonvascular Plants Green Algae (*Selenastrum capricornutum)*	EC_{50} = 2.4 ppb	Moderately Toxic	U.S. EPA, 2003 MRID 42218401. Blasberg, J.; Hicks, S.; Bucksath, J. (1991) Acute Toxicity of Diuron to Selenastrum capricornutum Printz: Final Report: Lab Project Number: 39335: AMR-2046-91. Unpublished study prepared by ABC Labs., Inc. 33 p.
EPTC	Aquatic Plant Toxicity Green Algae	EC_{50} = 1.36 ppm	Moderately Toxic	U.S. EPA, 1999
Hexazinone	Aquatic Plant Toxicity Blue-Green Algae (*Anabaena flos-aquae)*	EC_{50} = 0.21 ppm	Highly Toxic	U.S. EPA, 1994 MRID 43302701. Thompson, S. (1994) Hexazinone (DPX-A3674): Influence on Growth and Reproduction of Two Select Algal Species: Lab Project Number: AMR 3011-94: 335-94: 9785. Unpublished study prepared by Wildlife International Ltd. and E.I. du Pont de Nemours & Co. 75 p.
Imazamox	No Data Available			
Imazethapyr	No Data Available			
Metribuzin	Aquatic Plant Toxicity – Vascular Duckweed *(Lemna gibba)*	EC_{50} = 0.13 ppm NOEC = 0.018 ppm	Highly Toxic	U.S. EPA, 1998b MRID 43893501. Boeri, R.; Magazu, J.; Ward, T. (1995) Toxicity of Sencor to the Duckweed, Lemna gibba G3: (Amended Report): Lab Project Number: 667-MI: 106982. Unpublished study prepared by T. R. Wilbury Labs, Inc. 32 p.
	Aquatic Plant Toxicity – Non-Vascular Green Algae (*Kirchneria subcapitata)*	EC_{50} = 0.021 ppm NOEC = 0.004 ppm	Very Highly Toxic	U.S. EPA, 1998b MRID 43133601. Gagliano, G.; Orr, W. (1994) Acute Toxicity of SENCOR Technical to the Green Alga (Selenastrum capricornutum): Lab Project Number: SE881402. Unpublished study prepared by Miles, Inc. Sponsor report number: 106417. 33 p.

Table N-45. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data - Aquatic

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Aquatic Plant Toxicity Marine diatom (*Skeletonema costatum)*	EC_{50} = 0.0087 ppm NOEC = 0.0058 ppm	Very Highly Toxic	U.S. EPA, 1998b MRID 43867701. Bowers, L. (1995) Toxicity of (carbon 14)-Sencor to the Marine Diatom, Skeletonema costatum: Lab Project Number: SE881602: 106992. Unpublished study prepared by Bayer Corp. 34 p.
Norfluzaon	Aquatic Plant Toxicity – Non-Vascular Green Algae (*Kirchneria subcapitata)*	EC_{50} = 13 ppb NOEC = 6.23 ppb	Slightly Toxic	U.S. EPA, 1996a MRID 42080406. Hughes, J.; Alexander, M. (1991) The Toxicity of Norflurazon to Selenastrum capricornutum: Lab Project Number: B462-06-1. Unpublished study prepared by Malcolm Pirnie, Inc. 35 p.
Paraquat	Aquatic Plant Toxicity *Selenastrum capricornutum* (Green Algae)	EC_{50} = 0.32 ppm NOEC = 0.08 ppb LOEC = 0.20 ppb	Highly Toxic	U.S. EPA, 1997b MRID 42601002. 42601002 Smyth, D.; Sankey, S.; Penwell, A. (1992) Paraquat Dichloride: Toxicity to the Green Alga Selenastrum capricornutum: Lab Project Number: BL4578/B: T168/G (FT11/92). Unpublished study prepared by Imperial Chemical Industries PLC. 23 p.
Picloram	Aquatic Plant Toxicity *Selenastrum capricornutum* (Green Algae)	EC_{50} = 36.9 mg/L	Slightly Toxic	U.S. EPA, 1995
Pronamide	No Data Available			
Sethoxydim	No Data Available			
Terbacil	Aquatic Plant Toxicity Freshwater diatom - *Navicula pelliculosa*	EC_{50} = 0.011 ppm NOEC = 0.007 ppm	Very Highly Toxic	U.S. EPA, 1998c MRID 43909802. Hughes, J.; Alexander, M. (1996) DPX-D732-66: Influence on Growth and Reproduction of Navicula pelliculosa: Lab Project Number: AMR 3723-95: 10376: 19-03-1. Unpublished study prepared by Carolina Ecotox, Inc. and Haskell Lab for Toxicology and Industrial Medicine. 62 p.
Trifluralin	Aquatic Plant Toxicity *Selenastrum capricornutum* (Green Algae)	EC_{50} = 7.52 ppb NOEC = 5.37 ppb	Moderately Toxic Likely to be more toxic than reported in the study	U.S. EPA, 1996b MRID 41934502. Adams, E.; Cocke, P. (1990) Toxicity of Trifluralin to a Freshwater Green Alga (Selenastrum capriconutum) in a Static Test System: Lab Project Number: J00989. Unpublished study prepared by Lilly Research Labs. 43 p.

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Birds				
Glyphosate	Avian Subacute Dietary Toxicity Mallard Duck (*Anas platyrhynchos*)	>4640 ppm	Reproductive Impairment. No more than slightly toxic to upland game birds and waterfowl Practically Non-Toxic	U.S. EPA, 1993a MRID 00108107. Fink, R. (1973) Final Report: Eight-day Dietary LC50-Mallard Ducks: Technical CP67573: Project No. 241-107. (Unpublished study received Jul 12, 1974 under 5F1536; prepared by Environmental Sciences Corp., submitted by Monsanto Co., Washington, DC; CDL:094171-I)
	Avian Chronic Toxicity Bobwhite Quail (*Colinus virginianus*)	>4640 ppm		U.S. EPA, 1993a MRID 00108207. Fink, R.; Beavers, J. (1978) Final Report: One-generation Reproduction study—Bobwhite Quail: Glyphosate Technical: Project No. 139-141. (Unpublished study received Nov 13, 1978 under 524-308; prepared by Wildlife International, Ltd., submitted by Monsanto Co., Washington, DC; CDL:235924-B)
2,4-D	Avian Acute Oral Toxicity Mallard Duck (*Anas platyrhynchos*)	>1000 mg ae/kg	Practically Non-Toxic	U.S. EPA, 2005a MRID 00160000. Hudson, R.; Tucker, R.; Haegele, M. (1984) Handbook of toxicity of pesticides to wildlife: Second edition. US Fish and Wildlife Service: Resource Publication 153. 91 p.
	Avian Acute Dietary Toxicity Bobwhite Quail (*Colinus virginianus*), Mallard Duck (*Anas platyrhynchos*)	>5620 mg ae/kg	Practically Non-Toxic	U.S. EPA, 2005a MRID 41586101. Culotta, J.; Hoxter, K.; Foster, J.; et al. (1990) 2, 4-D (2,4-Dichloroxyacetic Acid): A Dietary LC50 Study with the Northern Bobwhite. Lab Project Number: 103-306. Unpublished study prepared by Wildlife International Ltd. 55 p. U.S. EPA, 2005a MRID 41546202. Culotta, J. ; Foster, J. ; Grimes, J. et al. (1990) A Dietary LC50 Study with the Mallard: Lab Project Number: 103-307. Unpublished study prepared by Wildlife International Ltd. 42 p.
	Avian Chronic Toxicity Bobwhite Quail (*Colinus virginianus*)	NOEC = 962 ppm LOEC >962 ppm, based on cracked eggs and laid eggs	Moderately Toxic	U.S. EPA, 2005a MRID 45336401. Mitchell, L.; Beavers, J.; Martin, K. et al. (1999) 2,4-D Acid: A Reproduction Study with the Northern Bobwhite: Final Report: Lab Project Number: 467-106. Unpublished study prepared by Wildlife International, Ltd. 181 p.

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
2,4-DB	Avian Acute Oral Toxicity Bobwhite Quail (*Colinus virginianus*)	LD_{50} = 1536 mg a.i./kg-bw NOAEC = 464 mg a.i./kg-bw	Reduction in body wt, feed consumption. Depression, wing droop, etc. Slightly Toxic	U.S. EPA, 2005b MRID 41370102. Pederson, C. (1989) 2,4-DB Technical Acid: 21-Day Acute Oral LD50 Study in Bobwhite Quail: Final Report: Lab Project ID: # 89 QD 132. Unpublished study prepared by Bio-Life Associates, Ltd. 33 p.
	Avian Subacute Dietary Toxicity Peking Duck *(Anas domesticus*)	LC_{50} >1000 mg a.i./kg-diet	Practically Non-Toxic	U.S. EPA, 2005b MRID 00092162. Weatherholtz, W.M. (1969) Final Report: Acute Toxicity Study-Ducklings: Project No. 656113. (Unpublished study received Dec 16, 1970 under 1F1089; prepared by TRW, Inc., submitted by Rhodia, Inc., New Brunswick, N.J.; CDL:090849-E)
Benefin	Avian Chronic Toxicity Northern Bobwhite Quail (*Colinus virginianus*)	NOAEC <96 ppm a.i. LOAEC = 96 ppm a.i.	Developmental effects: decrease in number of surviving hatchlings, decreased egg set, and decrease in 14-day hatchling survivor weight.	U.S. EPA, 2004b MRID 42145502. Murray, A.; Seacat, J.; Grothe, D. (1991). The Toxicity of Benefin to Bobwhite in a One-Generation Reproduction Study: Lab Project Number: A00690. Unpublished study prepared by Lilly Research Labs. 470 p.
	Avian Chronic Toxicity Mallard Duck *(Anas platyrhynchos)*	NOAEC = 288 ppm a.i.	Increase in the percentage of cracked eggs	U.S. EPA, 2004b MRID 42145501. Murray, A.; Smith, J.; Grothe, D. (1991) The Toxicity of Benefin to Mallards in a One-Generation Reproduction Study: Lab Project Number: A01090. Unpublished study prepared by Lilly Research Labs. 437 p.
Bromoxynil	Avian Acute Oral Toxicity Bobwhite Quail (*Colinus virginianus*)	LD_{50} = 359 mg a.i./kg	Moderately Toxic	U.S. EPA 1998a MRID 00114101. Fletcher, D. (1981) Report to Union Carbide Agricultural Products Company: Acute Oral Toxicity Study with Bromoxynil Octanoate, Technical, in Bobwhite Quail: BLAL No. 81 QD 6. (Unpublished study received Aug 31, 1982 under 264-204; prepared by Bio-Life Assoc., Ltd., submitted by Union Carbide Agricultural Products Co., Inc., Research Triangle Park, NC; CDL:248229-B)

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Avian Subacute Dietary Toxicity Bobwhite Quail (*Colinus virginianus*)	LC_{50} = 4530 ppm a.i.	Slightly Toxic	U.S. EPA, 1998a MRID 00114105. Fletcher, D. (1981) Report to Union Carbide Agricultural Products Company: 8-day Dietary LC50 Study with Bromoxynil Octanoate in Bobwhite Quail: BLAL No. 81 QC 9. (Unpublished study received Aug 31, 1982 under 264-204; prepared by Bio-Life Assoc., Ltd., submitted by Union Carbide Agricultural Products Co., Inc., Research Triangle Park, NC; CDL:248229-F)
	Avian Chronic Toxicity Mallard Duck *(Anas platyrhynchos)*	NOAEL = 102 ppm a.i. LOAEL = 340 ppm	Based on number of eggs laid and set, number of viable embryos, number of live 3-week embryos, and lesions of old yolk peritonitis or regressing ovary Can impair the reproduction of birds at dietary concentrations greater than 102 ppm	U.S. EPA, 1998a MRID 42004102. Beavers, J.; Sipler, O.; Smith, G.; et al (1991) Bromoxynil Octanoate: One-Generation Reproduction Study with the Mallard (Anas platyhynchos): Lab Project Number: 171-124. Unpublished study prepared by Wildlife Int. Ltd. 241 p.
Clethodim	Avian Acute Oral Toxicity Bobwhite Quail (*Colinus virginianus*)	LD_{50} >2250 mg/kg	Practically Non-Toxic	MSDS, 2007
Clopyralid	No Data Available			
Diuron	Avian Acute Oral Toxicity Bobwhite Quail (*Colinus virginianus*)	LD_{50} = 940 mg/kg	Slightly Toxic	U.S. EPA, 2003 MRID 50150170
	Avian Subacute Dietary Toxicity Mallard Duck *(Anas platyrhynchos)*	LD_{50} = 1730 mg/kg	Slightly Toxic	U.S. EPA 2003 MRID 00022923 Hill, E.F.; Heath, R.G.; Spann, J.W.; et al. (1975) Lethal Dietary Toxicities of Environmental Pollutants to Birds: Special Scientific Report—Wildlife No. 191. (U.S. Dept. of the Interior, Fish and Wildlife Service, Patuxent Wildlife Research Center; unpublished report)
EPTC	Avian Acute Toxicity	LD_{50} >2510 mg/kg	Non-Toxic	U.S. EPA, 1999

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Hexazinone	Avian Acute Oral Toxicity Bobwhite Quail (*Colinus virginianus*)	LD_{50} = 2251 mg/kg	Practically Non-Toxic	U.S. EPA, 1994 MRID 00073988. Fink, R.; Beavers, J.B.; Brown, R. (1978) Final Report: Acute Oral LD50—Bobwhite Quail: Project No. 112-121. (Unpublished study received May 23, 1978 under 352-387; prepared by Wildlife International, Ltd., and Washington College, submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:233989-A)
	Avian Subacute Dietary Toxicity Bobwhite Quail (*Colinus virginianus*)	LC_{50} >5000 ppm	Practically Non-Toxic	U.S. EPA, 1994 MRID 0072663. Dudeck, S.H.; Bristol, K.L. (1980) Avian Dietary Toxicity (LC50) Study in Bobwhite Quail: Project No. 201-547. Final rept. (Unpublished study received Jan 23, 1981 under 352-387; prepared by Hazleton Laboratories America, Inc., submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:244106-A)
	Avian Chronic Toxicity Bobwhite Quail (*Colinus virginianus*)	NOEC < 100 ppm	Effect on survivor weight	U.S. EPA, 1994 MRID 41764901. Beavers, J.; Campbell, S.; Smith, G.; (1991) H 17,705: A One Generation Reproduction Study With the Northern Bobwhite (Colinus virginianus): Lab Project Number: 112-225: 772-90. Unpublished Study prepared by Wildlife International Ltd. 168 p.
Imazamox	Avian Acute Oral Toxicity Bobwhite Quail (*Colinus virginianus*) and Mallard Duck *(Anas platyrhynchos)*	LD_{50} >1950 mg/kg	Practically Non-Toxic	U.S. EPA, 1997a. Imazamox – Pesticide Fact Sheet.
	Avian Subacute Dietary Toxicity Bobwhite Quail (*Colinus virginianus*) and Mallard Duck *(Anas platyrhynchos)*	LC_{50} >5572 ppm		
	Avian Chronic Toxicity Bobwhite Quail (*Colinus virginianus*) and Mallard Duck *(Anas platyrhynchos)*	NOEC >2000 ppm LOEC >2000 ppm		
Imazethapyr	No Data Available			
Metribuzin	Avian Acute Oral Toxicity Northern Bobwhite Quail (*Colinus virginianus*)	LD_{50} = 169.2 mg/kg	Moderately Toxic	U.S. EPA, 1998b EPA Accession No. 255025
	Avian Subacute Dietary Toxicity Bobwhite Quail (*Colinus virginianus*)	LC_{50} >4000 ppm	Practically Non-Toxic	U.S. EPA, 1998b EPA Accession No. 255025

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Avian Subacute Dietary Toxicity Mallard Duck *(Anas platyrhynchos)*	LC_{50} >5000 ppm	Practically Non-Toxic	U.S. EPA, 1998b MRID 00065507. Lamb, D.W.; Burke, M.A. (1977) Dietary Toxicity of ~®æSencor Technical to Bobwhite Quail and Mallard Ducks: Report No. 51593. (Unpublished study received Apr 13, 1977 under 3125-270; submitted by Mobay Chemical Corp., Kansas City, Mo.; CDL:229312-A)
	Avian Chronic Toxicity Mallard Duck *(Anas platyrhynchos)*	NOEC = 368 ppm LOEC > 368 ppm	Not reported	U.S. EPA, 1998b MRID 43860501. Hancock, G. (1995) Effect of Technical SENCOR on Mallard Reproduction: Lab Project Number: SE740801: 106983. Unpublished study prepared by Bayer Corp. 107 p.
Norfluzaon	Avian Acute Oral Toxicity Mallard Duck *(Anas platyrhynchos)*	LD_{50} >2510 mg/kg	Practically Non-Toxic	U.S. EPA, 1996a MRID 00048362. Fink, R.; Beavers, J.B.; Brown, R. (1980) Final Report: Acute Oral LD50-Mallard Duck: Project No. 131-113. (Unpublished study received Nov. 3, 1980, under 11273-24; prepared by Wildlife International, Ltd.; submitted by Sandoz, Inc., Crop Protection, San Diego, Calif.; CDL:243646-A)
	Avian Acute Oral Toxicity Bobwhite Quail (*Colinus virginianus*)	LD_{50} >1000 mg/kg	Slightly Toxic	U.S. EPA, 1996a MRID 00063622. Gough, B.J.; Shellenberger, T.E. (1971) Letter sent to Zenas B. Noon, Jr. dated May 18, 1971: Acute toxicological evaluations of San-9789 with fish and wildlife. (Unpublished study received Nov. 14, 1972, under 3G1310; prepared by Gulf South Research Institute, Atchafalaya Basin Laboratories, submitted by Sandoz, Inc. Homestead, Fla.; CDL:092234-F)
	Avian Subacute Dietary Toxicity Bobwhite Quail (*Colinus virginianus*)	LC_{50} >10000 ppm	Practically Non-Toxic	U.S. EPA, 1996a MRID 00037051. Fink, R. (1972) Final Report: Eight-Day Dietary LC50—Bobwhite Quail: Project No. 620-124. (Unpublished study received on unknown date under 2G1338; prepared by Environmental Sciences Corp.; submitted by Sandoz-Wander, Inc., Homestead, Fla.; CDL: 093577-C)

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Avian Subacute Dietary Toxicity Mallard Duck *(Anas platyrhynchos)*	LC_{50} >10000 ppm	Practically Non-Toxic	U.S. EPA, 1996a MRID 00077292. Fink, R. (1972) Final Report: Eight-Day Dietary LC50—Mallard Ducks: Project No. 620-125. (Unpublished study received Nov 14, 1972 under 3G1310; prepared by Environmental Sciences Corp., submitted by Sandoz, Inc., Homestead, Fla.; CDL:092234-G)
	Avian Chronic Toxicity Bobwhite Quail (*Colinus virginianus*)	NOEC = 40 ppm LOEC = 200 ppm	Reduced hatching success	U.S. EPA, 1996a MRID 42615301. Beavers, J.; Sipler, O.; Jaber, M. (1992) Norflurazon Technical: A One-generation Reproduction Study with the Bobwhite (Colinus virginianus): Lab Project Number: 131-151. Unpublished study prepared by Wildlife International, Ltd. 164 p.
	Avian Chronic Toxicity Mallard Duck *(Anas platyrhynchos)*	NOEC = 40 ppm LOEC = 200 ppm	Hatching weight affected	U.S. EPA, 1996a MRID 42615392. Beavers, J.; Sipler, O.; Jaber, M. (1992) Norflurazon Technical: A One-generation Reproduction Study with the Mallard (Anas platyrhynchos): Lab Project Number: 131-152. Unpublished study prepared by Wildlife International, Ltd. 163 p.
Paraquat	Avian Acute Oral Toxicity Bobwhite Quail (*Colinus virginianus*)	LD_{50} = 176 mg/kg – cation equivalent	Moderately Toxic	U.S. EPA, 1997b MRID 00029001. Fink, R.; Beavers, J.B.; Grimes, J.; et al. (1979) Acute Oral LDæ50¬--Bobwhite Quail: Paraquat dichloride Technical Salt (SX1142): Project No. 162-121. Final Rept. (Unpublished study received Feb 21, 1980 under 239-2422; prepared by Wildlife International, Ltd., submitted by Chevron Chemical Co., Richmond, Calif.; CDL:241819-A)
	Avian Subacute Dietary Toxicity Bobwhite Quail (*Colinus virginianus*)	LC_{50} = 981 ppm	Moderately Toxic	U.S. EPA, 1997b MRID 00022923. Hill, E.; Heath, R.; Spann, J. (1975) U.S. Department of Interior, Fish and Wildlife: Lethal Dietary Toxicity of Environmental Pollutants to Birds. Patuextant Wildlife Research Center.

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Avian Chronic Toxicity Mallard Duck *(Anas platyrhynchos)*	NOEC = 30 ppm LOEC = 100 ppm	Percent viable eggs, eggs set, normality of hatchlings and number of 14-day old survival affected	U.S. EPA, 1997b MRID 00110455. Fink, R.; Beavers, J.; Joiner, G.; et al. (1982) One-generation Reproduction—Mallard Duck: Paraquat Technical (SX-1305): Project No. 162-145. Final rept. (Unpublished study received Aug 18, 1982 under 239-2186; prepared by Wildlife International Ltd., submitted by Chevron Chemical Co., Richmond, CA; CDL: 248133-D)
Picloram	Avian Acute Oral Toxicity Mallard Duck *(Anas platyrhynchos)*	LD_{50} >2150 mg/kg	Practically Non-Toxic	U.S. EPA, 1995 MRID 00157173. Beavers, J. (1983) An Acute Oral Toxicity Study in the Mallard with Picloram Technical: Final Report: Project No. 103-221. Unpublished study prepared by Wildlife International Ltd. 15 p.
Pronamide	Avian DietaryToxicity	LD_{50} >5000 ppm	Practically Non-Toxic	MSDS, 2006
Sethoxydim	Avian Acute Oral Toxicity Mallard Duck *(Anas platyrhynchos)*	LD_{50} >2150 mg/kg	Practically Non-Toxic	U.S. EPA, 2005
	Avian Subacute Dietary Toxicity Mallard Duck *(Anas platyrhynchos)*	LC_{50} >5620 ppm	Practically Non-Toxic	
	Avian Chronic Toxicity Mallard Duck *(Anas platyrhynchos)*	LOAEC = 100 ppm	Number of hatchlings affected	
Terbacil	Avian Acute Oral Toxicity Northern Bobwhite Quail (*Colinus virginianus*)	LD_{50} >2250 mg/kg	Practically Non-Toxic	U.S. EPA, 1998c MRID 00157177. Beavers, J. (1986) H #14,673: An Acute Oral Toxicity Study with the Bobwhite: Final Report: Project No. 112-168. Unpublished study prepared by Wildlife International Ltd. 17 p.
	Avian Subacute Dietary Toxicity Mallard Duck *(Anas platyrhynchos)*	LC_{50} >5000 pm	Practically Non-Toxic	U.S. EPA, 1998c EPA Accession No. 251146
Trifluralin	Avian Acute Oral Toxicity Northern Bobwhite Quail (*Colinus virginianus*)	LD_{50} >2000 mg/kg	Practically Non-Toxic	U.S. EPA, 1996b MRID 00137573. Cochrane, R.; Hudson, H.; Emmerson, J.; et al. (1983) The Toxicity of Trifluralin (Compound 36352) to Bobwhite in a Fourteen-day Acute Oral Study: Study A02383. (Unpublished study received Feb 16, 1984 under 1471-70; submitted by Elanco Products Co., Div. of Eli Lilly and Co., Indianapolis, IN; CDL:252411-A)

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Avian Subacute Dietary Toxicity Bobwhite Quail (*Colinus virginianus*)	LC_{50} >5000 ppm	Practically Non-Toxic	U.S. EPA, 1996b MRID 00138857. Kehr, C.; Emmerson, J.; Brannon, D.; et al. (1983) The Toxicity of Trifluralin (Compound 36352) to Bobwhite in a Five-day Dietary Study: Study 7016-77. (Unpublished study received Jan 24, 1984 under 1471-70; submitted by Elanco Products Co., Div. of Eli Lilly and Co., Indianapolis, IN; CDL:252283-A)
	Avian Chronic Toxicity Bobwhite Quail (*Colinus virginianus*)	NOEC = 452.3 ppm LOEC = 910.5 ppm	Cracked eggs percentage of eggs laid increased	U.S. EPA, 1996b MRID 40334706. Beavers, J.; Dukes, V.; Jaber, M. (1987) Trifluralin Technical: A One-generation Reproduction Study with the Bobwhite (Colinus virginianus): Project N. 228-101. Unpublished study prepared by Wildlife International Ltd. 89 p.
Terrestrial Invertebrates (bees)				
Glyphosate	Acute Oral Toxicity Honey bees (*Apis mellifera*)	LD50 >100 µg/bee	Practically Non-Toxic	U.S. EPA, 1993a MRID 00026489. Fraser, W.D.; Jenkins, G. (1972) The Acute Contact and Oral Toxicities of CP67573 and Mon2139 to Worker Honey Bees. (Unpublished study received on unknown date under 4G1444; prepared by Huntingdon Research Centre, submitted by Monsanto Co., Washington, D.C.; CDL:093848-R)
	Acute Contact Toxicity Honey bees (*Apis mellifera*)	LD50 >100 µg/bee	Practically Non-Toxic	
2,4-D	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD50 >100 µg/bee	Practically Non-Toxic	U.S. EPA, 2005a MRID 44517304. Palmer, S.; Krueger, H. (1997) 2,4-D Dimethylamine Salt: An Acute Contact Toxicity Study with the Honey Bee: Lab Project Number: 467-102: 467/052297/BLDNC.EFA/SUB467. Unpublished study prepared by Wildlife International Ltd. 32 p. {OPPTS 850.3020}
2,4-DB	Acute Contact Toxicity Honeybee (*Apis mellifera*)	LD_{50} = 14.5 µg/bee	Practically Non-Toxic	U.S. EPA, 2005b Accession No. 18842
Benefin	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} >10 µg/bee	Practically Non-Toxic	U.S. EPA, 2004b MRID 41613812. Hoxter, K.; Jaber, M. (1990) The Acute Contact Toxicity of Benefin to the Honey Bee: Lab Project Number: 151-115. Unpublished study prepared by Wildlife International Ltd. 30 p.
Bromoxynil	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} = 14.5 µg/bee	Practically Non-Toxic	U.S. EPA, 1998a Accession No. 18842

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Clethodim	No Data Available			
Clopyralid	No Data Available			
Diuron	Acute Oral/Contact Toxicity Honey bee *(Apis meliferus)*	LD_{50} = 145 mg/kg	Practically Non-Toxic	U.S. EPA, 2003 MRID 00036935. Atkins, E.L.; Greywood, E.A.; Macdonald, R.L. (1975) Toxicity of Pesticides and Other Agricultural Chemicals to Honey Bees: Laboratory Studies. By University of California, Dept. of Entomology: UC, Cooperative Extension. (Leaflet 2287; published study.)
EPTC	Acute Oral/Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} >12.05 µg/bee	Non-Toxic	U.S. EPA, 1999
Hexazinone	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} >100 µg/bee	Relatively Non-Toxic	U.S. EPA, 1994 MRID 41216502. Hoxter, K.; Thompson, M.; Jaber, M. (1989) An Acute Contact Toxicity with the Honey Bee: Project ID 112-217. Unpublished study prepared by Wildlife International Ltd. 15 p.
Imazamox	Acute Oral/Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} >25 µg/bee	Practically Non-Toxic	U.S. EPA, 1997a Imazamox – Pesticide Fact Sheet.
Imazethapyr	No Data Available			
Metribuzin	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} = 60.4 µg/bee	Practically Non-Toxic	U.S. EPA, 1998b EPA Accession No. 028772
Norfluzaon	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} >235 µg/bee	Practically Non-Toxic	U.S. EPA, 1996a MRID 00146168. Atkins, E. (1985) Letter sent to N. Galiher dated May 20, 1985: Bee adults toxicity dusting test summary. 17 p.
Paraquat	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} >48 µg/bee	Relatively Non-toxic	U.S. EPA, 1997a MRID 05001991. 05001991 Stevenson, J.H. (1978) The acute toxicity of unformulated pesticides to worker honey bees (Apis mellifera). Plant Pathology 27(1):38-40.
Picloram	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LC_{50} >1000 ppm	Practically Non-Toxic	U.S. EPA, 1995
Pronamide	No Data Available			
Sethoxydim	No Data Available			
Terbacil	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} = 193 µg/bee	Practically Non-Toxic	U.S. EPA, 1998c MRID 00018842
Trifluralin	Acute Contact Toxicity Honey bee *(Apis mellifera)*	LD_{50} >100 µg/bee	Practically Non-Toxic	U.S. EPA, 1996b MRID 05001991. Stevenson, J.H. (1978) The acute toxicity of unformulated pesticides to worker honey bees (apis mellifera). Plant Pathology 27(1): 38-40.

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Acute Oral Toxicity Honey bee *(Apis mellifera)*	LD_{50} >50 µg/bee	Practically Non-Toxic	U.S. EPA, 1996b
Reptile				
No data were available from the EPA RED documents or MSDS on the soil microorganism toxicity for the 20 herbicides used in alfalfa				
Terrestrial Plants				
Glyphosate	Seed Germination/Seedling Emergence – Monocots and Dicots	Applied at a rate up to 10.0 lb ai/A resulted in <25% effect on the spectrum of monocots and dicots tested	not expected to cause adverse effects on seed germination/seedling emergence	U.S. EPA, 1993a MRID 40159301. Bohn, J. (1987) An Evaluation of the Preemergence Herbicidal Activity of CP-70139: Lab Project ID: 056337. Unpublished study prepared by Monsanto Agricultural Co. 25 p.
2,4-D	Seedling Emergence Toxicity (Tier II) – Monocots Onion, Sorghum	EC_{25} ≥2.1 lbs ae/A	Not reported	U.S. EPA, 2005a MRID 42416802. Backus, P. (1992) Effect of 2,4-D Acid on Seed Germination/Seedling Emergence: Tier II: Lab Project Number: 5097-91-0389-BE-001: 91-0389. Unpublished study prepared by Ricerca, Inc. 223 p.
	Seedling Emergence Toxicity (Tier II) – Dicots Mustard	EC_{25} = 0.033 lbs ae/A	Not reported	
	Vegetative Vigor Toxicity (Tier II) Monocots Onion	EC_{25} <0.0075 lbs a.i./A	Not reported	U.S. EPA, 2005a MRID 42416801. Backus, P. (1992) Effect of 2,4-D Acid on Vegetative Vigor of Plants: Tier II: Lab Project Number: 91-0390: 5097-91-0390-BE-001. Unpublished study prepared by Ricerca, Inc. 124 p.
	Vegetative Vigor Toxicity (Tier II) Dicots Tomato	EC_{25} = 0.0075 lbs a.i./A	Not reported	
2,4-DB	Seedling Emergence Toxicity – Dicots Carrot *(Daucus carota)*	EC_{25} = 0.081 lbs ae/A NOAEC = 0.0028 lbs ae./A	Not reported	U.S. EPA, 2005b MRID 41605401. Hoberg, J. (1990) 2,4 DB Amine-Determination of Effects on Seedling Germination, Seed Emergence and Vegetative Vigor of Ten Plant Species: Lab Project Number: 10566-0289-6130-610: 90-4-3280. Unpublished study prepared by Springborn Laboratories, Inc. 150 p.
	Vegetative Vigor Toxicity (Tier II) Monocots Onion	EC_{25} = 0.070 lbs a.i/A NOAEC = 0.043 lbs a.i./A	Not reported	
Benefin	Seedling Emergence Toxicity – Monocots Sorghum	EC_{25} = 1.3 lbs a.i./A NOAEC = 0.75 ppm a.i./A	Not reported	U.S. EPA, 2004b MRID 43599201

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Vegetative Vigor Toxicity (Tier II) Dicot Soybean	EC_{25} = 2.3 lbs a.i./A EC_{05} = 0.38 lbs a.i./A	Not reported	
Bromoxynil	Seedling Emergence Toxicity (Tier II) – Dicots Lettuce	EC_{25} = 0.014 lbs a.i./A (Heptanoate)	Affects shoot length	U.S. EPA, 1998a MRID 43059603. Hoberg, J. (1993) Bromoxynil Heptanoate-Determination of Effects on Seed Germination, Seedling Emergence and Vegetative Vigor of Ten Plant Species: Lab Project Number: 93-10-5003: 10566.0493. 6287.610. Unpublished study prepared by Springborn Labs., Inc., Environmental Sciences Div. 217 p.
	Vegetative Vigor Toxicity (Tier II) Dicot Cabbage	EC_{25} = 0.011 lbs a.i./A (Heptanoate)	Affects shoot weight	
	Seed Germination – Dicot Tomato	EC_{25} >0.45 lbs a.i./A	Affects germination and radicle length	U.S. EPA, 1998a MRID 43273801. Hoberg, J. (1994) Bromoxynil Octanoate–Determination of Effects on Seed Germination of Ten Plant Species: Final Report: Lab Project Number: 94-4-5225: 10566.0394.6339.610. Unpublished study prepared by Springborn Lab., Inc. 72 p.
Clethodim	No Data Available			
Clopyralid	No Data Available			
Diuron	Seedling Emergence Toxicity (Tier II) – Monocots Onion	EC_{25} = 0.099 lbs a.i./A	Not reported	U.S. EPA, 2003 MRID 44113401. Heldreth, K.; McKelvey, R. (1996) Influence of Diuron on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Supplement No. 1: Lab Project Number: AMR 2069-91: MR 10335. Unpublished study prepared by E. I. du Pont de Nemours and Co. 240 p.
	Seedling Emergence Toxicity (Tier II) – Dicots Tomato	EC_{25} = 0.08 lbs a.i/A	Not reported	
	Vegetative Vigor Toxicity (Tier II) Monocots Wheat	EC_{25} = 0.021 lbs a.i./A	Not reported	
	Vegetative Vigor Toxicity (Tier II) Dicot Tomato	EC_{25} = 0.002 lbs a.i./A	Not reported	U.S. EPA, 2003 MRID 42398501. McKelvey, R.; Kuratle, H. (1992) Influence of Diuron on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Lab Project Number: AMR 2069-91. Unpublished study prepared by E.I. du Pont de Nemours and Co. 234 p.
EPTC	Seedling Emergence Toxicity (Tier II) – Monocots Wild Oats	EC_{25} = 0.10 lbs a.i./A	Not reported	U.S. EPA, 1999

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Hexazinone	Seedling Germination	EC_{25} >12.0 lbs a.i./acre	Not reported	U.S. EPA, 1994 MRID 43162501. McKelvey, R.; Heldreth, K. (1994) Influence of Hexazinone on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Lab Project Number: AMR 2678-93: AMR 2736-93. Unpublished study prepared by DuPont Agricultural Products. 351 p.
	Seedling Emergence Toxicity (Tier II) – Dicot Tomato	EC_{25} = 0.0064 lbs a.i./A	Not reported	
	Vegetative Vigor Toxicity (Tier II) – Rape	EC_{25} = 0.011 lbs a.i./A	Not reported	
Imazamox	No Data Available			
Imazethapyr	No Data Available			
Metribuzin	Seedling Emergence Toxicity (Tier II) – Monocots Onion	EC_{25} = 0.020 lbs a.i./A NOEC = 0.014 lbs a.i./A	Survival affected	U.S. EPA, 1998b MRID 42447803. Burge, C. (1992) Tier 2 Seed Germination, Seed Emergence, and Seedling Vigor Nontarget Phytotoxicity Study Using Metribuzin: Lab Project Number: 103800: SE201601. Unpublished study prepared by Miles, Inc. 90 p.
	Seedling Emergence Toxicity (Tier II) – Dicot Turnip	EC_{25} = 0.008% lbs a.i./A NOEC = 0.007% lbs a.i./A	Weight affected	
	Vegetative Vigor Toxicity (Tier II) – Monocots Onion	EC_{25} = 0.017 lbs a.i./A NOEC = 0.0112 lbs a.i./A	Height and weight affected	
	Vegetative Vigor Toxicity (Tier II) – Dicots Turnip	EC_{25} = 0.005 lbs a.i./A NOEC = 0.0028 lbs a.i./A	Weight affected	
Norfluzaon	Seedling Emergence Toxicity (Tier II) – Dicot Mustard	EC_{25} = 0.002 lbs a.i./A NOEC = 0.00064 lbs a.i./A	May cause detrimental effects	U.S. EPA, 1996a MRID 43312501. Backus, P. (1994) Effect of Norflurazon on Seedling Emergence (Tier II): Supplemental Test: Lab Project Number: 93-0139: 5745-93-0139-BE-001: 5745-93-0139-BE-000. Unpublished study prepared by Ricerca, Inc. 92 p.
	Seedling Germination – Dicot Radish	EC_{25} >100 lbs a.i./A NOEC = 2.0 lbs a.i./A	Not reported	U.S. EPA, 1996a MRID 42080404. Backus, P. (1991) Effect of Norflurazon on Seed Germination/Seedling Emergence (Tier II): Report Addendum: Lab Project Number: 3805-91-0009-BE-001-002. Unpublished study prepared by Ricerca, Inc. 337

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Vegetative Vigor Toxicity (Tier II) – Dicots Cucumber	EC_{25} = 0.06 lbs a.i./A NOEC = 0.016 lbs a.i./A	Not reported	U.S. EPA, 1996a MRID 42080405. Backus, P. (1991) Effect of Norflurazon on Vegetative Vigor of Plants (Tier II): Report Addendum: Lab Project Number: 5-910010-BE-001-002. Unpublished study prepared by Ricerca, Inc. 141 p.
Paraquat	Seedling Emergence Toxicity (Tier II) – Dicot Cocklebur	EC_{25} = 0.85 lbs cation/A	Not reported	U.S. EPA, 1997b MRID 42639601. Canning, L.; White, J. (1992) Paraquat: A Glasshouse Study to Evaluate the Effects on Seedling Emergence of a 300 g ai litre-1 (2.5 lb ai US gal-1) Soluble Concentrate Formulation on Terrestrial Non-Target Plants: Lab Project Number: 92JH089: RJ1280B. Unpublished study prepared by ICI Agrochemicals. 56 p.
	Vegetative Vigor Toxicity (Tier II) – Dicots Cocklebur	EC_{25} = 0.013 lbs cation/A	Not reported	
Picloram	No Data Available			
Pronamide	No Data Available			
Sethoxydim	Vegetative Vigor Toxicity (Tier II) Ryegrass	EC_{25} = 0.029 lbs a.i./A EC_{50} = 0.038 lbs a.i./A NOAEC = 0.025 lbs a.i./A	Not reported	U.S. EPA, 2005c
Terbacil	Seedling Emergence Toxicity (Tier II) – Dicot Rape	EC_{25} = 0.0149 lbs a.i./A NOEC = 0.063 lbs a.i./A	Dry weight affected	U.S. EPA, 1998c MRID 43895801. Heldreth, K.; McKelvey, R. (1996) Influence of Terbacil on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Supplement No. 1: Lab Project Number: AMR 2073-91: MR 10421. Unpublished study prepared by DuPont Agricultural Products. 414 p.
	Seedling Emergence Toxicity (Tier II) – Monocots Wheat	EC_{25} = 0.025 lbs a.i./A NOEC = 0.030 lbs a.i./A	Shoot height affected	U.S. EPA, 1998c MRID 42336701. McKelvey, R.; Kuratle, H. (1992) Influence of Terbacil on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Lab Project Number: AMD 2073-91. Unpublished study prepared by E. I. du Pont de Nemours and Comp. 228 p.

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Vegetative Vigor Toxicity (Tier II) – Dicots Cucumber	EC_{25} = 0.0058 lbs a.i./A NOEC = 0.0031 lbs a.i./A	Dry weight affected	U.S. EPA, 1998c MRID 43895801. Heldreth, K.; McKelvey, R. (1996) Influence of Terbacil on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Supplement No. 1: Lab Project Number: AMR 2073-91: MR 10421. Unpublished study prepared by DuPont Agricultural Products. 414 p.
	Vegetative Vigor Toxicity (Tier II) – Monocots Wheat	EC_{25} = 0.062 lbs a.i./A NOEC = 0.12 lbs a.i./A	Shoot height affected	U.S. EPA, 1998c MRID 42336701. McKelvey, R.; Kuratle, H. (1992) Influence of Terbacil on Seed Germination, Seedling Emergence, and Vegetative Vigor of Several Terrestrial Plants: Lab Project Number: AMD 2073-91. Unpublished study prepared by E. I. du Pont de Nemours and Comp. 228 p.
Trifluralin	Seedling Germination Onion	EC_{25} = 0.33 lbs a.i./A EC_{50} = 4.3 lbs a.i./A NOEC = 0.13 lbs a.i./A	Radicle length affected	U.S. EPA, 1996b MRID 42695601. Schwab, D. (1993) Evaluating the Effects of Trifluralin on the Germination of Non-Target Terrestrial Plants: Lab Project Number: 40619. Unpublished study prepared by ABC Laboratories, Inc. 42 p.
Soil Microorganisms				
No data were available from the EPA RED documents or MSDS on the soil microorganism toxicity for the 20 herbicides used in alfalfa				
Freshwater Invertebrates				
Glyphosate	Acute Toxicity to Freshwater Invertebrates *Chironomus plumosus*	48-hr LC_{50} = 55 ppm (31-97, 95% CL)	Slightly Toxic	U.S. EPA, 1993a
	Chronic Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	MATC > 50 -< 96 mg/L	Caused reduced reproductive capacity	U.S. EPA, 1993a MRID 00124763. McAllister, W.; McKee, M.; Schofield, M.; et al. (1982) Chronic Toxicity of Glyphosate (AB-82-036) to Daphnia magna under Flow-through Test Conditions: Chronic Toxicity Final Report ABC #28742. (Unpublished study received Dec 27, 1982 under 524-308; prepared by Analytical Bio-Chemistry Laboratories, Inc., submitted by Monsanto Co., Washington, DC; CDL:249160-A)

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
2,4-D	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	48-hr LC_{50} = 25 mg ae/L	Slightly Toxic	U.S. EPA, 2005a MRID 41158301. Alexander, H.; Mayes, M.; Gersich, F. (1983) The Acute Toxicity of (2,4-Dichlorophenoxy)acetic Acid to Representative Aquatic Organisms: Project Study ID: ES-DR-0002-2297-4. Unpublished study prepared by Dow Chemical U.S.A. 26 p.
	Chronic Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	NOEC = 79 mg ae/L LOEC = 151 mg ae/L MATC = 109 mf ae/L	NOEC is calculated based on number of young produced	U.S. EPA, 2005 MRID 41835211. Ward, T.; Boeri, R. (1991) Chronic Toxicity of 2,4-D to the Daphnid Daphnia magna: Lab Project Number: 9040-D. Unpublished study prepared by Resource Analysts, Inc./EnviroSystems Div. 38 p.
2,4-DB	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	48-hr EC_{50} = 25 mg a.i./L	Slightly Toxic	U.S. EPA, 2005b MRID 41407801. McNamara, P. (1990) 2,4 DB-acid– Acute Toxicity to Daphnids (*Daphnia magna*) during a 48hour Flow-through Acute Exposure: Final Report: Lab Report # 89-7-3031; Study # 10566.0289.6125.115. Unpublished study prepared by Springborn Laboratories, Inc., Environmental Sciences Div. 39p.
	Acute Toxicity to Freshwater Invertebrates – Stonefly (*Pteronarc ys sp.)*	48-hr EC_{50} = 15 mg a.i./L	Slightly Toxic	U.S. EPA, 2005b MRID 40094602
Benefin	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	48-hr EC_{50} = 2.18 ppm a.i.	Moderately Toxic	U.S. EPA, 2004b MRID 42390802. Newstead, J.; Brock, D. (1992) The Acute Toxicity of Balan EC (FN 0270) a Formulation Containing Benefin (EL-110, Compound 054521), to Daphnia magna in a Static Renewal Test System: Lab Project Number: C01692. Unpublished study prepared by Lilly Research Labs. 36 p.
Bromoxynil	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	EC_{50} = 11 ppb a.i. (Octanoate)	Very Highly Toxic	U.S. EPA, 1998a MRID 00109417. Harper, K.; Ball, I. (1964) The Acute Toxicity of NPH 1320 Formulation of M & B 10731 to (a) Daphnia (Crustacea cladocera): 1093/65/9. (Unpublished study received Jul 28, 1982 under 359-564; prepared by Huntingdon Research Centre, Eng., submitted by Rhone-Poulenc, Inc., Monmouth Junction, NJ; CDL:247924-E)

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	EC_{50} = 31 ppb a.i.(heptanoate)	Very Highly Toxic	U.S. EPA, 1998a MRID 43059602. Putt, A. (1993) Bromoxynil Heptanoate-Acute Toxicity to Daphnids (Daphnia magna) Under Flow-Through Conditions: Lab Project Number: 93-11-5050: 10566.0693.6304.115. Unpublished study prepared by Springborn Labs., Inc., Environmental Sciences Div. 74p.
	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	EC_{50} = 19,220 ppb a.i.	Slightly Toxic	U.S. EPA, 1998a MRID 00155070. Surprenant, D. (1985) Acute Toxicity of Bromoxynil Phenol to Daphnids (Daphnia magna): Study #565-0285-6110-110: Report #BW-85-9-1840. Unpublished study prepared by Springborn Bionomics, Inc. 15 p.
	Chronic Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	NOAEL = 2.5 ppb a.i. LOAEL = 5.9 ppb a.i. MATC = 3.8 ppb	Invertebrate reproductive impairment may occur at bromoxynil octanoate levels greater than 2.5 ppb.	U.S. EPA, 1998a MRID 41928302. Putt, A. (1991) Bromoxynil Octanoate: Chronic Toxicity to Daphnids (Daphnia magna) Under Flow-Through Conditions: Lab Project Number: 10566. 0990. 6166. 130: 91-4-3718. Unpublished study prepared by Springborn Laboratories, Inc. 73 p.
Clethodim	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	EC_{50} >1000 mg/L	Practically Non-Toxic	MSDS, 2007
Clopyralid	No Data Available			
Diuron	Acute Toxicity to Freshwater Invertebrates Scud *(Gammmarus fasciatus)*	48-hr EC_{50} = 0.16 ppm	Highly Toxic	U.S. EPA, 2003 MRID 40094602. Johnson, W.; Finley, M. (1980) Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates: Resource Publication 137. US Fish and Wildlife Service, Washington, D.C. 106 p.
	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	48-hr EC_{50} = 1.4 ppm	Moderately Toxic	
EPTC	Acute Toxicity to Freshwater Invertebrates	LC_{50} = 6.5 ppm	Moderately Toxic	U.S. EPA, 1999

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Hexazinone	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	EC_{50} = 151.6 ppm	Practically Non-Toxic	U.S. EPA, 1994 MRID. 00116269. Schneider, P. (1976) 48-hour LC50 to Daphnia magna: Haskell Laboratory Report No. 262-76. (Unpublished study received Dec 30, 1977; under 352-387; submitted by E.I. du Pont de Nemours & Co., Inc., Wilmington, DE; CDL:232556-A; 235401)
	Chronic Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	MATC = 48.5 ppm	Survival affected	U.S. EPA, 1994 MRID 41406002. Pierson, K. (1990) Chronic Toxicity of IN A3674-207 to Daphnia magna: Lab Project Number: HLR 68-90: MR-8705-001. Unpublished study prepared by E.I. du Pont de Nemours and Co., Inc. 198 p.
Imazamox	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	LC_{50} >122 ppm	Practically Non-Toxic	U.S. EPA, 1997a Imazamox – Pesticide Fact Sheet.
Imazethapyr	No Data Available			
Metribuzin	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	LC_{50} = 4.2 ppm	Moderately Toxic	U.S. EPA, 1998b MRID 00072083
	Chronic Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	NOEC = 1.29 ppm LOEC = 2.62 ppm MATC = 1.84 ppm	Length and number of offspring affected	U.S. EPA, 1998b MRID 42447802. Gagliano, G.; Bowers, L. (1992) Chronic Toxicity of Sencor Technical to the Waterflea (Daphnia magna) under Flow-through Conditions: Lab Project Number: 103248: SE840701. Unpublished study prepared by Miles, Inc. 75 p.
Norfluzaon	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	EC_{50} >15 ppm NOEC = 15 ppm	Slightly Toxic	U.S. EPA, 1996a MRID 00035709. Vilkas, A.G.; Browne, A.M. (1980) The Acute Toxicity of Norflurazon (99.4% Active Ingredient) to the Waterflea, Daphnia magna Straus: UCCES Project No. 11506-16-04. (Unpublished study including letter dated May 20, 1980, from R.J. McCormack to R.E. Stoll, received Jun 5, 1980, under 11273-19; prepared by Union Carbide Corp.; submitted by Sandoz, Inc. -- Crop Protection, San Diego, Calif.: CDL:242619-A)

Table N-46. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data — Terrestrial

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Chronic Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	NOEC = 1.0 ppm LOEC = 2.6 ppm MATC >1.0 <2.6 ppm	Percent survival and offspring production affected	U.S. EPA, 1996a EPA Accession No. FAONOR03
Paraquat	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	EC_{50} = 1.2 ppm	Moderately Toxic	U.S. EPA, 1997b MRID 00114473. 00114473 Wheeler, R. (1978) 48 Hour Acute Static Toxicity of Paraquat Dichloride Salt (SX957) to 1st Stage Nymph Waterfleas (Daphnia magna Straus). (Unpublished study received Sep 15, 1978 under 239-2422; submitted by Chevron Chemical Co., Richmond, CA; CDL:235419-A)
Picloram	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	LC_{50} = 34.4 mg/L	Slightly Toxic	U.S. EPA, 1995 MRID 00151783. Gersich, F.; Hopkins, D.; Milazzo, D. (1984) The Acute and Chronic Toxicity of Technical Picloram (4-Amino-3,5,6-trichloropicolinic acid) to Daphnia magna Straus: ES-690. Unpublished study pre pared by Dow Chemical USA. 16 p.
Pronamide	No Data Available			
Sethoxydim	No Data Available			
Terbacil	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	48-hr EC_{50} = 65 ppm	Slightly Toxic	U.S. EPA, 1998c MRID 00390018.
Trifluralin	Acute Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	EC_{50} = 560 ppb	Highly Toxic	U.S. EPA, 1996 MRID 40094602. Johnson, W.; Finley, M. (1980) Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates: Resource Publication 137. U.S. Fish and Wildlife Service, Washington, D.C. 106 p.
	Chronic Toxicity to Freshwater Invertebrates Waterflea *Daphnia magna*	NOEC = 2.4 ppb LOEC = 7.2 ppb MATC = 4.8 ppb	Survival affected	U.S. EPA, 1996b MRID 05008271. Macek, K.J.; Lindberg, M.A.; Sauter, S.; Buxton, K.S.; Costa, P.A. (1976) Toxicity of Four Pesticides to Water Fleas and Fathead Minnows. Duluth, Minn.: U.S. Environmental Protection Agency, Environmental Research Laboratory. (EPA report no. EPA-600/3-76-099; available from: NTIS, Springfield, VA; PB-262 912)

Table N-47. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data – Aquatic Marine

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
Marine and Estuarine Organisms				
Glyphosate	Acute Toxicity to Estuarine and Marine Organisms Atlantic oyster (*Crassostrea virginica*)	TL50 > 10 mg/L for 48 hours	Slightly Toxic	U.S. EPA, 1993a MRID 00108110. Bentley, R. (1973) Acute Toxicity of Roundup® (Technical) to Atlantic Oyster (Crassostrea virginica). (Unpublished study received Jul 12, 1974 under 5F1536; prepared by Bionomics, Inc., submitted by Monsanto Co., Washington, DC; CDL:094171-L)
2,4-D	Acute Toxicity to Estuarine and Marine Organisms Eastern oyster (*Crassostrea virginica)*	96-hr LC_{50} = 57 mg ae/L	Slightly Toxic	US, EPA 2005a MRID 42979701. Ward et al. (1993)
	Acute Toxicity to Estuarine and Marine Fish Tidewater silverside (*Menidia beryllina*)	96-hr LC_{50} = 175 mg ae/L	Practically Non-Toxic	U.S. EPA, 2005a MRID 41737307. Vaishnav, D.; Yurk, J.; Wade, B. (1990) 2,4-Dichlorophenoxyacetic Acid: Acute Toxicity to Tidewater Silverside (Menidia Beryllina) Under Flowthrough Conditions: Lab Project Number: 3903008000- 0210-3140. Unpublished study prepared by Environmental Science and Engineering Inc.37p.
2,4-DB	No Data Available			
Benefin	Acute Toxicity to Estuarine and Marine Invertebrates Mysid shrimp *(Americamysis bahia)*	EC_{50} = 0.043 ppm a.i.	Very Highly Toxic	U.S. EPA, 2004b MRID 41613804. Sousa, J. (1990) Benefin-Acute Toxicity to Mysid Shrimp (Mysidopsis bahia) Under Flowthrough Conditions: Lab Project Number: 90-06--3343; 1982.1289.6102.515. Unpublished study prepared by Spring born Laboratories, Inc. 55 p.
Bromoxynil	Acute Toxicity to Estuarine and Marine Invertebrates Mysid shrimp *(Americamysis bahia)*	LC_{50} = 65 ppb a.i.	Very Highly Toxic	U.S. EPA, 1998a MRID 43487601. Machado, M. (1994) Bromoxynil Octanoate Technical–Acute Toxicity to Mysids (Mysidopsis bahia) Under Flow-through Conditions: Final Report: Lab Project Number: 94-10-5502:10566.0894.6344.515. Unpublished study prepared by Springborn Labs, Inc. 70 p.
Clethodim	No Data Available			
Clopyralid	No Data Available			
Diuron	Acute Toxicity to Estuarine and Marine Invertebrates Striped mullet *(Mugil cephalus)*	96-hr LC_{50} = 6.3 ppm	Moderately Toxic	U.S. EPA, 2003 MRID 40228401.

Table N-47. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data – Aquatic Marine

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Acute Toxicity to Estuarine and Marine Invertebrates	96-hr LC_{50} = 6.7 ppm	Moderately Toxic	U.S. EPA, 2003 MRID 41418805
	Chronic Toxicity to Estuarine and Marine Organisms Sheepshead minnow *(Cypprinoden varieggatus)*	LOEC = 0.44 ppm	Reduces growth and affects survival	U.S. EPA, 2003 MRID 42312901. Ward, T.; Boeri, R. (1992) Early Life Stage Toxicity of DPX-14740-166 (Diuron) to the Sheepshead Minnow, Cyprinodon variegatus: Lab Project Number: 866-91. Unpublished study prepared by Resource Analysts, Inc. 513 p.
	Acute Toxicity to Estuarine and Marine Invertebrates Brown shrimp (Penaeus aztecus)	48-hr EC_{50} = 1 ppm	Moderately Toxic	U.S. EPA, 2003 MRID 40228401.
	Chronic Toxicity to Estuarine and Marine Invertebrates Mysid shrimp *(Americamysis bahia)*	NOEC = 0.27 ppm LOEC = 0.56 ppm	Affects growth and Reproduction	
EPTC	No Data Available			
Hexazinone	Acute Toxicity to Estuarine and Marine Invertebrates Grass shrimp	96-hr LC_{50} = 78 ppm	Slightly Toxic	U.S. EPA, 1994 MRID 00047164. Heitmuller, T. (1976) Acute Toxicity of H-9877 to Embryos of Eastern Oysters (Crassostrea virginica), to Grass Shrimp (Palaemonetes pugio), and to Fiddler Crabs (Uca pugilator). (Unpublished study received Jul 25, 1979 under 352378; prepared by EG&G Bionomics, submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:099674-B)
Imazamox	No Data Available			
Imazethapyr	No Data Available			
Metribuzin	Acute Toxicity to Estuarine and Marine Invertebrates Sheepshead minnow *(Cypprinoden varieggatus)*	LC_{50} = 85 ppm	Slightly Toxic	U.S. EPA, 1998b MRID 42094502. Gagliano, G. (1991) Raw Data Supplement for Acute Toxicity of Sencor Technical to Sheepshead Minnow (Cyprindon variegatus): Lab Project Number: 274-1285-6105-500: 91756-1. Unpublished study prepared by Springborn Bionomics, Inc. 13 p.
	Acute Toxicity to Estuarine and Marine Invertebrates Eastern oyster (*Crassostrea virginica)*	LC_{50} = 49.8 ppm	Slightly Toxic	U.S. EPA, 1998b MRID 47023411

Table N-47. Glyphosate and Other Commercial Herbicides – Comparative Most Sensitive Species Toxicity Data – Aquatic Marine

Herbicide	Test and Species Tested	Toxicity LC_{50}/LD_{50}	Effect/Conclusion	Reference
	Acute Toxicity to Estuarine and Marine Invertebrates Pink shrimp (*(Penaeus duorarum)*	LC_{50} = 48.3 ppm	Slightly Toxic	U.S. EPA, 1998b MRID 00106197. Heitmuller, T. (1975) Acute Toxicity of Sencor to Eastern Oysters (Crassostrea virginica), Pink Shrimp (Penaeus duorarum), and Fiddler Crabs (Uca pugilator): ¢submitter* 43851. (Unpublished study received Aug 19, 1975 under 3125-294; prepared by Bionomics–EG & G, Inc., submitted by Mobay Chemical Corp., Kansas City, MO; CDL:165011-A)
Norfluzaon	Acute Toxicity to Estuarine and Marine Invertebrates – shell deposition Eastern oyster	LC_{50} = 3.8 mg/L	Moderately Toxic	U.S. EPA, 1996a MRID 43041802. Graves, W.; Swigert, J. (1993) Norflurazon: A 96-Hour Shell Deposition Test with the Eastern Oyster (Crassostrea virginica): Lab Project Number: 131A-156A. Unpublished study prepared by Wildlife International Ltd. 43 p.
Paraquat	No Data Available			
Picloram	No Data Available			
Pronamide	No Data Available			
Sethoxydim	No Data Available			
Terbacil	Acute Toxicity to Estuarine and Marine Invertebrates Sheepshead minnow *(Cypprinoden varieggatus)*	96-hr LC_{50} = 108.5 ppm	Practically Non-Toxic	U.S. EPA, 1998c MRID 41896100
	Acute Toxicity to Estuarine and Marine Invertebrates Eastern oyster *(Crassostrea virginica)*	48-hr LC_{50} >4.9 ppm	Moderately Toxic	U.S. EPA, 1998c MRID 00012333. Bentley, R.E. (1973) Bioassay Report Submitted to E.I. du Pont de Nemours & Company, Newark, Delaware: Sinbar Terbacil Weed Killer, 80% Wettable Powder: Acute Toxicity of H-8309 to Atlantic Oyster (µ~Crassostrea virginicaµ~). (Unpublished study received Apr 11, 1974 under 352-317; prepared by Bionomics, Inc., submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:129203-C)
Trifluralin	Acute Toxicity to Estuarine and Marine Invertebrates Sheepshead minnow *(Cypprinoden varieggatus)*	LC_{50} = 190 ppb	Highly Toxic	U.S. EPA, 1996b MRID 42449901. Parrish, P.; Dyer, E.; Enos, J.; et al. (1978) Chronic Toxicity of Chlordane, Trifluralin, and Pentachlorophenol to Sheepshead Minnows (Cyprinodon variegatus): Lab Project Number: EPA-600/3-78-010. Unpublished study prepared by EG&G Bionomics 69 p.

The sixteen following herbicides are usedin conventional alfalfa to control weeds during the growing season: 2,4-DB, benefin, bromonoxynil, clethodim, diuron, EPTC, hexazinone, imazamox, imazethapyr, metribuzin, norfluzaon, paraquat, pronamide, sethoxydim, terbacil, and trifluralin. The following four herbicides are suggested to remove a stand of GT alfalfa 2,4-D, dicamba, clopyralid, and picloram. Glyphosate normally is recommended to remove stands of conventional alfalfa; however, it cannot be used to remove GT alfalfa. These herbicides are evaluated for their environmental impact via a method developed by New York State Integrated Pest Management Program, where the EIQ is formulated based on toxicity and environmental fate data for several herbicides and insecticides used on agricultural practices (Kovach et al., 1992 & updated annually). The EIQ has been used to organize the extensive toxicological data available on pesticides and compare these pesticides even though these pesticides have several modes of actions. The formula for determining the EIQ value of individual pesticides is listed below and is the average of the farm worker, consumer, and ecological components (Kovach et al., 1992 & updated annually). Further discussion on the development and methods can be found at http://nysipm.cornell.edu/publications/eiq/default.asp

$$EIQ=\{C[(DT*5)+(DT*P)]+[(C*((S+P)/2)*SY)+(L)]+[(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\}/3$$

DT = dermal toxicity,
C = chronic toxicity,
SY = systemicity,
F = fish toxicity,
L = leaching potential,
R = surface loss potential,
D = bird toxicity,
S = soil half-life,
Z = bee toxicity,
B = beneficial arthropod toxicity,
P = plant surface half-life.

The lower the EIQ value the less environmental impact the herbicide exerts on the environment. As table N-48 illustrates aside from EPTC, glyphosate is the most environmentally benign. Due to a lack of available data,the herbicide 2,4-DB was not included in the EIQ calculations. 2,4-DB is a selective systemic herbicide in the chlorophenoxy family, which in plants is converted to 2,4-D.. Ecotoxicologically, 2,4-DB was considered a risk to terrestrial plants (from spray drift and runoff after aerial and ground applications), freshwater fish (threatened and endangered species), and small and medium mammals (threatened and endangered species) by EPA when using the maximum application rate on alfalfa (EPA, 2005a). The environmental fate properties of the 20 pesticides are discussed in section 3.2 and the ecotoxicology in section 5.1 above.

As is evident from table N-48 all but EPTC have higher EIQ values and therefore pose a higher risk to the environment than glyphosate.

Table N-48. Environmental Impact Quotient Comparison of Alfalfa Herbicides (Kovach et al., 1992 & updated annually)

Herbicide	EIQ Total Value	Farm worker EIQ	Consumer EIQ	Ecology EIQ
Glyphosate	*15.30*	*8.00*	*5.00*	*33.00*
2,4-D	18.67	8.00	8.00	40.00
2,4-DB	Not Reported	Not Reported	Not Reported	Not Reported
Benefin	16.00	6.00	3.00	39.00
Bromoxynil	20.00	16.00	9.0	35.00
Clethodim	17.00	12.00	8.00	31.00
Clopyralid	18.10	8.00	8.00	38.35
Dicamba	28.00	16.00	9.00	59.00
Diuron	20.50	15.00	10.5	36.00
EPTC	9.40	6.00	4.00	18.30
Hexazinone	18.00	8.00	9.00	37.00
Imazamox	19.50	8.00	8.00	42.55
Imazethapyr	27.30	8.00	7.00	66.85
Metribuzin	28.40	8.00	8.00	69.10
Norfluzaon	18.80	9.00	9.50	38.03
Paraquat	31.00	8.00	5.00	79.95
Picloram	18.00	8.00	9.00	37.00
Pronamide	36.00	24.00	10.00	74.00
Sethoxydim	27.50	8.00	4.93	69.60
Terbacil	16.80	12.00	11.00	27.50
Trifluralin	18.80	9.00	5.50	42.00

These calculations are defined by Kovach and colleagues as such:

> Farm worker risk is defined as the sum of applicator exposure (DT*5) plus picker exposure (DT*P) times the long-term health effect or chronic toxicity (C). Chronic toxicity of a specific pesticide is calculated as the average of the ratings from various long-term laboratory tests conducted on small mammals. These tests are designed to determine potential reproductive effects (ability to produce offspring), teratogenic effects (deformities in unborn offspring), mutagenic effects (permanent changes in hereditary material such as genes and chromosomes), and oncogenic effects (tumor growth). Within the farm worker component, applicator exposure is determined by multiplying the dermal toxicity (DT) rating to small laboratory mammals (rabbits or rats) times a coefficient of five to account for the increased risk associated with handling concentrated pesticides. Picker exposure is equal to dermal toxicity (DT) times the rating for plant surface residue half-life potential (the time required for one-half of the chemical to break down). This residue factor takes into account the weathering of pesticides that occurs in agricultural systems and the days to harvest restrictions that may be placed on certain pesticides.
>
> The consumer component is the sum of consumer exposure potential (C*((S+P)/2)*SY) plus the potential groundwater effects (L). Groundwater effects are placed in the consumer component because they are more of a human health issue (drinking well contamination) than a wildlife issue. Consumer exposure is calculated as chronic toxicity (C) times the average for residue potential in soil and plant surfaces (because roots and other plant parts are eaten) times the systemic potential rating of the pesticide (the pesticide's ability to be absorbed by plants).

The ecological component of the model is composed of aquatic and terrestrial effects and is the sum of the effects of the chemicals on fish (F*R), birds (D*((S+P)/2)*3), bees (Z*P*3), and beneficial arthropods (B*P*5). The environmental impact of pesticides on aquatic systems is determined by multiplying the chemical toxicity to fish rating times the surface runoff potential of the specific pesticide (the runoff potential takes into account the half-life of the chemical in surface water).

The impact of pesticides on terrestrial systems is determined by summing the toxicities of the chemicals to birds, bees, and beneficial arthropods. Because terrestrial organisms are more likely to occur in commercial agricultural settings than fish, more weight is given to the pesticidal effects on these terrestrial organisms. Impact on birds is measured by multiplying the rating of toxicity to birds by the average half-life on plant and soil surfaces times three. Impact on bees is measured by taking the pesticide toxicity ratings to bees times the half-life on plant surfaces times three. The effect on beneficial arthropods is determined by taking the pesticide toxicity rating to beneficial natural enemies times the half-life on plant surfaces times five. Because arthropod natural enemies spend almost all of their life in agroecosystem communities (while birds and bees are somewhat transient), their exposure to the pesticides, in theory, is greater. To adjust for this increased exposure, the pesticide impact on beneficial arthropods is multiplied by five. Mammalian wildlife toxicity is not included in the terrestrial component of the equation because mammalian exposure (farm worker and consumer) is already included in the equation, and these health effects are the results of tests conducted on small mammals such as rats, mice, rabbits, and dogs.

After the data on individual factors were collected, pesticides were grouped by classes (fungicides, insecticides/miticides, and herbicides), and calculations were conducted for each pesticide. When toxicological data were missing, the average for each environmental factor within a class was determined, and this average value was substituted for the missing values. Thus, missing data did not affect the relative ranking of a pesticide within a class.

Researchers at Ghent University developed the pesticide occupational and environmental risk (POCER) indicator (Devos et al., 2008). POCER is a similar concept to EIQ and includes ten modules; (1) risk to pesticide operator; (2) risk to worker; (3) risk to bystander; (4) persistence in the soil; (5) risk of groundwater contamination; (6) acute risk to aquatic organisms; (7) acute risk to birds; (8) acute risk to bees; (9) acute risk to earthworms; and (10) risk to beneficial arthropods. The toxicological reference values used in the effect assessment are certified endpoints defined in Annex VI of Directive 91/414/EEC. Using GT corn and non-GT corn as an example, the POCER values for glyphosate or glufosinate used alone were about one sixth less than other herbicide regimes (31 regimes were evaluated). This environmental benefit of glyphosate over other herbicides was attributed to lower potential for leaching and lower toxicity to aquatic organisms (Devos et al., 2008).

Using the above standardized methods for ranking environmental impact, researchers have concluded that glyphosate is less harmful to the environment than many other herbicides and that the shift in glyphosate usage has resulted in a net lower environmental impact from herbicides.

5.3 Summary of Findings

The increase in glyphosate due to adoption of GT crops in 1996 has generated a number of studies that have been discussed in this section. Ecological effects, exposures, and risks from direct exposure to the 20 alfalfa herbicides were evaluated in this section, and section 3.4 evaluated the chemical fate. For all ecological receptors, the most sensitive toxicity endpoints that were publicly available were used for the EIQ assessment. Data sources for toxicity for each ecological receptor are referenced in each table. As table N-48 illustrates all of the common alfalfa herbicides pose a higher risk to the environment than glyphosate, excluding EPTC. Thus with the possible replacement or decreased reliance on these pesticides with glyphosate on GT alfalfa the environmental risk is decreased. Risk analysis incorporates toxicity and exposure data and without integrating these factors the assessment is limited. However, performing comparative Tier 1 risk assessments of all 20 herbicides to glyphosate will only assess the worst case scenario making these assessments, and they will be general and not conclusive. Actual herbicide use rates vary with the season, geography, biology of the weeds in the area, and cultivator. It is clear glyphosate use trends are increasing and that glyphosate is more toxicologically and environmentally benign than the pesticides glyphosate may be replacing.

Appendix N-1. References

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Appendix N-2. Supplemental Table 15 from Benbrook (2009)

Supplemental Table 15. Herbicide Use on Conventional and Herbicide-Tolerant (HT) Soybeans, 1996 - 2008.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008*
Acres Planted	64,205,000	70,005,000	72,025,000	73,730,000	74,266,000	74,075,000	73,923,000	73,404,000	75,208,000	72,032,000	75,522,000	64,741,000	75,718,000
HT Acres Planted	4,751,170	12,044,500	32,142,240	42,054,600	40,103,640	50,371,000	55,442,250	59,457,240	63,926,800	62,667,840	67,214,580	58,914,310	69,660,560
Percent Acres Treated													
HT Varieties	7.4%	17.0%	44.2%	55.8%	54.0%	68.0%	75.0%	81.0%	85.0%	87.0%	89.0%	91.0%	92.0%
RR Varieties	7.4%	14.5%	38.8%	50.4%	49.0%	63.0%	70.5%	76.5%	81.0%	83.0%	85.0%	87.0%	88.0%
Non-RR HT varieties	-	2.5%	5.4%	5.4%	5.0%	5.0%	4.5%	4.5%	4.0%	4.0%	4.0%	4.0%	4.0%
Glyphosate, All Soybeans	25.0%	29.0%	47.0%	62.8%	66.0%	76.0%	84.0%	87.5%	91.0%	93.0%	97.2%	98.0%	98.5%
Glyphosate, Non-RR Acres	17.6%	14.5%	8.2%	12.4%	17.0%	13.0%	13.5%	11.0%	10.0%	10.0%	12.2%	11.0%	10.5%
Crop Year Rates per Acre													
NASS Average All Herbicides	1.17	1.18	1.08	1.04	1.05	0.96	1.20	1.25	1.15	1.17	1.42	1.49	1.56
Glyphosate on RR Acres	0.69	0.79	0.90	0.90	0.88	0.85	1.04	1.07	1.10	1.13	1.36	1.43	1.50
Other Herbicides on RR Acres	0.20	0.20	0.30	0.30	0.30	0.22	0.27	0.25	0.12	0.12	0.14	0.15	0.15
All Herbicides on RR Acres	0.89	0.99	1.20	1.20	1.18	1.07	1.31	1.32	1.22	1.25	1.50	1.58	1.65
Conventional Varieties	1.19	1.22	1.13	0.84	0.90	0.73	0.88	0.97	0.80	0.59	0.70	0.52	0.49
Difference in Pounds per Acre Between RR and Conventional Varieties	-0.30	-0.23	0.07	0.36	0.28	0.34	0.42	0.34	0.41	0.66	0.80	1.06	1.16

*Total herbicide use and glyphosate use per acre on RR acres assumed to rise 5% from 2006 to 2007, and then again 5% from 2007 to 2008 due to the recent trends in the prevalence of glyphosate tolerant and resistant weeds (see Table 4.3). Crop Year Rates per Acre on conventional varieties for 2003 were from a special tabulation report from USDA's Economic Research Service.

Appendix N-3. Literature Search

1.0 Literature Search Strategy

Develop a risk assessment for increased glyphosate and other chemical use on wildlife, amphibians, plants and ecosystems

1.1 Purpose

The purpose of this literature search is to locate references about the potential impacts on wildlife, amphibians, plants, and ecosystems from increased glyphosate and other chemical use.

We propose that the following DIALOG databases be included in the search:

File 5: BIOSIS
File 6: NTIS
File 10: AGRICOLA
File 34: SciSearch
File 41: Pollution Abstracts
File 40: Enviroline
File 72: EMBASE
File 76: Environmental Sciences
File 79: Aqualine
File 98: General Science Abstracts
File 117: Water Resources Abstracts
File 144: PASCAL
File 154: MEDLINE
File 156:ToxFile
File 245: WATERNET™
File 250: CAB Abstracts
File 266: Federal Research In Progress (FEDRIP)
File 399: CA SEARCH®: Chemical Abstracts®

Descriptions of these files are available at http://library.dialog.com/bluesheets/.

1.2 Scope of Search

The search will focus any published references after 1999. A reference list with abstracts will be screened for relevance to the ecotoxicity of glyphosate. English language only publications will be retrieved.

The following list will be retrieved and expanded upon.

1.3 Strategy Overview

A list of search parameters is listed below.

1.4 Synonyms

Glyphosate
Glyphosate, isopropylamine salt
Glyphosate, sodium salt
Glyphosate, potassium

Glyphosate, ammonium
Glyphosate, sulfosate
N-(phosphonomethyl) glycine
Roundup®
Roundup Ultra®
Roundup WeatherMAX
Honcho®

1.5 Keywords

Acute
Adverse
Alfalfa
Ampibian
Aquatic
Arthropod
Bird
Bioconcentration factor
Cancer*
Carcino*
Chronic
Crop
Degradation
Derma*
Developmental

Dietary risk
Dissipat*
Dose
Ecosystem(s)
Ecotoxico*
Emission
Endpoint
Environmental health
Exposure(s)
Fish
Frog
Growth
Hazard quotient
Health effect(s)
Ingest*
Inhal*
Irritation
Invertabrate

Leach*
Mammal
Metabo*
Microorganism(s)
Mortality
Mutagen*
Neuro*
NOAEC
NOEC
Non-target organisms
Persistence
Reproduc*
Reptile
Residue
Risk
Risk quotient
Roundupnoff
Sensiti*
Soil
Spray drift
Subchronic
Survival

Terato*
Terrestrial
Tolerance
Toxic*
Use Patterns

1.6 Supplemental Websearch

www.scholar.google.com
Terms:
alfalfa AND glyphosate
alfalfa AND glyphosate AND risk
glyphosate AND occurence
glyphosate AND fate
glyphosate AND occurence

www.google.com
Terms:
2,4-D AND RED AND MSDS
2,4-DB AND RED AND MSDS
Benefin AND RED AND MSDS
Bromoxynil AND RED AND MSDS
Clethodim AND RED AND MSDS
Diuron AND RED AND MSDS
EPTC AND RED AND MSDS
Hexazinone AND RED AND MSDS
Imazamox AND RED AND MSDS
Imazethapyr AND RED AND MSDS
Metribuzin AND RED AND MSDS
Norfluzaon AND RED AND MSDS
Paraquat AND RED AND MSDS
Picloram AND RED AND MSDS
Promamide AND RED AND MSDS
Sethoxydim AND RED AND MSDS
Terbacil AND RED AND MSDS
Trifluralin AND RED AND MSDS
Roundup Ready label

1.7 Submission of Citations for Approval

Using reference management software, pooled information obtained from the various bibliographic databases will be screened to remove duplicates. Additionally, ICF will review the list prior to submission and eliminate any irrelevant citations. Information provided to U.S. EPA will include the following (when available):

Author(s). Publication Year. Title. Source Document Name, Volume, Page Numbers.
Abstract
Descriptors/Identifiers (i.e., keywords and subject headings

Literature Search Results:

```
File  10:AGRICOLA 70-2008/Apr
       (c) format only 2008 Dialog
```

```
  File 154:MEDLINE(R) 1990-2008/Jun 03
         (c) format only 2008 Dialog
  File 156:ToxFile 1965-2008/May W4
         (c) format only 2008 Dialog
  File 266:FEDRIP 2008/Feb
         Comp & dist by NTIS, Intl Copyright All Rights Res
  File 245:WATERNET(TM) 1971-2008Apr
         (c) 2008 American Water Works Association
  File  55:Biosis Previews(R) 1993-2008/Jun W1
         (c) 2008 The Thomson Corporation
  File   6:NTIS 1964-2008/Jun W2
         (c) 2008 NTIS, Intl Cpyrght All Rights Res
  File  41:Pollution Abstracts 1966-2008/May
         (c) 2008 CSA.
  File  40:Enviroline(R) 1975-2008/Apr
         (c) 2008 Congressional Information Service
  File  76:Environmental Sciences 1966-2008/Jun
         (c) 2008 CSA.
  File  24:CSA Life Sciences Abstracts 1966-2008/Mar
         (c) 2008 CSA.
  File 117:Water Resources Abstracts 1966-2008/Mar
         (c) 2008 CSA.
  File 144:Pascal 1973-2008/May W4
         (c) 2008 INIST/CNRS
  File  50:CAB Abstracts 1972-2008/Apr
         (c) 2008 CAB International
  File  44:Aquatic Science & Fisheries Abstracts 1966-2008/Mar
         (c) 2008 CSA.
  File  71:ELSEVIER BIOBASE 1994-2008/May W3
         (c) 2008 Elsevier B.V.
  File 143:Biol. & Agric. Index 1983-2008/Apr
         (c) 2008 The HW Wilson Co

S1      31158   GLYPHOSATE OR PHOSPHONOMETHYL()GLYCINE OR ROUNDUP OR RODEO
             OR AQUA()STAR OR SHACKLE OR GLYPHOSPHATE
S2      13844   RN=1071-83-6 OR PHOSPHONOMETHYLIMINOACETIC()ACID OR SILGLIF
              OR PONDMASTER OR AQUANEAT OR AQUAMASTER
S3      12713   (S1 OR S2)/2000:2008
S4    6842306   ACUTE OR SUBACUTE OR CHRONIC OR SUBCHRONIC OR INGEST? OR I-
             NHAL? OR DOSE OR DOSAGE OR DIETARY
S5    4866541   TOXIC? OR (HEALTH OR ADVERSE)(3N)(EFFECT OR EFFECTS OR RISK
              OR RISKS OR IMPACT OR IMPACTS) OR NEUROTOXIC? OR GENOTOXIC? -
             OR IMMUNOTOXIC?
S6    4789703   CANCER? OR CARCINO? OR TUMOR? OR NEOPLAS?
S7    4311730   DERMA? OR SKIN OR REPRODUCTI? OR TERATOL? OR TERATOGEN? OR
             IRRITAT? OR IRRITANT OR NEUROLOG?
S8    9723660   MUTAGEN? OR MUTAT? OR SENSITIZ? OR EXPOS? OR METABOLI?
S9    3685201   USAGE()PATTERN? ? OR SPRAY()DRIFT? OR TOLERANCE OR PERSIST-
             ENCE OR INHIBITION OR DEGRADATION OR ALFALFA OR LEACH?

S10   4011984   DISSIPAT? OR ENDPOINT? ? OR NOAEC OR NOEC OR SURVIVAL OR R-
             ESIDUE? ? OR MORTALITY OR ROUNDUPNOFF
S11   3068036   BIOCONCENTRATION()FACTOR OR BCF OR HAZARD()QUOTIENT OR EMI-
             SSION? ? OR SOIL OR SOILS
S12   3037946   ARTHOPOD? ? OR BIRD OR BIRDS OR ECOSYSTEM? ? OR ECOTOXIC? -
             OR INVERTEBRATE? ?
S13  10631892   MAMMAL? OR MAMMALS OR MAMMALIAN OR MICROORGANISM? ?
```

S14 206481 AMPHIBIAN? ? OR FROG OR FROGS OR TOAD OR TOADS OR SALAMANDER? ?
S15 1269061 FISH OR FISHES
S16 1094967 WILDLIFE OR AQUATIC OR TROUT OR GUPPIES OR MINNOWS OR DEER
S17 183586 FOXES OR WATERFOWL OR DUCKS OR LOONS OR MERGANSERS OR SALMON
S18 114502 OTTERS OR CLAMS OR SHELLFISH OR HERONS OR EGRETS OR OSPREY OR EAGLES
S22 11698 S3 NOT (S20 OR S21) (eliminate most foreign languages)
S23 2887 S22 AND S19
S24 1505 RD S23 (unique items)
S25 535 S24 AND (S4 OR S5 OR S6)
S26 698 S24 AND (S7 OR S8 OR S9)
S27 776 S24 AND (S10 OR S11)
S28 1184 S25 OR S26 OR S27 (all 3 sets of terms)

S29 162 S25 AND S26 AND S27 (multiple terms in cite)

30/6/3 (Item 3 from file: 50)
0008952114 CAB Accession Number: 20053221561
Accumulation of shikimate in corn and soybean *exposed* to various rates of *glyphosate*.
Publication Year: 2005

30/6/4 (Item 4 from file: 154)
26658890 PMID: 18504846
Acute *toxic* hazard evaluations of *glyphosate* herbicide on terrestrial vertebrates of the Oregon coast range.
May *2008*

30/6/6 (Item 6 from file: 50)
0008956849 CAB Accession Number: 20063000997
Alterations induced by *glyphosate* on lupin photosynthetic apparatus and nodule ultrastRoundupcture and some oxygen diffusion related proteins.
Publication Year: 2005

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Analysis of *glyphosate* and aminomethylphosphonic acid by capillary electrophoresis with electrochemiluminescence detection.
Publication Year: 2007

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Analysis of the *toxicity* of *glyphosate* and Faena(R) using the freshwater *invertebrates* Daphnia magna and Lecane quadridentata

30/6/11 (Item 11 from file: 55)
18840814 BIOSIS NO.: 200600186209
Applying weight gain in Pomacea lineata (spix 1824) (Mollusca: Prosobranchia) as a measure of herbicide *toxicity*
2005

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4781473 43913461 Holding Library: AGL
Assessment of *toxicity* of a *glyphosate* -based formulation using bacterial systems in lake water
2007

URL: http://dx.doi.org/10.1016/j.chemosphere.2006.12.020

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Biochemical and ultrastRoundupctural alterations in Nile tilapia (
Oreochromis niloticus) induced by *glyphosate* herbicide.
Book Title: Proceedings 11th International Symposium of the World Association of Veterinary Laboratory Diagnosticians and OIE Seminar on Biotechnology, Bangkok, Thailand, 9-13 November, 2003
Publication Year: 2003

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0008514013 CAB Accession Number: 20033176082
Boll abscission responses of *glyphosate*-resistant cotton (Gossypium hirsutum) to *glyphosate*.
Publication Year: 2003

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00685328 ENVIROLINE NUMBER: 05-14167
Can the Choice of *Endpoint* Lead to Contradictory Results of Mixture-*Toxicity* Experiments?
Jul 05

30/6/22 (Item 22 from file: 154)
15730410 PMID: 15095878
Chemical and biomonitoring to assess potential *acute* effects of Vision herbicide on native *amphibian* larvae in forest wetlands.
Apr *2004*

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0019859641 BIOSIS NO.: 200700519382
Combination of a pesticide *exposure* and a bacterial challenge: In vivo effects on immune response of Pacific oyster, Crassostrea gigas (Thunberg)
2007

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4307003 43655726 Holding Library: AGL
A comparative ecological risk assessment for herbicides used on spring wheat: the effect of *glyphosate* when used within a *glyphosate*-tolerant wheat system
2004

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0000274448 IP ACCESSION NO: 5832216
Comparative *acute* *toxicity* of the commercial herbicides *glyphosate* to neotropical tadpoles Scinax nasicus (Anura: Hylidae)
PUBLICATION DATE: *2003*

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4477186 43805039 Holding Library: AGL
Comparative analysis of the effects of locally used herbicides and their active ingredients on a wild-type wine Saccharomyces cerevisiae strain
2006
URL: http://pubs.acs.org/journals/jafcau/index.html

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0009509971 CAB Accession Number: 20083103403
Compared environmental balances of broad-spectRoundupm and selective herbicides.
Book Title: Environmental fate and ecological effects of pesticides
Publication Year: 2007

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4428862 43791928 Holding Library: AGL
A Comparative Risk Assessment of Genetically Engineered, *Mutagenic*, and Conventional Wheat Production Systems \h [electronic resource]
2005
URL: http://dx.doi.org/10.1007/s11248-005-1411-8

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00622807 ENVIROLINE NUMBER: 02-09575
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Aug 01

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0008723815 CAB Accession Number: 20043193096
Conventional soyabean plant and progeny response to *glyphosate*.
Publication Year: 2004

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Crop injury from sublethal rates of herbicide. I. Tomato.
Publication Year: 2001

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Publication Year: 2002

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Case study in benefits and risks of agricultural biotechnology: *Roundup* Ready soybeans.
Book Title: Market development for genetically modified foods
Publication Year: 2001

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4709127 43901339 Holding Library: AGL
Direct and indirect effects of the herbicides *Glyphosate*, Bentazone and MCPA on eelgrass (Zostera marina)
2007
URL: http://dx.doi.org/10.1016/j.aquatox.2007.01.004

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Use of the drosophila wing spot test in the *genotoxicity* testing of different herbicides.
Publication Year: 2000

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Detection of transgenic and endogenous plant DNA in digesta and tissues of sheep and pigs fed *Roundup* Ready canola meal.
Publication Year: 2006

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0008440975 CAB Accession Number: 20033093957
Determination of the herbicide *glyphosate* and its *metabolite* in biological specimens by gas chromatography-mass spectrometry. A Case of poisoning by *Roundup*(R) herbicide.
Publication Year: 2003

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Ecotoxicological risk assessment for *Roundup*(R) herbicide.
Publication Year: 2000

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2007
URL: http://dx.doi.org/10.1065/jss2007.04.224

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045311 NLM Doc No: NTIS/02923942 Sec. Source ID: NTIS/PB2003104525
Effects of Bromacil, Diuron, *Glyphosate*, and Sulfometuron-Methyl on Periphyton Assemblages and Rainbow *Trout*.
2003

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0008323461 CAB Accession Number: 20023173257
Effect of carrier volume on corn (Zea mays) and soybean (Glycine max) response to simulated drift of *glyphosate* and glufosinate.
Publication Year: 2002

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00611081 ENVIROLINE NUMBER: 01-17996
Effects of *Acute* *Exposure* to a Commercial Formulation of Glyposate on the Tadpoles of Two Species of Anurans
Oct 01

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0008800581 CAB Accession Number: 20053061482
The influence of different treatment length on the induction of micronuclei in bovine lymphocytes after *exposure* to *glyphosate*.
Publication Year: 2004

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18370247 BIOSIS NO.: 200510064747
Effect of *glyphosate* contaminated feed on Roundupmen fermentation parameters
and in sacco *degradation* of grass hay and corn grain
2005

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The effect of *glyphosate* on carbohydrate *metabolism* in the Indian catfish Heteropneustes fossilis (Bloch).
Publication Year: 2001

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0008612071 CAB Accession Number: 20043045175
Influence of *glyphosate* on photosynthetic properties of wild type and mutant strains of cyanobacterium Anabaena doliolum .
Publication Year: 2004

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Effect of *glyphosate* on various blood parameters of fresh water *fishes*, Heteropneustes fossilis .
Publication Year: 2006

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4639811 43891893 Holding Library: AGL
Effects of *glyphosate* on *soil* microbial communities and its mineralization in a Mississippi *soil*
2007
URL: http://dx.doi.org/10.1002/ps.1351

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3955906 23244378 Holding Library: AGL
The effect of the herbicide *glyphosate* on non-target spiders. I. Direct effects on Lepthyphantes tenuis under laboratory conditions
2001
URL: http://www.interscience.wiley.com/jpages/1526-498X/

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0009232568 CAB Accession Number: 20073080455
Effect of herbicides on Trichoderma harzianum .
Publication Year: 2006

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0001671293 IP ACCESSION NO: 5799221
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PUBLICATION DATE: *2003*

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Publication Year: 2003

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0009113200 CAB Accession Number: 20063200340
Effect of metosulam and *glyphosate* on flower abnormalities of strawberry.
Publication Year: 2006

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18010019 BIOSIS NO.: 200400380808
Influence of insecticidal toxins from Bacillus thuringiensis subsp. kurstaki on the *degradation* of *glyphosate* and glufosinate-ammonium in *soil* samples
2004

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0009367307 CAB Accession Number: 20073245031
Influence of pesticides on growth and spoRounduplation of Ascochyta cypericola .
Publication Year: 2007

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Book Title: The BCPC International Congress: Crop Science and Technology, Volumes 1 and 2. Proceedings of an international congress held at the SECC, Glasgow, Scotland, UK, 10-12 November 2003
Publication Year: 2003

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18166086 BIOSIS NO.: 200500073151
Effects of refining predicted *chronic* *dietary* intakes of pesticide *residues*: a case study using *glyphosate*
2004

30/6/68 (Item 68 from file: 50)
0009026430 CAB Accession Number: 20063095861
Influence of a range of dosages of MCPA, *glyphosate* , and thifensulfuron: tribenuron (2:1) on conventional canola (Brassica napus) and white bean (Phaseolus vulgaris) growth and yield.
Publication Year: 2006

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0009026346 CAB Accession Number: 20063095955
Effect of various pesticides on the non-target species Microctonus hyperodae , a biological control agent of Listronotus bonariensis .
Publication Year: 2006

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15730409 PMID: 15095877
Effects of Vision herbicide on *mortality*, avoidance response, and growth of *amphibian* larvae in two forest wetlands.
Apr *2004*

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0008725807 CAB Accession Number: 20043184107
The effects of subchronic exposure of Wistar rats to the herbicide glyphosate (Biocarb(R)).
Publication Year: 2004

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0007976555 CAB Accession Number: 20003021195
Influence of sublethal *glyphosate* rates on leaf mineral concentration of tomato.

Publication Year: 2000

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0009249000 CAB Accession Number: 20073056777
Evaluating *glyphosate* treatments on *roundup* ready *alfalfa* for crop injury and feed quality.
Publication Year: 2007

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16340693 BIOSIS NO.: 200100512532
An exploratory analysis of the effect of pesticide *exposure* on the risk of spontaneous abortion in an Ontario farm population
2001

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18132623 BIOSIS NO.: 200500039688
Field and semifield evaluation of impacts of transgenic canola pollen on *survival* and development of worker honey bees
2004

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0009175167 CAB Accession Number: 20073029990
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Publication Year: 2006

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0009099546 CAB Accession Number: 20063183330
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Publication Year: 2006

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0008583216 CAB Accession Number: 20043033506
Phytotoxic activity of root absorbed *glyphosate* in corn seedlings (Zea mays L.).
Publication Year: 2003

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0007990864 CAB Accession Number: 20003016083
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Publication Year: 2000

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0008797751 CAB Accession Number: 20053044974
Physiological and behavioural responses of Roundupditapes decussatus to *roundup* and reldan.
Publication Year: 2003

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0009261041 CAB Accession Number: 20073122116
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Publication Year: 2005

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Publication Year: 2006

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Publication Year: 2008

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Publication Year: 2004

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16347830 BIOSIS NO.: 200100519669
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2001

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15848429 PMID: 15230326
Growth and *survival* of five *amphibian* species *exposed* to combinations of pesticides.
Jul *2004*

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0009443255 CAB Accession Number: 20073293296
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Publication Year: 2007

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0007906976 CAB Accession Number: 20002303132
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Publication Year: 2000

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0008377518 CAB Accession Number: 20033017437
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Publication Year: 2002

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Publication Year: 2006

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Publication Year: 2000

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Publication Year: 2006

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4059934 23324987 Holding Library: AGL
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2003

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00723207 ENVIROLINE NUMBER: 07-20186
Influences of Environmental Factors and Antidote Addition on *Glyphosate* *Toxicity* to Freshwater *Fish*, Labeo rohita (Hamilton)
Aug 07

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0008507846 CAB Accession Number: 20033179267
The *ingestion* of Aeromonas salmonicida subsp. Salmonicida by *fish* blood phagocytes in vitro under influence of herbicides.
Publication Year: 2003

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Inhibition of Paracoccidioides brasiliensis by pesticides: Is this a partial explanation for the difficulty in isolating this fungus from the *soil*?
2002

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Initial screening of herbicides tolerated by native plants.
Publication Year: 2007

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0009185085 CAB Accession Number: 20073037698
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Publication Year: 2006

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Investigation of the herbicide *glyphosate* and the plant growth regulators chlormequat and mepiquat in cereals produced in Denmark.
Publication Year: 2001

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18534283 BIOSIS NO.: 200510228783
Isolation and characterization of endophytic bacteria from soybean (Glycine max) grown in *soil* treated with *glyphosate* herbicide
2005

30/6/105 (Item 105 from file: 10)
4818757 44029585 Holding Library: AGL
Longitudinal changes in microbial planktonic communities of a French river in relation to pesticide and nutrient inputs
2008
URL: http://dx.doi.org/10.1016/j.aquatox.2007.11.016

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0008533092 CAB Accession Number: 20033200447
Linking fluorescence induction curve and biomass in herbicide screening.
Publication Year: 2003

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0008294936 CAB Accession Number: 20023141455
A model on Agave tequilana Weber for detection of damaged DNA from diseased cells and cells *exposed* to *glyphosate*.
Publication Year: 2001

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15730408 PMID: 15095876
Multiple stress effects of Vision herbicide, pH, and food on zooplankton and larval *amphibian* species from forest wetlands.
Apr *2004*

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0009215291 CAB Accession Number: 20073086923
Monitoring of *Roundup* Ready soybean in Romania.
Publication Year: 2006

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0009150628 CAB Accession Number: 20063213806
Morphological responses of different eucalypt clones submitted to glyphosate drift.
Publication Year: 2007

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0009371755 CAB Accession Number: 20073254236
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Publication Year: 2007

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0008949274 CAB Accession Number: 20053212470
Matrix solid-phase dispersion extraction and determination by high-performance liquid chromatography with fluorescence detection of *residues* of *glyphosate* and aminomethylphosphonic acid in tomato fRoundupit.
Publication Year: 2005

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0009458833 CAB Accession Number: 20083018898
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Publication Year: 2007

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2007

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16224136 PMID: 15683179
Oral bioavailability of *glyphosate*: studies using two intestinal cell lines.
Jan *2005*

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0020129332 BIOSIS NO.: 200800176271
Oxidative stress biomarkers and heart function in bullfrog tadpoles *exposed* to *Roundup* Original (R)
2008

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0008953985 CAB Accession Number: 20053201727
Plasma enzymes in Clarias gariepinus *exposed* to *chronic* levels of *Roundup* (*glyphosate)*.
Publication Year: 2005

30/6/122 (Item 122 from file: 10)
4006383 23284250 Holding Library: AGL
Predicted impact of transgenic, herbicide-tolerant corn on drinking water quality in vulnerable watersheds of the mid-western USA
2002 URL: http://www.interscience.wiley.com/jpages/1526-498X/

30/6/123 (Item 123 from file: 50)
0009358132 CAB Accession Number: 20073201439
Pre-harvest *glyphosate* for weed control and as a harvest aid in cereals.
Publication Year: 2007

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0009262935 CAB Accession Number: 20073099434
Pesticide contamination inside farm and nonfarm homes.
Publication Year: 2005

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0008514031 CAB Accession Number: 20033176064
Rice (Oryza sativa) and corn (Zea mays) response to simulated drift of *glyphosate* and glufosinate.
Publication Year: 2003

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0008941279 CAB Accession Number: 20053199375
Rice (Oryza sativa) response to drift rates of *glyphosate*.
Publication Year: 2005

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16074964 PMID: 15559279
Reduced grazing rates in Daphnia pulex caused by contaminants: implications for trophic cascades.
Nov *2004*

30/6/131 (Item 131 from file: 10)
4708092 43878069 Holding Library: AGL
Relating olfactory *neurotoxicity* to altered olfactory-mediated behaviors in rainbow *trout* *exposed* to three currently-used pesticides
2007
URL: http://dx.doi.org/10.1016/j.aquatox.2006.11.006

30/6/132 (Item 132 from file: 50)
0008312147 CAB Accession Number: 20023154025
Reproductive abnormalities in *glyphosate*-resistant cotton caused by lower CP4-EPSPS levels in the male *reproductive* tissue.
Publication Year: 2002

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00717922 ENVIROLINE NUMBER: 07-12457
Review of Potential Environmental Impacts of Transgenic *Glyphosate* -Resistant Soybean in Brazil
Jun-Jul 07

30/6/134 (Item 134 from file: 50)
0008737391 CAB Accession Number: 20043209129
Residual and contact herbicide transport through field lysimeters via preferential flow.
Publication Year: 2004

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0009458598 CAB Accession Number: 20083019420
Risk assessment of pesticides for *soils* of the Central Amazon, Brazil: comparing outcomes with temperate and tropical data.
Publication Year: 2008

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18145344 BIOSIS NO.: 200500052409
Response of the pacific oyster Crassostrea gigas to pesticide *exposition* under experimental conditions
2004

30/6/137 (Item 137 from file: 50)
0009195492 CAB Accession Number: 20073052042
Shikimic acid accumulation in field-grown corn (Zea mays) following simulated *glyphosate* drift.
Publication Year: 2007

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0019924580 BIOSIS NO.: 200700584321
A summary of *acute* risk of four common herbicides to *birds* and *mammals*
2007

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0008334223 CAB Accession Number: 20023169906
Sensitivity of the rooted macrophyte Myriophyllum aquaticum (Vell.) Verdcourt to seventeen pesticides determined on the basis of EC SUB 50 .
Publication Year: 2002

30/6/144 (Item 144 from file: 154)
25229130 PMID: 17855366

StRoundupctural basis of *glyphosate* *tolerance* resulting from *mutations*
of Pro101 in Escherichia coli 5-enolpyRoundupvylshikimate-3-phosphate synthase.
Nov 9 *2007*

30/6/145 (Item 145 from file: 50)
0008782535 CAB Accession Number: 20053041105
Soybean response to plant growth regulator herbicides is affected by other postemergence herbicides.
Publication Year: 2005

30/6/146 (Item 146 from file: 50)
0009247492 CAB Accession Number: 20073074062
Tolerance of direct-seeded green onions to herbicides applied before or after crop emergence.
Publication Year: 2007

30/6/147 (Item 147 from file: 55)
17228558 BIOSIS NO.: 200300187277
Trifloxysulfuron-sodium: A new post emergence herbicide for use in cotton and sugarcane.
BOOK TITLE: Conference Proceedings BCPC Conference Weeds. Volume 1-2
2001

30/6/149 (Item 149 from file: 50)
0009509965 CAB Accession Number: 20083103409
Transport pathway of strongly sorbing pesticides through stRoundupctured drained *soils*. Book Title: Environmental fate and ecological effects of pesticides
Publication Year: 2007

30/6/150 (Item 150 from file: 55)
17303922 BIOSIS NO.: 200300262566
The *teratogenic* potential of the herbicide *glyphosate*-*Roundup*(R) in Wistar rats.
2003

30/6/151 (Item 151 from file: 50)
0008513370 CAB Accession Number: 20033177547
Toxicity of chemicals commonly used in Australian apple orchards to the European earwig Forficula auricularia L. (*Dermaptera*: Forficulidae).
Publication Year: 2003

30/6/152 (Item 152 from file: 50)
0009509923 CAB Accession Number: 20083103448
Toxicity determination on three sturgeon species *exposed* to the *glyphosate*.
Book Title: Environmental fate and ecological effects of pesticides
Publication Year: 2007

30/6/153 (Item 153 from file: 144)
17863363 PASCAL No.: 06-0462203
Toxicity of *glyphosate* as Glypro (R) and LI700 to red-eared slider (Trachemys scripta elegans) embryos and early hatchlings
2006

30/6/154 (Item 154 from file: 154)
16617123 PMID: 16193763
Toxicity of herbicides in highway *Roundupnoff*.
Sep *2005*

30/6/156 (Item 156 from file: 55)
18116593 BIOSIS NO.: 200500023658
Toxicity of pesticides to earthworm, Polypheritima elongata (Michaelsen)
2004

30/6/159 (Item 159 from file: 50)
0009466386 CAB Accession Number: 20083049187
Wheat response to simulated *glyphosate* drift.
Publication Year: 2007

30/6/160 (Item 160 from file: 50)
0008983814 CAB Accession Number: 20063055099
Yield and physiological response of nontransgenic cotton to simulated *glyphosate* drift.
Publication Year: 2005

30/6/161 (Item 161 from file: 50)
0009464511 CAB Accession Number: 20083049177
Yield and physiological response of peanut to *glyphosate* drift.
Publication Year: 2007

30/6/162 (Item 162 from file: 55)
15782120 BIOSIS NO.: 200000500433
(14C)*glyphosate* transport in undisturbed topsoil columns
2000

S31 925 S28 NOT (S29 OR HUMAN)
S32 464 S31 AND (S1 OR S2 OR S19)/TI
S33 228 S32 AND (S1 OR S2)/TI,DE AND S19/TI,DE

34/6/1 (Item 1 from file: 55)
19398523 BIOSIS NO.: 200700058264
Acute cytotoxicity in *mammal* cells *exposed* in vitro to a *glyphosate* -based formulation.
2006

34/6/2 (Item 2 from file: 55)
0020055267 BIOSIS NO.: 200800102206
Actue *toxic* effects of round-up herbicide on wood *frog* tadpoles (Rana sylvatica)
2007

34/6/3 (Item 3 from file: 55)
19326478 BIOSIS NO.: 200600671873
Aquatic macroinvertebrates in the Altes Land, an intensely used orchard region in Germany: Correlation between community stRoundupcture and potential for pesticide *exposure*
2006

34/6/4 (Item 4 from file: 10)
4076652 23339868 Holding Library: AGL
Aquatic *toxicity* of *glyphosate* -based formulations: comparison between different organisms and the effects of environmental factors

2003

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0020116582 BIOSIS NO.: 200800163521
Alfalfa containing the *glyphosate*-tolerant trait has no effect on feed intake, milk composition, or milk production of dairy cattle
2008

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18846865 BIOSIS NO.: 200600192260
Alterations induced by *glyphosate* on lupin photosynthetic apparatus and nodule ultrastRoundupcture and some oxygen diffusion related proteins
2005

34/6/8 (Item 8 from file: 76)
0001848606 IP ACCESSION NO: 6727320
An assessment of the hazard of a mixture of the herbicide *Rodeo* registered and the non-ionic surfactant R-11 registered to *aquatic* *invertebrates* and larval *amphibians*
PUBLICATION DATE: *2005*

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0020250234 BIOSIS NO.: 200800297173
Biochemical bases for a widespread *tolerance* of cyanobacteria to the phosphonate herbicide *glyphosate*
2008

34/6/11 (Item 11 from file: 55)
18505242 BIOSIS NO.: 200510199742
Biodegradation of *glyphosate* by wild yeasts
2004

34/6/12 (Item 12 from file: 50)
0009057643 CAB Accession Number: 20063130115
Chemical control of lotus (Nelumbo nucifera Gaertn) in *fish* culture pond and its impact on water quality.
Publication Year: 2005

34/6/13 (Item 13 from file: 55)
18193137 BIOSIS NO.: 200500099050
Chemical and microbiological *soil* characteristics controlling *glyphosate* mineralisation in Danish surface *soils*
2004

34/6/14 (Item 14 from file: 10)
4540678 43837610 Holding Library: AGL
Changes in microbial community stRoundupcture following herbicide (
glyphosate) additions to forest *soils*
2006
URL: http://dx.doi.org/10.1016/j.apsoil.2006.03.002

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0009242634 CAB Accession Number: 20073054556
Change in the enzyme spectra of *soil* *microorganisms* Micrococcus luteus CCM 248 and Stenotrophomonas maltophilia UKM V-257 under the effect of certain pesticides.

Publication Year: 2006

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0020280171 BIOSIS NO.: 200800327110
Characterization and plant expression of a *glyphosate*-tolerant enolpyRoundupvylshikimate phosphate synthase
2008

34/6/18 (Item 18 from file: 55)
0019634137 BIOSIS NO.: 200700293878
Chronic *exposure* to sub-lethal concentration of a *glyphosate*-based herbicide alters hormone profiles and affects *reproduction* of female Jundia (Rhamdia quelen)
2007

34/6/19 (Item 19 from file: 55)
18079093 BIOSIS NO.: 200400460322
Comparative effects of pH and Vision(R) herbicide on two life stages of four anuran *amphibian* species
2004

34/6/20 (Item 20 from file: 55)
18748524 BIOSIS NO.: 200600093919
Comparative effects of the *Roundup* and *glyphosate* on mitochondrial oxidative phosphorylation
2005

34/6/21 (Item 21 from file: 154)
17325875 PMID: 16998229
Comparative *genotoxicity* of the herbicides *Roundup*, Stomp and Reglone in plant and *mammalian* test systems.
Nov *2006*

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18338650 BIOSIS NO.: 200510033150
Comparison of broiler performance when fed diets containing corn grain with insect-protected (corn rootworm and European corn borer) and herbicide-tolerant (*Glyphosate*) traits, control corn, or commercial reference corn
2005

34/6/23 (Item 23 from file: 55)
18763895 BIOSIS NO.: 200600109290
Comparison of broiler performance when fed diets containing corn grain with insect-protected (Corn rootworm and European corn borer) and herbicide-tolerant (*Glyphosate*) traits, control corn, or commercial reference corn - Revisited (vol 84, pg 587, 2005)
2005

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17613093 BIOSIS NO.: 200300581812
Comparison of broiler performance when fed diets containing grain from *Roundup* Ready (NK603), YieldGardXRoundup Ready (MON810XNK603), non-transgenic control, or commercial corn.
2003

34/6/25 (Item 25 from file: 55)
0019727439 BIOSIS NO.: 200700387180
Comparison of the forage and grain composition from insect-protected and *glyphosate*-tolerant MON 88017 corn to conventional corn (Zea mays L.)
2007

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16669437 BIOSIS NO.: 200200262948
Comparison of swine performance when fed diets containing *Roundup* Ready(R) corn (GA21), parental line or conventional corn
2001

34/6/27 (Item 27 from file: 55)
17809226 BIOSIS NO.: 200400179983
The composition of grain and forage from *glyphosate*-tolerant wheat MON 71800 is equivalent to that of conventional wheat (Triticum aestivum L.).
2004

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0019523699 BIOSIS NO.: 200700183440
Conventional and real-time polymerase chain reaction assessment of the fate of transgenic DNA in sheep fed *Roundup* Ready (R) rapeseed meal
2006

34/6/29 (Item 29 from file: 144)
15697805 PASCAL No.: 02-0406115
Current methods for assessing safety of genetically modified crops as exemplified by data on *Roundup* Ready SUP 1 soybeans : Genetically modified food: Hazard identification and risk assessment
2002

34/6/30 (Item 30 from file: 154)
17181261 PMID: 16899736
The current status and environmental impacts of *glyphosate*-resistant crops: a review.
Sep-Oct *2006*

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17167599 BIOSIS NO.: 200300124709
A critical assessment of the potential *wildlife* *toxicity* of *glyphosate* in Ontario with consideration for endocrine disRoundupption.
2002

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16817442 PMID: 16373198
Cytogenetic effect of technical *glyphosate* on cultivated bovine peripheral lymphocytes.
Jan *2006*

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17229710 BIOSIS NO.: 200300188429
Cytotoxicity induced by herbicides *glyphosate* and alachlor in vitro.
2001

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0019635433 BIOSIS NO.: 200700295174
Degradation of *glyphosate* in *soil* and its effect on fungal population

2006

34/6/35 (Item 35 from file: 55)
18079821 BIOSIS NO.: 200400461050
Degradation of the herbicide *glyphosate* by actinomycetes
2004

34/6/36 (Item 36 from file: 55)
15583172 BIOSIS NO.: 200000301485
Delayed control of weeds in *glyphosate*-tolerant sugar beet and the consequences on aphid infestation and yield
2000

34/6/37 (Item 37 from file: 50)
0009026937 CAB Accession Number: 20063094934
The detection of chromosome aberrations by the *FISH* method in bovine peripheral lymphocytes after in vitro *glyphosate*-based herbicide *exposure*.
Publication Year: 2005

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17929653 BIOSIS NO.: 200400300410
Detection of recombinant marker DNA in genetically modified *glyphosate* -tolerant soybean and use in environmental risk assessment
2004

34/6/39 (Item 39 from file: 55)
18956110 BIOSIS NO.: 200600301505
Detection of transgenic and endogenous plant DNA in digesta and tissues of sheep and pigs fed Roundup Ready canola meal
2006

34/6/40 (Item 40 from file: 55)
18203742 BIOSIS NO.: 200500120807
Development and characterization of a CP4 EPSPS-based, *glyphosate* -tolerant corn event
2005

34/6/41 (Item 41 from file: 55)
0019528226 BIOSIS NO.: 200700187967
Development and characterization of *alfalfa* populations tolerant to *glyphosate*.
2006

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15588207 BIOSIS NO.: 200000306520
Developmental *toxicity* studies with *glyphosate* and selected surfactants in rats
2000

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17940714 BIOSIS NO.: 200400311471
Discovery and directed evolution of a *glyphosate* *tolerance* gene
2004

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15182283 PMID: 12746143
Ecological risk assessment for *aquatic* organisms from over-water uses of *glyphosate*.
May-Jun *2003*

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19116676 BIOSIS NO.: 200600462071
Ecotoxicological studies on the pejerrey (Odontesthes bonariensis, Pisces Atherinopsidae)
2006

34/6/46 (Item 46 from file: 10)
3871392 22086048 Holding Library: AGL
Ecotoxicological risk assessment for *roundup* herbicide
2000

34/6/47 (Item 47 from file: 55)
17477485 BIOSIS NO.: 200300446204
Efficacy of *glyphosate* and five surfactants for controlling giant salvinia.
2002

34/6/48 (Item 48 from file: 10)
4605020 43874017 Holding Library: AGL
Influence of conservation tillage and *glyphosate* on *soil* stRoundupcture
and organic carbon fractions through the cycle of a 3-year potato rotation in Atlantic Canada
2007
URL: http://dx.doi.org/10.1016/j.still.2006.04.004

34/6/49 (Item 49 from file: 55)
18853156 BIOSIS NO.: 200600198551
Influence of Cry1Ac toxin on mineralization and bioavailability of *glyphosate* in *soil*
2006

34/6/50 (Item 50 from file: 10)
3948680 23236975 Holding Library: AGL
Effects of *acute* *exposure* to a commercial formulation of *glyphosate* on the tadpoles of two species of anurans
2001

34/6/51 (Item 51 from file: 55)
17013026 BIOSIS NO.: 200200606537
Effect of feeding diets containing corn grain with *Roundup* (event GA21 or NK603), control, or conventional varieties on steer feedlot performance and carcass characteristics
2002

34/6/52 (Item 52 from file: 55)
19403590 BIOSIS NO.: 200700063331
Effects of feeding *Roundup* Ready (R) *alfalfa* on intake and milk production of dairy cows.
2006

34/6/53 (Item 53 from file: 10)
4333655 43741419 Holding Library: AGL

Effect of freezing and thawing on microbial activity and *glyphosate* *degradation* in two Norwegian *soils*
2005
URL: http://www.interscience.wiley.com/jpages/1526-498X/

34/6/54 (Item 54 from file: 10)
4672744 43899272 Holding Library: AGL
Effects of *glyphosate* and foliar amendments on activity of *microorganisms* in the soybean rhizosphere
2007

34/6/55 (Item 55 from file: 10)
4380802 43767771 Holding Library: AGL
Influence of *glyphosate* and its formulation (*Roundup*) on the *toxicity* and bioavailability of metals to Ceriodaphnia dubia
2005

34/6/58 (Item 58 from file: 154)
17191742 PMID: 16174533
Effect of *glyphosate* herbicide on acetylcholinesterase activity and *metabolic* and hematological parameters in piava (Leporinus obtusidens).
Oct *2006*

34/6/59 (Item 59 from file: 55)
0020017068 BIOSIS NO.: 200800064007
The effect of *glyphosate* on digestion horizontal gene transfer during in vitro Roundupminal fermentation of genetically modified canola
2007

34/6/60 (Item 60 from file: 55)
18449754 BIOSIS NO.: 200510144254
The effect of *glyphosate* on the frequency of micronuclei in bovine lymphocytes in vitro
2005

34/6/61 (Item 61 from file: 55)
17186188 BIOSIS NO.: 200300144907
Effect of *glyphosate* on growth, chlorophyll, and nodulation in *glyphosate*-resistant and susceptible soybean (Glycine max) varieties.
2000

34/6/62 (Item 62 from file: 55)
16170753 BIOSIS NO.: 200100342592
Effects of *glyphosate* on lignicolous freshwater fungi of Hong Kong
2001

34/6/63 (Item 63 from file: 55)
19393400 BIOSIS NO.: 200700053141
Influence of *glyphosate* on Rhizoctonia and Fusarium root rot in sugar beet
2006

34/6/64 (Item 64 from file: 55)
17434644 BIOSIS NO.: 200300393074
Effects of *glyphosate* on root diseases in *glyphosate*-tolerant soybeans.
2003

34/6/65 (Item 65 from file: 55)

16880375 BIOSIS NO.: 200200473886
Effect of *glyphosate* on atrazine *degradation* in *soil*
2002

34/6/66 (Item 66 from file: 55)
0019661986 BIOSIS NO.: 200700321727
Effects of *glyphosate* on *soil* microbial communities and its Mississippi *soil*
2007

34/6/67 (Item 67 from file: 55)
15478291 BIOSIS NO.: 200000196604
Effect of *glyphosate* on *soil* microbial activity and biomass
2000

34/6/68 (Item 68 from file: 55)
19145233 BIOSIS NO.: 200600490628
Effects of *glyphosate* (*Roundup* (R)) on glutathione-S-transferase activity in mudworms, lumbriculus variegates
2006

34/6/69 (Item 69 from file: 41)
0000291054 IP ACCESSION NO: 7355741
Effect of *Glyphosate* Rate and Spray Volume on Control of Giant Salvinia
PUBLICATION DATE: *2007*

34/6/70 (Item 70 from file: 144)
16245262 PASCAL No.: 03-0406315
Influence of *glyphosate*-tolerant (event nk603) and corn rootworm protected (event MON863) corn silage and grain on feed consumption and milk production in Holstein cattle
2003

34/6/71 (Item 71 from file: 55)
17789347 BIOSIS NO.: 200400170104
Effect of *glyphosate* *toxicity* on growth, pigment and alkaline phosphatase activity in cyanobacterium Anabaena doliolum: A role of inorganic phosphate in *glyphosate* *tolerance*.
2004

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0008267099 CAB Accession Number: 20023112697
Effect of herbicidal control of water hyacinth on *fish* health at the Ere channel, Ogun State, Nigeria.
Publication Year: 2002

34/6/73 (Item 73 from file: 55)
18295030 BIOSIS NO.: 200500212095
Effect of the herbicide *glyphosate* on liver lipoperoxidation in pregnant rats and their fetuses
2005

34/6/74 (Item 74 from file: 55)
16022114 BIOSIS NO.: 200100193953
Effect of the herbicide *glyphosate* on enzymatic activity in pregnant rats and their fetuses
2001

34/6/75 (Item 75 from file: 55)
15379018 BIOSIS NO.: 200000097331
Effects of herbicides on Fusarium solani f. sp. glycines and development of sudden death syndrome in *glyphosate*-tolerant soybean
2000

34/6/76 (Item 76 from file: 55)
17107788 BIOSIS NO.: 200300066507
Effects of herbicides on root rot and damping-off caused by Rhizoctonia solani in *glyphosate*-tolerant soybean.
2002

34/6/77 (Item 77 from file: 154)
17520900 PMID: 17166697
Effects of the herbicide *Roundup* on the epididymal region of drakes Anas platyrhynchos.
Feb *2007*

34/6/78 (Item 78 from file: 55)
17563801 BIOSIS NO.: 200300519164
The effect of johnsongrass (Sorghum halepense) control method on the incidence and severity of viRoundups diseases in *glyphosate*-tolerant corn (Zea mays).
2003

34/6/79 (Item 79 from file: 10)
4656412 43711275 Holding Library: AGL
Effects of incorporated corn *residues* on *glyphosate* mineralization and sorption in *soil*
2005
URL: http://agspace.nal.usda.gov/handle/10113/783

34/6/80 (Item 80 from file: 50)
0008323417 CAB Accession Number: 20023173364
The effect of nitrogenous additives to *glyphosate* for water hyacinth Eichhornia crassipes (Mart)Solms-Laub control.
Publication Year: 2002

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16880379 BIOSIS NO.: 200200473890
Effect of *Roundup* Ultra on microbial activity and biomass from selected *soils*
2002

34/6/82 (Item 82 from file: 55)
17478316 BIOSIS NO.: 200300447035
Effect of *Roundup* Ultra on atrazine *degradation* in *soil*.
2003

34/6/83 (Item 83 from file: 55)
0019699914 BIOSIS NO.: 200700359655
The influence of *roundup* on the dynamics of histological changes in organs of carps
2007

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18335235 BIOSIS NO.: 200510029735
Influence of *Roundup* Ready (R) soybean production systems and *glyphosate* application on pest and beneficial insects in wide-row soybean
2004

34/6/85 (Item 85 from file: 55)
17883376 BIOSIS NO.: 200400254133
Influence of *Roundup* Ready soybean production systems and *glyphosate* application on pest and beneficial insects in narrow-row soybean.
2004

34/6/86 (Item 86 from file: 55)
17883375 BIOSIS NO.: 200400254132
Influence of *Roundup* Ready soybean and *Roundup* Ultra herbicide on Geocoris punctipes (Say) (Heteroptera: Lygaeidae) in the laboratory.
2004

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0019780937 BIOSIS NO.: 200700440678
Effect of *roundup* 360 SL herbicide on the number of Aeromonas hydrophila and Pseudomonas fluorescens in lake water
2006

34/6/88 (Item 88 from file: 10)
4217830 43677817 Holding Library: AGL
Effects of thiophanate-methyl and *glyphosate* on asexual and sexual *reproduction* in the rotifer Brachionus calycifloRoundups Pallas
2004

34/6/89 (Item 89 from file: 55)
17419855 BIOSIS NO.: 200300388574
Effects of Atrazine and *Glyphosate* *ingestion* on body weight and nutritional well-being of Coturnix quail.
2002

34/6/90 (Item 90 from file: 55)
18140355 BIOSIS NO.: 200500047105
The effects of sub-*chronic* *exposure* of Wistar rats to the herbicide *Glyphosate*-Biocarb(R)
2004

34/6/91 (Item 91 from file: 55)
0020099473 BIOSIS NO.: 200800146412
The effect of sub-*acute* and sub-*chronic* *exposure* of rats to the *glyphosate*-based herbicide *Roundup*
2008

34/6/92 (Item 92 from file: 55)
18252938 BIOSIS NO.: 200500159110
The effect of Saccharomyces cerevisiae on the stability of the herbicide *glyphosate* during bread leavening
2005

34/6/93 (Item 93 from file: 55)
0019808198 BIOSIS NO.: 200700467939
Influence of *soil* moisture on root colonization of *glyphosate*-treated soybean by Fusarium species

2007

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0008240831 CAB Accession Number: 20023046981
Effects of silvicultural systems and vegetation control on tree growth in a coastal montane *ecosystem*: seven year results.
Publication Year: 2002

34/6/95 (Item 95 from file: 55)
15531055 BIOSIS NO.: 200000249368
Effects of 2,4-D, *glyphosate* and paraquat on growth, photosynthesis and chlorophyll-A synthesis of Scenedesmus quadricauda Berb 614
2000

34/6/96 (Item 96 from file: 144)
17977161 PASCAL No.: 07-0037753
Equal performance of taqman, MGB, molecular beacon, and SYBR green-based detection assays in detection and quantification of *roundup* ready soybean
2006

34/6/97 (Item 97 from file: 55)
17021705 BIOSIS NO.: 200200615216
Enhanced in vitro *toxicity* of the herbicide *glyphosate* to neuroblastoma cells chronically pre-treated with the organophosphate pesticide diazinon
2002

34/6/98 (Item 98 from file: 40)
00688705 ENVIROLINE NUMBER: 05-16659
Environmental Fate of Herbicides Trifluralin, Metazachlor, Metamitron and Sulcotrione Compared with That of *Glyphosate*, a Substitute Broad SpectRoundupm Herbicide for Different *Glyphosate*-Resistant Crops
Sep 05

34/6/99 (Item 99 from file: 55)
0020266079 BIOSIS NO.: 200800313018
Environmental fate and non-target impact of *glyphosate*-based herbicide (*Roundup* (R)) in a subtropical wetland
2008

34/6/100 (Item 100 from file: 55)
15848420 BIOSIS NO.: 200100020259
Evaluation of *glyphosate* resistance in transgenic lettuce
2000

34/6/101 (Item 101 from file: 55)
18302406 BIOSIS NO.: 200500206208
Evolution of a microbial acetyltransferase for modification of *glyphosate*: a novel *tolerance* strategy
2005

34/6/102 (Item 102 from file: 55)
18245749 BIOSIS NO.: 200500152814
Evaluation of transgenic cotton varieties and a *glyphosate* application on seedling disease incidence
2004

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18473297 BIOSIS NO.: 200510167797
Evaluation of transgenic cotton varieties and a *glyphosate* application on seedling disease incidence (vol 158, pg 363, 2004)
2005

34/6/104 (Item 104 from file: 50)
0008223474 CAB Accession Number: 20023037510
Experimental control of Reynoutria congeners: a comparative study of a hybrid and its parents.
Book Title: Plant invasions: species ecology and *ecosystem* management
Publication Year: 2001

34/6/105 (Item 105 from file: 55)
16840220 BIOSIS NO.: 200200433731
Expression of glpA/B operon in transgenic chloroplasts to degrade *glyphosate*
2002

34/6/106 (Item 106 from file: 55)
18338441 BIOSIS NO.: 200510032941
Expression of a wheat cytochrome P450 monooxygenase in yeast and its *inhibition* by *glyphosate*
2005

34/6/107 (Item 107 from file: 55)
0020254853 BIOSIS NO.: 200800301792
Escape and establishment of transgenic *glyphosate*-resistant creeping bentgrass Agrostis stolonifera in Oregon, USA: a 4-year study
2008

34/6/108 (Item 108 from file: 55)
0019676470 BIOSIS NO.: 200700336211
Establishment of submerged *aquatic* vegetation in everglades stormwater treatment areas: Value of early control of torpedograss (Panicum repens)
2007

34/6/109 (Item 109 from file: 55)
0019893198 BIOSIS NO.: 200700552939
Estimation of *toxicity* of *glyphosate*-based herbicides by biotesting method using Cladocera
2007

34/6/110 (Item 110 from file: 55)
17308466 BIOSIS NO.: 200300277185
Field efficacy assessment of transgenic *Roundup* Ready wheat.
2003

34/6/111 (Item 111 from file: 55)
16174885 BIOSIS NO.: 200100346724
Field response of *glyphosate*-tolerant soybean to herbicides and sudden death syndrome
2001

34/6/112 (Item 112 from file: 55)
17138671 BIOSIS NO.: 200300097390
Fungicidal effects of *glyphosate* and *glyphosate* formulations on four species of entomopathogenic fungi.

2002

34/6/113 (Item 113 from file: 55)
18179162 BIOSIS NO.: 200500086227
Formulated *glyphosate* activates the DNA-response checkpoint of the cell cycle leading to the prevention of G2/M transition
2004

34/6/114 (Item 114 from file: 55)
19150222 BIOSIS NO.: 200600495617
Physiological mechanisms of *glyphosate* resistance
2006

34/6/115 (Item 115 from file: 55)
17228606 BIOSIS NO.: 200300187325
Physiological and morphological effects of *glyphosate* applications on *glyphosate*-resistant cotton.
BOOK TITLE: Conference Proceedings BCPC Conference Weeds. Volume 1-2
2001

34/6/116 (Item 116 from file: 55)
19306201 BIOSIS NO.: 200600651596
Glyphosate and bioherbicide interaction for controlling kudzu (Pueraria lobata), redvine (BRoundupnnichia ovata), and tRoundupmpetcreeper (Campsis radicans)
2006

34/6/117 (Item 117 from file: 55)
19137976 BIOSIS NO.: 200600483371
Is *glyphosate* a developmental and/or *reproductive* *toxicant*? a critical analysis of the literature
2006

34/6/118 (Item 118 from file: 50)
0008976551 CAB Accession Number: 20063025598
Glyphosate affects soybean root exudation and rhizosphere *microorganisms*.
Publication Year: 2005

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0000288265 IP ACCESSION NO: 6909916
Glyphosate affects soybean root exudation and rhizosphere micro-organisms
PUBLICATION DATE: *2005*

34/6/120 (Item 120 from file: 55)
18202240 BIOSIS NO.: 200500109305
Glyphosate herbicide *degradation* in waterlogged *soil*
2004

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16017568 BIOSIS NO.: 200100189407
Glyphosate inhibits melanization of Cryptococcus neoformans and prolongs *survival* of mice after systemic infection
2001

34/6/122 (Item 122 from file: 55)

18763957 BIOSIS NO.: 200600109352
Glyphosate inhibits Roundupst diseases in *glyphosate*-resistant wheat and soybean
2005

34/6/123 (Item 123 from file: 55)
15873200 BIOSIS NO.: 200100045039
Glyphosate applied to genetically modified herbicide-tolerant sugar beet and 'volunteer' potatoes reduces populations of potato cyst nematodes and the number and size of daughter tubers
2000

34/6/124 (Item 124 from file: 55)
19036463 BIOSIS NO.: 200600381858
Glyphosate and previous crop *residue* effect on deleterious and beneficial *soil*-borne fungi from a peanut-corn-soybean rotations
2006

34/6/125 (Item 125 from file: 55)
16875063 BIOSIS NO.: 200200468574
Glyphosate-resistant goosegrass. Identification of a *mutation* in the target enzyme 5-enolpyRoundupvylshikimate-3-phosphate synthase
2002

34/6/126 (Item 126 from file: 55)
18717316 BIOSIS NO.: 200600062711
Glyphosate-resistant soybean management system effect on Sclerotinia stem rot
2005

34/6/127 (Item 127 from file: 154)
15267957 PMID: 12848496
Glyphosate-tolerant canola meal is equivalent to the parental line in diets fed to rainbow *trout*.
Jul 16 *2003*

34/6/128 (Item 128 from file: 55)
18937151 BIOSIS NO.: 200600282546
Gametic selection by *glyphosate* in soybean plants hemizygous for the CP4 EPSPS transgene
2006

34/6/129 (Item 129 from file: 55)
0019717164 BIOSIS NO.: 200700376905
Gene flow from GM *glyphosate*-tolerant to conventional soybeans under field conditions in Japan
2006

34/6/130 (Item 130 from file: 55)
0019651451 BIOSIS NO.: 200700311192
Genetically modified canola and Roundupminal bacteria: investigations of horizontal gene transfer and effects of *glyphosate* in vitro.
2006

34/6/131 (Item 131 from file: 55)
19100548 BIOSIS NO.: 200600445943

Genetic analysis of *glyphosate* *tolerance* in Halomonas variabilis strain HTG(7)
2006

34/6/132 (Item 132 from file: 55)
0020213151 BIOSIS NO.: 200800260090
Genotoxic potential of *glyphosate* formulations: Mode-of-action investigations
2008

34/6/134 (Item 134 from file: 50)
0008333643 CAB Accession Number: 20023175861
Herbicidal control of water hyacinth and its impact on *fish* growth and water quality.
Publication Year: 2002

34/6/135 (Item 135 from file: 10)
4823622 44034750 Holding Library: AGL
Herbicides, *glyphosate* resistance and *acute* *mammalian* *toxicity*: simulating an environmental effect of *glyphosate*-resistant weeds in the USA
2008
URL: http://dx.doi.org/10.1002/ps.1497

34/6/136 (Item 136 from file: 55)
17151542 BIOSIS NO.: 200300110261
How the *mutation* glycine96 to alanine confers *glyphosate* insensitivity to 5-enolpyRoundupvyl shikimate-3-phosphate synthase from Escherichia coli.
2002

34/6/137 (Item 137 from file: 55)
0019870466 BIOSIS NO.: 200700530207
Histopathological responses of the gill and liver tissues of Clarias gariepinus fingerlings to the herbicide, *glyphosate*
2006

34/6/138 (Item 138 from file: 10)
4059978 23325087 Holding Library: AGL
Ichthyophthirius multifiliis and Tetrahymena thermophila tolerate *glyphosate* but not a commercial herbicidal formulation
2003

34/6/139 (Item 139 from file: 55)
18846837 BIOSIS NO.: 200600192232
Identification of a *glyphosate*-resistant mutant of rice 5-enolpyRoundupvylshikimate 3-phosphate synthase using a directed evolution-strategy
2006

34/6/140 (Item 140 from file: 55)
0019957404 BIOSIS NO.: 200800004343
Identification of a new gene encoding EPSPS with high *glyphosate* resistance from the metagenomic library
2007

34/6/141 (Item 141 from file: 55)
17937828 BIOSIS NO.: 200400308585

Impact of *glyphosate* on the Bradyrhizobium japonicum symbiosis with
glyphosate-resistant transgenic soybean: A minireview
2004

34/6/142 (Item 142 from file: 10)
4307662 43661048 Holding Library: AGL
The impact of the herbicide *glyphosate* on leaf litter *invertebrates*
within Bitou bush, Chrysanthemoides monilifera ssp rotundata, infestations
2004
URL: http://www.interscience.wiley.com/jpages/1526-498X/

34/6/143 (Item 143 from file: 10)
4313605 43721508 Holding Library: AGL
The impact of insecticides and herbicides on the biodiversity and
productivity of *aquatic* communities
2005

34/6/145 (Item 145 from file: 55)
19388070 BIOSIS NO.: 200700047811
The impact of insecticides and herbicides on the biodiversity and
productivity of *aquatic* communities - Response
2006

34/6/146 (Item 146 from file: 55)
15794075 BIOSIS NO.: 200000512388
The induction of glutathione-S-transferase (GST) in the liver of Notemigonus
chrysoleucas in response to the herbicides *glyphosate* and triclopyr
2000

34/6/147 (Item 147 from file: 50)
0009389149 CAB Accession Number: 20073265931
Integrated weed control using a retardant *dose* of *glyphosate*: a new
management tool for water hyacinth?
Publication Year: 2007

34/6/148 (Item 148 from file: 10)
4859461 44034749 Holding Library: AGL
Integrating *soil* conservation practices and *glyphosate*-resistant
crops: impacts on *soil*
2008
URL: http://hdl.handle.net/10113/12231

34/6/149 (Item 149 from file: 40)
00732099 ENVIROLINE NUMBER: 08-12297
Interactions Between *Glyphosate* and Autochthonous *Soil* Fungi Surviving
in Aqueous Solution of *Glyphosate*
Apr 08

34/6/150 (Item 150 from file: 55)
16817340 BIOSIS NO.: 200200410851
Interaction of *glyphosate* *tolerance* with soybean cyst nematode resistance
2002

34/6/151 (Item 151 from file: 55)
0019890690 BIOSIS NO.: 200700550431
In vitro and in vivo evaluation of the *genotoxicity* of the herbicide
glyphosate in mice

2006

34/6/152 (Item 152 from file: 55)
18581240 BIOSIS NO.: 200510275740
In vitro evaluation of *glyphosate*-induced DNA damage in fibrosarcoma cells HT1080 and Chinese hamster ovary (CHO) cells.
2004

34/6/153 (Item 153 from file: 10)
4380835 43767826 Holding Library: AGL
Leaching of *glyphosate* and AMPA under two *soil* management practices in Burgundy vineyards (Vosne-Romanee, 21-France)
2005

34/6/154 (Item 154 from file: 10)
4319336 43739244 Holding Library: AGL
The lethal impact of *roundup* on *aquatic* and terrestrial *amphibians*
2005

34/6/155 (Item 155 from file: 55)
17434646 BIOSIS NO.: 200300393076
Microbial activity and atrazine *degradation* in *soil* from mixtures of *glyphosate* and atrazine.
2003

34/6/156 (Item 156 from file: 10)
4859626 44035810 Holding Library: AGL
Microbial respiration in *soils* of the Argentine pampas after metsulfuron methyl, 2,4-D, and *glyphosate* treatments
2008

34/6/157 (Item 157 from file: 55)
18725999 BIOSIS NO.: 200600071394
Molecular basis for the *glyphosate*-insensitivity of the reaction of 5-enolpyRoundupvylshikimate 3-phosphate synthase with shikimate
2005

34/6/158 (Item 158 from file: 55)
0019727690 BIOSIS NO.: 200700387431
The molecular basis of *glyphosate* resistance by an optimized microbial acetyltransferase
2007

34/6/159 (Item 159 from file: 55)
19273872 BIOSIS NO.: 200600619267
Molecular basis for the herbicide resistance of *Roundup* Ready crops
2006

34/6/160 (Item 160 from file: 50)
0008755339 CAB Accession Number: 20053015364
Monitoring of pesticide *residues* in drainage water and *fish* samples collected from different governorates, Egypt.
Publication Year: 2005

34/6/161 (Item 161 from file: 55)
16327678 BIOSIS NO.: 200100499517
Metabolism of the phosphonate herbicide *glyphosate* by a

non-nitrate-utilizing strain of Penicillium chrysogenum
2001

34/6/162 (Item 162 from file: 55)
0020143348 BIOSIS NO.: 200800190287
A metagenome approach to the study of phosphohydrolases and *glyphosate* transport and *degradation* in bacteria
2007

34/6/163 (Item 163 from file: 55)
0020052217 BIOSIS NO.: 200800099156
Mycotoxin occurrence and Aspergillus flavus *soil* propagules in a corn and cotton *glyphosate*-resistant cropping systems
2007

34/6/164 (Item 164 from file: 55)
17778324 BIOSIS NO.: 200400144985
The nematode Caenorhabditis elegans as a model of organophosphate-induced *mammalian* *neurotoxicity*.
2004

34/6/165 (Item 165 from file: 55)
0019539164 BIOSIS NO.: 200700198905
Nitrogenase activity, nitrogen content, and yield responses to *glyphosate* in *glyphosate*-resistant soybean
2007

34/6/166 (Item 166 from file: 55)
19002015 BIOSIS NO.: 200600347410
Nutrient digestibility in sheep fed diets containing *Roundup* Ready or conventional fodder beet, sugar beet, and beet pulp
2005

34/6/167 (Item 167 from file: 55)
16629990 BIOSIS NO.: 200200223501
Nutritional evaluation of Bt (MON810) and *Roundup* Ready(R) corn compared with commercial hybrids in broilers
2001

34/6/168 (Item 168 from file: 55)
17344841 BIOSIS NO.: 200300313560
A new *glyphosphate* *tolerance* strategy in transgenic crops.
2003

34/6/169 (Item 169 from file: 55)
19012060 BIOSIS NO.: 200600357455
New insights on *glyphosate* mode of action in nodular *metabolism*: Role of shikimate accumulation
2006

34/6/170 (Item 170 from file: 55)
16858458 BIOSIS NO.: 200200451969
Studies on a new group of biodegradable surfactants for *glyphosate*
2002

34/6/171 (Item 171 from file: 55)
18769979 BIOSIS NO.: 200600115374

Oxidative *degradation* of *glyphosate* and aminomethylphosphonate by manganese oxide
2005

34/6/172 (Item 172 from file: 55)
0020096663 BIOSIS NO.: 200800143602
Oxidative stress biomarkers and bioconcentration of reldan and *roundup* by the edible clam Roundupditapes decussatus
2007

34/6/173 (Item 173 from file: 40)
00731623 ENVIROLINE NUMBER: 08-03611
Oxidative Stress Biomarkers and Heart Function in Bullfrog Tadpoles *Exposed* to *Roundup* Original
Apr 08

34/6/174 (Item 174 from file: 55)
17572880 BIOSIS NO.: 200300527777
Plant phenology effects on *soil* microbial C and N cycling in a semiarid *ecosystem*.
2003

34/6/175 (Item 175 from file: 55)
16252653 BIOSIS NO.: 200100424492
Plant growth and nitrogenase activity of *glyphosate*-tolerant soybean in response to foliar *glyphosate* applications
2001

34/6/176 (Item 176 from file: 55)
15980030 BIOSIS NO.: 200100151869
Plastid-expressed 5-enolpyRoundupvylshikimate-3-phosphate synthase genes provide
high level *glyphosate* *tolerance* in tobacco
2001

34/6/177 (Item 177 from file: 55)
17871314 BIOSIS NO.: 200400240261
Performance of growing-finishing pigs fed diets containing *Roundup* Ready corn (event nk603), a nontransgenic genetically similar corn, or conventional corn lines.
2004

34/6/179 (Item 179 from file: 55)
16988476 BIOSIS NO.: 200200581987
Performance of lactating dairy cows fed *glyphosate*-tolerant corn (event NK603)
2002

34/6/180 (Item 180 from file: 55)
15784018 BIOSIS NO.: 200000502331
Progeny analysis of *glyphosate* selected transgenic soybeans derived from Agrobacterium-mediated transformation
2000

34/6/181 (Item 181 from file: 55)
18477773 BIOSIS NO.: 200510172273
Preemergence herbicide and *glyphosate* effects on seedling diseases in

glyphosate-resistant cotton
2005

34/6/182 (Item 182 from file: 55)
16988458 BIOSIS NO.: 200200581969
Protocols for detection of EPSP synthase gene in sheep fed diets containing *Roundup* Ready(R) canola
2002

34/6/183 (Item 183 from file: 55)
16974789 BIOSIS NO.: 200200568300
Persistence of transgenic DNA from *Roundup* Ready(R) canola during processing for feed and in vitro Roundupminal incubation
2002

34/6/184 (Item 184 from file: 55)
0019889751 BIOSIS NO.: 200700549492
Putative porin of Bradyrhizobium sp (Lupinus) bacteroids induced by *glyphosate*
2007

34/6/185 (Item 185 from file: 10)
4319337 43739245 Holding Library: AGL
Pesticides and *amphibians*: the importance of community context
2005

34/6/186 (Item 186 from file: 6)
2262545 NTIS Accession Number: MIC-103-01962/XAB
Pesticides in Ontario: A critical assessment of potential *toxicity* of agricultural products to *wildlife* , with consideration for endocrine disRoundupption, vol. 2: Triazine herbicides, *glyphosate*, and metolachlor (Technical report series no. no. 369)
c2002

34/6/187 (Item 187 from file: 55)
18047665 BIOSIS NO.: 200400418454
Use of quantitative real-time and conventional PCR to assess the stability of the cp4 epsps transgene from *Roundup* Ready(R) canola in the intestinal, Roundupminal, and fecal contents of sheep
2004

34/6/188 (Item 188 from file: 55)
19322751 BIOSIS NO.: 200600668146
ReconstRoundupction of enzymatic activity from split genes encoding *glyphosate*-tolerant EPSPS protein of Psedomonas fluorescens G2 strain by intein mediated protein complementation
2006

34/6/189 (Item 189 from file: 55)
0020231831 BIOSIS NO.: 200800278770
Redvine (BRoundupnnichia ovata) and tRoundupmpetcreeper (Campsis radicans) controlled
under field conditions by a synergistic interaction of the bioherbicide, Myrothecium verRoundupcaria, with *glyphosate*
2008

34/6/190 (Item 190 from file: 55)
0020042689 BIOSIS NO.: 200800089628
Relation between *mortality* of prickly sculpin and diurnal extremes in water quality at *Rodeo* Lagoon, Marin County, California
2007

34/6/191 (Item 191 from file: 55)
19397633 BIOSIS NO.: 200700057374
Roundup biactive modifies cadmium *toxicity* to Daphnia carinata
2006

34/6/192 (Item 192 from file: 55)
15987937 BIOSIS NO.: 200100159776
Roundup inhibits steroidogenesis by disRounduppting steroidogenic *acute* regulatory (StAR) protein expression
2000

34/6/193 (Item 193 from file: 55)
0019805173 BIOSIS NO.: 200700464914
Review of *glyphosate* and ALS-inhibiting herbicide crop resistance and resistant weed management
2007

34/6/194 (Item 194 from file: 55)
18072453 BIOSIS NO.: 200400440372
Results of a 13 week safety assurance study with rats fed grain from *glyphosate*-tolerant corn
2004

34/6/195 (Item 195 from file: 50)
0008704096 CAB Accession Number: 20043187113
Responses of farmland *wildlife* to genetically modified herbicide-tolerant crops.
Publication Year: 2004

34/6/196 (Item 196 from file: 55)
18615702 BIOSIS NO.: 200510310202
Response of gill atpase and liver esterase of Pseudorasobora parva to a two month *exposure* to *glyphosate* and metsulfuron methyl
2004

34/6/197 (Item 197 from file: 71)
03298590 2005038842
Response of gill ATPase and liver esterase of Pseudorasobora parva to a two month *exposure* to *glyphosate* and metsulfuron methyl

34/6/198 (Item 198 from file: 50)
0008392481 CAB Accession Number: 20033050366
Response of Typha latifolia L. to cutting, competition, water level and *glyphosate* under field conditions.
Publication Year: 2002

34/6/199 (Item 199 from file: 55)
18716267 BIOSIS NO.: 200600061662
Roundupst control in *glyphosate*-tolerant wheat following application of the herbicide *glyphosate*
2005

34/6/200 (Item 200 from file: 55)
0019821153 BIOSIS NO.: 200700480894
Resistance to *glyphosate* in the cyanobacterium Microcystis aeRoundupginosa as
result of pre-selective *mutations*
2007

34/6/201 (Item 201 from file: 10)
4439392 43795987 Holding Library: AGL
Sublethal effects of the herbicide *glyphosate* on *amphibian* metamorphosis and development
2005

34/6/202 (Item 202 from file: 55)
18902939 BIOSIS NO.: 200600248334
Substitution of Ala-183 to Thr in 5-enolpyRoundupvylshikimste 3-phosphate
synthase of E-coli (k12) and transformation of this constRoundupct to rapeseed
(Brassica napus) for reducing of *glyphosate* affinity
2005

34/6/203 (Item 203 from file: 55)
18690500 BIOSIS NO.: 200600035895
Safety assessment and feeding value for pigs, poultry and Roundupminant animals of pest protected (Bt) plants and herbicide-tolerant (*glyphosate*, glufosinate) plants: interpretation of experimental results observed worldwide on GM plants
2004

34/6/204 (Item 204 from file: 55)
17434643 BIOSIS NO.: 200300393073
Soil biological processes are influenced by *Roundup* Ready soybean production.
2003

34/6/205 (Item 205 from file: 55)
15649416 BIOSIS NO.: 200000367729
Soil fungi and herbicidal activity of *glyphosate* on seedlings of
selected conifer and broadleaf species
2000

34/6/206 (Item 206 from file: 10)
4687654 43837865 Holding Library: AGL
Soil Microbial Activity Is Affected by *Roundup* WeatherMax and Pesticides Applied to Cotton (Gossypium hirsutum)
2006
URL: http://hdl.handle.net/10113/666

34/6/207 (Item 207 from file: 10)
4345921 43735813 Holding Library: AGL
Soil microbial and nematode communities as affected by *glyphosate* and tillage practices in a *glyphosate*-resistant cropping system
2005

34/6/208 (Item 208 from file: 10)
4070843 23329624 Holding Library: AGL

Soil carbon and nitrogen mineralization as affected by atrazine and *glyphosate*
2002

34/6/209 (Item 209 from file: 10)
4543722 43852442 Holding Library: AGL
Spatial variability of *glyphosate* mineralization and *soil* microbial characteristics in two Norwegian sandy loam *soils* as affected by surface topographical features
2006
URL: http://dx.doi.org/10.1016/j.soilbio.2005.08.014

34/6/210 (Item 210 from file: 55)
17124601 BIOSIS NO.: 200300083320
Suitability of transgenic *glyphosate*-resistant soybeans to green cloverworm (Lepidoptera: Noctuidae).
2002

34/6/211 (Item 211 from file: 55)
17658152 BIOSIS NO.: 200400028909
Synthesis, characterization, and in vitro antitumor activity of osteotropic diam(m)ineplatinum(II) complexes bearing a N,N-bis(phosphonomethyl)glycine ligand.
2003

34/6/212 (Item 212 from file: 50)
0008616052 CAB Accession Number: 20043055447
Syposium on 'A tiered assessment of Vision(R) (*glyphosate*) effects on *amphibians*', Annual Meeting of the Society of Environmental *Toxicology* and Chemistry (SETAC), 2001.
Publication Year: 2004

34/6/213 (Item 213 from file: 55)
18383270 BIOSIS NO.: 200510077770
Tolerance of Bradyrhizobium strains to *glyphosate* formulations
2005

34/6/214 (Item 214 from file: 55)
17241794 BIOSIS NO.: 200300200513
Tolerance to Hoplolaimus columbus in *glyphosate*-resistant, transgenic soybean cultivars.
2002

34/6/215 (Item 215 from file: 55)
16631351 BIOSIS NO.: 200200224862
Use of transgenic *glyphosate*-*tolerance* in sugar beet to control aphids and potato cyst nematodes
BOOK TITLE: Conference Proceedings BCPC Conference Pests Diseases
2000

34/6/217 (Item 217 from file: 154)
26328898 PMID: 17933590
Toxicity and effects of a *glyphosate* -based herbicide on the Neotropical *fish* Prochilodus lineatus.
Mar *2008*

34/6/218 (Item 218 from file: 55)

0020041052 BIOSIS NO.: 200800087991
The *toxic* effects of sub-*chronic* *exposure* of *glyphosate*-based herbicide *Roundup* on the rats
2007

34/6/219 (Item 219 from file: 154)
15950438 PMID: 15352482
Toxicity of *glyphosate*-based pesticides to four North American *frog* species.
Aug *2004*

34/6/220 (Item 220 from file: 40)
00708711 ENVIROLINE NUMBER: 07-01067
Toxicity of *Glyphosate* as Glypro and LI700 to Red-Eared Slider (Trachemys scripta elegans) Embryos and Early Hatchlings
Oct 06

34/6/221 (Item 221 from file: 10)
3885075 22090983 Holding Library: AGL
Toxicity of *glyphosate* and triclopyr using the *frog* embryo *teratogenesis* assay--Xenopus
2000

34/6/222 (Item 222 from file: 55)
17558692 BIOSIS NO.: 200300514055
Toxicity test of *roundup* on the fiddler crab Uca pugnax (Smith) and the ribbed mussel Geukensia demissa (Dillwyn).
2003

34/6/223 (Item 223 from file: 55)
17526654 BIOSIS NO.: 200300480609
A T42M substitution in bacterial 5-enolpyRoundupvylshikimate-3-phosphate synthase (EPSPS) generates enzymes with increased resistance to *glyphosate*.
2003

34/6/224 (Item 224 from file: 144)
17115056 PASCAL No.: 05-0182167
Vadose zone processes and chemical transport : *Leaching* of *glyphosate* and amino-methylphosphonic acid from danish agricultural field sites
2005

34/6/225 (Item 225 from file: 55)
17407681 BIOSIS NO.: 200300366400
Vegetation management and *ecosystem* disturbance: Impact of *glyphosate* herbicide on plant and animal diversity in terrestrial systems.
2003

34/6/226 (Item 226 from file: 55)
17816952 BIOSIS NO.: 200400184638
As the worm turns: Eisenia fetida avoids *soil* contaminated by a *glyphosate*-based herbicide.
2004

34/6/227 (Item 227 from file: 55)
17252827 BIOSIS NO.: 200300211546
The 5-enolpyRoundupvylshikimate-3-phosphate synthase of *glyphosate*-tolerant

soybean expressed in Escherichia coli shows no severe allergenicity.
2003

34/6/228 (Item 228 from file: 55)
18351483 BIOSIS NO.: 200510045983
5-EnolpyRoundupvylshikimate-3-phosphate synthase from Staphylococcus aureus is
insensitive to *glyphosate*
2005

S35 697 S31 NOT S33
S36 219 S35/2006:2008 (most recent 3 yrs of general hits)

37/6/1 (Item 1 from file: 50)
0009366526 CAB Accession Number: 20073246328
The absence of *glyphosate* *residues* in wet *soil* and the adjacent watercourse after a forestry application in new bRoundupnswick.
Publication Year: 2007

37/6/2 (Item 2 from file: 10)
4808334 43991334 Holding Library: AGL
Acute and *chronic* *toxicity* of *glyphosate* compounds to glochidia and juveniles of Lampsilis siliquoidea (Unionidae)
2007

37/6/3 (Item 3 from file: 40)
00722421 ENVIROLINE NUMBER: 07-19308
Acute and *Chronic* *Toxicity* of Pesticide Formulations (Atrazine, Chlorpyrifos, and Permethrin) to Glochidia and Juveniles of Lampsilis siliquoidea
Oct 07

37/6/4 (Item 4 from file: 154)
25219146 PMID: 17716950
Acute effects of *glyphosate* herbicide on *metabolic* and enzymatic parameters of silver catfish (Rhamdia quelen).
Nov *2007*

37/6/5 (Item 5 from file: 50)
0009432127 CAB Accession Number: 20073281121
Adsorption of *glyphosate* on clays and *soils* from Parana State: effect of pH and competitive adsorption of phosphate.
Publication Year: 2007

37/6/6 (Item 6 from file: 154)
17094058 PMID: 16785173
Agricultural pesticide *residues* in farm ditches of the Lower Fraser Valley, British Columbia, Canada.
2006

37/6/7 (Item 7 from file: 10)
4628128 43913924 Holding Library: AGL
Amphipod Performance Responses to Decaying Leaf Litter of Phragmites Australis and Typha Angustifolia from a Lake Erie Coastal Marsh
2006

URL: http://dx.doi.org/10.1672/0277-5212(2006)26[1079:APRTDL]2.0.CO;2

37/6/8 (Item 8 from file: 55)
0019757573 BIOSIS NO.: 200700417314
Applicable control measure against Orobanche ramosa in tomato plants
2007

37/6/9 (Item 9 from file: 50)
0009227830 CAB Accession Number: 20073070587
Application of a GIS-AF/RF model to assess the risk of herbicide *leaching* in a citRoundups-growing area of the Valencia Community, Spain.
Publication Year: 2006

37/6/11 (Item 11 from file: 154)
17546264 PMID: 17295264
Assessment of the potential *toxicity* of herbicides and their *degradation* products to nontarget cells using two *microorganisms*, the bacteria Vibrio fischeri and the ciliate Tetrahymena pyriformis.
Feb *2007*

37/6/12 (Item 12 from file: 154)
25582581 PMID: 17978956
Biodegradation of the herbicide *glyphosate* by filamentous fungi in platform shaker and batch bioreactor.
Nov *2007*

37/6/13 (Item 13 from file: 55)
0019837557 BIOSIS NO.: 200700497298
A bioluminescent signal system: detection of chemical *toxicants* in water
2007

37/6/14 (Item 14 from file: 50)
0009069087 CAB Accession Number: 20063141701
Chlorination kinetics of *glyphosate* and its by-products: modeling approach.
Publication Year: 2006

37/6/15 (Item 15 from file: 50)
0009091903 CAB Accession Number: 20063171894
The chemical control of the environmental weed basket asparagus (Asparagus aethiopicus L. cv. Sprengeri) in Queensland.
Publication Year: 2006

37/6/16 (Item 16 from file: 55)
0019554615 BIOSIS NO.: 200700214356
Chemical control of Prosopis farcta (Banks and Sol.) M acbride in the Jordan Valley
2007

37/6/17 (Item 17 from file: 55)
0019661984 BIOSIS NO.: 200700321725
Chemical cotton stalk destRoundupction for maintenance of host-free periods for
the control of overwintering boll weevil in tropical and subtropical climates
2007

37/6/18 (Item 18 from file: 50)
0009188168 CAB Accession Number: 20073016559
Are chemical or mechanical treatments more sustainable for forest vegetation management in the context of the TRIAD?
Publication Year: 2006

37/6/19 (Item 19 from file: 154)
17282654 PMID: 17022425
Changes in juvenile coho *salmon* electro-olfactogram during and after short-term *exposure* to current-use pesticides.
Oct *2006*

37/6/20 (Item 20 from file: 55)
19137488 BIOSIS NO.: 200600482883
Characterization of 5-enolpyRoundupvylshikimate 3-phosphate synthase gene from Camptotheca acuminata
2006

37/6/21 (Item 21 from file: 55)
19104254 BIOSIS NO.: 200600449649
Characterization of 5-enolpyRoundupvylshikimate-3-phosphate synthase from Sclerotinia sclerotioRoundupm
2006

37/6/22 (Item 22 from file: 50)
0009411658 CAB Accession Number: 20073286762
Cold weather application of *glyphosate* for garlic mustard (Alliaria petiolata) control.
Publication Year: 2007

37/6/23 (Item 23 from file: 55)
0019711535 BIOSIS NO.: 200700371276
Cloning, expression, and functional characterization of the Dunaliella salina 5-enolpyRoundupvylshikimate-3-phosphate synthase gene in Escherichia coli
2007

37/6/24 (Item 24 from file: 55)
18952798 BIOSIS NO.: 200600298193
Cultivation of black tRoundupffle to promote reforestation and land-use stability
2006

37/6/25 (Item 25 from file: 55)
0019582681 BIOSIS NO.: 200700242422
Combination effects of herbicides on plants and algae: do species and test systems matter?
2007

37/6/26 (Item 26 from file: 50)
0009077304 CAB Accession Number: 20063150473
Comparison of the behaviour of three herbicides in a field experiment under bare *soil* conditions.
Publication Year: 2006

37/6/27 (Item 27 from file: 10)
4763430 43942844 Holding Library: AGL

Comparison of Broiler Performance and Carcass Parameters When Fed Diets Containing Combined Trait Insect-Protected and *Glyphosate*-Tolerant Corn (MON 89034 x NK603), Control, or Conventional Reference Corn
2007

37/6/28 (Item 28 from file: 10)
4854853 43982937 Holding Library: AGL
Comparison of Broiler Performance and Carcass Parameters When Fed Diets Containing Soybean Meal Produced from *Glyphosate*-Tolerant (MON 89788), Control, or Conventional Reference Soybeans
2007

37/6/29 (Item 29 from file: 10)
4763428 43942842 Holding Library: AGL
Comparison of Broiler Performance When Fed Diets Containing Grain from Second-Generation Insect-Protected and *Glyphosate*-Tolerant, Conventional Control or Commercial Reference Corn
2007

37/6/30 (Item 30 from file: 50)
0009451813 CAB Accession Number: 20083034146
Comparison of broiler performance when fed diets containing event DP-356<O>43-5 (Optimum GAT), nontransgenic near-isoline control, or commercial reference soybean meal, hulls, and oil.
Publication Year: 2007

37/6/31 (Item 31 from file: 55)
0020020662 BIOSIS NO.: 200800067601
Comparison of broiler performance when fed diets containing event DP-356O43-5 (Optimum GAT), nontransgenic near-isoline control, or commercial reference soybean meal, hulls, and oil
2007

37/6/32 (Item 32 from file: 55)
0019880625 BIOSIS NO.: 200700540366
Compatibility of selected pesticides with three entomopathogenic fungi of sugarcane pests
2007

37/6/33 (Item 33 from file: 50)
0009420684 CAB Accession Number: 20083003561
Concentrations and specific loads of *glyphosate*, diuron, atrazine, nonylphenol and *metabolites* thereof in French urban sewage sludge.
Publication Year: 2007

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Publication Year: 2006

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2007

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2007

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Publication Year: 2006

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Publication Year: 2006

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intermediate analogues.
Nov 20 *2007*

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Publication Year: 2007

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Feb 06

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Jul *2007*

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Publication Year: 2007

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Publication Year: 2007

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PUBLICATION DATE: May 7, 2007

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Publication Year: 2007

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Publication Year: 2006

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Publication Year: 2007

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Effects of cover crop *residue* and preplant herbicide on early leaf spot of peanut
2007

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Publication Year: 2007

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2007

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4740621 43981564 Holding Library: AGL
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2007
URL: http://dx.doi.org/10.1007/s00128-007-9277-5

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0020061006 BIOSIS NO.: 200800107945
The effects of *glyphosate* isopropylamine and trifluralin on the carbon mineralization of olive tree *soils*
ORIGINAL LANGUAGE TITLE: Zeytin Topraklarinin Karbon Mineralizasyonuna *Glyphosate* Isopropylamine ve Trifluralin'in Etkileri
2007

37/6/57 (Item 57 from file: 50)
0009274575 CAB Accession Number: 20073141131
The effect of the *glyphosate* , 2,4-D, atrazine and nicosulfuron herbicides upon the edaphic Collembola (Arthropoda: Ellipura) in a no tillage system.
Publication Year: 2007

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Publication Year: 2007

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Effect of some herbicides on the biomass production of Trichoderma and Gliocladium spp.
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Publication Year: 2007

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2007

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Feb *2006*

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PUBLICATION DATE: *2006*

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2006

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Effect of heavy metals and herbicides on immune capacities in Pacific oyster, Crassostrea gigas .
Publication Year: 2006

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Publication Year: 2006

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Effect of lactofen application timing on yield and isoflavone concentration in soybean seed.
Publication Year: 2007

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2006

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Publication Year: 2007

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Aug *2006*

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Effects induced by agrochemical on epithelial morphology on gills of guppy (Poecilia vivipara)
2007

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0009128644 CAB Accession Number: 20063198239
Effect of integrated weed-management practices on growth and yield of wet-seeded rice (Oryza sativa) and their residual effect on succeeding pulse crop.
Publication Year: 2006

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Effect of in vivo pollutant *exposure* and pathogen injection on phagocytosis gene expression in the pacific oyster, Crassostrea gigas *2006*

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Effects of pesticides on community composition and activity of sediment microbes--responses at various levels of microbial community organization.
Apr *2008*

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17148090 PMID: 16862293
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May *2006*

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4740619 43981562 Holding Library: AGL
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URL: http://dx.doi.org/10.1007/s00128-007-9269-5

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Effects of post-emergent herbicides on Trichoderma harzianum, a potential biocontrol agent against Sclerotinia sclerotioRoundupm in soybean cropping *2007*

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Publication Year: 2007

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0009200511 CAB Accession Number: 20073055992
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Publication Year: 2007

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00708230 ENVIROLINE NUMBER: 07-00525
Influence of Watershed System Management on Herbicide Concentrations in Mississippi Delta Oxbow Lakes
Nov 1, 06

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4710422 43939195 Holding Library: AGL
  Effect of external or internal fecal contamination on numbers of bacteria on prechilled broiler carcasses
  2007

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0009185816   CAB Accession Number: 20073038175
   Effects of sublethal *glyphosate* rates on fresh market tomato.
   Publication Year: 2007

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26524182   PMID: 18453404
   Effects of *soil* phosphoRoundups status on environmental risk assessment of
glyphosate and glufosinate-ammonium.
May-Jun *2008*

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0019838201   BIOSIS NO.: 200700497942
Effect of solarization and cowpea cover crop on plant-parasitic nematodes,
  pepper yields, and weeds
2007

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0009178118   CAB Accession Number: 20073006655
   Effects of surface sorption on microbial *degradation* of *glyphosate*.
   Publication Year: 2006

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   Environmental fate and non-target impact of *glyphosate*-based herbicide (*Roundup*) in a subtropical wetland.
Mar *2008*

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0009328247   CAB Accession Number: 20073199982
   Environmental impacts of transgenic herbicide-resistant crops.
   Publication Year: 2007

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   Publication Year: 2006

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0009290078   CAB Accession Number: 20073132555
   Enzymatic activity of *soil* contaminated with triazine herbicides.
   Publication Year: 2007

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   Evaluation of herbicides against dodder (Cuscuta reflexa) infesting the hedges of bougainvillea (Bougainvillaea purpurea) and cleridendron (Cleridendron splendena).
   Publication Year: 2007

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Evaluation of Herbicide Impact on Periphyton Community StRoundupcture Using the
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PUBLICATION DATE: *2006*

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National Poisons Centre During 2005
PUBLICATION DATE: *2007*

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Publication Year: 2006

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0019498205 BIOSIS NO.: 200700157946
Evaluation of soybean cultivars with the Rps1k gene for partial resistance or field *tolerance* to Phytophthora sojae
2006

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0009192152 CAB Accession Number: 20073044758
Exploring improved pesticide management in sub-tropical environments with GIS-supported fate modeling.
Publication Year: 2006

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Expression of CP4 EPSPS in microspores and tapetum cells of cotton (Gossypium hirsutum) is critical for male *reproductive* development in response to late-stage *glyphosate* applications.
Publication Year: 2006

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Do escaped transgenes persist in nature? The case of an herbicide resistance transgene in a weedy Brassica rapa population.
Mar *2008*

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0001969157 IP ACCESSION NO: 7168505
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PUBLICATION DATE: *2006*

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00699916 ENVIROLINE NUMBER: 06-13112
Faba Bean Nitrogen Fixation in a Wheat-Based Rotation Under Rainfed Mediterranean Conditions: Effect of Tillage System
Aug-Sep 06

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Facilitated transport of diuron and *glyphosate* in high copper vineyard *soils*.
Publication Year: 2007

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Field study on the occurrence of ground beetles and spiders in genetically modified, herbicide-tolerant corn in conventional and conservation tillage systems
2006

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Publication Year: 2007

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Book Title: Environmental fate and ecological effects of pesticides
Publication Year: 2007

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Photodegradation of *glyphosate* in the ferrioxalate system.
Publication Year: 2007

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4823620 44034748 Holding Library: AGL
Fate of *glyphosate* in *soil* and the possibility of *leaching* to ground and surface waters: a review
2008
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Fate of the herbicides *glyphosate*, glufosinate-ammonium, phenmedipham, ethofumesate and metamitron in two Finnish arable *soils*.
Publication Year: 2006

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Publication Year: 2007

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Phosphate and *glyphosate* mobility in *soil* columns amended with *roundup*.
Publication Year: 2007

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Publication Year: 2006

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Publication Year: 2007

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Publication Year: 2007

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2006

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Publication Year: 2006

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Publication Year: 2006

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2006

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0009205759 CAB Accession Number: 20073058961
Herbicide effects on plant disease.
Publication Year: 2007

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18970895 BIOSIS NO.: 200600316290
Herbicidal inhibitors of amino acid biosynthesis and herbicide-tolerant crops
2006

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0002044377 IP ACCESSION NO: 8013133
Herbicide and Native Grass Seeding Effects on Sulfur Cinquefoil (Potentilla Recta) - Infested Grasslands
PUBLICATION DATE: *2008*

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Herbicidal *tolerance* of Trichoderma spp - a potential biocontrol agent of *soil* borne plant pathogens
2006

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0009323216 CAB Accession Number: 20073158143
How pesticides used on hard surfaces end up in drinking water.
Publication Year: 2006

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4575453 43878403 Holding Library: AGL
Histological, digestive, *metabolic* , hormonal and some immune factor responses in Atlantic *salmon*, Salmo salar L., fed genetically modified soybeans
2007
URL: http://dx.doi.org/10.1111/j.1365-2761.2007.00782.x

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0009466387 CAB Accession Number: 20083049186
Impact of fall and early spring herbicide applications on insect injury and *soil* conditions in no-till corn.
Publication Year: 2007

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04029149 2008079895
Impact of *glyphosate*-tolerant soybean and glufosinate-tolerant corn production on herbicide losses in surface *Roundupnoff*

37/6/129 (Item 129 from file: 55)
18804772 BIOSIS NO.: 200600150167
Improved resistance management for durable disease control: A case study of phoma stem canker of oilseed rape (Brassica napus)
2006

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In-capillary derivatization and laser-induced fluorescence detection for the analysis of organophosphoRoundups pesticides by micellar electrokinetic chromatography.
Publication Year: 2007

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Inhibition of adenosine kinase by phosphonate and bisphosphonate derivatives.
Feb *2006*

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An intercomparison study of the determination of *glyphosate* , chlormequat and mepiquat *residues* in wheat.
Publication Year: 2007

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19150209 BIOSIS NO.: 200600495604
Interactions between chemical herbicides and the candidate bioherbicide Microsphaeropsis amaranthi

2006

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The interaction between seven-year-old Pinus patula trees, competition from Roundupbus cuneifolius and herbicides in KwaZulu-Natal.
Publication Year: 2006

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Interactions of Colletotrichum tRoundupncatum with herbicides for control of scentless chamomile (Matricaria perforata)
2006

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0019659460 BIOSIS NO.: 200700319201
Interactions of alternate hosts, postemergence grass control, and rootworm-resistant transgenic corn on western corn rootworm (Coleoptera : Chrysomelidae) damage and adult emergence
2007

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4687771 43839499 Holding Library: AGL
Interference to hardwood regeneration in northeastern North America: assessing and countering ferns in northern hardwood forests
2006

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19364842 BIOSIS NO.: 200700024583
In vivo P-31 and H-1 HR-MAS NMR spectroscopy analysis of the unstarved Aporrectodea caliginosa (Lumbricidae)
2006

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03559337 2006340751
In vivo SUP31P and SUP1H HR-MAS NMR spectroscopy analysis of the unstarved Aporrectodea caliginosa (Lumbricidae)

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17138082 PMID: 16845715
Invasion and control of water hyacinth (Eichhornia crassipes) in China.
Aug *2006*

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0019693452 BIOSIS NO.: 200700353193
Isolation and *mutation* of recombinant EPSP synthase from pathogenic bacteria Pseudomonas aeRoundupginosa
2007

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Juneberry growth is affected by weed control methods.
Publication Year: 2008

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0009299102 CAB Accession Number: 20073162616
Laboratory studies on *glyphosate* transport in *soils* of the Maresme

area near Barcelona, Spain: transport model parameter estimation.
Publication Year: 2007

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0020184182 BIOSIS NO.: 200800231121
Long-term orchard groundcover management systems affect *soil* microbial communities and apple replant disease severity
2008

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03994611 2008050490
Long-term orchard groundcover management systems affect *soil* microbial communities and apple replant disease severity

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Late-season redroot pigweed control in sugarbeet with over-the-top *glyphosate*.
Publication Year: 2006

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18920500 BIOSIS NO.: 200600265895
Live shearing free-ranging guanacos (Lama guanicoe) in Patagonia for sustainable use
2006

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Microbiological parameters of *soil* set aside before and after desiccation.
Publication Year: 2006

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19076346 BIOSIS NO.: 200600421741
MicroTom-a high-throughput model transformation system for functional genomics
2006

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17075406 PMID: 16532367
Molecular identification and expression of differentially regulated genes of the European flounder, Platichthys flesus, submitted to pesticide *exposure*.
May-Jun *2006*

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0009404170 CAB Accession Number: 20073278737
Management of cotton grown under overhead sprinkle and sub-surface drip irrigation.
Publication Year: 2006

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16986026 PMID: 16586140
Managing tree-of-heaven (Ailanthus altissima) in parks and protected areas: a case study of Rondeau Provincial Park (Ontario, Canada).
Jun *2006*

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18956108 BIOSIS NO.: 200600301503
Metabonomic strategy for the investigation of the mode of action of the phytotoxin (5S,8R,13S,16R)-(-)-pyrenophorol using H-1 nuclear magnetic resonance fingerprinting
2006

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Measurement and modelling of *glyphosate* fate compared with that of herbicides replaced as a result of the introduction of *glyphosate* - resistant oilseed rape.
Publication Year: 2008

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Non-target impact of deltamethrin on *soil* arthropods of maize fields under conventional and no-tillage cultivation
2007

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26596976 PMID: 18320130
Occurrence of *glyphosate* in surface waters of southern ontario.
Apr *2008*

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0009291033 CAB Accession Number: 20073125570
Study on the photocatalytic *degradation* of *glyphosate* by TiO SUB 2 photocatalyst.
Publication Year: 2007

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4735910 43975889 Holding Library: AGL
Oviposition site selection: pesticide avoidance by gray treefrogs
2007

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0009080493 CAB Accession Number: 20063139522
Plant biotechnology: ecological case studies on herbicide resistance.
Publication Year: 2006

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0020121879 BIOSIS NO.: 200800168818
Production of cloned blastocysts using epithelial cells cultured from bovine semen
2008

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0009138214 CAB Accession Number: 20063227229
Preferential flow estimates to an agricultural tile drain with implications for *glyphosate* transport.
Publication Year: 2006

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0020052413 BIOSIS NO.: 200800099352
A preliminary investigation into the use of biosensors to screen stomach

contents for selected poisons and dRoundupgs
2007

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18831171 BIOSIS NO.: 200600176566
Prevalence and numbers of bacteria in broiler crop and gizzard contents
2006

37/6/166 (Item 166 from file: 55)
0019936303 BIOSIS NO.: 200700596044
Potential for sediment-applied acetic acid for control of invasive Spartina alterniflora
2007

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0009358321 CAB Accession Number: 20073201139
Putative porin of Bradyrhizobium sp. (Lupinus) bacteroids induced by *glyphosate*.
Publication Year: 2007

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Publication Year: 2006

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Publication Year: 2007

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Publication Year: 2007

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2006

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2007

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2006

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Jun *2007*

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2007
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Publication Year: 2008

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Publication Year: 2006

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Publication Year: 2008

Appendix N-4. Terrestrial Residue Exposure Model Output Data

Table N-49. Avian Estimated Food Consumption from TREX model

Avian Class	Body Weight (g)	Ingestion (F dry) (g bw/day)	Ingestion (F wet) (g/day)	% body wt consumed	FI (kg-diet/day)
Small	20	5	23	114	2.28E-02
Mid	100	13	65	65	6.49E-02
Large	1000	58	291	29	2.91E-01

Table N-50. Avian Adjusted Acute Toxicity Dose from TREX model

Avian Body Weight (g)	Adjusted LD50 (mg/kg-bw)
20	1440.86
100	1834.29
1000	2591.00

Table N-51. Avian Dose-based Estimated Environmental Concentration (EEC) from TREX model

Dose-based EECs (mg/kg-bw)	Avian Classes and Body Weights		
	small	**mid**	**large**
	20 g	**100 g**	**1000 g**
Short Grass	1102.93	628.94	281.58
Tall Grass	505.51	288.26	129.06
Broadleaf plants/Small Insects	620.40	353.78	158.39
Fruits/pods/seeds/Large insects	68.93	39.31	17.60

Table N-52. Mammalian Estimated Food Consumption from TREX model

Mammalian Class	Body Weight	Ingestion (Fdry) (g bwt/day)	Ingestion (Fwet) (g/day)	% body wt consumed	FI (kg-diet/day)
Herbivores/ insectivores	**15**	3	14	95	1.43E-02
	35	5	23	66	2.31E-02
	1000	31	153	15	1.53E-01
Grainvores	**15**	3	3	21	3.18E-03
	35	5	5	15	5.13E-03
	1000	31	34	3	3.40E-02

Table N-53. Mammalian Adjusted Endpoints from TREX model

Mammalian Class	Body Weight	Adjusted LD50	Adjusted NOAEL
Herbivores/ insectivores	15	9494.63	384.62
	35	7682.17	311.20
	1000	3322.77	134.60
Grainvores	15	9494.63	384.62
	35	7682.17	311.20
	1000	3322.77	134.60

Table N-54. Mammalian Dose-Based Estimated Environmental Concentration (EEC) from TREX model

Dose-Based EECs (mg/kg-bw)	Mammalian Classes and Body weight					
	Herbivores / insectivores			Granivores		
	15 g	35 g	1000 g	15 g	35 g	1000 g
Short Grass	923.31	638.13	147.95			
Tall Grass	423.19	292.48	67.81			
Broadleafplants/Small Insects	519.36	358.95	83.22			
Fruits/pods/seeds/Large insects	57.71	39.88	9.25	12.82	8.86	2.05