# Scoping/Screening Level Risk Assessment on Fluazifop-P-butyl
# FINAL REPORT

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# Preface

This is a revision to SERA TR-056-05-02-02a, Scoping/Screening Level Risk Assessment on Fluazifop-P-butyl, dated March 28, 2014. The report has been modified for compliance with Section 508 of the Rehabilitation Act of 1973 as amended by the Workforce Investment Act of 1998. The compliance report is attached to the PDF version of this risk assessment.

# Table of Contents

iv

## LIST OF TABLES

# LIST OF FIGURES

# LIST OF APPENDICES

# ACRONYMS, ABBREVIATIONS, AND SYMBOLS

| | |
|---|---|
| ACCase | acetyl coenzyme-A carboxylase |
| ACGIH | American Conference of Governmental Industrial Hygienists |
| AEL | adverse-effect level |
| a.e. | acid equivalent |
| a.i. | active ingredient |
| a.k.a. | also known as |
| a.s. | active substance |
| ALS | acetolactate synthase |
| APHIS | Animal and Plant Health Inspection Service |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| ASAE | American Society of Agricultural Engineers |
| BCF | bioconcentration factor |
| bw | body weight |
| calc | calculated value |
| CBI | confidential business information |
| ChE | cholinesterase |
| CI | confidence interval |
| cm | centimeter |
| CNS | central nervous system |
| COC | crop oil concentrates |
| DAA | days after application |
| DAT | days after treatment |
| DER | data evaluation record |
| d.f. | degrees of freedom |
| EC | emulsifiable concentrate |
| $EC_x$ | concentration causing X% inhibition of a process |
| $EC_{25}$ | concentration causing 25% inhibition of a process |
| $EC_{50}$ | concentration causing 50% inhibition of a process |
| ECOTOX | ECOTOXicology (database used by U.S. EPA/OPP) |
| EHE | 2-ethylhexyl ester |
| EFED | Environmental Fate and Effects Division (U.S. EPA/OPP) |
| ExToxNet | Extension Toxicology Network |
| F | female |
| FH | Forest Health |
| FIFRA | Federal Insecticide, Fungicide and Rodenticide Act |
| FQPA | Food Quality Protection Act |
| g | gram |
| GLP | Good Laboratory Practices |
| ha | hectare |
| HED | Health Effects Division (U.S. EPA/OPP) |
| HQ | hazard quotient |
| HRAC | Herbicide Resistance Action Committee |
| IARC | International Agency for Research on Cancer |
| IRED | Interim Reregistration Eligibility Decision |
| IRIS | Integrated Risk Information System |

| | |
|---|---|
| $k_a$ | absorption coefficient |
| $k_e$ | elimination coefficient |
| kg | kilogram |
| $K_{o/c}$ | organic carbon partition coefficient |
| $K_{o/w}$ | octanol-water partition coefficient |
| $K_p$ | skin permeability coefficient |
| L | liter |
| lb | pound |
| $LC_{50}$ | lethal concentration, 50% kill |
| $LD_{50}$ | lethal dose, 50% kill |
| LOAEL | lowest-observed-adverse-effect level |
| LOC | level of concern |
| $LR_{50}$ | 50% lethal response [EFSA/European term] |
| m | meter |
| M | male |
| mg | milligram |
| mg/kg/day | milligrams of agent per kilogram of body weight per day |
| mL | milliliter |
| mM | millimole |
| mPa | millipascal, (0.001 Pa) |
| MOS | margin of safety |
| MRID | Master Record Identification Number |
| MSDS | material safety data sheet |
| MSO | methylated seed oil |
| MW | molecular weight |
| NAWQA | USGS National Water Quality Assessment |
| NCI | National Cancer Institute |
| NCOD | National Drinking Water Contaminant Occurrence Database |
| NIOSH | National Institute for Occupational Safety and Health |
| NIS | nonionic surfactant |
| NOAEL | no-observed-adverse-effect level |
| NOEC | no-observed-effect concentration |
| NOEL | no-observed-effect level |
| NOS | not otherwise specified |
| N.R. | not reported |
| OM | organic matter |
| OPP | Office of Pesticide Programs |
| OPPTS | Office of Pesticide Planning and Toxic Substances |
| OSHA | Occupational Safety and Health Administration |
| Pa | Pascal |
| PBPK | physiologically-based kinetic |
| ppm | parts per million |
| RBC | red blood cells |
| RED | re-registration eligibility decision |
| RfD | reference dose |
| SERA | Syracuse Environmental Research Associates |

| | |
|---|---|
| TEP | typical end-use product |
| T.G.I.A. | Technical grade active ingredient |
| TIPA | Triisopropanolamine |
| TRED | Tolerance Reassessment Eligibility Decision |
| UF | uncertainty factor |
| U.S. | United States |
| USDA | U.S. Department of Agriculture |
| U.S. EPA | U.S. Environmental Protection Agency |
| USGS | U.S. Geological Survey |
| VMD | volume median diameter (for droplet size distributions) |
| WHO | World Health Organization |
| WWSA | Weed Science Society of America |

# COMMON UNIT CONVERSIONS AND ABBREVIATIONS

| To convert ... | Into ... | Multiply by ... |
|---|---|---|
| acres | hectares (ha) | 0.4047 |
| acres | square meters (m$^2$) | 4,047 |
| atmospheres | millimeters of mercury | 760 |
| centigrade | Fahrenheit | 1.8°C+32 |
| centimeters | inches | 0.3937 |
| cubic meters (m$^3$) | liters (L) | 1,000 |
| Fahrenheit | centigrade | 0.556°F-17.8 |
| feet per second (ft/sec) | miles/hour (mi/hr) | 0.6818 |
| gallons (gal) | liters (L) | 3.785 |
| gallons per acre (gal/acre) | liters per hectare (L/ha) | 9.34 |
| grams (g) | ounces, (oz) | 0.03527 |
| grams (g) | pounds, (oz) | 0.002205 |
| hectares (ha) | acres | 2.471 |
| inches (in) | centimeters (cm) | 2.540 |
| kilograms (kg) | ounces, (oz) | 35.274 |
| kilograms (kg) | pounds, (lb) | 2.2046 |
| kilograms per hectare (hg/ha) | pounds per acre (lb/acre) | 0.892 |
| kilometers (km) | miles (mi) | 0.6214 |
| liters (L) | cubic centimeters (cm$^3$) | 1,000 |
| liters (L) | gallons (gal) | 0.2642 |
| liters (L) | ounces, fluid (oz) | 33.814 |
| miles (mi) | kilometers (km) | 1.609 |
| miles per hour (mi/hr) | cm/sec | 44.70 |
| milligrams (mg) | ounces (oz) | 0.000035 |
| meters (m) | feet | 3.281 |
| ounces (oz) | grams (g) | 28.3495 |
| ounces per acre (oz/acre) | grams per hectare (g/ha) | 70.1 |
| ounces per acre (oz/acre) | kilograms per hectare (kg/ha) | 0.0701 |
| ounces fluid | cubic centimeters (cm$^3$) | 29.5735 |
| pounds (lb) | grams (g) | 453.6 |
| pounds (lb) | kilograms (kg) | 0.4536 |
| pounds per acre (lb/acre) | kilograms per hectare (kg/ha) | 1.121 |
| pounds per acre (lb/acre) | mg/square meter (mg/m$^2$) | 112.1 |
| pounds per acre (lb/acre) | μg/square centimeter (μg/cm$^2$) | 11.21 |
| pounds per gallon (lb/gal) | grams per liter (g/L) | 119.8 |
| square centimeters (cm$^2$) | square inches (in$^2$) | 0.155 |
| square centimeters (cm$^2$) | square meters (m$^2$) | 0.0001 |
| square meters (m$^2$) | square centimeters (cm$^2$) | 10,000 |
| yards | meters | 0.9144 |

Note: All references to pounds and ounces refer to avoirdupois weights unless otherwise specified.

# CONVERSION OF SCIENTIFIC NOTATION

| Scientific Notation | Decimal Equivalent | Verbal Expression |
|---|---|---|
| $1 \cdot 10^{-10}$ | 0.0000000001 | One in ten billion |
| $1 \cdot 10^{-9}$ | 0.000000001 | One in one billion |
| $1 \cdot 10^{-8}$ | 0.00000001 | One in one hundred million |
| $1 \cdot 10^{-7}$ | 0.0000001 | One in ten million |
| $1 \cdot 10^{-6}$ | 0.000001 | One in one million |
| $1 \cdot 10^{-5}$ | 0.00001 | One in one hundred thousand |
| $1 \cdot 10^{-4}$ | 0.0001 | One in ten thousand |
| $1 \cdot 10^{-3}$ | 0.001 | One in one thousand |
| $1 \cdot 10^{-2}$ | 0.01 | One in one hundred |
| $1 \cdot 10^{-1}$ | 0.1 | One in ten |
| $1 \cdot 10^{0}$ | 1 | One |
| $1 \cdot 10^{1}$ | 10 | Ten |
| $1 \cdot 10^{2}$ | 100 | One hundred |
| $1 \cdot 10^{3}$ | 1,000 | One thousand |
| $1 \cdot 10^{4}$ | 10,000 | Ten thousand |
| $1 \cdot 10^{5}$ | 100,000 | One hundred thousand |
| $1 \cdot 10^{6}$ | 1,000,000 | One million |
| $1 \cdot 10^{7}$ | 10,000,000 | Ten million |
| $1 \cdot 10^{8}$ | 100,000,000 | One hundred million |
| $1 \cdot 10^{9}$ | 1,000,000,000 | One billion |
| $1 \cdot 10^{10}$ | 10,000,000,000 | Ten billion |

# EXECUTIVE SUMMARY

1
2   Fluazifop-P-butyl is a post-emergent herbicide used to control both annual and perennial grasses.
3   This document provides a screening level/scoping risk assessment for human health effects and
4   ecological effects to support an assessment of the environmental consequences of using
5   fluazifop-P-butyl in Forest Service vegetation management programs.
6
7   In contrast to full risk assessments, scoping/screening level risk assessments are designed to
8   determine if adequate data are available for the conduct of a full risk assessment (scoping), and,
9   if possible, to give the Forest Service an indication of the most likely risks associated with the
10  use of the pesticide under consideration (screening).  The most significant differences between
11  scoping/screening level and full Forest Service risk assessments are that scoping/screening level
12  risk assessments rely more heavily on secondary sources than full risk assessments.
13
14  Formulations of fluazifop-P-butyl are not specifically labeled for applications to forests but are
15  used in forestry related applications including the control of grasses in tree farms, conifer
16  nurseries, and conifer plantations as well as applications to rights-of-way, utility lines, fence
17  lines, and several other non-crop sites.  Fluazifop-P-butyl, the active ingredient (the a.i.), is
18  rapidly converted to fluazifop-P, the acid equivalent (a.e.) which is a weak acid.  Because the a.e.
19  is much more persistent than the a.i., the exposure assessments given in the current risk
20  assessment are based on the a.e.
21
22  All indications from the Forest Service are that the most common method of application for
23  fluazifop-P-butyl, which has not been used before in Forest Service programs, will involve either
24  directed foliar (e.g., spot treatment) or broadcast foliar applications.  Fluazifop-P-butyl is also
25  labeled for aerial applications, which are considered in this risk assessment.  Fluazifop-P-butyl is
26  labeled for single application rates of about 0.1 to 0.375 lb a.i./acre (0.0854 to 0.32 lb a.e./acre).
27  The maximum seasonal application rate for fluazifop-P-butyl is 1.125 lb a.i./acre (0.96075 lb
28  a.e./acre) as three single applications of 0.375 lb a.i./acre with a minimum application interval of
29  14 days.  The current risk assessment explicitly considers a single application at the rate of 0.375
30  lb a.i./acre (0.32 lb a.e./acre) as well as both two and three applications of 0.375 lb a.i./acre with
31  a 14-day application interval.
32
33  **Human Health**
34  The quantitative risk characterization is based on the hazard quotient (HQ), which is defined as
35  the anticipated exposure divided by a toxicity value.  An HQ of greater than 1 is defined as the
36  level of concern—i.e., the exposure exceeds the level of concern.  For the human health risk
37  assessment, the toxicity values are the acute RfD of 0.43 mg a.e./kg bw/day, a surrogate
38  intermediate RfD of 0.017 mg a.e./kg bw/day for workers, and a chronic RfD of 0.0063 mg
39  a.e./kg bw/day for longer-term exposures.  As discussed in Section 3.3, these toxicity values are
40  taken from the most recent EPA human health risk assessment (U.S. EPA/OPP/HED 2011a) but
41  are adjusted from units of a.i. (fluazifop-P-butyl) to units of a.e (fluazifop-P acid).  Similarly, all
42  exposure estimates given in the workbooks that accompany this risk assessment are given in
43  units of a.e.
44
45  Based on the toxicity values and the central estimates of exposure, workers involved in ground
46  broadcast spray and aerial applications of fluazifop-P-butyl do not appear to be at risk.  This

1  conclusion is consistent with the risk characterization for these worker groups expressed in U.S.
2  EPA/OPP/HED (2011a).  The central estimate of the HQ for backpack workers (HQ=2),
3  however, modestly exceeds the level of concern.  U.S. EPA/OPP/HED (2011a) does not assess
4  backpack workers.  Based on upper bound estimates of exposures, most of the HQs exceed the
5  level of concern by factors of up to 43.  These estimates indicate that measures to limit or
6  otherwise mitigate worker exposures are warranted.
7
8  For the general public, none of the acute exposure scenarios substantially exceed the level of
9  concern, except for accidental exposure scenarios involving a spill of fluazifop-P-butyl into a
10 small pond.  At the upper bounds, the acute (non-accidental) exposure scenario for the
11 consumption of contaminated vegetation reaches the level of concern following one application
12 (HQ=1) and modestly exceeds the level of concern following two applications (HQ=1.3) and
13 three applications (HQ=1.4).
14
15 Longer-term exposure scenarios involving the consumption of contaminated vegetation are a
16 much greater concern than acute exposures with the central estimates of longer-term exposures
17 reaching the level of concern following one application (HQ=1) and exceeding the level of
18 concern following two applications (HQ=2) and three applications (HQ=3).  The upper bound
19 HQs for these scenarios substantially exceed the level of concern—i.e., upper bound HQs of 10
20 following a single application, 19 following two applications, and 29 following three
21 applications.  The longer-term exposure scenarios involving dietary exposure developed in the
22 current Forest Service risk assessment are much more severe than the dietary exposure scenarios
23 used in U.S. EPA risk assessments.  Nonetheless, the exposure scenarios for the consumption of
24 contaminated vegetation reflect potential exposures for individuals consuming treated vegetation
25 following forestry applications of fluazifop-P-butyl.  These longer-term scenarios for the
26 consumption of contaminated vegetation are standard exposure scenarios used in all Forest
27 Service risk assessments for pesticides applied to vegetation and are considered relevant by the
28 Forest Service.
29
30 While the risk characterization for fluazifop-P-butyl is relatively severe, particularly for longer-
31 term exposure scenarios, the approach used in the current risk assessment is not the most
32 conservative approach that could be adopted.  As discussed in the dose-response assessment for
33 chronic toxicity (Section 3.3.2), the chronic RfD for fluazifop-P-butyl is based on a NOAEL of
34 0.75 mg a.i./kg bw/day from a reproduction study in rats.  A standard chronic toxicity study in
35 rats yields a somewhat lower NOAEL of 0.5 mg a.i./kg bw/day.  The rationale for using the
36 higher NOAEL is not clearly articulated in the EPA risk assessments on fluazifop-P-butyl.  If the
37 lower NOAEL were used to derive a chronic RfD, the HQs discussed above would increase by a
38 factor of 1.5.  Adopting a lower RfD, however, would not have a substantial qualitative impact
39 on the risk characterization, and the current Forest Service risk assessment defers to the most
40 recent EPA human health risk assessment (U.S. EPA/OPP/HED 2011a).
41

**Ecological Effects**

Fluazifop-P-butyl is an effective herbicide for the control of many annual and perennial grass weeds (i.e., Poaceae monocots); however, it is much less toxic to dicots and non-Poaceae monocots. Consequently, applications of fluazifop-P-butyl do not appear to pose a risk to terrestrial dicots or non-Poaceae monocots. This risk characterization is supported by several field studies. Consistent with the labelled uses of fluazifop-P-butyl, this herbicide is more toxic in post-emergent foliar applications than pre-emergent/soil applications. Drift is the scenario of greatest concern for nontarget sensitive Poaceae monocots. Adverse effects in sensitive species of nontarget plants (i.e., Poaceae) could also occur in some cases if contaminated water is used for irrigation. Runoff and wind erosion of soil from the treated site do not appear to pose risks to nontarget plants.

The risk characterization of mammals and birds is constrained by the lack of field studies involving exposure of mammals and birds to applications of fluazifop-P-butyl. Consequently, the risk characterization is based solely on laboratory studies and modeled estimates of exposure. Longer-term exposures to mammals and birds are a concern for exposure scenarios involving the consumption of contaminated vegetation. Following three applications, the upper bound HQs reach up to 57 for a small bird and 146 for a small mammal. Following one or two applications, the HQs are lower, but some scenarios exceed the level of concern (HQ=1). The HQs for mammals are of greater concern because of a possible association between exposure levels and endpoints involving reproductive capacity (i.e., decreased testes weight). There are no data to suggest that levels of long-term exposure to fluazifop-P-butyl will cause adverse effects in birds. Furthermore, acute exposures associated with the consumption of contaminated vegetation by birds do not appear to pose a hazard. For mammals, some of the acute HQs associated with the consumption of contaminated vegetation exceed the level of concern (i.e., a maximum HQ of 7). The highest levels of exposure are associated with the consumption of contaminated short grasses, which enhances the level of concern for acute exposures, because fluazifop-P-butyl is applied to grasses. For chronic exposures, the consumption of treated contaminated grasses is less plausible, because fluazifop-P-butyl will kill most treated grasses with the exception of resistant grasses. Exposure scenarios for mammals and birds involving contaminated water are of much less concern than those associated with contaminated vegetation. This is a common pattern in herbicide risk assessments. Some scenarios for the consumption of contaminated fish by a canid, large mammalian carnivore, and piscivorous bird result in HQs that exceed the level of concern at the upper bounds of estimated exposures.

For most herbicides, risks to terrestrial invertebrates are characterized using toxicity data on the honeybee as a surrogate species. Based on these data, no risks to terrestrial insects would be anticipated. For fluazifop-P-butyl, however, toxicity data are available from the European literature and some mesocosm and field studies published in the open literature. Based on the results of one bioassay on a predatory mite (*Typhlodromus pyri*), risks to sensitive species of terrestrial arthropods could be substantial (i.e., an HQ of 80 for direct spray). Based on another bioassay in this species as well as toxicity data on other terrestrial arthropods, risks are apparent but could be much lower (i.e., an HQ of 2 for direct spray). Many of the most relevant studies are summarized only briefly in a review by the European Food Safety Authority (EFSA 2012). The full studies summarized in EFSA (2012) were not available for the preparation of the current risk assessment and no interpretation of the inconsistent toxicity data on *Typhlodromus pyri* can

1    be offered.  Published field studies indicate that applications of fluazifop-P-butyl used to enhance
2    the growth of wildflowers can be beneficial to both bees and butterflies.  These field studies,
3    however, do not exclude the possibility of direct adverse effects in sensitive species of terrestrial
4    arthropods.
5
6    The risk characterization for aquatic plants is variable.  The characterization of risks to aquatic
7    macrophytes is limited in that data are available on only one genus, *Lemna*, an aquatic non-
8    Poaceae monocot.  No risks to *Lemna* are anticipated, even in the event of an accidental spill.
9    By analogy to the more extensive data on terrestrial plants, it seems likely that risks to aquatic
10   dicots and other non-Poaceae monocots would also be low.  In the absence of toxicity data,
11   potential risks to aquatic Poaceae monocots are a concern; however, these risks cannot be
12   assessed quantitatively.  Some species of algae do appear to be at risk (HQs up to 150) in non-
13   accidental exposure scenarios.  Both sensitive and tolerant species of algae could be adversely
14   affected in the event of an accidental spill.
15
16   The risk characterization for aquatic animals is somewhat less variable than that for aquatic
17   plants.  Except for an accidental spill, exposure scenarios involving fish do not appear to present
18   a risk.  Aquatic invertebrates are more sensitive than fish to fluazifop-P-butyl.  While the central
19   estimates and lower bounds of exposures are not a concern, some of the upper bound estimates
20   of exposure lead to HQs (1.4 to 4) that modestly exceed the level of concern (HQ=1).
21
22   While relatively little information is available on soil-dwelling organisms including soil
23   microorganisms, this information suggests that fluazifop-P-butyl is not likely to adversely affect
24   this group of organisms.
25
26   No data are available on the toxicity of fluazifop-P-butyl to reptiles and amphibians.
27   Consequently, no risk characterization is developed for these groups of organisms.
28
29   While the risk characterization for fluazifop-P-butyl focuses on the potential for direct toxic
30   effects, there is potential for secondary effects in virtually all groups of nontarget organisms.
31   Terrestrial applications of any effective herbicide, including fluazifop-P-butyl, are likely to alter
32   vegetation within the treatment area.  This alteration could have secondary effects on terrestrial
33   or aquatic animals, including changes in food availability and habitat quality.  These secondary
34   effects may be beneficial to some species (e.g., bees and butterflies as noted above) and
35   detrimental to other species; moreover, the magnitude of secondary effects is likely to vary over
36   time.  While these concerns are acknowledged, they are not specific to fluazifop-P-butyl or
37   herbicide applications in general.  Any effective method for vegetation management, including
38   mechanical methods which do not involve fluazifop-P-butyl or any other herbicide, could be
39   associated with secondary effects on both animals and nontarget vegetation.

# 1. INTRODUCTION

## 1.1. Chemical Specific Information

### 1.1.1. General Considerations

Fluazifop-P-butyl is an herbicide used to control both annual and perennial grasses. This document provides a screening level/scoping risk assessment for human health effects and ecological effects associated with the use of fluazifop-P-butyl in Forest Service vegetation management programs.

In contrast to full risk assessments, scoping/screening level risk assessments are designed to determine if adequate data are available for the conduct of a full risk assessment (scoping) and, if possible, to give the Forest Service an indication of the most likely risks associated with the use of the pesticide under consideration (screening). The most significant differences between scoping/screening level and full Forest Service risk assessments are that scoping/screening level risk assessments rely more heavily on secondary sources than full risk assessments and may not subject to peer review. Although the Forest Service has elected to have the current risk assessment peer reviewed, the discussion of studies on most groups of nontarget organisms is still based largely on summaries of studies provided in U.S. EPA/OPP risk assessments rather than full copies of or Data Evaluation Records for the studies submitted to the U.S. EPA/OPP. A major exception to the reliance of secondary sources involves the substantial open literature on terrestrial plants which is addressed in some detail in the current risk assessment.

This risk assessment is somewhat complicated by the various forms of fluazifop (Table 1). As with several herbicides, fluazifop is a carboxylic acid and fluazifop-butyl is the butyl ester of this acid. As discussed further in Section 2.2.1, the fluazifop acid has a chiral carbon and thus can form enantiomers, stereoisomers that are nonsuperimposable mirror images of each other. Fluazifop-P-butyl is the butyl ester of fluazifop-P, which is the [R] enantiomer of fluazifop.

Also as with several herbicides that are esters of weak acid, fluazifop-P is the active herbicidal agent. Fluazifop-P-butyl is rapidly hydrolyzed to fluazifop-P both by plants and in soil (Section 2.2.1). Consequently, data on both fluazifop-P-butyl and fluazifop-P are covered in the current risk assessment. In addition, fluazifop-butyl (i.e., a mixture of [R] and [S] enantiomers) is metabolized in mammals predominantly (97%) to the [R] enantiomer, fluazifop-P. Thus, fluazifop-butyl and fluazifop-P-butyl are … "*similar, if not identical in toxicity*" (U.S. EPA/OPP/HED 2004a), at least in mammals. Because of these similarities in toxicity, the current risk assessment addresses studies not only on the [R] enantiomers, fluazifop-P-butyl and fluazifop-P, but also studies on mixtures of the enantiomers.

Throughout this risk assessment, the nomenclature summarized in Table 1 is used to differentiate among the different agents under consideration. Following the approach used by U.S. EPA/OPP/HED (2004a), the notations *[R]* and *[S]* are used to identify the individual stereoisomers of both the acid and ester. If the test agent is a mixture of the enantiomers, the *[RS]* notation is used—e.g., [RS] fluazifop or [RS] fluazifop-P-butyl. When the stereochemical composition is not clearly indicated in the available studies, the term *fluazifop* is used for the acid and the term *fluazifop- butyl* is used for the ester without the *[RS]* notation. The terms

1  *fluazifop* and *fluazifop-butyl* are also used when a statement is made that applies equally to the
2  enantiomers.
3
4  Also following the convention used in U.S. EPA/OPP/HED (2004a) as well as the great
5  preponderance of the literature on fluazifop and fluazifop-butyl, *fluazifop-P* is used rather than
6  the equivalent term *[R] fluazifop* for both the acid and the ester.  The origin of and rationale for
7  the *-P* notation as a convention to designate the [R] stereoisomer is not clear; however, this
8  convention is used almost universally in the literature for fluazifop-P as well as similar
9  herbicides such as quizalofop-P (e.g., Mallory-Smith and Retzinger 2003).

## 10    1.1.2. Available Reviews
11  As noted above, the current document is a scoping/screening level risk assessment and relies
12  heavily on existing reviews, which is not the case in a full Forest Service risk assessment.  Table
13  2 summarizes the reviews identified to date on the toxicity and environmental fate of fluazifop-
14  P-butyl and related compounds.  In an attempt to ensure that the most recent U.S. EPA/OPP
15  reviews were identified, Freedom of Information Act (FOIA) requests were submitted to the U.S.
16  EPA (EPA-HQ-2013-009201, EPA-HQ-2013-010361).  In response, U.S. EPA provided the
17  most recent human health risk assessment (U.S. EPA/OPP/HED 2011a) and most recent
18  ecological risk assessments (U.S. EPA/OPP/EFED 2008, 2010a).
19
20  In terms of the human health risk assessment, the available reviews on fluazifop-P-butyl clearly
21  support the development of a screening level risk assessment.  The U.S. EPA's Office of
22  Pesticide Programs has prepared several human health risk assessments on fluazifop-P-butyl that
23  are extremely detailed (e.g., U.S. EPA/OPP/HED 2004a; 2005a; 2011a).  In addition, these EPA
24  risk assessments are supported by several additional documents that address special topics
25  relating to both potential health effects (U.S. EPA/OPP/HED 2004b,c) as well as exposure (U.S.
26  EPA/OPP/HED 2010c,e).  These EPA documents are the basis for the information used in the
27  human health risk assessment presented in Section 3.  Information from these EPA documents is
28  supplemented by several recent reviews from Europe (EFSA 2012; European Commission
29  2011a), a summary of registrant studies by the California EPA (CalEPA 2002) and a published
30  review by one of the developers of fluazifop-P-butyl (Ishihara Sangyo Kaisha 1990).  All of
31  these reviews focus on registrant-submitted studies, which are classified as Confidential Business
32  Information (CBI) and are not publically available.  Accordingly, the full studies were not
33  available for the conduct of the current risk assessment.  Nonetheless, the EPA risk assessments
34  and related documents, supplemented by the other reviews noted above, provide a robust and
35  credible summary of the registrant studies relating to human health effects.
36
37  The available reviews on the ecological effects of fluazifop-P-butyl also support the development
38  of a screening level risk assessment.  As noted above, the U.S. EPA provided two recent
39  ecological risk assessments on fluazifop-P-butyl (U.S. EPA/OPP/EFED 2008, 2010a).  The most
40  recent document, however, provides only a brief and cursory summary of the registrant-
41  submitted studies and would not, in itself, be sufficient in support of a screening level
42  assessment.  The 2008 document, however, is a standard and complete U.S. EPA/OPP/EFED
43  ecological risk assessment and is sufficient to support a screening level ecological risk
44  assessment.  A limitation in U.S. EPA/OPP/EFED (2008) risk assessment, however, is that the
45  summaries of acute toxicity studies for several groups of organisms (e.g., fish and aquatic

1    invertebrates) report $LC_{50}$ values but not NOAECs.  As discussed further in Section 4, the Forest
2    Service prefers to use NOAECs rather than $LC_{50}$ values for risk characterizations.
3
4    The limitation in the data summaries provided in U.S. EPA/OPP/EFED (2008) is addressed, at
5    least partially, using ECOTOX, an ECOTOXicology Database available at
6    http://cfpub.epa.gov/ecotox/.  This database contains reasonably detailed albeit tabular
7    summaries of several registrant-submitted studies on the toxicity of fluazifop-P-butyl and related
8    compounds to several groups of organisms—e.g., fish, aquatic invertebrates, aquatic plants,
9    birds, and nontarget plants.  Information from ECOTOX is supplemented by information from
10   Pesticide Ecological Effects Database (U.S. EPA/OPP 2005b) which provides additional details
11   on studies summarized in ECOTOX.  The information from the ECOTOX databases is
12   considered reliable and is used directly in the current Forest Service risk assessment.
13
14   ECOTOX (2013) also contains summaries of open literature publications.  As discussed below,
15   the open literature studies were obtained for the current risk assessment.  While ECOTOX
16   summaries of open literature studies are not used directly, they provide a measure of quality
17   assurance for the discussion of the open literature studies.
18
19   A recent review by the European Food Safety Commission (EFSA 2012) contains information
20   on the ecological effects of fluazifop-P-butyl.  Some of the study summaries from this review are
21   detailed and are used in the current risk assessment to supplement the data from ECOTOX
22   (2013).  Other reviews (European Commission 2011b; Tomlin 2004) are less detailed and are
23   used only to ensure that all relevant information has been identified.
24
25   The publication by Nishiuchi and Asano (1979) is a compendium of toxicity values on several
26   pesticides including fluazifop-P-butyl.  This article is written in Japanese but is summarized in
27   ECOTOX.  As noted in Table 2, data from Nishiuchi and Asano (1979) has been rejected by the
28   U.S. EPA/OPP in several risk assessments on the California Red-legged Frog (e.g., U.S.
29   EPA/OPP 2009b) because control groups were not used in the study.  Data from the compendia
30   by Nishiuchi and Asano (1979) are discussed in Section 4.1 as appropriate but are not used
31   quantitatively in this risk assessment.
32
33   In the U.S. EPA registration review program, pesticide registrations are reviewed on a 15-year
34   cycle.  According to U.S. EPA/OPP (2013a), the EPA will not be opening a docket on the
35   registration review of fluazifop-P-butyl until 2015.  Thus, the EPA's registration review
36   documents are not available for the current risk assessment.
37
38   A scoping/screening level risk assessment on clethodim was recently prepared for the Forest
39   Service (SERA 2013a).  While fluazifop-P-butyl is an aryloxyphenoxy propionate herbicide and
40   clethodim is a cyclohexanedione herbicide, both classes of herbicides share a similar mechanism
41   of action—i.e., the inhibition of acetyl coenzyme-A carboxylase (ACCase) activity.
42   Consequently, and in the interest of economy, some of the discussions of mechanism of action
43   and related literature in SERA (2013a) are incorporated into the current document on fluazifop-
44   P-butyl.

1    **1.1.3. Scoping of Open Literature**
2    As part of the scoping effort, an initial search of the open literature was conducted using
3    TOXLINE (http://toxnet.nlm.nih.gov) and ECOTOX (http://cfpub.epa.gov/ecotox/).  A topical
4    overview of the open literature on fluazifop-P-butyl and related compounds is provided in Table
5    3. While the open literature on fluazifop-P-butyl is modest (i.e., a total of 92 citations in the
6    initial TOXLINE search), the open literature on fluazifop-P-butyl and other related compounds
7    (Table 1) is substantial (i.e., a total of 545 citations in initial TOXLINE search).

8    *1.1.3.1. Human Health Effects*
9    In terms of the human health risk assessment, many studies are available in the open literature.
10   As summarized in the upper portion of Table 3, these studies include several publications on
11   dermal absorption, mechanism of action, metabolism/pharmacokinetics, toxicology, and worker
12   exposure.  The most important studies appear to be those on dermal absorption and worker
13   exposure.  As detailed in Section 3.2, several exposure assessments for the general public and
14   workers involve dermal absorption, and workers are the group most likely to encounter the
15   highest levels of exposure.  While the current document is a screening-level risk assessment,
16   these studies are reviewed in some detail and are used quantitatively in the human health risk
17   assessment.  The other studies on humans and experimental mammals do not quantitatively
18   impact the risk assessment but are incorporated at least briefly into the human health risk
19   assessment as appropriate.

20   *1.1.3.2. Terrestrial Plants*
21   The published literature relevant to the ecological risk assessment is focused largely on effects in
22   plants.  This focus would be expected for any herbicide that has been in use for over 25 years.  In
23   Table 3, the list of studies under general effects in terrestrial plants includes only those papers
24   that have information relating to effects on nontarget plants.  Many more papers on efficacy are
25   available, and some of these efficacy studies are listed in Section 5 (References) and summarized
26   further in Appendix 4 (Table A4-6).  As with all Forest Service risk assessments on herbicides,
27   efficacy studies are not covered extensively; nevertheless, some of these studies are used to
28   define differences in sensitivity between target and nontarget plants.   Table 3 also summarizes
29   studies concerned specifically with toxicity to nontarget plants.  U.S. EPA/OPP risk assessments
30   typically focus on registrant-submitted studies rather than phytotoxicity studies from the open
31   literature; however, that is not the case with fluazifop-P-butyl.  As discussed in Section 4.1.2.5,
32   the U.S. EPA/OPP waived the requirement for standard Tier 2 assays for effects on dicots and
33   monocots.  Consequently, the studies on nontarget plants from the open literature are used
34   quantitatively in the current risk assessment.  There are several studies that address the
35   development of resistance in target plant species.  Although the issue of resistance relates
36   primarily to efficacy, these studies are discussed briefly with a focus on the apparent
37   mechanisms of resistance and the quantitative measures of resistance (Section 4.1.2.5.5).

38   *1.1.3.3. Other Terrestrial Species*
39   There is relatively little information regarding the effects of fluazifop-P-butyl and other related
40   compounds on terrestrial nontarget groups.  The three avian studies (Varnagy et al. 1996, 1999;
41   Varga et al. 1999) are from the Hungarian literature but are published in English.  The earlier
42   study by Varnagy et al. (1996), which involved exposures to chicken eggs, is not used
43   quantitatively.

Most of the studies regarding the effects of fluazifop-P-butyl and related compounds on terrestrial insects (Table 3) involve secondary effects due to phytotoxicity. Fluazifop-P-butyl is noted specifically by the Fish and Wildlife Service (2012a,b) as a concern for endangered and threatened butterflies, with particular reference to the study by Russell and Schultz (2010). This study is discussed in Section 4.1.2.4 along with a field study on the impact of fluazifop-P-butyl on butterflies (Blake et al. 2011a).

Forest Service risk assessments always consider information on the effects of pesticides on microorganisms, and there are several relevant studies in the open literature (Table 3).

No information on the toxicity of fluazifop-P-butyl or related compounds to reptiles or amphibians were encountered in the published literature; furthermore, no form of fluazifop is included in the Database of Reptile and Amphibian Toxicology Literature (Pauli et al. 2000). The lack of toxicity data on reptiles and amphibians is common even for pesticides with a substantial open literature.

### 1.1.3.4. Aquatic Species
The open literature concerning the effects of fluazifop-P-butyl and related compounds on aquatic animals is limited to two studies on fish (Schramm et al. 1998; Tejada et al. 1994) and two studies on aquatic invertebrates (Tantawy 2002; Zidan et al. 2002). The data on aquatic plants are more abundant; however, most of the studies are on algae (Table 3), including a series of publications by Ma and coworkers (Ma 2002; Ma et al. 2002a,b, 2004, 2006), which are commonly used in both EPA and Forest Service risk assessments. There is only one study on aquatic macrophytes (Michel et al. 2004). The lack of multiple studies on aquatic macrophytes is not unusual for pesticide registrations.

### 1.1.3.5. Chemical Properties, Environmental Fate, and Monitoring
The information on the chemical properties and environmental fate of fluazifop-P-butyl and related compounds is adequate to support a risk assessment. While the literature from U.S. EPA/OPP (Section 1.2.3) is adequate to support exposure assessments for fluazifop-P-butyl, environmental fate studies in the open literature are useful and are cited in both EPA assessments and the current Forest Service risk assessment. In addition, several monitoring studies are available in which fluazifop was detected in surface water.

## 1.1.4. Conclusions in Scoping
The readily available data on fluazifop-P-butyl and related compounds are clearly adequate to support a screening level risk assessment. Moreover, the level of detail in EPA studies on mammals and the additional human exposure studies from the open literature would support a standard peer reviewed risk assessment.

The data available to support the ecological risk assessment are more limited. For some groups of organisms (e.g., mammalian wildlife and terrestrial as well as aquatic plants), the data are sufficient to support both a screening level risk assessment as well as a standard peer reviewed risk assessment. The quality of summaries of the studies on birds and aquatic animals is more limited. Nonetheless, the study summaries from ECOTOX and the risk assessments from U.S. EPA/OPP support a screening level assessment.

In addition to the FOIA to the U.S. EPA (Section 1.1.2), SERA contacted Syngenta Crop Protection, LLC ("Syngenta").   As discussed in Section 2.2, Syngenta is the primary registrant for fluazifop-P-butyl and is responsible for the majority of studies submitted to U.S. EPA/OPP in support of the registration.  Syngenta kindly provided a number of Data Evaluation Records (DERs) to SERA. DERs are summaries and evaluations of registrant-submitted studies prepared by the U.S. EPA.  The information from the DERs is incorporated into this risk assessment and is discussed in several subsections of the ecological risk assessment (Section 4.0) as appropriate.

## 1.2. General Information

This document has four chapters, including the introduction, program description, risk assessment for human health effects, and risk assessment for ecological effects or effects on wildlife species.  Each of the two risk assessment chapters has four major sections, including an identification of the hazards, an assessment of potential exposure to this compound, an assessment of the dose-response relationships, and a characterization of the risks associated with plausible levels of exposure.

This is a technical support document which addresses some specialized technical areas. Nevertheless an effort was made to ensure that the document can be understood by individuals who do not have specialized training in the chemical and biological sciences.  Certain technical concepts, methods, and terms common to all parts of the risk assessment are described in plain language in a separate document (SERA 2011a).  The human health and ecological risk assessments presented in this document are not intended to be comprehensive summaries of all of the available information.  Nonetheless, the information presented in the appendices and the discussions in chapters 2, 3, and 4 of the risk assessment are intended to be detailed enough to support a review of the risk analyses.

As discussed in Section 1.1, the Forest Service may update and/or expand this risk assessment and welcomes input from the general public and other interested parties on the selection of studies included in the risk assessment.  This input is helpful, however, only if recommendations for including additional studies specify why and/or how the new or not previously included information would be likely to alter the conclusions reached in the risk assessments.

As with all Forest Service risk assessments, almost no risk estimates presented in this document are given as single numbers.  Usually, risk is expressed as a central estimate and a range, which is sometimes quite large.  Because of the need to encompass many different types of exposure as well as the need to express the uncertainties in the assessment, this risk assessment involves numerous calculations, most of which are relatively simple.  Simple calculations are included in the body of the document [typically in brackets].  The results of some calculations within brackets may contain an inordinate number of significant figures in the interest of transparency – i.e., to allow readers to reproduce and check the calculations.  In all cases, these numbers are not used directly but are rounded to the number of significant figures (typically two or three) that can be justified by the data.

Some of the calculations, however, are cumbersome.  For those calculations, EXCEL workbooks (sets of EXCEL worksheets) are included as attachments to this risk assessment.  As discussed further in Section 2.4, three workbooks are included with the current risk assessment— Attachment 1 for a single application, Attachment 2 for two applications, Attachment 3 for three

1    applications of fluazifop-P-butyl.  The worksheets in these workbooks provide the detail for the
2    exposure estimates and hazard quotients cited in the body of the document.  Documentation for
3    the use of these workbooks is presented in SERA (2011b).
4
5    The EXCEL workbooks are an integral part of the risk assessment.  The worksheets contained in
6    these workbooks are designed to isolate the numerous calculations from the risk assessment
7    narrative.  In general, all calculations of exposure scenarios and quantitative risk
8    characterizations are derived and contained in the worksheets.  In these worksheets as well as in
9    the text of this risk assessment, the hazard quotient is calculated as the ratio of the estimated
10   exposure to a toxicity value, typically a no adverse effect level or concentration (i.e., NOAEL or
11   NOAEC).  Both the rationale for the calculations and the interpretation of the hazard quotients
12   are contained in this risk assessment document.
13

# 2. PROGRAM DESCRIPTION

## 2.1. Overview

Fluazifop-P-butyl is a selective postemergence herbicide used for the control of annual and perennial grass weeds. Formulations of fluazifop-P-butyl are not specifically labeled for applications to forests but are used in forestry related applications including the control of grasses in tree farms, conifer nurseries, and conifer plantations as well as applications to rights-of-way, utility lines, fence lines, and several other non-crop sites.

Fluazifop-P-butyl was developed in the late 1980s and is currently off patent. Consequently, numerous fluazifop-P-butyl formulations are available; however, they are not all labeled for uses relevant to Forest Service programs. For the current risk assessment, Fusilade DX is taken as the representative formulation most likely to be used by the Forest Service. Fusilade DX and many other formulations of fluazifop-P-butyl contain inerts including petroleum distillates. The potential impact of these inert components on this risk assessment is discussed in Section 3.1.14 (human health) and Section 4.1 (ecological effects).

Fluazifop-P-butyl, the active ingredient (the a.i.), is rapidly converted to fluazifop-P, the acid equivalent (a.e.) which is a weak acid. Because the a.e. is much more persistent than the a.i., the exposure assessments given in the current risk assessment are based on the a.e. While most toxicity studies on fluazifop-P-butyl present values in units of a.i., these values are converted to units of a.e. in the development of the risk characterization using a conversion factor of 0.854 a.e./a.i [327.26 g/mole fluazifop-acid divided by 383.37 g/mole fluazifop-butyl rounded to three significant place following the decimal], the same a.i. to a.e. conversion factor used in U.S. EPA/OPP/EFED (2008).

All indications from the Forest Service are that the most common method of application for fluazifop-P-butyl, which has not previously been used in Forest Service programs, will involve either directed foliar (e.g., spot treatments) or broadcast foliar applications. Fluazifop-P-butyl is also labeled for aerial applications, which are considered in this risk assessment. Fluazifop-P-butyl is labeled for single application rates of about 0.1 to 0.375 lb a.i./acre (0.0854 to 0.32 lb a.e./acre). The maximum seasonal application rate for fluazifop-P-butyl is 1.125 lb a.i./acre (0.96075 lb a.e./acre) as three single applications of 0.375 lb a.i./acre with a minimum application interval of 14 days. The current risk assessment explicitly considers both a single application at the rate of 0.375 lb a.i./acre (0.32 lb a.e./acre) as well as both two and three applications of 0.375 lb a.i./acre with a 14-day application interval—i.e., the three-application scenario is the maximum seasonal rate. The consequences of using lower application rates are discussed in the risk characterization for human health effects (Section 3.4) and ecological effects (Section 4.4).

Because fluazifop-P-butyl has not been used previously in Forest Service programs, the impact of its use by the Forest Service relative to agricultural use cannot be assessed directly. Based on use statistics from California, however, it appears that agricultural uses of fluazifop-P-butyl are much greater than forestry related uses.

1    **2.2. Chemical Description and Commercial Formulations**

2      **2.2.1. Chemical Structures and Stereochemistry**
3    Most Forest Service risk assessments do not require an elaborate discussion of chemical
4    structure; however, fluazifop-P-butyl is atypical because of issues associated with
5    stereochemistry and metabolites.  Table 1 provides an overview of the major chemical structures
6    discussed in this section, and the relevance of these structures to the risk assessment is discussed
7    below.
8
9    Fluazifop-P-butyl is the common name for butyl (R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]
10   phenoxy] propanoate:
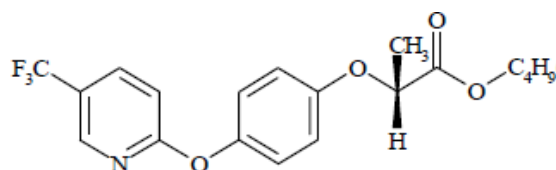


11
12   Fluazifop-P-butyl is the butyl alcohol (HO-CH$_2$-CH$_2$-CH$_3$) ester of fluazifop-P,
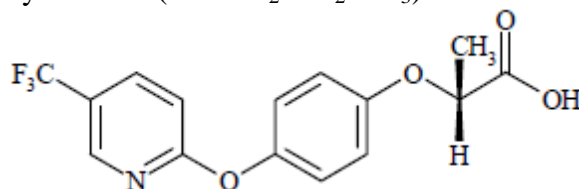


13
14   which is more formally referred to as (R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl] oxy] phenoxy]
15   propanoic acid following CAS naming conventions.
16
17   Fluazifop-P is also an ester – i.e., the ester of 4-((5-(trifluoromethyl)-2-pyridinyl)oxy)-phenol
18   [CAS No. 69045-85-8]
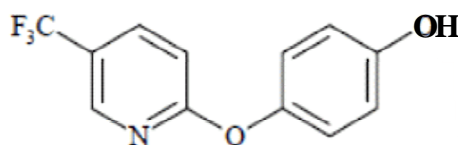


19
20   with (R)-2-hydroxypropionic acid,
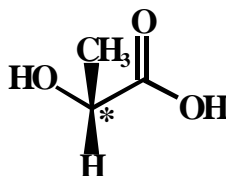


21
22   which is more commonly referred to as [R]-lactic acid.
23
24   The 2-carbon in lactic acid (marked above with an asterisk) has four different substituents,
25   including a hydrogen, a hydroxyl group (OH), a methyl group (CH$_3$), and a carboxylic acid
26   group (COOH).  The 2-carbon of lactic acid is referred to as *chiral*, indicating the compound can
27   form nonsuperimposable mirror images (i.e., enantiomers) which are often referenced as the left-
28   handed [S] enantiomer and right-handed [R] enantiomer.  The triangular thick lines in the above
29   illustration of [R]-lactic acid are a convention to indicate that methyl and hydrogen substituents

9

of the chiral carbon are above the plane of the image. As illustrated above, the chirality of lactic acid carries over to the structures of both fluazifop-P and fluazifop-P-butyl.

A consideration of the stereochemistry of fluazifop-P-butyl is important to the current risk assessment for several reasons. In terms of herbicidal activity, only the [R] enantiomer is active (e.g., Gronwald 1991). This pattern, however, does not hold for other groups of organisms. As noted in Section 1.1.1 and detailed further in the human health risk assessment (Section 3) and ecological risk assessment (Section 4), the information in the open literature as well as the unpublished studies on fluazifop-P-butyl is limited; however, it appears that the toxicity of fluazifop-P-butyl to animals is similar to that of [RS] fluazifop-butyl. In addition, the [S] enantiomer of fluazifop-butyl is hydrolyzed in soil to [S]-fluazifop which is then converted to [R]-fluazifop within 1 to 2 days (Bewick 1986; Gronwald 1991; Muller and Buser 1997). Consequently, it is sensible to consider information on fluazifop-butyl (i.e., enantiomer blends) as well as fluazifop-P-butyl in order to expand the data that may be used in the current risk assessment.

## 2.2.2. Active Ingredient and Acid Equivalents

Fluazifop-P-butyl is a member of the aryloxyphenoxy propionate herbicides which include clodinafop, cyhalofop-butyl, diclofop, fenoxaprop, haloxyfop, propaquizafop, and quizalofop-P. Both aryloxyphenoxy propionate herbicides and the cyclohexanedione herbicides (e.g., clethodim) are phytotoxic through the inhibition of acetyl coenzyme-A carboxylase (ACCase) activity (Burden et al. 1990; Mallory-Smith and Retzinger 2003).

Fluazifop-P-butyl is used in the post-emergent control of both annual and perennial grass weeds and is relatively nontoxic to broadleaves (dicots) as well as monocots that are not classified as true grasses—i.e., Gramineae or Poaceae (e.g., Haga et al. 1987; Ishihara Sangyo Kaisha 2013). The herbicidal properties of [RS] fluazifop-butyl were first reported by Plowman et al. (1980). The phytotoxicity of fluazifop-P-butyl is discussed in Section 4.1.2.5.

The initial patent for [RS] fluazifop-butyl was granted to Ishihara Sangyo Kaisha [GB 1599121], and commercial development of this herbicide was conducted jointly by Ishihara Sangyo Kaisha and ICI Plant Protection (Tomlin 2004b). The earliest label for technical grade fluazifop-P-butyl in the U.S. EPA/OPP label system is 1986 (http://oaspub.epa.gov/apex/pesticides/ f?p=PPLS:8:0::NO::P8_PUID,P8_RINUM:3019,100-1001) and is issued to the Agricultural Chemicals Division of ICI Americas Inc. The EPA label site indicates that a conditional registration was granted on August 25, 1986 and that the registration for fluazifop-P-butyl was transferred to Syngenta Crop Protection on February 23, 2011. As discussed in Section 2.2.3, Syngenta supplies the formulation of fluazifop-P-butyl most likely to be used by the Forest Service.

As discussed in Section 2.2.1 and illustrated in Figure 1, fluazifop-P-butyl is the butyl ester of fluazifop-P, a weak acid. Following standard conventions in Forest Service risk assessments involving esters of weak acids, a consistent distinction is made between the active ingredient (a.i.) and acid equivalents (a.e.). For the current risk assessment, fluazifop-P-butyl is the a.i. and fluazifop-P is the a.e. Many of the toxicity studies conducted on fluazifop-P-butyl report exposures in units of a.i. rather than a.e. In the exposure assessments, however, the units of exposure are expressed in units of a.e., because fluazifop-P-butyl is rapidly converted to

1    fluazifop-P, which is much more persistent than fluazifop-P-butyl.  For the risk characterization,
2    concentrations or doses in units of a.i. are converted to units of a.e. by multiplying the a.i. value
3    by the ratio of the molecular weight of fluazifop-P acid (327.26 g/mole) to the molecular weight
4    of fluazifop-P-butyl (383.37 g/mole)–i.e., 327.26 g a.i./mole ÷ 383.37 g a.e./mole ≈ 0.85364
5    a.e/a.i.  For the sake of clarity, it is noted that considerations of stereochemistry do not impact
6    a.i. (fluazifop-P-butyl) to a.e. (fluazifop-P) conversions.
7
8    Selected chemical and physical properties of fluazifop-P-butyl are summarized in Table 4, and
9    the chemical and physical properties of fluazifop-P are summarized in Table 5.  In terms of
10   practical impact on the risk assessment, the most significant differences between fluazifop-P-
11   butyl and fluazifop-P concern lipophilicity and persistence.  Fluazifop-P-butyl has a high
12   octanol-water partition coefficient ($K_{ow} \approx$ 31,600); whereas, fluazifop-P has a much lower $K_{ow}$ of
13   0.16 at a neutral pH.  The much higher lipophilicity of fluazifop-P-butyl relative to fluazifop-P is
14   also reflected in binding to soil.  Estimates of $k_{oc}$ values for fluazifop-P-butyl range from 3000 to
15   nearly 6000 (Table 4); whereas, the $k_{oc}$ for fluazifop-P is only about 8.3 (Table 5).  Although
16   these properties might suggest a low potential for transport following applications to soil, the
17   reality is that fluazifop-P-butyl is rapidly hydrolyzed to fluazifop-P, and, as indicated in Table 4,
18   the soil hydrolysis of fluazifop-P occurs in only a few hours (U.S. EPA/OPP/HED 2004a, p. 11).
19   As discussed in Section 3.1.3.1, a similar pattern is observed in mammalian studies in which
20   both [RS] fluazifop-butyl and fluazifop-P-butyl are rapidly metabolized to fluazifop-P via ester
21   hydrolysis.
22
23   In the Tier 2 environmental fate modeling for applications of fluazifop-P-butyl, the U.S.
24   EPA/OPP/EFED (2004d) elected to use the environmental fate data on fluazifop-P rather than
25   explicitly model the conversion the fluazifop-P-butyl to fluazifop-P.  Given the rapidity in the
26   degradation of fluazifop-P-butyl to fluazifop-P, this is a sensible approach.  A similar approach is
27   taken in the current Forest Service risk assessment, as detailed in Section 3.2.3.4.

28       **2.2.3. Commercial Formulations**
29   Formulations of fluazifop-P-butyl listed at www.greenbook.net are summarized in Table 6 and
30   include Fusilade DX (Syngenta), Fusilade II, Turf and Ornamental Herbicide (Syngenta),
31   Ornamec 170 Grass Herbicide (PBI/Gordon Corporation), and Ornamec Over-the-top
32   (PBI/Gordon Corporation).  Of these herbicides, only Fusilade DX is labeled specifically for
33   Christmas tree plantings, nursery beds, and seedling establishment—i.e., uses that may be
34   relevant to Forest Service programs.  As noted in Table 6, applications of Fusilade DX to
35   conifers are not permitted in California; however, U.S. EPA/OPP has issued a Special Local
36   Needs Label for applications of Fusilade DX in California to control grasses in wilderness areas.
37   Fusilade II is specifically labeled for applications to rights-of-way, and the Forest Service has
38   indicated that some programs may include fluazifop-P applications to rights-of-way—e.g., power
39   lines, pipelines, roadsides (Bakke 2013).
40
41   In addition to www.greenbook.net, there are many sources of information on pesticides
42   formulations—e.g., http://iaspub.epa.gov, http://www.cdms.net/LabelsMsds, and
43   http://www.cdpr.ca.gov/docs/label/.  For example, the pesticide data base maintained by the
44   Pesticide Action Network lists 52 active formulations of fluazifop-P-butyl, many of which
45   include other active ingredients in addition to fluazifop-P-butyl.  It is beyond the scope of the
46   current Forest Service risk assessment to consider all commercially available formulations of

1   fluazifop-P-butyl, and doing so would serve little purpose because pesticide formulations are
2   constantly being developed and/or changed, particularly for pesticides that are off patent.  In
3   addition, Forest Service risk assessments do not generally address formulations that contain more
4   than one active ingredient.  In considering formulations with multiple active ingredients, the
5   Forest Service uses an EXCEL application, WorksheetMaker (SERA 2011b), which has been
6   adapted to allow for the assessment of either mixture formulations or tank mixtures.
7   Consequently, formulations of fluazifop-P-butyl that also contain other active ingredients are not
8   considered further in this risk assessment.
9
10  Based on the above considerations, the current Forest Service risk assessment focuses on
11  Fusilade DX as a representative formulation of fluazifop-P-butyl.  This focus, however, is not
12  intended to be exclusive.  Other formulations of fluazifop-P-butyl are available commercially,
13  and new formulations of fluazifop-P-butyl may become available at some point in the future.
14  The Forest Service may elect to use other formulations of fluazifop-P-butyl registered for
15  applications relevant to forestry.  If other formulations are used in Forest Service programs,
16  however, attempts should be made to identify information on the inerts in the formulations
17  (discussed further below) as well as the toxicity of the formulations to ensure that the
18  formulation under consideration is comparable to the formulations explicitly designated in
19  Table 4.
20
21  One exception to the inclusion of other formulations of fluazifop-P-butyl is Fusilade Max.  As
22  discussed in Section 4.1.2.4.1, available data suggest that Fusilade Max is more toxic than
23  technical grade fluazifop-P-butyl or other formulations of fluazifop-P-butyl to the honey bee.
24  Furthermore, studies from European literature suggest that Fusilade Max may be toxic to other
25  terrestrial arthropods at application rates as low as 0.005 lb a.e./acre (Section 4.1.2.4.2).   In the
26  absence of other data, studies with Fusilade Max are sometimes used in this risk assessment.
27  This approach should be regarded as conservative (i.e., protective).
28
29  Pesticide formulations contain other ingredients, sometimes referred to as *inerts*, and the identity
30  of the other ingredients is typically classified as proprietary or Confidential Business Information
31  (CBI).  U.S. EPA/OPP (2010c, p. 5-14) encourages but does not require the disclosure of most
32  inerts on product labels.  One exception, however, involves petroleum distillates, xylene or
33  xylene range aromatic solvents at ≥10% (U.S. EPA/OPP (2010c, p. 5-7), which must be
34  specified on product label.  All of the formulations listed in Table 6 contain other ingredients that
35  are specified as petroleum distillates, hydrocarbons, and/or xylene range aromatic solvents.
36
37  Table 6 includes information on the density and pH of the formulations taken from the Material
38  Safety Data Sheets (MSDS) for the formulations.  Differences in such characteristics of pesticide
39  formulations are important to risk assessments in that the differences may be related to
40  differences in inerts that are used in the different formulations.  The density, pH, and other
41  characteristics (e.g., % a.i.) of the two Syngenta formations, Fusilade DX and Fusilade II, are
42  essentially identical.
43
44  Table 7 provides a more detailed summary of the other ingredients in the formulations listed in
45  Table 6 based on the MSDS for the formulations.  As illustrated in Table 7, different suppliers
46  may elect to provide different levels of detail in their MSDS.  PBI Gordon lists the identities of

the inerts, the corresponding CAS number, as well as the percentage of each inert in the
formulation.  The MSDSs from Syngenta, however, does not provide CAS numbers, and the only
statement concerning the concentration of any specified inerts is that the formulations contain
less than 5% naphthalene.  The lack of specificity in the percentage of inerts in the MSDS limits
any component-based assessment of the potential significance of inerts in the formulation.  As
discussed further in Section 3.1.14 as well as in various sections of the ecological risk
assessment (Section 4), the assessment of inerts in formulations such as Fusilade DX is based on
a comparison of toxicity information on the formulation with toxicity information on the active
ingredient, in this case fluazifop-P-butyl.

As summarized in Table 6, the product label for Fusilade DX recommends the use of crop oil
concentrates, once-refined vegetable oil, or nonionic surfactants as adjuvants.  The impact of
inerts and adjuvants on the human health risk assessment is addressed in Section 3.1.14, and data
on the impact of inerts and adjuvants on the ecological risk assessment are addressed in Section
4.1, as the available data warrant.

Experimental formulations of fluazifop-P-butyl in water dispersible granules (Bell et al. 1998)
are not available commercially in the United States and are not considered further in this risk
assessment.

## 2.3. Application Methods
Fusilade DX may be applied in either ground or aerial broadcast applications as well as in
directed foliar application (i.e., spot treatments).  Forest Service Region 5 (California and
Hawaii) indicated that clethodim (a herbicide with uses similar to fluazifop-P-butyl) is most
likely to be applied along roadsides, power lines, pipelines, rights-of-way, and other disturbance
areas that are being restored back to chaparral (VinZant 2013), and Bakke (2013) indicated that
similar application sites are being considered for fluazifop-P-butyl.  The list of potential target
species for fluazifop-P-butyl summarized in Table 8 includes target species identified by the
Forest Service as well as the target species identified on the Special Local Needs label for
Fusilade DX.

Different application methods involve different amounts of herbicide used by workers in a single
day, based on the number of acres treated per day and the application rate.  Application rates are
discussed in Section 2.4, and assumptions involving the number of acres that a worker might
treat in a single day are discussed further in Section 3.2.2 (worker exposure assessments).

## 2.4. Mixing and Application Rates
As discussed in the previous section, Fusilade DX is a formulation of fluazifop-P-butyl labeled
for uses that appear to be most relevant to Forest Service needs—i.e., conifer plantings, nursery
beds, and seedling establishment.  While other formulations of fluazifop-P-butyl may be used,
Fusilade DX is used as the representative formulation of fluazifop-P-butyl in the current risk
assessment.

As summarized in Table 6, the recommended single-application labeled rates for Fusilade DX
are 6 to 24 ounces per acre.  As also summarized in Table 6, Fusilade DX contains 2 lbs
a.i./gallon [2 lbs a.i./128 oz.].  Thus, the application rates of 6 to 24 ounces per acre correspond
to 0.09375 to 0.375 lb a.i./acre [2 to 24 oz. x 2 lb a.i./128 oz.].  Using the a.i. to a.e. conversion

1  factor of 0.854 a.e/a.i. (Section 2.2.2), these application rates correspond to approximately 0.08
2  to 0.32 lb a.e./acre.
3
4  The maximum cumulative seasonal application rate is 3 applications of 24 ounces per acre with a
5  minimum application interval of 14 days.  This corresponds to a maximum labeled seasonal or
6  cumulative application rate of 1.125 lb a.i./acre [3 applications x 24 oz./acre/application x
7  1 gal/128 oz. x 2 lbs a.i./acre] or about 0.96 lb a.e./acre [1.125 lb a.i./acre x 0.85364 a.e/a.i. =
8  0.9603451 lb a.e./acre].
9
10  The current Forest Service risk assessment explicitly considers three application scenarios:
11  one application at 0.375 lb a.i./acre, two applications at 0.375 lb a.i./acre with a 14-day
12  application interval and three applications at 0.375 lb a.i./acre with 14-day application intervals.
13  The consequences of using lower application rates are discussed in the risk characterization for
14  human health effects (Section 3.4) and ecological effects (Section 4.4).  The exposure scenarios
15  are detailed in EXCEL workbooks provided as attachments to the current risk assessment—i.e.,
16  Attachment 1 for a single application, Attachment 2 for two applications, and Attachment 3 for
17  three applications.
18
19  In addition to application rates, application volumes, meaning the number of gallons of pesticide
20  solution applied per acre, have an impact on the estimates of potential risk.  The extent to which
21  a formulation of fluazifop-P-butyl is diluted prior to application primarily influences dermal and
22  direct spray scenarios, both of which depend on 'field dilution' (i.e., the concentration of
23  fluazifop-P-butyl in the applied spray).  In all cases, the higher the concentration of herbicide
24  (i.e., equivalent to the lower dilution of the herbicide), the greater is the risk.  As summarized in
25  Table 6, the recommended application volumes for fluazifop-P-butyl formulations range from
26  5 to 40 gallons/acre for ground applications (with a minimum volume of 10 gallons/acre for
27  dense grass) and 5 to 10 gallons/acre for aerial applications.
28
29  In the EXCEL workbooks that accompany this risk assessment, the range of application volumes
30  is taken as 5 to 40 gallons per acre to encompass the application volumes that could be used in
31  both aerial and ground applications.  The central estimate of the application volume is taken as
32  20 gallons/acre, the minimum ground application volume for dense grass.
33
34  The selection of application rates and dilution volumes in this risk assessment is intended to
35  reflect plausible estimates of potential exposures.  In the assessment of specific program
36  activities, the application rates and volumes can be changed in Worksheet A01 of the EXCEL
37  workbooks that accompany this risk assessment (Attachments 1 and 2) to reflect the rates and
38  volumes actually used in a particular Forest Service program or project.

## 2.5. Use Statistics
40  Forest Service risk assessments attempt to characterize the use of an herbicide or other pesticide
41  in Forest Service programs relative to the use of the herbicide or other pesticide in agricultural
42  applications.  Forest Service pesticide use reports up to the year 2004 are available on the Forest
43  Service web site (http://www.fs.fed.us/ foresthealth/pesticide/reports.shtml).  While this dated
44  information is not clearly relevant to the current use of pesticides by the Forest Service,
45  fluazifop-P-butyl is not listed as a pesticide used by the Forest Service during 2004, the most
46  recent year for which data are available.

1
2   Information on the agricultural use of pesticides is compiled by the U.S. Geological Survey
3   (USGS) (http://water.usgs.gov/nawqa/pnsp/usage/maps/).  The USGS (2013) reports estimated
4   uses as fluazifop rather than fluazifop-P-butyl.  As noted in the EPA Tolerance Reassessment for
5   fluazifop-P-butyl (U.S. EPA/OPP 2005a, p. 2), fluazifop-P-butyl is currently the only form of
6   fluazifop registered as a pesticide.  Consequently, the use data for fluazifop reported by USGS
7   (2013) must apply to fluazifop-P-butyl.  Nonetheless, it is unclear whether the USGS (2013) is
8   reporting the use data in units of fluazifop-P-butyl (a.i.) or in units of fluazifop-P (a.e.).
9
10  The agricultural use of fluazifop-P-butyl in 2009 (the most recent year for which data are
11  available from USGS) is estimated by the USGS (2013) to range from about 200,000 lbs
12  (Figure 2) to somewhat over 400,000 lbs (Figure 3).  The greatest use of fluazifop-P-butyl is in
13  the central United States running from North Dakota to Kansas and eastwards to Michigan and
14  Kentucky.  Based on use data by crop (also summarized in Figure 2 and Figure 3), fluazifop-P-
15  butyl is currently used almost exclusively on soybeans.  The temporal pattern in the use of
16  fluazifop-P-butyl is noteworthy with a sharp decrease in use from a maximum of about 1.3
17  million pounds in 1997 to as little as 0.1 million pounds in 2008.
18
19  Detailed pesticide use statistics are compiled by the state of California.  The use statistics from
20  California for 2011, the most recent year for which statistics are available, indicate that a total of
21  about 9073.64 pounds of fluazifop-P-butyl were used in California (CDPR 2013, p. 340).  The
22  major use relevant to Forest Service programs appears to be rights-of-way management (about
23  801 lbs or 8.8% of total use in California).  Based on these use statistics from California,
24  agricultural uses of fluazifop-P-butyl are much greater than uses related to forestry.  CDPR
25  (2013, p. 339) does report that a total of 8.38 lbs of fluazifop-butyl (presumably relating to the
26  mixture of the [RS] enantiomers were also applied in 2011.  As noted in U.S. EPA/OPP/HED
27  (2004a, p. 5), the registration for fluazifop-butyl (the enantiomer mixture) has been cancelled.
28  While somewhat speculative, it seems likely that this application of the [RS] enantiomers
29  involved an older stock which was acquired prior to the cancellation of the registration for
30  fluazifop-butyl.
31
32  The relevance of the California statistics to the current Forest Service risk assessment is not
33  clear.  As indicated in Table 6, Fusilade DX is not labeled for applications to conifers as well as
34  other nonbearing crops in California (Fusilade DX label SCP 1070A-L5A 0513, 4026127, p. 32)
35  but the U.S. EPA issued a Special Local Needs label for applications of Fusilade DX in
36  California for the control of grasses in wilderness areas.
37

# 3. HUMAN HEALTH

## 3.1. HAZARD IDENTIFICATION

### 3.1.1. Overview

Based on acute assays for systemic toxicity, fluazifop-P-butyl is relatively nontoxic. The U.S. EPA uses a classification system for acute responses ranging from Category I (most severe response) to Category IV (least severe response). Fluazifop-P-butyl is classified as Category III to Category IV for acute oral, dermal, and inhalation exposures. Fluazifop-P-butyl is not likely to cause substantial skin irritation (Category IV) or eye irritation (Category IV). These classifications, however, apply to fluazifop-P-butyl itself and not necessarily formulations of fluazifop-P-butyl. Based on the Material Safety Data Sheets, the Fusilade formulations most likely to be used in Forest Service programs may cause slight eye irritation and moderate skin irritation. The U.S. EPA determined that fluazifop-P-butyl is not a skin sensitizer. The product labels for some Fusilade formulations, however, indicate that repeated or prolonged exposures may cause skin sensitization.

Studies on the subchronic and chronic toxicity of technical grade fluazifop-butyl or fluazifop-P-butyl are available in dogs, hamsters, and rats. The durations of exposure used in these studies range from 90 days in subchronic studies to about 2 years in chronic studies. Rats appear to be somewhat more sensitive than dogs or mice to fluazifop-butyl and fluazifop-P-butyl, and male rats appear to be more sensitive than female rats. The most common signs of toxicity in the subchronic and chronic studies are decreases in body weight gain and increases in relative or absolute liver weights. There are, however, no reports of liver necrosis (i.e., cell death) associated with exposures to fluazifop-butyl or fluazifop-P-butyl.

Decreases in food conversion efficiency were observed in one reproduction study in rats and a subchronic study in hamsters. This effect, however, is not seen in other reproduction studies in rats and rabbits as well as in a chronic study in hamsters. While decreases in food conversion efficiency could be associated with changes in endocrine function, the most recent risk assessment on fluazifop-P-butyl by the U.S. EPA's Office of Pesticide Programs indicates that fluazifop-P-butyl has been subject to *in vitro* assays for androgen and estrogen binding and no evidence of receptor binding was noted.

Fluazifop-P-butyl has not been assayed specifically for effects on the nervous system and immune system. Because of changes in the EPA requirements for pesticide registration, such studies will probably be conducted at some point. Based on currently available information, there is no evidence that fluazifop-P-butyl is likely to cause direct damage to nerve tissue or have an impact on immune function.

Formulations of fluazifop-P-butyl contain petroleum solvents, including naphthalene. The primary effects of naphthalene and petroleum solvents involve CNS depression or other signs of neurotoxicity. Fluazifop-P-butyl is degraded in the environment to several different metabolites; however, as is common with many pesticides, the toxicity of the metabolites is not well characterized.

As discussed in Section 2.1, the quantitative consideration of risks associated with applications of fluazifop-P-butyl is based on acid equivalents.  The U.S. EPA/OPP/HED documents that form the basis of much of the human health risk assessment (Table 2), however, cite doses for fluazifop-P-butyl as the a.i. (i.e., fluazifop-P-butyl itself) rather than the a.e. (fluazifop-P acid).  In order to facilitate a comparison of the EPA documents and the current risk assessment, this hazard identification adopts the EPA approach, and all doses of fluazifop-P-butyl given in this section are expressed in units of mg a.i./kg bw, unless otherwise specified.  The conversion of dose to acid equivalents (a.e.) is handled in the dose-response assessment (Section 3.3).

### 3.1.2. Mechanism of Action

As noted in Section 2.2 and as discussed further in Section 4.1.2.5 (hazard identification for terrestrial plants), the phytotoxicity of fluazifop-butyl is based on the inhibition of acetyl coenzyme-A carboxylase (ACCase) activity.   ACCase occurs in mammals, plants, bacteria, yeast, and fungi (More et al. 2012; Tong 2005).  Deficiencies in some ACCase activities in mammals are associated with decreased body weight and reduced body fat (Tong 2005).

As reviewed by Tong (2005), ACCase is a key enzyme in fatty acid metabolism and catalyzes the carboxylation of acetyl-CoA to produce malonyl-CoA.  Consequently, compounds which inhibit mammalian ACCase are potentially useful drugs to control obesity (Tong 2005).  Kemal and Casida (1992) examined the inhibition of rat liver ACCase activity by fluazifop-P-butyl and characterized the inhibition as competitive with a Km (50% binding) of $38 \mu M$ ($\approx 14.5$ mg/L).  As discussed in Section 4.1.2.5, an $ED_{50}$ of about 1-3 $\mu M$ ($\approx 0.38$ to 1 mg/L) for the inhibition of ACCase in sensitive species of plants is associated with fluazifop.  While fluazifop-P and fluazifop-P-butyl may have a lesser affinity for mammalian ACCase, compared with the ACCase in sensitive species of plants, the prevalence of weight loss in mammalian studies on fluazifop compounds as well as some studies which indicate a decrease in food conversion efficiency seem to suggest that weight loss in mammals following exposure to fluazifop-P-butyl or fluazifop-butyl could be associated with the inhibition of mammalian ACCase.

As discussed in several sections below and summarized in Appendix 1, decreases in body weight gain are noted in many toxicity studies on fluazifop-butyl and fluazifop-P-butyl (e.g., U.S. EPA/OPP/HED 2004d, 2011a).  Decrease in body weight gain is common sign of toxicity observed in many pesticide exposure studies.  Nonetheless, increased weight gain was observed in a 2-generation reproduction study (i.e., MRIDs 00088859, 92067050, as discussed further in Section 3.1.9.2).  Changes in body weight gain may be associated with specific mechanisms such as an impact on endocrine function or may be a secondary response associated with changes in food consumption or other toxic effects.  As discussed further in Section 3.1.8 (Effects on Endocrine System), fluazifop-P-butyl has not evidenced agonist or antagonist activity with various estrogen and androgen receptors.  Thus, there is no basis for asserting that decreases in body weight gain seen in several toxicity studies with fluazifop-butyl or fluazifop-P-butyl are likely to be associated with a direct impact on endocrine function.

As also summarized in Appendix 1 and discussed in U.S. EPA/OPP/HED (2011a), another common response noted in toxicity studies with fluazifop-butyl or fluazifop-P-butyl is increased liver weight.  Increases in liver weight are often associated with the induction of cytochrome P450 and the proliferation of smooth endoplasmic reticulum in the liver (e.g., Coon 2005).  The induction of cytochrome P450 in mice by fluazifop-butyl was demonstrated by Krijt et al.

1 (1993), and liver enlargement with the proliferation of smooth endoplasmic reticulum in rats
2 following exposure to fluazifop (presumably as a racemic mixture) was demonstrated by Kostka
3 et al. (2002).

### 3.1.3. Pharmacokinetics and Metabolism

5 Pharmacokinetics concerns the behavior of chemicals in the body, including their absorption,
6 distribution, alteration (metabolism), and elimination as well as the rates at which these
7 processes occur. This section of the risk assessment addresses the pharmacokinetic processes
8 involved in fluazifop-butyl exposure, including a general discussion about metabolism (Section
9 3.1.3.1), with a focus on the kinetics of absorption (Section 3.1.3.2) and excretion (Section
10 3.1.3.3). Absorption kinetics, particularly the kinetics of dermal absorption, is important to this
11 risk assessment because many of the exposure scenarios (Section 3.2) involve dermal exposure.
12 Rates of excretion are generally used in Forest Service risk assessments to evaluate the likely
13 body burdens associated with repeated exposure.
14
15 In addition to the general consideration about how fluazifop-butyl behaves in the body, another
16 consideration is the behavior of fluazifop-P-butyl in the environment and the extent to which the
17 metabolism of fluazifop-butyl in the environment must be considered quantitatively in the risk
18 assessment. The consideration of environmental metabolites is discussed in Section 3.1.15.1.

#### 3.1.3.1. Metabolism

20 For pesticide registration, the U.S. EPA/OPP generally requires a relatively standard metabolism
21 study in rats in which the compound is administered by both intravenous and oral routes. The
22 information available on the metabolism of fluazifop-butyl, however, is more extensive. As
23 summarized in U.S. EPA/OPP/HED (2011a), the EPA reviewed one standard metabolism study
24 with fluazifop-butyl in rats, a metabolism study in dogs with fluazifop-butyl and a metabolism
25 study in hamsters with fluazifop-P-butyl. The metabolism studies in rats, hamsters, and dogs
26 reviewed in U.S. EPA/OPP/HED (2011a) indicate that fluazifop-butyl and fluazifop-P-butyl are
27 rapidly metabolized to fluazifop acid. Other than the hydrolysis of fluazifop-butyl to fluazifop,
28 no further metabolism of fluazifop-butyl is noted in human studies (Clark et al. 1993; Woollen
29 1993). In terms of potential differences in risks associated with fluazifop-butyl relative to
30 fluazifop-P-butyl, it is important to note that fluazifop[S] is rapidly converted to fluazifop[R] –
31 i.e., the enantiomer of fluazifop-P-butyl. Thus, exposures to fluazifop-butyl—i.e., a mixture of
32 the [R] and [S] enantiomers—are essentially identical to exposures to fluazifop-P-butyl. Both
33 types of exposures will involve the formation of fluazifop[R]. As discussed in the following
34 sections of this hazard identification, there appears to be no difference in effects of fluazifop-
35 butyl, compared with fluazifop-P-butyl.
36
37 In addition to these studies on experimental mammals, several metabolism studies with
38 fluazifop-butyl are available in the open literature, including studies in humans. McCracken and
39 coworkers (McCracken et al. 1990, 1992, 1993a) demonstrated that fluazifop-butyl is
40 metabolized to fluazifop acid by microsomal and cytosol fractions from the liver, lung, and skin
41 of rats as well as by red blood cells and plasma. As noted in Section 3.1.2, fluazifop-butyl is a
42 substrate for cytochrome P450, and metabolism by microsomes would be expected. The
43 metabolism of fluazifop-butyl by cytosol fractions (which do not contain substantial amounts of
44 cytochrome P450) suggest that esterases in addition to cytochrome P450 are involved in the
45 hydrolysis of fluazifop-butyl to fluazifop acid. The study by McCracken et al. (1993a), which

involved human tissues, notes that, compared with rat esterases, human plasma esterases metabolize fluazifop-butyl much more slowly.  Nonetheless, another metabolism study in humans, conducted with a Fusilade formulation of fluazifop-butyl, notes that fluazifop acid is the only major metabolite of fluazifop-butyl and that the only other metabolites appeared to be conjugates of fluazifop (Woollen et al. 1991).   Although the identity of the conjugates was not determined in the study by Woollen et al. (1991), the conjugation of weak acids with compounds such as sulfates and glucuronides is a common metabolic pathway in mammals (e.g., Hansel and Morris 1996).

### 3.1.3.2. Dermal Absorption
Most of the occupational exposure scenarios and many of the exposure scenarios for the general public involve the dermal route of exposure.  For these exposure scenarios, dermal absorption estimates are compared with an estimated acceptable level of oral exposure based on subchronic or chronic toxicity studies in animals.  In applying this approach, it is necessary to assess the extent to which fluazifop-butyl is likely to be absorbed from the skin surface.

Two types of dermal exposure scenarios are considered in this risk assessment: immersion and accidental spills.  In the scenarios involving immersion, the concentration of the chemical in contact with the surface of the skin is assumed to remain constant or at least nearly so during exposure.  As detailed in SERA (2011a), the calculation of absorbed dose for dermal exposure scenarios involving immersion requires an estimate of the dermal permeability coefficient ($K_p$) expressed in cm/hour, and the rate of absorption is assumed to be essentially constant.  In exposure scenarios involving direct sprays or accidental spills where the compound is deposited directly on the skin, the concentration or amount of the chemical on the surface of the skin is assumed to be the limiting factor in dermal absorption.  For these scenarios first-order dermal absorption rate coefficients ($k_a$), expressed as a proportion of the deposited dose absorbed per unit time—e.g., hour$^{-1}$—are used in the exposure assessment.

### 3.1.3.2.1. First-Order Dermal Absorption
Data relevant to assessing the first-order dermal absorption rate coefficient ($k_a$) for fluazifop-butyl in humans are presented in Ramsey et al. (1992), U.S. EPA/OPP/HED (2011a), and Chester and Hart (1986).  The data from Ramsey et al. (1992) are also included in several subsequent publications by the same group of investigators (Auton et al. 1993a,b; Ramsey et al. 1994).  Trebilcock et al. (1994) examined the use of tape stripping to assess the movement of fluazifop-butyl in human skin.  This study, which focuses primarily on method development, is not suitable for estimating dermal absorption rates.  Several additional studies are available on dermal absorption in rats (e.g., Auton et al. 1993a, Hilton et al. 1994; Rawlings et al. 1994b).  Because of the availability of human data, however, the absorption studies in rats are not considered further.

The paper by Ramsey et al. (1992) is by far the most detailed and best documented study on the dermal absorption of fluazifop-butyl.  In this study, fluazifop-butyl was applied at doses of 2, 20, or 200 mg to an 800 cm$^2$ area on the back of six volunteers per exposure level.  A uniform volume of 0.25 ml was used in each application; thus, the concentrations of fluazifop-butyl in the solutions were 0.05%, 0.5%, and 5% in the 2, 20, and 200 mg dose groups, respectively.  The application sites were not occluded, the treated areas were washed after 8 hours, and the treated individuals showered after 24 hours.  Dermal absorption was assayed from urinary excretion

1 with urine samples collected for up to 216 hours after dermal dosing. The results from the
2 dermal absorption study from Ramsey et al. (1992) are summarized in Table 9 of the current risk
3 assessment. The average dermal absorption decreased with increasing dose—i.e., about 8% in
4 the 2 mg dose group, 3.6% in the 20 mg dose group, and 1.6% in the 200 mg dose group.
5
6 As discussed by Kissel (2010), a decrease in the proportion of the absorbed dose with increasing
7 dermal loading—i.e., mg of agent per $cm^2$ of skin—is common for many chemicals. As noted in
8 Table 9, the loadings associated with the doses of 2, 20, and 200 mg are 0.0025, 0.025, and 0.25
9 $mg/cm^2$. As illustrated in Figure 4, the decrease in the percent dermal absorption (Abs%) with
10 increasing dermal loading (L) follows an exponential relationship:
11
12 $$Abs\% = 0.96 L^{-0.348} \tag{1}$$
13
14 U.S. EPA/OPP/HED (2011a, pp. 15) and U.S. EPA/OPP/HED (2004d, p. 20-21) summarize a
15 similar study, which may be a partial submission of the high and low dose portions of the study
16 by Ramsey et al. (1992). The EPA summaries indicate that groups of six individuals were
17 exposed to fluazifop-butyl at doses of 2 or 200 mg over a skin surface of 800 $cm^2$. U.S.
18 EPA/OPP/HED (2004d, p. 20-21) notes that the study authors (NOS) report an absorption factor
19 of 8% is reported for the low dose group and a factor of 1.6% is reported for the high dose group.
20 Based on a reanalysis of the data, the EPA derived somewhat different absorption rates—i.e., 9%
21 for the low dose group and 2% for the high dose group. Documentation of EPA's reanalysis of
22 the data, however, was not identified during the conduct of this risk assessment.
23
24 The only other data available on the dermal absorption of fluazifop-butyl in humans is from the
25 occupational exposure study by Chester and Hart (1986). This study, which is discussed in
26 greater detail in Section 3.2.2.1, examined occupational exposures of groups of backpack
27 workers and ground spray workers during applications of fluazifop-butyl. Based on estimates of
28 the total dose deposited on the skin of the workers and the amounts of fluazifop-butyl excreted in
29 their urine, Chester and Hart (1986, Table IV, p. 148) estimate the dermal absorption at 1.3 (0.4
30 to 1.8) % for backpack workers and 11 (0.2 to 56) % for ground spray workers. Based on
31 individual data provided in Table II of Chester and Hart (1986, p.148), the one worker with an
32 estimated dermal absorption of 56% is a clear outlier. All other workers had estimates of dermal
33 absorption in the range of 0.2% to 11%. The basis for estimates of dermal absorption rates given
34 by Chester and Hart (1986) are not detailed, and this paper is clearly focused on estimating
35 absorbed doses for the two groups of workers rather than dermal absorption rates.
36
37 In the absence of information on first-order dermal absorption rates, quantitative structure
38 activity relationships (QSAR) are used to estimate these rates (SERA 2011a, Section 3.1.3.2.2,
39 Equation 3). As detailed in Worksheet B03b of Attachments 1, 2, and 3, the QSAR methods
40 estimate a dermal absorption rate of about 0.0024 (0.00084 – 0.0070) hour$^{-1}$ based on a $K_{ow}$
41 value of 31,600 and a molecular weight of 383.37 g/mole (Table 4). These properties are within
42 the range of values on which the algorithm is based—i.e., $K_{ow}$ values ranging from 0.0015 to
43 3,000,000 and molecular weights ranging from 60 to 400 g/mole. The QSAR method is based
44 exclusively on dermal absorption data from studies in humans using a skin loading of 0.004
45 $mg/cm^2$ (i.e., Feldmann and Maibach 1969, 1970, 1974).
46

1    Based on the dermal absorption data reviewed by U.S. EPA/OPP/HED (2004a, 2011a) as
2    discussed above, the EPA elected to use two dermal absorption factors: *2% for high exposures*
3    *and 9% for low exposures* (U.S. EPA/OPP/HED 2011a, p. 5).  The EPA does not quantify or
4    specify the definitions of high and low exposures.  In practice, the EPA exposure scenarios
5    involving dermal exposure appear to be based solely on the 9% dermal absorption factor.  As
6    noted in U.S. EPA/OPP/HED (2011a, p. 9): *Given this, use of the 9% factor in combination with*
7    *high levels of exposure would result in a conservative estimate of risk.*
8
9    Forest Service risk assessments typically do not use absorption factors analogous to those used
10   by U.S. EPA, because Forest Service risk assessments include accidental exposure scenarios
11   involving exposure periods from 1 minute to 1 hour (Section 3.2.2.2).  As an alternative and as
12   noted above, dermal absorption rate coefficients ($k_a$) are derived based on the following
13   equation:

$$\ln \frac{M_t}{M_0} = Ln(1 - P) = -k_a t$$

14                                                                                          (2)

$$k_a = \frac{\ln(1 - P)}{t}$$

15
16   where $P$ is the proportion absorbed, $M_0$ is the amount applied and $M_t$ is the amount unabsorbed at
17   time, t, after application.  In practice, the analysis involves the regression of the natural log of the
18   proportion of the compound unabsorbed against time and $k_a$ is estimated from the slope of the
19   regression.
20
21   As discussed above and illustrated in Figure 4, there is a clear inverse relationship between
22   dermal loading and absorption, which is not uncommon.  In such cases, the $k_a$ used in the risk
23   assessment is based on dermal loadings that are most representative of the exposure scenarios
24   considered in the risk assessment.  As discussed further in Section 3.2.2.2 (accidental dermal
25   exposures) and detailed in the attachments that accompany this risk assessment (i.e., Worksheets
26   C03a and C03b), the dermal loadings in exposure scenarios based on first-order dermal
27   absorption are about 0.015 (0.008 to 0.06) mg/cm$^2$.  These loadings are most similar to the 0.025
28   mg/cm$^2$ mid-dose exposure group from Ramsey et al. (1992), as summarized in Table 9.
29
30   In addition to the exposure scenarios based directly on first-order dermal absorption rate
31   coefficients, first-order dermal absorption rate coefficients are also used to adjust the
32   occupational exposure rates (mg/kg bw per lb handled) used in the worker exposure assessment
33   for backpack applications.  The details of this method are given in SERA (2013b).  As discussed
34   further in Section 3.3.2, an occupational exposure study involving backpack applications of
35   fluazifop-butyl (Chester and Hart 1986, p. 148, Table IV) reports dermal loadings of 0.036
36   (0.025 to 0.051) µg/cm$^2$ [i.e., dermal exposures of 209 (138-294) mg over a 5800 cm$^2$ skin
37   surface area].  Again, these dermal loadings are most similar to the mid-dose group (0.025
38   mg/cm$^2$ skin loading) from the study by Ramsey et al. (1992).  As detailed in Table 10, the 90%
39   confidence interval—i.e., the lower 5% bound and upper 95% bound—for the percent absorption
40   from the mid-dose group in Ramsey et al. (1992) is about 3.4% (2.8% to 4%).
41
42   As indicated in Equation 2 above, the estimate of the $k_a$ requires an estimate of the duration of
43   exposure (*t*).  This is somewhat problematic for the study by Ramsey et al. (1992) because the

1   skin was washed at 8 hours following exposure but the individuals did not shower for 24 hours
2   after exposure. As noted by Ramsey et al. (1992), washing the skin surface only removed about
3   50% of the fluazifop-butyl. Assuming that the remainder of the compound was effectively
4   removed by showering at 24 hours, the functional duration of exposure is estimated at 16 hours
5   [8 hours + (24 hours – 8 hours) * 0.5]. Based on this period of functional exposure, the $k_a$ for
6   fluazifop-butyl in the mid-dose group from the study by Ramsey et al. (1992) is 0.00233
7   (0.00173 to 0.00254) hour$^{-1}$.
8
9   The central estimate of 0.00233 hour$^{-1}$ from Ramsey et al. (1992) is almost identical to the
10  central estimate of about 0.0024 hour$^{-1}$ from QSAR discussed above and detailed in Worksheet
11  B03b in the attachments to this risk assessment. The confidence interval from Ramsey et al.
12  (1992)—i.e., 0.00173 to 0.00254 hour$^{-1}$), however, is much narrower than that from the QSAR
13  algorithm (i.e., 0.00084 – 0.0070 hour$^{-1}$). Given the high variability in the estimates of dermal
14  absorption from Chester and Hart (1985, Table IV, p. 148), it seems more prudent and protective
15  to use the estimates of $k_a$ from the QSAR algorithm. Consequently, for the current Forest
16  Service risk assessment, the first-order dermal absorption rate coefficients are taken as 0.0024
17  (0.00084 – 0.0070) hour$^{-1}$.

18              **3.1.3.2.2. Zero-Order Dermal Absorption**
19  Exposure scenarios involving the assumption of zero-order dermal absorption require an estimate
20  of dermal permeability ($K_p$) in units of cm/hour. No experimental estimates of a $K_p$ for
21  fluazifop-butyl have been identified. Several estimates of dermal absorption rates, in units of
22  $\mu g/cm^{-2} h^{-1}$, are reported in the literature (e.g., Auton et al. 1994; Chester and Hart 1985; Hilton
23  et al. 1984). While these types of measurements can be used to estimate a $K_p$ (i.e., by dividing
24  by the concentration of the compound in the exposure media), the studies in the open literature
25  are not designed for this purpose and do not involve essentially constant concentrations—i.e.,
26  where the amount of fluazifop-butyl clearly saturates absorption.
27
28  In the absence of experimental data, Forest Service risk assessments generally use a QSAR
29  algorithm developed by the EPA (U.S. EPA/ORD 1992, 2007). This approach is discussed in
30  further detail in SERA (2011a, Section 3.1.3.2.1). As with the algorithm for estimating the first-
31  order dermal absorption rate constant, the EPA algorithm is based on molecular weight and $K_{ow}$
32  (U.S. EPA/ORD 1992, 2007). The molecular weight and $K_{ow}$ values used for estimating the $K_p$
33  are identical to those used in the estimate of the first-order dermal absorption rate constants (i.e.,
34  a 31,600 and a molecular weight of 383.37 g/mole).
35
36  The EPA algorithm is derived from an analysis of 95 organic compounds with $K_{ow}$ values
37  ranging from about 0.0056 to 309,000 and molecular weights ranging from approximately 30 to
38  770 (U.S. EPA/ORD 1992, 2007). These ranges of $K_{ow}$ and molecular weight values encompass
39  the estimates of the corresponding values for fluazifop-butyl.
40
41  Details of the implementation of the algorithms are given in Worksheet B03a in the EXCEL
42  workbooks for fluazifop-butyl (Attachments 1, 2 and 3). Using the EPA algorithm results in an
43  estimated dermal permeability ($K_p$) of about 0.012 (0.006 to 0.026) cm/hour.

1       *3.1.3.3. Excretion*
2   Although excretion rates are not used directly in either the dose-response assessment or risk
3   characterization, excretion half-lives can be used to infer the effect of longer-term exposures on
4   body burden, based on the *plateau principle* (e.g., Goldstein et al. 1974, p. 320 ff.).  Under the
5   assumption of first-order elimination, the first-order elimination rate coefficient (*k*) is inversely
6   related to the half-life ($T_{50}$) [$k = ln(2) \div T_{50}$].  If a chemical with a first-order elimination rate
7   constant of *k* is administered at fixed time interval (*t\**) between doses, the body burden after the
8   $N^{th}$ dose ($X_{N\,Dose}$)relative to the body burden immediately following the first dose ($X_{1\,Dose}$) is:
9

$$\frac{X_{N\,Dose}}{X_{1Dose}} = \frac{\left(1 - \left(e^{-kt*}\right)^{N}\right)}{1 - e^{-kt*}}$$

10                                                                                                                                (3)

11
12  As the number of doses (*N*) increases, the numerator in the above equation approaches a value
13  of 1.  Over an infinite period of time, the plateau or steady-state body burden ($X_{Inf}$) can be
14  calculated as:

$$\frac{X_{Inf}}{X_{1}} = \frac{1}{1 - e^{-kt*}}$$

15                                                                                                                                (4)

16
17  Whole-body half-lives are most appropriate for estimating steady-state body burdens.
18
19  As reviewed by U.S. EPA/OPP/HED (2011a), fluazifop-butyl is excreted rapidly and primarily
20  (80%-92%) in the urine.  Similar excretion patterns are reported in the open literature (Auton et
21  al. 1993b, 1994; Chester and Hart 1986; Ramsey et al. 1992; Rawlings et al. 1994a; Woollen et
22  al. 1991).  The prevalence of urinary excretion is true for most weak acids.  U.S. EPA/OPP/HED
23  (2011a, p. 15) summarizes a kinetic study in three male volunteers in which an oral dose of
24  fluazifop-butyl (0.07 mg/kg bw) was completely excreted within 4 to 6 days.  Based on the EPA
25  description, this study appears to be identical to Woollen et al. (1991) which reports urinary
26  eliminations half-lives of 14 (9-21) hours.  The study also summarizes a pharmacokinetic study
27  in dogs with a similar urinary half-life of about 20 hours.
28
29  The urinary half-lives of 14 (9-21) hours corresponds to first-order urinary excretion rate
30  coefficients ($k_e$) of about 1.2 (0.83 to 1.8) day$^{-1}$.  When these rate coefficients are substituted into
31  the above equation for the plateau principle (Eq. 4), the estimated plateau for fluazifop-butyl is
32  about 1.4 (1.2 to 1.8).  In other words, over very prolonged periods of exposure, the maximum
33  increase in the body burden of fluazifop-butyl should be less than a factor of 2.

34      **3.1.4. Acute Oral Toxicity**
35  The standard acute oral toxicity studies are typically used to determine $LD_{50}$ values—i.e., the
36  dose estimated to be lethal to 50% of the animals.  $LD_{50}$ values as well as other measures of
37  acute toxicity discussed in following sections are used by the U.S. EPA/OPP to categorize
38  potential risks.  U.S. EPA/OPP uses a ranking system for response ranging from Category I
39  (most severe response) to Category IV (least severe response).  Details of the categorization
40  system used by the Agency are detailed in SERA (2011a, Table 4) as well as the U.S. EPA's
41  Label Review Manual (U.S. EPA/OPP 2010c, p. 7-2).
42

1    The acute toxicity studies in mammals are summarized in Appendix 1, Table A1-1.  The acute
2    oral $LD_{50}$ values for fluazifop-butyl (one study in rats) and fluazifop-P-butyl (one study in rats
3    and one study in mice) are summarized in Appendix 1, Table A1-1.  The studies in rats provide
4    definitive $LD_{50}$ values, and the $LD_{50}$ in mice is indefinite—i.e., expressed as >2000 mg/kg bw.
5    The definitive $LD_{50}$ values for rats span a range of about 1.9—i.e., from the $LD_{50}$ of 1940 mg/kg
6    bw for fluazifop-butyl in male rats to the $LD_{50}$ of 3680 mg/kg bw for fluazifop-P-butyl in male
7    rats.  Based on these studies, U.S. EPA/OPP/HED (2011a) classifies fluazifop-butyl and
8    fluazifop-P-butyl as Category III for acute oral toxicity.
9
10   Based on the acute $LD_{50}$ studies, no systematic differences are apparent between male and
11   female rats; furthermore, the one study for which confidence intervals are available (MRID
12   00162439) indicates that the differences between male and female rats are not statistically
13   significant.  No substantial differences are apparent between the toxicity of fluazifop-butyl and
14   fluazifop-P-butyl.  As discussed in Section 3.1.3.1, fluazifop[S] is rapidly converted to
15   fluazifop[R]; thus, no differences in the toxicity of fluazifop-butyl (a mixture of [R] and [S]
16   enantiomer) and fluazifop-P-butyl (the [R] enantiomer) would be expected.
17
18   In addition to the standard acute $LD_{50}$ assays, two acute toxicity studies are available in the open
19   literature (Kostka et al. 2002; Krijt et al. 1993) and one unpublished acute toxicity study that is
20   not covered in the literature from U.S. EPA/OPP was submitted to the U.S. EPA's Office of
21   Toxic Substances (U.S. EPA/OTS 1992c).  These studies are also summarized in Appendix 1,
22   Table A1.
23
24   The study by Kostka et al. (2002) involved gavage dosing of male rats with fluazifop acid for up
25   to 14 days with doses ranging from 56 to 891 mg/kg bw.  Decreases in body weight with no
26   change in food or water consumption were noted at doses of 446 and 891 mg/kg bw.  As noted in
27   Section 3.1.2 and discussed further in Section 3.1.5, decreased body weight is the most common
28   observation in toxicity studies on fluazifop-butyl and fluazifop-P-butyl.  The paper by Kostka et
29   al. (2002) is focused primarily on the effects of fluazifop on the liver.  The doses associated at
30   decreased body weight (i.e., 446 and 891 mg/kg bw) were also associated with substantial
31   increases in liver weight (30% to 40%), which is also an endpoint commonly observed in studies
32   on fluazifop-butyl and fluazifop-P-butyl.  Slight increases in liver weight (i.e., about 15%) along
33   with changes in biochemical parameters (e.g., increased catalase activity) were observed at doses
34   as low as 56 mg/kg bw.  This observation is noteworthy because the acute RfD for fluazifop-
35   butyl is based on a NOEL of 50 mg/kg bw/day from a developmental study in rats (Section 3.3).
36   The proximity of the dose of 56 mg/kg bw associated with liver effects in the study by Kosta et
37   al. (2002) is not of substantial concern.  As discussed in Section 3.1.2, increases in liver weight
38   as well as other biochemical parameters appear to be related to the induction of cytochrome P450
39   which is generally considered to be an adaptive response to compounds that are metabolized by
40   cytochrome P450.
41
42   The multiple dose study in rats summarized by Krijt et al. (1993) as well as the dietary study by
43   Krijt et al. (1993) observed increases in liver weight.  Krijt et al. (1993) noted that the increase in
44   liver weight (about a factor of 2) was accompanied by a similar increase (about a factor of 1.6) in
45   cytochrome P450 activity.  Both of these studies involved doses substantially in excess of no-
46   effect levels used in the dose-response assessment (Section 3.3).

1
2    In addition to information from the open literature and EPA documents, the Material Safety Data
3    Sheets (MSDS) for formulations of fluazifop-P-butyl contain some information on the toxicity of
4    the formulations—i.e., acute oral and dermal $LD_{50}$ values, an acute inhalation $LC_{50}$ value, and
5    information on eye and skin irritation as well as dermal sensitization.  The U.S. EPA/OPP
6    requires that these assays are conducted on each distinct formulation of a pesticide product (U.S.
7    EPA/OPP 2010c).  Information on these assays is summarized in Appendix 1 (Table A1-8) for
8    Fusilade DX and Fusilade II.  That the information for Fusilade DX is identical to the
9    information for Fusilade II suggests that U.S. EPA/OPP viewed the two formulations as
10   sufficiently similar to one another that only one set of formulation toxicity studies was
11   conducted.  The oral $LD_{50}$ values for these formulations are discussed in this section, and data
12   from the other assays are discussed in the appropriate sections below.
13
14   The MSDS for both Fusilade DX and Fusilade II report indefinite oral $LD_{50}$ values of >5000
15   mg/kg bw for the rat.  The indefinite $LD_{50}$ values (i.e., values reported as greater than a specific
16   value) indicate that an $LD_{50}$ could not be calculated and that the highest dose tested, in this case
17   5000 mg/kg bw, caused less than 50% mortality.   Both MSDSs clearly indicate that the toxicity
18   values are based on assays of the formulation and not a.i. and that the units of the toxicity values
19   are given as the formulation.  Both formulations contain 24.5% fluazifop-P-butyl.  Thus, the
20   acute oral $LD_{50}$ of >5000 mg formulation/kg bw corresponds to >1225 mg a.i./kg bw.
21
22   As discussed above, U.S. EPA/OPP/HED (2011a) reports definitive $LD_{50}$ values for the rat that
23   range from 1940 mg a.i./kg bw to 3680 mg/kg bw for fluazifop-butyl and fluazifop-P-butyl.  All
24   of these $LD_{50}$ values for fluazifop-P-butyl and fluazifop-butyl are above the formulation $LD_{50}$
25   when expressed in units of a.i.  Because the formulation $LD_{50}$ is indefinite, the interpretation of
26   the relationship between the formulation $LD_{50}$ and the $LD_{50}$ values for fluazifop-butyl and
27   fluazifop-P-butyl is limited.  The most that can be asserted is that these studies are consistent
28   with the assumption that the toxicity of the formulations is attributable to the active ingredient
29   rather than other ingredients (a.k.a., *inerts*) in the formulation.  Information on the other
30   ingredients in the fluazifop-P-butyl formulations is discussed further in Section 3.1.14.2.

31       **3.1.5. Subchronic or Chronic Systemic Toxic Effects**
32   As discussed in SERA (2011a, Section 3.1.5), *subchronic* and c*hronic* are somewhat general
33   terms which refer to studies involving repeated dosing.  Some repeated dose studies are designed
34   to detect specific toxic endpoints, like reproductive and neurological effects.  Except for some
35   comments in this subsection on general signs of toxicity, these more specialized studies are
36   discussed in subsequent subsections of this hazard identification.  The focus of this subsection is
37   toxicity studies designed to detect more general signs of systemic toxicity and to quantify no-
38   observable-effect levels (NOAELs) for the identified endpoints as well as levels associated with
39   adverse effects—i.e., lowest-observed-effect-levels (LOAELS).
40
41   The subchronic and chronic toxicity studies on fluazifop-butyl and fluazifop-P-butyl are
42   summarized in Appendix 1 (Table A1-2), and an overview of these studies is given in Table 11.
43   Since no subchronic or chronic toxicity studies are published in the open literature, all of the
44   toxicity studies relevant to the current risk assessment were submitted to the U.S. EPA/OPP in
45   support of the registration of fluazifop-P-butyl.  The summaries of these studies given in
46   Appendix 1, Table A1-2 are taken primarily from U.S. EPA/OPP/HED (2011a), i.e., the most

recent human health risk assessment, with additional details from U.S. EPA/OPP/HED (2004d), the Hazard Identification Assessment.

As summarized in Table 11, subchronic (90 days) studies are available on dogs, hamsters, and rats (two studies) and chronic studies are available on dogs (1 year), hamsters (80 weeks), and rats (about 2 years). There are no consistent patterns in species sensitivity in these studies. For dogs and hamsters, the subchronic NOAELs are higher by factors of about 5 to 6 than the chronic NOAELs and suggest a moderately strong dose-duration relationship. This is not the case, however, for rats in which the subchronic and chronic NOAELs are comparable. As discussed in Section 3.1.3.3, fluazifop-butyl is rapidly excreted and there is no basis for suggesting increases in body burden during prolonged periods of exposure. This notion is consistent with similar subchronic and chronic NOAELs in rats but not with the higher subchronic, relative to chronic, NOAELs in dogs and hamsters. Speculatively, the pattern in dogs and hamsters suggests rates of damage that exceed rates of repair rather than an increase in body burdens with increasing duration.

Another noteworthy difference in these studies is the diversity of the most sensitive endpoints among dogs, hamsters, and rats in the chronic studies—i.e., adrenal and thymus changes in dogs, testicular, ovarian changes along with liver inflammation and cataracts in hamsters, and kidney damage and ovarian cysts with increased mortality in rats. Except for the ovarian changes seen in hamsters and rats, there are no apparent similarities in sensitive endpoints among these three species.

### 3.1.6. Effects on Nervous System

In severely poisoned animals, virtually any chemical may cause gross signs of toxicity which might be attributed to neurotoxicity—e.g., incoordination, tremors, or convulsions. A direct neurotoxicant, however, is defined as a chemical that interferes with the function of nerves, either by interacting with nerves directly or by interacting with supporting cells in the nervous system. This definition of a direct neurotoxicant distinguishes agents that act directly on the nervous system (direct neurotoxicants) from those agents that might produce neurological effects secondary to other forms of toxicity (indirect neurotoxicants). U.S. EPA has developed a battery of assays to test for neurotoxicity (Group E in U.S. EPA/OCSPP 2013), and U.S. EPA/OPP requires neurotoxicity studies for pesticides when standard toxicity studies or other considerations such as chemical structure suggest that concerns for effects on the nervous system are credible.

Both the U.S. EPA/OPP Hazard Identification Assessment Review Committee (U.S. EPA/OPP/HED 2004d) and the most recent U.S. EPA/OPP human health risk assessment (U.S. EPA/OPP/HED 2011a) specifically address concerns for neurotoxicity. The conclusion from the more recent human health risk assessment is given below:

> *The assessment team concluded that there was not a concern for neurotoxicity*
> *resulting from exposure to fluazifop-P-butyl at relevant exposure levels. There*
> *was no evidence of clinical signs indicative of neurotoxicity or neuropathology*
> *in the available studies. Marginal increases in brain weights at termination were*
> *seen in a sub-chronic toxicity study in a rats and a carcinogenicity study in*

*hamsters, but only at high doses. A developmental neurotoxicity study is not*
*required at this time.*

U.S. EPA/OPP/HED 2011a, p. 19.

The reference to the brain weights refers to slight increases (2.5% in male hamsters and 1.6% in females) in the 3000 ppm exposure group of the chronic study in hamsters (MRIDs 4534501/46082905), a 4% increase in brain weights in male and female hamsters in the subchronic study (MRID 46082902), and a 2.9% increase in brain weight in female rats in the 2000 ppm dose group (MRID 46158402). As noted in U.S. EPA/OPP/HED (2011a, p.19), the increases in brain weights were not accompanied by histological lesions in the brain, and the toxicological significance of the minor changes in brain weights is not clear. The EPA reviews do not provide information concerning the statistical significance of the increases in brain weights.

In the absence of signs of neurotoxicity in the many acute and longer-term toxicity studies on fluazifop-butyl and fluazifop-P-butyl, the EPA assessment that fluazifop-P-butyl is not likely to be neurotoxic is reasonable. A similar assessment of the potential neurotoxicity of fluazifop-P-butyl is briefly stated in the assessment of fluazifop-P-butyl by the European Food Safety Authority (EFSA, 2012, p. 7). In terms of the potential significance of slight increases in brain weight noted in the above statement by U.S. EPA/OPP/HED (2011a, p. 19), it is notable that changes in brain weight are not commonly associated with neurotoxicity (Sellers et al. 2007).

Notwithstanding the above considerations, U.S. EPA/OPP/HED (2011a, p. 16) notes that Revised Part 158 Data Requirements now require a 90-day neurotoxicity study for registered pesticides. As discussed in Section 1.1.2, fluazifop-P-butyl is scheduled for registration review starting in 2015. It seems likely that a neurotoxicity study on fluazifop-P-butyl will be conducted as part of the upcoming registration review.

### 3.1.7. Effects on Immune System

There is very little direct information on which to assess the potential immunotoxicity of fluazifop-P-butyl. The only studies specifically related to the effects of fluazifop-P-butyl on immune function are skin sensitization studies (Section 3.1.11). While these studies provide support for asserting that fluazifop-P-butyl is not likely to cause skin sensitization, they provide no information useful for directly assessing the potential for fluazifop-P-butyl to impair immune function.

In addition to assays for immunotoxicity, typical subchronic or chronic animal bioassays conduct morphological assessments of the major lymphoid tissues, including bone marrow, major lymph nodes, spleen and thymus (organ weights are sometimes measured as well), and blood leukocyte counts. These assessments can detect signs of inflammation or injury indicative of a direct toxic effect of the chemical on the lymphoid tissue. Changes in morphology/cellularity of lymphoid tissue and blood, indicative of a possible immune system stimulation or suppression, can also be detected.

Most of the earlier EPA assessments of fluazifop-P-butyl (e.g., assessments prior to 2011 in Table 2) do not specifically address potential concerns for the impact of fluazifop-P-butyl on immune function. The most recent human health risk assessment of fluazifop-P-butyl, however,

1   does address concerns for the impact of fluazifop-P-butyl on immune function based on the
2   standard toxicity studies (U.S. EPA/OPP/HED 2011a, p. 17).  The most relevant observations are
3   those associated with effects on the thymus, spleen weights, bone marrow, and lymphatic tissue
4   at the 25 and 125 mg/kg bw/day doses in the chronic study on dogs (MRIDs MRID 00131462,
5   00131463, 92067018).  While these effects are all suggestive of a potential impact on immune
6   function, the EPA discussion notes that the colony of dogs used in this study may have had pre-
7   existing health issues that contributed to the responses to fluazifop-P-butyl.  In addition, the
8   interpretation of the results is compromised by several other issues associated with comparisons
9   between the control and exposed groups.  Furthermore, the EPA notes the lack of any endpoints
10  associated with immune function in the chronic studies in rats as well as the subchronic study in
11  dogs.
12
13  As with neurotoxicity, recent changes to pesticide regulations (40 CFR § 158) now require
14  immunotoxicity assays as a condition for pesticide registration (U.S. EPA/OPP/HED 2011a, p.
15  17).  These requirements, however, were not in effect when fluazifop-P-butyl was registered.  As
16  discussed above, fluazifop-P-butyl will undergo registration review starting in 2015, and studies
17  specific to the assessment of immune suppression may be conducted as part of this process.

18      **3.1.8. Effects on Endocrine System**
19  Assessments of the direct effects of chemicals on endocrine function are most often based on
20  mechanistic studies on estrogen, androgen, or thyroid hormone systems (i.e., assessments on
21  hormone synthesis, hormone receptor binding, or post-receptor processing).  The U.S. EPA has
22  developed a detailed approach to the assessment of potential endocrine disruptors (U.S. EPA
23  2014).  As part of this effort, U.S. EPA/OPP has developed a battery of screening assays for
24  endocrine disruption which can be found at: http://www.epa.gov/ocspp/pubs/frs/
25  publications/Test_Guidelines/series890.htm.  Fluazifop-P-butyl, however, was not among the
26  compounds listed to be screened in these assays (U.S. EPA/OPP/HED 2011a).
27
28  Notwithstanding the above, both U.S. EPA/OPP/HED (2011a, p. 28) and the earlier report from
29  the EPA Hazard Identification Assessment Committee (U.S. EPA/OPP/HED 2004d, p. 33)
30  indicate that *in vitro* assays were conducted on both fluazifop-P-butyl and *acid metabolites*
31  (NOS) using recombinant yeast strains sensitive to human estrogen or androgen receptors.  Both
32  documents indicate that no estrogen or androgen activities were noted.  Details of these studies
33  and references to MRID study numbers, however, are not provided in either of the EPA
34  documents.  Based on these summaries, it is not clear if additional testing for endocrine activity
35  will be required as part of the registration review for fluazifop-P-butyl.
36
37  In terms of functional effects that have important public health implications, effects on endocrine
38  function could be expressed as diminished or abnormal reproductive performance.  This issue is
39  addressed specifically in the following section (Section 3.1.9).

## 3.1.9. Reproductive and Developmental Effects

### 3.1.9.1. Developmental Studies

No studies on the developmental effects of fluazifop-butyl or fluazifop-P-butyl were identified in the open literature. A review by Sesline and Jackson (1994) indicates that fluazifop-butyl has been identified by the U.S. EPA as a teratogen—i.e., a compound that causes birth defects. As discussed below, this statement is consistent with the summaries of registrant-submitted studies given in EPA documents on fluazifop-P-butyl. Sesline and Jackson (1994) specify a *Fulsilade* formulation, which appears to be a misspelling of Fusilade, as a teratogen. Pesticide formulations, however, are not typically used in developmental studies, and no studies on a Fusilade formulation were identified in the EPA literature.

Developmental studies are used to assess the potential of a compound to cause malformations and signs of toxicity during fetal development. These studies typically entail gavage administration of the chemical compound to pregnant rats or rabbits on specific days of gestation. Teratology assays as well as studies on reproductive function (Section 3.1.9.2) are generally required by the EPA for the registration of pesticides. Very specific protocols for developmental studies are established by U.S. EPA/OPPTS and are available at http://www.epa.gov/opptsfrs/publications/ OPPTS Harmonized .

Standard developmental studies on fluazifop-P-butyl and fluazifop-butyl were conducted in rats and rabbits. Details on these studies are given in Appendix 1 (Table A1-3) and an overview of these studies is given in Table 12. Two studies were conducted on rabbits, one study using fluazifop-butyl (MRID 00088856) and the other study using fluazifop-P-butyl (MRID 46082904). Five studies were conducted on rats, two studies using fluazifop-butyl (MRIDs 00088857 and 00088858) and three studies using fluazifop-P-butyl (MRIDs 46158401, 46082903, and 46082013). Several of these studies involved more than one submission to the U.S. EPA and are associated with more than one MRID number. The multiple MRID numbers are included in Appendix 1 (Table A1-3), but only the initial MRID number is cited in Table 12.

Differences in the apparent sensitivities of rabbits and rats vary between maternal effects and fetal effects. In terms of maternal toxicity, rabbits appear to be somewhat more sensitive than rats based on a comparison of the maternal LOAELs in rabbits (i.e., 50 and 90 mg/kg bw/day) to the upper range of the maternal NOAELs in rats (i.e., 100 mg/kg bw/day). Based on fetal toxicity, rats appear to be more sensitive than rabbits based on higher NOAELs in rabbits (10 to 30 mg/kg bw/day) relative to the LOAEL in rats (5 mg/kg bw/day) seen in two of the three studies on rats.

Developmental studies involve multiple daily dosing of pregnant animals, typically from Day 6 or 7 of gestation through to Day 20 to 28 of gestation. In terms of a practical impact on the current risk assessment, the distinction made by the U.S. EPA/OPP between developmental effects and teratogenic effects (malformations) is important. Developmental effects typically involve changes in body or organ weight as well as effects that may be associated with a delay in growth (e.g., delayed ossification). Teratogenic effects are frank malformations. Malformations could be associated with an exposure occurring on a single day. Developmental effects, however, are commonly associated with effects caused by several days of exposure.

1 For fluazifop, doses associated with malformations, specifically an increase in the incidence of
2 diaphragmatic hernia, occur at higher doses (i.e., LOAELs of 200 mg/kg bw/day) than
3 developmental effects (LOAELs of 5 to 20 mg/kg bw/day for delayed ossification).  As
4 discussed further in Section 3.3 (Dose-Response Assessment for Humans), these differences in
5 the endpoints for developmental studies are the basis for the different ways in which these
6 studies are used.  The higher NOAEL of 50 mg/kg bw/day for malformations is used as the basis
7 for the acute RfD because the malformations are presumed to be associated with a single
8 exposure.  The lower NOAEL of 2 mg/kg bw/day for developmental effects is used as the basis
9 for the assessment of short-term occupational exposures (1-30 days) because the developmental
10 effects are assumed to be associated with exposures that occur over a period of several days (i.e.,
11 about 14 to 23 days).

12 ### 3.1.9.2. Reproduction Studies
13 Multi-generation reproduction studies typically involve dietary exposures of a group of rats or
14 mice referred to as the *parental generation* or $P_1$.  Male and female animals are selected from
15 this group and mated.  Exposure of the female continues through gestation and after delivery.
16 Offspring from the parental generation, typically referred to as $F_1$, are then continued on dietary
17 exposure through sexual maturity.  The $F_1$ offspring are mated (and then referred to as the P2
18 generation) producing an $F_2$ generation.  This is the basic design of a "2-generation" study,
19 although variations on this design are sometimes used, and occasionally the study is carried over
20 to a third generation.  Multi-generation reproduction studies typically focus on effects on
21 reproductive capacity—i.e., the number of young produced and their survival.
22
23 As detailed in Appendix 1, Table A1-3, U.S. EPA/OPP/HED (2004a,d; 2011a) summarizes the
24 results of a 2-generation reproduction study in rats (MRID 00088859, 92067050).  In this study,
25 rats were exposed to fluazifop-butyl in the diet at concentrations of 0, 10, 80, or 250 ppm.  The
26 durations of the exposures varied by generation—i.e., 100 days for the parental generation, 120
27 days for the $F_1$ generation, and up until weaning for the $F_2$ generation.  No adverse effects were
28 noted for any animals (parental or offspring) at the 10 ppm exposure level.  In the mid-dose
29 group, effects were noted in both males from the parental generation and offspring.   Parental
30 males evidenced a decrease in spleen weights.  Males from the $F_1$ and $F_2$ generations evidenced a
31 decrease in absolute and relative testes and epididymal weights.  Female offspring evidenced
32 decreases in pituitary and uterine weights.  In the high-dose group, parental females evidenced
33 increases in liver and kidney weights as well as geriatric nephropathy.  The EPA documents do
34 not describe the geriatric nephropathy in detail; however, it probably indicates changes in the
35 kidney typically seen in older animals.
36
37 As discussed further in Section 3.3 (Dose-Response Assessment), the chronic RfD for fluazifop-
38 P-butyl is based on the low dose group NOAEL for parental males and offspring using an
39 estimated dose of 0.74 mg/kg bw/day with a corresponding LOAEL of 5.8 mg/kg bw/day (U.S.
40 EPA/OPP 2011a).  This approach is somewhat unusual in that chronic RfDs are typically based
41 on chronic feeding studies unless the NOAEL from the reproduction study is below the NOAEL
42 from the standard chronic feeding study.  As discussed in Section 3.1.5 and summarized in
43 Appendix 1 (Table A1-2), the chronic feeding study in rats yielded a NOAEL of 0.51 mg/kg
44 bw/day for males and 5.2 mg/kg/day for females with corresponding LOAELs of 4.15 mg/kg
45 bw/day for males and 16 mg/kg bw/day for females.  As with the reproduction study, the
46 NOAEL dose of 0.51 mg/kg bw/day is based on a dietary concentration of 10 ppm.  The

somewhat lower mg/kg bw/day dose given for the chronic study, relative to the reproduction study, is to be expected since the period of exposure in the chronic study (106 to 107 weeks) was longer than that in the reproduction study (up to 120 days).

The U.S. EPA/OPP documents reviewed in the preparation of this Forest Service risk assessment (i.e., the documents specified in Table 2) do not explicitly discuss the rationale for using the somewhat higher NOAEL of 0.74 mg/kg bw/day from the reproduction study rather than the NOAEL of 0.51 mg/kg bw/day from the chronic rat feeding study. This dose selection for the chronic RfD is discussed further in the dose-response assessment (Section 3.3).

As summarized at the end of Table A1-3 in Appendix 1, EFSA (2012) provides brief summaries of *reproduction toxicity studies* (note the plural form) and note a NOAEL of 0.8 mg/kg bw/day. This study or studies are not referenced. As noted in the same table for MRID 00088859, the 2-generation study described in detail in EPA documents, the NOAELs were 0.74 mg/kg bw/day for males and the corresponding dose in females was 0.88 mg/kg bw/day. It seems reasonable to speculate that the NOAEL of 0.8 mg/kg bw/day reported by EFSA (2012) is from MRID 00088859 based on the averaging of the mg/kg bw/day dose for the 10 ppm dietary dose group.

### 3.1.10. Carcinogenicity and Mutagenicity

A number of different test systems for mutagenicity (e.g., bacterial assays, mammalian cell culture assay, and assays for chromosome aberrations) are required for pesticide registration. These assays were conducted on fluazifop-butyl and fluazifop-P-butyl and provided no evidence of mutagenicity (U.S. EPA/OPP/HED 2011a, p. 24). This assessment is consistent with reviews of mutagenicity studies on fluazifop-butyl and fluazifop-P-butyl from the European literature (EFSA 2012; FAO/WHO 2000).

As summarized in Appendix 1 (Table A1-2) and discussed in Section 3.1.5, fluazifop-butyl was assayed for carcinogenicity in a chronic feeding study with rats (MRID 41563703) and fluazifop-P-butyl was assayed for carcinogenicity in a chronic feeding study in hamsters (MRID 4534501, 46082905). No increases in the incidences of tumors were observed in either species. Based on these studies as well as the supporting studies on mutagenicity, the most recent EPA risk assessment on fluazifop-P-butyl notes the following:

> *Fluazifop-P-butyl is classified as "not likely to be carcinogenic to humans"*
> *and no mutagenic potential was observed in adequate in vivo and in vitro*
> *studies with fluazifop-P-butyl.*
>
> U.S. EPA/OPP/HED 2011a, p. 5

This position is repeated in other EPA risk assessments on fluazifop-P-butyl (Table 2) as well as the European reviews that address carcinogenicity (i.e., EFSA 2012; FAO/WHO 2000).

### 3.1.11. Irritation and Sensitization (Effects on the Skin and Eyes)

The U.S. EPA/OPP requires standard studies on skin and eye irritation as well as skin sensitization for pesticide registration (U.S. EPA/OCSPP 2013). As with acute oral toxicity, the U.S. EPA/OPP uses a ranking system for responses ranging from Category I (most severe response) to Category IV (least severe response) for all three groups of endpoints discussed in this subsection (e.g., U.S. EPA/OPP 2011a).

### 3.1.11.1. Skin Irritation

Assays for skin irritation and sensitization are summarized in Appendix 1, Table A1-4. Assays for skin irritation were conducted on both fluazifop-butyl (MRID 00088853) and fluazifop-P-butyl (MRID 00162441). Both studies found mild dermal irritation that cleared within 72 hours. The most recent EPA human health risk assessment (U.S. EPA/OPP/HED 2011a, p. 59) classifies both fluazifop-butyl and fluazifop-P-butyl as a Category IV skin irritant—i.e., the least hazardous category. This classification is consistent with the review of fluazifop-P-butyl by the European Food Safety Authority (EFSA 2012, p. 30).

### 3.1.11.2. Skin Sensitization

Information on the skin sensitization assays for fluazifop-butyl and fluazifop-P-butyl are also summarized in Appendix 1, Table A1-4. Unlike the case with skin irritation, the available information on skin sensitization contains apparent inconsistencies.

The U.S. EPA/OPP/HED (2011a) cites standard sensitization assays in guinea pigs indicating that neither fluazifop-butyl (MRID 00088854) nor fluazifop-P-butyl (MRID 00162441) cause skin sensitization. This assessment is consistent with statements on skin sensitization given in the review of fluazifop-P-butyl by the World Health Organization (FAO/WHO 2000, p. 16). The review by the European Food Safety Authority of fluazifop-P and fluazifop-P-butyl (EFSA 2012) , however, indicates that fluazifop-P-butyl does cause skin sensitization and that labels for formulations containing fluazifop-P-butyl must include the following statement: *May cause sensitization by skin contact* (EFAS 2012, p. 7). As indicated in Appendix 1 (Table A1-8), the MSDSs for both Fusilade DX and Fusilade II contain the following language: *Repeated and/or prolonged contact may cause skin sensitization*.

The reasons for the discrepancies between the statements in the EPA and WHO documents, compared with the statements from EFSA and the MSDS for the Fusilade formulations, are not apparent. The two MRID studies cited in U.S. EPA/OPP/HED (2011a) involved technical grade fluazifop-butyl (93.3%) and fluazifop-P-butyl (86.3%). As noted in Section 3.1.4, the EPA requires skin sensitization assays on distinct pesticide formulations (U.S. EPA/OPP 2010c). Summaries of the results of skin sensitization assays with Fusilade formulations were not identified in the EPA literature (Table 2).

Given the wording on the MSDS for the Fusilade formulations, it appears that skin sensitization assays on one or both of the Fusilade formulations may have evidenced a skin sensitization response. In the absence of additional information, skin sensitization is viewed as an endpoint of concern in the current risk assessment.

### 3.1.11.3. Ocular Effects

Standard eye irritation studies in rabbits were conducted with technical grade fluazifop-butyl (MRID 00088855) and technical grade fluazifop-P-butyl (MRID 00162441). These studies are summarized in Appendix 1, Table A1-5. Based on these studies, U.S. EPA/OPP/HED (2011a, p. 59) classifies fluazifop-butyl and fluazifop-P-butyl as Category IV, the lowest hazard category. The EPA summaries of these studies indicate that fluazifop-P-butyl caused mild irritation which cleared within 3 days; however, no description of eye irritation is given for fluazifop-butyl. It is not clear whether the results in the two bioassays were substantially different or if the summary of the study on fluazifop-P-butyl is simply somewhat more elaborated than the summary on

fluazifop-butyl.  The classification of fluazifop-butyl and fluazifop-P-butyl as minimally
irritating to eyes is consistent with the evaluation by EFSA (2012) and the MSDS for Fusilade
DX and Fusilade II (Appendix 1, Table A1-8).

### 3.1.12. Systemic Toxic Effects from Dermal Exposure
As summarized in Appendix 1 (Table A1-6), acute dermal toxicity studies are available on
technical grade fluazifop-butyl (MRID 00162439) and fluazifop-P-butyl (MRID 00093819).  In
addition, a repeated dose (21-day) study is available on technical grade fluazifop-butyl (MRID
00093819).  All of these studies were conducted in rabbits, and are cited in the most recent EPA
human health risk assessment on fluazifop-P-butyl (U.S. EPA/OPP/HED 2011a).  A relatively
detailed summary of the repeated dose study is given in U.S. EPA/OPP/HED (2004a).

#### *3.1.12.1. Acute Studies*
The acute toxicity studies on fluazifop-butyl and fluazifop-P-butyl are unremarkable, with both
reporting indefinite $LD_{50}$ values of >2000 mg/kg bw.  Based on these studies, the EPA classifies
fluazifop-P-butyl as Category III for acute dermal toxicity (U.S. EPA/OPP/HED 2011a, p. 59).
The classification of fluazifop-P-butyl as Category III appears to reflect the maximum dose
tested rather than an assessment of greater hazard than a Category IV compound.  In order to
classify a compound as Category IV for acute dermal toxicity, the dose tested must be greater
than 5000 mg/kg bw (U.S. EPA/OPP 2010c, p. 7-2).

Two reviews of fluazifop-P-butyl from the European literature cite an indefinite acute dermal
$LD_{50}$ value of >2110 mg/kg bw for fluazifop-P-butyl (EFSA 2012 , p. 30, FAO/WHO 2000, p.
16), but do not provide a reference citation for the study associated with this indefinite $LD_{50}$.

As summarized in Appendix 1 (Table A1-6), the Material Safety Data Sheets (MSDS) for
Fusilade DX and Fusilade II cite an acute dermal $LD_{50}$ value for rabbits of >2000 mg/kg bw.  As
discussed previously, the MSDS for these formulations both specify that the toxicity values
apply to the "*Finished Product*"—i.e., the formulations rather than the active ingredient.  Given
as acid equivalents, the $LD_{50}$ of >2000 mg formulation/kg bw corresponds to >490 mg a.i./kg
bw.  Because the dermal $LD_{50}$ values for fluazifop-P-butyl and the formulations are all indefinite,
these data are not useful for assessing the toxic potential of the other ingredients in the fluazifop-
P-butyl formulations.

#### *3.1.12.2. Repeated Dose Study*
In the 21-day repeated dose study on fluazifop-butyl (Appendix 1, Table A1-6), overt signs of
toxicity included death in 1/10 male rats in the 500 mg/kg bw/day dose group as well as 4/10
males and 5/10 females in the 2000 mg/kg bw/day dose group.  Effects suggestive of kidney
damage (e.g., pathological changes in the glomerulus) were noted; however, it is unclear whether
the effects reported in the summary of this study in U.S. EPA/OPP/HED (2004a) were caused
directly by fluazifop-P-butyl or secondary to other effects.  No adverse effects were noted in the
100 mg/kg bw/day dose groups.

As discussed further in Section 3.2 (exposure assessment for human health effects), many of the
exposure scenarios considered in this risk assessment involve dermal exposures.  The repeated-
dose dermal toxicity study on fluazifop-butyl reinforces concern that dermal exposures have the
potential to cause systemic toxicity.

### 3.1.13. Inhalation Exposure

The acute inhalation studies on fluazifop-butyl and fluazifop-P-butyl are summarized in
Appendix 1 (Table A1-7). Unlike most other endpoints discussed in this hazard identification,
the reported data on the inhalation toxicity of fluazifop-P-butyl are somewhat disparate.

The human health risk assessments and supporting documentation from U.S. EPA/OPP/HED
(2004a,b,c,d; 2005a, 2011a) are typically consistent with each other in terms of summarizing
studies and selecting studies for use in the various assessments. This is not the case, however,
for inhalation exposures. The U.S. EPA/OPP/HED (2004a, p. 20) support document for the
tolerance reassessment of fluazifop-P-butyl uses a relatively standard acute inhalation study
(MRIDs 46082901 and 41563701) on technical grade fluazifop-butyl (97%) which reports acute
$LC_{50}$ values of >2.3 to >4.37 mg/L to classify fluazifop-butyl as Category III for acute inhalation
exposures. This study is not cited in the most recent EPA human health risk assessment on
fluazifop-P-butyl (U.S. EPA/OPP/HED 2011a).

As an alternative, EPA/OPP/HED (2011a, p. 59) uses a study on a mixture of fluazifop-P-butyl
and fenoxyprop-P-ethyl to derive an acute $LC_{50}$ of >1.7 mg/L expressed as fluazifop-P-butyl.
This indefinite $LC_{50}$ also leads to a classification of fluazifop-P-butyl as Category III for acute
inhalation exposures. Like fluazifop-P-butyl, fenoxyprop-P-ethyl is an aryloxyphenoxy
propionate herbicide used to control grasses (U.S. EPA/OPP 2007b). U.S. EPA/OPP/HED
(2011a) does not discuss why the document used the mixture inhalation study rather than the
studies cited in U.S. EPA/OPP/HED (2004a, p. 20). Perhaps, the EPA gave preference to the
mixture study simply because it involved fluazifop-P-butyl rather than fluazifop-butyl.

A more important discrepancy, however, involves the inhalation $LC_{50}$ values reported on the
MSDS for Fusilade DX and Fusilade II. As summarized in Appendix 1 (Table A1-8), the MSDS
report definitive $LC_{50}$ values of 0.54 mg/L for a 4-hour exposure (a standard duration in these
types of bioassays). The MSDS also note that identity of the animal used in the $LC_{50}$ study is
…"*Not Available*". No inhalation studies were identified in the literature on fluazifop-butyl or
fluazifop-P-butyl with a reported inhalation $LC_{50}$ of 0.54 mg/L. Moreover, the notation that the
identity of the test animal is unknown does not make sense and diminishes the credibility of the
MSDS.

The European literature cites an indefinite acute inhalation $LC_{50}$ of >5.2 mg/L in rats for
fluazifop-P-butyl (EFSA 2012, p. 30; FAO/WHO 2000, p. 16). No details concerning this study
are provided in the European reviews.

### 3.1.14. Adjuvants and Other Ingredients

#### *3.1.14.1. Other Ingredients*

U.S. EPA is responsible for regulating both the active ingredients (a.i.) in pesticide formulations
as well as any other chemicals that may be added to the formulation. As implemented, these
regulations affect only pesticide labeling and testing requirements. The term *inert* was used to
designate compounds that are not classified as active ingredient on the product label. While the
term *inert* is codified in FIFRA, some inerts can be toxic, and the U.S. EPA now uses the term
*Other Ingredients* rather than *inerts* (http://www.epa.gov/opprd001/inerts/). For brevity, the

following discussion uses the term *inert*, recognizing that *inerts* may be biologically active and potentially hazardous components.

The identities of inerts in pesticide formulations are generally considered trade secrets and need not be disclosed to the general public. Nonetheless, all inert ingredients as well as the amounts of the inerts in the formulations are disclosed to and reviewed by the U.S. EPA as part of the registration process. Some inerts are considered potentially hazardous and are identified as such on various lists developed by the federal government and state governments. Material Safety Data Sheets (MSDS) sometimes specify inerts used in pesticide formulations. U.S. EPA/OPP (2010c, p. 5-14) encourages but does not generally require expanded inert statements on product labels which specifically identify the inert ingredients in the product. One notable exception, however, involves petroleum distillates including xylene or xylene range solvents that are part of the formulation and at a concentration of ≥10%. In this case, the product label must contain the following statement: *Contains petroleum distillates, xylene or xylene range aromatic solvents* (U.S. EPA/OPP 2010d, p. 5-7).

Table 7 summarizes the product labels of all of the formulations of fluazifop-P-butyl explicitly covered in the current risk assessment. As noted in Section 2, the Fusilade but not the Ornamec formulations are likely to be used in Forest Service programs. Information on the Ornamec formulations is included in Table 7 simply as an example of a relatively detailed summary of the other ingredients in the formulations. The Fusilade formulations provide relatively little detail on the composition of the other ingredients. Nonetheless, the predominant inerts in both the Fusilade and Ornamec formulations consist of petroleum distillates.

Petroleum distillates, including aromatic hydrocarbons, are complex mixtures (e.g., ATSDR 1995, 1999). Thus, it is possible that the specific constituents in the petroleum distillates of the different liquid formulations of fluazifop-P-butyl differ at least somewhat from one another. As reviewed by ATSDR (1999), petroleum distillates can induce a wide range of toxic effects, particularly effects on the nervous system. The U.S. EPA/OPP has not yet completed their RED for aromatic hydrocarbons (http://www.epa.gov/pesticides/reregistration/status.htm). Petroleum distillates may also contain naphthalene as well as other aromatics. As detailed in U.S. EPA/OPP (2008a), naphthalene is a pesticide registered for use as an insecticide and insect repellant. For example, naphthalene is the active ingredient in mothballs.

Given the complexity and variability of petroleum distillates and the limited information about the identity of the petroleum components in fluazifop-P-butyl formulations, it is difficult to assess the extent to which the petroleum distillates contribute to the toxicity of the formulations. One approach is to compare the toxicity of the formulations, expressed in units of active ingredient, to the toxicity of the active ingredient itself. As discussed in previous sections, however, this approach cannot be applied to fluazifop-P-butyl, because the relevant acute toxicity data on the formulations consist primarily of indefinite $LD_{50}$ or $LC_{50}$ values. As discussed in Section 3.1.4, the definitive oral $LD_{50}$ values for fluazifop-butyl and fluazifop-P-butyl along with the indefinite $LD_{50}$ values for the Fusilade formulations are consistent with the assumption that the toxicity of the formulations is attributable to the active ingredient rather than other ingredients (a.k.a., *inerts*) in the formulations.

1    As discussed further in the ecological risk assessment (Section 4.1.3), definitive $LC_{50}$ values for
2    fluazifop-butyl and/or fluazifop-P-butyl are available along with data on some fluazifop-P-butyl
3    formulations for aquatic organisms.  The relevance of these data to human health risks is tenuous
4    at best.

5         *3.1.14.2. Adjuvants*
6    As summarized in Table 6, adjuvants, including nonionic surfactants, methylated seed oils, or
7    vegetable oil concentrates are recommended for the Fusilade DX and Fusilade II formulations.
8    These adjuvants are commonly used with herbicides to improve efficacy.  Product labels
9    recommend the use of nonionic surfactants at a concentration of 0.25% v/v, methylated seed oil,
10   vegetable oil at a concentration of 1% (v/v), or other commercially available adjuvants.
11
12   Although methylated seed oils and vegetable oil concentrates are somewhat vague terms, there is
13   no basis for asserting that these adjuvants are likely to enhance the toxicity of fluazifop-P-butyl
14   to humans.  Several seed and vegetable oils are approved food additives (Clydesdale 1997);
15   moreover, many vegetable and fruit oils are classified as *minimal risk inerts* (U.S. EPA/OPPTS
16   2009).  Nonionic surfactants comprise a large and complex group of materials (e.g., Kosswig
17   1994).  In the absence of mammalian studies regarding the potential toxicity of fluazifop-P-butyl
18   in combination with various nonionic surfactants, it is not possible to generalize about potential
19   hazards to human health.  As discussed further in the ecological risk assessment, some nonionic
20   surfactants are much more toxic than fluazifop-P-butyl to aquatic species (Section 4.1.3.5).

21   **3.1.15. Impurities and Metabolites**

22        *3.1.15.1. Metabolites*
23   As discussed in Section 3.1.3.1, metabolism studies in mammals as well as humans indicate that
24   fluazifop-butyl and fluazifop-P-butyl are rapidly hydrolyzed to fluazifop-P (i.e., primarily the
25   fluazifop[R] enantiomer).  With the exception of conjugation reactions, however, fluazifop[R]
26   enantiomer is not further metabolized, at least, in detectable quantities.
27
28   In the environment, however, fluazifop-P is extensively metabolized, and the major metabolites
29   are 2-(4-hydroxyphenoxy) propionic acid (a.k.a. Metabolite III), 2-(4-hydroxyphenoxy)-5-
30   trifluoromethylpyridine (a.k.a. Metabolite IV), and 5-trifluoromethyl-2-pyridone (a.k.a.
31   Metabolite X).  The structures of these compounds are given in the lower section of Figure 1.
32   The analysis in U.S. EPA/OPP/HED (2004c) focuses exclusively on a discussion of the
33   environmental metabolites and residue chemistry of fluazifop-P-butyl.  U.S. EPA/OPP/HED
34   (2004c) indicates that no toxicity data were available on these metabolites.  Following standard
35   practice, U.S. EPA/OPP/HED (2004c, p. 4) recommends that the major environmental
36   metabolites should be considered to be as toxic as the parent compound.  In practical terms, this
37   amounts to using input parameters for exposure models (e.g., environmental half-lives) adjusted
38   to encompass fluazifop-P (the acid) as well as the major environmental metabolites.  This
39   recommendation as well as the input parameters selected in U.S. EPA/OPP exposure assessments
40   for fluazifop-P-butyl are discussed further in the exposure assessment (Section 3.2).
41
42   For some exposure scenarios, like the consumption of contaminated fruit or broadleaf vegetation
43   (Section 3.2.3.7), there is a concern that the estimates of exposure may not adequately
44   encompass exposures to metabolites of fluazifop-P acid.  These instances are noted and

1  emphasized in the exposure assessment (Section 3.2) and discussed further in the risk
2  characterization (Section 3.4).
3
4  Consistent with the EPA review, U.S. EPA/OPP/HED (2004c), there are no mammalian toxicity
5  data on metabolites for use in the current risk assessment.  As discussed further in Section 4.1.3
6  (hazard identification for aquatic organisms), acute toxicity studies have been conducted on 5-
7  trifluoromethyl-2-pyridone (a.k.a. Metabolite X) in fish, aquatic invertebrates, and algae.  These
8  studies consistently indicate that 5-trifluoromethyl-2-pyridone is less toxic than fluazifop-P-
9  butyl.  While these studies may not be directly or quantitatively applicable to the human health
10  risk assessment, these studies in aquatic organisms are the only data available on the toxicity of
11  5-trifluoromethyl-2-pyridone and this information diminishes concern for the toxicity of 5-
12  trifluoromethyl-2-pyridone.

13      *3.1.15.2. Impurities*
14  There is no information in the published literature or the summaries of registrant-submitted
15  studies from EPA documents (Table 2) concerning the impurities in fluazifop-P-butyl.
16  Nonetheless, virtually no chemical synthesis yields a totally pure product.  As summarized in
17  Appendix 1, the reported levels of purity of fluazifop-P-butyl in mammalian toxicology studies
18  range from about 86% to over 99%.  Thus, up to 14% of technical grade fluazifop-P-butyl may
19  consist of impurities.  Registrants disclose the nature of impurities in their formulations to the
20  U.S. EPA; however, the identities of the impurities are not disclosed to the public, because that
21  information may provide insight into the manufacturing process, which is considered proprietary
22  and is protected under FIFRA (Section 10).  Proprietary information on the identities of these
23  impurities was not available for the preparation of the current Forest Service risk assessment.
24
25  To some extent, concern for impurities in technical grade fluazifop-P-butyl is reduced because
26  most of the existing toxicity studies were conducted with the technical grade product or
27  formulated products.  Thus, any toxic impurities present in the technical grade product are likely
28  to be encompassed by the available toxicity studies.

29      **3.1.16. Toxicological Interactions**
30  In terms of the mechanism of action, fluazifop-P is a weak acid excreted predominantly in the
31  urine.  Many weak acids, both naturally occurring and man-made, are excreted in the urine via
32  active transport processes in the kidney (e.g., Schnermann and Sayegh 1998).  Thus, it is likely
33  that fluazifop-P, the major metabolite of fluazifop-P-butyl in humans (Section 3.1.3.1), would
34  influence and would be influenced by other weak acids excreted by the kidney.  These
35  influences, however, would be significant only at relatively high doses that saturated the active
36  transport processes involved in the excretion of weak acids by the kidney.
37
38  As discussed in Section 3.1.2, fluazifop-butyl is a substrate for cytochrome P450 which is
39  involved in the hydrolysis of fluazifop-butyl to fluazifop acid prior to excretion.  Cytochrome
40  P450 is a variable set of enzymes that are both induced by and involved in the metabolism of
41  many naturally occurring as well as man-made compounds (e.g., Coon 2005).  Thus, exposures
42  to other compounds that serve as inducers or substrates for cytochrome P450 could impact the
43  metabolism or excretion of fluazifop-P-butyl.  In the absence of other information, the impact
44  that these interactions might have on the toxicity of fluazifop-P-butyl cannot be further
45  characterized.  Like kidney excretion, metabolic reactions involving cytochrome P450 are

1    saturable processes.  Thus, it seems reasonable to suggest that these interactions would be
2    substantial only at relatively high levels of exposure in which cytochrome P450 would be
3    induced or the metabolism of fluazifop-P-butyl would be competitively inhibited by other
4    substrates of cytochrome P450.

1    **3.2.  EXPOSURE ASSESSMENT**

2       **3.2.1. Overview**
3    Two types of exposure assessments are considered: general exposure and accidental/incidental
4    exposure.  For workers, the term *general exposure* is used to designate exposures involving
5    absorbed dose estimates based on handling a specified amount of chemical during specific types
6    of applications.  For the general public, the term *general exposure* is used to designate exposures
7    that might be expected following a typical application of fluazifop-P-butyl.  The
8    accidental/incidental exposure scenarios involve specific events that may occur during any type
9    of application.  All applications are expressed in units of acid equivalents (a.e., fluazifop-P acid)
10   rather than active ingredient (a.i., fluazifop-P-butyl).  Exposure assessments (i.e., those for
11   workers as well as members of the general public and ecological receptors) are based on the
12   maximum single application rate of 0.375 lb a.i./acre, which is equivalent to 0.32 lb a.e./acre.
13   The exposures associated with a single application are detailed in Attachment 1.  The exposures
14   associated with two and three applications with a 14-day application interval are detailed in
15   Attachments 2 and 3, respectively.  For most exposure scenarios, exposure and consequent risk
16   will scale linearly with the application rate.  The consequences of using lower application rates
17   are considered in the risk characterization (Section 3.4).

18      **3.2.2. Workers**

19         ***3.2.2.1. General Exposures***

20            **3.2.2.1.1. Standard Estimates**
21   As described in SERA (2011a), worker exposure rates are expressed in units of mg of absorbed
22   dose per kilogram of body weight per pound of chemical handled.  Based on analyses of several
23   different pesticides using a variety of application methods, exposure rates are estimated for three
24   different types of applications: directed foliar (backpack), boom spray (hydraulic ground spray),
25   and aerial.  The worker exposure rates are summarized in Table 13 of the current Forest Service
26   risk assessment.  The worker exposure rates in Table 13 are taken from a recent update and
27   reevaluation of the methods used to estimate worker exposure (SERA 2013b).  All exposure
28   rates are based on biomonitoring studies of worker exposures during pesticide applications.
29
30   As discussed further in Section 3.2.3.1.1 (Likelihood and Magnitude of Exposure), most
31   exposure scenarios included in the current risk assessment are accompanied by estimates of
32   variability and/or uncertainty and are expressed as a central value (most likely exposure) as well
33   as estimates of the upper and lower bounds of exposure.  The revised worker exposure rates from
34   SERA (2013b) are elaborated to include both 95% confidence intervals as well as 95%
35   prediction intervals.  As discussed in SERA (2013b), the 95% confidence intervals should be
36   interpreted as the region defining ranges of average exposures in groups of workers.  The 95%
37   prediction intervals should be interpreted as the region in which most exposures for individual
38   workers may occur.
39
40   Another elaboration in the new worker exposure methods involves the adjustment for exposure
41   rates in backpack workers based on differences in dermal absorption.  As Section 4.2.1.1 of
42   SERA (2013b) explains, different exposure rates are based on data for backpack workers
43   applying glyphosate, 2,4-D, and triclopyr BEE.  In developing backpack worker exposure rates

1  for another pesticide, one of these three rates is selected based on the first-order dermal
2  absorption rate coefficients for these pesticides and the pesticide under consideration.  As
3  discussed in Section 3.1.3.2.1, the central estimate of the first-order dermal absorption rate
4  coefficient for fluazifop-P-butyl is taken as 0.0024 hour$^{-1}$.  This estimate is based on quantitative
5  structure-activity relationships detailed in Worksheet B03b of Attachments 1, 2, and 3 and is
6  supported by and is virtually identical to the estimated first-order dermal absorption rate
7  coefficient of 0.00233 hour$^{-1}$ derived from the dermal absorption study in humans by Ramsey et
8  al. (1992).
9
10  The first-order dermal absorption rate coefficient of 0.0024 hour$^{-1}$is only modestly higher than
11  the corresponding coefficient of 0.0021 hour$^{-1}$ for triclopyr BEE as discussed in SERA (2013b).
12  Following the approach detailed in SERA (2013b, Equation 22), the exposure rates for triclopyr
13  BEE derived in SERA (2013) are multiplied by the adjustment factor of about 1.14 [0.0024
14  hour$^{-1}$ ÷ 0.0021 hour$^{-1}$ ≈ 1.14286]—i.e., the coefficient for fluazifop-P-butyl divided by the
15  coefficient for triclopyr BEE—and the central estimate of the exposure rate for backpack
16  workers applying fluazifop-P-butyl is estimated at 0.011 with 95% confidence intervals of
17  0.0008 to 0.015 and 95% prediction intervals of 0.00023 to 0.069 mg/kg bw/day per lb a.i.
18  handled.  Details of these calculations are provided in Worksheet C01a-Sup of Attachments 1, 2,
19  and 3.
20
21  In addition to the application rate and absorbed dose rate, the other factor affecting worker
22  exposure is the number of acres per day that a worker will treat.  Estimates of the number of
23  acres per day that a worker might treat are also given in Table 13.  These values are based on
24  treatment rates used in several Forest Service Environmental Impact Statements (USDA/Forest
25  Service 1989a,b,c).
26
27  Based on the above methods and the maximum single application rate of 0.32 lb a.e./acre, the
28  estimates of worker exposures are given in Worksheets C01a (backpack directed foliar
29  applications), C01b (ground broadcast applications), and C01c (aerial applications) of
30  Attachment 1, 2, and 3.  The specific estimates are discussed further in Section 3.2.2.1.4 and
31  compared to estimates from U.S. EPA/OPP/HED (2011a) and the worker exposure study of
32  Chester and Hart (1986).

### 3.2.2.1.2. EPA Estimates

34  As discussed in SERA (2013b, Section 1.1), the U.S. EPA uses deposition-based methods rather
35  than the absorption-based methods used in Forest Service risk assessments.  The deposition-
36  based methods typically use the Pesticide Handlers Exposure Database (PHED 1995).  U.S.
37  EPA/OPP summarized surrogate exposures from PHED for 37 exposures scenarios, involving
38  mixer-loaders, flaggers, and applicators, for several different types of formulations (e.g., liquid,
39  granular, and wettable powders) applied with ground or aerial equipment (Keigwin 1998).  Using
40  the estimates of deposited dose and concentration of the pesticide in air, the absorbed dose for
41  workers can be calculated if estimates are available on absorption rates for inhalation and dermal
42  exposure.  Table 14 provides an overview, adopted from Keigwin (1998), of the standard
43  exposure rates used by the U.S. EPA.
44
45  The specific worker exposure assessments derived in the most recent EPA human health risk
46  assessment are given in Table 8 and 9 of U.S. EPA/OPP/HED (2011a).  Typically, the EPA

1   summaries of such assessments specify all of the inputs and give explicit estimates of both
2   dermal and inhalation doses in units of mg/kg bw.  The estimates for fluazifop-P-butyl are
3   somewhat unusual in that the worker exposure rates are not specified and only the dermal dose is
4   given explicitly.  Nonetheless, the total absorbed doses for the worker groups can be estimated
5   from the Margins of Exposure (MOEs).  The margin of exposure is defined as:

6

7   $$MOE = \frac{NOAEL}{Exposure} \qquad (5)$$

8

9   Taking Table 9 from U.S. EPA/OPP/HED (2011a) as an example, the margin of exposure for
10  aerial applications is given as 746 and the margin of exposure for groundboom equipment is
11  given as 813.  Both of these MOEs are based on the chronic NOAEL of 0.74 mg/kg bw/day from
12  the reproduction study in rats (MRID 00088859 as summarized in Appendix 1, Table A1-3).
13  Rearranging the above equation to solve for *Exposure*, these MOEs are associated with doses of
14  about 0.00099 mg/kg bw for aerial applications [0.74 mg/kg ÷ 746] and 0.00091 mg/kg bw for
15  ground applications [0.74 mg/kg ÷ 813].

16

17  To verify the above calculations of the estimated doses, an attempt was made to reconstruct the
18  PHED exposure assessments given in Table 9 of U.S. EPA/OPP/HED (2011a).  These
19  reconstructions are given in Worksheet PHED-Grnd for ground broadcast applications and
20  Worksheet PHED-Aerial for aerial applications.  These worksheets follow Worksheet C01c (the
21  last of the standard assessments for workers discussed in Section 3.2.2.1.1).  The dermal doses
22  reported in U.S. EPA/OPP/HED (2011a) are identical to doses that would be obtained using the
23  worker exposure rates in Scenario 7 (aerial) and Scenario 13 (groundboom) of Keigwin (1988).
24  These scenarios are highlighted in Table 14 of the current Forest Service risk assessment.  The
25  inhalation exposures associated with these scenarios from Keigwin (1988) lead to somewhat
26  higher MOEs—i.e., about 863 for groundboom applications and 762 for aerial applications,
27  which indicates that the EPA used somewhat higher inhalation exposure rates (U.S.
28  EPA/OPP/HED 2011a).  The differences between the MOEs reported in U.S. EPA/OPP/HED
29  (2011a) and the MOEs from the reconstructions given in Worksheets PHED-Grnd and PHED-
30  Aerial are insubstantial.

31

32  A more noteworthy discrepancy, however, is a statement made in EPA's discussion of the
33  worker exposure assessments: "…*occupational exposures for the new uses of fluazifop-P-butyl*
34  *were found to range from a high of 0.07 mg/Kg/day to a low of 0.006 mg/Kg/day*" (U.S.
35  EPA/OPP/HED 2011a, p. 48).  The discussion then references Tables 8 and 9 of the EPA risk
36  assessment.  The lower bound dose noted in U.S. EPA/OPP/HED (2011a) is consistent with the
37  higher reported doses and MOEs in Tables 8 and 9 of the EPA risk assessment.  The upper
38  bound dose of 0.07 mg/kg bw/day, however, would be associated with an MOE of only about 11
39  using the chronic NOAEL of 0.74 mg/kg bw/day [0.74 mg/kg bw ÷ 0.07 mg/kg bw/day ≈
40  10.571] or an MOE of about 29 using the subchronic NOAEL of 2 mg/kg bw [2 mg/kg bw ÷
41  0.07 ≈ 28.57].  Both of these MOEs would be substantially less than the acceptable margin of
42  exposure (MOE = 100) used in U.S. EPA/OPP/HED (2011a, Section 4.4.4.1, p. 21).  The EPA
43  document notes that none of the worker exposures exceeds the Agency's level of concern: *In*
44  *reaching or exceeding the LOC of 100, the resulting MOEs indicate these risks are not of*

*concern* (U.S. EPA/OPP/2011a, p. 9). A margin of exposure in the range of 11 to 29, however, is less than the acceptable margin of exposure, and this would exceed the level of concern.

The reasons for the discrepancy in the EPA's estimated worker doses of up to 0.07 mg/kg bw/day and the acceptable MOEs discussed by the Agency are not apparent. As summarized in Table 15 of the current risk assessment, only the upper bound of the prediction intervals using the absorption based methods typically employed in Forest Service risk assessments exceed the dose of 0.07 mg/kg bw/day discussed in the EPA risk assessment.

### 3.2.2.1.3. Chester and Hart 1986

One worker exposure study involving applications of fluazifop-butyl was identified in the open literature (Chester and Hart 1986). In this study, workers applied fluazifop-butyl by backpack and vehicle-mounted spray equipment. While Chester and Hart (1986) do not specify the formulation of fluazifop-butyl that was used, the paper references unpublished internal reports from the Plant Protection Division of Imperial Chemical Industries indicating that a Fusilade formulation was used, at least in the study with vehicle-mounted sprays. Estimates of the absorbed doses for workers were based on pharmacokinetic studies done on human volunteers (discussed in Section 3.1.3 of the current risk assessment) and complete urine samples for 9 days following applications.

Chester and Hart (1986) estimated absorbed doses of 0.03 (0.02-0.04) mg/kg bw/day for backpack applications and 0.007(0.001 – 0.03) mg/kg bw/day for ground spray applications. While this is the type of worker exposure study on which the derivation of worker exposure rates in SERA (2013) are based, Chester and Hart (1986) do not provide information on the amount of fluazifop-butyl handled by the workers. Thus, worker exposure rates in units of mg/kg bw/day per lb handled cannot be derived from this study.

### 3.2.2.1.4. Estimates Used in Risk Assessment

A summary and comparison of the worker exposures is given in Table 15 for the worker exposures derived in the current risk assessment using the methods from SERA (2013b), the worker exposures given in U.S. EPA/OPP/HED (2011a), and the worker exposures from the study by Chester and Hart (1986). Note that both U.S. EPA/OPP/HED (2011a) and Chester and Hart (1986) give the estimated doses for workers in units of mg a.i./kg bw/day. In the worksheets that accompany this risk assessment, all exposures are given in units of mg a.e. For the comparison given in Table 15, the estimated doses for workers given in the workbooks that accompany this risk assessment are divided by 0.854 a.e./a.i. and all of the doses given in Table 15 are expressed in units of mg a.i./kg bw/day.

As summarized in Table 15, the estimated doses for workers based on tables from U.S. EPA/OPP/HED (2011a) are lower than the central estimates of doses using the methods from SERA (2013)—i.e., by a factor of about 4.6 for ground spray [$0.0042 \div 0.00091 \approx 4.615$] and a factor of about 3.7 for aerial applications [$0.0037 \div 0.00099 \approx 3.7373$]. While these differences might be viewed as substantial, the discussions in SERA (2013b) note that high variability in estimates of worker exposure, and this variability is expressed in the confidence and prediction intervals for the worker exposure rates from SERA (2013b). For example, the 90% confidence intervals span a factor of about 13 [$0.013 \div 0.00099 \approx 13.13$] and the prediction intervals span a factor of 7000 [$0.35 \div 0.00005 = 7000$] for the ground spray workers. Thus, given the variability

1    among average exposure noted in different worker exposure studies as well as the variability
2    among individual workers, differences of a factor of 4 or 5 are not remarkable.
3
4    The above comparison of the exposure assessments from EPA/OPP/HED (2011a) to the
5    assessments based on the methods in SERA (2013b) is somewhat distorted by differences in
6    underlying assumptions.  As detailed in U.S. EPA/OPP/HED (2011a, Table 9, p. 50), the worker
7    exposure assessments are based on the assumption that aerial applications involve treating 350
8    acres and ground spray applications involve treating 80 acres.  As summarized in Table 13 of the
9    current risk assessment, the estimates from SERA (2013b) are based on standard assumptions
10   used in all Forest Service risk assessments: aerial operations may involve treating 490 (240-800)
11   acres and ground spray operations may involve treating 112 (66-168) acres.  In Table 15, the
12   values given in braces {} under the EPA column are adjusted to use the same number of acres as
13   the central estimates from SERA (2013).  Based on this more appropriate comparison, the
14   differences between the SERA (2013) and EPA estimates are reduced—i.e., a factor of 3.5 for
15   ground spray [$0.0042 \div 0.0012 = 3.5$] and 2.6 for aerial applications [$0.0037 \div 0.0014 \approx 2.643$].
16
17   While the estimates of worker exposures using the methods from SERA (2013b) are somewhat
18   higher than those from U.S. EPA/OPP/HED (2011a), the estimates from SERA (2013b) are
19   somewhat lower than those from the worker exposure study with fluazifop-butyl (Chester and
20   Hart 1986).  Based on the central estimates of exposure, the doses from Chester and Hart (1986)
21   are higher than the estimated doses using the methods from SERA (2013b) by a factor of about
22   1.7 for both backpack applications [$0.03 \div 0.018 \approx 1.67$] and ground spray applications [$0.007 \div$
23   $0.0042 \approx 1.67$].  Again, however, given the high variability in worker exposure estimates,
24   differences of a factor of about 2 are inconsequential.  This comparison, however, is not to imply
25   that the study by Chester and Hart (1986) should be viewed as strong support for the estimates
26   using the methods from SERA (2013).  As noted in Section 3.2.2.1.3, Chester and Hart (1986) do
27   not provide information on the amount of fluazifop-butyl that the workers applied.
28   Notwithstanding this reservation, the study by Chester and Hart (1986) presumably involved
29   typical backpack and ground spray operations.  The relative concordance of the worker
30   exposures from Chester and Hart (1986) with the estimates from SERA (21013b), which are
31   based on typical Forest Service applications, are at least moderately supportive of the exposure
32   estimates based on the methods in SERA (21013b).
33
34   Given the relative concordance of the study by Chester and Hart (1986) with the estimates based
35   on the standard methods used in Forest Service risk assessments (SERA 2013b) as well as the
36   modest differences between the estimates from U.S. EPA/OPP/HED (2011a) and the standard
37   SERA (2013b) methods, the current risk assessment estimates worker exposures using the SERA
38   (2013b) methods—i.e., the worker exposures in the last column of Table 15.  While the central
39   estimates of exposure do not differ remarkably from those in U.S. EPA/OPP/HED (2011a), the
40   EPA only provides central estimates and does not provide estimates of variability.  As discussed
41   further in Section 3.4.2 (Risk Characterization for Workers), the upper bounds associated with
42   worker exposures have a substantial impact on the characterization of potential risks.

43       *3.2.2.2. Accidental Exposures*
44   Irritation to the skin and eyes of workers are most likely to be associated with accidental spills or
45   splashes of pesticide solutions.  Nonetheless, fluazifop-P-butyl and formulations of fluazifop-P-
46   butyl are not strong irritants to either the skin (Section 3.1.11.1) or eyes (Section 3.1.11.3).

1    Quantitative exposure and dose-response assessments for skin and eye irritation are not
2    developed in this or other Forest Service risk assessments; however, these effects are considered
3    qualitatively in the risk characterization (Section 3.4.2).
4
5    Generally, dermal exposure is the predominant route of exposure for pesticide applicators
6    (Ecobichon 1998; van Hemmen 1992), and accidental dermal exposures are considered
7    quantitatively in all Forest Service risk assessments. The two types of dermal exposures
8    modeled in the risk assessments include direct contact with a pesticide solution and accidental
9    spills of the pesticide onto the surface of the skin. In addition, two exposure scenarios are
10   developed for each of the two types of dermal exposure, and the estimated absorbed dose for
11   each scenario is expressed in units of mg chemical/kg body weight. Both sets of exposure
12   scenarios are summarized in Worksheet E01 of the EXCEL workbooks that accompany this risk
13   assessment—i.e., Attachments 1, 2 and 3. Additionally, Worksheet E01 references other
14   worksheets in which the calculations of each exposure assessment are detailed.
15
16   Exposure scenarios involving direct contact with solutions of fluazifop-P-butyl are characterized
17   either by immersion of the hands in a field solution for 1 minute or wearing pesticide
18   contaminated gloves for 1 hour. The assumption that the hands or any other part of a worker's
19   body will be immersed in a chemical solution for a prolonged period of time may seem
20   unreasonable; however, it is possible that the gloves or other articles of clothing worn by a
21   worker may become contaminated with a pesticide. For these exposure scenarios, the key
22   assumption is that wearing gloves grossly contaminated with a chemical solution is equivalent to
23   immersing the hands in the solution. In both cases, the chemical concentration in contact with
24   the skin and the resulting dermal absorption rate are essentially constant.
25
26   For the scenarios involving contaminated gloves, the assumption of zero-order absorption
27   kinetics is appropriate—i.e., the concentration of the pesticide in solution is constant or nearly
28   so. For these types of exposures, the rate of absorption is estimated based on a zero-order dermal
29   absorption rate ($K_p$). Details regarding the derivation of the $K_p$ value for fluazifop-P-butyl are
30   provided in Section 3.1.3.2.2.
31
32   The amount of the pesticide absorbed per unit time depends directly on the concentration of the
33   chemical in solution. For terrestrial applications, the current risk assessment uses an application
34   volume of 20 gallons/acre with a range of 5 to 40 gallons/acre, which encompasses the potential
35   range of application volumes used in ground and aerial applications (Section 2.4). At an
36   application rate of 0.32 lb a.e./acre, the estimated concentrations in a field solution are 1.9 mg
37   a.e./mL with a range of 0.96 to 7.7 mg a.e./mL (Worksheet A01 in the attachments).
38
39   The details of the accidental dermal exposure scenarios involving first-order absorption consist
40   of spilling a chemical solution on to the lower legs or spilling a chemical solution on to the
41   hands, at least some of which adheres to the skin. The absorbed dose is then calculated as the
42   product of the amount of chemical on the skin surface (i.e., the amount of liquid per unit surface
43   area multiplied by the surface area of the skin over which the spill occurs and the chemical
44   concentration in the liquid), the first-order absorption rate coefficient, and the duration of
45   exposure. The first-order dermal absorption rates coefficients ($k_a$) are derived in
46   Section 3.1.3.2.1.

### 3.2.3.  General Public

#### *3.2.3.1. General Considerations*

##### 3.2.3.1.1. Likelihood and Magnitude of Exposure
As noted in Section 2.3, the Forest Service may apply formulations of fluazifop-P-butyl along roadsides, power lines, pipelines, and rights-of-way.  Although some of these applications may be made at locations remote from the general public, exposures to members of the general public cannot be excluded.  Because of the conservative exposure assumptions used in the current risk assessment, neither the probability of exposure nor the number of individuals who might be exposed has a substantial impact on the risk characterization presented in Section 3.4.  As noted in Section 1 (Introduction) and detailed in SERA (2011a, Section 1.2.2.2), the exposure assessments developed in this risk assessment are based on *Extreme Values* rather than a single value.  Extreme value exposure assessments, as the name implies, bracket the most plausible estimate of exposure (referred to statistically as the central or maximum likelihood estimate) with lower and upper bounds of credible exposure levels.

This Extreme Value approach is essentially an elaboration on the concept of the *Most Exposed Individual* (MEI), sometimes referred to as the M*aximum Exposed Individual.*  As this name implies, exposure assessments that use the MEI approach attempt to characterize the extreme but still plausible upper limits of exposures.  This common approach to exposure assessment is used by U. S. EPA, other government agencies, and the International Commission on Radiological Protection (e.g., ATSDR 2002; ICRP 2005; Payne-Sturges et al. 2004).  In the current risk assessment, all upper bounds on exposure are intended to encompass exposures to the MEI.

In addition to this upper bound MEI value, the Extreme Value approach used in this risk assessment provides a central estimate of exposure as well as a lower bound on exposure.  Although not germane to assessing the upper bound risk, the point of using the central estimate, and especially the lower bound estimate, is not to lessen concern.  To the contrary, the central and lower estimates of exposure are used to assess the prospect of mitigation—e.g., protective measures to limit exposure.  If lower bound exposure estimates exceed a level of concern, there is strong indication that the pesticide cannot be used in a manner that will lead to acceptable estimates of risk.

In addition to concern for the most exposed individual, there is concern for individuals who may be more sensitive than most members of the general population to fluazifop-P-butyl exposure.  This concern is considered in the dose-response assessment (Section 3.3) which bases exposures on the most sensitive endpoint in the most sensitive species and uses an uncertainty factor for sensitive individuals.  Atypical sensitivities—i.e., special conditions that might increase an individual's sensitivity to a particular agent—are also considered separately in the risk characterization (Section 3.4.4).

##### 3.2.3.1.2. Summary of Assessments
The exposure scenarios developed for the general public are summarized in Worksheet E03 of the EXCEL workbooks that accompany this risk assessment—i.e., Attachments 1, 2, and 3.  As with the worker exposure scenarios, details about the assumptions and calculations used in these

1 assessments are given in the detailed calculation worksheets in the EXCEL workbook
2 (Worksheets D01a–D11).
3
4 For fluazifop-P-butyl, a standard set of exposure assessments used in all Forest Service risk
5 assessments for broadcast applications are considered.  As summarized in Worksheet E03, the
6 kinds of exposure scenarios developed for the general public include acute accidental, acute non-
7 accidental, and longer-term or chronic exposures.  The accidental exposure scenarios assume that
8 an individual is exposed to the compound of concern either during or shortly after its application.
9 Non-accidental exposures involve dermal contact with contaminated vegetation as well as the
10 consumption of contaminated fruit, vegetation, water, or fish.  The longer-term or chronic
11 exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated
12 fruit, water, or fish.  All of the non-accidental exposure scenarios are based on levels of exposure
13 to be expected following a single application (Attachment 1), two applications (Attachment 3) or
14 three applications (Attachment 3) of fluazifop-P-butyl at 0.32 lb a.e./acre with an application
15 interval of 14 days for the multiple applications.  The upper bounds of the exposure estimates for
16 the non-accidental scenarios involve conservative assumptions intended to reflect exposure for
17 the MEI (*Most Exposed Individual*).  The impact of lower application rates of fluazifop-P-butyl
18 on the risk characterization is discussed in Section 3.4.
19
20 The nature of the accidental exposure scenarios is intentionally extreme.  The non-accidental,
21 acute exposure scenarios are intended to be conservative but plausible, meaning that it is not
22 unreasonable to assume that the magnitude of exposures in the non-accidental exposure scenarios
23 could occur in the routine use of fluazifop-P-butyl.  This interpretation does not extend to the
24 longer-term exposure scenarios.  The longer-term exposure scenarios essentially assume that an
25 individual will consume either treated vegetation, fruits, or water from a treated area every day
26 over a prolonged period of time.  Despite its unlikelihood, this exposure scenario warrants
27 consideration.  As discussed further in Section 3.4.3, this scenario is an important consideration
28 in the interpretation of hazard quotients associated with longer-term exposures to contaminated
29 vegetation.

30     *3.2.3.2. Direct Spray*
31 Direct sprays involving ground applications are modeled in a manner similar to accidental spills
32 for workers (Section–3.2.2.2).  In other words, it is assumed that the individual is sprayed with a
33 solution containing the compound and that an amount of the compound remains on the skin and
34 is absorbed by first-order kinetics.  Two direct spray scenarios are given, one for a young child
35 (D01a) and the other for a young woman (D01b).
36
37 For the young child, it is assumed that a naked child is sprayed directly during a ground
38 broadcast application and that the child is completely covered (that is, 100% of the surface area
39 of the body is exposed).  This scenario is intentionally extreme.  As discussed in Section
40 3.2.3.1.1, the upper limits of this exposure scenario are intended to represent the *Extreme Value*
41 upper limits of exposure for the *Most Exposed Individual* (MEI).
42
43 The exposure scenario involving the young woman (Worksheet D01b) is somewhat less extreme.
44 In this scenario, it is assumed that the lower legs and feet of a woman are accidentally sprayed
45 with a pesticide.  The choice of a young woman rather than an adult male in this scenario is
46 common to many of the exposure assessments and relates to concerns for both the *Most Exposed*

1  *Individual* (MEI) as well as the most sensitive individual.  As discussed in Section 3.1.9 and
2  summarized in Table 12, fluazifop-P-butyl has been shown to cause adverse effects in offspring,
3  sometimes at doses not associated with signs of maternal toxicity.  Consequently, the exposure of
4  a young woman of reproductive age is used to better assess the potential for adverse effects in
5  the population at risk of effects associated with exposures during pregnancy—i.e., the most
6  exposed and the most sensitive individual.  For this exposure scenario, assumptions are made
7  regarding the surface area of the skin and the body weight of the individual, as detailed in
8  Worksheet A03.  The rationale for using specific values in these and other exposure scenarios as
9  well as the sources of the specific values is provided in documentation for the preparation of
10  Forest Service risk assessments (SERA 2011a) and the worksheets that accompany Forest
11  Service risk assessments (SERA 2011b).

12  ### *3.2.3.3. Dermal Exposure from Contaminated Vegetation*
13  In this exposure scenario, it is assumed that fluazifop-P-butyl is sprayed on to vegetation and that
14  a young woman comes in contact with sprayed vegetation or other contaminated surfaces at
15  some period after the spray operation (Worksheet D02).  For these exposure scenarios, some
16  estimates of dislodgeable residue (a measure of the amount of the chemical that could be freed
17  from the vegetation) and the rate of transfer of the chemical from the contaminated vegetation to
18  the surface of the skin must be available.
19
20  As detailed in Durkin et al. (1995), dermal transfer rates are reasonably consistent for numerous
21  pesticides, and the methods and rates derived in Durkin et al. (1995) are used as defined in
22  Worksheet D02.  The topic of dislodgeable residues is not addressed in the available literature on
23  fluazifop-P-butyl, which leads to uncertainty.  For this exposure scenario, a default dislodgeable
24  residue rate of 0.1 of the nominal application rate is used.  The uncertainties associated with this
25  exposure scenario do not have a substantial impact on the risk assessment.  As detailed in
26  Section 3.4.3 (Risk Characterization for the General Public), hazard quotients for this scenario
27  are far below the level of concern.
28
29  The exposure scenario assumes a contact period of 1 hour and further assumes that the chemical
30  is not effectively removed by washing for 24 hours.  Other approximations used in this exposure
31  scenario include estimates of body weight, skin surface area, and first-order dermal absorption
32  rates, as discussed in Section 3.2.3.2 (Direct Spray).

*3.2.3.4. Contaminated Water*

### 3.2.3.4.1. Accidental Spill

The accidental spill scenario assumes that a young child consumes contaminated water shortly after an accidental spill of a field solution into a small pond. The calculation of the concentration of fluazifop in water following the spill is given in Worksheet B04b, and the estimate of the dose to a small child is given in Worksheet D05. Because this scenario is based on the assumption that exposure occurs shortly after the spill, no dissipation or degradation is considered. Since this exposure scenario is based on assumptions that are somewhat arbitrary and highly variable, the scenario may overestimate exposure. The actual chemical concentrations in the water will vary according to the amount of compound spilled, the size of the water body into which it is spilled, the time at which water consumption occurs, relative to the time of the spill, and the amount of contaminated water that is consumed. All Forest Service risk assessments assume that the accidental spill occurs in a small pond with a surface area of about one-quarter of an acre (1000 m$^2$) and a depth of 1 meter. Thus, the volume of the pond is 1000 m$^3$ or 1,000,000 liters.

A spill volume of 100 gallons with a range of 20 to 200 gallons is used to reflect plausible spill events. These spill volumes are used in all Forest Service risk assessments involving terrestrial applications unless program specific considerations suggest that other values are more appropriate. The fluazifop-P-butyl concentrations in the field solution are also varied to reflect the plausible range of concentrations in field solutions—i.e., the material that might be spilled— using the same values as in the accidental exposure scenarios for workers (Section 3.2.2.2). Based on these assumptions, the estimated concentration of fluazifop-P-butyl in a small pond ranges from about 0.07 to 5.8 mg a.e./L, with a central estimate of about 0.7 mg a.e./L (Worksheet B04b).

### 3.2.3.4.2. Accidental Direct Spray/drift for a Pond or Stream

This scenario involves the accidental direct spray or incidental spray drift to a small pond and a small stream. The exposure scenarios involving drift are less severe but more plausible than the accidental spill scenario described in the previous section. For each water body, two sets of drift scenarios are given, one based on fine droplets and the other on coarse droplets. The product label for Fusilade DX notes that: *The most effective way to reduce drift potential is to apply large droplets*. On the other hand, product labels for both Fusilade DX and Fusilade II also note the following: ***DO NOT USE FLOOD TYPE OR OTHER SPRAY NOZZLE TIPS WHICH DELIVER COARSE, LARGE DROPLET SPRAYS***. The capitalization and bold text are included in the labels.

The product labels for Fusilade DX and Fusilade II do not specify or otherwise recommend specific droplet size distributions. The lack of droplet size specifications on the product labels is unfortunate. There is a reasonably consistent nomenclature on particle size distributions (e.g., ASABE 2013 Droplet Spectra; Fritz et al. 2012; Hopkins et al. 2009; Womac 2000). Nonetheless and as illustrated in Figure 5, there are substantial overlaps in particle sizes within the distributions. In the current Forest Service risk assessment, coarse droplet estimates are based on Tier 1 using ASAE Coarse to Very Coarse drop size distributions (VMD≈440 μm) for aerial applications and on ASAE fine to Medium Coarse drop size distributions (VMD≈340 μm) for ground applications. As illustrated in Figure 5, the two most coarse categorizations of particle size distributions have VMD values of >500 μm – i.e., Extra Coarse (>500 μm) and

1 Ultra Coarse (>650 µm). While somewhat speculative, it seems reasonable to suggest that the
2 labeled recommendation to avoid the use of "flood type" sprays would deal with VMDs of >500
3 µm which would not typically be used in Forest Service applications.
4
5 The distinction between fine and coarse droplet sizes applies only to aerial and ground broadcast
6 applications. Drift from backpack applications are always modeled using coarse droplet sizes
7 (SERA 2011b).
8
9 U.S. EPA typically uses a 2-meter-deep pond to develop exposure assessments. If such a pond is
10 directly sprayed with fluazifop-P-butyl at an application rate of 0.32 lb a.e./acre, the peak
11 concentration in the pond would be about 0.036 mg a.e./L (Worksheet B04c1 and B04c2). This
12 concentration is more than 16 times less than the upper bound of the peak concentration of
13 5.8 mg a.e./L after the accidental spill (Section 3.2.3.4.1, Worksheets B04a) [5.8 mg a.e./L ÷
14 0.36 mg a.e./L ≈ 16.111].
15
16 Worksheets B04c1 (fine droplets) and B04c2 (coarse droplets) also model concentrations in a
17 small pond at distances of from 25 to 900 feet down wind based on standard values adapted from
18 AgDrift for the different terrestrial broadcast application methods considered in this risk
19 assessment (SERA 2011b). Based on these estimates, fluazifop-P-butyl concentrations in a small
20 pond contaminated by drift from an application made 25 feet upwind would be about
21 0.0003 mg a.e./L for backpack applications (coarse droplets). For broadcast applications, the
22 concentrations at 25 feet downwind would range from about 0.001 mg a.e./L (low boom ground
23 applications) to 0.008 mg a.e./L (aerial) using fine droplets (Worksheet B04c1) and about 0.0004
24 mg a.e./L (low boom ground applications) to 0.005 mg a.e./L (aerial) using coarse droplets
25 (Worksheet B04c2).
26
27 Similar calculations can be made for scenarios involving a stream contaminated either by direct
28 spray or drift (Worksheets B04d1 and B04d2). For this scenario, the resulting water
29 concentrations depend on the surface area of the stream and the rate of water flow in the stream.
30 The stream modeled in Gleams-Driver simulations (Section 3.2.3.4.3) is about 6 feet wide
31 (1.82 meters), and it is assumed that the pesticide is applied along a 1038-foot (316.38 meters)
32 length of the stream with a flow rate of 710,000 L/day. Using these values, the concentration in
33 stream water after a direct spray is estimated at about 0.03 mg a.e./L. For backpack applications,
34 the concentration in a small stream that is 25 feet downwind is estimated at about 0.0002 mg
35 a.e./L. For broadcast applications, the concentrations at 25 feet downwind would range from
36 about 0.001 mg a.e./L (low boom ground applications) to 0.007 mg a.e./L (aerial) using fine
37 droplets (Worksheet B04d1) and about 0.0003 mg a.e./L (low boom ground applications) to
38 0.004 mg a/e//L (aerial) using coarse droplets (Worksheet B04d2).

### 3.2.3.4.3. GLEAMS Modeling

The Forest Service developed a program, Gleams-Driver, to estimate expected peak and longer-term pesticide concentrations in surface water. Gleams-Driver serves as a preprocessor and postprocessor for GLEAMS (Knisel and Davis 2000). GLEAMS is a field scale model developed by the USDA/ARS and has been used for many years in Forest Service and other USDA risk assessments (SERA 2007a; SERA 2011c). Gleams-Driver offers the option of conducting exposure assessments using site-specific weather files from Cligen, a climate generator program developed and maintained by the USDA Agricultural Research Service (USDA/NSERL 2005). Gleams-Driver was used in the current risk assessment to model fluazifop-P-butyl concentrations in a small stream and a small pond.

As summarized in Table 16, nine locations are used in the Gleams-Driver modeling. As discussed in SERA (2007a), these locations are standard sites used in Forest Service risk assessments for Gleams-Driver simulations and are intended to represent combinations of precipitation (dry, average, and wet) and temperature (hot, temperate, and cool). The characteristics of the fields and bodies of water used in the simulations are summarized in Table 17. For each location, simulations were conducted using clay (high runoff, low leaching potential), loam (moderate runoff and leaching potential), and sand (low runoff, high leaching potential) soil textures. For each combination of location and soil, Gleams-Driver was used to simulate pesticide losses to surface water from 100 modeled applications at a unit application rate of 1 lb a.i./acre, and each of the simulations was followed for a period of about 1½ years post application. Note that an application rate of 1 lb a.i./acre is used as a convention in all Forest Service risk assessments to avoid rounding limitations in GLEAMS outputs. All exposure concentrations discussed in this risk assessment are based on an application rate of 0.32 lb a.e./acre.

Table 18 summarizes the chemical-specific values used in Gleams-Driver simulations. For the most part, the chemical properties used in the Gleams-Driver simulations are based on the parameters used by the Environmental Fate and Effects Division (EFED) of the U.S. EPA's Office of Pesticides Programs modeling of fluazifop-P-butyl (U.S. EPA/OPP/EFED 2010a). The EPA modeling efforts are discussed below (Section 3.2.3.4.4). In the current risk assessment, most of the model input values are based on the environmental fate studies submitted to the U.S. EPA by registrants as well as standard values for GLEAMS modeling recommended by Knisel and Davis (2000). The notes to Table 18 indicate the specific sources of the chemical properties used in the GLEAMS modeling effort.

Details of the results for the Gleams-Driver runs are provided in Appendix 8 (single application), Appendix 9 (two applications with a 14-day application interval), and Appendix 10 (three applications with 14 day application intervals). A summary of the results for the Gleams-Driver runs are presented in Table 19, along with a summary of other modeling efforts which are discussed further in the following subsection. The uses of all of the available modeling estimates in developing the exposure assessments for the current risk assessment are discussed in Section 3.2.3.4.6.

### 3.2.3.4.4. Other Modeling Efforts

Other efforts to model concentrations of fluazifop-P-butyl in surface water are summarized in Table 19, which also summarizes the surface water modeling conducted for the current risk

1  assessment (Section 3.2.3.4.3). To estimate concentrations of a pesticide in ambient water as
2  part of a screening level risk assessment, the U.S. EPA typically uses Tier 1 screening models
3  (e.g., GENEEC, FIRST, and SCIGROW). For more refined and extensive risk assessment, the
4  Agency will typically use PRZM/EXAMS, a more Tier 2 modeling system. The U.S. EPA/OPP
5  typically models pesticide concentrations in water at the maximum labeled rate. All of the
6  concentrations given in Table 19 involved applications at 0.32 lb a.e./acre, identical to the
7  maximum rate used in the GLEAMS-Driver simulations and with one exception (U.S.
8  EPA/OPP/EFED 2008) involved three applications. As also noted in Table 19, EPA used
9  application intervals of 14 to 21 days.
10
11  The highest concentrations estimated in the EPA assessments involved the application of the
12  FIRST model—i.e., a peak concentration of about 53 ppb and a longer-term concentration of
13  about 11 ppb. This is to be expected in the Tier 1 models, which are intended to be extremely
14  conservative. The PRZM/EXAMS modeling resulted in lower estimates of both peak
15  concentrations—i.e., about 1.35 to 33.4 ppb—and longer-term concentrations—i.e., about 0.7 to
16  6.84 ppb.
17
18  Excluding the results from the FIRST model, the midpoint of the range of peak concentrations
19  from the EPA assessments is about 17.4 ppb [(1.35 + 33.4) ÷ 2 ≈ 17.375]. This concentration is
20  not substantially different from the central estimate of the peak concentration (16 ppb) from the
21  GLEAMS-Driver simulations for a small pond involving three applications of fluazifop-P-butyl.
22  The midpoint of the range for longer-term concentrations from the EPA assessments is about 3.8
23  ppb [(0.74 + 6.84) ÷ 2 ≈ 3.79], which is only modestly below the average concentration of 6.53
24  ppm from the GLEAMS-Driver simulations.
25
26  The upper bound estimates from the GLEAMS-Driver simulations, however, are substantially
27  higher than the peak concentrations modeled by EPA. For three applications, the peak
28  concentration from GLEAMS-Driver for a small pond is 150 ppb, which is a factor of about 5
29  higher than the peak concentration reported by EPA [150 ÷ 33.4≈ 4.491]. For the longer-term
30  concentrations, the upper bound from GLEAMS-Driver is about 61 ppb, which is a factor of
31  about 9 higher than the upper bound from the EPA modeling [61.4 ÷ 6.84 ≈ 8.977].
32
33  The comparisons of the EPA and Gleams-Driver results for fluazifop-P-butyl are similar to many
34  other comparisons noted in other Forest Service risk assessments. Because Gleams-Driver is
35  applied to numerous site/soil combinations and because 100 simulations are conducted for each
36  site/soil combination, the upper bound values from Gleams-Driver often exceed the
37  concentrations obtained from either the Tier 2 PRZM/EXAMS modeling or the more
38  conservative Tier 1 modeling from EPA. Because the overall intent of Gleams-Driver is to
39  estimate both central estimates and uncertainty bounds associated with the central estimates, the
40  conservative Tier I models from EPA typically yield concentrations higher than the central
41  estimate from Gleams-Driver. All of these patterns are evident in the surface water modeling for
42  fluazifop-P-butyl.

43  ### 3.2.3.4.5. Monitoring Data
44  Monitoring studies are most useful in evaluating the credibility of environmental modelling, such
45  as the efforts detailed in Sections 3.2.3.4.3 and 3.2.3.4.4. For this type of evaluation, however,
46  the monitoring data must be associated with defined applications of the compound under review

1  or at least some estimate of the regional use of the compound.  No such studies are available for
2  fluazifop-P-butyl.  One publication (Coupe et al. 1998) that specifically focuses on this type of
3  assessment—i.e., the relationship of pesticide use to surface water contamination—provides data
4  on the use of fluazifop in the Mississippi delta but does not provide information on the detection
5  of fluazifop in surface water.
6
7  The highest detected concentration of fluazifop-P-butyl in surface water is 0.2 µg/L from a river
8  in Spain (Martinez et al. 2000, Table 4, p. 477).  Similar concentrations are reported in FANPP
9  (2013a)—i.e., 0.06 to 0.17 µg/L—for surface water in California.  Much lower concentrations of
10  about 0.0041 µg/L are reported for a stream in Northern Ireland (Scott and McConvey 2005).
11  Fluazifop-butyl was not detected in Danish ground water at a detection limit of 0.004 µg/L
12  (Spliid and Koppen 1998) and was not detected in Italian rainwater (Trevisan et al. 1993).
13  Because none of these studies provide information on applications of fluazifop-P-butyl, they are
14  not useful in assessing the credibility of the surface water modeling for fluazifop-P-butyl.
15
16  In the interest of completeness, it is noted that very low air concentrations of fluazifop-P-butyl
17  (i.e., 0.02 to 0.007 ng/m$^3$) were detected in an agricultural area in Canada (White et al. 2006).
18  As discussed in Section 3.1.13, the lowest reported 4-hour inhalation $LC_{50}$ for fluazifop-P-butyl
19  is 0.54 mg/L.  This $LC_{50}$ is equivalent to 540 mg/m$^3$, which is in turn equivalent to 540,000,000
20  ng/m$^3$.  This concentration is a factor of 27 billion times greater than the peak concentration of
21  0.02 ng/m3 reported by White et al. (2006).

22          **3.2.3.4.6. Concentrations in Water Used for Risk Assessment**
23  The concentrations of fluazifop-P-butyl in water used in the current risk assessment are
24  summarized in Table 20.  The concentrations are specified as water contamination rates
25  (WCRs)—i.e., the concentrations in water expected at a normalized application rate of 1 lb
26  a.e./acre, converted to units of ppm (a.e.) or mg a.e./L per lb a.e./acre.  In Table 19, the summary
27  of all of the modeling efforts, units of exposure are expressed as ppb or µg/L, as a matter of
28  convenience, for an application rate of 0.32 lb a.e./acre.  In Table 20, however, ppb is converted
29  to mg/L (ppm) because mg/L is the unit of measure used in the EXCEL workbooks for
30  contaminated water exposure scenarios in both the human health and ecological risk
31  assessments.  The water contamination rates are entered in Worksheet B04Rt in Attachment 1
32  (single application), Attachment 2 (two applications with a 14-day application interval) and
33  Attachment 3 (three applications with 14-day application intervals).  The values in Worksheet
34  B04Rt are linked to the appropriate scenario-specific worksheets in the EXCEL workbooks and
35  the concentrations are adjusted to an application rate of 0.32 lb a.e./acre.
36
37  These water contamination rates are based on the GLEAMS-Driver modeling discussed in
38  Section 3.2.3.4.3.  The GLEAMS-Driver modeling is reasonably consistent with the FIRST and
39  PRZM/EXAMS modeling as discussed in Section 3.2.3.4.4 and summarized in Table 19.  As
40  summarized in Table 19, the Gleams-Driver simulations of the small pond are somewhat higher
41  than those for a small stream.  Consequently, the Gleams-Driver simulations for the small pond
42  are used to derive the Water Contamination Rates given in Table 20.
43
44  Like most of the estimates provided in this risk assessment, the water contamination rates given
45  in Table 20 are expressed as the central estimate with associated lower and upper bounds.  The
46  central estimate and upper bound are taken directly from the GLEAMS-Driver modeling for one

application (Appendix 8), two applications (Appendix 9), and three applications (Appendix 10).
The peak concentrations are given in Table 7, and the longer-term concentrations are given in
Table 8 of each of these appendices.

The lower bounds of the water contamination rates are taken as one-tenth of the central estimate.
As detailed in the GLEAMS-Driver appendices, the lower bound for many of the site/soil
combinations is zero. Although setting a practical lower bound may seem somewhat arbitrary,
the lower bounds based on one-tenth of the central estimates are reasonably close to the upper
levels of exposure associated with drift at 25 feet from the application site (Table 19). From a
practical perspective, the lower bound exposure levels have no impact on the risk
characterization for either the human health risk assessment (Section 3.4) or the ecological risk
assessment (Section 4.4).

As noted in 3.2.3.4.5, monitoring data on concentrations of fluazifop-P-butyl in surface water are
much lower than estimates based on either the PRZM/EXAM modeling from EPA or the
GLEAMS-Driver conducted in the current risk assessment. The monitoring data, however, are
not associated with defined applications of fluazifop-P-butyl and cannot be used to assess the
plausibility of modelled estimates. While the Gleams-Driver estimates are reasonably consistent
with U.S. EPA/OPP modeling (Section 3.2.3.4.4), the lack of monitoring data to assess the merit
of the modeled concentrations adds uncertainty to this risk assessment.

### 3.2.3.5. Oral Exposure from Contaminated Fish

Many chemicals may be concentrated or partitioned from water into the tissues of aquatic
animals or plants. This process is referred to as bioconcentration. Generally, bioconcentration is
measured as the ratio of the concentration in the organism to the concentration in the water. For
example, if the concentration in the organism is 5 mg/kg and the concentration in the water is
1 mg/L, the bioconcentration factor (BCF) is 5 L/kg [5 mg/kg ÷ 1 mg/L]. As with most
absorption processes, bioconcentration depends initially on the duration of exposure but
eventually reaches steady state. Details regarding the relationship of the bioconcentration factor
to standard pharmacokinetic principles are provided in Calabrese and Baldwin (1993).

Three sets of exposure scenarios are presented: one set for acute exposures following an
accidental spill (Worksheets D08a and D08b), one set for acute exposures based on expected
peak concentrations of fluazifop-P-butyl in water (Worksheets D09c and D09d), and another set
for chronic exposures based on estimates of longer-term concentrations in water (Worksheets
D09a and D09b). The two worksheets for each set of scenarios are included to account for
different consumption rates of caught fish among the general population and subsistence
populations. Details of these exposure scenarios are provided in Section 3.2.3.5 of SERA
(2011a).

The scenarios associated with consumption of contaminated fish are based on the same
concentrations of fluazifop-P-butyl in water used for the accidental spill scenario (Section
3.2.3.4.1.) and the drinking water exposure estimates (Section 3.2.3.4.6).

This exposure scenario also requires estimates of the bioconcentration factor. Experimental
bioconcentration factors are required by the EPA as part of the registration process. As
summarized in Table 4, two bioconcentration studies were submitted to the EPA and are

summarized in U.S. EPA/OPP/EFED (2008).  One study appears to be a relatively standard study in bluegills in which bioconcentration factors of 120 are reported for muscle and 410 for whole fish (MRID 93196 and MRID 92067035).

The other study (MRID 93195) appears to be a mesocosm experiment with catfish conducted over a period of 65 days.  This study reports much lower bioconcentration factors of 1.1 in muscle and 2.1 in whole fish.  In the mesocosm study, fluazifop-butyl was applied to loamy sand soil.  The soil was flooded after 14 days, at which time the catfish were added for an exposure period of 65 days.

As noted in Section 2.2.1 and discussed in detail in U.S. EPA/OPP/EFED (2008), fluazifop-butyl is rapidly hydrolyzed in soil to fluazifop acid.  The lower bioconcentration factors in the catfish study are probably due to the hydrolysis of fluazifop-butyl to fluazifop acid prior to and/or shortly after the addition of the catfish to the mesocosm.  The study in bluegills appears to have measured the bioconcentration of fluazifop-butyl; whereas, the study in catfish appears to have measured the bioconcentration of fluazifop acid.  This supposition is supported by the estimated bioconcentration factor of 3.16 for fluazifop acid from EPI-Suite (2011) summarized in Table 5.

For the current risk assessment, the higher BCF of 120 for fish muscle from the bluegill study is used for acute exposure scenarios in which the primary exposures to fish could be fluazifop-P-butyl.  For the chronic exposure scenarios, the lower BCF of 1.1 in the muscle of catfish is used because any longer-term exposures following applications of fluazifop-P-butyl will involve fluazifop acid rather than the butyl ester.  This approach is identical to the approach used for the exposure scenario involving  the consumption of fish by wildlife (Section 4.2.2.5), except that whole fish bioconcentration factors are used rather than the bioconcentration factors for fish muscle.

### 3.2.3.6. Dermal Exposure from Swimming in Contaminated Water

Some geographical sites maintained by the Forest Service or Forest Service cooperators include surface water in which members of the general public might swim.  The extent to which this might apply to areas treated with fluazifop-P-butyl is unclear.

To assess the potential risks associated with swimming in contaminated water, an exposure assessment is developed for a young woman swimming in surface water for 1 hour (Worksheet D10).  Conceptually and computationally, this exposure scenario is virtually identical to the contaminated gloves scenario used for workers (Section 3.2.2.2)—i.e., a portion of the body is immersed in an aqueous solution of the compound at a fixed concentration for a fixed period of time.

As in the corresponding worker exposure scenario, the 1-hour period of exposure is somewhat arbitrary given that longer periods of exposure are plausible.  Nonetheless, the 1-hour period is intended as a unit exposure estimate.  In other words, both the absorbed dose and consequently the risk will increase linearly with the duration of exposure, as indicated in Worksheet D10.  Thus, a 2-hour exposure would lead to an HQ that is twice as high as that associated with an exposure period of 1 hour.

In cases in which this or other similar exposures approach a level of concern, further
consideration is given to the duration of exposure in the risk characterization (Section 3.4).  For
fluazifop-P-butyl, however, the HQs for this scenario are far below the level of concern.  As
indicated in Worksheet E04 of Attachment 3 (three applications), the upper bound HQ for this
scenario is 0.002.  Thus, for this scenario to reach a level of concern (HQ=1.0), the period of
exposure would need to be 500 hours or about 21 days.

As with the exposure scenarios for the consumption of contaminated fish, the scenarios for
exposures associated with swimming in contaminated water are based on the peak expected
water concentrations of fluazifop-P-butyl used to estimate acute oral exposures associated with
contaminated water (Section 3.2.3.4.6).

### *3.2.3.7. Oral Exposure from Contaminated Vegetation*
Although none of the Forest Service applications of fluazifop-P-butyl will involve crop
treatment, crop treatments may be conducted on some Forest Service lands by individuals or
organizations with authorization from the Forest Service to use Forest Service lands for the
cultivation of crops.  All such agricultural applications are subject to U.S. EPA/OPP regulatory
constraints (e.g., tolerance limits) and exposures associated with agricultural applications are not
explicitly considered in Forest Service risk assessments.  As discussed further in Section 3.4.3
(Risk Characterization for the General Public), exposures to pesticides associated with
agricultural applications of pesticides are below, and often far below, the exposure assessments
developed for forestry applications of pesticides.

For pesticides that may be applied to vegetation, Forest Service risk assessments include
standard exposure scenarios for the acute and longer-term consumption of contaminated
vegetation.  Two sets of exposure scenarios are provided: one for the consumption of
contaminated fruit and the other for the consumption of contaminated vegetation.  These
scenarios are detailed in Worksheets D03a (fruit) and D03b (broadleaf vegetation) for acute
exposure and Worksheets D04a (fruit) and D04b (broadleaf vegetation) for chronic exposures.

The pesticide contamination on fruit and vegetation is estimated using the empirical relationships
between application rate and concentration on different types of vegetation (Fletcher et al. 1994).
The rates provided by Fletcher et al. (1994) are based on a reanalysis of data originally compiled
by Hoerger and Kenaga (1972) and represent estimates of pesticide concentration in different
types of vegetation (mg chemical/kg vegetation) after a normalized application rate of 1 lb.
a.e./acre.  Although the EPA human health risk assessments do not consider this exposure
scenario, the residue rates recommended by Fletcher et al. (1994) are used by U.S. EPA/OPP in
their ecological risk assessment of fluazifop-P-butyl (U.S. EPA/OPP/EFED 2008).

The residue rates recommended by Fletcher et al. (1994) are given in Table 21 of the current
Forest Service risk assessment.  Fletcher et al. (1994) and Hoerger and Kenaga (1972) provide
only central and upper bound estimates of residue rates.  Accordingly, the lower bound estimates
in Table 21 are made under the assumption that the ratio of the central estimate to the upper
bound estimate is identical to the ratio of the lower bound estimate to the central estimate (i.e.,
the variability is log-symmetrical).  As summarized in Table 21, Fletcher et al. (1994) provide
residue rates for four different classes of plant material, including short grass, tall grass,
broadleaf vegetation, and fruits.  While all four groups of plant material are used in the

1 ecological risk assessment (Section 4.2.2), only broadleaf vegetation and fruit are used in the
2 human health risk assessment.
3
4 For longer-term exposures, the time-weighted-average concentrations are estimated using the
5 initial pesticide concentration, the half-life on vegetation, the number of applications, and the
6 application interval. These calculations are detailed in Worksheet B05a (fruit) and Worksheet
7 B05b) for broadleaf vegetation. In these worksheets, the half-lives are identical to those used in
8 the Gleams-Driver modeling—i.e., a central estimate of 7.5 days with a range of 6.6 to 8.7 days.
9
10 In the study by Kulshrestha et al. (1995), technical grade fluazifop-P-butyl (85.6% purity) was
11 applied to soybean at a rate of 0.5 kg/ha (≈0.446 lb a.i./acre) and residues on the soybean foliage
12 were sampled for up to 90 days after exposure. The residues were assayed as fluazifop-P acid
13 derivatized to the methyl ester using gas liquid chromatography. Kulshrestha et al. (1995) report
14 a half-life of 7.9 days with a correlation coefficient of 0.96 ($r^2$≈0.92) but do not report a
15 confidence interval on this estimate. Consequently, the mean residues data reported in
16 Kulshrestha et al. (1995, Table 2, p. 279) were reanalyzed using the standard exponential decay
17 model. While the authors report residues for up to 90 days, residues at 90 days were below the
18 limits of detection. Thus, only the data from the day of application to 60 days after application
19 were used in the reanalysis. Details of this reanalysis are given in Worksheet B06 of the
20 attachments to this risk assessment.
21
22 As illustrated in Figure 6, the mean residue data are well fit using a standard first-order decay
23 function ($r^2$=0.981, $p$=2.07x10$^{-6}$) yielding a half-life of 7.51 with a 95% confidence interval of
24 6.60-8.71 days. The modest difference between the half-life reported by Kulshrestha et al.
25 (1995) and the half-life from the reanalysis is probably attributable to the use of the individual
26 data in the study and the use of mean estimates in the reanalysis. For the current risk assessment,
27 a half-life of 7.51 days with a 90% confidence interval of 6.60-8.71 days is used in order to
28 consider, to the extent possible, the variability in the data.
29
30 As discussed further in Section 3.4.3 (Risk Characterization for the General Public), the exposure
31 scenarios associated with the consumption of contaminated fruit and broadleaf vegetation are a
32 concern, particularly for longer-term exposures. As with the exposure scenarios for the
33 consumption of contaminated fish (Section 3.2.3.5), longer-term exposures for the consumption
34 of contaminated vegetation are likely to involve fluazifop-P acid rather than fluazifop-P-butyl,
35 which is accounted for in the data from Kulshrestha et al. (1995). The analytical method used by
36 Kulshrestha et al. (1995), however, does not appear to account for the possibly greater
37 persistence of the metabolites of fluazifop-P. Thus, the use of the half-lives from the study by
38 Kulshrestha et al. (1995) could underestimate the longer-term residues of fluazifop-P
39 metabolites.
40
41 For longer-term exposure scenarios associated with the consumption broadleaf vegetation, the
42 likelihood and plausibility of such exposures will be low for herbicides that are toxic to broadleaf
43 vegetation. Fluazifop-P-butyl, however, is most toxic to true grasses but relatively nontoxic to
44 dicots (Section 4.1.2.5.2). Thus, the phytotoxicity of fluazifop-P-butyl does not diminish
45 concern for the consumption of broadleaf vegetation.

## 3.3. DOSE-RESPONSE ASSESSMENT

### 3.3.1. Overview

Table 22 provides an overview of the dose-response assessment for human health used in this risk assessment. The available data on the toxicity of fluazifop-butyl and fluazifop-P-butyl to mammals is reasonably complete, and the toxicity values derived in the most recent EPA human health risk assessment (U.S. EPA/OPP/HED 2011a) are adopted without modification. Forest Service risk assessments typically defer to the U.S. EPA in the derivation of toxicity values used in the human health risk assessment, unless there is a compelling reason to differ with the EPA. While there are concerns with the chronic RfD derived by the U.S. EPA, as discussed further in Section 3.3.2, the derivation of an alternate RfD would not have a substantial impact on the risk assessment.

### 3.3.2. Chronic RfD

The U.S. EPA has not derived an agency-wide RfD for fluazifop-P-butyl or fluazifop-butyl — i.e., there is no RfD for these herbicides listed on the U.S. EPA Integrated Risk Information System (http://www.epa.gov/iris/).

The most recent U.S. EPA/OPP human health risk assessment on fluazifop-P-butyl derives a chronic RfD of 0.0074 mg/kg/day (U.S. EPA/OPP/HED 2010a). As summarized in Appendix 1 (Table A1-3) and discussed in Section 3.1.9.2, the RfD is based on a 2-generation reproduction study in rats fed fluazifop-butyl at dietary concentrations of 0, 10, 80, or 250 ppm for up to 120 days. The RfD is based on a NOAEL for parental male rats in the 10 ppm group, equivalent to a dose of 0.74 mg/kg bw/day based on dose estimates provided by the EPA. At 30 ppm (5.8 mg/kg bw/day), parental generation male rats evidenced a decrease in spleen weights, and a decrease in absolute and relative testes and epididymal weights was noted in male offspring. In deriving the chronic RfD, the EPA uses an uncertainty factor of 100 (10 for species-to-species extrapolation and 10 for sensitive subgroups in the human population) [0.75 mg/kg/day ÷ 100 mg/kg/day = 0.0075 mg/kg bw/day].

There is some concern with the chronic RfD, based on the chronic toxicity data on fluazifop-butyl. As discussed in Section 3.1.5 and summarized in Table 11, the NOAEL for male rats in a 2-year chronic feeding study is somewhat lower than NOAEL of 0.75 mg/kg bw/day from the reproduction study—i.e., the chronic NOAEL of 0.5 mg/kg bw/day from MRID 41563703 as detailed in Appendix 1 (Table A1-2). Typically, the U.S. EPA/OPP derives chronic RfDs based on chronic/lifetime toxicity studies, and bases a chronic RfD on a multi-generation reproduction study only if the NOAEL from the reproduction study is below the NOAEL from the corresponding chronic toxicity study. This is not the case for fluazifop-P-butyl, and the rationale for using the reproduction NOAEL of 0.75 mg/kg bw/day rather than the chronic NOAEL of 0.5 mg/kg bw/day is not discussed in U.S. EPA/OPP/HED (2011a) and is not otherwise apparent.

Forest Service risk assessments typically defer to the U.S. EPA in the derivation of toxicity values used in the human health risk assessment, unless there is a compelling reason to differ with the EPA. In the absence of an articulated or otherwise apparent rationale for using the higher NOAEL from the reproduction study, the use of a somewhat lower NOAEL from a chronic study that the EPA classifies as "Acceptable" could be viewed as compelling. In the case of fluazifop-P-butyl, however, the differences between the NOAELs are not substantial.

While there are concerns with using the higher NOAEL, the small difference between the magnitudes of the NOAELs is such that it does not seem necessary to propose an alternate chronic RfD. In addition and as noted in Section 1.1, copies of the full studies have been reviewed by the U.S. EPA/OPP/HED but the full studies were not available for the conduct of the current Forest Service risk assessment. Thus, the current risk assessment will adopt the RfD from U.S. EPA/OPP/HED (2011a) and concerns for the NOAEL from U.S. EPA/OPP/HED (2011a) are discussed qualitatively in the risk characterization (Section 3.4).

The European Food Safety Authority (EFSA 2012, p. 7) recommends a somewhat higher chronic value of 0.01 mg/kg/day. This value is designated as an ADI (Acceptable Daily Intake) which is essentially equivalent to a chronic RfD. The EFSA (2012, p. 7) states that this ADI is based on an "*overall long-term NOAEL of 1 mg/kg bw/day*" and an uncertainty factor of 100. EFSA (2012) does not identify or provide a citation or citations for the NOAEL. As summarized in Table 11 and detailed further in Appendix 1 (Table A1-2), a chronic NOAEL of 1 mg/kg bw/day was not identified in the literature reviewed as part of the current Forest Service risk assessment. In the absence of a more complete justification by EFSA (2012), the ADI of 0.01 mg/kg bw/day cannot be further evaluated.

A final detail with the chronic RfD involves the units of measure used to report the chronic RfD by the U.S. EPA. The discussion in U.S. EPA/OPP/HED (2011a) and other related EPA documents (Table 2) do not consistently or explicitly designate doses as active ingredient (a.i.) or acid equivalents (a.e.). As discussed in Section 2, all exposure assessments used in the current Forest Service risk assessment are based on acid equivalents using a conversion factor of 0.854 a.e./a.i. Based on the study descriptions in U.S. EPA/OPP/HED (2011a), it appears that the doses are expressed in units of a.i. Thus, the chronic RfD appears to be 0.0074 mg a.i./kg/day. For the current Forest Service risk assessment, this RfD is adjusted to 0.0063 mg a.e./kg bw/day [0.0074 mg a.i./kg/day x 0.854 a.e./a.i. = 0.0063196 mg a.e./kg bw/day].

### 3.3.3. Acute RfD

The U.S. EPA/OPP sometimes derives acute RfDs for pesticides. Typically, acute RfDs are based on developmental studies under the assumption that the endpoint observed in the developmental study could be associated with a single dose of the pesticide. The EPA has followed this approach with fluazifop-P-butyl.

Based on the NOAEL of 50 mg/kg bw/day from a developmental study in rats (MRIDs 00088857 and 92067047), the EPA derived an acute RfD of 0.5 mg/kg bw/day using an uncertainty factor of 100 (U.S. EPA/OPP/HED 2011a, p. 68). The rationale for this uncertainty factor is identical to the rationale for the uncertainty factor used for the chronic RfD (Section 3.3.2). As detailed in Appendix 1 (Table A1-3), this NOAEL is associated with a LOAEL of 200 mg/kg bw/day based on delayed ossification and diaphragmatic hernias in offspring. As summarized in Appendix 1 (Table A1-3), the developmental study in rats used by U.S. EPA/OPP/HED (2011a) is supported by another developmental study in rats (MRID 00088858) which yielded a NOAEL of 10 mg/kg bw/day and a LOAEL of 200 mg/kg bw/day. Specifically, MRID 00088858 supports the LOAEL from MRIDs 00088857 and 92067047. The lower NOAEL of 10 mg/kg bw/day from MRID 00088858 is an artifact of the experimental design and does not call into question the NOAEL of 50 mg/kg bw/day from MRIDs 00088857 and 92067047).

Because the NOAEL is applicable to female rats and offspring, the EPA notes that the acute RfD is applicable to women of child-bearing age. The EPA did not derive an acute RfD for the general population. The rationale for not doing so is as follows: *An appropriate endpoint attributable to a single dose was not available in the database including the developmental toxicity studies* (U.S. EPA/OPP (2011a, p. 68). Forest Service risk assessments typically apply an acute RfD based on a developmental study to exposure scenarios for both males and females. The rationale for this approach is that all Forest Service risk assessments are intended to encompass the most sensitive subgroup (Section 3.2.3.1.1). As discussed further in Section 3.3.3 (Surrogate RfD for Occupational Exposures), the U.S. EPA/OPP uses a similar rationale in their risk assessment for workers.

The EFSA (2012, p. 7) proposes a lower acute RfD of 0.017 mg a.e./kg bw/day, specifically noting that this acute RfD is expressed as fluazifop acid. This acute RfD is based on a NOAEL of 2 mg/kg bw/day from a developmental study in rats and an uncertainty factor of 100. While not specifically cited in EFSA (2012), the NOAEL of 2 mg/kg bw/day appears to be based on MRID 46082903, as summarized in Appendix 1 (Table A1-3), with a corresponding LOAEL of 5 mg/kg bw/day based on delayed ossification. As discussed further in Section 3.2.3.1.1, these MRIDs are used in U.S. EPA/OPP/HED (2011a) as the basis for the risk characterization for short-term exposures in workers. The U.S. EPA/OPP/HED would not typically use a NOAEL based on a LOAEL for delayed ossification for an acute RfD because delayed ossification would not be associated with an exposure occurring over the course of a single day.

For the current Forest Service risk assessment, the acute RfD of 0.5 mg/kg bw/day is used to characterize risks associated with exposures occurring over a single day. As with the chronic RfD (Section 3.3.2), the acute RfD from the EPA appears to be expressed in units of a.i. (fluazifop-P-butyl) rather than a.e. (fluazifop-P acid). Consequently, the acute RfD from EPA is adjusted to 0.43 mg a.e./kg bw/day using the conversion factor of 0.854 a.e./a.i. [0.5 x 0.854 = 0.427], as discussed in Section 2.1.

### 3.3.4. Surrogate RfD for Occupational Exposures

Instead of explicitly deriving RfDs for occupational exposure, the EPA typically identifies a NOAEL from an appropriate study in mammals and recommends a margin of exposure (MOE). Often, the EPA uses the same longer-term toxicity value used to derive the chronic RfD, in which case, the recommended MOE will be identical to the uncertainty factor used to derive the chronic RfD.

This approach is taken in U.S. EPA/OPP/HED (2011a, Table 1a, p. 28) for longer-term occupational exposures of 1 to 6 months. The NOAEL is identified as 0.74 mg/kg/day and is based on the same study used to derive the chronic RfD (Section 3.3.2). The level of concern is set with a target MOE of 100. Thus, the functional RfD for longer-term occupational exposures is identical to the chronic RfD—i.e., 0.74 mg/kg/day ÷ 100 = 0.0074 mg/kg/day).

Somewhat atypically, the EPA also uses a NOAEL of 2 mg/kg bw/day for shorter-term exposures of 1 to 30 days (U.S. EPA/OPP/HED 2011a, p. 28) This NOAEL is also used with a MOE of 100 to characterize risks for workers (U.S. EPA/OPP/HED 2011a, p. 49). The NOAEL of 2 mg/kg bw/day is based on MRIDs 46082913 and 46082903, as summarized in Appendix 1

(Table A1-3). The NOAEL of 2 mg/kg bw/day is associated with a LOAEL of 5 mg/kg bw/day based on an increased incidence of hydroureter (abnormal distension of the ureter with urine) and delayed ossification in rat offspring.

As with the acute RfD (Section 3.3.3), the basis for the shorter-term occupational exposure involves developmental effects. The EPA, however, specifically notes that this short-term exposure criterion is applied to all population subgroups. The rationale for this approach is given as:

> *Since females of child-bearing age cannot be excluded or treated separately from the general population should regulatory and/or mitigation measures be necessary, it is incumbent upon the Agency to address the potential risks of the most sensitive population as representative of the entire population.*
> U.S. EPA/OPP/HED (2011a, p. 71)

As discussed in Section 3.3.3 (Acute RfD), this is essentially the same rationale used in all Forest Service risk assessments in the application of acute RfDs based on developmental studies to both males and females. In other words, the acute RfD, which is based on a response in female animals, is applied to exposure scenarios that may involve either males and females because females *…cannot be excluded or treated separately from the general population.*

For the current risk assessment, the surrogate RfD of 0.02 mg/kg bw/day [2 mg/kg bw/day ÷ 100] is used to characterize short-term (1-30 days) exposures in workers. Because the U.S. EPA uses both this shorter-term value as well as the chronic RfD for characterizing risks to workers, Worksheet E02 in the attachments to this risk assessment was modified accordingly to make the risk characterization for workers comparable with the EPA risk characterization. These risks are discussed further in Section 3.4.2.

As with the acute and chronic RfDs, the NOAEL of 2 mg/kg bw/day from MRID 46082903 involved a study with fluazifop-P-butyl, and the NOAEL appears to be expressed in units of fluazifop-P-butyl. Consequently, the surrogate short-term occupational RfD of 0.02 mg/kg bw/day is adjusted to 0.017 mg a.e./kg bw/day using the conversion factor of 0.854 a.e./a.i. as discussed in Section 2.1 [0.02 x 0.854 = 0.0.01708].

### 3.3.5. Dose-Severity Relationships

Forest Service risk assessments sometimes consider dose-severity relationships in an effort to more fully characterize potential risks in exposure scenarios where the doses exceed the RfD. For fluazifop-P-butyl, this consideration is important because several of the exposure scenarios for both workers and members of the general public lead to estimated doses that substantially exceed the RfDs (Section 3.4).

As summarized in Table 22, the ratios of the LOAEL to the corresponding NOAEL are 4 for the acute RfD [200 ÷ 50], about 8 for the chronic RfD [5.8 ÷ 0.74 ≈ 7.837], and 2.5 for the shorter-term surrogate occupational RfD [5 ÷ 2]. While these ratios might not reflect dose-severity responses in human populations, they are the most objective basis for assessing potential concerns for exceedances in the RfDs. As discussed further in Section 3.4, an additional factor to consider is the uncertainty factor of 100 used in the derivation of all of the RfDs.

## 3.4. RISK CHARACTERIZATION

### 3.4.1. Overview
The quantitative risk characterization is based on the hazard quotient (HQ), which is defined as the anticipated exposure divided by a toxicity value. An HQ of 1 is defined as the level of concern—i.e., if an HQ exceeds 1, the exposure exceeds the level of concern. For the human health risk assessments the toxicity values are the acute RfD of 0.43 mg a.e./kg bw/day, a surrogate intermediate RfD of 0.017 mg a.e./kg bw/day for workers, and a chronic RfD of 0.0063 mg a.e./kg bw/day for longer-term exposures. As discussed in Section 3.3, these toxicity values are taken from the most recent EPA human health risk assessment (U.S. EPA/OPP/HED 2011a) but are adjusted from units of a.i. (fluazifop-P-butyl) to units of a.e (fluazifop-P acid). Similarly, all exposure estimates given in the workbooks that accompany this risk assessment are given in units of a.e.

Based on the toxicity values and the central estimates of exposure, workers involved in mechanical ground spray and aerial applications of fluazifop-P-butyl do not appear to be at risk. This conclusion is consistent with the risk characterization for these worker groups by the U.S. EPA/OPP/HED (2011a). The central estimate of the HQ for backpack workers, however, modestly exceeds the level of concern (HQ=2). U.S. EPA/OPP/HED (2011a) did not assess backpack workers. Based on upper bound estimates of exposures, most of the HQs exceed the level of concern by factors of up to 43. These estimates indicate that measures to limit or otherwise mitigate worker exposures are warranted.

For the general public, none of the acute exposure scenarios substantially exceed the level of concern, except for accidental exposure scenarios involving a spill of fluazifop-P-butyl into a small pond. At the upper bounds, the acute (non-accidental) exposure scenario for the consumption of contaminated vegetation reaches the level of concern following one application (HQ=1) and modestly exceeds the level of concern following two applications (HQ=1.3) and three applications (HQ=1.4).

Longer-term exposure scenarios involving the consumption of contaminated vegetation are a much greater concern than acute exposures with the central estimates of longer-term exposures reaching the level of concern following one application (HQ=1) and exceeding the level of concern following two applications (HQ=2) and three applications (HQ=3). The upper bound HQs for these scenarios substantially exceed the level of concern—i.e., upper bound HQs of 10 following a single application, 19 following two applications, and 29 following three applications. The longer-term exposure scenarios involving dietary exposure developed in the current Forest Service risk assessment are much more severe than the dietary exposure scenarios used in U.S. EPA risk assessments. Nonetheless, the exposure scenarios for the consumption of contaminated vegetation reflect potential exposures for individuals consuming contaminated vegetation following forestry applications of fluazifop-P-butyl. The distinction between exposure following forestry applications and exposures following agricultural applications is important in that forestry applications are not regulated by tolerance limits. These longer-term scenarios for the consumption of contaminated vegetation are standard exposure scenarios used in all Forest Service risk assessments for pesticides applied to vegetation and are considered relevant by the Forest Service.

1
2   While the risk characterization for fluazifop-P-butyl is relatively severe, particularly for longer-
3   term exposure scenarios, the approach used in the current risk assessment is not the most
4   conservative approach that could be adopted.  As discussed in the dose-response assessment for
5   chronic toxicity (Section 3.3.2), the chronic RfD for fluazifop-P-butyl is based on a NOAEL of
6   0.75 mg a.i./kg bw/day from a reproduction study in rats.  A standard chronic toxicity study in
7   rats yields a somewhat lower NOAEL of 0.5 mg a.i./kg bw/day.  The rationale for using the
8   higher NOAEL is not clearly articulated in the EPA risk assessments on fluazifop-P-butyl.  If the
9   lower NOAEL were used to derive a chronic RfD, the HQs discussed above would increase by a
10  factor of 1.5.  Adopting a lower RfD, however, would not have a substantial qualitative impact
11  on the risk characterization, and the current Forest Service risk assessment defers to the most
12  recent EPA human health risk assessment, U.S. EPA/OPP/HED (2011a).

13  ### 3.4.2. Workers
14  The quantitative risk characterization for workers is summarized in Table 23.  The HQs given in
15  this table are taken from Worksheets E02 in Attachment 3 (three applications).  Note that the
16  HQs for workers are identical in the EXCEL workbooks for one, two, and three applications.
17  Accidental exposure scenarios model only a single event.  The general exposure scenarios
18  assume that the worker will repeatedly apply the pesticide—i.e., a longer-term toxicity value is
19  used.  Thus, the risk to the worker remains the same, whether the worker is repeatedly applying
20  the pesticide to the same field or applying the pesticide to different fields.
21
22  Table 23 is divided into two sections.  The upper section gives the Hazard Quotients (HQs)—i.e.,
23  the estimated dose divided by the appropriate RfD or surrogate RfD, as discussed in Section 3.3.
24  HQs are the standard numerical expression of the risk characterization used in Forest Service risk
25  assessments with a level of concern of 1 (i.e., HQ=1).  If the HQ exceeds 1, concern for potential
26  adverse effects is triggered.
27
28  The lower section of Table 23 gives the Margins of Exposure (MOE) that correspond to the HQs.
29  The MOE is the appropriate animal NOAEL divided by the estimated exposure.  The MOE is
30  used by the U.S. EPA/OPP with a defined level of concern.  In the case of fluazifop-P-butyl, an
31  MOE of less than 100 triggers concern.
32
33  HQs and MOEs are essentially reciprocal expressions.  Assuming that the level of concern for
34  the MOE is equal to the uncertainty factor used to derive the RfD, the MOE associated with a
35  particular HQ is simply the uncertainty factor divided by the HQ.  In the case of fluazifop-P-
36  butyl, the EPA uses an MOE of 100 to trigger concern and the uncertainty factor used for all of
37  the RfDs is also 100.  Margins of exposure are not typically discussed explicitly in Forest
38  Service risk assessments.  An exception is made with the current risk assessment to facilitate the
39  comparison of the risk characterization for workers offered by U.S. EPA/OPP/HED (2011a) and
40  the risk characterization developed in the current risk assessment.

41      #### 3.4.2.1. Accidental Exposures
42  The only accidental exposure scenario that leads to an excursion above the level of concern
43  [HQ=1] is the upper bound of the HQ for wearing contaminated gloves for 1 hour [HQ=6].  As
44  summarized in Table 12, the HQ for this and other accidental exposure scenarios is based on the
45  acute RfD of 0.5 mg/kg bw/day which, in turn, is based on a NOAEL of 50 mg/kg bw/day with a

corresponding LOAEL of 200 mg/kg bw/day based on diaphragmatic hernias noted in a developmental study in rats (MRIDs 00088857 and 00088858). As discussed in Section 3.3.2, the RfD of 0.5 mg/kg bw/day appears to be expressed as fluazifop-P-butyl, and the values used in the attachments to derive the HQs are based on exposures expressed as acid equivalents; thus, the RfD is adjusted to 0.43 mg a.e./kg bw/day.

The HQ of 6 is greater than the dose spacing of the NOAEL and LOAEL [200÷50=5]; thus, the upper bound HQ for wearing contaminated gloves for 1 hour is regarded with concern. Because of the endpoint on which the acute RfD is based (i.e., fetal effects) the greatest concern would be for female workers of child-bearing age.

As noted in Section 3.3.2, the acute RfD is based on an uncertainty factor of 100, a factor of 10 for potentially sensitive individuals and a factor of 10 for species-to-species extrapolation. As discussed in Section 3.1, no remarkable or consistent patterns in sensitivity among species are apparent for fluazifop-P-butyl based on studies in mice, rats, hamsters, dogs. As with many pesticides, however, no toxicity data are available on primates. Thus, concern for the potentially greater sensitivity of humans, relative to laboratory mammals, is not substantially alleviated.

In practical terms, the most sensible interpretation of the HQ of 6 reflects what should be standard practice in any pesticide application—i.e., hands should be washed and gloves should be replaced as soon as possible after they become contaminated. This caution is particularly important for women of child-bearing age.

As discussed in Section 3.1.11, fluazifop-P-butyl is not a strong skin or eye irritant. Nonetheless, prudent measures and care should be taken handling any pesticide to avoid contact with the skin or eyes. This type of cautionary language is appropriately included in the product labels for Fusilade formulations. A somewhat greater concern involves the potential for skin sensitization. As discussed in Section 3.1.11.2, U.S. EPA/OPP/HED (2011a) notes that neither fluazifop-butyl nor fluazifop-P-butyl is a skin sensitizer. The review by the European Food Safety Authority, however, indicates that fluazifop-P-butyl is a skin sensitizer and cautionary language concerning the potential for skin sensitization is included in the MSDS and product labels for Fusilade DX and Fusilade II. Consequently, workers who develop skin reactions, even in the absence of gross exposures, during or after handling fluazifop-P-butyl should receive appropriate medical attention.

### 3.4.2.1. General Exposures

#### 3.4.2.1.1. Central Estimates
At the central estimates of exposure, the only HQ to exceed a level of concern (HQ=1) is the HQ for backpack workers involved in longer-term application programs. Using the criteria defined in U.S. EPA/OPP/HED (2011a, p. 27-28), *longer-term* would be defined as 1 to 6 months. As detailed in U.S. EPA/OPP (2013a), the occupational exposures developed by the U.S. EPA are based on average or "best-fit" estimates. Consequently, the central estimates of risk from the current Forest Service risk assessments are compared with the corresponding estimates of risk from the most recent EPA human health risk assessment (U.S. EPA/OPP/HED 2011a).

For backpack workers, the central estimate of the HQ is 2.  As discussed in 3.3.5, the ratio of the LOAEL to the NOAEL for the study on which the chronic RfD is based is 8.  Because the HQ is well below 8, it is not clear that adverse effects would be anticipated in backpack workers, based on the central estimates of exposure.  Nonetheless, the endpoint on which the LOAEL is based, a decrease in testes weights, is relatively severe, and care as well as risk mitigation in longer-term applications of fluazifop-P-butyl may be warranted.

Confidence in the risk characterization based on the central estimates of exposure is relatively high.  As discussed in Section 3.2.2.1, the estimated exposures for backpack workers and ground broadcast workers are consistent with the Chester and Hart (1986) study.  As summarized in Table 15 and discussed in Section 3.2.2.1.2, the estimated exposures for ground spray and aerial applications are higher than the estimates in U.S. EPA/OPP/HED (2011a) by a factor of about 5 for ground spray workers [0.0042 ÷ 0.00091 ≈ 4.66] and a factor of about 4 for aerial applications [0.0037 ÷ 0.00099 ≈ 3.73].  As also summarized in Table 15, the differences between the exposure estimates developed in the current risk assessment and the exposure estimates developed by the EPA (U.S. EPA/OPP/HED 2011a) are more modest when the EPA estimates are modified to consider the same amount of pesticide handled as used in the current Forest Service risk assessment.  With this normalization, the exposure estimates used in the current Forest Service risk assessment are higher than the EPA estimates by a factor of 3.5 for backpack applications [0.0042 ÷ 0.0012 = 3.5] and a factor of 2.6 for aerial applications [0.0037 ÷ 0.0014 ≈ 2.64].  Given the substantial variability in worker exposures as well as the exposure assumptions, these differences are not remarkable.

For ground broadcast and aerial applications, the qualitative risk characterization given in the current risk assessment is qualitatively consistent with the risk characterization given in U.S. EPA/OPP/HED (2011a) in that the level of concern is not reached for either of these worker groups.  The MOEs derived in U.S. EPA/OPP/HED 2011a (Table 8, p. 49) are 2000 for ground spray and 1763 for aerial applications based on short-term exposures.  The corresponding MOEs derived in the current risk assessment are 472 for ground spray workers and 542 for aerial applications.  For the longer-term exposures, the MOEs from U.S. EPA/OPP/HED 2011a (Table 9, p. 50) are 813 for ground spray and 746 for aerial applications.  The corresponding MOEs derived in the current risk assessment are 176 for ground broadcast workers and 201 for aerial workers.  Details of these calculations are given in Table 23 and Worksheet E02 in Attachments 1, 2, and 3.

The EPA assessment (U.S. EPA/OPP/HED 2011a) does not cover backpack applications of fluazifop-P-butyl.

### 3.4.2.1.2. Lower and Upper Bound Estimates
As detailed in SERA (2009, Sections 2.2 and 4.1), one basic difference between the risk characterizations for workers in Forest Service risk assessments compared with risk characterizations from the U.S. EPA is that Forest Service risk assessments provide estimates of risks based on upper bound as well as lower bound exposures.  As discussed in the previous section, the U.S. EPA/OPP provides point estimates—i.e., single values based on average or best-fit estimates (U.S. EPA/OPP 2013a).  As detailed in SERA (2013b), Forest Service risk assessments provide both confidence intervals and prediction intervals for the HQs relating to worker exposures.  As discussed in SERA (2013b), confidence intervals may be viewed as the

range in which average values would fall if a new study were conducted – i.e., another group of workers were sampled and the average were taken. The prediction interval may be viewed as the range in which a new single measurement might be found if a measurement were taken of a new individual.

As discussed in Section 3.2.3.1.1, the lower bound estimates of risk are intended to assess whether or not a pesticide can be used safely even under reasonably good conditions—e.g., acceptable worker hygiene practices, good site conditions. For fluazifop-P-butyl, all of the lower bounds of the exposure estimates for workers are below the level of concern (HQ=1) with HQs ranging from 0.006 (the lower prediction interval for aerial applications) to 0.6 (the lower confidence interval for backpack applications (Table 23).

Based on upper bounds of estimated exposures, most of the HQs exceed the level of concern, and several of the exceedances are substantial (Table 23). As discussed in Section 3.3 (Dose-Response Relationships), U.S. EPA/OPP/HED (2011a) characterizes risks to workers for both short-term and longer-term exposures, and the same approach is used in the current Forest Service risk assessment. Shorter-term exposures are characterized with a surrogate RfD of 0.017 mg a.e./kg bw/day (Section 3.3.4) and longer-term exposures are characterized with the chronic RfD of 0.0063 mg a.e./kg bw/day (Section 3.3.2). As discussed in Section 3.3.4 (Dose-Severity Relationships), HQs of 2.5 would be a clear concern for shorter-term scenarios and HQs of 8 would be a clear concern for longer-term exposure scenarios.

Based on the HQs for shorter-term exposures, the upper bound confidence intervals exceed the level of concern (HQ=1) for backpack applications (HQ=2) and aerial applications (HQ=1.1). The upper bound confidence interval for aerial applications only modestly exceeds the level of concern. The exceedance for backpack applications is greater (HQ=2) and approaches the level of clear concern for adverse effects (HQ=2.5). The upper bound prediction intervals for shorter-term exposures are 10 to 16 and all of these HQs substantially exceed the level of clear concern for adverse effects in short-term exposures (HQ=2.5).

Based on the HQs for longer-term exposures, the upper bound confidence intervals exceed the level of concern (HQ=1) for backpack applications (HQ=6), ground broadcast spray (HQ=1.7), and aerial applications (HQ=3). The upper bound confidence interval for ground broadcast applications only modestly exceeds the level of concern and is well-below the level for clear concern in longer-term exposures (HQ=8). The exceedance for backpack applications is greater (HQ=6) and approaches the level of clear concern for adverse effects following longer-term exposure (HQ=8). The upper bound prediction intervals of the HQs for longer-term exposures are 28 to 43, and all of these HQs substantially exceed the level of clear concern for adverse effects following longer-term exposures (HQ=8).

As detailed in SERA (2013b), the upper bound exposures for the prediction interval would most likely reflect adverse conditions during the application (e.g., rough terrain) and/or poor worker practices in terms of limiting exposures. A mitigating factor in poor terrain could involve the assumptions on which the exposure assessment is based. As summarized in Table 13, the upper bounds of the numbers of acres treated per day are used with the upper bounds of the worker exposure rates. In the case of applications in particularly rough terrain that is difficult to treat,

1 the use of upper bound treatment rates (i.e., acres treated per day) with upper bound exposure
2 rates may not be realistic.  This argument is not considered further in the current risk assessment
3 which does not explicitly involve site-specific applications; nonetheless, this consideration could
4 have merit in a specific planned application of fluazifop-P-butyl.
5
6 The characterization of risk for workers that uses both confidence and prediction intervals
7 combined with considerations of both shorter-term and longer-term exposures and dose-severity
8 relationships is admittedly cumbersome.  In plain language, the current Forest Service risk
9 assessment concurs with the risk characterization for workers developed in U.S. EPA/OPP/HED
10 (2011a): Based on the central estimates of exposure, ground broadcast and aerial applications of
11 fluazifop-P-butyl do not appear to pose risks to workers.  Based on upper bound estimates of
12 exposures, however, caution is warranted, and measures to limit or otherwise mitigate worker
13 exposures are justified.  Backpack workers may be at greater risk based on central as well as
14 upper bound levels of exposure, particularly when workers are involved in longer-term
15 applications.  Even in shorter-term backpack applications, the central estimate of the HQ for
16 workers (HQ=0.9) approaches a level of concern (HQ=1).

17 ### 3.4.3. General Public
18 The risk characterizations for members of the general public are summarized in Table 24 for
19 acute exposures and Table 25 for longer-term exposures.  All HQs for the acute exposure
20 scenarios are based on the acute RfD from U.S. EPA/OPP/HED (2011a) corrected for acid
21 equivalents—i.e., 0.043 mg a.e./kg bw/day, as discussed in Section 3.3.3.  All HQs for the
22 longer-term exposure scenarios are based on the chronic RfD from U.S. EPA/OPP/HED (2011a)
23 corrected for acid equivalents—i.e., 0.0063 mg a.e./kg bw/day, as discussed in Section 3.3.2.
24 These tables are based on Worksheet E04 in the attachments to this risk assessment—i.e.,
25 Attachment 1 for a single application, Attachment 2 for two applications, and Attachment 3 for
26 three applications.

27 #### 3.4.3.1. Accidental Exposures
28 The two general types of accidental exposure scenarios considered include dermal exposure
29 through accidental spray and oral exposure through the consumption of contaminated water or
30 fish following an accidental spill.  Like the accidental exposure scenarios for workers, the
31 accidental exposure scenarios for members of the general public are the same for one, two, and
32 three applications—i.e., accidental exposures are assumed to occur only once.
33
34 None of the exposure scenarios involving dermal exposure lead to HQs that exceed the level of
35 concern (HQ=1).  The highest HQ is 0.5, the upper bound HQ for the accidental spray of naked
36 child.  The naked child scenario is intended to be extreme.  While the upper bound for this
37 exposure scenario is below the level of concern, it is worth noting that this exposure scenario
38 covers a 1-hour exposure period.  In other words, the assumption is made that the pesticide is
39 effectively removed from the surface of the child after 1 hour.  Thus, a longer period of exposure
40 (in this example about 2.25 hours) would result in an HQ of 1, which reaches the level of
41 concern.  As with any event involving accidental exposure to a pesticide, prudent measures
42 should be taken promptly to mitigate the exposure.
43
44 All of the HQs associated with an accidental spill exceed the level of concern (HQ=1) at least at
45 the upper bounds of exposures.  For the consumption of contaminated water by a child, the

1  exceedance at the upper bound of the HQ is modest (HQ=1.5). In addition, this scenario
2  assumes that the child consumes 1 liter of water—i.e., about the amount that a child might
3  consume over the course of a single day.
4
5  The upper bound HQs for the consumption of contaminated fish by an adult are more
6  substantial—i.e., an upper bound HQ of 4 for members of the general public and 18 for members
7  of subsistence populations who may consume a larger quantity of caught fish. As discussed in
8  Section 3.3.5 (Dose-Severity Relationships), the ratio of the LOAEL to the corresponding
9  NOAEL used to derive the acute RfD is 4—i.e., a LOAEL of 200 divided by the NOAEL of 50
10  mg/kg bw]. The endpoint associated with the LOAEL is the development of diaphragmatic
11  hernias in rat offspring from a developmental study (MRIDs 00088857). In the event of an
12  accidental spill of fluazifop-P-butyl, vigorous efforts would be justified to minimize exposures
13  associated with the consumption of contaminated fish by members of the general public,
14  particularly women of child-bearing age.

15        *3.4.3.2. Acute Non-Accidental Exposures*
16  The risk characterization for acute non-accidental exposures is relatively simple. All scenarios
17  involving contaminated water as well as contact with contaminated vegetation are below the
18  level of concern (HQ=1). The highest of these HQs is 0.5, and this HQ is associated with the
19  upper bound for the consumption of contaminated fish by subsistence populations following
20  three applications of fluazifop-P-butyl at the maximum application rate. This HQ is based on
21  both upper bounds of estimated concentrations of fluazifop-P-butyl in water as well as upper
22  bound estimates for the consumption of fish.
23
24  The only exposure scenario that triggers a level on concern (HQ>1) involves the consumption of
25  contaminated broadleaf vegetation following two applications (upper bound HQ of 1.3) or three
26  applications (HQ 1.4) of fluazifop-P-butyl. These are very modest excursions above the acute
27  RfD. While these excursions, by definition, would not be viewed as acceptable, it is not clear
28  that these exposures would be associated with any observable effects.
29
30  As discussed in Section 2, fluazifop-P-butyl will be used to treat grassy weeds and will not be
31  intentionally applied to vegetation or fruits that might be consumed by humans in a treated area.
32  While the inadvertent application of fluazifop-P-butyl to edible vegetation would not be likely in
33  backpack (i.e., directed foliar) applications, the inadvertent application of fluazifop-P-butyl to
34  edible vegetation seems plausible in ground broadcast applications and likely in aerial
35  applications, if consumable vegetation is in the treated area.

36        *3.4.3.3. Longer-term Exposures*
37  As with the acute exposure scenarios, all of the scenarios involving contaminated water are
38  substantially below the level of concern (HQ=1). The highest HQ for this group is 0.3 for the
39  consumption of contaminated water following two or three applications. Note that identical HQs
40  for two and three applications are an artifact of rounding conventions. In Forest Service risk
41  assessments, HQs between 0.1 and 0.9 are rounded to one significant place. The underlying
42  exposures are 0.00176 mg/kg bw/day for two applications and 0.00219 mg/kg bw/day for three
43  applications. Dividing these values by the chronic RfD of 0.0063 mg/kg bw/day leads to HQs of
44  about 0.2786 for two applications and 0.3483 for three applications, both of which round to an
45  HQ of 0.3.

1
2 As summarized in Table 25, the longer-term HQs associated with the consumption of
3 contaminated broadleaf vegetation are much greater than the corresponding acute HQs. Based
4 on the central estimate of exposures, the HQ reaches a level of concern following a single
5 application (HQ=1), and exceeds the level of concern following two applications (HQ=2) and
6 three applications (HQ=3). Based on the upper bound levels of exposure, the HQs substantially
7 exceed the level of concern following one application (HQ=10), two applications (HQ=19), and
8 three applications (HQ=29).
9
10 As discussed in the hazard identification (Sections 3.1.5 and 3.1.9.2), both the reproduction study
11 on which the chronic RfD is based and the chronic toxicity study in rats indicate that males are
12 more sensitive than females. The endpoint of concern in the reproduction study on which the
13 RfD is based involved decreased testicular weight which was seen at a dose that was a factor of
14 about 8 higher than the NOAEL. In the chronic toxicity study (MRID 41563703 as summarized
15 in Appendix 1, Table A1-3), the LOAELs in male rats involved kidney damage and increased
16 mortality which also occurred at a dose of about a factor of 8 times greater than the NOAEL
17 [$4.15 \div 0.51 \approx 8.13$]. Thus, as discussed in Section 3.3.5 (Dose-Severity Relationships), chronic
18 HQs in excess of 8 are a clear cause for concern.
19
20 Based on the relationships discussed above, the upper bound HQs of 10 for two applications and
21 19 for three applications are clearly a substantial concern. Based on the observations in rats,
22 concerns would be higher for males than for females, and, clearly, the endpoints of concern
23 would be considered severe—i.e., decreased testicular weight, kidney damage, and mortality.
24
25 Notwithstanding the above considerations, the results from animal studies may not be directly
26 transferable to assessing risks in humans in both quantitative terms (i.e., the relationship of
27 NOAELs to LOAELs) and in qualitative terms (i.e., the specific effect that might be caused in
28 humans). While this is a general limitation in most pesticide risk assessments, and the limitation
29 is acknowledged, animal studies are used for and are often the only source of estimating
30 acceptable or tolerable levels of exposure in humans.
31
32 Another consideration in interpreting the exceedances in chronic exposures to contaminated
33 vegetation involves the plausibility of the exposure scenarios. As discussed in 3.2.3.6, the
34 exposure scenario assumes that edible vegetation is contaminated and that an individual
35 consumes this vegetation in amounts that account for the typical consumption of vegetation by
36 humans over a prolonged period of time. In other words, this scenario could be most relevant to
37 subsistence populations who gather most of the vegetation that they consume from a treated area.
38 In addition to subsistence populations, other individuals may gather wild plants regarded as
39 delicacies (e.g., Peterson and Peterson 1977) but such individuals would often consume lesser
40 amounts of contaminated vegetation from treated areas for a prolonged period than the estimates
41 used in the current risk assessment. While the exposure scenarios for the longer-term
42 consumption of contaminated vegetation may be viewed as highly conservative and perhaps
43 limited to only a minority of the general population, this scenario is a standard in all Forest
44 Service risk assessments for pesticides applied to vegetation, and this scenario is considered
45 relevant by the Forest Service.
46

1  It should be noted that the types of exposure scenarios for contaminated vegetation that are
2  routinely used in Forest Service risk assessments are not considered in pesticide risk assessments
3  conducted by the U.S. EPA/OPP.  For example, the total chronic dietary assessment for
4  fluazifop-P-butyl from the U.S. EPA/OPP/HED (2010a, Table 6, 12) estimates doses in the range
5  of 0.0006 to 0.007 mg/kg bw/day. For comparison, the exposure assessments for the
6  consumption of contaminated vegetation used in the current Forest Service risk assessments are
7  in the range of about 0.0004 to 0.06 mg/kg bw/day following one application and 0.001 to 0.18
8  mg/kg bw/day following three applications.
9
10  The reason for the substantial differences between EPA exposure assessments and the exposure
11  assessments given in the current Forest Service risk assessment relates to differences in both
12  assessment methods and underlying assumptions.  As detailed in U.S. EPA/OPP/HED (2011a),
13  the U.S. EPA uses a dietary exposure model that estimates total pesticide consumption from
14  commercially purchased foods based on dietary patterns as well as pesticide residue data from
15  FDA market basket surveys (e.g., Egan 2013) and the USDA Pesticide Data Program (e.g., Punzi
16  et al. 2005).  This type of exposure assessment is appropriate for a consideration of risks
17  associated with agricultural applications for which tolerance limits are set by the EPA.
18  Tolerance limits, however, are applicable and enforced in agricultural applications but are not
19  applicable to forestry uses of a pesticide.  This is essentially the rationale used by the Forest
20  Service to assess dietary exposures associated with the consumption of contaminated vegetation
21  following forestry applications.

22     ### 3.4.4. Sensitive Subgroups
23  As with sethoxydim (SERA 2001) and clethodim (SERA 2013a), there is no information to
24  assess whether or not specific groups or individuals may be especially sensitive to the systemic
25  effects of fluazifop-P-butyl.  As indicated in Section 3.1.3, the mechanism of action for the acute
26  and chronic toxicity in mammals is unclear.  Effects noted in experimental mammals include
27  decreases in food consumption as well as decreased body weight and the occurrence of liver and
28  kidney pathology.  These effects, however, occur only at high doses, and it is not clear that
29  exposures to fluazifop-P-butyl following the types of applications proposed by the Forest Service
30  would aggravate responses in individuals with metabolic disorders.

31     ### 3.4.5. Connected Actions
32  No data are available regarding the toxicity of fluazifop-P-butyl in combination with other
33  pesticides in mammals.  As noted in Section 2, formulations of fluazifop-P-butyl contain
34  petroleum solvents and/or surfactants.  There is no information, however, suggesting that these
35  agents have a substantial impact on the toxicity of fluazifop-P-butyl to humans or experimental
36  mammals.  As discussed in Section 3.1.14.2, the very limited information on the toxicity of
37  fluazifop-P-butyl formulations suggests that the contribution of the other ingredients is not
38  substantial.

### 3.4.6. Cumulative Effects

Cumulative effects may involve either repeated exposures to an individual agent or simultaneous exposures to the agent of concern (in this case fluazifop-P-butyl) and other agents that may cause the same effect or effects by the same or a similar mode of action.

In the tolerance reassessment for fluazifop-P-butyl, the EPA declines to assess whether other pesticides may have cumulative effects with fluazifop-P-butyl:

> *EPA has not made a common mechanism of toxicity finding as to fluazifop-P-butyl and any other substances, and fluazifop-P-butyl does not appear to produce a toxic metabolite that is also produced by other substances. For the purposes of this tolerance action, therefore, EPA has not assumed that fluazifop-P-butyl has a common mechanism of toxicity with other substances.*
>
> U.S. EPA/OPP/HED (2005a, p. 3)

As noted in the current risk assessment (Section 2.2.2), fluazifop-P-butyl is an aryloxyphenoxy propionate herbicide and shares a common mechanism of phytotoxic actions with other aryloxyphenoxy propionate herbicides as well as cyclohexanedione herbicides, like clethodim (Burden et al. 1990; Mallory-Smith and Retzinger 2003). The relevance of this common mechanism of phytotoxic action to potential effects in humans, however, is not clear.

# 4. ECOLOGICAL RISK ASSESSMENT

## 4.1. HAZARD IDENTIFICATION

### 4.1.1. Overview

The open literature on the impact of fluazifop-butyl and fluazifop-P-butyl on terrestrial vegetation is robust. With the exceptions of reptiles and amphibians, at least minimal information is available on other groups of organisms. The key information on receptors other than terrestrial plants, however, is taken from EPA risk assessments (U.S. EPA/OPP/EFED 2008, 2010a) as well as assessments of fluazifop-P-butyl from the European literature, particularly the review by the European Food Safety Authority (EFSA 2012). Most of the studies covered in these reviews are unpublished; full copies or detailed summaries of most of these studies were not available for the preparation of the current risk assessment. While the summaries from the EPA and the European literature are useful, the lack of detail in and inconsistencies among the available reviews lead to uncertainties which are highlighted, as necessary, in the current risk assessment.

U.S. EPA/OPP/EFED (2008, p. 31) classifies fluazifop-P-butyl as *Practically Non-toxic* to birds and terrestrial invertebrates and only *Slightly Toxic* to mammals. These classifications are commonly applied to herbicides. Fluazifop-P-butyl, however, is classified as *Very Highly Toxic* to fish and invertebrates. These classifications are well supported by the information presented in U.S. EPA/OPP/EFED (2008) as well as other reviews of fluazifop-P-butyl (Table 2). As with most ecological risk assessments, toxicity data are available on only a few species, relative to the numerous species likely to be exposed to fluazifop-P-butyl; thus, the hazard assessment for most groups of terrestrial nontarget species is constrained.

Fluazifop-P-butyl is toxic to true grasses—i.e., monocots which are members of the Poaceae (a.k.a. Gramineae) family—at application rates as low as 0.01 kg a.i./ha (≈0.0076 lb a.e./acre). Fluazifop-P-butyl, however, is much less toxic to other monocots, dicots, and algae. There is a substantial open literature indicating that fluazifop-P-butyl is only minimally phytotoxic to non-Poaceae monocots at application rates ranging from about 0.25 to over 3 kg a.i./ha (≈0.2 to 2.3 lb a.e./acre). Similarly, numerous publications indicate that dicots are tolerant of fluazifop-P-butyl at applications rates on the order of about 0.75 to up to 6 kg a.i./ha (≈0.7 to 5.6 lb a.e./acre).

The application of any effective herbicide will damage at least some vegetation, and this damage may alter the suitability (either positively or negatively) of the treated area for terrestrial and aquatic organisms in terms of habitat, microclimate, or food supply. These secondary effects (i.e., effects on the organism that are not a consequence of direct exposure to fluazifop-P-butyl) would occur with any equally effective method of vegetation management—i.e., mechanical or herbicide use. The potential for secondary effects is acknowledged but not otherwise considered in the hazard identification for nontarget species, except for some fluazifop-P-butyl field studies in terrestrial invertebrates.

## 4.1.2. Terrestrial Organisms

### *4.1.2.1. Mammals*
The toxicity studies on mammals used to assess the potential hazards of fluazifop-P-butyl to humans (Appendix 1) are applicable to the risk assessment for mammalian wildlife. While the toxicity of fluazifop-P-butyl to plants is understood relatively well (Section 4.1.2.5), the mechanism of action in mammals is unclear (Section 3.1.2). Field studies to investigate the impact of fluazifop-P-butyl on mammalian wildlife were not found in the available literature. As discussed in Section 3.1 and summarized in Appendix 1, decreased body weight gain is a common effect observed in experimental mammals exposed to fluazifop-P-butyl in acute, subchronic, and chronic toxicity studies. In terms of the productivity of mammalian wildlife, adverse effects on reproduction and development are also a concern. As discussed in Section 3.3 and summarized in Table 22, all of the toxicity values used quantitatively in the human health risk assessment are from either developmental or reproduction studies.

While human health risk assessments typically focus on the most sensitive species, the ecological risk assessment is concerned with differences in toxicity among species. As summarized in Appendix 1 (Table A1-1), almost all of the acute toxicity studies were conducted in rats and involve gavage exposure. Only one indefinite $LD_{50}$ of >2000 mg/kg bw is available in mice (EFSA 2012, p. 30). Based on this one study in mice and the reported definitive $LD_{50}$ values in rats (i.e., about 1900 to 3700 mg/kg bw), the difference in the sensitivities between mice and rats cannot be assessed well, but appear to be negligible.

Subchronic and chronic toxicity studies are available in dogs, hamsters, and rats (Table 11) and reproduction studies are available in rabbits and rats (Table 12). The only consistent pattern in these studies is that rats appear to be more sensitive than the other species on which data are available. The difference in sensitivity is most marked in the subchronic studies in which the NOAEL for rats is about 0.5 mg/kg bw/day, the NOAEL in dogs is 25 mg/kg bw/day, and the NOAEL in hamsters is close to 80 mg/kg bw/day.

A common concern with weak acids (which would include fluazifop-P) is the potential increased sensitivity of dogs and other canid species. As discussed in the Forest Service risk assessments for triclopyr (SERA 2011d), dogs have an impaired capacity to excrete some weak acids and, as a result, are sometimes much more sensitive than other mammals to weak acids. As discussed above, the available toxicity studies indicate that dogs are not more sensitive than other mammals to fluazifop-P-butyl. In addition, Woollen et al. (1993) cite an unpublished study that indicates that the half-life for fluazifop-butyl in dogs is about 20 hours, which is not substantially different from the half-life 9 to 21 hours in humans, as discussed in Section 3.1.3.3. Thus, canids are not regarded as a sensitive subgroup for exposures to fluazifop-P-butyl.

The only other consistent pattern in the mammalian toxicity studies is the greater sensitivity of male rats compared with female rats. This difference in sensitivity is apparent in the NOAELs from the chronic toxicity study in rats (0.5 mg/kg bw/day for male rats and 5.2 mg/kg bw/day for female rats from MRID 41563703) and from the reproduction study in rats (0.74 mg/kg bw/day for male rats and 7.1 mg/kg bw/day for female rats from MRID 00088859). As discussed further in Section 4.3.2.1, the toxicity values for mammalian wildlife are based on toxicity data from rats, and separate toxicity values are not derived for male and female rats. In terms of impacts on

| 1 | populations of mammals, it seems sensible to base the risk assessment on the most sensitive sex |
| 2 | as well as the most sensitive species, and there is no reason to derive an alternate assessment for |
| 3 | the more tolerant sex. |

4    ### *4.1.2.2. Birds*

5    #### 4.1.2.2.1 Standard Studies

All of the information on studies submitted to the U.S. EPA/OPP is taken from the most detailed
EPA ecological risk assessment (U.S. EPA/OPP/EFED 2008) and ECOTOX, as discussed in
Section 1.1.2.  Information on standard toxicity studies in birds from the European literature is
taken from FAO/WHO (2000).  For the most part, the studies summarized in FAO/WHO (2000)
appear to be identical to the studies summarized in U.S. EPA/OPP/EFED (2008).  In addition to
these secondary sources, Data Evaluation Records (DERs) were available on several of the
studies as specified in Appendix 2.

A standard set of toxicity studies—i.e., acute gavage studies (Appendix 2, Table 1), acute dietary
studies (Appendix 2, Table 2), and reproduction studies (Appendix 2, Table 3) were submitted to
the U.S. EPA/OPP in support of the registration of fluazifop-P-butyl.  The U.S. EPA/OPP
typically requires these studies to be conducted on both mallard ducks and bobwhite quail.
Acute dietary studies are available in quail, mallards, and pheasants, and reproduction studies are
available in both quail and mallards.  Acute gavage studies were conducted in mallards;
however, corresponding studies with bobwhite quail were not identified.

One acute dietary study on pheasants reporting an $LC_{50}$ of 18,500 ppm (a.i.) is taken from
ECOTOX, but this study is not summarized in U.S. EPA/OPP/EFED (2008).  U.S.
EPA/OPP/EFED (2008, Table 4-4, p. 73 and p. 180) does, however, report a dietary study in
pheasants with a slightly higher $LC_{50}$ of 20,767 ppm (a.i.).  The summary of this study
(designated as MRID 00087482) on p. 180 of the EPA risk assessment has the notation,
"*Fluazifop-butyl (Dieldrin), 99.6%*".  A DER for this study is available (Ross et al. 1980a).
Based on this DER, the notation concerning dieldrin refers to the use of dieldrin as a positive
control for the study.

A general consideration in the risk assessment on fluazifop-P-butyl is the relevance of toxicity
data on fluazifop-butyl (i.e., the blend of [R] and [S] enantiomers) to the assessment of the risks
associated with fluazifop-P-butyl.  The data on birds are consistent with the data on mammals in
which no marked differences between the toxicities of fluazifop-butyl and fluazifop-P-butyl to
birds are apparent.  Comparisons between fluazifop-P-butyl and fluazifop-butyl are limited,
however, because all of the gavage $LD_{50}$ values and most of the dietary $LC_{50}$ values are
indefinite—i.e., the values are specified as greater than (>) the highest dose or concentration
tested.  For the acute gavage studies in mallards, all of the $LD_{50}$ values are indeterminate—i.e.,
an $LD_{50}$ of >4270 mg a.e./kg bw for fluazifop-butyl and $LD_{50}$ values of >3528 mg a.e./kg bw and
>3382 mg/kg bw for fluazifop-P-butyl.  For the acute dietary studies, the reported $LC_{50}$ values
for fluazifop-butyl are >21,348 ppm (a.e.) for mallards and 15,799 ppm (a.e.) for pheasants.  The
dietary $LC_{50}$ values for fluazifop-P-butyl are all >4000 ppm (a.e.).  The lower concentrations for
fluazifop-P-butyl relative to fluazifop-butyl simply reflect the lower doses used in the studies on
fluazifop-P-butyl and cannot be used to infer differences in toxic potency.

1 As with studies included in the human health risk assessment, the U.S. EPA/OPP uses a
2 classification system for categorizing the acute toxicity of pesticides to various groups of
3 nontarget species (see SERA 2011a, Table 16 with discussion in Section 4.1.2 of SERA 2011a).
4 Based on the dietary $LC_{50}$ values, U.S. EPA/OPP/EFED (2008, p. 11) classifies fluazifop-P-butyl
5 as *practically nontoxic* to birds.
6
7 In addition to the standard acute toxicity studies in birds, standard reproduction studies were
8 conducted in both mallards and quail. DERs for both of these studies were available for the
9 conduct of the current risk assessment—i.e., the study in mallards (MRID 00093801) is Roberts
10 et al. (1981a) and the study in quail (MRID 00093802) is Roberts et al. (1981b). These studies
11 are summarized in Appendix 2 (Table A2-3) and less detailed summaries are given in U.S.
12 EPA/OPP/EFED (2008) and FAO/WHO (2000). No statistically significant ($p<0.05$) signs of
13 toxicity or effects on reproduction were noted at dietary concentrations of 43 ppm (a.e.). In both
14 studies, some adult mortality was noted that was not attributed to treatment. In U.S.
15 EPA/OPP/EFED (2008, Appendix C) both of these studies are classified as Supplemental. In the
16 DERs, these studies are classified as Core.

17 ### 4.1.2.2.2 Open Literature
18 The open literature on birds consists of three studies from the Hungarian literature (Varga et al.
19 1999; Varnagy et al. 1996, 1999). The studies by Varga et al. (1999) and Varnagy et al. (1996)
20 both involved egg injection—i.e., pheasant eggs in the former study and chicken eggs in the
21 latter study—using a 12.5% a.i. formulation identified as Fusilade S. Both studies noted embryo
22 lethality. These types of studies are commonly used as screening tools to examine the potential
23 developmental effects of chemicals. Given the route of exposure, however, these studies are not
24 directly useful in the hazard identification.
25
26 Varnagy et al. (1999) describe a field study in pheasants involving Fusilade S (which appears to
27 be a European formulation of fluazifop-P-butyl) in combination with Sumithion 50 EC.
28 Sumithion is a formulation of fenitrothion, an organophosphate insecticide. Varnagy et al.
29 (1999) monitored the concentration of these compounds in the food consumed by the pheasants.
30 At reported concentrations of up to 2250 ppm Fusilade (presumably referring to concentrations
31 of fluazifop-P-butyl), no deaths attributable to toxicity were noted. Because of co-exposure to
32 the organophosphate, this study is not directly useful in the current risk assessment.
33 Nonetheless, it seems worth noting that the functional NOAEL of 2250 ppm fluazifop-P-butyl is
34 consistent with the standard bioassay data on birds (Section 4.1.2.2.1).

35 ### *4.1.2.3. Reptiles and Amphibians (Terrestrial Phase)*
36 No information regarding the toxicity of fluazifop-P-butyl or related compounds (Table 1) to
37 reptiles or terrestrial-phase amphibians was identified in the open literature or in the available
38 reviews (Table 2). Neither the database maintained by Pauli et al. (2000) nor the open literature
39 includes information on the toxicity of fluazifop-P-butyl to reptiles or terrestrial-phase
40 amphibians.
41
42 Risks to terrestrial phase amphibians are addressed in the EPA ecological risk assessments on
43 fluazifop-P-butyl prepared by the Environmental Fate and Effects Division (EFED) of U.S.
44 EPA/OPP (U.S. EPA/OPP/EFED 2008, 2010a,b). In these ecological risk assessments as well as

many similar ecological risk assessments prepared by U.S. EPA/OPP, birds are used as surrogates for terrestrial phase amphibians and reptiles (e.g. U.S. EPA/OPP/EFED 2008, p. 36).

A concern with the use of birds as a surrogate for amphibians involves the permeability of amphibian skin to pesticides and other chemicals. While no data are available on the permeability of amphibian skin to fluazifop-P-butyl, Quaranta et al. (2009) noted that the skin of the frog *Rana esculenta* is much more permeable to several pesticides than pig skin and that these differences in permeability are consistent with differences in the structure and function of amphibian skin relative to mammalian skin.

### *4.1.2.4. Terrestrial Invertebrates*

Insects have coenzyme-A carboxylase (ACCase) enzymes (e.g., Goldring and Read 1993; Russell and Schultz 2010) but information on the similarity of insect ACCase to ACCase in plants and the effect of fluazifop-butyl on insect ACCase activity has not been identified. As discussed further in Section 4.1.2.5 (Terrestrial Plants), differences in plant ACCase enzymes at least partially accounts for the observed sensitivity differences among plants exposed to fluazifop-P-butyl. Thus, the presence of ACCase in insects or other terrestrial invertebrates does not imply that fluazifop-P-butyl is likely to be highly toxic to these animals.

### 4.1.2.4.1. Toxicity to Honeybees

The honey bee is the standard test organism for assessing the potential effects of pesticides on terrestrial invertebrates. For pesticides registered for broadcast applications, which may result in honey bee exposures, U.S. EPA requires an acute contact study with the technical grade pesticide.

As summarized in Appendix 3, Table A3-1, standard oral and contact assays in honeybees are summarized in U.S. EPA/OPP/EFED (2008, Appendix C), and additional details of these studies are available from ECOTOX. Bioassays are available on technical grade fluazifop-butyl and a 25 EC formulation (MRID 00093809) as well as a 13.8% formulation (MRID 00162453). The 25 EC formulation appears to correspond to the Fusilade formulations explicitly considered in the current risk assessment (Table 6). In addition to these studies, the review by the European Food Safety Authority reports contact and $LD_{50}$ values for fluazifop-P-butyl (presumably technical grade) and Fusilade Max (EFSA 2013). Fusilade Max is a 13.7% (w/w) formulation fluazifop-P-butyl (http://www.syngenta.com/ country/ie en/Product_Guide/ Herbicides/Pages/FusiladeMax.aspx).

A DER is available for MRID 00093809 (Smailes and Wilkinson 1979). As summarized in Appendix 3 (Table A3-1), there are minor discrepancies between the summary of this study in the DER and in U.S. EPA/OPP/EFED (2008). The DER was prepared in 1982, and it is not unusual for the EPA to reevaluate studies in the preparation of a risk assessment. Consequently, the summary in U.S. EPA/OPP/EFED (2008) is used in the current risk assessment.

As with data on other groups of organisms, the toxicity data on bees indicate no substantial differences in the toxicity of technical grade fluazifop-butyl and fluazifop-P-butyl. U.S. EPA/OPP/EFED (2008) reports a definitive oral $LD_{50}$ for fluazifop-butyl of 180 µg/bee, and EFSA (2012) reports an indefinite $LD_{50}$ of >200 µg/bee for fluazifop-P-butyl. In the absence of additional details on both studies, this apparent difference is not remarkable. The contact $LD_{50}$

1   of >240 µg/bee for fluazifop-butyl reported by EPA/OPP/EFED (2008) is consistent with the
2   contact $LD_{50}$ of >200 µg/bee for fluazifop-P-butyl reported by EFSA (2012).
3
4   The only remarkable inconsistency in the honeybee toxicity data concerns the data from MRID
5   00162453 summarized in ECOTOX for a 13.8% formulation of fluazifop-butyl which reports a
6   contact $LD_{50}$ of 54 µg/bee with a corresponding NOAEL of >200 µg/bee. This NOAEL is given
7   only in ECOTOX. This inconsistency is noteworthy because the contact $LD_{50}$ of 54 µg a.e./bee
8   (reported as 63 µg a.i./bee in ECOTOX) is the lowest toxicity value reported for bees. The
9   reported NOAEC of >200 µg/bee, however, is over 3 times greater than the reported $LD_{50}$ [200 ÷
10   63 ≈ 3.17], which makes no sense. The current Forest Service risk assessment does not
11   explicitly include a 13.8% formulation of fluazifop-P-butyl. Given the lack of detail and
12   apparent inconsistency in the report on MRID 00162453 and the questionable relevance of
13   13.8% formulations to Forest Service uses of fluazifop-P-butyl, the data from MRID 00162453
14   are not used quantitatively in the current risk assessment. The $LD_{50}$ of 63 µg a.i./bee, however,
15   is cited and used in the EPA ecological risk assessment, U.S. EPA/OPP/EFED (2008, p. 55).
16   The EPA risk assessment, however, does not cite the NOAEL given in ECOTOX.

17                         **4.1.2.4.2. Toxicity to Other Terrestrial Arthropods**
18   Information on the toxicity of fluazifop-P-butyl on terrestrial arthropods other than the honeybee
19   is summarized in Appendix 3 (Table A3-2). This information is from the European literature.
20   Most of the studies are reported in the review of fluazifop-P-butyl by the European Food Safety
21   Authority (2012), which provides little experimental detail. This is also true for the open
22   literature publication by Hautier et al. (2005), also from the European literature. All of these
23   studies appear to be laboratory assays rather than field studies. The available field studies are
24   discussed in the following section.
25
26   Toxicity studies are available on spiders, mites, and four orders of insects, including Coleoptera,
27   Diptera, Hymenoptera, and Neuroptera, and all toxicity values are expressed as application rate
28   equivalents. The only formulation specified in these studies is Fusilade Max. As noted in
29   Section 4.1.2.4.1, Fusilade Max is a 13.7% (w/w) formulation of fluazifop-P-butyl which is not
30   being considered for use in Forest Service programs. As also in Section 4.1.2.4.1, the toxicity
31   data in honeybees indicates that Fusilade Max may be more toxic than the 24.5% a.i. Fusilade
32   formulations that are being considered by the Forest Service.
33
34   There are substantial differences in the sensitivity of different arthropods to the formulations of
35   fluazifop-P-butyl covered in the European literature. The most sensitive organism appears to be
36   a predatory mite, *Typhlodromus pyri*. EFSA (2012, p. 70) reports an $LR_{50}$ (a term that
37   functionally corresponds to the $LD_{50}$) of 5.6 g a.s./ha. The term "a.s." is an abbreviation used in
38   the OECD literature for "active substance" (e.g., http://www.oecd.org/env/ehs/pesticides-
39   biocides/1944058.pdf). In the case of fluazifop-P-butyl, this term probably designates fluazifop-
40   P-butyl itself rather than the acid equivalent. Under this assumption, the application rate of 5.6 g
41   a.s./ha corresponds to about 0.0043 lb a.e./acre [0.0056 kg a.s./ha x 0.892 lb/acre per kg/ha x
42   0.854 a.e./a.i. = 0.0042659 lb a.e./acre]. This application rate is below the maximum application
43   rate considered in the current risk assessment by a factor of over 70 [0.32 lb a.e./acre ÷ 0.0043 lb
44   a.e./acre ≈ 74.4186].
45

The high sensitivity of *Typhlodromus pyri* to fluazifop-P-butyl is noted as a concern by EFSA (2012). In the absence of additional details on this study, the following discussion from the EFSA review is given *verbatim* with bolded text added for emphasis:

> *The in-field risk to non-target arthropods (Typhlodromus pyri and Aphidius*
> *rhopalosiphi) was assessed as high at the first tier according to the guidance*
> *SETAC (2001). Extended laboratory studies on T. pyri were submitted and the*
> *magnitude of effects (60%) was slightly above the recommended trigger*
> *(i.e.50%). However, the off-field risk was assessed as low and, based on the*
> *residue decline and the time of application, the experts concluded that **recovery in***
> ***the treated field area for the most sensitive species may occur within one year***.
>
> EFSA 2012, p. 12

The nature of the *extended laboratory studies* is not clear and may refer to a 3-dose study on *Typhlodromus pyri* with Fusilade Max, which is also summarized in Appendix 3 (Table A3-2). The summary of this study in EFSA (2012) reports the results as an $LR_{50}$ of 0.174 g a.s./ha or about 0.132 lb a.e./acre [0.174 kg a.s./ha x 0.892 lb/acre per kg/ha x 0.854 a.e./a.i. = 0.1325476 lb a.e./acre]. EFSA (2012) also indicates that an 8% impact on reproduction was observed at the lowest application rate of 15 g a.i./ha. EFSA (2012), however, does not discuss the discrepancy between the reported $LR_{50}$ of 5.6 g a.i. and the much higher $LR_{50}$ of 177 g a.i./ha, presumably from the *extended laboratory studies*.

EFSA (2012) does not provide details of the bioassay on *Typhlodromus pyri*, and it is not clear if the exposure was dietary or involved direct spray. Given that this species is a predatory mite, it seems likely that the exposure involved direct spray. The next most sensitive species was a parasitic wasp, *Aphidius rhopalosiphi* [Hymenoptera: Aphidiinae] with a reported $LR_{50}$ of about 0.137 lb a.e./acre. Note that this $LR_{50}$ for *Aphidius rhopalosiphi* is virtually identical to the higher $LD_{50}$ for *Typhlodromus pyri* (i.e., 0.132 lb a.e./acre).

The toxicity data for other species included in the EFSA (2012) review and the publication by Hautier et al. (2005) generally indicate far lesser sensitivity in other arthropods. Hautier et al. (2005), however, does not provide any detailed information on dose-response relationships, indicating only that an unspecified Fusilade formulation caused less than 30% mortality at an application rate of about 0.38 lb a.e./acre.

### 4.1.2.4.3. Field Studies in Arthropods

The impact of fluazifop-butyl or fluazifop-P-butyl on terrestrial insects is addressed in several mesocosm and two field studies in the open literature (Appendix 3, Table A3-3). The term *mesocosm* is used somewhat loosely in this discussion to characterize studies in which exposures consist of insects and host plants. The studies by Blake et al. (2011a,b) would be classified as true field studies; whereas, the other studies summarized in Appendix 3, Table A3-3, would be classified as simple mesocosm studies (i.e., the insect and host vegetation). While the papers by Blake et al. (2011a,b) and Russell and Schultz (2010) are relatively detailed reports, the papers by De Freitas Bueno et al. (2008) and House et al. (1987) provide only cursory summaries of information relevant to fluazifop-P-butyl, and are not discussed further.

The most severe effect reported on insects is a 21% decrease in survival of the small cabbage white butterfly larvae following direct spray of a 24.5% Fusilade formulation both in combination with and without a soy-based nonionic surfactant (Russell and Schultz 2010). As noted in Section 1.1.3.3, this study is cited by the Fish and Wildlife Service (2012a,b) in a Federal Register notice concerning endangered and threatened butterflies. While this study is cited, however, there is no discussion of the results from the study in the notice by the Fish and Wildlife Service. The formulation of fluazifop-P-butyl used by Russell and Schultz (2010) is specified only as a 24.5% Fusilade formulation. This description is consistent with both Fusilade DX and Fusilade II, both of which are explicitly encompassed in the current risk assessment. While Russell and Schultz (2010) do not explicitly state the application rate, they state that the maximum application rate was used. This paper is a U.S. publication from Washington State and the application rate was probably 0.32 lb a.e./acre. The herbicide and the herbicide/surfactant blend were applied to mustard plants (*Brassica rapa*) onto which newly hatched larvae had been placed. Larvae were observed every 2 days through pupation, and observations on adults were made shortly after emergence. As summarized in Appendix 3 (Table A3-3), the decrease in survival cannot be attributed to the surfactant because a separate exposure to the surfactant alone resulted in an increase in survival. Other observed effects include statistically significant but modest decreases in wing surface area (-10%) and pupal weight (-6%). As discussed by Russell and Schultz (2010), these effects could be secondary to effects on the host plant (mustard plants) rather than direct toxicity to the insect. The small white cabbage butterfly is not a threatened or endangered species (http://ecos.fws.gov/tess_public/).

Russell and Schultz (2010) conducted a similar bioassay on Puget Blue butterfly (*Icaricia icarioides blackmorei*) larvae on lupine. The Puget Blue is also not a threatened or endangered species, at least currently, but two other subspecies of *Icaricia icarioides* are listed as endangered—i.e., *Icaricia icarioides fenderi* and *Icaricia icarioides missionensis*. In the Puget Blue assay, the only effects reported by Russell and Schultz (2010) are a somewhat earlier emergence of pupae and an increase in survival. The increased survival, relative to untreated controls, was observed with the surfactant alone, with the Fusilade formulation alone, and with the combination of the Fusilade formulation and the surfactant.

The field studies by Blake et al. (2011a,b) indicate that applications of Fusilade Max are beneficial to mixed populations of butterflies (0.092 lb a.e./acre) and bumble bees (0.072 lb a.e./acre from Blake et al. 2011b). Both of these studies involved long-term observations following applications of the Fusilade Max formulations. The study in butterflies was conducted over a 2-year period (Blake et al. 2011a), and the study in bumblebees was conducted over a 3-year period (Blake et al. 2011b) following the applications of Fusilade Max. In these studies, the beneficial effects are clearly secondary and attributable to the beneficial impact of fluazifop-P-butyl on the wild flower populations. As discussed in previous sections, it appears that a formulation of fluazifop-P-butyl consistent with Fusilade Max may be atypically toxic to the honeybee (Section 4.1.2.4.1) and may be toxic to some nontarget arthropods, particularly *Typhlodromus pyri* (Section 4.1.2.4.2).

It should be emphasized that the studies by Blake et al. (2011a,b) showing beneficial effects to insects do not contradict the Russell and Schultz (2010) study demonstrating adverse effects in other insects. The studies by Russell and Schultz (2010) involved observations of individual

1  organisms over a relatively short-term period following a controlled exposure.  Field studies such
2  as those published by Blake et al. (2011a,b) cannot rule out a direct toxic effect because only the
3  populations of organisms were monitored over a prolonged period following application.
4  Nonetheless, the field studies on populations do suggest that the beneficial effect on habitat (i.e.,
5  vegetation management) may outweigh or at least outlast any possible direct toxic effects for
6  species of insects that rely on wildflowers.

7          **4.1.2.4.4. Earthworms**
8  Studies on the toxicity of fluazifop-butyl to earthworms are summarized in Appendix 3 (Table
9  A3-4).  The descriptions of all of these studies are taken from EFSA (2012).  As noted
10  previously, the summaries of the studies in EFSA (2012) are cursory.  Notwithstanding this
11  limitation, the reported toxicity data for fluazifop-butyl clearly indicate that this herbicide is not
12  toxic to earthworms at high concentrations (i.e., $LC_{50} > 1,000$ mg/kg soil) and excessive
13  application rates (up to 3.8 lb a.e./acre).
14
15  The data on earthworms also include a 14-day bioassay on 5-trifluoromethyl-2-pyridone.  As
16  illustrated in Figure 1, this environmental metabolite is referred to in the literature concerning
17  fluazifop-butyl as Compound X or Metabolite X.  The reported $LC_{50}$ for this metabolite is
18  identical to that for fluazifop-butyl—i.e., >1,000 mg/kg soil.  While these indefinite $LD_{50}$ values
19  cannot be used to define relative toxicity, this report is one of the very few bioassays on a
20  fluazifop-butyl metabolite and indicates that this metabolite does not appear to be remarkably
21  more toxic than fluazifop-butyl.  As discussed further in Section 4.1.3, Metabolite X is less toxic
22  than fluazifop-butyl to fish, aquatic invertebrates, and algae.

23      *4.1.2.5. Terrestrial Plants (Macrophytes)*

24          **4.1.2.5.1. Mechanism of Action**
25  As indicated in Section 2.2, the mechanism of action involved in the phytotoxicity of fluazifop-
26  P-butyl and other aryloxyphenoxy propionate herbicides is the inhibition of acetyl coenzyme-A
27  carboxylase (ACCase).  Based on this mechanism, fluazifop-P-butyl is categorized as a Group 1
28  herbicide under the system used by the Weed Science Society of America and a Class A
29  herbicide under the system used by the Herbicide Resistance Action Committee.  Other similarly
30  classified aryloxyphenoxy propionate herbicides include clodinafop, cyhalofop-butyl, diclofop,
31  fenoxaprop, haloxyfop, propaquizafop, and quizalofop-P.  Cyclohexanedione herbicides (e.g.,
32  clethodim, alloxydim, butroxydim, cycloxydim, sethoxydim, and tralkoxydim) also act through
33  the inhibition of ACCase (Mallory-Smith and Retzinger 2003).  ACCase is a key enzyme in fatty
34  acid metabolism and catalyzes the carboxylation of acetyl-CoA to produce malonyl-CoA (Abell
35  1996; Burton et al. 1989; Dotray et al. 1993; Focke and Lichtenthaler 1987; Kobek and
36  Lichtenthaler 1990; Lichtenthaler et al. 1991; Maier et al. 1994; Rendina et al. 1990; Tong
37  2005).  Fluazifop-P-butyl inhibits the production of chlorophyll in grass leaves, leading to
38  chlorosis, and also inhibits the growth of grass roots (Derr et al. 1985a; Kabanyoro 2001).
39
40  Fluazifop-P-butyl is rapidly absorbed by plant leaves and then rapidly hydrolyzed to fluazifop
41  acid, which is the phytotoxic agent (Balinova and Lalova 1992; Carr 1986a; Derr et al. 1985b).
42  Fluazifop sensitivity differences among monocots are related to differences in the rate of
43  absorption (Derr et al. 1985a).  While fluazifop acid is highly mobile in phloem, fluazifop-butyl
44  is not (Brudenell et al. 1995; Hicks and Jordan 1984).  The transport of fluazifop acid from

leaves to roots appears to be variable. Rapid translocation to roots was observed in soybeans (Balinova and Lalova 1992) and quackgrass (Chandrasena and Sagar 1986b); however, other studies report relatively little transport from leaves to roots (Carr et al. 1986a; Derr et al. 1985a).

The phytotoxicity of fluazifop is limited to the [R] enantiomer, fluazifop-P (e.g., Gronwald 1991; Harwood 1988; Walker et al. 1988a,b). The specificity of the phytotoxicity to the [R] enantiomer was noted in several other herbicides, including diclofop, haloxyfop, and quizalofop (Gronwald 1991). As discussed further in Section 4.1.2.5.2, true grasses (i.e., monocots of the Poaceae/Gramineae family) are much more sensitive than dicots and non-Poaceae monocots to fluazifop-P (Walker et al. 1988a,b). As discussed by Herbert et al. (1997), the basis for the sensitivity of Poaceae monocots and the tolerance of dicots is attributable to differences in the structure of acetyl coenzyme-A carboxylase (ACCase) between grasses (i.e., a multifunctional protein) and dicots (i.e., a multi-enzyme complex). The tolerance of non-Poaceae monocots to fluazifop-P is not specifically discussed in the literature but is presumably due to differences in the structure of ACCases between these groups of plants. *In vitro* assays note substantial inhibition of ACCase in Poaceae monocots at fluazifop-P concentrations in the range of 1 to 5 $\mu$M [i.e., $\approx$0.327 to 1.635 mg a.e./L] (Burton et al. 1989; Gronwald 1991). In the common pea (*Pisum sativum*, a dicot), however, fluazifop-P-butyl had no impact on ACCase activity at concentrations of up to 100 $\mu$M (i.e., $\approx$33 mg/L).

Fluazifop-P-butyl is much more toxic to grasses than other groups of plants, and its mechanism of action in grasses is well understood. Nonetheless, fluazifop-P-butyl can impact some dicots, albeit at high levels of exposure. The specific mechanism of action of fluazifop-P-butyl in some dicots has not been well characterized. Using a dilute (1:250) solution of fluazifop-P-butyl, Chronopoulou et al. (2012) note an induction of glutathione transferases in the leaves of the common bean (*Phaseolus vulgaris*, a dicot) and suggest that this induction may be a general stress response. Luo et al. (2004) report that a 5 $\mu$M solution of fluazifop-P-butyl causes signs of oxidative stress in seedlings of the bristly starbur (*Acanthospermum hispidum*), another dicot.

### 4.1.2.5.2. Phytotoxicity
#### *4.1.2.5.2.1. Overview of Information*
In general, the registration requirements for herbicides involving assays on terrestrial plants are relatively rigorous, since terrestrial vegetation is the target for terrestrial herbicides. The testing requirements typically include bioassays for vegetative vigor (i.e., post-emergence applications), bioassays for seedling emergence (i.e., pre-emergence applications), and bioassays for seed germination. These assays usually include four species of monocots from at least two families and six species of dicots from at least four families.

Apparently, the EPA, somewhat atypically, did not require the standard phytotoxicity assays for the registration of fluazifop-P-butyl. The two most recent ecological risk assessments from the EPA both note that: *No toxicity data have been submitted regarding the toxicity of fluazifop-p-butyl to plants* (U.S. EPA/OPP/EFED 2008, p. 35; U.S. EPA/OPP/EFED 2010a, p. 4). The most detailed ecological risk assessment from the EPA does indicate that these assays are viewed as data requirements for fluazifop-P-butyl (U.S. EPA/OPP/EFED 2008, p. 9). As noted in Section 1.1.2, fluazifop-P-butyl will be undergoing registration review (U.S. EPA/OPP 2013a), and it is possible that these standard bioassays will be required to support the registration review.

While documentation for what appears to be the waiver by the EPA of standard plant bioassays has not been encountered, the ecological risk assessments from the EPA suggest that the tests may have been waived based on the presumption of toxicity to monocots and lack of toxicity to dicots:

> *Although there are no acceptable data to assess the possible risks of fluazifop-p-butyl to dicot species, risks are presumed to be minimal due to the fact that fluazifop-p-butyl is an herbicide with a mode of action specific to monocot plants and is routinely applied to a variety of dicot plant crops at similar application rates and there are no reported incidents of damage to dicot plant species in the EIIS* [EFED's Ecological Incident Information System] *database for registered uses.*
>
> U.S. EPA/OPP/EFED 2008, p. 19

Although standard registrant-submitted studies are not available, there is a reasonably robust open literature on the toxicity of fluazifop-P-butyl to terrestrial plants, as summarized in several tables of Appendix 4:

Table A4-1: Monocots Greenhouse Toxicity Studies, Pre-Emergence
Table A4-2: Dicots Greenhouse Toxicity Studies – Pre-Emergence
Table A4-3: Monocots Greenhouse Toxicity Studies, Post-Emergence
Table A4-4: Dicots Greenhouse Toxicity Studies – Post-Emergence
Table A4-5: Ferns Greenhouse Toxicity Studies, Post-Emergence 8
Table A4-6: Field Studies with Fluazifop

An overview of this literature is given in Table 26. While efficacy or field studies are typically considered apart from laboratory or greenhouse studies, the two types of studies are reasonably consistent and reinforcing and are considered together in the current discussion. Most studies from the open literature on the phytotoxicity of fluazifop-P-butyl express exposures in units of kg a.i./ha rather than lb a.e./acre. To facilitate a review of the current risk assessment, units of kg a.i./ha are maintained in the following discussion. In the dose-response assessment (Section 4.3.2.5), units are converted to lb a.e./acre to maintain consistency with the exposure assessment.

#### 4.1.2.5.2.2. Toxicity to Monocots

One substantial elaboration on the hazard identification from the U.S. EPA/OPP involves the distinction between true grasses (i.e., monocots in the family Poaceae, also termed Gramineae) and monocots from other families. Numerous greenhouse and field studies clearly indicate that fluazifop-P-butyl is toxic to most species of Poaceae at application rates as low as about 0.01 kg a.i./ha, based on greenhouse studies, and only modestly higher application rates of about 0.035 kg a.i./ha, based on field studies. Monocots from other families, however, are much less sensitive to fluazifop-P-butyl.

#### 4.1.2.5.2.2.1. True Grasses (Poaceae/Gramineae)

Differences in sensitivities to fluazifop-P-butyl among the true grasses are apparent, although most studies indicate that the differences are not pronounced. Two studies suggest that red fescue may be somewhat less sensitive than other true grasses to fluazifop-P-butyl, evidencing

1  relatively minor damage compared with other true grasses following application rates of up to
2  0.18 kg a.i./ha (Blake et al. 2012; Cisar and Jagschitz 1984a).  In addition to the studies
3  summarized in Table 26, Haga et al. (1987, Table 2, p. 314) noted only moderate damage in two
4  species of Poaceae—i.e., *Imperata cylindrica* (3/10) and *Miscanthus sinensis* (4/10) at an
5  application rate of 0.25 kg a.i./ha).  In this publication, visual damage was ranked on a scale from
6  0 (no damage) to 10 (complete kill).  While damage to these Poaceae species was only moderate
7  at an application rate of 0.25 kg a.i./ha, both species of Poaceae were severely damaged at an
8  application rate of 1 kg a.i./ha.
9
10  The most remarkable tolerance in a true grass, however, is reported in the field study by Calkins
11  et al. (1996) indicating that blue fescue (*Festuca ovina* var. *glauca*) evidenced relatively little
12  damage following applications of fluazifop-P-butyl at 1.12 kg a.i./ha.    The study by Calkins et
13  al. (1996) is a survey involving the application of several herbicides to several species of
14  nontarget plants for weed control.  The results reported in Calkins et al. (1996) are not detailed
15  and are expressed as signs of visual injury rated on a score from 0 (dead plants) to 5 (excellent
16  condition).  The field study appears to have been long-term with treatments repeated for 2
17  additional years following the initial application.  When fluazifop-P-butyl was applied at a rate
18  of 1.12 kg a.i./ha, the response of blue fescue was rated as 3.5 in the treated group relative to
19  scores of 3.9 in both non-weeded and manually weeded control groups.  In this study, blue
20  fescue was injured by other herbicides including Goal (a formulation of oxyflurfen) and Rout (a
21  formulation containing oxyflurfen and oryzalin).  Studies to corroborate the tolerance level of
22  fescue to fluazifop-P-butyl reported by Calkins et al. (1996) were not identified in the open
23  literature.
24
25          *4.1.2.5.2.2.2. Other Monocots*
26  Other non-Poaceae monocots are much less sensitive than the true grasses to fluazifop-P-butyl,
27  and the distinction between *sensitive* and *tolerant* non-Poaceae monocots is based largely on the
28  severity of the observed responses rather than responses at different application rates.
29
30  In addition to the assays on the Poaceae discussed in the previous section, Haga et al. (1987)
31  assayed two species of Cyperaceae (sedges) and one species each of Commelinaceae
32  (spiderworts), Liliaceae (lilies), and Araceae (taro).  At application rates of 0.25 and 1 kg a.i./ha,
33  minimal damage (1/10) was noted.  In addition, Rokich et al. (2009) noted no damage in two
34  species of Anthericacae (3- to 4-month-old *Sowerbaea laxiflora* and *Thysanotus manglesianus*)
35  at application rates of up to 3.4 kg a.i./ha.  These observations are consistent with the field study
36  by Calkins et al. (1996) which noted no adverse effects on lilies from the families
37  Xanthorrhoeaceae and Asparagaceae at an application rate of up to 1.12 kg a.i./ha.  While not
38  summarized in Table 26, the tolerance of Xanthorrhoeaceae is also supported in the field study
39  by Skroch et al. (1990) in which no adverse effects were observed in two species of
40  Xanthorrhoeaceae from this family at lower applications rates of ≈0.2 kg a.i./ha.
41
42  At high application rates, fluazifop-P-butyl has caused adverse responses in some non-Poaceae
43  monocots.  In the study by Rokich et al. (2009), severe visual damage as well as a reduction in
44  plant height (≈34%) was observed in 4- to 5-month-old *Sowerbaea laxiflora* (Anthericacae)
45  following an application of 1.69 kg a.i./ha fluazifop-P-butyl.  As noted above, adverse effects
46  were not observed in 3- to 4-month-old plants of this species at applications up to 3.4 kg a.i./ha.

In addition, 4- to 5-month-old Haemodoraceae (*Anigozanthos manglesii*) evidenced a modest but statistically significant reduction in height (≈20%) following foliar as well as separate soil applications of fluazifop-P-butyl at 1.69 kg a.i./ha. Somewhat surprisingly, 4- to 5-month-old *Thysanotus manglesianus* [Anthericacae] evidenced leaf burn with some leaf drop (but no effect on plant height) following soil but not foliar applications of fluazifop-P-butyl at 1.69 kg a.i./ha. Damage to some non-Poaceae was observed in the field study by Calkins et al. (1996)—see the discussion of this study in the previous section. Most notably, a miniature dwarf bearded iris [Iridaceae] evidenced relatively severe damage (i.e., score of 1.7 vs 3.5 in weeded control) following an application of fluazifop-P-butyl at 1.12 kg a.i./ha. In addition, a daylily [Xanthorrhoeaceae] also evidenced damage at the same application rate (i.e., score of 2.6 vs 3.3 in weeded control). These responses in Iridaceae and Xanthorrhoeaceae appear to have been more severe than the response in *Festuca ovina*, a Poaceae (i.e., a score of 3.5 vs 3.9 in weed control) at the same application rate. As discussed in Section 4.1.2.5.2.2.1, the response in *Festuca ovina* is one of the few examples of an apparently tolerant Poaceae.

While the above paragraph discusses examples of non-Poaceae that appear to be atypically sensitive to fluazifop-P-butyl, all of the adverse responses occurred following application rates of at least 1.12 kg a.i./ha, equivalent to about 0.85 lb a.e./acre. This application rate is more than twice the maximum registered single application rate [0.85 lb a.e./acre ÷ 0.32 lb a.e./acre ≈ 2.656] and close to the maximum seasonal application rate [0.85 lb a.e./acre ÷ 0.96 lb a.e./acre ≈ 0.8854] for fluazifop-P-butyl.

### 4.1.2.5.2.3. Toxicity to Dicots and Other Plants

As with the discussion of non-Poaceae monocots, the discussion of sensitive and tolerant dicots focuses on different severities of responses, most of which occur at high applications relative to the application rates generally effective in the control of Poaceae monocots—i.e., at or below about 0.2 kg a.e./acre. As detailed in Appendix 4 (Table A4-4) and summarized in Table 26, most greenhouse studies on dicots note no adverse effects at application rates of 0.75 to up to 6 kg a.i./ha. These studies are supported by many field studies in which application rates of about 0.1 to 1.6 kg a.i./ha had no adverse effect on dicots (Appendix 4, Table A4-6).

Based on the available toxicity studies, the red clover (*Trifolium pratense*) appears to be the most sensitive species of dicot. In the study by Blake et al. (2012), red clover evidenced visible damage (chlorosis) which was dose-related following applications of 0.09375, 0.1875, and 0.75 kg/ha. Over the 21-day observation period, however, the damage was transient and declined from Days 7 to 21 (Days 3 to 21 at the highest rate). By Day 21, damage was apparent but statistically significant only at the highest application rate. In addition to leaf damage, the biomass of red clover was significantly reduced (Blake et al. 2012, Figure 1 and Table 2). This is the only report of an adverse effect on a dicot in the range of application rates considered in the current risk assessment.

In a study of the responses of Australian plants to fluazifop-P-butyl, Rokich et al. (2009) report damage in two species of dicots—i.e., *Acacia lasiocarpa* (a lower-story shrub) and *Eucalyptus gomphocephala* (Australian Tuart tree). Soil applications of 1.69 kg a.i./ha to 4- to 5-month-old shrubs were associated with visible leaf damage. This effect, however, was not seen in 4- to 5-month-old shrubs following similar foliar exposures. In addition, 3- to 4-month-old shrubs

evidenced no adverse effects following foliar applications of fluazifop-P-butyl at rates up to 3.4 kg a.i./ha. Thus, in the shrub, somewhat older plants appeared to be more sensitive than younger plants. The reverse pattern, however, is evident with *Eucalyptus gomphocephala*. A dose-related decrease in plant height (a maximum of about 35%) and modest leaf damage was observed in 3- to 4-month-old trees following foliar applications of 0.42, 0.84, 1.69, or 3.4 kg a.i./ha fluazifop-P-butyl. In 4- to 5-month-old trees, however, no damage was apparent following either foliar or soil applications of fluazifop-P-butyl at 1.69 kg a.i./ha.

The only other report of damage to a dicot involves a brief note by Talbert et al. (1995) indicating that applications of fluazifop-P (not otherwise specified) at rates of 0.84 and 1.68 kg/ha were associated with transient leaf curl in "*Gaillardia red plumme*" following field applications for the control of grassy weeds. The crop species presumably refers to *Gaillardia pulchella*. Because fluazifop-P had been registered in the United States as an herbicide, it seems likely that this report involves fluazifop-P rather than fluazifop-P-butyl.

### *4.1.2.5.2.4. Pre-Emergent vs Post-Emergent Exposures*

As discussed in Section 2, fluazifop-P-butyl is registered as a post-emergent herbicide and is not registered for pre-emergent applications. Nonetheless, some studies examine the impact of pre-emergent applications in both monocots (Appendix 4, Table A4-1) and dicots (Appendix 4, Table A4-2), although these studies are few compared with the numerous studies on post-emergent applications. The most relevant studies are summarized in the lower section of Table 26. All of the studies are greenhouse experiments, and no pre-emergent field trials of fluazifop-P-butyl were identified in the published literature.

For the most part, the studies on pre-emergent applications parallel those on post-emergent applications. As noted by Derr et al. (1985c), fluazifop-butyl offers effective control of several Poaceae monocots (i.e., goosegrass, crabgrass, and giant foxtail) at application rates comparable to the effective rates in post-emergent applications (i.e., 0.035 kg a.i./ha). As detailed further in (Appendix 4, Table A4-1), however, some species such as corn are adversely damaged by fluazifop-butyl applications but at rates much higher (i.e., 0.1 to 0.3 kg a.i./ha) than those that are effective in post-emergent applications. Except for the study by Rokich et al. (2009), no information is available on pre-emergent applications in non-Poaceae monocots, and this study notes only that Haemodoraceae is not sensitive to pre-emergent applications at 0.84 kg a.i./ha.

Some studies indicate that dicots may be affected by pre-emergent applications of fluazifop-butyl or fluazifop-P-butyl at rates comparable to those causing effects in some dicots in post-emergent applications. The most sensitive dicot appears to be cucumber, in which a 34% reduction in stem length was noted following pre-emergent applications of fluazifop-butyl at 0.56 kg a.i./ha (Boucounis et al. 1988). As discussed in Section 4.1.2.5.2.3, red clover appears to be a dicot that is relatively sensitive to fluazifop-P-butyl (rates of 0.1 to 0.75 kg a.i./ha) based on the study by Blake et al. (2012). The same investigators noted that pre-emergent applications of fluazifop-P-butyl at 0.75 kg a.i./ha caused only mild signs of toxicity in red clover (i.e., <5% visual damage).

Rokich et al. (2009) is the only other study noting signs of toxicity in a dicot following pre-emergent applications. Rokich et al. (2009) assayed two formulations of fluazifop-P-butyl (Fusilade (NOS) and Fusilade Forte) at comparable application rates. At a pre-emergent

application rate of 0.84 kg a.i./ha Fusilade Forte to *Eucalyptus gomphocephala*, no emergence
occurred with seeds planted at a depth of 20 mm.  With the other Fusilade formulation, however,
emergence from seeds planted at 20 mm was greater, relative to control seeds.  It should be noted
that the paper by Rokich et al. (2009) is from the Australian literature and it is not clear that the
formulations used by these investigators are registered or used in the United States.  The only
information provided by Rokich et al. (2009) on Fusilade Forte is that this formulation "…
*possesses unique inbuilt 'isolink' surfactant technology to ensure maximum leaf surface
coverage, in addition to special penetrants to aid rapid movement of the active ingredient*".  It is
not clear, however, that the surfactant would account for the differences in pre-emergent
applications; hence, the effects on emergence noted in this study may have been incidental.

### 4.1.2.5.3. Resistance
Resistance is a common concern with many herbicides, including fluazifop-P-butyl.  As with
differences in sensitivity among different groups of plants (Section 4.1.2.5.1), the mechanism of
resistance in plants involves differences in acetyl coenzyme-A carboxylases (ACCases)
(Catanzaro et al. 1993a; Cocker et al. 2001; Herbert et al. 1997; Moss et al. 2003) as well as
differences in the rate of metabolism of fluazifop-P-butyl (Alarcón-Reverte and Moss 2008;
Cocker et al. 2001).  Moss et al. (2003) note that the resistant allele for insensitive ACCase in a
species of foxtail (*Alopecurus myosuroides*) shows complete dominance.

As is typically the case, the ratios of equally effective doses in sensitive and resistant strains are
highly variable, ranging from about 5.7 for strains of Johnsongrass based on shoot dry mass
(Burke et al. 2006a) to about 970 for strains of Italian rye-grass (*Lolium multiflorum*) based on
reductions in foliage fresh weight (Cocker et al. 2001, Table 1, p. 590).  The study by Cocker et
al. (2001) is particularly interesting in that these investigators also assayed ACCase activity in
the sensitive and resistant strains (Cocker et al. 2001, Table 5, p. 593) and noted differences in
sensitivity up to only a factor of about 8.8.  As discussed by Cocker et al. (2001), these
differences argue for the importance of factors other than tolerant ACCase in the development of
resistance, at least in this species.  Intermediate resistance factors are  reported for several other
species of grass (Burke et al. 2006b; Catanzaro et al. 1993a; Moss et al. 2003; Smeda et al.
1997).

The development of cross-resistance is also common with herbicides, and there are reports of the
cross-resistance of grasses to fluazifop-P-butyl and other aryloxyphenoxy propionate and
cyclohexanedione herbicides (Bradley and Hagood 2001; Michitte et al. 2003).

### 4.1.2.6. Terrestrial Microorganisms
Studies on terrestrial microorganisms are not required for pesticide registration in the United
States, and the EPA ecological risk assessments on fluazifop-P-butyl (U.S. EPA/OPP/EFED
2008, 2010a) do not address effects on terrestrial microorganisms. Microorganisms possess
ACCase, and various ACCase inhibitors are proposed or are used as microbicides (e.g. Kurth et
al. 2009; More et al. 2012).  As with mammalian ACCases, the ACCases in bacteria are
structurally different from ACCases in plants (e.g., Tong 2005).

Little information is available on the effect of fluazifop-P-butyl on soil microorganisms.  Abdel-
Mallek et al. (1996) conducted a laboratory soil assay in which soil fungal populations were
monitored over an 8-week period in clay soil containing fluazifop-butyl at concentrations of 0.6,

3, or 6 mg/kg soil (dry weight).  No effects were noted at the lowest concentration.  At 3 mg/kg soil, fungi populations were reduced by about 50% over the first 2 weeks of the study.  At 6 mg/kg soil, fungi populations were also reduced by about 50%, and the decrease was apparent in observations at 1, 2, and 8 weeks but not at 6 weeks (Abdel-Mallek et al. 1996, Table 1, p. 153). Abdel-Mallek et al. (1996) also assayed responses of five species (pure cultures) of soil fungi— i.e., *Aspergillus flavus*, *Aspergillus niger*, *Alternaria alternate*, *Cunninghamella echinulata*, and *Trichoderma harzianum*—in liquid media at fluazifop-butyl concentrations of 2, 12, or 24 mg/L. Growth inhibition (assayed as dry weight of fungi) was noted only at the 24 mg/L concentration and only for two species—i.e., *Aspergillus flavus* and *Alternaria alternate*.

The observations by Abdel-Mallek et al. (1996) are consistent with the earlier study by Gardner and Storey (1985) which noted the incomplete inhibition of germination and growth in *Beauveria bassiana* (an entomogenous soil fungus) at fluazifop-butyl (as an early Fusilade 4E formulation) concentrations of 6 mg/L and higher.

As discussed in Section 4.2.5 (exposure assessment for terrestrial microorganisms), the maximum concentration of fluazifop-P in soil following three applications of fluazifop-P-butyl at the maximum application rate of 0.32 lb a.e./acre is about 0.25 mg/kg soil (dry weight) [0.77 ppm/(lb/acre) x 0.32 lb a.e./acre = 0.2464].  While the studies by Abdel-Mallek et al. (1996) and Gardner and Storey (1985) are relevant to the hazard identification, the study by Abdel-Mallek et al. (1996) is clearly the most relevant for assessing potential risks to soil microorganisms and is discussed further in Section 4.3.2.6 (dose-response assessment for terrestrial microorganisms).

Other published information on the toxicity of fluazifop-P-butyl to soil microorganisms is less detailed and of marginal relevance.  An English abstract of a paper from the Russian literature (Sapundzhieva and Kuzmanova 1987) notes inhibition of soil fungi following application of a 20% Fusilade formulation (NOS).  The precise application rate, however, is not apparent.  The review by the European Food Safety Authority (EFSA 2012) reports variable effects on soil microorganisms based on nitrogen mineralization (-21.6% to 13.1%) and carbon mineralization (-7.7% to 14.4%) following an application of Fusilade Max at an application rate of 3.75 kg a.i./ha.  Very few details are provided in EFSA (2013), and the relevance of these reported effects to the current risk assessment is marginal, given that the application rate noted in EFSA (≈2.86 lb a.e./acre) is substantially higher than the maximum application considered in the current risk assessment (i.e., 0.32 lb a.e./acre).

## 4.1.3. Aquatic Organisms

### 4.1.3.1. Fish

The U.S. EPA/OPP typically requires acute toxicity data in both freshwater and saltwater fish as well as longer-term toxicity studies.  For many pesticides, the EPA requires at least some toxicity studies on formulations as well as the active ingredient.  While full lifespan studies with fish are conducted on some pesticides, they are unusual.  Typically, the longer-term toxicity studies consist of early life stage (i.e., egg-to-fry) studies.

The available toxicity data on fish are summarized in Appendix 5 in the following tables:

Table A5-1: Acute Toxicity to Freshwater Fish

3
4    An overview of these studies is presented in Table 27, which provides a summary of $LC_{50}$ values
5    and NOAECs (when available) for acute toxicity studies and NOAEC and LOAEC values for the
6    longer-term studies.
7
8    Most of the available toxicity studies on fluazifop-butyl are studies submitted to the U.S EPA
9    and are summarized U.S. EPA/OPP/EFED (2008).  As noted in Appendix 5, DERs were
10   available on the acute toxicity studies with fluazifop-butyl in fathead minnows (MRID
11   00093808, Wilson et al. 1981) and bluegills (MRID 00087485, Hill et al. 1981) as well as an
12   acute toxicity study with the Fusilade 4E formulation with sheepshead minnow (MRID
13   00152173, Hill 1985).  A DER was also available on an early life stage study in fathead
14   minnows (MRID 00093808, Wilson et al. 1981).
15
16   Some additional unpublished studies are summarized in FAO/WHO (2000) and EFSA (2012).
17   Information from the open primary literature is limited to an $LD_{50}$ in tilapia from Tejada et al.
18   (1994) and field observations in trout (Schramm et al. 1998).  The study by Tejada et al. (1994)
19   is discussed below.  The paper by Schramm et al. (1998) reports changes in liver function and
20   morphology in brown trout from streams with detectable levels of fluazifop as well as many
21   other contaminants.  This paper cannot be used to assess the impact of fluazifop-P-butyl on trout
22   and is not considered further in this risk assessment.
23
24   The acute toxicity data on fluazifop-butyl are reasonably consistent with all but one of the $LC_{50}$
25   values ranging from 0.25 mg a.e./L (*Nile tilapia*) to 1.2 mg a.e./L (rainbow trout).  One notable
26   exception, however, is the $LC_{50}$ of 99.9 mg a.e./L or 117 mg a.i./L (MRID 00087483) for
27   rainbow trout from U.S. EPA/OPP/EFED (2008, p. 179).  The EPA indicates that this $LC_{50}$ was
28   conducted on fluazifop-butyl.  EFSA (2012) indicates an $LC_{50}$ in trout of 117 mg a.e./L based on
29   an assay using fluazifop acid.  Syngenta was queried on this discrepancy and has confirmed that
30   the entry in EFSA (2012) is correct.  The rainbow trout bioassay in MRID 00087483 was
31   conducted on fluazifop acid.
32
33   The review by EFSA (2011) also provides the only information on the toxicity of a metabolite of
34   fluazifop-P-butyl, 5-trifluoromethyl-2-pyridone, which is referenced in the literature on fluazifop
35   as Compound X or Metabolite X.  Based on the bioassay of Compound X in rainbow trout,
36   Compound X is less toxic than fluazifop-butyl by a factor of 200 [240 mg/L ÷ 1.2 mg a.e./L].  As
37   with earthworms (Section 4.1.2.4.4.) and as discussed further below, Compound X is also much
38   less toxic than fluazifop-butyl to both aquatic invertebrates (Section 4.1.3.3) and algae (Section
39   4.1.3.4.1).
40
41   Data are available on the toxicity of fluazifop-P-butyl formulations.  Two of the studies are for
42   unspecified 25.8% a.i. formulations (MRID 00087486; MRID 00087484) and are summarized in
43   U.S. EPA/OPP/EFED (2008).  As indicated in Table 6, the percent 25.8% a.i. in these
44   formulations is similar to the nominal 24.5% a.i. in Fusilade DX and Fusilade II.  An $LC_{50}$ for
45   Fusilade Max (12.5% a.i.) is also reported in EFSA (2012).  The toxicity data in rainbow trout
46   indicate that Fusilade Max is more toxic than the 25.8% a.i. formulation(s) by about a factor of  3

1    [4.2 mg/L ÷ 1.37 mg/L ≈ 3.066].  Nonetheless, all of the toxicity data on the fluazifop-P-butyl
2    formulations indicate that the formulations are less toxic than fluazifop-butyl when the units of
3    dosing are expressed in units of mg a.e./L.  Hence, the inerts in these formulations do not seem to
4    contribute to the toxicity of the formulations to fish.  As discussed further in Section 4.1.3.3, the
5    opposite pattern is seen with aquatic invertebrates—i.e., the formulations of fluazifop-butyl are
6    much more toxic than technical grade fluazifop-butyl to aquatic invertebrates.
7
8    As noted above, a DER is available on the study with Fusilade 4E in sheepshead minnow (MRID
9    00152173, Hill 1985).  In the EPA ecological risk assessment on fluazifop-P-butyl (U.S.
10   EPA/OPP/EFED  2008), the $LC_{50}$ reported for this study is 6.85 mg a.e./L.  This $LC_{50}$ appears to
11   be based on the $LC_{50}$ of 8.1 mg/L reported in the DER under the assumption that the units used
12   in the DER are mg a.i./L [8.1 mg/L x 0.854 a.e./a.i. ≈ 6.91 mg a.e./L].  The DER, however,
13   appears to express units in terms of the formulation (46.83% a.i.).  Correcting for the percent a.i.
14   in the formulation, the $EC_{50}$ value in acid equivalents should be about 3.2 mg a.e./L [8.1 mg
15   formulation/L x 0.4683 a.i./formulation x 0.854 a.e./a.i. ≈ 3.2394 mg a.e./L].
16
17   While not discussed in U.S. EPA/OPP/EFED (2008), the study by Hill (1985, (MRID 00152173)
18   also assayed a formulation blank—i.e., the formulation without the a.i.  As detailed in Appendix
19   5 (Table A5-2), the $LC_{50}$ for the formulation blank is reported as 10.4 mg formulation/L, which
20   is only modestly higher than the $LC_{50}$ reported for the full formulation with the a.i.—i.e., 8.1 mg
21   formulation/L.  Based on this relationship, the discussion in the DER notes:
22
23          *Comparison of the results for Fusilade 4E and the Fusilade blank indicated*
24          *the solvent used in the formulation was a major contributing factor to the*
25          *toxicity determined in the study.*
26                                                              Hill 1985, DER, p. 5.
27
28   As noted above and discussed further in Section 4.1.3.3, this assessment is consistent with the
29   formulation toxicity data in aquatic invertebrates.  In the absence of DERs on the other
30   formulation studies in fish, the reporting of units in U.S. EPA/OPP/EFED (2008) for the other
31   registrant-submitted formulation studies cannot be verified.
32
33   Several of the studies summarized in U.S. EPA/OPP/EFED (2008) report both $LC_{50}$ values and
34   NOECs, and some of the studies report slopes of the dose-response curves.  While it is not clear
35   if the slopes are based on common or natural logarithms of the concentrations, it is apparent that
36   the slopes are steep and that most of the NOAECs are only modestly below the $LC_{50}$ values, by
37   factors of less than 4.  The only exception is a formulation bioassay in rainbow trout (MRID
38   00087484) in which the NOAEC is a factor of about 12 below the $LC_{50}$ [4.2 ÷ 0.34 ≈ 12.353].
39
40   Based on the $LC_{50}$ values for fathead minnows (Table 27), the EPA classifies fluazifop-P-butyl
41   as *Very Highly Toxic* to fish (U.S. EPA/OPP/EFED 2008, p. 43).
42
43   While no full lifespan toxicity studies are available in fish, early life stage studies are available
44   on fluazifop-butyl (MRID 00093808), fluazifop-P-butyl (EFSA 2012; FAO/WHO 2000), and
45   fluazifop acid (EFSA 2012).  These studies report NOAECs of >0.203 mg a.e./L (fluazifop-
46   butyl),  0.07 mg a.e./L (fluazifop-P-butyl), and 1.46 mg a.e./L for fluazifop acid.  Note that the

greater than (>) symbol is explicitly used by the U.S. EPA to indicate that adverse effects were not observed at the highest concentration tested.  Based on the DER for MRID 00093808 (Wilson et al. 1981), it is clear that no adverse effects on any reproductive parameters were noted.  At the highest concentration assayed (0.238 mg a.i./L or 0.203 a.e./L), mean body weights were depressed with respect to untreated controls but not with respect to solvent controls (details in Appendix 5, Table A5-3).  A handwritten note on the DER indicates that individual animal data were submitted by the registrant and that these data supported a classification of 0.203 mg a.e./L as a NOAEC.  The individual animal data, however, are not given in the DER.

In addition to the standard toxicity studies in fish, U.S. EPA/OPP/EFED (2008, p. 75), reports one incident in the Ecological Incident Information System maintained by EFED of a fish kill associated with fluazifop-P-butyl, as fully summarized below:

> *1998 A fish kill occurred in a small pond in Phillipstown, IL, killing about 200 catfish, largemouth bass, crappie, and red ear sunfish. The kill happened following application with a tank mix of Fusion (fluazifop-p-butyl and fenoxaprop-p-ethyl) and Flexstar (Fomesafen Sodium) to nearby soybeans. The treated area was separated from the pond by a minimum of 100 feet with thick hedgerow and mature trees in between. The pond was 1110 acre and about 10 feet deep. On the evening following the application there was a 0.9" rainfall. Winds were reported to be between 10 and 20 mph. There was no evidence of damage to plants around the pond. This suggests that there were not significant amounts of drift of the herbicides into the pond, but the pond could have been contaminated by runoff from the fields after the rainfall. Fomesafen sodium is not likely the: cause of the fish mortality since it is practically nontoxic to fish. Fenoxaprop-p-ethyl could have contributed to the cause because it is highly toxic to fish.*

### 4.1.3.2. Amphibians

As with terrestrial phase amphibians, there are no data to characterize the toxicity of fluazifop-butyl or fluazifop-P-butyl to aquatic phase amphibians.  The EPA risk assessments on fluazifop-P-butyl do not cite any registrant-submitted studies on aquatic-phase amphibians (U.S. EPA/OPP/EFED 2008, 2010a), which is not unusual, since toxicity data on aquatic-phase amphibians are not required for most pesticide registrations.  The general lack of toxicity data on aquatic-phase amphibians extends to the open literature and the database maintained by Pauli et al. (2000).

As noted in the EPA problem formulation for fluazifop-P-butyl (U.S. EPA/OPP/EFED 2008, p. 32), toxicity data on fish are used as a surrogate for aquatic-phase amphibians.  This is a standard practice in EPA ecological risk assessments.

### 4.1.3.3. Aquatic Invertebrates

The available toxicity data on aquatic invertebrates are summarized in Appendix 6 in the following tables:

Table A6-1: Acute Toxicity to Freshwater Invertebrates
Table A5-2: Acute Toxicity to Saltwater Invertebrates

1    Table A5-3: Chronic Toxicity to Aquatic Invertebrates

2    **4.1.3.3.1. Acute Studies**
3    An overview of acute toxicity studies is presented in Table 28, which provides a summary of
4    $LC_{50}$ values and NOAECs (when available).  An overview of the chronic toxicity studies is
5    presented in Table 29, which provides a summary of NOAEC and LOAEC values (when
6    available).
7
8    Two studies from the open literature summarized in Appendix 6 (Table A6-1) are not included in
9    Table 28 —i.e., Nishiuchi and Asano (1979) and Tantawy (2002).  The study by Nishiuchi and
10   Asano (1979) reports an $LC_{50}$ of >40 ppm for a Fusilade formulation in a species of mayfly
11   (*Cloeon dipterum*) nymphs.  This study is from the Japanese literature and is published in
12   Japanese.  A translated copy of this publication was obtained for the current risk assessment.  As
13   noted in Section 1.1.2., the U.S. EPA/OPP rejected this study in several risk assessmenOts on the
14   California Red-legged Frog (e.g., U.S. EPA/OPP 2009b) because control groups were not used in
15   the study.  While the reported indefinite $LC_{50}$ is consistent with definitive $LC_{50}$ values reported in
16   *Daphnia magna* (Table 28), any indefinite $LC_{50}$ is only minimally useful.  As with the EPA risk
17   assessments, the Nishiuchi and Asano (1979) study is not considered quantitatively in the current
18   risk assessment.  Tantawy (2002) reports an $LC_{50}$ of 17.6 and an $LC_5$ of 1.76 for fluazifop-P-
19   butyl (NOS) in *Biomphalaria alexandrina*, an Egyptian snail that is a vector for *Schistosoma*
20   *mansoni*, cause of schistosomiasis.  The paper by Tantawy (2002) provides few experimental
21   details, and it cannot be determined if the $LC_{50}$ value is reported in units of formulation, a.i., or
22   a.e.  This $LC_{50}$ value would not have a quantitative impact on the risk assessment but would
23   expand the class of species on which data are available.  In the absence of better documentation
24   of the units for the toxicity value, however, the paper by Tantawy (2002) is not considered useful
25   in the hazard identification for aquatic invertebrates.
26
27   Apart from the above two studies, there are uncertainties in some of the reported $LC_{50}$ values in
28   Table 28.  U.S. EPA/OPP/EFED (2008) reports an $LC_{50}$ of 8.5 mg a.e./L in *Daphnia magna*
29   (MRID 00087488).  In ECOTOX, however, the $LC_{50}$ is reported as indefinite with a value of >10
30   mg a.i./L ($\approx$8.54 mg a.e./L).  Given the other daphnid toxicity data on fluazifop-P-butyl, it seems
31   likely that the definitive $LC_{50}$ of 8.5 mg a.e./L reported in U.S. EPA/OPP/EFED (2008) should
32   have been reported as an indefinite $LC_{50}$.of >8.5 mg a.e./L.  In the absence of additional details
33   on the study, however, no clearer determination can be made.
34
35   As summarized in Table 28 and detailed further in Appendix 6 (Table A6-1) a series of studies
36   were conducted in *Daphnia magna* using 1:1, 1:7, and 1:14 blends of the [R]:[S] enantiomers.
37   U.S. EPA/OPP/EFED (2008, Appendix C, p. 190) indicates that the test substance was fluazifop-
38   butyl.  Two DERs are available for this study (Jealotts Hill Research Station 1983; Hamer and
39   Hill 1983), both of which indicate that the test substance was fluazifop acid rather than fluazifop-
40   butyl.  This ambiguity does not have a substantial impact on the current risk assessment because
41   these studies are not used quantitatively.
42
43   Another issue involves the reported $LC_{50}$ of 240 mg a.e./L for fluazifop-butyl from MRID
44   00087490, as summarized in U.S. EPA/OPP/EFED (2008).  An identical $LC_{50}$ of 240 mg a.e./L
45   is reported by EFSA (2012) for fluazifop acid.  The two identical $LC_{50}$ values for fluazifop-butyl
46   and fluazifop acid may be correct but seems unlikely for a weak acid and the corresponding

ester.  Again, in the absence of the studies on which the EPA and EFSA summaries are based, this issue cannot be resolved.

Notwithstanding the uncertainties in the data as discussed above, a clear difference is apparent in the toxicity data on aquatic invertebrates compared with corresponding data on fish.  For the freshwater aquatic invertebrates, the formulations appear to be much more toxic than technical grade fluazifop-butyl.  Ignoring the indefinite $LC_{50}$ of >8.5 mg a.e. for fluazifop-butyl, the formulations appear to be more than a 100 times more toxic than the technical grade material to *Daphnia magna*—i.e., $LC_{50}$ values of 240 to 466 mg a.e./L for technical grade fluazifop-butyl and $LC_{50}$ values of about 1.8 to 5.5 mg a.e./L for formulations.  As with fish, the data indicate that Fusilade Max is about 3 times more toxic than the formulations under consideration by the Forest Service—i.e., an $LC_{50}$ of 1.79 mg a.e./L for Fusilade Max and 5.14 to 5.5 mg a.e./L for 24 to 25% formulations considered in U.S. EPA/OPP/EFED (2008).

Saltwater invertebrates are substantially more sensitive to technical grade fluazifop-P-butyl ($LC_{50}$s of 0.083 to 0.46 mg a.e./L) than are freshwater invertebrates ($LC_{50}$s of >240 a.e./L).  This difference, however, is not reflected in the apparent sensitivities to formulations of fluazifop-butyl or fluazifop-P-butyl—i.e., $LC_{50}$ values of about 2 to 4 mg a.e./L for freshwater invertebrates and corresponding values of about 3.5 to 5 mg a.e./L for saltwater invertebrates.

As with fish, 5-trifluoromethyl-2-pyridone (Metabolite X) is less toxic than fluazifop-butyl or fluazifop-P-butyl to *Daphnia magna* by about a factor of 2 to 3.

Based on the $LC_{50}$ values in *Daphnia magna* (Table 28), the EPA classifies fluazifop-P-butyl as *Very Highly Toxic* to freshwater invertebrates (U.S. EPA/OPP/EFED 2008, p. 43).

### 4.1.3.3.2. Reproduction Studies

As summarized in Table 29, the longer-term studies with technical grade fluazifop-butyl in aquatic invertebrates indicate a clear and pronounced impact of duration.  Unlike the case with fish, the longer-term NOAECs for aquatic invertebrates are substantially below the acute NOAECs, although the difference is much more pronounced in freshwater invertebrates compared with saltwater invertebrates.  Taking the lowest acute chronic NOAECs for freshwater and saltwater invertebrates in bioassays of fluazifop-butyl, the chronic NOAECs are lower than the acute NOAECs by a factor of nearly 1000 for freshwater invertebrates [$82.8 \div 0.0854 \approx 967$] and about 3 for marine/estuarine invertebrates [$0.040 \div 0.014 \approx 2.8571$].

A DER (Edwards et al. 1981) for the chronic study in *Daphnia magna* (MRID 00093807) indicates that a new chronic study in *Daphnia magna* is required.  The DER was prepared in 1991.  A new study has not been identified.

### *4.1.3.4. Aquatic Plants*

Bioassays on both algae and aquatic macrophytes are typically required to support herbicide registration.  As with terrestrial plants (Section 4.1.2.5), standard assays in algae and aquatic macrophytes do not appear to have been required for the registration of fluazifop-P-butyl.  The lack of registrant-submitted studies on algae and aquatic macrophytes is noted explicitly in recent EPA ecological risk assessments (U.S. EPA/OPP/EFED 2008, p. 19; U.S. EPA/OPP/EFED 2010a, p. 8).

1
2 U.S. EPA/OPP/EFED (2008, p. 9) indicates that bioassays in a *Lemna* species are required for
3 fluazifop-P-butyl. As discussed in Section 1.1.2, fluazifop-P-butyl is undergoing registration
4 review and bioassays on *Lemna* may be required as part of this process.
5
6 As summarized in Table 30 and detailed further in Appendix 7, several algal bioassays on
7 fluazifop-P-butyl and formulations of fluazifop-P-butyl are cited in European reviews (e.g.,
8 EFSA 2012; FAO/WHO 2000), and additional toxicity studies are published in the open
9 literature (Felix et al. 1988; Ma 2002; Ma et al. 2002a,b, 2004, 2006; Michel et al. 2004;
10 Perschbacher et al. 1997). Except for the paper by Perschbacher et al. (1997), which was
11 conducted in the United States, all of these toxicity studies on algae are from the European
12 literature (EFSA 2012; FAO/WHO 2000; Felix et al. 1988) or Chinese literature (the
13 publications by Ma and coworkers). Perschbacher et al. (1997) used an unspecified Fusilade
14 formulation. Studies summarized in EFSA (2012) involved technical grade fluazifop-P-butyl,
15 fluazifop acid, 5-trifluoromethyl-2-pyridone (Metabolite X), and Fusilade Max. The studies by
16 Ma and coworkers involved an unspecified 53% EC formulation.

17 **4.1.3.4.1. Algae**
18 While data are available on the toxicity of fluazifop-P-butyl and related compounds to nine
19 different species of algae (Table 30), only *Pseudokirchneriella subcapitata* and *Navicula*
20 *pelliculosa* have been assayed with more than one form of fluazifop or formulation.
21
22 *Pseudokirchneriella subcapitata* has been assayed using technical grade fluazifop-P-butyl,
23 fluazifop acid, 5-trifluoromethyl-2-pyridone (Metabolite X), and Fusilade Max. While the
24 bioassays on fluazifop-P-butyl and fluazifop acid are indefinite, they suggest that fluazifop-P-
25 butyl may be more toxic than fluazifop acid, similar to the observations in fish (4.1.3.1) and
26 aquatic invertebrates (4.1.3.3). Also as with fish and aquatic invertebrates, the 5-trifluoromethyl-
27 2-pyridone metabolite of fluazifop-P-butyl appears to be much less toxic than fluazifop-P-butyl.
28 Fusilade Max has been assayed in *Pseudokirchneriella subcapitata* with and without sediment.
29 As noted in Table 30, the $EC_{50}$ without sediment (0.02 mg a.e./L) is much lower than the $EC_{50}$
30 with sediment (0.128 mg a.e./L). As summarized in Table 4, fluazifop-P-butyl may bind to
31 sediment ($K_{oc}$ values of 2010 to 5700), which may explain the apparent decrease in toxicity in a
32 sediment/water system. Similarly, unless sterile sediment was used, the decrease in toxicity to
33 algae could be due to the more rapid metabolism of fluazifop-P-butyl to fluazifop acid. In the
34 absence of additional details on the design and conduct of these studies, these suppositions
35 cannot be elaborated.
36
37 The bioassays on *Navicula pelliculosa* involved both technical grade fluazifop-P-butyl and
38 Fusilade Max. As with *Pseudokirchneriella subcapitata*, the $EC_{50}$ for the Fusilade formulation
39 (0.118 mg a.e./L) is less than the $EC_{50}$ for technical grade fluazifop-P-butyl ($EC_{50}$ 0.44 mg
40 a.e./L); however, the magnitude of the difference—i.e., about a factor of 4 [0.44 ÷ 0.118 ≈ 3.73]
41 —is much less than the factor of over 77 with *Pseudokirchneriella subcapitata* [>1.54 ÷ 0.02
42 >77].
43
44 Most of the bioassays with the Chinese 53% EC formulation yielded $EC_{50}$ values that are higher
45 (i.e., 0.89 to 22.8 mg a.e./L) than those for Fusilade Max (i.e., 0.02 to 0.18 mg a.e./L). Since
46 there is no species overlap in the algae assayed with the Chinese and Fusilade Max formulations,

it is not clear if these differences are attributable to differences in the toxicity of the two formulations, differences in species sensitivities to the formulations, other experimental details, or a combination of factors.

The bioassay with *Dunaliella bioculata* by Felix et al. (1988) was conducted at a Sandoz facility in Switzerland. The paper specifies that a formulated product was used but does not identify or otherwise describe the formulation. The $EC_{50}$ ($\approx$0.327 mg a.e./L) reported by Felix et al. (1988) is similar to the $EC_{50}$ for Fusilade Max in *Navicula pelliculosa* (0.188 mg a.e./L), which may be coincidental.

The only other information on the effect of fluazifop-P-butyl on algae is a mesocosm study by Perschbacher et al. (1997) with an unspecified Fusilade formulation. In this study, 500 liter pools were over-sprayed with the formulation at rates equivalent to 0.001, 0.01, and 0.1 kg a.i./ha. No effects on algal populations (based on estimates of chlorophyll a and phytoplankton productivity) were noted over a 48-hour observation period. In this study, the depth of the pools was 0.7 m. The highest application of 0.1 kg a.i./ha is equivalent to 0.0854 kg/ha, which is in turn equivalent to 8.85 mg/m$^2$ [85,400 mg/10,000 m$^2$]. Using the water depth of 0.7 m, the initial concentration in the water (assuming complete mixing) would be about 0.006 mg/L [8.85 mg/m$^2$ x 0.7 m/1000 L/m$^3$ = 0.006195 mg/L]. The lack of effects on algae noted in the Perschbacher et al. (1997) publication seems consistent with the toxicity data on algae, discussed above.

### 4.1.3.4.2. Aquatic Macrophytes

As summarized in the bottom section of Table 30, levels of exposure to fluazifop-P-butyl or fluazifop-P-butyl formulations that cause adverse effects in *Lemna* have not been determined. The reported $EC_{50}$ values for *Lemna gibba* are indeterminate—i.e., >1.2 mg a.e./L for technical grade fluazifop-P-butyl and >11.6 mg a.e./L for Fusilade Max. Based on the study by Michel et al. (2004), *analytical grade* fluazifop-P-butyl (NOS) caused no effect based on growth in a 7-day bioassay of *Lemna paucicostata* at a concentration of 1 mM (i.e., $\approx$327 mg a.e./L).

*Lemna* is a monocot of the family Araceae. The available data on this monocot genus is consistent with data on terrestrial non-Poaceae monocots (Section 4.1.2.5.2.2.2) indicating that fluazifop-P-butyl appears to be highly selective to Poaceae monocots but is relatively nontoxic to other monocots.

### *4.1.3.5. Surfactants*

As noted in Section 3.1.14.2, nonionic surfactants, methylated seed oils, or vegetable oil concentrates are recommended for applications of fluazifop-P-butyl formulations. It is beyond the scope of the current risk assessment to review the toxicity of all the adjuvants recommended for use with fluazifop-P-butyl or the potential impact of these adjuvants on aquatic organisms.

As discussed above, fluazifop-P-butyl is toxic to aquatic animals. At least some of the recommended nonionic surfactants may be equally toxic to some aquatic animals. For example, the review by McLaren/Hart (1995) compiles $LC_{50}$ values for fish and $EC_{50}$ values for aquatic invertebrates in assays of several nonionic surfactants used with other herbicides. The acute toxicity values for these surfactants cover a wide-range of $LC_{50}$ values (i.e., about 1 to >1000 mg/L).

1
2  Based on the label instructions for fluazifop-P-butyl formulations likely to be used in Forest
3  Service programs, the recommended concentration for nonionic surfactants is 0.25% to 0.5% v/v
4  (Table 6).  Assuming a surfactant density of 1 g/mL for illustration, 0.5% w/v corresponds to a
5  concentration of 5000 mg/L.  In order to assess potential hazard to aquatic organisms, however,
6  the dilution of the surfactant must be considered.  Three applications of fluazifop-P-butyl at a
7  rate of 0.32 lb a.e./acre with a 14-day application interval may be taken as a reasonable example.
8  As detailed in Attachment 3 (Worksheet B04a), the peak expected concentration of fluazifop-P-
9  butyl in surface water would be about 0.47 mg a.e./L.  If 0.5% surfactant is added to a
10  representative formulation containing 20.09% a.e. (Table 6), the peak concentration of the
11  surfactant in surface water would be about 0.01 mg/L [0.47 mg a.e./L x 0.5% ÷ 20.09%  a.e. ≈
12  0.011196 mg/L].
13
14  As discussed in the EPA ecological risk assessments on fluazifop-P-butyl (U.S. EPA/OPP 2008),
15  the standard criterion used by U.S. EPA/OPP is a level of concern for endangered species of
16  0.05, meaning that the ratio of the anticipated concentration in water to the acute $LC_{50}$ should be
17  no greater than 0.05.  Using a very toxic surfactant with an acute $LC_{50}$ of 1 mg/L, the ratio of the
18  anticipated concentration of the surfactant in water (0.011 mg/L) to the $LC_{50}$ of 1 mg/L is
19  0.011—i.e., below the 0.05 level of concern by a factor greater than 4 [0.05 ÷ 0.011 ≈ 4.545].
20  Thus, there is no apparent basis for asserting that the use of surfactants with fluazifop-P-butyl
21  applications is likely to pose an acute hazard to aquatic species.  The use of a relatively nontoxic
22  surfactant (e.g., an $LC_{50}$ of 1000 mg/L) would result in a correspondingly lower ratio and lesser
23  assessment of potential risk.
24
25  The above discussion applies only to potential acute risks.  Since a useful compendium on the
26  longer-term toxicity of nonionic surfactants to aquatic organisms is not available, the potential
27  for longer-term risks cannot be assessed.
28

## 4.2. EXPOSURE ASSESSMENT

### 4.2.1. Overview

A standard set of exposure assessments for terrestrial and aquatic organisms is provided in the EXCEL workbooks for fluazifop-P-butyl. Attachment 1 details the exposure assessments for a single application at the maximum single application rate of 0.32 lb a.e./acre. Attachment 2 details the exposure assessments for two applications at an application rate of 0.32 lb a.e./acre an application interval of 14 days. Attachment 3 details the exposure assessments for three applications (the maximum seasonal application rate) at 0.32 lb a.e./acre with application intervals of 14 days.

As in the human health risk assessment, three general types of exposure scenarios are considered: accidental, acute non-accidental, and longer-term. Exposure assessments for mammals are detailed in Worksheet G01a for mammals and in Worksheet G01b for birds. For both mammals and birds, the highest exposure scenarios are associated with the consumption of contaminated vegetation. This is a common pattern for foliar applications of any pesticide. The highest exposures are associated with the consumption of contaminated short grass by a small mammal or bird.

For terrestrial plants, five exposure scenarios are considered quantitatively: direct spray, spray drift, runoff, wind erosion, and the use of contaminated irrigation water. The highest exposures for terrestrial plants are associated with direct spray and spray drift.

Exposures of aquatic plants and animals to fluazifop-P-butyl are based on essentially the same information used to assess the exposure to terrestrial species from contaminated water.

As with the exposure assessment for human heath (Section 3.2), all exposure assessments involving applications of fluazifop-P-butyl are expressed in units of fluazifop acid, and units of fluazifop acid are also used in the dose-response assessment (Section 4.3). It is noted that at least some acute exposure scenarios could involve fluazifop-P-butyl or a combination of fluazifop-P-butyl and fluazifop acid, which is considered further in the selection of toxicity values (Section 4.3).

### 4.2.2. Mammals and Birds

All exposure scenarios for terrestrial animals are summarized in Worksheet G01 in the EXCEL workbooks that accompany this risk assessment (Attachments 1, 2 and 3). An overview of the mammalian and avian receptors considered in the current risk assessment is given in Table 31. These data are discussed in the following subsections. Because of the relationship of body weight to surface area as well as to the consumption of food and water, for any type of exposure, the dose for small animals is generally higher, in terms of mg/kg body weight, than the dose for large animals. The exposure assessment for mammals considers five nontarget mammals of varying sizes: small (20 g) and medium (400 g) sized omnivores (e.g., mouse and squirrel), a 5 kg canid, a 70 kg herbivore, and a 70 kg carnivore. Four standard avian receptors are considered: a 10 g passerine, a 640 g predatory bird, a 2.4 kg piscivorous bird, and a 4 kg herbivorous bird. Because of presumed differences in diet, (i.e., the consumption of food items), all of the mammalian and avian receptors are not considered in all of the exposure scenarios (e.g., the 640 g predatory bird is not used in the exposure assessments for contaminated

vegetation).  Toxicity data are not available on terrestrial-phase amphibians (Section 4.1.2.3); accordingly, exposure assessments for these terrestrial vertebrates are not developed.

### 4.2.2.1. Direct Spray

The unintentional direct spray of wildlife during broadcast applications of a pesticide is a credible exposure scenario, similar to the accidental exposure scenarios for the general public discussed in Section 3.2.3.2.  In a scenario involving exposure to direct spray, the amount of pesticide absorbed depends on the application rate, the surface area of the organism, and the rate of absorption.

For this risk assessment, two direct spray or broadcast exposure assessments are conducted.  The first spray scenario (Worksheet F01a) concerns the direct spray of half of the body surface of a 20 g mammal during a pesticide application.  This exposure assessment assumes first-order dermal absorption using the first-order dermal absorption rate coefficient ($k_a$) discussed in Section 3.1.3.2.  The $k_a$ used in this risk assessment is identical to the $k_a$ used in the human health risk assessment (Section 3.1.3.2).  The second exposure assessment (Worksheet F01b) assumes complete absorption over Day 1 of exposure.  This assessment is included in an effort to encompass increased exposures due to grooming.

Exposure assessments for the direct spray of a large mammal are not developed.  As discussed further in Section 4.4.2.1, the direct spray scenarios lead to HQs far below the level of concern, and an elaboration for body size would have no impact on the risk assessment.

### 4.2.2.2. Dermal Contact with Contaminated Vegetation

As discussed in the human health risk assessment (Section 3.2.3.3), the approach for estimating the potential significance of dermal contact with contaminated vegetation is to assume a relationship between the application rate and dislodgeable foliar residue as well as a transfer rate from the contaminated vegetation to the skin.  Unlike the human health risk assessment for which estimates of transfer rates are available, there are no transfer rates available for wildlife species.  Wildlife species are more likely than humans to spend long periods of time in contact with contaminated vegetation.  It is reasonable to assume that for prolonged exposures, equilibrium may be reached between pesticide levels on the skin, rates of dermal absorption, and pesticide levels on contaminated vegetation.  Since data regarding the kinetics of this process are not available, a quantitative assessment for this exposure scenario cannot be made in the ecological risk assessment.

For fluazifop, as well as most other herbicides and insecticides applied in broadcast applications, the failure to quantify exposures associated with dermal contact adds relatively little uncertainty to the risk assessment, because the dominant route of exposure will be the consumption of contaminated vegetation, as addressed in the following section.

### 4.2.2.3. Ingestion of Contaminated Vegetation or Prey

 In foliar applications of pesticides, the consumption of contaminated vegetation is an obvious concern.  Except for the large carnivorous mammal and the predatory bird, exposure assessments for the consumption of contaminated vegetation are developed for all mammals and birds listed in Table 31.

1     The initial concentrations of fluazifop-P-butyl on contaminated food items are based on the U.S.
2     EPA/OPP (2001) adaptation of the residue rates from Fletcher et al. (1994), as summarized in
3     Table 21. The methods of estimating the peak and time-weighted average concentrations of
4     fluazifop-P-butyl in vegetation are identical to those used in the human health risk assessment
5     (Section 3.2.3.7). As summarized in Table 21, fruit and short grass comprise the food
6     commodities with the lowest pesticide residue rates (fruit) and the highest pesticide residue rates
7     (short grass). Tall grass and broadleaf forage plants are estimated to have intermediate residue
8     rates. For each of these four types of vegetation, both acute and longer-term exposure scenarios
9     are developed, as detailed in Worksheet G01a for mammals and Worksheet G01b for birds, in
10    the attachments to this risk assessment.
11
12    The acute and chronic exposure scenarios are based on the assumption that 100% of the diet is
13    contaminated, which may not be realistic for some acute exposures and seems an unlikely event
14    in chronic exposures—i.e., animals may move in and out of the treated areas. While estimates of
15    the proportion of the diet contaminated could be incorporated into the exposure assessment, the
16    estimates would be an essentially arbitrary set of adjustments. The proportion of the
17    contaminated diet is linearly related to the resulting HQs, and its impact is discussed further in
18    the risk characterization (Section 4.4.2.1).
19
20    The estimated food consumption rates by various species of mammals and birds are based on
21    field metabolic rates (kcal/day), which, in turn, are based on the adaptation of estimates from
22    Nagy (1987) by the U.S. EPA/ORD (1993). These allometric relationships account for much of
23    the variability in food consumption among mammals and birds. There is, however, variability
24    not apparently related to body weight, which is remarkably constant among different groups of
25    organisms (Table 3 in Nagy 1987). As discussed by Nagy (2005), the estimates from the
26    allometric relationships may differ from actual field metabolic rates by about ±70%.
27    Consequently, in all worksheets involving the use of the allometric equations for field metabolic
28    rates, the lower bound is taken as 30% of the estimate and the upper bound is taken as 170% of
29    the estimate.
30
31    The estimates of field metabolic rates are used to calculate food consumption based on the
32    caloric value (kcal/day dry weight) of the food items considered in this risk assessment and
33    estimates of the water content of the various foods. Estimates of caloric content are summarized
34    in Table 22. Most of the specific values in Table 22 are taken from Nagy (1987) and U.S.
35    EPA/ORD (1993).
36
37    Along with the exposure scenarios for the consumption of contaminated vegetation, similar sets
38    of exposure scenarios are provided for the consumption of small mammals by either a predatory
39    mammal (Worksheet F10a) or a predatory bird (Worksheet F10b) and the consumption of
40    contaminated insects by a small mammal, a larger (400 g) mammal, and a small bird
41    (Worksheets F09a-c). The residue rates for insects are taken from the U.S. EPA/OPP (2001)
42    adaptation of the residue rates in Fletcher et al. (1994), as summarized in Table 21.

43         *4.2.2.4. Ingestion of Contaminated Water*
44    The methods for estimating concentrations of fluazifop in water are identical to those used in the
45    human health risk assessment (Section 3.2.3.4.6.1). The only major differences in the exposure
46    estimates concern the body weight of and the quantity of water consumed by the mammal or

1   bird. Like food consumption rates, water consumption rates, which are well characterized in
2   terrestrial vertebrates, are based on allometric relationships in mammals and birds, as
3   summarized in Table 31. From these estimates, exposure scenarios involving the consumption
4   of contaminated water are developed for mammals and birds for accidental spills (Worksheets
5   F02a-f), expected peak concentrations (Worksheets F08a-f), and expected longer-term
6   concentrations (Worksheets F16a-f) of Attachments 1, 2 and 3.
7
8   Like food consumption, water consumption in birds and mammals varies substantially with diet,
9   season, and many other factors; however, quantitative estimates regarding the variability of water
10  consumption by birds and mammals is not well documented in the available literature and is not
11  considered in the exposure assessments. Nevertheless, as summarized in Table 20, the upper and
12  lower bound estimates of concentrations of fluazifop in surface water vary substantially (i.e., by
13  a factor of over 94 [0.047 mg/L ÷ 0.005 mg/L] for acute exposures and a factor of over 100 [0.2
14  mg/L ÷ 0.002] for chronic exposures). Given this degree of variability in the estimated
15  concentrations of fluazifop in surface water, it is unlikely that a quantitative consideration of the
16  variability in water consumption rates of birds and mammals would have a substantial impact on
17  the risk characterization. In addition and as discussed further in Section 4.4.2.1 (risk
18  characterization for mammals) and Section 4.4.2.2 (risk characterization for birds), exposures
19  associated with the consumption of contaminated surface water are far below the level of
20  concern (HQ=1). Consequently, even extreme variations on the consumption of contaminated
21  water by mammals and birds would have no impact on the risk characterization for mammals
22  and birds.

23          *4.2.2.5. Consumption of Contaminated Fish*
24  In addition to the consumption of contaminated vegetation, insects, and other terrestrial prey
25  (Section 4.2.2.3), the consumption of contaminated fish by piscivorous species is a potentially
26  significant route of exposure to fluazifop-P-butyl (acute exposures) and fluazifop acid (longer-
27  term exposures). Exposure scenarios are developed for the consumption of contaminated fish
28  after an accidental spill (Worksheets F03a-c), expected peak exposures (Worksheets F011a-c),
29  and estimated longer-term concentrations (Worksheets F17a-c). These exposure scenarios are
30  applied to 5 and 70 kg carnivorous mammals as well as a 2.4 kg piscivorous bird. The 70 kg
31  carnivorous mammal is typical of a black bear (which does not actively hunt fish) but could be
32  representative of a small or immature brown bear (*Ursus arctos*), which is an endangered species
33  that actively feeds on fish (Reid 2006). As summarized in Table 31, the 5 kg mammal is
34  representative of a fox, and the 2.4 kg bird is representative of a heron.
35
36  Exposure levels associated with the consumption of contaminated fish depend on the
37  concentration of the compound in water and the bioconcentration factor for the compound in
38  fish. The concentrations of fluazifop in water are identical to those discussed in Section 4.2.2.4.
39  As discussed in Section 3.2.3.5, fluazifop acid is not likely to accumulate in fish, but fluazifop-P-
40  butyl may accumulate substantially. Thus, for acute exposure scenarios, the bioconcentration
41  factor of 120 from MRIDs 93196 and 92067035 is used and, presumably, applies to fluazifop-P-
42  butyl. For longer-term exposure scenarios, the bioconcentration factor of 2.1 from MRID 93195
43  is used and, presumably, applies to fluazifop acid. As noted in Section 4.1.1, all exposures are
44  expressed in units of fluazifop acid, regardless of the bioconcentration factor, and this conversion
45  has no impact on the hazard quotients discussed in Section 4.4.

## 4.2.3. Terrestrial Invertebrates

### 4.2.3.1. Direct Spray and Drift

Estimated levels of exposure associated with broadcast terrestrial applications of fluazifop-P-butyl are detailed in Worksheet G09 of Attachments 1, 2 and 3 (the EXCEL workbooks for fluazifop-P-butyl). This is a custom worksheet which includes aerial, ground broadcast (high boom and low boom), and backpack applications.

Honeybees are used as a surrogate for other terrestrial insects, and honeybee exposure levels associated with broadcast applications are modeled as a simple physical process based on the application rate and planar surface area of the bee. The planar surface area of the honeybee (1.42 $cm^2$) is based on the algorithms suggested by Humphrey and Dykes (2008) for a bee with a body length of 1.44 cm.

The amount of a pesticide deposited on a bee during or shortly after application depends on how close the bee is to the application site as well as foliar interception of the spray prior to deposition on the bee. The estimated proportions of the nominal application rate at various distances downwind given in G09 are based on Tier 1 estimates from AgDRIFT (Teske et al. 2002) for distances of 0 (direct spray) to 900 feet downwind of the treated site. Further details of the use of AgDRIFT are discussed in Section 4.2.4.2 (Off-Site Drift) with respect to nontarget vegetation.

In addition to drift, foliar interception of a pesticide may occur. The impact of foliar interception varies according to the nature of the canopy above the bee. For example, in studies investigating the deposition rate of diflubenzuron in various forest canopies, Wimmer et al. (1993) report that deposition in the lower canopy, relative to the upper canopy, generally ranged from about 10% (90% foliar interception in the upper canopy) to 90% (10% foliar inception by the upper canopy). In Worksheet G09, foliar interception rates of 0% (no interception), 50%, and 90% are used.

During broadcast applications of a pesticide, it is likely that terrestrial invertebrates other than bees will be subject to direct spray. As discussed in further detail in Section 4.3.2.3 (dose-response assessment for terrestrial invertebrates), toxicity data on other terrestrial invertebrates are available from EFSA (2012). These data involve exposures expressed in units of application rate. Thus, other than the nominal application rate for fluazifop-P-butyl, additional exposure assumptions are not necessary.

### 4.2.3.2. Ingestion of Contaminated Vegetation or Prey

Like terrestrial mammals and birds, terrestrial invertebrates may be exposed to fluazifop-P-butyl through the consumption of contaminated vegetation or contaminated prey. As with consumption scenarios for mammals (Section 4.2.3.2), estimates of residues on contaminated vegetation or prey are based on estimated residue rates (i.e., mg/kg residues per lb applied) from Fletcher et al. (1994), as summarized in Table 21.

An estimate of food consumption is necessary to calculate a dose level for a foraging herbivorous insect. Insect food consumption varies greatly, depending on the caloric requirements in a given life stage or activity of the insect and the caloric value of the food to be consumed. The derivation of consumption values for specific species, life stages, activities, and

food items is beyond the scope of the current analysis. Nevertheless, general food consumption values, based on estimated food consumption per unit body weight, are readily available.

Reichle et al. (1973) studied the food consumption patterns of insect herbivores in a forest canopy and estimated that insect herbivores may consume vegetation at a rate of about 0.6 of their body weight per day (Reichle et al. 1973, pp. 1082 to 1083). Higher values (i.e., 1.28-2.22 in terms of fresh weight) are provided by Waldbauer (1968) for the consumption of various types of vegetation by the tobacco hornworm (Waldbauer 1968, Table II, p. 247). The current risk assessment uses food consumption factors of 1.3 (0.6 to 2.2) kg food /kg bw. The lower bound of 0.6 is taken from Reichle et al. (1973), and the central estimate and upper bound are taken from the range of values provided by Waldbauer (1968).

A summary of the estimated exposures in terrestrial herbivorous insects is given in Worksheet G08a and details of the calculations for these scenarios are provided in Worksheets G07a, G07b, G07c, and G07d of the EXCEL workbooks that accompany this risk assessment (Attachments 1, 2, and 3). These levels pertain to the four food items included in the standard residue rates provided by Fletcher et al. (1994) at summarized in Table 21.

### 4.2.3.3. Contaminated Soil

Forest Service risk assessments do not typically include estimates of soil exposures, because toxicity values for soil invertebrates are not typically available. As discussed in Section 4.1.2.4.4, however, brief summaries of toxicity studies are available in earthworms with fluazifop-P-butyl and 5-trifluoromethyl-2-pyridone (Metabolite X) and these studies indicate no effects at concentrations of 1000 mg/kg soil. As summarized in Appendix 10, Table A10-2, the estimated peak concentrations of fluazifop in the top 12 inches of soil are 0.41 (0.311 - 0.88) mg a.e./kg (dry weight) soil following three applications of fluazifop-P-butyl at a unit application rate of 1 lb a.e./acre (i.e., the application rate used in the Gleams-Driver modeling). At the maximum labeled application rate of 0.32 lb a.e./acre for fluazifop-P-butyl, the estimated peak concentrations of fluazifop acid would be about 0.13 (0.010 to 0.28) mg a.e./kg (dry weight) soil. These levels of exposure are far below the NOAEC of 1000 mg/kg soil for fluazifop-P-butyl ($\approx$854 mg a.e./kg soil). Consequently, there is no basis for asserting that fluazifop-P-butyl is likely to pose a risk to earthworms.

### 4.2.4. Terrestrial Plants

Generally, the primary hazard to nontarget terrestrial plants associated with the application of most herbicides is unintended direct deposition or deposition of spray drift. In addition, herbicides may be transported off-site by percolation or runoff or by wind erosion of soil resulting in deposition of contaminated soil onto nontarget vegetation. As noted in Section 4.1.2.5 (Hazard Identification for Terrestrial Plants) and discussed further in Section 4.3.2.5 (Dose-Response Assessment for Terrestrial Plants), the toxicity data on fluazifop-P-butyl are sufficient to interpret risks associated with these exposure scenarios. Consequently, exposure assessments are developed for each of these exposure scenarios, as detailed in the following subsections. These exposure assessments are detailed in Worksheet G04 (runoff), Worksheet G05 (direct spray and drift), Worksheet G06a (contaminated irrigation water), and Worksheet G06b (wind erosion) for directed or broadcast foliar applications. These worksheets are included in the attachments that accompany this risk assessment.

### 4.2.4.1. Direct Spray

Unintended direct spray will result in an exposure level equivalent to the application rate. For many types of herbicide applications, it is plausible that some nontarget plants immediately adjacent to the application site could be sprayed directly. This type of scenario is modeled in the worksheets that assess off-site drift (see Section 4.2.4.2 below).

### 4.2.4.2. Off-Site Drift

Estimates of off-site drift are modeled using AgDRIFT. These estimates are summarized in Worksheets G05a and G05b of the EXCEL workbooks for fluazifop-P-butyl (Attachments 1, 2, and 3). These are custom worksheets that include estimates of drift for aerial, ground broadcast, and backpack applications. The drift estimates used in the current risk assessment are based on AgDRIFT (Teske et al. 2002) using Tier 1 analyses for aerial and ground broadcast applications. The term *Tier 1* is used to designate relatively generic and simple assessments which can be viewed as plausible upper limits of drift.

In Worksheet G05a, aerial drift estimates are based on Tier 1 using ASAE Fine to Medium drop size distributions. Tier 1 estimates of drift for ground broadcast applications are modeled using both low boom and high boom options in AgDRIFT. For both types of applications, the values are based on Very Fine to Fine drop size distributions (VDM≈137 µm) and the 90th percentile values from AgDRIFT. The use of small droplet sizes in Worksheet G05a is intended to generate extremely conservative estimates of drift that would not be anticipated in typical Forest Service applications.

In Worksheet G05b, aerial drift estimates are based on Tier 1 using ASAE Coarse to Very Coarse drop size distributions (VMD≈440 µm) and the ground broadcast applications are based on ASAE fine to Medium Coarse drop size distributions (VMD≈340 µm). As discussed in Section 3.2.3.4.2, the product labels for all formulations of fluazifop-P-butyl explicitly considered in this risk assessment (Table 4) specifically note that flood type nozzles which deliver coarse droplet sizes should not be used in aerial or ground applications. As also discussed in Section 3.2.3.4.2, the labels do not specify droplet size distributions but flood type applications are typically associated with VMD values of >500 µm. Thus, modeling of coarse droplets in Worksheet G05b (VMD≈440 µm) are consistent with likely Forest Service practice and are not excluded by the label language.

Drift associated with backpack applications (directed foliar applications) is likely to be much less than drift from ground broadcast applications. Few studies are available for quantitatively assessing drift after backpack applications. For the current risk assessment, estimates of drift from backpack applications are based on an AgDRIFT Tier 1 run of a low boom ground application using Fine to Medium/Coarse drop size distributions as well as 50th percentile estimates of drift (rather than the 90th percentile used for ground broadcast applications).

The values for drift used in the current risk assessment should be regarded as little more than generic estimates similar to the water concentrations modeled using GLEAMS (Section 3.2.3.4.3). Actual drift will vary according to a number of conditions—e.g., the topography, soils, weather, drop size distribution, carrier, and the pesticide formulation.

1 ***4.2.4.3. Runoff and Soil Mobility***
2 Terrestrial plant exposures associated with runoff and sediment losses from the treated site to an
3 adjacent untreated site are summarized in Worksheet G04 of the EXCEL workbooks for
4 fluazifop-P-butyl (Attachments 1, 2, and 3).
5
6 Any pesticide can be transported from the soil at the application site by runoff, sediment loss, or
7 percolation.  Runoff, sediment loss, and percolation are considered in estimating contamination
8 of ambient water (Section 3.2.3.4).  Only runoff and sediment loss are considered in assessing
9 off-site soil contamination.  This approach is reasonable because off-site runoff and sediment
10 transport will contaminate the off-site soil surface and could have an impact on non-target plants.
11 Percolation, on the other hand, represents the amount of herbicide transported below the root
12 zone, which may affect water quality but should not affect off-site vegetation.  As with the
13 estimates of fluazifop-P-butyl in surface water, estimates of runoff and sediment losses are
14 modeled for clay, loam, and sand at nine sites that represent different temperatures and rainfall
15 patterns, as specified in Table 16.
16
17 The exposure scenario for runoff and sediment losses assumes that the pesticide is lost from the
18 treated field and spread uniformly over an adjacent untreated field of the same size.  This
19 assumption is admittedly arbitrary.  Much more severe exposures could occur if all of the runoff
20 losses were distributed into a much smaller area.  Conversely, lower exposures would occur if
21 runoff losses were distributed from the treated field to a much larger area.
22
23 For fluazifop-P-butyl, the results of the standard GLEAMS modeling of runoff and sediment
24 losses are summarized in Appendix 8 for a single application, Appendix 9 for two applications,
25 and Appendix 10 for three applications.  Note that amount of runoff and sediment loss will vary
26 substantially with different types of climates—i.e., temperature and rainfall—as well as soils,
27 with no or very little runoff or sediment loss anticipated in predominantly sandy soils.  The input
28 parameters used to estimate runoff and sediment losses are identical to those used in the Gleams-
29 Driver modeling for concentrations of fluazifop-P-butyl in surface water as discussed in Section
30 3.2.3.4 and summarized in Table 17 (site characteristics) and Table 18 (chemical-specific input
31 parameters).
32
33 For a single application, the runoff for fluazifop-P-butyl as a proportion of the application rate is
34 taken as 0.0009 (0.00009 to 0.037).  The central estimate and upper bound are taken directly
35 from the Gleams-Driver modeling—i.e., the median and empirical upper 95% bound, as detailed
36 in Appendix 8 (Table A8-1)—rounding all values to one significant place.  The lower bound is
37 effectively zero—i.e., for sandy soils regardless of temperature and rainfall rates.  The lower
38 bound value of 0.0009 is simply the central estimate divided by 10.  Much lower loss rates are
39 plausible—i.e., in areas with predominantly sandy soils, as discussed further in the risk
40 characterization (Section 4.4.2.5.2).
41
42 For two applications, the runoff as a proportion of the application rate is taken as 0.002 (0.0002
43 to 0.06).  For three applications, the runoff as a proportion of the application rate is taken as
44 0.0025 (0.00025 to 0.073).  As with the single application, the central estimate and upper bound
45 are taken directly from the Gleams-Driver modeling—i.e., the median and empirical upper 95%
46 bound, as detailed in Appendix 9 (Table A9-1) for two applications and Appendix 10 (Table

1  A10-1) for three applications—rounding all values to one significant place. Also as with the
2  single application, the lower bound is effectively zero and the effective lower bound values
3  simply the central estimates divided by 10.

4  ### *4.2.4.4. Contaminated Irrigation Water*
5  Forest Service risk assessments include this standard scenario for the use of contaminated water
6  for irrigation. The exposure levels associated with this scenario depend on the pesticide
7  concentration in the ambient water used for irrigation and the amount of irrigation water used.
8  Concentrations in ambient water are based on the peak concentrations modeled in the human
9  health risk assessment, as discussed in Section 3.2.3.4.6.
10
11 The amount of irrigation used will depend on the climate, soil type, topography, and plant
12 species under cultivation. Thus, the selection of an irrigation rate is somewhat arbitrary. In the
13 absence of any general approach for determining and expressing the variability of irrigation
14 rates, the application of 1 inch of irrigation water with a range of 0.25 to 2 inches is used in this
15 risk assessment. Details of the calculations used to estimate the functional application rates
16 based on irrigation using contaminated surface water are provided in Worksheet G06a of the
17 EXCEL workbooks for fluazifop-P-butyl (Attachments 1, 2 and 3).
18
19 While the labels and/or EPA documents for some herbicides specifically state that water
20 potentially contaminated with herbicides should not be used for irrigation, no such language was
21 identified on the product labels for Fusilade DX and Fusilade II.

22 ### *4.2.4.5. Wind Erosion*
23 Wind erosion can be a major transport mechanism for soil (e.g., Winegardner 1996), and wind
24 erosion is also associated with the environmental transport of herbicides adsorbed to soil (Buser
25 1990). Wind erosion leading to off-site movement of pesticides is likely to be highly site-
26 specific. The amount of fluazifop-P-butyl that might be transported by wind erosion depends on
27 several factors, including application rate, depth of incorporation into the soil, persistence in the
28 soil, wind speed, and topographical and surface conditions of the soil. Under desirable
29 conditions—e.g., relatively deep (10 cm) soil incorporation, low wind speed, and surface
30 conditions which inhibit wind erosion—it is unlikely that a substantial amount of fluazifop-P-
31 butyl would be transported by wind.
32
33 For this risk assessment, the potential effects of wind erosion are estimated in Worksheet G06b
34 in Attachments 1, 2 and 3. In this worksheet, it is assumed that fluazifop-P-butyl is incorporated
35 into the top 1 cm of soil, which is identical to the depth of incorporation used in GLEAMS
36 modeling (Table 18). Average soil losses are estimated to range from 1 to 10 tons/ha/year with a
37 central estimate of 5 tons/ha/year. These estimates are based on the results of agricultural field
38 studies which found that wind erosion may account for annual soil losses ranging from 2 to 6.5
39 metric tons/ha (Allen and Fryrear 1977).
40
41 As noted in Worksheet G06b, offsite losses are estimated to reach as much as 0.014% of the
42 application rate. Larney et al. (1999), however, report that wind erosion of other herbicides
43 could be associated with losses up to 1.5% of the nominal application rate following soil
44 incorporation or 4.5% following surface application. This difference appears to be due to the
45 much higher soil losses noted by Larney et al. (1999)—i.e., up to 56.6 metric tons/ha from a

1   fallow field.  The losses reflected in Worksheet G06b may be somewhat more realistic for forest
2   or rangeland applications, because forestry applications of herbicides are rarely made to fallow
3   areas.  As noted by Patric (1976), total soil erosion from all sources in well-managed forests is
4   typically in the range of about 0.12-0.24 tons/ha/year [0.05 to 0.10 ton/acre/year], substantially
5   below the range from 1 to 10 tons/ha/year used in Worksheet G06b.  Thus, losses due to wind
6   erosions following pesticide applications under forest canopies or heavily vegetated areas may be
7   much less than the estimates used in this risk assessment.
8
9   In any event, the higher offsite losses reported by Larney et al. (1999) are comparable to
10  exposures associated with offsite drift at distances of about 50 feet from the application site
11  following low boom and high boom ground broadcast applications (Worksheet G05).  All of the
12  estimates for wind erosion and offsite drift are likely to vary dramatically according to site
13  conditions and weather conditions.

14  ### 4.2.5. Terrestrial Microorganisms
15  As summarized in Section 4.1.2.6, the study by Abdel-Mallek et al. (1996) indicates no adverse
16  effects on soil fungi at a concentration of 0.6 mg/kg soil (dry weight).  Given these toxicity data,
17  the exposure assessment for soil dwelling invertebrates (Section 4.2.3.3) is relevant.  As
18  discussed in Section 4.2.3.3, the maximum expected soil concentration in the top 12 inches of
19  soil is about 0.13 (0.010 to 0.28) mg a.e./kg soil (dry weight).

20  ### 4.2.6. Aquatic Organisms
21  The concentrations of fluazifop in surface water used to estimate exposures for aquatic species
22  are identical to those used in the human health risk assessment, as discussed in Section
23  3.2.3.4.6.1 and summarized in Table 20.
24

## 4.3. DOSE-RESPONSE ASSESSMENT

### 4.3.1. Overview

An overview of the toxicity values used in the ecological risk assessment is given in Table 33. The derivation of each of these values is discussed in the following subsections. The available toxicity data support separate dose-response assessments in eight classes of organisms: terrestrial mammals, birds, terrestrial invertebrates (honeybees, other sensitive insects, and earthworms), terrestrial plants, fish, aquatic invertebrates, aquatic algae, and aquatic macrophytes. Different units of exposure are used for different groups of organisms, depending on the nature of exposure and the way in which the toxicity data are expressed. To maintain consistency with the exposure assessment, which is necessary for the development of hazard quotients (HQs) in the risk characterization (Section 4.4.), all toxicity values given in Table 33 are expressed as acid equivalents (a.e.).

### 4.3.2. Toxicity to Terrestrial Organisms

#### *4.3.2.1. Mammals*

In characterizing risk to mammalian wildlife, Forest Service risk assessments generally consider the NOAELs on which the acute and chronic RfDs used in the human health risk assessment are based. As summarized in Table 22 and discussed in Section 3.3, the acute RfD is based on a NOAEL of 50 mg a.i./kg bw fluazifop-butyl from a developmental study in rats in which the LOAEL (based on diaphragmatic hernias in offspring) is 200 mg a.i./kg bw (MRIDs 00088857 and 00088858). For acute exposure scenarios for mammalian wildlife, the NOAEL of 50 mg a.i./kg bw is adjusted to units of acid equivalents and rounded to two significant places—i.e., 50 mg a.i./kg bw x 0.854 a.e./a.i. = 42.7 mg a.e./kg bw ≈ 43 mg a.e./kg bw.

As also summarized in Table 22 and discussed in Section 3.3, the chronic RfD is based on a NOAEL of 0.74 mg a.i./kg bw/day fluazifop-butyl, also from a developmental study in rats in which the LOAEL (based on decreased testes weight) is 5.8 mg/kg bw/day (MRIDs 000088859, 92067022, and 92067050). As with the acute NOAEL, the chronic NOAEL is adjusted to acid equivalents—i.e., 0.74 mg a.i./kg bw/day x 0.854 a.e./a.i. = 0.63196 mg a.e./kg bw—and rounded to two significant places.

With any weak acid, there is a concern that dogs and perhaps other canid species could be more sensitive than other mammals, because canids do not excrete weak acids as well as other mammals (e.g., SERA 2011d). This is not the case for fluazifop acid. As discussed in the human health risk assessment, dogs appear to be less sensitive than rats to fluazifop-butyl (Section 3.1.5), and the excretion of fluazifop by dogs is comparable to that in humans (Section 3.1.3.3). Consequently, the acute NOAEL of 43 mg a.e./kg bw and the chronic NOAEL of 0.63 mg a.e./kg bw/day are used for canids without modification.

It should be noted that the dose-response assessment for mammals differs from the dose-response assessment used by U.S. EPA/OPP/EFED (2008, pp. 54-55). For acute exposures, the EPA uses the oral $LD_{50}$ of 1940 mg a.i./kg bw (MIRD 00162439). The use of an $LD_{50}$ is a standard practice by U.S. EPA/OPP/EFED. The Forest Service prefers to use an acute NOAEL rather than an acute $LD_{50}$ for risk characterization (SERA 2009).

1  In U.S. EPA/OPP/EFED (2008), the approach for chronic exposures is unclear.  In Table 3-7 of
2  the EPA risk assessment, a NOAEL of "0.74 ppm a.i." from MRID 92067050 is designated (U.S.
3  EPA/OPP/EFED 2008, p. 55).  This value is functionally identical to the 0.74 mg a.i./kg bw/day
4  dose used in the current risk assessment, as discussed above.  In the derivation of mammalian
5  risk quotients, however, the EPA designates a 2-generation reproduction NOAEL of "14.8 ppm"
6  (U.S. EPA/OPP/EFED 2008, p. 74, Table 4-5).  This value appears to be derived from the
7  NOAEL for female rats in the 2-generation reproduction study (MRID 00088859, 92067050)—
8  i.e., [17.5 mg a.i./kg bw/day x 0.854 a.e./a.i. = 14.945 mg a.e./kg bw/day.].

9      ***4.3.2.2. Birds***

10          **4.3.2.2.1. Acute Exposures**
11  The available toxicity studies in birds consist of standard assays submitted to the U.S. EPA/OPP
12  in support of the registration of fluazifop-p-butyl (Section 4.1.2.2.1) as well as a few publications
13  in the open literature (Section 4.1.2.2.2).  The latter group of studies, however, is not useful for
14  deriving toxicity values.
15
16  As noted in Section 4.1.2.2.1, the EPA uses an acute oral $LC_{50}$ of 20,767 ppm (a.i.) for the
17  development of acute dietary risk quotients for birds (U.S. EPA/OPP/EFED 2008, p. 73, Table 4-
18  4).  As in the dose-response assessment for mammals, the Forest Service prefers to use acute
19  NOAECs rather than $LC_{50}$ values.
20
21  As summarized in Appendix 2 (Table A2-2), dietary NOAELs range from 2545 ppm a.e. in
22  mallards (MRID 40859401) to 6996 ppm a.e. in pheasants (ECOTOX 2013).  For the current
23  Forest Service risk assessment, the lower NOAEL of 2545 ppm a.e. (2545 mg a.e./kg food) for
24  mallards is used.  No information is available on the food consumption during the mallard study.
25  Taking a food consumption value of 0.42 kg food/kg body weight from an acute dietary study in
26  mallards with aminopyralid (SERA 2007b), the dose for the mallards is taken as 1069 mg a.e./kg
27  bw [2545 mg a.e./kg food x 0.42 kg food/kg body weight = 1068.9 mg a.e./kg bw].  Gavage
28  dosing is more stressful to animals than dietary exposures; hence, NOAELS for gavage
29  administration are generally lower than those for short-term dietary exposures.  This is not the
30  case with fluazifop-P-butyl.
31
32  As summarized in Appendix 2 (Table A2-1), a gavage NOAEL of about 3528 mg a.e./kg bw is
33  available for mallards (MRID 40829201).  Thus, the estimated NOAEL of 1069 mg a.e./kg bw
34  from the dietary study may be viewed as conservative and perhaps overly so.  Conversely, a
35  concern with using default values for food consumption concerns the possible impact of
36  fluazifop-butyl on food consumption in birds.  Based on the DER for a different acute dietary
37  study in mallards (MRID 00087481, Ross et al. 1980a), food consumption in mallards was
38  substantially reduced at dietary concentrations of fluazifop-butyl as low as 6554 ppm (a.i.),
39  corresponding to about 5600 ppm (a.e.).  Food consumption data are not reported in the DERs or
40  other study summaries for any of the acute dietary studies in birds.  If food consumption were
41  reduced in MRID 40829201, the dietary NOAEL expressed as mg a.e./kg bw would be
42  underestimated.

1   **4.3.2.2.2. Longer-term Exposures**
2   As summarized in Appendix 2 (Table A2-3), the only longer-term studies in birds are the
3   standard avian reproduction studies in mallards and quail, both of which yield a dietary NOAEL
4   of 50 ppm a.i. or 43 ppm a.e. (43 mg a.e./kg food).  The chronic NOAEL of 50 ppm a.i. is used
5   in U.S. EPA/OPP/EFED (2008, p. 73, Table 4-4) in the development of chronic risk quotients for
6   birds.
7
8   Based on the average of the reported food consumption and body weights for birds in the DERs
9   for these studies, the dietary concentration of 43 mg a.e./kg food corresponds to about 4.9 mg
10  a.e./kg bw/day for mallards and 3.3 mg a.e./kg bw/day for quail.  For characterizing risks to birds
11  associated with longer-term exposures, the somewhat lower NOAEL for quail is used in the
12  current risk assessment.

13  *4.3.2.3. Reptiles and Amphibians (Terrestrial Phase)*
14  Since toxicity data are not available for terrestrial-phase reptiles or amphibians (Section 4.1.2.3),
15  no dose-response assessment can be derived for these groups of organisms.

16  *4.3.2.4. Terrestrial Invertebrates*
17  In most Forest Service risk assessments as well as EPA risk assessments the honeybee is used as
18  a surrogate species for terrestrial insects. Often, the honeybee bioassays are the only toxicity data
19  for terrestrial invertebrates.  For fluazifop-P-butyl, however, data are available on other species
20  of insects as well as earthworms.  These three sets of data are considered separately in the
21  following subsections and are used separately in the risk characterization (Section 4.4.2.4).

22  **4.3.2.4.1. Honeybee (Standard Surrogate Species)**
23  As discussed in Section 4.1.2.4 and summarized in Appendix 3, standard oral and contact
24  bioassays are available in honeybees.  These studies are summarized in U.S. EPA/OPP/EFED
25  2008 (Appendix C), and additional details on NOAELs are available in ECOTOX.  In the
26  ecological risk assessment (U.S. EPA/OPP/EFED 2008, p. 73, Table 4-3), the EPA uses the
27  acute contact $LD_{50}$ of 63 µg a.i./bee (MRID 00162453) to estimate risk quotients for the
28  consumption of contaminated vegetation and fruit by a terrestrial insect.  As discussed in Section
29  4.1.2.4.1, ECOTOX indicates a NOAEL for this study of 200 µg/bee, which appears to be an
30  error; accordingly, this NOAEL is not used in the current Forest Service risk assessment.  In
31  addition, the formulation used in this study (13.8% a.i.) corresponds to Fusilade Max but not
32  formulations that will be used in Forest Service programs—i.e., 24.5% a.i. formulations such as
33  Fusilade DX and Fusilade II.  Consequently, the contact $LD_{50}$ of 63 µg a.i./bee from MRID
34  00162453 is not used in the current Forest Service risk assessment because studies on other
35  formulations more similar to those that might be used in Forest Service programs are available.
36
37  As with other receptors considered in the current risk assessment, the Forest Service prefers to
38  use NOAELs rather than $LD_{50}$ values for risk characterization (SERA 2009).  For the current risk
39  assessment, the oral NOAEL of 85.4 µg a.e./bee (MRID 00093809) for a 25% EC formulation of
40  fluazifop-butyl is used to characterize risks associated with oral exposures.  While the specific
41  formulation used in this study is not identified, the 25% a.i. formulation is similar to
42  formulations that might be used in Forest Service programs.  Typical body weights for worker
43  bees range from 81 to 151 mg (Winston 1987, p. 54).  Taking 116 mg as an average body

1     weight, a dose of 85.4 µg/bee corresponds to about 736 mg a.e./kg bw [0.0854 mg a.e. ÷
2     0.000116 kg ≈ 736.207 mg/kg bw].
3
4     For direct spray and drift exposure scenarios, the current risk assessment uses the contact
5     NOAEL of 81µg a.e./bee from MRID 00093809, which also used a 25% EC formulation of
6     fluazifop-butyl. Taking the same approach used with the oral toxicity study, the dose to the bee
7     is estimated as 698 mg a.e./kg bw [0.081 mg a.e. ÷ 0.000116 kg ≈ 698.276 mg/kg bw].

8              **4.3.2.4.2. Other Terrestrial Arthropods**
9     In addition to the standard toxicity studies on the honeybee, additional data on terrestrial
10     arthropods include what appear to be standard bioassays (Section 4.1.2.4.2; Appendix 3, Table
11     A3-2) as well as field/mesocosm studies (Section 4.1.2.4.3; Appendix 3, Table A3-3). Most of
12     the information on other terrestrial arthropods appears to have been generated after the recent
13     EPA ecological risk assessments, (U.S. EPA/OPP/EFED 2008, 2010a), and the discussions of
14     risks to insects in the EPA risk assessments include only the toxicity data on bees.
15
16     As discussed in Section 4.1.2.4.2, the most sensitive terrestrial arthropod (based on mortality)
17     appears to be *Typhlodromus pyri* [Acarina: Phytoseiidae] with a reported $LD_{50}$ of 5.6 g a.i./ha or
18     about 0.004 lb a.e./acre (EFSA 2012). As noted in Appendix 3 (Table A3-2), this study involved
19     Fusilade Max. As noted in the previous discussion of honeybees (Section 4.3.2.4.2), Fusilade
20     Max appears to be more toxic than 25% a.i. formulations to the honeybee. In the absence of data
21     on the effects of 25% a.i. formulations on *Typhlodromus pyri*, the studies on Fusilade Max from
22     EFSA (2012) are used in the current risk assessment.
23
24     EFSA (2012) also reports another and a much higher $LD_{50}$ of 174 g a.i./ha (≈0.13 lb a.e./acre) for
25     *Typhlodromus pyri*. As noted in Section 4.1.2.4.2, EFSA (2012) does not discuss the
26     discrepancy between the reported $LD_{50}$ of 5.6 g a.i. and the much higher $LD_{50}$ of 177 g a.i./ha
27     (≈0.13 lb a.e./acre), presumably from the *extended laboratory studies*. The lower $LD_{50}$ is about a
28     factor of 74 higher than the application rate of 0.32 lb a.e./acre being considered by the Forest
29     Service [0.32 lb a.e./acre ÷ 0.0043 lb a.e./acre ≈ 74.4186]. The higher $LD_{50}$ is a factor of about
30     2.5 higher than this application rate [0.32 lb a.e./acre ÷ 0.13 lb a.e./acre ≈ 2.4615]. These
31     differences obviously have a substantial impact on risk characterization.
32
33     The magnitude of the difference between the lower and higher $LD_{50}$ values for *Typhlodromus*
34     *pyri* is a factor of over 30 [177 g a.i./ha ÷ 5.6 g a.i./ha ≈ 31.607]. While details of the two
35     experiments (or sets of experiments) with *Typhlodromus pyri* are not available, the difference in
36     the $LD_{50}$ values between the two studies appears to be beyond the range of normal variability,
37     and it seems likely that the two studies used different protocols. In the absence of additional
38     information, the more relevant study cannot be identified. Consequently, the risk
39     characterizations for potentially sensitive terrestrial insects will be based on both the lower $LD_{50}$
40     of 0.004 lb a.e./acre and the higher $LD_{50}$ of 0.13 lb a.e./acre (Section 4.4.2.4.2). Note that the
41     higher $LD_{50}$ for *Typhlodromus pyri* (177 g a.i./ha) is very close to the $LD_{50}$ of 0.137 lb a.e./acre
42     for *Aphidius rhopalosiphi* [Hymenoptera: Aphidiinae] reported in EFSA (2012).
43
44     Other species of terrestrial arthropods appear to be much more tolerant to fluazifop-P-butyl.
45     Presumably, the increased mortality (21%) in larvae of the small cabbage white butterfly
46     reported in the study by Russell and Schultz (2010) is associated with an application rate of 0.32

lb a.e./acre.  While this study does not demonstrate a dose-response relationship (i.e., only a single dose was used), the mortality in this study is supported by $LD_{50}$ values in more tolerant species from the review by EFSA (2012).  The potential effects of fluazifop-P-butyl on more tolerant species of insects are handled qualitatively in the risk characterization (Section 4.4.2.4.2).

The field studies by Blake et al. (2011a,b) clearly indicate that applications of fluazifop-P-butyl may enhance the growth of wildflowers and that this form of vegetation management can benefit several groups of insects including bees and butterflies.  These types of field studies do not, however, contradict the toxicity data.  Consequently, the field studies by Blake et al. (2011a,b) are not used quantitatively in the dose-response assessment but are considered qualitatively in the risk characterization (Section 4.4.2.4.2).

### 4.3.2.4.3. Earthworm
As discussed in Section 4.1.2.4.4, screening studies summarized by EFSA (2012) indicate no adverse effects on earthworms at soil concentrations of >1000 mg/kg (dry weight) for either fluazifop-butyl or 5-trifluoromethyl-2-pyridone (Metabolite X).  A formal dose-response assessment for earthworms is not conducted in the current risk assessment due to the limited nature of the available toxicity data and the lack of experimental details on these studies.  Nonetheless, the NOAECs are considered further in the risk characterization for earthworms, relative to the concentrations of fluazifop-P-butyl likely to occur in soil (Section 4.4.2.4.3).

### *4.3.2.5. Terrestrial Plants (Macrophytes)*
The dose-response assessment for terrestrial plants in most Forest Service risk assessments is based on standard registrant-submitted phytotoxicity studies, and the species and endpoints selected for the dose-response assessment are typically those used by the U.S. EPA/OPP/EFED.  As detailed in Section 4.1.2.5, however, this approach cannot be used for fluazifop-P-butyl because the EPA did not require standard phytotoxicity studies.  In the ecological risk assessments from EPA (U.S. EPA/OPP/EFED 2008, 2010a), risks to nontarget plants are addressed qualitatively—i.e., risks to monocots are presumed and risks to dicots are classified as minimal (e.g., U.S. EPA/OPP/EFED 2008, p. 9).

Notwithstanding the above assessment from EPA, the available toxicity data on fluazifop-P-butyl and fluazifop-butyl support a dose-response assessment in terrestrial plants at least to the level of defining exposures for sensitive and tolerant groups of terrestrial plants.  The only substantial elaboration of the EPA's qualitative assessment is that the sensitivity of monocots is limited to true grasses (Section 4.1.2.5.2.2.1) and does not appear to extend to other monocots (Section 4.1.2.5.2.2.2).  The toxicity values selected below are based on the toxicity values summarized in Table 26 with additional details from Appendix 4 (Tables A4-1 to A4-6).

### 4.3.2.5.1. Sensitive Monocots (Poaceae)
True grasses (i.e., members of Poaceae/Gramineae family) are defined as sensitive species.  Apparently due to the high toxicity of fluazifop-P-butyl to true grasses, clear NOAECs for true grasses have not been determined.  Consequently, $EC_{50}$ values or LOAECs are used rather than NOAECs for true grasses.

Based on information in the review by EFSA (2012), corn appears to be the most sensitive species of Poaceae with an $EC_{50}$ for growth of 0.0091 kg a.i./ha. This $EC_{50}$ is supported by LOAELs for several other Poaceae in the range of 0.02 to 0.04 kg a.i./ha. The $EC_{50}$ for corn is equivalent to about 0.007 lb a.e./acre [0.0091 kg a.i./ha x 0.892 ha/acre x 0.854 a.e./a.i. $\approx$ 0.006932 lb a.e./acre]. Forest Service risk assessments seldom use $EC_{50}$ or similar estimates (e.g., $LD_{50}$) for risk characterization and often divide values such as an $EC_{50}$ by factors of 10 to 20 to estimate an NOAEC. This approach is not taken for fluazifop-P-butyl. As detailed further in Section 4.4.2.5, the risk characterization for exposures in sensitive species of monocots is unambiguous; hence, there would be little purpose in attempting to estimate a NOAEC, given the substantial body of information on fluazifop-P-butyl, which failed to define an NOAEC in sensitive species/populations of Poaceae.

For soil applications (which are relevant for the assessment of offsite nontarget damage to plants due to runoff losses), a LOAEL of 0.035 kg a.i./ha in goosegrass, crabgrass, and giant foxtail is used from the study by Derr et al. (1985c). This LOAEL may be considered as severe if not more so than an $EC_{50}$ in that the exposure was associated with 73-95% control of the target grasses. Somewhat higher LOAELs ($\approx$0.094 kg a.i./ha) are available from the study by Blake et al. (2012) on several other Poaceae. The application rate of 0.035 kg a.i./ha is equivalent to about 0.027 lb a.e./acre [0.035 kg a.i./ha x 0.892 ha/acre x 0.854 a.e./a.i. $\approx$ 0.0266619 lb a.e./acre].

As summarized in Table 26, not all Poaceae are as sensitive to fluazifop-P-butyl as the sensitive species/populations of Poaceae used in the above dose-response assessment. The distinction between sensitive and tolerant species/populations of Poaceae is discussed further in the risk characterization (Section 4.4.2.5).

### 4.3.2.5.2. Tolerant Terrestrial Plants

As summarized in Table 26 and discussed in Section 4.1.2.5.2, the preponderance of the reasonably extensive information on the toxicity of fluazifop-butyl and fluazifop-P-butyl to non-Poaceae indicates that these plants are tolerant, and most often highly tolerant. The tolerant plants include non-Poaceae monocots as well as dicots. Based on a single study in a fern (*Pteridophyte* sp.), these organisms also appear to be highly tolerant of exposures to fluazifop-P-butyl.

For foliar exposures, a NOAEC of 1 kg a.i./ha or about 0.76 lb a.e./acre is used for the risk characterization for typically tolerant species of terrestrial plants [1 kg a.i./ha x 0.892 ha/acre x 0.854 a.e./a.i. = 0.761768 lb a.e./acre]. As summarized in Table 26, the application rate of about 1 kg a.e./ha is well-documented as an NOAEC for non-Poaceae monocots as well as dicots in both greenhouse studies (Haga et al.1987; Blake et al. 2012) and field studies (Appendix 4, Table A4-6).

While few studies are available on pre-emergent and/or soil exposures relative to the numerous studies on foliar/post-emergent exposures, the studies by both Rokich et al. (2009) and Blake et al. (2012) support a pre-emergent NOAEC of 0.75 kg a.i./ha, which is equivalent to about 0.57 lb a.e./acre [0.75 kg a.i./ha x 0.892 ha/acre x 0.854 a.e./a.i. = 0.571326 lb a.e./acre]. Thus, 0.57 lb a.e./acre is taken as a NOAEC for pre-emergent exposures in typically tolerant species of non-Poaceae monocots and dicots.

1

2 Some dicots may evidence transient damage from fluazifop-P-butyl at levels of exposure
3 substantially below the above toxicity values. For example, Blake et al. (2012) noted transient
4 damage (e.g., chlorosis) in red clover following an application of fluazifop-P-butyl at rates as
5 low as 0.1 kg a.i./ha ($\approx$ 0.07 lb a.e./acre). As with tolerant or resistant Poaceae
6 (Section 4.3.2.5.1), issues associated with atypically sensitive non-Poaceae are discussed further
7 in the risk characterization (Section 4.4.2.5).

### 4.3.2.6. Terrestrial Microorganisms

9 As discussed in Section 4.1.2.6, the paper by Abdel-Mallek et al. (1996) is the most relevant
10 study for assessing potential risks in soil microorganisms and defines a NOAEC for soil fungi of
11 0.6 mg/kg soil (dry weight). This is the only bioassay of microorganisms in a soil matrix. EFSA
12 (2012) notes effects on nitrogen and carbon mineralization following an application rate of about
13 2.86 lb a.e./acre but the relevance of these effects to the much lower registered application rates
14 for fluazifop-P-butyl (i.e., up to 0.32 lb a.e./acre) is unclear.

## 4.3.3. Aquatic Organisms

### 4.3.3.1. Fish

17 As discussed in Section 4.1.3.1, there is a relatively standard set of acute and early life stage studies
18 on fluazifop-P-butyl as well as related compounds and formulations. U.S. EPA/OPP/EFED (2008,
19 pp. 71-72) uses the $LC_{50}$ of 0.32 mg a.e./L to characterize acute risks to freshwater fish and the
20 NOAEC of $\geq$0.203 mg a.e./L from an early life stage study to assess longer-term risks to freshwater
21 fish. Both of these studies involved fathead minnows and are attributed to MRID 00093808.

22

23 U.S. EPA/OPP/EFED (2008) derives separate toxicity values for saltwater/estuarine fish. Deriving
24 separate toxicity values for freshwater and saltwater organisms is a standard practice in EPA
25 ecological risk assessments. Because of the many potential nontarget species relative to the number
26 of species on which toxicity data are available, Forest Service risk assessments will generally select
27 the most sensitive as well as the most tolerant species (freshwater or saltwater) for the dose-response
28 assessment unless there is a clear reason to do otherwise.

### 4.3.3.1.1. Acute Toxicity

30 As summarized in Table 27, the $LC_{50}$ of 0.32 mg a.e./L is the lowest reported $LC_{50}$ in the studies
31 reviewed by the EPA. In the paper from the open literature, Tejada et al. (1994) report a modestly
32 lower $LC_{50}$ of 0.25 mg a.e./L in the Nile tilapia. Tejada et al. (1994), however, do not report an
33 NOAEC. The current Forest Service risk assessment will use the acute NOAEC of 0.203 mg a.e./L
34 for fathead minnows—i.e., the NOAEC from the acute study used by U.S. EPA—to characterize
35 risks to sensitive species of fish following acute exposures. For tolerant species, the acute NOAEC
36 of 0.68 mg a.e./L for technical grade fluazifop-butyl in rainbow trout is used for risk characterization.
37 This may be viewed as somewhat conservative in that higher NOAECs are available for formulations
38 of fluazifop-butyl and still higher NOAECs are available for sheepshead minnow (an
39 estuarine/saltwater species). Given the lack of experimental detail available on the studies in fish,
40 this modestly conservative approach appears justified.

### 4.3.3.1.2. Chronic Toxicity

42 For longer-term exposures, the current risk assessment will use the NOAEC of 0.203 mg a.e./L from
43 the early life stage study in the fathead minnow. Given the patterns of toxicity in the acute studies

1  (i.e., fathead minnows appear to be sensitive species based on acute toxicity studies), the longer-term
2  NOAEC in fathead minnows is applied to sensitive species.
3
4  U.S. EPA/OPP/EFED (2008, pp. 72) uses a relative potency method to approximate a longer-term
5  NOAEC of 4.3 mg a.e./L in sheepshead minnow. As detailed in U.S. EPA/OPP/EFED (2008, p. 23,
6  footnote 1), this approximation involves multiplying the longer-term NOAEC in the fathead minnow
7  by the ratio of the lowest $LC_{50}$ in sheepshead minnows (6.86 mg a.e./L) to the corresponding $LC_{50}$ in
8  fathead minnows (0.32 mg a.e./L) to [0.203 x 6.86 ÷ 0.32 ≈ 4.3518]. This approach is not used in the
9  current risk assessment. As detailed further in Section 4.4.3.1, none of the longer-term exposures in
10 fish exceed the level of concern for the presumably sensitive species. Thus, an extrapolated
11 elaboration for presumably tolerant species of fish is unnecessary.

12  *4.3.3.2. Amphibians*
13 As noted in Section 4.1.3.2, no information is available on the toxicity of fluazifop-butyl or
14 fluazifop-P-butyl to aquatic-phase amphibians. Consequently, no dose-response assessment is
15 proposed for this group of organisms.

16  *4.3.3.3. Aquatic Invertebrates*

17      **4.3.3.3.1. Acute Toxicity**
18 U.S. EPA/OPP/EFED (2008, pp. 71-72) uses an $EC_{50}$ value of 5.14 mg a.e./L (*Daphnia magna*,
19 MRID 00087489) for characterizing risks to sensitive species of freshwater invertebrates and an
20 $EC_{50}$ value of 0.083 mg a.e./L (Pacific oyster, MRID 00131460, 98.6% fluazifop-butyl) for
21 assessing risks to sensitive species of aquatic invertebrates.
22
23 As summarized in Table 28, acute toxicity data are available on one species of freshwater
24 invertebrate (*Daphnia magna*) and five species of saltwater/estuarine invertebrates (Pacific
25 oyster, American oyster, fiddler crab, pink shrimp and opossum shrimp). Given the much larger
26 number of aquatic invertebrates that might be exposed to any pesticide, Forest Service risk
27 assessments will typically identify the most sensitive and most tolerant invertebrates on which
28 data are available as representative of sensitive and tolerant organisms in freshwater and
29 saltwater.
30
31 Based on the $EC_{50}$ values, the most sensitive species is the Pacific oyster. Rather than using the
32 $EC_{50}$ of 0.083 mg a.e./L, the current risk assessment will use the NOAEC of 0.048 mg a.e./L. A
33 modestly lower NOAEC of 0.041 mg a.e./L is reported for opossum shrimp (MRID 00093806).
34 The difference between these two NOAECs is insubstantial and preference is given to the
35 NOAEC for the Pacific oyster both to maintain consistency with the EPA study selection and
36 because $EC_{50}$ values are preferable to NOAECs in ranking species sensitivities. In the absence
37 of additional details on the studies in question—e.g., the number and spacing of concentrations
38 tested—this approach seems reasonable.
39
40 The highest acute $EC_{50}$ values are reported for bioassays of technical grade fluazifop-butyl and
41 fluazifop-P-butyl in *Daphnia magna*—i.e., $EC_{50}$ values of >200 mg a.e./L as summarized in
42 Table 28. Unlike the case with fish, however, the available data indicate that fluazifop-P-butyl
43 formulations are much more toxic (i.e., $EC_{50}$ values in the range of 1.79 to 5.14 mg a.e./L) than
44 unformulated fluazifop-P-butyl. Because acute exposures will most likely involve the

formulated product, the acute toxicity data on technical grade fluazifop-butyl are not considered further for the dose-response assessment.

As summarized in Table 28, the only formulation acute $LC_{50}$ with a corresponding NOAEC for *Daphnia magna* is 5.14 mg a.e./L (MRID 00087489).  As noted above, this is the study used by U.S. EPA/OPP/EFED (2008) for the dose-response assessment for freshwater invertebrates.  For the current risk assessment, the NOAEC of 1.07 mg a.e./L is used to characterize risks for tolerant species of aquatic invertebrates.

### 4.3.3.3.2. Chronic Toxicity

The longer-term toxicity studies on fluazifop-butyl, fluazifop-P-butyl, and formulations are summarized in Table 29.  The U.S. EPA/OPP/EFED (2008, Table 4-2, p. 72) uses the reproduction NOAEC of 0.0148 mg a.e./L for opossum shrimp (MRID 00093805) to assess risks to estuarine/marine invertebrates and the reproduction NOAEC of 0.0854 mg a.e./L to assess risks to freshwater aquatic invertebrates (MRID 00093807).

As with the ecological risk assessment from EPA, the current Forest Service risk assessment uses the reproduction NOAEC of 0.0148 mg a.e./L for opossum shrimp (MRID 00093805) to characterize risks of longer-term exposures for sensitive species of aquatic invertebrates and the NOAEC of 0.0854 mg a.e./L to characterize risk for more tolerant species of aquatic invertebrates.

Given that there are only two species on which longer-term toxicity data are available and given that the range of reported NOAECs varies by only a factor of about 6 [0.0854 mg a.e./L ÷ 0.0148 mg a.e./L ≈ 5.7703], there is no expectation that the available data will necessarily encompass the variability that could be evidenced in several aquatic invertebrates which might be exposed to fluazifop-P-butyl.

### *4.3.3.4. Aquatic Plants*

As summarized in Table 30 and discussed in Section 4.1.3.4, several bioassays are available on the toxicity of fluazifop-P-butyl and related compounds to algae and three bioassays are available on the toxicity of fluazifop-P-butyl to aquatic macrophytes.  This literature is not addressed in U.S. EPA/OPP/EFED (2008; 2010a), the EPA ecological risk assessments on fluazifop-P-butyl.  Consequently, the following sections contain no discussion of concordance with the EPA risk assessments.

### 4.3.3.4.1. Algae

The data on algae are highly variable and, as discussed in Section 4.1.3.4, this could be due to differences in species sensitivities, differences in the toxicity of different formulations, a combination of these factors, or other factors that cannot be identified from the available summaries.  The only clear pattern based on the summaries from EFSA (2012) is that Fusilade Max is much more toxic than technical grade fluazifop-P-butyl.  The greater toxicity of Fusilade Max relative to other formulations has been discussed previously with respect to honeybees (Section 4.1.2.4.1).

For sensitive species, the $EC_{50}$ of 0.02 mg a.e./L for Fusilade Max assayed in *Pseudokirchneriella subcapitata* (EFSA (2012) is the lowest reported $EC_{50}$ for fluazifop-P-butyl

or other fluazifop-P-butyl formulations.  As noted above, Fusilade Max appears to be more toxic to honeybees than Fusilade formulations that are representative of formulations that the Forest Service proposes to use (Section 4.1.2.4.1).  In the absence of information on the toxicity of Fusilade DX or Fusilade II to algae, however, the $EC_{50}$ of 0.02 mg a.e./L is used in the current risk assessment to characterize risks in sensitive species of algae.  In the absence of a NOAEC from this study, the $EC_{50}$ is divided by 20 to approximate an NOAEC (SERA 2011a, Section 4.3.2, p. 98).  Thus, the NOAEC for *Pseudokirchneriella subcapitata* is estimated as 0.001 mg a.e./L.

Based on the series of studies by Ma and coworkers, the highest $EC_{50}$ is 22.8 mg a.e./L—i.e., the $EC_{50}$ for *Scenedesmus obliquus* using a 53% a.i. formulation, presumably from China.   As with potentially sensitive species, the $EC_{50}$ is divided by 20 and the NOAEC is estimated as 1.14 mg a.e./L.

The need to use toxicity data for formulations other than those likely to be used by the Forest Service and the need to extrapolate an NOAEC from an $EC_{50}$ greatly diminish confidence in the risk assessment for potentially sensitive and tolerant species of algae.  This is emphasized further in the risk characterization (Section 4.4.3.4.1).

### 4.3.3.4.2. Aquatic Macrophytes
The available data on aquatic macrophytes is sparse—i.e., limited to two indefinite $EC_{50}$ values in *Lemna gibba* from EFSA (2012) and one reported NOAEC in *Lemna paucicostata* from Michel et al. (2004).  The paper by Michel et al. (2004) is essentially a methods development paper in a species of *Lemna* that is not commonly used in risk assessment.  While the bioassay on fluazifop-P-butyl is not described in detail, the publication does clearly indicate that fluazifop-P-butyl caused no effect at a concentration of 1,000 µM (Michel et al. 2004, Table 2, p. 1076 of paper), equivalent to about 327 mg a.e./L.  This documentation is superior to the brief summaries in EFSA (2012) of the bioassays in the more commonly used species, *Lemna gibba*.  Consequently, the concentration of 327 mg a.e./L is used in the current risk assessment.

Because no data are available on other species of aquatic macrophytes, the NOAEC of 327 mg a.e./L is considered applicable to apparently tolerant species.  In the absence of additional data, no dose-response assessment is proposed for potentially sensitive species of aquatic macrophytes.  As discussed further in Section 4.4.3.4.2, potentially sensitive species of aquatic macrophytes would include aquatic Poaceae monocots.

1    **4.4. RISK CHARACTERIZATION**

2      **4.4.1. Overview**
3    Fluazifop-P-butyl is an effective herbicide for the control of many annual and perennial grass
4    weeds (i.e., Poaceae monocots); however, it is much less toxic to dicots and non-Poaceae
5    monocots.  Consequently, applications of fluazifop-P-butyl do not appear to pose a risk to
6    terrestrial dicots or non-Poaceae monocots.  This risk characterization is supported by several
7    field studies.  Consistent with the labelled uses of fluazifop-P-butyl, this herbicide is more toxic
8    in post-emergent foliar applications than pre-emergent/soil applications.  Drift is the scenario of
9    greatest concern for nontarget sensitive Poaceae monocots.  Adverse effects in sensitive species
10   of nontarget plants (Poaceae) could also occur in some cases if contaminated water is used for
11   irrigation.  Runoff and wind erosion of soil from the treated site do not appear to pose risks to
12   nontarget plants.
13
14   The risk characterization of mammals and birds is constrained by the lack of field studies
15   involving exposure of mammals and birds to applications of fluazifop-P-butyl.  Consequently,
16   the risk characterization is based solely on laboratory studies and modeled estimates of exposure.
17   Longer-term exposures to mammals and birds are a concern for exposure scenarios involving the
18   consumption of contaminated vegetation.  Following three applications, the upper bound HQs
19   reach to 57 for a small bird and 146 for a small mammal.  Following one or two applications, the
20   central estimates of the HQs are lower, but some scenarios exceed the level of concern (HQ=1).
21   The HQs for mammals are of greater concern because of a possible association between
22   exposure levels and endpoints involving reproductive capacity (i.e., decreased testes weight).
23   There are no data to suggest that levels of long-term exposure to fluazifop-P-butyl will cause
24   adverse effects in birds.  Furthermore, acute exposures associated with the consumption of
25   contaminated vegetation by birds do not appear to pose a hazard.  For mammals, some of the
26   acute HQs associated with the consumption of contaminated vegetation exceed the level of
27   concern (i.e., a maximum HQ of 7).  The highest levels of exposure are associated with the
28   consumption of contaminated short grasses, which enhances the level of concern for acute
29   exposures, because fluazifop-P-butyl is applied to grasses.  For chronic exposures, the
30   consumption of treated contaminated grasses is less plausible, because fluazifop-P-butyl will kill
31   most treated grasses with the exception of resistant grasses.  Exposure scenarios for mammals
32   and birds involving contaminated water are of much less concern than those associated with
33   contaminated vegetation.  This is a common pattern in herbicide risk assessments.  Some
34   scenarios for the consumption of contaminated fish by a canid, large mammalian carnivore, and
35   piscivorous bird result in HQs that exceed the level of concern at the upper bounds of estimated
36   exposures.
37
38   For most herbicides, risks to terrestrial invertebrates are characterized using toxicity data on the
39   honeybee as a surrogate species.  Based on these data, no risks to terrestrial insects would be
40   anticipated.  For fluazifop-P-butyl, however, toxicity data are available from the European
41   literature, and some mesocosm and field studies are published in the open literature.   Based on
42   the results of one bioassay on a predatory mite (*Typhlodromus pyri*), risks to sensitive species of
43   terrestrial arthropods could be substantial (i.e., an HQ of 80 for direct spray).   Based on another
44   bioassay in this species as well as toxicity data on other terrestrial arthropods, risks are apparent
45   but could be much lower (i.e., an HQ of 2 for direct spray).  Many of the most relevant studies

are summarized only briefly in a review by the European Food Safety Authority (EFSA 2012). The full studies summarized in EFSA (2012) were not available for the preparation of the current risk assessment and no interpretation of the inconsistent toxicity data on *Typhlodromus pyri* can be offered. Published field studies indicate that applications of fluazifop-P-butyl used to enhance the growth of wildflowers can be beneficial to both bees and butterflies. These field studies, however, do not exclude the possibility of direct adverse effects in sensitive species of insects.

The risk characterization for aquatic plants is variable. The characterization of risks to aquatic macrophytes is limited in that data are available on only one genus, *Lemna*, an aquatic non-Poaceae monocot. No risks to *Lemna* are anticipated, even in the event of an accidental spill. By analogy to the more extensive data on terrestrial plants, it seems likely that risks to aquatic dicots and other non-Poaceae monocots would also be low. In the absence of toxicity data, potential risks to aquatic Poaceae monocots are a concern; however, these risks cannot be assessed quantitatively. Some species of algae do appear to be at risk (HQs up to 150) in non-accidental exposure scenarios. Both sensitive and tolerant species of algae could be adversely affected in the event of an accidental spill.

The risk characterization for aquatic animals is somewhat less variable than that for aquatic plants. Except for an accidental spill, exposure scenarios involving fish do not appear to present a risk. Aquatic invertebrates are more sensitive than fish to fluazifop-P-butyl. While the central estimates and lower bounds of exposures are not a concern, some of the upper bound estimates of exposure lead to HQs (1.4 to 4) that modestly exceed the level of concern (HQ=1).

While relatively little information is available on soil-dwelling organisms including soil microorganisms, this information suggests that fluazifop-P-butyl is not likely to adversely affect this group of organisms.

No data are available on reptiles and terrestrial or aquatic amphibians. Consequently, no risk characterization is developed for these groups of organisms.

While the risk characterization for fluazifop-P-butyl focuses on the potential for direct toxic effects, there is potential for secondary effects in virtually all groups of nontarget organisms. Terrestrial applications of any effective herbicide, including fluazifop-P-butyl, are likely to alter vegetation within the treatment area. This alteration could have secondary effects on terrestrial or aquatic animals, including changes in food availability and habitat quality. These secondary effects may be beneficial to some species (e.g., bees and butterflies as noted above) and detrimental to other species; moreover, the magnitude of secondary effects is likely to vary over time. While these concerns are acknowledged, they are not specific to fluazifop-P-butyl or herbicide applications in general. Any effective method for vegetation management, including mechanical methods which do not involve fluazifop-P-butyl or any other herbicide, could be associated with secondary effects on both nontarget animals and vegetation.

1    **4.4.2. Terrestrial Organisms**

2        *4.4.2.1. Mammals*
3    Table 34 gives an overview of the risk characterization for mammals associated with acute and
4    longer-term exposure scenarios following three applications of fluazifop-P-butyl.  This table is
5    taken from Worksheet G02a of Attachment 3.

6

7    Table 34 does not include the accidental exposure scenarios.  As discussed in Section 4.2.2, the
8    accidental exposure scenarios involve direct spray and the consumption of contaminated water or
9    fish following an accidental spill.  These accidental exposure scenarios are identical for one, two,
10   or three applications.  The only accidental exposure scenarios that exceed the level of concern
11   (HQ=1) are the upper bound HQs for the consumption of contaminated fish by a 5 kg canid
12   (HQ=9) and a 70 kg carnivore (HQ=13).

13

14   For the acute non-accidental exposure scenarios, the central estimates of the HQs are below the
15   level of concern except for the small mammal consuming contaminated grass (central HQ = 1.4).
16   The upper bounds HQs for a small mammal exceeds the level of concern for the consumption of
17   broadleaf vegetation (HQ=4), tall grass (HQ=3), and short grass (HQ=7).  The upper bound HQ
18   for a 400 g mammal consuming short grass (HQ=1.7) also modestly exceeds the level of
19   concern.

20

21   The HQs associated with the longer-term consumption of contaminated vegetation are much
22   higher, reflecting the substantial difference between the acute NOAEC (43 mg a.e./kg bw) and
23   the longer-term NOAEC (0.63 mg a.e./kg bw/day).  Two of the lower bound HQs for a small
24   mammal modestly exceed the level of concern—i.e., an HQ of 1.2 for contaminated broadleaf
25   foliage and an HQ of 2 for contaminated short grass.  Several of the central estimates associated
26   with the consumption of contaminated vegetation exceed the level of concern and some by
27   substantial margins.  The central estimates of the HQs are highest for the small mammal, ranging
28   from 3 for the consumption of contaminated fruit to 26 for the consumption of contaminated
29   short grass.  All of the upper bound HQs for the consumption of contaminated vegetation exceed
30   the level of concern for all receptors (20 g, 400 g, and 70 kg mammals) and all forms of
31   vegetation.  The upper bound HQs range from 1.6 (the consumption of contaminated fruit by a
32   large mammal) to 146 (the consumption of short grass by a small mammal).

33

34   As discussed in Section 3.2.3.7, concern for the longer-term exposure scenarios involving the
35   consumption of contaminated broadleaf vegetation is not reduced because fluazifop-P-butyl is
36   relatively nontoxic to broadleaf vegetation.  Conversely, fluazifop-P-butyl is highly toxic to
37   grasses.  Consequently, concern for the exceedances in exposure scenarios associated with the
38   longer-term consumption of grasses by mammals is reduced.

39

40   In addition to the exposure scenarios for contaminated vegetation, the upper bounds of the HQs
41   for contaminated fish also exceed the level of concern—i.e., an HQ of 7 for a 70 kg carnivore
42   and HQ of 10 for a 5 kg canid.

43

44   As summarized in Table 22 and discussed in Section 3.3, the acute NOAEL of 50 mg a.i./kg bw
45   is derived from a developmental study (submitted in both MRID 00088857 and MRID
46   92067047) with a LOAEL of 200 mg a.i./kg bw.  The HQ associated with this LOAEL is about 4

1  [200 ÷ 50].  The LOAEL is based on diaphragmatic hernias in offspring.  The acute exceedances
2  might be associated with conditions that could impair the ability of offspring to survive and/or
3  develop normally; however, overt signs of toxicity would probably not be observed.  Acute HQs
4  at or above 4 are noted only at upper bound exposures for the small mammal consuming
5  broadleaf vegetation (HQ=4) or short grass (HQ=7).
6
7  The acute risk characterization given above for acute exposure scenarios is not consistent with
8  U.S. EPA/OPP/EFED (2008, p. 7) which notes that *...no acute risks are expected for mammals.*
9  As discussed in Section 4.3.2.1, a major difference between the current Forest Service risk
10  assessment and the EPA risk assessment is the EPA's use of an acute oral $LD_{50}$ of 1940 mg
11  a.i./kg bw (MIRD 00162439) for risk characterization, which is about 39 times greater than the
12  acute NOAEL 50 mg a.i./kg bw used in the current risk assessment [1940 mg a.i./kg bw ÷ 50 mg
13  a.i./kg bw = 38.8].
14
15  As also summarized in Table 22, the longer-term NOAEL of 0.74 mg a.i./kg bw/day is
16  associated with a LOAEL of 5.8 mg a.i./kg bw/day, with a corresponding HQ of about 8 [5.8 mg
17  a.i./kg bw/day ÷ 0.74 mg a.i./kg bw/day ≈ 7.838].  The chronic LOAEL is associated with
18  decreased testes weight in male offspring.  This chronic exceedance could be associated with
19  diminished reproductive capacity.  As with the acute exceedances, there would be no expectation
20  of overt signs of toxicity.
21
22  The risk characterization for longer-term exposures discussed above is reasonably consistent
23  with U.S. EPA/OPP/EFED (2008, p. 7) which notes that *... the chronic mammalian RQ* [risk
24  quotient] *values exceed the Agency's LOC* [level of concern] *for all proposed uses except for*
25  *mammals feeding only on fruits, pods, large insects or seeds.* The minor differences between the
26  current risk assessment and the EPA risk assessment reflect differences in the mammalian
27  receptors that are considered and the methods used to estimate food consumption.
28
29  As discussed in Section 4.2.2.3, the exposure assessments for mammalian wildlife assume that
30  100% of the diet of the receptor is contaminated.  For some mammals, particularly the canid and
31  the 70 kg mammal, this assumption might be conservative and in some cases extremely
32  conservative for longer-term exposures if only moderate or small areas are treated with
33  fluazifop-P-butyl.   In such cases, the receptors could move in and out of the treated areas and a
34  small proportion of the diet would be contaminated.  Given the magnitude of the HQs, however,
35  these considerations do not have a substantial impact on the risk characterization.

36      ***4.4.2.2. Birds***
37  Table 35 gives an overview of the risk characterization for birds associated with acute and
38  longer-term exposure scenarios following three applications of fluazifop-P-butyl.  This table is
39  taken from Worksheet G02b of Attachment 3.
40
41  As with the corresponding table for mammals (Table 34), Table 35 does not include the
42  accidental exposure scenarios.  For birds, all of the accidental exposure scenarios are below the
43  level of concern (HQ=1).  The highest accidental HQ for birds is 0.6, the upper bound HQ for the
44  consumption of contaminated fish by a piscivorous bird.
45

118

Unlike the case with mammals (Section 4.4.2.1), none of the acute non-accidental exposure scenarios lead to HQs that exceed the level of concern. The highest acute HQ is 0.7, the upper bound for the consumption of short grass by a small bird following three applications of fluazifop-P-butyl. The major factor in the much less severe acute risk characterization for birds, relative to mammals, is the difference in the toxicity values—i.e., an NOAEC of 1069 mg/kg bw for birds and an NOAEL of 43 mg/kg bw for mammals.

For chronic exposures, the NOAEC for birds (3.3 mg a.e./kg bw/day) is only modestly higher than the NOAEC for mammals (0.63 mg a.e./kg bw/day), and the longer-term risk characterization for birds is similar (although somewhat less severe) than that for mammals. None of the lower bound chronic HQs substantially exceed the level of concern. Based on the central estimates of exposure, the HQs exceed the level of concern for a small bird consuming short grass (HQ=12), tall grass (HQ=5), and broadleaf vegetation (HQ=7) as well as a large bird consuming contaminated grass (HQ=1.4). The upper bound estimates of the HQ substantially exceed the level of concern—i.e., HQs of up to 8 for a large bird and 69 for a small bird consuming contaminated short grass.

As discussed in Section 4.3.2.2, the reproduction studies in birds from which the NOAEL of 3.3 mg a.e./kg bw/day is taken do not identify an adverse effect level. Consequently, it is not possible to associate specific adverse effects with HQs that exceed the level of concern (HQ=1). Nonetheless, concerns would be minimal for modest exceedances (e.g., HQ=1.4) and more substantial for greater exceedances.

The qualitative risk characterization for birds given in the current risk assessment is similar to that in U.S. EPA/OPP/EFED (2008, Table 4-4, p. 73)—i.e., no acute risks to birds are anticipated; however, exposures involving short grasses modestly exceed the EPA's level of concern. Numerically, the EPA gives an RQ (risk quotient) of <1.8 based on the bobwhite quail and mallard duck NOAEC of 50 ppm. For the same exposure scenario, the central estimates of the HQs in the current risk assessment range from 1.4 (large bird) to 12 (small bird). The EPA does not derive lower or upper bound HQs. The EPA RQs and the HQs in the current risk assessment differ primarily due to disparities in the exposure assessments.

### 4.4.2.3. Reptiles and Amphibians (Terrestrial Phase)
Risks to reptiles and terrestrial phase amphibians cannot be characterized directly because of the lack of data on the toxicity of fluazifop-P-butyl to these groups of organisms. As discussed in Section 4.1.2.3, the U.S. EPA/OPP/EFED typically uses data on birds as a surrogate for reptiles and terrestrial phase amphibians. Given the very limited data available on birds as well as other concerns relating to absorption noted in Section 4.1.2.3, this approach seems tenuous for fluazifop-P-butyl.

### 4.4.2.4. Terrestrial Invertebrates

#### 4.4.2.4.1. Honeybee (Standard Surrogate Species)
Based on the available oral toxicity data on the honeybee and using this species as a surrogate for herbivorous insects, there is no basis for asserting that herbivorous insects would be at risk following the consumption of contaminated vegetation. As detailed in Attachment 3

(three applications), Worksheet G03b, the highest HQ is 0.2, the upper bound HQ associated with the consumption of contaminated grass.

Based on the available contact toxicity data on the honeybee, there is no basis for asserting that fluazifop-P-butyl would cause adverse effects following direct spray or surface contamination of the insect due to spray drift. As summarized in Worksheet G09 of the workbooks that accompany this risk assessment, the HQ associated with direct spray is only 0.03—i.e., below the level of concern by a factor of over 30. HQs based on drift with or without foliar interception are much lower.

### 4.4.2.4.2. Other Terrestrial Arthropods

As discussed in Section 4.3.2.4.2, brief summaries of toxicity studies on insects other than the honeybee are included in the assessment by the European Food Safety Authority (2012). The lowest reported $LD_{50}$ is 0.004 lb a.e./acre for *Typhlodromus pyri*, a predatory mite. A subsequent study on this species yielded a much higher $LD_{50}$ of 0.13 lb a.e./acre. As noted in Section 4.3.2.4.2, the more relevant study cannot be identified due to the lack of information on these studies. Given this lack of information, the risk characterization for potentially sensitive terrestrial arthropods is based on both the lower $LD_{50}$ of 0.004 lb a.e./acre as well as the higher $LD_{50}$ of 0.13 lb a.e./acre. The HQs for sensitive arthropods are given in Worksheet G10 of the workbooks that accompany this risk assessment (Attachments 1 to 3). The worksheet is included in this risk assessment as Table 36. The HQs in Table 36 are different from all other HQs discussed in the current risk assessment because the values are based on an $LD_{50}$ rather than an estimated NOAEC. Following the approach generally used by the U.S. EPA/OPP/EFED, the levels of concern may be viewed as variable, ranging from 0.5 for direct toxicity to 0.1 for threatened or endangered species.

Based on the lower $LD_{50}$ of 0.004 lb a.e./acre, the HQ for direct spray is 80—i.e., the exposure would exceed the $LD_{50}$ by a factor of 80. This HQ requires little elaboration. Assuming that the $LD_{50}$ of 0.004 lb a.e./acre is relevant; the death of insects that are similarly sensitive to fluazifop-P-butyl as are *Typhlodromus pyri* would be anticipated. HQs reach or exceed the LOC of 0.1 at distances of 900 feet for aerial application (HQ=1.0) and high boom ground broadcast application (HQ=0.1), 500 feet for low boom ground broadcast application (HQ=0.2), and 100 feet for backpack directed foliar application (HQ=0.2). As discussed above, these HQs are all based on an $LD_{50}$ and hence the level of concern is variable, ranging from 0.5 for direct toxicity to 0.1 for threatened or endangered species.

Based on the higher $LD_{50}$ of 0.13 lb a.e./acre, the HQ for direct spray is 2. While this HQ is much lower than the corresponding HQ for direct spray discussed above, an exposure at twice the $LD_{50}$ would be associated with substantial rates of mortality. These rates, however, cannot be estimated without information on the slope of the dose-response curve. The offsite HQs reach or exceed the level of concern only at distances of about 100 feet for aerial applications (HQ=0.2) and 50 feet for high boom ground broadcast application (HQ=0.1).

There are obvious and substantial concerns with this risk characterization. The studies cited by EFSA (2012) were conducted with Fusilade Max (13.7% a.i.), and their relevance in assessing risks associated with formulations of ≈25% a.i. (i.e., Fusilade DX and Fusilade II) that might be used in Forest Service Programs is not clear. Furthermore, since EFSA (2012) provides few

details on how the studies were conducted and assessed, there is little confidence in the high HQs based on the lower $LD_{50}$.  Instead, confidence is much greater in the lower HQs based on the higher $LD_{50}$ because the higher $LD_{50}$ is supported by a similar $LD_{50}$ in another species—i.e., the $LD_{50}$ of 0.137 lb a.e./acre for *Aphidius rhopalosiphi* [Hymenoptera: Aphidiinae] also reported in EFSA (2012).

As noted in Section 4.1.2.4.2, EFSA (2012, p. 12) does offer an interpretation of the data on *Typhlodromus pyri* which is essentially a risk characterization worth repeating:  …*the off-field risk was assessed as low and, based on the residue decline and the time of application, the experts concluded that recovery in the treated field area for the most sensitive species may occur within one year*.

Based on the HQs discussed above, the current risk assessment concurs with the statement that adverse effects on terrestrial arthropods could be observed in the treated site following applications of fluazifop-P-butyl but that offsite effects would be less substantial.  The statement concerning a 1-year recovery period, however, is less clearly supported.  EFSA (2012) does not discuss in detail fluazifop-P-butyl half-lives on vegetation.  Based on the upper bound half-life of 8.7 days (Table 18), the dissipation coefficient for fluazifop-P-butyl on vegetation is about 0.07967 days$^{-1}$ [ln(2)÷8.7 days].  Taking the most conservative approach by using the HQ of 80 and a level of concern of 0.1 (threatened and endangered species), the time required for an HQ of 80 to reach an HQ of 0.1 would be about 84 days—i.e., $80 \times e^{-0.07967 \times 83.9037} = 0.1$.  Based on these crude calculations, a recovery period of about 3 months seems possible.  Depending on the life cycle of the insect, however, functional recovery (i.e., repopulation) could take longer to occur, and the estimate of 1 year by EFSA (2012) could be reasonable.

Concern for sensitive species of terrestrial arthropods is enhanced by the Russell and Schultz (2010) publication as discussed in Section 4.1.2.4.3.  While the field studies by Blake et al. (2011a,b) clearly indicate that applications of fluazifop-P-butyl may be beneficial to some insects over the longer-term due to changes in vegetation, these field studies do not diminish concern for the potential for direct toxic effects on sensitive species of arthropods.

### 4.4.2.4.3. Earthworm
A quantitative risk characterization for earthworms is not developed.  Nonetheless, as discussed in the hazard identification (Section 4.1.2.4.4), fluazifop-P-butyl as well as 5-trifluoromethyl-2-pyridone (Metabolite X) are not toxic to earthworms at soil concentrations that substantially exceed those anticipated from field applications of fluazifop-P-butyl.

### *4.4.2.5. Terrestrial Plants*

### 4.4.2.5.1. Direct Spray and Spray Drift
The HQs for sensitive and tolerant species of terrestrial plants are summarized in Worksheet G05a (fine droplets) and Worksheet G05b (coarse droplets).  These worksheets are customized to reflect the use of four sets of values for drift: aerial application, ground high-boom broadcast application, ground low-boom broadcast application, and directed foliar backpack application.

As detailed in Section 4.2.4.2, all estimates of drift are based on AgDRIFT (Teske et al. 2002).  As detailed in Section 4.3.2.5 and summarized in Table 23, all HQs are based on NOAELs from

studies on vegetative vigor (foliar applications)—i.e., a NOAEL of 0.007 lb a.e./acre for sensitive species of Poaceae monocots and a NOAEL of 0.76 lb a.e./acre for dicots and tolerant species of non-Poaceae monocots.

Fluazifop-P-butyl is an effective herbicide for the control of grassy weeds. If sensitive species of Poaceae monocots are directly sprayed with fluazifop-P-butyl at the maximum application rate of 0.32 lb a.e./acre, the impact on the true grasses will be severe (HQ=46). Following a direct spray, the HQ for tolerant species (i.e., dicots and tolerant species of monocots) is 0.6—i.e., no adverse effects would be anticipated.

Based on estimates of drift using AgDRIFT, risks to sensitive monocots remain above the level of concern downwind from the application site. As summarized in Worksheet G05a for the application of fine droplets, the risks will be greatest with aerial applications (HQ=1.4 at 300 feet down wind). The HQs for fine droplet applications, however, should be viewed as essentially accidental exposures and misapplications of fluazifop-P-butyl. For coarse droplet applications, which would be the norm in actual applications in Forest Service programs, the risks to sensitive species of nontarget vegetation fall below the level of concern at a distance of 300 feet downwind (HQ=0.4) for aerial applications. As discussed in Section 3.2.3.4.2, some product labels for fluazifop-P-butyl prohibit flood type nozzle tips which deliver large droplet sprays but very large droplets (e.g., >500 µm) are not typically used by the Forest Service in pesticide applications.

To put it simply, directed spray ground applications using coarse droplets (i.e., the most likely type of application to be used by the Forest Service) are not likely to damage offsite nontarget Poaceae monocots at distances as close to 25 feet from the application site. Other types of vegetation—i.e., tolerant non-Poaceae monocots and dicots—are not likely to be damaged even if sprayed directly.

### 4.4.2.5.2. Soil Exposures by Runoff

Risks to nontarget vegetation associated with runoff and sediment losses to a field adjacent to the treated site are estimated in Worksheet G04 of the EXCEL workbook attachments that accompany this risk assessment. The risk characterization for soil exposures is unambiguous. Even following three applications at the maximum application rate and minimum application interval of 14 days, the upper bound of the HQ for sensitive species (i.e., true grasses) is only 0.9, approaching but not exceeding the level of concern (HQ=1). For tolerant species of plants (e.g., non-Poaceae monocots and most dicots), the maximum HQ is 0.03, below the level of concern by a factor of about 33. Given the extreme value approach used in the GLEAMS-Driver modeling on which the exposure assessment is based (Section 3.2.3.4.3), there is no basis for asserting that runoff of fluazifop-P-butyl (most likely as fluazifop acid) is likely to adversely affect nontarget or even target vegetation. While fluazifop-P-butyl can be phytotoxic in pre-emergent or soil applications (Section 4.1.2.5.2.4), these types of applications are less phytotoxic than foliar applications.

### 4.4.2.5.3. Contaminated Irrigation Water

The HQs for nontarget plants associated with using fluazifop-P-butyl contaminated surface water for irrigation are summarized in Worksheet G06a. For a single application (Attachment 1), the HQs are 0.2 (0.003 to 5) for sensitive species and 0.003 (0.00006 to 0.06) for tolerant species of

terrestrial plants.  For two applications (Attachment 2), the HQs are 0.4 (0.009 to 8) for sensitive species and 0.005 (0.0001 to 0.1) for tolerant species of terrestrial plants.  For three applications (Attachment 3), the HQs are 0.5 (0.01 to 10) for sensitive species and 0.006 (0.0002 to 0.1) for tolerant species of terrestrial plants.  The identical upper bound of 0.1 for sensitive species of plants following two and three applications is an artifact of the rounding.  The underlying values are about 0.10429 for two applications and about 0.11956 for three applications.

Based on these HQs, there is no basis for asserting that tolerant species of plants (e.g., non-Poaceae monocots and most dicots) will be damaged if contaminated water is used for irrigation.  In most cases, no damage should be seen in sensitive species (i.e., Poaceae/true grasses).  At the upper bounds of estimated exposures, however, HQs in the range of 5 to 10 could be associated with detectable damage to sensitive monocots.

As discussed in Section 4.2.4.4, the product labels for Fusilade II and Fusilade DX do not include cautionary language concerning the use of contaminated surface water for irrigation.  The lack of cautionary language concerning the use of contaminated surface water on the product labels is not a substantial concern, except for highly sensitive crops (e.g., corn).

### 4.4.2.5.4. Wind Erosion

Risks to nontarget vegetation associated with wind erosion of contaminated soils are insubstantial.  At the maximum seasonal rate—i.e., three applications at 0.32 lb a.e./acre with a 14-day application interval, the upper bound HQ for sensitive species is 0.006, below the level of concern by a factor of over 166 (Worksheet G06b in Attachment 3).  As detailed in Section 4.2.4.5, substantial uncertainties are associated with this exposure scenario, and the expected loss rates for soil are intended to represent forestry applications.  Much higher loss rates (i.e., up to a factor of about 8.7) could occur if fluazifop-P-butyl were to be applied inadvertently to fallow soil.  Even within this range of uncertainty, the HQs for both sensitive and tolerant species indicate that wind erosion is not a substantial concern relative to other routes of exposure, particularly direct spray or drift (Section 4.4.2.5.1).

### 4.4.2.6. Terrestrial Microorganisms

As with most other Forest Service risk assessments, a quantitative risk characterization for terrestrial microorganisms is not developed in the current risk assessment because the available data do not support a quantitative risk characterization.  Based on the NOAEC for soil fungi of 0.6 mg/kg soil (dry weight) (Section 4.3.2.6) and the highest estimated concentrations of fluazifop-P-butyl in soil following three applications of fluazifop-P-butyl at 0.32 lb a.e./acre— i.e., 0.13 (0.010 to 0.28) mg a.e./kg soil (dry weight)—there is no basis for asserting that soil fungi would be adversely affected by applications of fluazifop-P-butyl.

Notwithstanding the above, the data on the potential effects of fluazifop-P-butyl on soil microorganisms are viewed as marginal given the numerous soil microorganisms that could be exposed to fluazifop-P-butyl.  The statements in EFSA (2012) on the variable effects of fluazifop-P-butyl on carbon and nitrogen mineralization by soil microorganisms (Section 4.1.2.6) are not given in sufficient detail to allow for an elaboration of the risk characterization for soil microorganisms.

1  **4.4.3. Aquatic Organisms**
2  The risk characterization for aquatic organisms is summarized in Table 37 (fish), Table 38
3  (aquatic invertebrates), Table 39 (algae), and Table 40 (aquatic macrophytes). Each of these
4  tables summarizes the relevant HQs for the accidental spill scenario, the non-accidental acute
5  exposures, and longer-term exposures. The latter two sets of scenarios include the HQs for 1, 2,
6  and three applications. These tables are a minor reformatting of Worksheet G03 in Attachment 1
7  (one application), Attachment 2 (two applications with a 14-day application interval), and
8  Attachment 3 (three applications with 14-day application intervals).

9  *4.4.3.1. Fish*
10  As summarized in Table 37, the HQs for fish are below the level of concern (HQ=1), except for
11  the accidental exposure scenarios.
12
13  The upper bounds of the HQs for the accidental spill scenarios are 25 for sensitive species of fish
14  and 9 for tolerant species of fish. As detailed in Worksheet B04b of the attachments to this risk
15  assessment, the upper bound HQs are based on a water concentration of about 5.8 mg a.e./L
16  fluazifop-P-butyl. As summarized in Table 27, the acute $LC_{50}$ values for technical grade
17  fluazifop-butyl and formulations of fluazifop-butyl range from about 0.25 mg a.e./L (Tejada et
18  al. 1994) to 4.2 mg a.e./L (MRID 00087484). In the event of a serious accidental spill similar to
19  that developed in the current risk assessment (Section 3.2.3.4.1), fish mortality would probably
20  be observed.
21
22  For the non-accidental exposures, none of the HQs exceed the level of concern. The highest HQ
23  is 0.7—i.e., the upper bound of the acute HQ for sensitive species of fish following three
24  applications of fluazifop-P-butyl. There is no basis for asserting that fish will be adversely
25  impacted due to exposures to fluazifop-P-butyl anticipated in the normal use of this herbicide in
26  Forest Service programs.
27
28  Some of the HQs for two and three applications are identical in Table 37. This is also true for
29  other groups of organisms discussed below. As discussed in Section 4.4.2.5.3, the identical HQs
30  for two and three applications is an artifact of rounding—i.e., HQs below 1 are rounded to the
31  nearest significant decimal. For example, the upper bound HQs for tolerant species of fish
32  following two and three applications are both 0.2. The underlying value in the G03 worksheets
33  is 0.192941176 for two applications and 0.221176471 for three applications. Other such
34  similarities are not discussed further in the following sections for other groups of aquatic
35  organisms; nonetheless, the differences in the underlying value can be verified by an
36  examination of the G03 worksheet in the attachments.

37  *4.4.3.2. Amphibians*
38  As noted in Sections 4.1.3.2 and 4.3.3.2, no information is available on the toxicity of fluazifop-
39  butyl or fluazifop-P-butyl to aquatic-phase amphibians. Consequently, no risk characterization is
40  developed for this group of organisms.

41  *4.4.3.3. Aquatic Invertebrates*
42  As with the HQs for fish (Table 37), the HQs for aquatic invertebrates are above the level of
43  concern for the accidental spill scenario. The upper bound HQs are 121 for sensitive species and
44  5 for tolerant species. As with the fish scenario, these upper bound HQs are based on a water

1  concentration of about 5.8 mg a.e./L fluazifop-P-butyl.  As summarized in Table 28 and
2  discussed in Section 4.1.3.3, the formulations of fluazifop-P-butyl are much more toxic than
3  technical grade fluazifop-P-butyl to *Daphnia magna*, and the dose-response assessment does not
4  consider the relatively high $LC_{50}$ values for technical grade fluazifop-P-butyl in *Daphnia magna*.
5  For the accidental spill scenario, this approach is clearly justified.  Excluding these high $LC_{50}$
6  values, the acute $LC_{50}$ values range from about 0.083 mg a.e./L (Pacific oyster, MRID
7  00131460) to 5.5 mg a.e./L (*Daphnia magna*, 25% a.i. EC formulation, MRID 00087488).  Thus,
8  even for presumably tolerant species of aquatic invertebrates, detectable mortality could be seen
9  following an accidental spill.  For sensitive species, the upper bound level of exposure is a factor
10 of about 70 above the $LC_{50}$ [5.8 mg a.e./L ÷ 0.083 mg a.e./L ≈ 69.88]m and mortality in sensitive
11 species of aquatic invertebrates could be complete or nearly so.

13 None of the central estimates or lower bounds of the HQs for acute non-accidental or longer-
14 term exposures exceed the level of concern.

16 For acute exposures, the upper bound HQs exceed the level of concern for sensitive species (HQs
17 of 1.5 to 3).  The upper bound acute HQs are associated with concentrations of fluazifop-P-butyl
18 in water of about 0.074 mg a.e./L (one application) to 0.15 mg a.e./L (three applications).  As
19 summarized in Table 28, the lowest acute $LC_{50}$ value for aquatic invertebrates is 0.083 mg a.e./L
20 (Pacific oyster, MRID 00131460).  If this saltwater species is representative of sensitive
21 freshwater species, detectable and substantial mortality would be expected.  The $LC_{50}$ values for
22 fluazifop-P-butyl in freshwater invertebrates range from about 1.8 to 5.5 mg a.e./L, and all of
23 these $LC_{50}$ values are for *Daphnia magna*.  In the absence of toxicity data on additional species
24 of freshwater invertebrates, the applicability of the lower $LC_{50}$ values in saltwater species to
25 potentially sensitive freshwater invertebrates cannot be assessed further.

27 For longer-term exposures, the upper bound HQs also exceed the level of concern for sensitive
28 species (HQs of 1.8 to 4).  These upper bound HQs are associated with estimated concentrations
29 of fluazifop-P-butyl (most likely as fluazifop acid) of about 0.027 mg a.e./L (one application) to
30 0.064 mg a.e./L (three applications).  As summarized in Table 29, these concentrations are
31 modestly below the LOAEC of 0.066 mg a.e./L for the most sensitive saltwater species
32 (opossum shrimp, MRID 00093805) and substantially below the LOAEC of 0.213 mg a.e./L for
33 *Daphnia magna* (MRID 00093807).  While these relationships cannot exclude the possibility of
34 longer-term effects in aquatic invertebrates, concern is less than that associated with acute
35 exposures.  As with the acute exposures, the few species on which data are available, relative to
36 the numerous species that might be exposed to fluazifop-P-butyl, limits the risk characterization.

37     *4.4.3.4. Aquatic Plants*

38         **4.4.3.4.1. Algae**
39 As detailed in Section 4.3.3.4.1 (the dose-response assessment for algae), the toxicity data on
40 algae are highly variable, which may be due to differences in species sensitivities, differences in
41 the toxicity of different formulations, a combination of these factors, or other factors that cannot
42 be identified from the available summaries of the bioassays on algae.  Another limitation with
43 the data on algae is that few NOAECs are available (Table 30).  Thus, for both sensitive and
44 tolerant species, NOAECs are estimated by dividing the $EC_{50}$ values by a factor of 20 (SERA
45 2011a, Section 4.3.2, p. 98).  While this procedure is a standard practice in Forest Service risk

1 assessments and is consistent with the approach used by U.S. EPA/OPP/EFED, the use of this
2 method introduces additional uncertainties into the dose-response assessment, which carry over
3 to the risk characterization.
4
5 Within the above limitations, which are substantial, the HQs for algae (Table 39) suggest that
6 sensitive species of algae could be adversely affected by fluazifop-P-butyl based on the central
7 estimates of the non-accidental HQs (which range from 2 to 16) and the upper bounds of the
8 HQs (which range from 27 to 150).
9
10 The acute concentrations of fluazifop-P-butyl in water associated with the central estimates of
11 the HQs range from about 0.0064 mg a.e./L (central estimate for one application) to 0.15 mg
12 a.e./L (upper bound, three applications).  As summarized in Table 30, the reported $EC_{50}$ values
13 for algae range from 0.02 to 22.8 mg a.e./L.  It appears that tolerant species of algae would not
14 be exposed to fluazifop-P-butyl at a sufficient level to cause detectable adverse effects.  In some
15 cases, however, sensitive species could be adversely affected to the extent that their populations
16 might decrease.
17
18 The longer-term HQs for algae are associated with longer-term concentrations of fluazifop-P-
19 butyl in water in the range from about 0.0024 mg a.e./L (central estimate for one application) to
20 0.064 mg a.e./L (upper bound, three applications).  Only the upper bound concentrations would
21 appear to pose a longer-term risk to sensitive species of algae.  As discussed in Section 3.2.3.4.3,
22 the concentrations of fluazifop-P-butyl in water used in the current risk assessment are based on
23 modeling nine different locations with substantially different climates.  In specific applications
24 of fluazifop-P-butyl, site-specific modeling would be necessary to better characterize potential
25 impacts on sensitive species of algae.

26            **4.4.3.4.2. Macrophytes**
27 As discussed in Section 4.3.3.4.2, toxicity data on aquatic macrophytes are limited to bioassays
28 on *Lemna*, a monocot but not a true grass.  As summarized in Table 40, all HQs for this
29 presumably tolerant genus of aquatic plants are well-below the level of concern.  The upper
30 bound of the HQ for the accidental spill is 0.02—i.e., below the level of concern by a factor of
31 50.  As with the risk characterization for terrestrial non-Poaceae monocots and terrestrial dicots,
32 there is no basis for asserting that applications of fluazifop-P-butyl would adversely impact
33 *Lemna*.  By analogy to tolerant terrestrial plants, the largely benign risk characterization for
34 *Lemna* may apply to other non-Poaceae aquatic monocots as well as aquatic dicots.
35
36 The lack of data on aquatic Poaceae monocots, however, is a concern.  In the absence of toxicity
37 data on aquatic Poaceae monocots (e.g. Crow and Hellquist 2000; Martínez-y-Pérez et al. 2007),
38 however, this concern cannot be further elaborated.
39

# 5. REFERENCES

NOTE: The initial entry for each reference in braces {} simply specifies how the reference is cited in the text.  The final entry for each reference in brackets [] indicates the source for identifying the reference.

| | |
|---|---|
| Clethodim-XX | References from clethodim risk assessment which are also relevant to fluazifop-P-butyl. |
| DER01 | DERs provided by Syngenta on Feb. 27, 2014. |
| E-Docket | www.regulations.gov (n=113) Docket IDs: Note: Most of the entries are for tolerances/use or other administrative actions.  Administrative entries not directly relevant to the risk assessment have not been downloaded. |
| FOIA01 | Added from response to FOIA EPA-HQ-2013-009201. |
| FOIA02 | Added from response to FOIA EPA-HQ-2013-010361. |
| FS01 | Comments from the Forest Service on preliminary program description. |
| Internet | References obtained from various sites on the Internet. |
| SET00 | Papers from preliminary scoping. |
| SET01 | TOXLINE, ECOTOX, and limited tree search of reviews. |
| SET02 | Additional references identified in U.S. EPA/OPP/EFED 2008 and other sources. |
| SET03 | Tree search of open literature. |
| SET04-05 | Supplemental papers. |
| Sec | Summary of citation from a secondary source. |
| Std | Standard references used in most Forest Service risk assessments. |
| Syngenta | Communications from Syngenta |

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{U.S. EPA/OPP 2012} U.S. EPA (U.S. Environmental Protection Agency/Office of Pesticide Programs).  2012. Occupational Pesticide Handler Unit Exposure Surrogate Reference Table.  Report dated March, 2012.  Available at: http://www.epa.gov/opp00001/science/handler-exposure-table.pdf.  [Std]

{U.S. EPA/OPP 2013a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2013a.  Pesticide Product Label System.  Available at: http://iaspub.epa.gov/apex/pesticides.  Information for fluazifop-P-butyl accessed on September 25, 2013.  [Set00]

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{U.S. EPA/OPP/EFED 2003a} U.S. EPA/OPP/EFED (U.S. Environmental Protection Agency/Office of Pesticide Programs/Environmental Fate and Effects Division). 2003a. Tier 1 Drinking Water Assessment for Fluazifop-p-butyl. Report dated October 29, 2003. [Set00]

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{U.S. EPA/OPP/EFED 2010b} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Environmental Fate and Effects Division). 2010b. Drinking Water Assessment for the Section 3 Registration of Fluazifop-p-butyl for New Use on Bananas, Plantains, Citrus, Grapes and Sugar Beets. Document dated May 25, 2010. EPA Document Name: EPA-HQ-OPP-2009-0980-0009.pdf. Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2009-0980-0009. [FOIA01]

{U.S. EPA/OPP/HED  2004b} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Health Effects Division). 2004b. Fluazifop-P-butyl. Revised TRED - Report on FQPA Tolerance Reassessment Progress and Interim Risk Management Decisions. Residue Chemistry Considerations. Case No. 2285. Report dated December 8, 2004. [Set00]

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{U.S. EPA/OPP/HED 2004a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Health Effects Division).  2004a.  Fluazifop-P-butyl: Revised HED Chapter of the Tolerance Reassessment Eligibility Document (TRED). PC Code: 122809, Case # 2285, DP Barcode: D291903.  Report dated December 10, 2004.  [Set00]

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{U.S. EPA/OPP/HED 2011b} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs).  2010b.  Fluazifop-P-Butyl. Amended Section 3 Registration Request to Add New Uses on Bananas, Citrus, Grapes, and Sugar Beets. Summary of Analytical Chemistry and Residue Data.  Document dated January 4, 2011.  EPA Document Name: EPA-HQ-OPP-2009-0980-0007.pdf.  Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2009-0980-0007.  [FOIA01]

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{USDA/FS. 1989a} USDA/FS (U.S. Department of Agriculture/Forest Service). 1989a. Final Environmental Impact Statement: Vegetation Management in the Coastal Plain/Piedmont, Management Bulletin R8-MB-23, dated January, 1989. 1213 pp. [Std]

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{Varnagy et al. 1996} Varnagy L; Varga T; Hlubik I; Budai P; Moln R E. 1996. Toxicity of the Herbicides Flubalex, Fusilade S and Maloran 50 WP to Chicken Embryos after Administration as Single Compounds or in Combination. Acta Veterinaria Hungarica. 44(3):363-76. [Set01 - ToxL Fluazifop Full]

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{Winegardner. 1996} Winegardner DL. 1996. An Introduction to Soils for Environmental Professionals. CRC Press, Boca Raton, Florida. 270 pp.[Std]

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**Table 1: Nomenclature Used in This Risk Assessment for Agents**

| Agent | CAS No.[1] | Description |
|---|---|---|
| **Acid Forms** | | |
| Fluazifop-P | 83066-88-0 | The [R] enantiomer of [RS]fluazifop. |
| Fluazifop | 69335-91-7 [2] | [RS]fluazifop – both the [R] and [S] enantiomers |
| **Butyl Ester Forms** | | |
| Fluazifop-P-butyl | 79241-46-6 | The butyl ester of fluazifop-P (a.k.a. [R] fluazifop). |
| [RS] Fluazifop-butyl | 69806-50-4 | A mixture of the butyl esters of the [R] and [S] enantiomers of fluazifop. |

[1] CAS numbers from ChemIDplus (http://chem.sis.nlm.nih.gov/chemidplus/).

[2] Several additional CAS numbers have been assigned to compounds designated as *fluazifop* with no stereochemistry specified – i.e., 121958-44-9, 86023-37-2, 87168-00-1, and 93171-48-3.

See Section 1.1.1 for discussion.
See Figure 1 for illustration of structures.

**Table 2: Relevant Reviews and Related Documents on Fluazifop-P-butyl**

| Reference [# pages][1] | Comment |
|---|---|
| CalEPA 2002 [15 pp.] | Summary of registrant studies on toxicity to mammals. May supplement the information in U.S. EPA/OPP/HED (2004a,b, 2011a). |
| ECOTOX 2013 | EPA database on ecotoxicity values for both terrestrial and aquatic species. Information from this database is used as a source for registrant submitted studies. Information directly from ECOTOX is supplemented with information from the Pesticide Ecological Effects Database (U.S. EPA/OPP 2005b) |
| EFSA 2012 [77 pp.] | Review of studies relevant to environmental fate, human health, and ecological effects. Information is cited primarily to other EU documents/reviews and the primary studies (which appear to be registrant submitted studies) are not identified. Most studies summaries provide only toxicity values and study quality cannot be assessed with confidence. Information on Compound X. |
| European Commission 2011a [25 pp.] | Focuses primarily on studies relevant to the human health effects of Compound X – i.e., 5-trifluoromethyl-2-pyridone. No ecotoxicity data. Based on U.S. EPA/OPP (2004c) – i.e., the metabolism review committee – it does not appear that the information in European Commission (2011a) will quantitatively impact the risk assessment. This is also consistent with the conclusions in European Commission (2011a). |
| European Commission 2011b [56 pp.] | Tabular summaries of data (toxicity and fate) as well as modeled estimates of exposure. Summarizes ecotoxicity values (pp. 42-54) but no study details. Summary of metabolite structures (pp. 55-56) but no toxicity data. This study is not used in the current risk assessment. |
| FANPP 2013a,b | Fluoride Action Network web pages with links to EPA and other sites as well as a summary of data. Used primarily to check literature search. |
| FAO/WHO 2000 [21 pp.] | Brief review of chemical and physical properties as well as mammalian and ecological toxicity studies. Very little detail. No primary literature is cited. |
| FWS 2012a [22 pp.] | No detailed data. Cites data Russell and Schultz (2010, p. 53) study on potential effects to butterflies. See FWS (2012b) for full reference. |
| HSDB 200 [12 pp.] | Brief review of information relevant to environmental fate and human health effects. Most citations are to other secondary sources. No primary literature is cited. |
| Ishihara Sangyo Kaisha 1990 [6 pp.] | Summary of chemical-physical properties and mammalian studies from the original developer of fluazifop. May be useful in supplementing EPA/OPP reviews. |
| Nishiuchi and Asano 1979 | This is a compendium covering the effect of several pesticides on **aquatic organisms**. Article is written in Japanese and is summarized in ECOTOX. This paper has been rejected by U.S. EPA/OPP in various CRLF analyses (e.g. U.S. EPA/OPP/EFED 2009a). |
| NMFS 2012 [783 pp.] | Biological opinion on oryzalin, pendimethalin, and trifluralin. Discusses fluazifop-P-butyl only as a tank mix with pendimethalin. Marginal use in current RA. |
| Tomlin 2004 [3 pp.] | E-Pesticide Manual. Brief summary of fate and toxicity data. |
| **U.S. EPA/EFED 2008 [208 pp.]** | U.S. EPA/OPP Ecological Fate and Effects Division risk assessment for new uses on peanuts and beans and amended uses on soybeans. This is a standard and relatively detailed ecological risk assessment. |
| U.S. EPA/OPP/EFED 2010a [126 pp.] | U.S. EPA/OPP Ecological Fate and Effects Division risk assessment for new uses on bananas, plantains, citrus, grapes, and sugar beets. Most recent ERA but all except the first 8 pages consist of appendices of data requirements. No detailed summary of studies. |
| U.S. EPA/OPP/EFED 2010b [27 pp.] | Drinking water exposure assessment for most recent human health risk assessment (U.S. EPA/OPP/HED 2011a). |
| **U.S. EPA/OPP HED 2004a [97 pp.]** | U.S. EPA/OPP Health Effects Division toxicology chapter in support of the T-RED. This will form the basis for the human health risk assessment. This will be the key source of data for HHRA. |
| U.S. EPA/OPP/HED 2004b [67 pp.] | U.S. EPA/OPP Health Effects Division residue chemistry in support of the T-RED. Data on fate may be useful in exposure assessments. |
| U.S. EPA/OPP/HED 2004c [40 pp.] | U.S. EPA/OPP report by the Metabolism Assessment Review Committee. Will be useful in discussion of metabolites in HHRA. No ecotoxicity data. |
| U.S. EPA/OPP/HED 2005a [14 pp.] | This is the T-RED (tolerance reassessment). Less detailed than U.S. EPA/OPP/HED (2004a,b,c) documents but will be consulted for consistency with other EPA documents. |
| U.S. EPA/OPP/HED 2010a [27 pp.] | Recent dietary and drinking water exposure assessment for HHRA. |
| **U.S. EPA/OPP/HED 2011a [78 pp.]** | Most recent HHRA. Screened to ensure that all material is consistent with U.S. EPA/OPP 2004a. |

[1] Key reviews are indicated by light green shading with the most relevant reviews designated by bold font. Some U.S. EPA/OPP tolerances and other narrowly focused documents – e.g., exposure assessments, registration status, use applications, etc. – are not summarized above but are discussed in the text as appropriate in the text and are listed in Section 5 (References).

See Section 1.1.2 for discussion.

**Table 3: Summary of Open Literature Most Relevant to Fluazifop-P-butyl Risk Assessment**
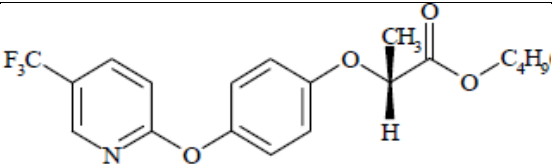
| Topic | Citations[1] |
|---|---|
| **Human Health** | |
| Dermal Absorption | Auton et al. 1993a,b, 1994; Clark et al. 1993; Dick and Scott 1992; Hilton et al. 1994; Ramsey et al. 1994; Rawlings et al. 1994b; Trebilcock et al. 1994; |
| Mechanism | Kemal and Casida 1992; Kostka et al. 2002; Krijt et al. 1993, 1997; |
| Metabolism | McCracken et al. 1990, 1993a,b,c; Mutch et al. 1990; Williams et al. 1990; |
| Pharmacokinetics | Ramsey et al. 1992; Rawlings et al. 1994a; Woollen et al. 1991; |
| Toxicology | Mousa 1982; Sesline and Jackson 1994; U.S. EPA/OTS 1992a,b,c; |
| Worker Exposure | Chester and Hart 1986; Woollen 1993; |
| **Terrestrial Species** | |
| Birds | Varnagy et al. 1996, 1999; Varga et al. 1999 |
| Invertebrates, Terrestrial | Agnello et al. 1986a,b, 1987; De Freitas Bueno et al. 2008; Hautier et al. 2005; House et al. 1987; Russell and Schultz 2010 |
| Plants, Terrestrial *General* [2] | Balinova and Lalova 1992; Banks and Tripp 1983; Barnwell and Cobb 1993; Boucounis et al. 1988; Burden et al. 1989,1990; Carr 1986a,b; Catanzaro et al. 1993; Chandrasena and Sagar 1986a,b, 1987; Chronopoulou et al. 2012; Clay et al. 1990; Cocker et al. 2001; Clarke et al. 1998; ; Dekker and Chandler 1985; Derr et al. 1985a,b,c; Gilreath 1987; Gronwald 1991; Haga et al. 1987; Harwood 1988; Herbert et al. 1997; Nalewaja and Skrzypczak 1986; Nalewaja et al. 1986; Page et al. 1994; Talbert et al. 1995, 1996; Walker et al. 1988; Walker et al. 1988; |
| *Nontarget plants* | Baldos 2009; Blake et al. 2012; Boucounis et al. 1988; Calkins et al. 1996; Defrank 1990; Chernicky and Slife 1986; Clay et al. 1990; Doohan et al. 1986; Skroch et al. 1990; Street and Snipes 1987; Svenson et al. 1985; |
| *Resistance in plants* | Alarcón-Reverte and Moss 2008; Beckie and Morrison 1993; Bradley and Hagood 2001; Burke et al. 2006a,b; Catanzaro et al. 1993a,b; Cisar and Jagschitz 1984a; Cocker et al. 2001; Rosenberg 1997; Yu et al. 2007 |
| Soil Microorganisms | Abdel-Mallek et al. 1996a,b; Gardner and Storey 1985; Sapundzhieva and Kuzmanova 1987; |
| **Aquatic Species** | |
| Fish | Schramm et al. 1998; Tejada et al. 1994; |
| Invertebrates, Aquatic. | Tantawy 2002; Zidan et al. 2002; |
| Plants, Aquatic | Felix et al. 1988; Ma 2002; Ma et al. 2002a,b, 2004, 2006; Michel et al. 2004 (*Lemna*); Perschbacher et al. 1997; |
| **Environmental Fate** | |
| Environmental Fate and Properties | Bewick 1986; Buhler and Burnside 1984b ; Chamberlain et al. 1996; Clegg 1987; Frigerio et al. 1987; Gennari et al. 1991; Kah and Brown 2007a,b; Kah et al. 2007; Kulshrestha et al. 1992, 1995; Mills and Simmons 1998; Miyazaki 1997; Negre et al. 1988, 1993; Patumi et al. 1987; Rick et al. 1987; Smith 1987; Spliid et al. 2006; |
| Monitoring | Carabias Martinez et al. 2000; Coupe et al. 1998; Spliid and Koppen 1998; Trevisan et al. 1993; White et al. 2006; |

[1] Full bibliographic citations are given in Section 5.

[3] Papers on mechanisms, metabolism, and other related topics. There is a large literature on efficacy and a partial listing of these studies is given in Section 5.

See Section 1.1.3 for discussion.

**Table 4: Chemical and Physical Properties of Fluazifop-P-butyl**

| Item | Value | Reference[1] |
|---|---|---|
| | **Identifiers** | |
| Common name: | Fluazifop-P-butyl | Tomlin 2004 |
| CAS Name | butyl (R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy]propanoate | Tomlin 2004 |
| | (R)- 2-(4-((5-(trifluoromethyl)-2-pyridinyl)oxy)phenoxy) propanoic acid, butyl ester | U.S. EPA/OPP 2004b, Table 1 |
| CAS No. | 79241-46-6 | Tomlin 2004; U.S. EPA/OPP 2004b, Table 1 |
| Chemical Group (Fluazifop-P) | Aryloxyphenoxy propionate | Mallory-Smith and Retzinger 2003; U.S. EPA/OPP 2004a |
| Development Codes | PP005; ICIA0005 (both ICI); SL-118 (Ishihara Sangyo). | Tomlin 2004 |
| | PP009 | Plowman et al. 1980 |
| | PP009: fluazifop-P-butyl PP005: fluazifop-butyl | U.S. EPA/OPP/HED 2004a, Table 4.1a, footnote a. |
| IUPAC Name | butyl (R)-2-[4-(5-trifluoromethyl-2-pyridyloxy) phenoxy]propionate | Tomlin 2004 |
| | (R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy]propanoic acid | Mallory-Smith and Retzinger 2003 |
| | butyl (2R)-2-(4-{[5-(trifluoromethyl)pyridin-2-yl]oxy} phenoxy)propanoate | U.S. EPA/OPP 2004b, Table 1 |
| Molecular formula | $C_{19}H_{20}F_3NO_4$ | Tomlin 2004; U.S. EPA/OPP 2004b |
| Mechanistic group (Fluazifop-P) | WWSA Group 1/HRAC Class A: Inhibitors of acetyl CoA carboxylase (ACCase) | Mallory-Smith and Retzinger 2003 |
| EPA PC Code | 122809 | U.S. EPA/OPP 2004b |
| Smiles Code without stereochemistry | `CCCCOC(=O)C(C)Oc1ccc(Oc2ccc(cn2)C(F)(F)F)cc1` | Tomlin 2004 |
| | `CCCCOC(=O)[C@@H](C)Oc1ccc(Oc2ccc(cn2)C(F)(F)F)cc1` | Tomlin 2004 |
| Smiles Code with stereochemistry | `n1cc(C(F)(F)F)ccc1Oc2ccc(OC(C)C(=O)OCCCC)cc2` | EPI Suite 2011 |
| Structure |  | U.S. EPA/OPP 2004b, Table 1 |
| | **Chemical Properties**[1] | |
| a.i. to a.e. conversion | 0.85364 [327.26 g/mole ÷ 383.37 g/mole] *In calculations, this value is rounded to 0.854 to maintain consistency with calculations in U.S. EPA/OPP/EFED 2008.* | See Section 2.2.2 |
| Aqueous photolysis | Half-life of 6 days (pH 5) | Tomlin 2004 |
| Boiling point | 154 °C/0.02 mmHg | Tomlin 2004 |
| Density | 1.20 g/cm$^3$ | U.S. EPA/OPP 2004a, MRID 92067999 |
| Form | Colorless liquid | Tomlin 2004 |
| Henry's Law Constant | 1.1 x 10$^{-2}$ Pa m$^3$ mol$^{-1}$ | Tomlin 2004 |

| Item | Value | | | Reference[1] |
|---|---|---|---|---|
| Hydrolysis | **$DT_{50}$ (days)** | **pH at 25°C** | | Tomlin 2004 |
| | >30 | 5 | | |
| | 78 | 7 | | |
| | ≈1.2 [29 hrs] | 9 | | |
| | Stable at pH 4 and 7. Half-life of 2.5 days at pH 9. | | | Negre et al. 1998 |
| $K_{ow}$ | ≈31,600 [logP = 4.5] (20 °C) | | | Tomlin 2004; U.S. EPA/OPP 2004a, MRID 92067999; EFSA 2012 |
| Molecular weight (g/mole) | 383.37 | | | U.S. EPA/OPP 2004a,b, MRID 92067999 |
| | 383.4 | | | EFSA 2012; Tomlin 2004 |
| Melting point | -20 °C | | | Tomlin 2004 |
| | 164 °C at 0.02 mm Hg Decomposes at 210 °C | | | U.S. EPA/OPP 2004b, Table 1 |
| Photolysis | Stable | | | Tomlin 2004 |
| Specific gravity | 1.22 (20 °C) | | | Tomlin 2004 |
| Thermal decomposition | | | | Tomlin 2004 |
| Vapor pressure | 0.033 mPa (20 °C) | | | Tomlin 2004 |
| | $3 \times 10^{-8}$ kPa at 20 °C | | | U.S. EPA/OPP 2004a, MRID 92067999 |
| Water solubility | 1 mg/L | | | U.S. EPA/OPP 2004a,b |
| | 1.1 mg/l (20 °C) | | | Tomlin 2004 |
| | 2.0 mg/L | | | Knisel and Davis 2000; Plowman et al. 1980; Rick et al. 1987 |
| | 0.5568 mg/L (Estimated) | | | EPI-Suite 2011 |
| **Environmental Properties** | | | | |
| Bioconcentration in fish (BCF) | Bluegill sunfish 410 - whole fish 120 – muscle 4800 – viscera Fluazifop-butyl. All values based on total $C^{14}$. Degradates III and X made up 21%-25% each of the total residues. This is a laboratory study and was classified as supplemental by U.S. EPA/OPP/EFED (2008, p. 95). | | | U.S. EPA/OPP/EFED 2008 citing MRID 93196 and MRID 92067035 |
| | Catfish 2.1 - whole fish 1.1 – muscle 8.0 – viscera Fluazifop-butyl. All values based on total $C^{14}$. This is a field study and was not classified by U.S. EPA/OPP/EFED (2008, p. 95). | | | U.S. EPA/OPP/EFED 2008 citing MRID 93195, 1981 |
| | 320 | | | EFSA 2012 |
| Field dissipation | ≈3.5 to 6.25 days [Values appear to be for ester and not both ester and acid.] | | | El-Metwally and Shalby 2007 |
| Foliar washoff fraction | 0.4 | | | Knissel and Davis 2000 |
| Foliar half-life | 5 days | | | Knissel and Davis 2000 |
| | 5 days (soybean) abstract | | | Kulshrestha et al. 1992 |

| Item | Value | Reference[1] |
|---|---|---|
| | 7.9 days (soybean) as reported.<br>7.5 (6.6-8.7) days based on reanalysis. See Section 3.2.3.7 for discussion. | Kulshrestha et al. 1995 |
| $K_{oc}$ | 3000 | Knissel and Davis 2000 |
| | 5700 | USDA/ARS 1995 |
| | 2010 | Spliid et al. 2006 |
| Sediment half-life | ≈2080 days [50,000] (Estimate) | EPI-Suite 2011 |
| Soil half-life (NOS) | 21 days | Knissel and Davis 2000 |
| | <1 day (non-sterile soil)<br>3 days (sterile soil) | Negre et al. 1988 |
| | 11 to 23 days (as fluazifop acid) | Smith 1987 |
| Soil half-life, aerobic | A few hours | U.S. EPA/OPP 2004a, p. 11 |
| Soil dissipation half-life | 5.5 days | Kulshrestha et al. 1992 |
| | Biphasic:<br>   Initial phase (to 14 day): 6.2 to 7.2 days<br>   Terminal phase (14-90 days): 17.7 to 24.6. | Kulshrestha et al. 1995 |
| | <7 to 21 days (four studies) | U.S. EPA/OPP/EFED 2008, MRID 87495. |
| | 120 days [2880 hours] (Estimate)<br>`Note: This appears to be for fluazifop and`<br>`  the ester.` | EPI-Suite 2011 |
| Water Half-life | 60 days [1440 hours] (Estimate) | EPI-Suite 2011 |

[1] There a many sources of information on the standard values for fluazifop-P-butyl – e.g., molecular weight. In general, only two sources as cited for each value. More than two sources are cited only to highlight apparent discrepancies.

See Section 2.2.2 for discussion.

**Table 5: Chemical and Physical Properties of Fluazifop-P**

| Item | Value | Reference |
|---|---|---|
| | **Identifiers** | |
| Common name: | Fluazifop-P | Tomlin 2004 |
| CAS Name | (R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl] oxy]phenoxy]propanoic acid | Tomlin 2004 |
| CAS No. | 83066-88-0 | Tomlin 2004 |
| IUPAC Name | (R)-2-[4-(5-trifluoromethyl-2-pyridyloxy) phenoxy]propionic acid | Tomlin 2004 |
| Mechanistic group | WWSA Group 1/HRAC Class A: Inhibitors of acetyl CoA carboxylase (ACCase) | Mallory-Smith and Retzinger 2003 |
| Chemical Group | Aryloxyphenoxy propionate | Mallory-Smith and Retzinger 2003 |
| Molecular formula | $C_{15}H_{12}F_3NO_4$ | Tomlin 2004 |
| Smiles Code | `n1cc(C(F)(F)F)ccc1Oc2ccc(OC(C)C(=O)O)cc2` | EPI-Suite 2011 |
| Structure (resolved [R] stereo- isomer) |  Fluazifop-P | U.S. EPA/OPP 2004b, Table 3 |
| Structure (racemic, without stereochemistry) |  Fluazifop | U.S. EPA/OPP 2004b, Table 3 |
| | **Chemical Properties**[1] | |
| Form | Pale yellow, glass-like material | Tomlin 2004 |
| Henry's Law Constant | $3 \times 10^{-7}$ Pa m$^3$ mol$^{-1}$ (calc.) | Tomlin 2004 |
| Hydrolysis | Stable at pH 5 to 9 at 25°C | Tomlin 2004 |
| | 78 days at pH 7 | U.S. EPA/OPP 2004a, p. 11 |
| Kow | | Tomlin 2004 |
| | ≈1510 [Log Kow = 3.18]<br>Note: This measured value is probably at acidic pH. See above from Tomlin 2004. | EPI-Suite 2011 |
| | ≈1510 [Log Kow = 3.18]<br>Cited as measured value. | Chamberlain et al. 1996 |
| MW (g/mole) | 327.3 | Tomlin 2004 |
| | 327.26 | EPI-Suite 2011 |
| pKa | 2.8 | U.S. EPA/OPP 2003a, Table 2, MRID 41900604 |
| | 3.22 [specified as fluazifop] | Chamberlain et al. 1996 |
| | 2.98 [fluazifop-P] | Kah and Brown 2007b; Kah et al 2007 |
| Vapor pressure | $7.9 \times 10^{-4}$ mPa (20 °C) | Tomlin 2004 |

Kow sub-table:

| pH (20°C) | ≈Kow | Log Kow |
|---|---|---|
| 2.6 | 1260 | 3.1 |
| 7 | 0.16 | -0.8 |

Note: These appear to be measured values.

| Item | Value | Reference |
|------|-------|-----------|
| Water solubility | 780 mg/L (20 °C) [pure water] | Tomlin 2004 |
| | 40.52 mg/L [Experimental] 327.25 [Estimated] | EPI-Suite 2011 |
| | 780 mg/L (fluazifop-P) | Kah and Brown 2007b; Kah et al. 2007 U.S. EPA/OPP/EFED 2010b, MRID 46190602 |
| **Environmental Properties** | | |
| Bioconcentration factor (BCF) | 3.16 | EPI-Suite 2011 |
| Foliar half-life | None identified. | N/A |
| Kd | 0.27-1.57 (fluazifop-P) | Kah and Brown 2007 |
| Koc | 8.3 mL/g | U.S. EPA/OPP (2003a, Table 2) |
| | 25.93 - 31 0.8 | U.S. EPA/OPP/EFED 2008 citing MRID 46190603; Kah and Brown 2007 |
| | 8.3 to 51 | U.S. EPA/OPP/EFED 2008 citing MRID 41900604 |
| | 39-84 (fluazifop-P) | Kah and Brown 2007b |
| | 25-60 (fluazifop-P) | Kah et al. 2007 |
| Sediment Half-life | ≈2080 days [50,000 hours] (Estimate) | EPI-Suite 2011 |
| Soil half-life (NOS) | 35-140 days | USDA/ARS 1995 |
| Soil half-life, aerobic | 30 days Upper bound of 11 half-lives for ace and butyl ester. | U.S. EPA/OPP 2010b citing MRIDs 46190602 and 87493, 92067032. |
| | 18 days (mean of 5 values, used in SCIGROW modeling) 22 days (upper 90% confidence limit of 5 values, used in FIRST modeling) | U.S. EPA/OPP (2003a, Table 2) |
| | 120 days [2880 hours] (Estimate) | EPI-Suite 2011 |
| | 2-168 days (p. 1338, individual values not included). | Kah and Brown 2007b |
| | 6.0-31 days (Table 4 of paper for individual values) | Kah et al. 2007 |
| Soil half-life, anaerobic | 1-3 years | U.S. EPA/OPP 2004a and U.S. EPA/OPP/EFED 2003a, MRID 92067033 |
| Water half-times | 78 days | U.S. EPA/OPP 2003a, Table 2, MRID 41598002 |
| | 60 days [1440 hours] (Estimate) | EPI-Suite 2011 |

[1] There a many sources of information on the standard values for fluazifop-P-butyl – e.g., molecular weight. In general, only two sources as cited for each value. More than two sources are cited only to highlight apparent discrepancies.

See Section 2.2.2 for discussion.

**Table 6: Selected Fluazifop-P-Butyl Formulations**

| Formulation, Supplier, EPA Registration Number | Composition/ Characteristics[1] | Application Information, Methods and Rates[2] |
|---|---|---|
| Fusilade DX<br>Syngenta<br>EPA Reg. No. 100-1070<br>EPA SLN No. CA-110010 | 24.5% a.i. on label and MSDS. (20.09 % a.e.)<br>2 lbs. a.i./gallon<br>(1.708 lbs a.e./gallon)<br><br>75.5% inerts, *Contains petroleum distillates.*<br><br>Density: 0.9807 g/ml @ 68°F (20°C)<br><br>pH: 6.2 (1% w/w dilution in deionized water) | Relevant Labeled Uses: Conifers – Christmas tree plantings, nursery beds, and seedling establishment. **Application to conifers is not applicable in California.** In California, however, the EPA has issued a Special Local Need Label for the control of wild oats, perennial ryegrass, ripgut brome, red brome, and soft brome in wildlands.<br>Application rates: 0.09375 to 0.375 lb. a.i./acre (6-24 oz./acre). Rates are variable based on target species and location. Consult label.<br>Maximum Seasonal Rate: 1.125 lb a.i./acre/season [3 applications of 24 oz/day]<br>Minimum Application Interval: 14 days<br>Adjuvants: COC or NIS<br>Crop oil concentrates (COC) or once-refined vegetable oil concentrate with 15-20% emulsifier at 0.5-1% v/v (ground). 1 pt. of COC per acre for aerial.<br>NIS with 75% surface active agent at 0.25%-0.5% v/v for ground application. 1 pt./acre for aerial application.<br>Application Volumes<br>  Ground Application: 5-40 gals./acre, minimum of 20 gals/acre for dense grass.<br>  Aerial Application: 5-10 gal./acre. |
| Fusilade II, Turf and Ornamental Herbicide.<br>Syngenta<br>EPA Reg. No. 100-1084<br><br>Cannot be used in Nassau and Suffolk Counties in NY. | 24.5% a.i. on label and MSDS. (20.09 % a.e.)<br>2 lbs. a.i./gallon<br>(1.708 lbs a.e./gallon)<br><br>75.5% inerts, *Contains petroleum hydrocarbons.*<br><br>Density: 0.98 g/ml @ 68°F (20°C)<br><br>pH: 6.2 (1% w/w dilution in deionized water) | Relevant Labeled Uses: Non-crop areas including rights-of-way. **Not specifically labeled for applications to conifers.**<br>Application rates: ≈0.094 to 0.38 lb. a.i./acre (6-24 oz./acre). Rates are variable based on target species and location. Consult label.<br>Maximum Seasonal Rate: None specified for conifers.<br>Adjuvants: COC or NIS<br>COC or once-refined vegetable oil concentrate with 15-20% emulsifier at 0.5-1% v/v (ground). 1 pt. of COC per acre for aerial.<br>NIS with 75% surface active agent at 0.25%-0.5% v/v for ground application. 1 pt./acre for aerial application.<br>Application Volumes<br>  Ground Application: 5-40 gals./acre, minimum of 20 gals/acre for dense grass.<br>  Aerial Application: 5-10 gal./acre. |

| Formulation, Supplier, EPA Registration Number | Composition/ Characteristics[1] | Application Information, Methods and Rates[2] |
|---|---|---|
| Ornamec 170 Grass Herbicide<br>PBI/Gordon Corporation<br>EPA Reg. No. 2217-751 | 1.7% a.i. on label and MSDS.<br>0.125 lb. a.i./gallon (0.107 lb a.e./gallon)<br><br>98.3% inerts, *Contains petroleum distillates.*<br><br>Density: 7.44 lbs./gal.<br>Specific gravity: 0.89037<br><br>pH: N.S. | Relevant Labeled Uses: **Not specifically labeled for applications to conifers. No other relevant uses are apparent on the product label**. Labeled specifically for ornamentals.<br>Application rates: 0.0059-0.0088 lb./1000 ft$^2$ (6-9 oz./1000 ft$^2$). Equivalent to ≈0.257 to 0.3855 lb. a.i./acre.<br>Maximum Seasonal Rate: 1.1 lbs. a.i./acre/season.<br>Adjuvants: None specified.<br>Application Volumes<br>   Ground Application: N.S. Spray to coverage but not to runoff.<br>   Aerial Application: N/A |
| Ornamec Over-the-top<br><br>PBI/Gordon Corporation<br><br>EPA Reg. No. 2217-728 | 6.75% a.i. on label and MSDS.<br>0.5 lbs. a.i./gallon (0.427 lb a.e./gallon)<br><br>93.25% inerts, *Contains petroleum distillates, xylene or xylene range aromatic solvent.*<br><br>Density: 7.43 lbs./gal.<br>Specific gravity: 0.89121<br><br>pH: N.S. | Relevant Labeled Uses: Control of grasses in non-crop areas with ornamentals, trees, shrubs, and ground cover. **No specific forestry applications.**<br>Application rates: 64-96 oz./acre (0.25–0.375 lb. a.i./acre).<br>Maximum Seasonal Rate: N.S.<br>Adjuvants: Nonionic surfactant with at least 75% surface wetting agent at 0.25% v/v.<br>Application Volumes<br>   Ground Application: Minimum of 30 gallons/acre.<br>   Aerial Application: N/A |

[1] The % inerts and notations on inerts are taken from product label. See Table 7 for additional details.

[2] Unless otherwise noted, application rates are for the control of grasses on conifers.

[3] a.i. is (+) isomer (fluazifop-P-butyl).

KEY: COC=crop oil concentrates; NIS = non-ionic surfactant.

Note: Syngenta also provides a mixture formulation, Fusion, which contains 24.15% fluazifop-P-butyl and 6.76% fenoxaprop-P-ethyl. Mixture formulations and tank mixtures are not explicitly covered in this or other Forest Service risk assessments. See Section 2.2.3 for discussion.

**Note: Individuals involved in field applications must consult the relevant product label for details. More specific directions for or limitations on applications may exist in some specific locations. Summaries in this table are limited to forestry and other relevant non-agricultural applications.**

**Table 7: Disclosed Inerts in Fluazifop-P-butyl Formulations**

Sources: Material Safety Data Sheets

| Formulation (Supplier) /a.i., Inerts | Inert[1] | CAS No. from MSDS | % w/w from MSDS |
|---|---|---|---|
| Fusilade DX (Syngenta) 24.5% a.i., 75.5% total inerts | Naphthalene | N.S. | <5% |
| | Petroleum distillates, light paraffinic | N.S. | N.S. |
| | Petroleum Solvent | N.S. | N.S |
| Fusilade II (Syngenta) 24.5% a.i. 75.5% total inerts | Naphthalene | N.S. | <5% |
| | Petroleum distillates, light paraffinic | N.S. | N.S. |
| | Petroleum Solvent | N.S. | N.S |
| Ornamec 170 (PBI Gordon) 1.7% a.i. 98.3% total inerts | 1,2,4-trimethylbenzene | 95636 | 9.0% |
| | Ethyl benzene | 100414 | 1.7% |
| | Petroleum solvent | 64742956 | 11.3% |
| | Xylenes | 1330207 | 0.9% |
| Ornamec Over-the-top (PBI Gordon) 6.75% a.i. 93.25% total inerts | 1,2,4-trimethylbenzene | 95636 | 9.6% |
| | Ethyl benzene | 100414 | 2.0% |
| | Petroleum solvent | 64742956 | 13.6% |
| | Xylenes | 1330207 | 7.0% |

[1] Chemical names as indicated on MSDS.

See Section 2.2.3 for initial discussion.

**Table 8: Potential Target Species for Fluazifop-P-butyl**

| Scientific Name | Common Name(s) | Sources |
|---|---|---|
| *Avena fatua* | Wild oats | SLN-CA |
| *Bromus diandrus* | Ripgut brome | FS/R5 and SLN-CA |
| *Bromus hoardeaceus* | Soft brome | FS/R5 and SLN-CA |
| *Bromus madritensis* | Compact brome | FS/R5 |
| *Bromus rubens* | Red brome | FS/R5 and SLN-CA |
| *Bromus subvelutinus* | Hoary brome | FS/R5 |
| *Bromus tectorum* | Cheat grass | FS/R5 and FS/R6 |
| *Brachypodium sylvaticum* | False brome | FS/R6 |
| *Lolium perenne* | Perennial ryegrass | SLN-CA |
| *Hordeum murinum* | Wall barley/ False barley | FS/R5 |
| *Phalaris arundinacea* | Reed canarygrass | FS/R6 |
| *Piptatherum milaceum* | Smilo grass | FS/R5 |
| *Poa bulbosa* | Bulbous bluegrass | FS/R5 |
| *Schismus barbatus* | Mediterranean grass | FS/R5 |
| *Taeniatherum canput-medusae* | Medusahead rye | FS/R5 and FS/R6 |
| *Ventenata sp.* | Wiregrass | FS/R6 |
| *Vulpia myuros* | Rat's tail fescue | FS/R5 |

Sources: FS/R5 from Bakke 2013; VinZant 2013
FS/R6 email from Shawna Bautista
SLN-CA from Syngenta Section 24(c) Special Local Need Label for Fusilade DX Herbicide.
See Section 2.3 for discussion.

**Table 9: Dermal Absorption of fluazifop-butyl in humans from Ramsey et al. 1992**

| Body Weights of Subjects (kg) | Dose (mg) | Dermal Loading (mg/cm$^2$)[1] | Fluazifop-butyl Absorption (µg) | % Absorption |
|---|---|---|---|---|
| 86 | 2 | 0.0025 | 109 | 5.5 |
| 67 | 2 | 0.0025 | 169 | 8.5 |
| 80 | 2 | 0.0025 | 161 | 8.5 |
| 76 | 2 | 0.0025 | 202 | 10.1 |
| 77 | 2 | 0.0025 | 170 | 8.5 |
| 61 | 2 | 0.0025 | 145 | 7.3 |
| | | | Average for 2 mg: | 8.0 |
| 83 | 20 | 0.025 | 644 | 3.2 |
| 79 | 20 | 0.025 | 451 | 2.3 |
| 83 | 20 | 0.025 | 921 | 4.6 |
| 67 | 20 | 0.025 | 625 | 3.2 |
| 80 | 20 | 0.025 | 660 | 3.3 |
| 81 | 20 | 0.025 | 729 | 3.6 |
| | | | Average for 20 mg: | 3.6 |
| 86 | 200 | 0.25 | 4340 | 2.2 |
| 68 | 200 | 0.25 | 2809 | 1.7 |
| 80 | 200 | 0.25 | 3421 | 1.4 |
| 76 | 200 | 0.25 | 3225 | 1.6 |
| 77 | 200 | 0.25 | 2244 | 1.1 |
| 61 | 200 | 0.25 | 3585 | 1.18 [2] |
| | | | Average for 200 mg: | 1.6 |

[1] Compound applied to 800 cm$^2$ area of the back of each subject.

[2] A value of 1.18% is given in the Ramsey et al. (1992) paper but this value appears to be a typographical error. Based on the reported dose (200,000 µg) and the amount absorbed (3,585 µg), the percent absorption would be about 1.79%. The value of 1.8% is consistent with the average value of 1.6% given by Ramsey et al. (1992) for the high dose group. The value of 1.18% yields a group average of 1.53%.

Source: Ramsey et al. 1992, p. 251, Table 1.
See Figure 4 for illustration.
See Section 3.1.3.2.1 for discussion.

**Table 10: Confidence Bounds for Dermal Absorption from Ramsey et al. 1992**

| Item Number | Value | Square of Error |
|---|---|---|
| 1 | 3.2 | 0.027778 |
| 2 | 2.3 | 1.137778 |
| 3 | 4.6 | 1.521110 |
| 4 | 3.2 | 0.027778 |
| 5 | 3.3 | 0.004444 |
| 6 | 3.6 | 0.054444 |

| Statistic | Value |
|---|---|
| Average | 3.366667 |
| SSE | 2.773332 |
| Sample Standard Deviation | 0.744759 |
| Critical Value of t at 0.1 | 2.015 |
| Value of 5% Lower Bound | 2.7540131 |
| Value of 95% Upper Bound | 3.9793209 |

Data from the mid-dosed group in Ramsey et al. 1992 as detailed in Table 10.

See Section 3.1.3.2.1 for discussion.

**Table 11: Overview of Subchronic and Chronic Studies in Mammals**

| Species[1] | Duration[2] | NOAEL (mg/kg/day) | LOEAL (mg/kg bw/day): Major signs of toxicity |
|---|---|---|---|
| Dog | 90 d | 25 | 125/250: Body weight loss, liver toxicity |
| Dog | 1 y | 5 | 25: Alterations in adrenal gland and thymus. |
| Hamster* | 90 d | 78.3 (M) 79.0 (F) | 291.9/319.6 (M/F): Decreases in food conversion efficiency, body weight gain, and food consumption. |
| Hamster* | 80 w | 12.5 (M) 12.1 (F) | 47.5/45.5: Reduced sperm and testicular degeneration as well as liver inflammation and eye cataracts in males and ovarian hyperplasia in females. |
| Rats | 90 d | 0.7 | 7.1: liver and kidney histopathology |
| Rats | 90 d | 0.5 | 5: Decreased spleen and testicular weights with hematological changes in males. |
| Rats | 106 w 107 w | 0.51 [M] 5.2 [F] | 4.15/16 (M/F): Kidney damage and increased mortality. Increased incidence of ovarian cysts at the LOAEL for females. |

[1] Species marked with an asterisk (*) indicate studies with fluazifop-P-butyl. All other studies used fluazifop-butyl.

[2] d=days; w=weeks' y=year

**Table 12: Overview of Developmental Studies in Mammals**

| Species[1] | Maternal NOAEL (mg/kg bw/day) | Maternal LOAEL (mg/kg bw/day) | Fetal NOAEL (mg/kg bw/day) | Fetal LOAEL[4] (mg/kg bw/day) | MRID[2] |
|---|---|---|---|---|---|
| Rabbit | 30 | 90 | 30 | 90 | 00088856 |
| Rabbit* | 10 | 50 | 10 | 50 | 46082904 |
| Rats | 200 | N/A[3] | N/A[3,5] <br> **50** [6] | 10[5] <br> 200 | 00088857 |
| Rats | 200 | N/A[3] | 1[5] <br> 10 | 5[5] <br> 200 | 00088858 |
| Rats* | 20 | 300 | 1 | 20 | 46158401 |
| Rats* | 100 | N/A[3] | **2[7]** | 5 | 46082903 |
| Rats* | 100 | N/A[3] | **2[7]** | 5 | 46082013 |

[1] Species marked with an asterisk (*) indicate studies with fluazifop-P-butyl. All other studies used fluazifop-butyl.

[2] Only the initial MRID from Appendix 1, Table A1-3 is included.

[3] N/A: A NOAEL or LOAEL was not observed.

[4] All effects are developmental unless otherwise noted.'

[5] The values in the upper section based on developmental effects (e.g., decreased fetal weight or delayed ossification) and values given below these are based on malformations (i.e., diaphragmatic hernia).

[6] Basis for Acute (1 day) RfD.

[7] EPA basis for short-term (1 to 30 days) occupational risks.

**Table 13: Worker Exposure Rates**

**Absorbed Dose Rates** (mg/kg bw/day per lb applied)

| Worker Group | Central Estimate | Lower C.I. | Upper C.I. | Lower P.I. | Upper P.I. |
|---|---|---|---|---|---|
| Directed foliar | 0.08 | 0.02 | 0.06 | 0.1 | 0.5 |
| Broadcast foliar | 0.0001 | 0.00004 | 0.0002 | 0.000002 | 0.005 |
| Aerial | 0.00002 | 0.000006 | 0.00007 | 0.0000005 | 0.0008 |

CI: Confidence Interval.
PI: Prediction Interval.

**Treatment Rates: Acres Treated per Day**

| Worker Group | Central | Lower | Upper |
|---|---|---|---|
| Directed foliar | 4.4 | 1.5 | 8.0 |
| Broadcast foliar | 112 | 66 | 168 |
| Aerial | 490 | 240 | 800 |

Source: SERA (2013).
See Section 3.2.2.1 for discussion.

**Table 14: Worker Exposure Rates Used in EPA Risk Assessments**

| Scenario | No clothing[1] | Single Layer, No gloves[1] | Single layer, Gloves[1] | Inhalation[1] |
|---|---|---|---|---|
| 1. Dry flowable, open mixing and loading | 1.1 | 0.066 | 0.066 | 0.00077 |
| 2. Granular, open mixing and loading | 0.032 | 0.0084 | 0.0069 | 0.0017 |
| 3. All liquids, open mixing and loading | 3.1 | 2.9 | 0.023 | 0.0012 |
| 4. Wettable powder, open mixing and loading | 6.7 | 3.7 | 0.17 | 0.04342 |
| 5. Wettable powder, water soluble bags | 0.039 | 0.021 | 0.0098 | 0.00024 |
| 6. All liquids, closed mixing and loading | | | 0.0086 | 0.000083 |
| 7. Aerial-fixed wing, enclosed cockpit/liquid[2] | 0.0050 | **0.0050** | 0.0022 | **0.000068** |
| 8. Aerial-fixed wing, enclosed cockpit/granular | 0.0044 | 0.0017 | 0.0017 | 0.0013 |
| 9. Helicopter application, enclosed cockpit | | 0.0019 | 0.0019 | 0.0000018 |
| 10. Aerosol application | 480 | 190 | 81 | 1.3 |
| 11. Airblast application, open cockpit | 2.2 | 0.36 | 0.24 | 0.0045 |
| 12. Airblast application, enclosed cockpit | | | 0.019 | 0.00045 |
| 13. Groundboom applications, open cab[2] | 0.046 | **0.014** | 0.014 | **0.00074** |
| 14. Groundboom applications, enclosed cab | 0.010 | 0.0050 | 0.0051 | 0.000043 |
| 15. Solid broadcast spreader, open cab, AG | 0.039 | 0.0099 | | 0.0012 |
| 16. Solid broadcast spreader, enclosed cab, AG | 0.0021 | 0.0021 | 0.0020 | 0.00022 |
| 17. Granular bait dispersed by hand | | | 71 | 0.47 |
| 18. Low pressure handwand | 25 | 12 | 7.1 | 0.94 |
| 19. High pressure handwand | 13 | 1.8 | 0.64 | 0.079 |
| 20. Backpack applications | 680 | | | 0.33 |
| 21. Hand gun (lawn) sprayer | | | 0.34 | 0.0014 |
| 22. Paintbrush applications | 260 | 180 | | 0.280 |
| 23. Airless sprayer (exterior house stain) | 110 | 38 | | 0.830 |
| 24. Right-of-way sprayer | 1.9 | 1.3 | 0.39 | 0.0039 |
| 25. Flagger/Liquid | 0.053 | 0.011 | 0.012 | 0.00035 |
| 26. Flagger/Granular | 0.0050 | | | 0.00015 |
| 27. WP or liquid/open pour/airblast/open cab | 26 | | | 0.021 |
| 28. WP or liquid/open pour/airblast/closed cab | 0.88 | 0.37 | 0.057 | 0.0013 |
| 29. Liquid or DF /open pour/ground boom/closed cab | 0.22 | 0.089 | 0.029 | 0.00035 |
| 30. Granule/open pour/belly grinder | 210 | 10 | 9.3 | 0.062 |
| 31. Push type granular spreader | | 2.9 | | 0.0063 |
| 32. Liquid/open pour/low pressure handwand | 110 | 100 | 0.43 | 0.030 |
| 33. WP/open pour/low pressure handwand | | | 8.6 | 1.1 |
| 34. Liquid/open pour/backpack | | | 2.5 | 0.03 |
| 35. Liquid/open pour/high pressure handwand | | | 2.5 | 0.12 |
| 36. Liquid/open pour/garden hose end sprayer | 34 | | | 0.0095 |
| 37. Liquid/open pour/termiticide injection | | | 0.36 | 0.0022 |

[1] All rates are in units of mg/lb a.i. handled.

[2] These entries are discussed in the risk assessment.

Source: Keigwin 1988

See Section 3.2.2.1.2 for discussion.

**Table 15: Comparison of Worker Exposure Estimates**

All exposures in units of mg a.i./kg bw/day

| Worker Group | Chester and Hart 1986 | U.S. EPA/OPP 2011a | This Risk Assessment[5] |
|---|---|---|---|
| Backpack | 0.03 (0.02-0.04)[1] | N/A | 0.018 (0.0045 – 0.045) [0.0038-0.21] |
| Ground spray | 0.007 (0.001 – 0.03) [2] | 0.00091[3] {0.0012}[6] | 0.0042 (0.00099-0.013) [0.00005-0.35] |
| Aerial | N/A | 0.00099[3] {0.0014}[6] | 0.0037 (0.00054-0.021) [0.000045-0.24] |
| Range of worker exposures (NOS) | N/A | 0.006 to 0.07[4] | N/A |

[1] Chester and Hart (1986), p. 141.

[2] Chester and Hart (1986), p. 144.

[3] Based on MOE (NOEL ÷ Dose) given in U.S. EPA/OPP/HED (2011a), Table 9, p. 50 and the NOAL of 0.74 mg/kg bw – i.e., Dose = NOAEL ÷ MOE. Reported MOEs are 813 for ground broadcast and 746 for aerial.

[4] Range of worker exposures (NOS) given by U.S. EPA/OPP/HED (2011a), p. 48: … *occupational exposures for the new uses of fluazifop-P-butyl were found to range from a high of 0.07 mg/Kg/day to a low of 0.006 mg/Kg/day.*

[5] From Worksheets C01a (backpack), C02b (ground broadcast), and C02c (aerial) in the attachments that accompany this risk assessment. Confidence intervals are given in parentheses and prediction intervals are given in braces []. The values in these worksheets are divided by 0.854 a.e./a.i. to adjust the rates to units of a.i. rather than a.e.

[6] The rates in braces {} are adjusted to use number of treated acres used in standard Forest Service risk assessments. These values are more comparable to the values in the last column of this table as discussed further in Section 3.2.2.1.4.

See Section 3.2.2.1.4 for discussion.

**Table 16: Precipitation, Temperature and Classifications for Standard Test Sites**

| Location | Precipitation | Temperature | Average Annual Rainfall (inches) | Average Annual Temperature (°F) |
|---|---|---|---|---|
| HI, Hilo | Wet | Warm | 126.06 | 73.68 |
| WA, Quillayute [1] | Wet | Temperate | 95.01 | 49.14 |
| NH, Mt. Washington | Wet | Cool | 98.49 | 27.12 |
| FL, Key West | Average | Warm | 37.68 | 77.81 |
| IL, Springfield | Average | Temperate | 34.09 | 52.79 |
| MI, Sault Ste. Marie | Average | Cool | 32.94 | 40.07 |
| AR, Yuma Test Station | Dry | Warm | 3.83 | 73.58 |
| CA, Bishop | Dry | Temperate | 5.34 | 56.02 |
| AK, Barrow | Dry | Cool | 4.49 | 11.81 |

[1] Based on composite estimation in WEPP using a latitude of 47.94 N and a longitude of -124.54 W.  See SERA (2006c) for details.

**Table 17: Field and Waterbody Parameters Used in Gleams-Driver Modeling**

| Field Characteristics | Description | Pond Characteristics | Description |
|---|---|---|---|
| Type of site and surface (FOREST) | Field (0) | Surface area | 1 acre |
| Treated and total field areas | 10 acres | Drainage area: | 10 acres |
| Field width | 660 feet | Initial Depth | 2 meters |
| Slope | 0.1 (loam and clay) 0.05 (sand) | Minimum Depth | 1 meter |
| Depth of root zone | 36 inches | Maximum Depth | 3 meters |
| Cover factor | 0.15 | Relative Sediment Depth | 0.02 |
| Type of clay | Mixed | | |
| Surface cover | No surface depressions | | |

| Stream Characteristics | Value |
|---|---|
| Width | 2 meters |
| Flow Velocity | 6900 meters/day |
| Initial Flow Rate | 710,000 liters/day |

| GLEAMS Crop Cover Parameters[3] | Description | Value |
|---|---|---|
| ICROP | Weeds | 78 |
| CRPHTX | Maximum height in feet. | 3 |
| BEGGRO | Julian day for starting growth | 32 |
| ENDGRO | Julian day for ending growth | 334 |

| Application, Field, and Soil Specific Factors [1] | Code[3] | Clay | Loam | Sand |
|---|---|---|---|---|
| Percent clay (w/w/): | CLAY | 50% | 20% | 5% |
| Percent silt (w/w/): | SILT | 30% | 35% | 5% |
| Percent sand (w/w/): | N/A | 20% | 45% | 90% |
| Percent Organic Matter: | OM | 3.7% | 2.9% | 1.2% |
| Bulk density of soil (g/cc): | BD | 1.4 | 1.6 | 1.6 |
| Soil porosity (cc/cc): | POR | 0.47 | 0.4 | 0.4 |
| Soil erodibility factor (tons/acre): | KSOIL | 0.24 | 0.3 | 0.02 |
| SCS Runoff Curve Number [2]: | CN2 | 83 | 70 | 59 |
| Evaporation constant (mm/d): | CONA | 3.5 | 4.5 | 3.3 |
| Saturated conductivity below root zone (in/hr): | RC | 0.087 | 0.212 | 0.387 |
| Saturated conductivity in root zone (in/hr) | SATK | 0.087 | 0.212 | 0.387 |
| Wilting point (cm/cm): | BR15 | 0.28 | 0.11 | 0.03 |
| Field capacity (cm/cm): | FC | 0.39 | 0.26 | 0.16 |

[1] The qualitative descriptors are those used in the QuickRun window of Gleams-Driver. Detailed input values for the soil types are given in the sub-table below which is adapted from SERA (2007b, Tables 2 and 3). All fields are run for about 6 months before the pesticide is applied in early summer.

[2] From Knisel and Davis (Table H-4), *Clay*: Group D, Dirt, upper bound; *Loam*: Group C, woods, fair condition, central estimate; *Sand*: Group A, meadow, good condition, central estimate.

[3]Codes used in documentation for GLEAMS (Knisel and Davis 2000) and Gleams-Driver (SERA 2007a)

**Table 18: Chemical parameters used in Gleams-Driver modeling**

**All values for fluazifop-P unless otherwise specified.**

| Parameter | Values | Note/Reference |
|---|---|---|
| Half-life (days) | | |
|    Aquatic Sediment | 1056 | Note 1 |
|    Foliar | 7.5 (6.6-8.7) | Note 2 |
|    Soil | 23 (15 to 32) | Note 3 |
|    Water | 82 | Note 4 |
| Soil $K_{o/c}$, mL/g | 8.3 to 51 | Note 5 |
| Sediment $K_d$, mL/g | 0.27-1.57 | Note 6 |
| Water Solubility, mg/L | 780 | Note 7 |
| Foliar wash-off fraction | 0.4 | Knisel and Davis 2000 |
| Fraction applied to foliage | 0.5 | Default |
| Depth of Soil Incorporation | 1 cm | Default |

| | |
|---|---|
| Note 1 | Upper confidence bound of four half-lives from U.S. EPA/OPP/EFED (2010b citing MRIDs 87493 and 92067032). |
| Note 2 | Reanalysis of mean residue data from Kulshrestha et al. (1995, Table 2, p. 279). Application of fluazifop-P-butyl but analysis of fluazifop-P. $C^{14}$ label not used. Knissel and Davis (2000) report a half-life on vegetation of 5 days. No foliar half-lives identified for fluazifop-P expressed a $C^{14}$. These values may not adequately account for metabolites of fluazifop-P. See Section 3.2.3.7 for discussion. |
| Note 3 | U.S. EPA/OPP/EFED (2010b) uses 30 days base on 90% upper bound of 11 half-lives citing MRIDs MRID 46190602 and 87493, 92067032. Values used here are based on same data but use the mean and 90% confidence interval – i.e., 5% and 95% bounds. |
| Note 4 | Upper confidence bound of four half-lives from U.S. EPA/OPP/EFED (2010b) citing MRID 46190605. |
| Note 5 | U.S. EPA/OPP/EFED 2008 citing MRID 41900604. Higher Koc values (25.93-51) are reported in U.S. EPA/OPP/EFED (2010b) citing MRID 46190602 as well as values published by Kah and Brown (2007). |
| Note 6 | Kah and Brown 2007. |
| Note 7 | U.S. EPA/OPP/EFED 2010b citing MRID 46190602 as well as Kah and Brown 2007b; Kah et al. 2007. |

Note: The database for Gleams-Driver includes only central estimates for the above parameters. The uniform distribution is used for ranges in the simulations discussed in this risk assessment were implemented using the Full Run feature in Gleams-Driver.

**Table 19: Summary of Modeled Concentrations in Surface Water**
**All concentrations in units of ppb or μg a.e./L for an application rate of  0.32 lb a.e./acre**

| Scenario | Peak | Long-Term Average |
|---|---|---|
| Modeling for This Risk Assessment | | |
| **Accidental Spill** (Section 3.2.3.4.1) | 700 (70-5,800) | |
| **Direct Spray and Spray Drift** | | |
| Pond, Direct Spray (Section 3.2.3.4.2) | 36 | N/A |
| Pond, drift at 25 feet (Section 3.2.3.4.2) | 0.3-8 | N/A |
| Stream, Direct Spray (Section 3.2.3.4.2) | 30 | N/A |
| Stream, drift at 25 feet (Section 3.2.3.4.2) | 0.2-7 | N/A |
| **Gleams-Driver** | | |
| **Single Application (see Appendix 8 for details)** | | |
| Pond, Section 3.2.3.4.4 | 6.27 (0-73.9) | 2.39 (0-26.6) |
| Stream, Section 3.2.3.4.4 | 3.42(0-42.9) | 0.170 (0-1.57) |
| **Two Applications at 14-day Interval (see Appendix 9 for details)** | | |
| Pond, Section 3.2.3.4.4 | 11.6 (0-131) | 4.48 (0-51.2) |
| Stream, Section 3.2.3.4.4 | 6.30 (0-86.4) | 0.336 (0-3.17) |
| **Three Applications at 14-day Intervals (see Appendix 10 for details)** | | |
| Pond, Section 3.2.3.4.4 | 16.2 (0 to 150) | 6.59 (0 to 62.4) |
| Stream, Section 3.2.3.4.4 | 8.51 (0-115) | 0.490 (0 to 4.32) |
| **EPA Modeling** | | |
| U.S. EPA/OPP/EFED 2003a, FIRST, Tier 1.  Three applications at 0.375 lb a.i./acre with 14 day interval. | 53.327 | 11.336 |
| U.S. EPA/OPP/EFED 2004a, PRZM/EXAMS, Index Reservoir, 3 applications at 0.375 lb a.i./acre (0.32 lb a.e./acre) with 21-day interval. CA Fruit. PCA 0.87, ranges from Appendix A | 5.6 (2.7 to 26) | 1.5 (0.74 to 6.84) |
| U.S. EPA/OPP/EFED 2008, PRZM/EXAMS, **2 applications** at 0.36 kg a.e./ha (0.32 lb a.e./acre) | 1.35 to 14.3 | N/A |
| U.S. EPA/OPP/EFED 2010a, PRZM/EXAMS, cites 2008 and 2010 EFED risk assessments. | 26.2 to 33.4 | N/A |
| U.S. EPA/OPP/EFED 2010b, Three ground applications, at 0.36 kg a.e./ha (0.32 lb a.e./acre) with 14-day interval. CAGrapes, CAWineGrape, NYGrapesSTD and Citrus using Index Reservoir.  Table 3, p. 7. | 8.7 to 27.3 | 2.0 to 4.4 |

See Section 3.2.3.4.3 for a discussion of the GLEAMS-Driver modeling.
See Section 3.2.3.4.4 for a discussion of the EPA modeling.

**Table 20: Concentrations of fluazifop-P (a.e.) in surface water used in this risk assessment**

| Foliar Broadcast, one application | Peak[1] | Longer-term[1] |
|---|---|---|
| Central | 0.020 | 0.0075 |
| Lower | 0.002 | 0.00075 |
| Upper | 0.23 | 0.083 |
| **Foliar Broadcast, two applications** | **Peak[1]** | **Longer-term[1]** |
| Central | 0.036 | 0.014 |
| Lower | 0.0036 | 0.0014 |
| Upper | 0.41 | 0.16 |
| **Foliar Broadcast, three applications** | **Peak[1]** | **Longer-term[1]** |
| Central | 0.05 | 0.02 |
| Lower | 0.005 | 0.002 |
| Upper | 0.47 | 0.20 |

[1] All concentrations given as Water Contamination Rates – concentrations in units of mg a.i./L expected at an application rate of 1 lb a.i./acre.  Units of mg a.e./L are used in the EXCEL workbook that accompanies this risk assessment.

Working Note: The above are all based on GLEAMS-Driver modeling of the pond, with the lower bound set at 0.1 of the average.  All values are rounded to 2 significant digits.  These are all water contamination rates and are taken from Table 7 (peak) and Table 8 (longer-term) of Appendix 8 (one application), Appendix 9 (two applications), and Appendix 10 (three applications).

See Section 3.2.3.4.6 for discussion.

**Table 21: Estimated residues in food items per lb a.i. applied**

All concentration given in units of ppm (mg agent/kg food) per lb/acre.

| Food Item | Central [a] | Lower [b] | Upper [a] |
|---|---|---|---|
| Short grass | 85 | 30 | 240 |
| Tall grass | 36 | 12 | 110 |
| Broadleaf/forage plants and small insects | 45 | 15 | 135 |
| Fruits, pods, seeds, and large insects | 7 | 3.2 | 15 |

[a] U.S. EPA/EFED 2001, p. 44 as adopted from Fletcher et al. (1994).
[b] Central values × (Central Value ÷ Upper Value).

**Table 22: Summary of toxicity values used in human health risk assessment**

## Acute – single exposure

| Element | Derivation of  RfD |
|---|---|
| EPA Document | U.S. EPA/OPP/ HED 2011a |
| Study | MRIDs 00088857 and 92067047 |
| NOAEL Dose | 50 mg a.i./kg bw |
| LOAEL Dose | 200 mg a.i./kg bw |
| LOAEL Endpoint(s) | Diaphragmatic hernias |
| Species, sex | Rats, fetuses |
| Uncertainty Factor/MOE | 100 |
| Equivalent RfD | 0.5 mg a.i./kg bw/day [**0.43 mg a.e./kg bw/day**] |

## Chronic – lifetime exposure

| Element | Derivation of  RfD |
|---|---|
| EPA Document | U.S. EPA/OPP/ HED 2011a |
| Study | MRIDs 000088859, 92067022, and 92067050 |
| NOAEL Dose | 0.74 mg/kg bw/day |
| LOAEL Dose | 5.8 mg/kg bw/day |
| LOAEL Endpoint(s) | Rats, male |
| Species, sex | Decrease testes weight |
| Uncertainty Factor/MOE | 100 |
| Equivalent RfD | 0.0074 mg a.i./kg bw/day [**0.0063 mg a.e./kg bw/day**] |

## Occupational – 1 to 6 month exposure periods

| Element | Derivation of  RfD |
|---|---|
| EPA Document | U.S. EPA/OPP/HED 2011a, p. 49 |
| Study | MRIDs 46082903 supported by MRID 46158401 |
| NOAEL Dose | 2 mg/kg bw/day |
| LOAEL Dose | 5 mg/kg bw/day |
| LOAEL Endpoint(s) | Increased incidence of hydroureter (abnormal distension of the ureter with urine) and delayed ossification. |
| Species, sex | Rat, female and offspring |
| Uncertainty Factor/MOE | 100 |
| Equivalent RfD | 0.02 mg/kg bw/day<br>**0.017 mg a.e./kg bw/day** |

[1] The toxicity values from EPA are expressed in units of fluazifop-P-butyl (mg a.i./kg bw/day).  For the workbooks that accompany this risk assessment, all exposure values are in units of fluazifop-P (a.e.).  Consequently, the toxicity values from EPA are adjusted to units of a.e. using the conversion factor of 0.854 a.e./a.i. as discussed in Section 2.1.  The a.e. values are bolded in this table.

See Section 3.3 for discussion.

**Table 23: Risk Characterization for Workers**

# Summary of Hazard Quotients

**Accidental/Incidental: Dose ÷ 0.43 mg a.e./kg bw Acute RfD**

| Scenario | Receptor | Central | Lower CI | Upper CI |
|---|---|---|---|---|
| Contaminated Gloves, 1 min. | Worker | 1E-02 | 3E-03 | 9E-02 |
| Contaminated Gloves, 1 hour | Worker | 0.6 | 0.2 | **6** |
| Spill on Hands, 1 hour | Worker | 1E-03 | 2E-04 | 1E-02 |
| Spill on lower legs, 1 hour | Worker | 3E-03 | 4E-04 | 3E-02 |

**General Exposures - Short-term: Dose ÷ 0.0017 mg a.e./kg bw Short-term Surrogate RfD**

| Worker Group | Central | Lower PI | Lower CI | Upper CI | Upper PI |
|---|---|---|---|---|---|
| Backpack Applications: | 0.9 | 0.2 | 0.2 | **2** | **10** |
| Ground Broadcast Applications: | 0.2 | 2E-03 | 5E-02 | 0.6 | **16** |
| Aerial Applications: | 0.2 | 2E-03 | 3E-02 | **1.1** | **12** |

**General Exposures - Longer-Term: Dose ÷ 0.00063 mg a.e./kg bw Chronic RfD**

| Worker Group | Central | Lower PI | Lower CI | Upper CI | Upper PI |
|---|---|---|---|---|---|
| Backpack Applications: | **2** | 0.5 | 0.6 | **6** | **28** |
| Ground Broadcast Applications: | 0.6 | 7E-03 | 0.1 | **1.7** | **43** |
| Aerial Applications: | 0.5 | 6E-03 | 0.1 | **3** | **33** |

# Summary of Worker Margins of Exposure

**General Exposures - Short-term: 1.7 mg a.e./kg bw NOAEL ÷ Exposure**

| Worker Group | Central | Lower PI | Lower CI | Upper CI | Upper PI |
|---|---|---|---|---|---|
| Backpack Applications: | 110 | 528 | 443 | **44** | **10** |
| Ground Broadcast Applications: | 474 | 40246 | 2012 | 158 | **6** |
| Aerial Applications: | 542 | 44271 | 3689 | **95** | **8** |

**General Exposures – Intermediate: 0.63 mg a.e./kg bw NOAEL ÷ Exposure**

| Worker Group | Central | Lower PI | Lower CI | Upper CI | Upper PI |
|---|---|---|---|---|---|
| Backpack Applications: | **41** | 196 | 164 | **16** | **4** |
| Ground Broadcast Applications: | 176 | 14915 | 746 | **59** | **2** |
| Aerial Applications: | 201 | 16406 | 1367 | **35** | **3** |

**CI: Confidence Interval    PI: Prediction Interval**

Source: Worksheet E02 in Attachments 1, 2, and 3.
See Section 3.4.2 for discussion.

**Table 24: Risk Characterization for the General Public, Acute Exposures**

**Accidental Acute Exposures (dose in mg/kg/event)**

| Scenario | Receptor | Central | Lower | Upper |
|---|---|---|---|---|
| Direct Spray of Child, whole body | Child | 4E-02 | 7E-03 | 0.5 |
| Direct Spray of Woman, feet and lower legs | Adult Female | 4E-03 | 7E-04 | 5E-02 |
| Water consumption (spill) | Child | 0.1 | 8E-03 | **1.5** |
| Fish consumption (spill) | Adult Male | 0.5 | 5E-02 | **4** |
| Fish consumption (spill) | Subsistence Populations | **2** | 0.2 | **18** |

**Non-Accidental Acute Exposures**

| Number of Applications / Scenario | Receptor | Central | Lower | Upper |
|---|---|---|---|---|
| **One Application** | | | | |
| Vegetation Contact, shorts and T-shirt | Adult Female | 4E-03 | 1E-03 | 1E-02 |
| Contaminated Fruit | Adult Female | 9E-03 | 4E-03 | 0.1 |
| Contaminated Vegetation | Adult Female | 0.1 | 8E-03 | **1.0** |
| Swimming, one hour | Adult Female | 5E-05 | 2E-06 | 1E-03 |
| Water consumption | Child | 1E-03 | 7E-05 | 2E-02 |
| Fish consumption | Adult Male | 4E-03 | 4E-04 | 5E-02 |
| Fish consumption | Subsistence Populations | 2E-02 | 2E-03 | 0.2 |
| **Two Applications** | | | | |
| Vegetation Contact, shorts and T-shirt | Adult Female | 4E-03 | 1E-03 | 1E-02 |
| Contaminated Fruit | Adult Female | 1E-02 | 5E-03 | 0.2 |
| Contaminated Vegetation | Adult Female | 0.2 | 1E-02 | **1.3** |
| Swimming, one hour | Adult Female | 8E-05 | 4E-06 | 2E-03 |
| Water consumption | Child | 2E-03 | 1E-04 | 3E-02 |
| Fish consumption | Adult Male | 7E-03 | 7E-04 | 8E-02 |
| Fish consumption | Subsistence Populations | 4E-02 | 4E-03 | 0.4 |
| **Three Applications** | | | | |
| Vegetation Contact, shorts and T-shirt | Adult Female | 4E-03 | 1E-03 | 1E-02 |
| Contaminated Fruit | Adult Female | 1E-02 | 5E-03 | 0.2 |
| Contaminated Vegetation | Adult Female | 0.2 | 1E-02 | **1.4** |
| Swimming, one hour | Adult Female | 1E-04 | 6E-06 | 2E-03 |
| Water consumption | Child | 3E-03 | 2E-04 | 4E-02 |
| Fish consumption | Adult Male | 1E-02 | 1E-03 | 9E-02 |
| Fish consumption | Subsistence Populations | 5E-02 | 5E-03 | 0.5 |

Sources: Worksheets E04 of Attachments 1, 2, and 3.
See Sections 3.4.3.1 and 3.4.3.2 for discussion.

**Table 25: Risk Characterization for the General Public, Chronic Exposures**

All values expressed as Hazard Quotients (Exposure ÷ Chronic RfD)

| Number of Applications / Scenario | Receptor | Central | Lower | Upper |
|---|---|---|---|---|
| **One Application** | | | | |
| Contaminated Fruit | Adult Female | 7E-02 | 3E-02 | **1.3** |
| Contaminated Vegetation | Adult Female | 1.0 | 6E-02 | **10** |
| Water consumption | Adult Male | 0.1 | 8E-03 | 0.1 |
| Fish consumption | Adult Male | 6E-04 | 6E-05 | 7E-04 |
| Fish consumption | Subsistence Populations | 5E-03 | 5E-04 | 5E-03 |
| **Two Applications** | | | | |
| Contaminated Fruit | Adult Female | 0.1 | 6E-02 | **3** |
| Contaminated Vegetation | Adult Female | **2.0** | 0.1 | **19** |
| Water consumption | Adult Male | 2E-02 | 1E-03 | 0.3 |
| Fish consumption | Adult Male | 1E-04 | 1E-05 | 1E-03 |
| Fish consumption | Subsistence Populations | 9E-04 | 9E-05 | 1E-02 |
| **Three Applications** | | | | |
| Contaminated Fruit | Adult Female | 0.2 | 9E-02 | **4** |
| Contaminated Vegetation | Adult Female | **3** | 0.2 | **29** |
| Water consumption | Adult Male | 3E-02 | 2E-03 | 0.3 |
| Fish consumption | Adult Male | 2E-04 | 2E-05 | 2E-03 |
| Fish consumption | Subsistence Populations | 1E-03 | 1E-04 | 1E-02 |

Sources: Worksheets E04 of Attachments 1, 2, and 3.
See Section 3.4.3.3 for discussion.

179

**Table 26: Toxicity Studies in Terrestrial Plants**

| Group | Sensitive | Tolerant |
|---|---|---|
| **Post-emergence** | | |
| **Poaceae/Gramineae Monocots** | | |
| Greenhouse | 0.0091 kg a.i./ha, $ED_{50}$ growth, Corn (EFSA 2011). $ED_{50}$s of 0.02 to 0.04 kg a.i./ha for several other species (Appendix 4, Table A4-3). | 0.18 kg a.i./ha, Red fescue, some visual damage (Blake et al. 2012). Supported by little visual damage to red fescue at 0.15 lb/acre from (Cisar and Jagschitz 1984a). |
| Field | 0.035 kg a.i./ha: smooth crabgrass, moderate control (Cisar and Jagschitz 1984b) $\geq 0.07$ kg a.i./ha, Many species of grasses, good control (Appendix 4, Table A4-6). | 0.0375 to 0.075 lb/ac, Red fescue (*Festuca rubra*) and bluegrass, and bentgrass, minimal injury (Cisar and Jagschitz 1984b) 1.12 kg/ha, blue fescue (*Festuca ovina*), minor damage (Calkins et al. 1996) |
| **Other monocots** | | |
| Greenhouse | 1.69 kg a.i./ha, Some Anthericacae and Haemodoraceae, modest reduction in plant height or leaf damage (Rokich et al. 2009). Most pronounced in 4-5 month of plants. | 1 kg a.i./ha, No or little damage to Cyperaceae (2 sp.), Commelinaceae (1 sp.), Liliaceae (1 species), or Araceae (1 sp.) (Haga et al.1987). 3.4 kg a.i./ha, 3-4 month old Anthericacae (2 sp.) no adverse effect (Rokich et al. 2009) |
| Field | 1.12 kg a.i./ha, Iridaceae (miniature dwarf bearded iris) and Xanthorrhoeaceae (after dark daylily), relatively pronounced visual damage (Calkins et al. 1996). | 1.12 kg a.i./ha, One species of Xanthorrhoeaceae (young love daylily) and one species of Asparagaceae (plantain lily), no adverse effects (Calkins et al. 1996). 0.19 lb a.i./acre [0.21 kg a.i./ha]: Two species of Xanthorrhoeaceae, No signs of damage (Skroch et al. 1990) |
| **Dicots** | | |
| Greenhouse | ≈0.1 to 0.75 kg a.i./ha: Red clover (most sensitive dicot) transient chlorosis from Day 7 to 14 but not significant effect by Day 21 (Blake et al. 2012). 0.4 kg a.i./ha: Dose-related decreases in plant in 2 Australian dicots (Rokich et al. 2009). | 0.75 to 1 kg a.i./ha: No toxicity in many species and families (Blake et al. 2012, Haga et al. 1984) 6 kg a.i./ha: Minimal reduction in growth in soybean (Buhler and Burnside 1984b) |
| Field | 0.84 and 1.68 kg Fluazifop-P (NOS)/ha: Indian blanket (*Gaillardia pulchella*), transient and slight injury. | ≈0.1 to 1.6 kg a.i./ha: Many species. No injury (Appendix 4, Table A4-6). |
| **Pre-emergence** | | |
| **Poaceae/Gramineae Monocots** | | |
| Greenhouse | 0.035 kg a.i./ha, Several grasses, 73-95% control (Derr et al. 1985c) | Not defined |
| **Other monocots** | | |
| Greenhouse | None identified | 0.84 kg a.i./ha, two species of Haemodoraceae, no significant effects (Rokich et al. 2009) |
| **Dicots** | | |
| Greenhouse | 0.56 kg a.i./ha, Cucumber, 34% reduction in stem length (Boucounis et al. 1998) 0.75 kg a.i./ha, Red clover, <5% visual damage (Blake et al. 2012). | 0.75 kg a.i./ha, Several species of dicots, no effects (Blake et al. 2012) 0.84 kg a.i./ha, Several species of Australian dicots, no effects (Rokich et al. 2009) |
| **Ferns (only 1 study)** | | |
| Greenhouse | None Identified | 1 kg/ha, several species of Pteridophyte, no effects (Haga et al. 1987) |

Source: Appendix 4, Tables A4-1 to A4-6.

See Section 4.1.2.5.2 for discussion.

**Table 27: Toxicity Data in Fish**

## ACUTE TOXICITY

| Species<br>Agent | LC$_{50}$<br>(mg a.e./L)[1] | NOAEC<br>(mg a.e./L) | Reference |
|---|---|---|---|
| **Freshwater** | | | |
| **Fluazifop-butyl** | | | |
| Nile tilapia | 0.25 | N.R. | Tejada et al. 1994 |
| Fathead minnow | 0.32 | 0.23 | MRID 00093808 |
| Bluegill | 0.45 | 0.31 | MRID 00087485 |
| Carp | 1.12 | N.R. | FAO/WHO 2000 |
| Rainbow trout | 1.2<br>[Slope=15.2] | 0.68 | MRID 00131458 |
| **Fluazifop Acid** | | | |
| Rainbow trout | 117 | N.R. | EFSA 2012 |
| **Metabolite X** | | | |
| Rainbow trout | 240 | N.R. | EFSA 2012 |
| **Formulations** | | | |
| Bluegill, 25.8% formulation | 2.28<br>[Slope=10.1] | 1.92 | MRID 00087486 |
| Rainbow trout, 25.8% formulation | 4.2<br>[Slope=13.2] | 0.34 | MRID 00087484 |
| Rainbow trout, Fusilade Max, 12.5 % EC | 1.37 | N.R. | EFSA 2012 |
| **Saltwater** | | | |
| **Formulations** | | | |
| Sheepshead minnow | 3.21 | N.R. | MRID 00152173 |
| Sheepshead minnow | 9.4 | 2.56 | Accession No. ACC070630 |

## LONGER-TERM TOXICITY

| Species,<br>Agent | NOAEC<br>(mg a.e./L) | LOAEC<br>(mg a.e./L) | Reference |
|---|---|---|---|
| Fathead minnow,<br>fluazifop-butyl | >0.203 | N/A | MRID 00093808 |
| Fathead minnow<br>fluazifop-P-butyl | 0.07 | N/A | EFSA 2012; FAO/WHO 2000 |
| Fathead minnow<br>fluazifop acid | 1.46 | N/A | EFSA 2012 |

[1] Values for Metabolite X are given in units of mg metabolite/L. All other values are given as mg a.e./L.

[2] U.S. EPA/OPP/EFED (2008) reports and LC$_{50}$ of 6.86 mg a.e./L. This value, however, appear to be an error. See Section 4.1.3.1 for discussion.

N.R.: Not reported.

N/A: Not available.

Source: Appendix 5, Tables A5-1 (freshwater) and A5-2 (saltwater)

See Section 4.1.3.1 for discussion.

**Table 28: Acute Toxicity Data in Aquatic Invertebrates**

| Species / Agent | EC$_{50}$ (mg a.e./L)[1] | NOAEC (mg a.e./L) | Reference |
|---|---|---|---|
| **Freshwater** | | | |
| **Fluazifop-butyl** | | | |
| *Daphnia magna*, 97.8% a.i. | 240 | 82.8 | MRID 00087490[3] |
| **Fluazifop-P-butyl** | | | |
| *Daphnia magna*, 94.8% | >8.5 [4] | 8.5 | MRID 00087488 |
| *Daphnia magna*, [R]:[S]::1:1[2] | 473 | 162 | MRID 00162452 |
| *Daphnia magna*, [R]:[S]::1:7[2] | 466 | 254 | MRID 00162452 |
| *Daphnia magna*, [R]:[S]::1:14[2] | 352 | 138 | MRID 00162452 |
| **Fluazifop Acid** | | | |
| *Daphnia magna*, NOS | 240 | N.R. | EFSA 2012 |
| **Metabolite X** | | | |
| *Daphnia magna*, NOS | 681 | N.R. | EFSA 2012 |
| **Formulations** | | | |
| *Daphnia magna*, 24% a.i. | 5.14 | 1.07 | MRID 00087489 |
| *Daphnia magna*, EC 25% a.i. | 5.5 | N.R. | MRID 00087488 |
| *Daphnia magna*, Fusilade Max | 1.79 | N.R. | EFSA 2012 |
| **Saltwater** | | | |
| **Fluazifop-butyl** | | | |
| Pacific oyster, 98.6% a.i. | 0.083 | 0.048 | MRID 00131460 |
| Opossum shrimp, 98.6% | 0.184 | 0.041 | MRID 00093806 [5] |
| **Fluazifop-P-butyl** | | | |
| Opossum shrimp, 92.2% a.i. | 0.44 | 0.17 | MRID 00131460 |
| Opossum shrimp, NOS | 0.46 | N.R | EFSA 2012 |
| American oyster, 90% a.i. | 0.40 | 0.15 | MRID 41900601 |
| American oyster, NOS | 0.45 | N.R. | EFSA 2012 |
| **Formulations** | | | |
| Fiddler crab, 25.4% a.i. | 3.5 | 2.1 | MRID 00093806 |
| Pink shrimp, 25.4% a.i. | 5.1 | 2.6 | MRID 00093804 |

[1] Values for Metabolite X are given in units of mg metabolite/L. All other values are given as mg a.e./L.

[2] Specified blends of the [R] and [S] enantiomers. U.S. EPA/OPP/EFED (2008) indicates that the test substance was fluazifop-butyl. The DERs for this study (Jealotts Hill Research Station 1983; Hamer and Hill 1983) indicates that the test substance was fluazifop acid. See discussion in Section 4.1.3.3.

[3] It is unclear if this was a study on fluazifop-butyl or fluazifop acid. See discussion in Section 4.1.3.3.

[4] The EC$_{50}$ is reported as >10 mg a.i./L in ECOTOX but as 10 mg a.i./L or 8.5 mg a.e./L in U.S. EPA/OPP/EFED (2008, p. 190). The DER for this study (Getty et al. 1979) confirms and is consistent with ECOTOX – i.e., no effects observed at any concentration.

[5] DER (Hollister et al. 1980/1981) available and consistent with summary in U.S. EPA/OPP/EFED (2008). The DER, however, does not cover the assay of a 25.4% formulation in the fiddler crab.

N.R.: Not reported.

Source: Appendix 6, Tables A6-1 (freshwater) and A6-2 (saltwater).

See Section 4.1.3.3 for discussion.

**Table 29: Longer-term Toxicity Data in Aquatic Invertebrates**

All studies on fluazifop-butyl

| Species, Duration, Purity (if available) | NOAEC (mg a.e./L) | LOAEC (mg a.e./L) | Reference |
|---|---|---|---|
| *Daphnia magna*, 21 days, 97.2% a.i. | 0.0854 | 0.213 | MRID 00093807[2] |
| Opossum shrimp, 28 days | 0.0148 | 0.066[1] | MRID 00093805 |
| Opossum shrimp, 28 days | 0.041 | N.R. | EFSA 2012 |

[1] This value is specified as an $LC_{50}$ in ECOTOX.  This submission not discussed in U.S. EPA/OPP/EFED (2008).

[2] A relatively standard DER is available (Edwards et al. 1981).  The DER (prepared in 1991) indicates that a new study will be required.  No new study has been encountered.

N.R.: Not reported.

Source: Appendix 6, Tables A6-3.
See Section 4.1.3.3 for discussion.

**Table 30: Toxicity to Algae and Aquatic Macrophytes**

## ALGAE

| Agent / Species | EC$_{50}$ (mg a.e./L)[1] | NOAEC (mg a.e./L) | Reference[2] |
|---|---|---|---|
| **Fluazifop-P-butyl** | | | |
| *Pseudokirchneriella subcapitata* | >1.54 | 0.75 | EFSA 2012 (+) |
| *Navicula pelliculosa* | 0.44 | N.R. | EFSA 2012 (+) |
| **Fluazifop Acid** | | | |
| *Pseudokirchneriella subcapitata* | >40 | N.R. | EFSA 2012 |
| **Metabolite X** | | | |
| *Pseudokirchneriella subcapitata* | 340 | N.R. | EFSA 2012 |
| **Formulations** | | | |
| **Fusilade Max (EC125 g/L)** | | | |
| *Pseudokirchneriella subcapitata* | 0.02 | N.R. | EFSA 2012 |
| *Pseudokirchneriella subcapitata* | 0.128[3] | N.R. | EFSA 2012 |
| *Navicula pelliculosa* | 0.188 | N.R. | EFSA 2012 |
| **Chinese 53% EC formulation** | | | |
| *Chlorella pyrenoidosa* | 13.3 | N.R. | Ma 2002 |
| *Chlorella pyrenoidosa* | 13.4 | N.R. | Ma et al. 2002b |
| *Chlorella vulgaris* | 18.5 | N.R. | Ma et al. 2002a |
| *Raphidocelis subcapitata* | 0.89 | N.R. | Ma et al. 2006 |
| *Scenedesmus obliquus* | 22.8 | N.R. | Ma 2002 |
| *Scenedesmus quadricauda* | 15.6 | N.R. | Ma et al. 2004 |
| **Unspecified formulation** | | | |
| *Dunaliella bioculata* | 0.327[4] | 0.033 | Felix et al. 1988 |

## AQUATIC MACROPHYTES

| Agent / Species | EC$_{50}$ (mg a.e./L)[1] | NOAEC (mg a.e./L) | Reference[2] |
|---|---|---|---|
| **Fluazifop-P-butyl** | | | |
| *Lemna gibba* | >1.2 | N.R. | EFSA 2012 (+) |
| *Lemna paucicostata* | N.R. | 327 | Michel et al. 2004 |
| **Fusilade Max (EC125 g/L)** | | | |
| *Lemna gibba* | >11.6 | N.R. | EFSA 2012 (+) |

[1] Values for Metabolite X are given in units of mg metabolite/L.  All other values are given as mg a.e./L.  If multiple endpoints are available, only the most sensitive endpoint is give.

[2] A reference followed by (+) indicates that the study is summarized in more than one review.   See Appendix 7, Table A7-1 for details.

[3] Assayed in sediment/water system.

[4] A 60% reduction in growth.

N.R.: Not reported.

Source: Appendix 7, Tables A7-1 (algae) and A7-2 (macrophytes).
See Section 4.1.3.4 for discussion.

**Table 31: Terrestrial Nontarget Animals Used in Ecological Risk Assessment**

## MAMMALS [1]

| Animal | Representative Species | W[4] | Food Consumption[5] | Water Consumption |
|---|---|---|---|---|
| Small mammal | Mice | 20 | $2.514\ W^{0.507}$ [Eq 3-48] | $0.099\ W^{0.9}$ [Eq 3-17] |
| Larger mammal | Squirrels | 400 | $2.514\ W^{0.507}$ [Eq 3-48] | $0.099\ W^{0.9}$ [Eq 3-17] |
| Canid | Fox | 5,000 | $0.6167\ W^{0.862}$ [Eq 3-47] | $0.099\ W^{0.9}$ [Eq 3-17] |
| Large Herbivorous Mammal | Deer | 70,000 | $1.518\ W^{0.73}$ [Eq 3-46] | $0.099\ W^{0.9}$ [Eq 3-17] |
| Large Carnivorous Mammal | Bear | 70,000 | $0.6167\ W^{0.862}$ [Eq 3-47] | $0.099\ W^{0.9}$ [Eq 3-17] |

## BIRDS [2]

| Animal | Representative Species | W[4] | Food Consumption[5] | Water Consumption |
|---|---|---|---|---|
| Small bird | Passerines | 10 | $2.123\ W^{0.749}$ [Eq 3-36] | $0.059\ W^{0.67}$ [Eq 3-15] |
| Predatory bird | Owls | 640 | $1.146\ W^{0.749}$ [Eq 3-37] | $0.059\ W^{0.67}$ [Eq 3-15] |
| Piscivorous bird | Herons | 2,400 | $1.916\ W^{0.704}$ [Eq 3-38] | $0.059\ W^{0.67}$ [Eq 3-15] |
| Large herbivorous bird | Geese | 4,000 | $1.146\ W^{0.749}$ [Eq 3-37] | $0.059\ W^{0.67}$ [Eq 3-15] |

## INVERTEBRATES [3]

| Animal | Representative Species | W[4] | Food Consumption[5] |
|---|---|---|---|
| Honey bee [7] | *Apis mellifera* | 0.000116 | ≈2 (1.2 to 4)[6] |
| Herbivorous Insects | Various | Not used | 1.3 (0.6 to 2.2) |

[1] Sources: Reid 2006; U.S. EPA/ORD 1993.

[2] Sources: Sibley 2000; Dunning 1993; U.S. EPA/ORD 1993.

[3] Sources: Humphrey and Dykes 2008; Reichle et al. 1973; Winston 1987

[4] Body weight in grams.

[5] For vertebrates, based on allometric relationships estimating field metabolic rates in kcal/day for rodents (omnivores), herbivores, and non-herbivores. For mammals and birds, the estimates are based on Nagy (1987) as adapted by U.S. EPA/ORD (1993). The equation numbers refer to U.S. EPA/ORD (1993). See the following table for estimates of caloric content of food items. For herbivorous insects, consumption estimates are based on fractions of body weight (g food consumed/g bw) from the references in Note 3.

[6] For honeybees, food consumption based on activity and caloric requirements. Used only when estimates of concentrations in nectar and/or pollen can be made, which is not the case in the current risk assessment.

[7] A surface area of 1.42 cm2 is used for the direct spray scenario of the honey bee. This value is based on the algorithms suggested by Humphrey and Dykes (2008) for a bee with a body length of 1.44 cm.

See data on food commodities in following table.
See Sections 4.2.2 and 4.2.3.2 for discussion.

**Table 32: Diets: Metabolizable Energy of Various Food Commodities**

| Food Item | Animal Group | Caloric Value [1] (kcal/g bw) | Water Content [2] | Comment/Source(s) |
|---|---|---|---|---|
| Fruit | Mammals | 1.1 | 0.77 | See Footnote 3 |
|  | Birds | 1.1 | 0.77 | See Footnote 4 |
| Fish | Mammals | 4.47 | 0.70 | Water content from Ali et al. (2005). |
|  | Birds | 3.87 | 0.70 | Water content from Ali et al. (2005). |
| Insects | Mammals | 4.47 | 0.70 | Water contents from Chapman 1998 ( p. 491). Typical ranges of 60-80%. |
|  | Birds | 4.30 | 0.70 | Water contents from Chapman 1998 ( p. 491). Typical ranges of 60-80%. |
| Vegetation (NOS) | Mammals | 2.26 | 0.85 | See Footnote 5 |
|  | Birds | 2.0 | 0.85 | See Footnote 5 |

[1] Metabolizable energy. Unless otherwise specified, the values are taken from U.S. EPA/ORD (1993), Table 3-1, p. 3-5 as adopted from Nagy 1987.

[2] From U.S. EPA/ORD (1993), Table 4-2, p. 4-14 unless otherwise specified.

[3] Based on a gross caloric value of 2.2 kcal/g bw (U.S. EPA/ORD 1993, Table 4-2). An assimilation factor for mammals eating fruit not identified. Use estimate for birds (see below).

[4] Based on a gross caloric value of 2.2 kcal/g bw (U.S. EPA/ORD 1993, Table 4-2) and an assimilation factor for the consumption of fruit by birds of 51% [2.2 kcal/g bw x 0.51 ≈ 1.1 kcal/g bw]

[5] Based on a gross caloric value of 4.2 kcal/g bw for dicot leaves (U.S. EPA/ORD 1993, Table 4-2). For birds, the value is corrected by an assimilation factor for the consumption leaves by birds of 47% [4.2 kcal/g bw x 0.47 = 1.974 kcal/g bw]

See Sections 4.2.2.3 for discussion.

**Table 33: Summary of toxicity values used in ecological risk assessment**

| Group/Duration Organism | | Endpoint | Toxicity Value (a.e.) | Reference |
|---|---|---|---|---|
| **Terrestrial Animals** | | | | |
| **Acute** | | | | |
| Non-canine Mammals | | Basis for Acute RfD | 43 mg/kg bw | Section 4.3.2.1. |
| Canine Mammals | | No indication more sensitive | N/A | Section 4.3.2.1. |
| Birds | | Mallard acute dietary | 1069 mg/kg bw | Section 4.3.2.2.1 |
| Herbivorous Insect (oral) | | Oral NOAEL from honey bee | 736 mg/kg bw | Section 4.3.2.4.1 |
| Honey Bee (contact) | | Contact NOAEL | 698 mg/kg bw | Section 4.3.2.4.1 |
| Sensitive insects | | *Typhlodromus pyri* $LD_{50}$ | 0.004 and 0.13 lb/acre | Section 4.3.2.4.2 |
| **Longer-term** | | | | |
| Mammal | | Basis for Chronic RfD | 0.63 mg/kg bw/day | Section 4.3.2.1 |
| Bird | | Reproductive, quail | 3.3 mg/kg bw/day | Section 4.3.2.2.2 |
| **Terrestrial Plants** | | | | |
| Soil | Sensitive | Sensitive monocot, LOAEL | 0.027 lb/acre | Section 4.3.2.5.1 |
| | Tolerant | Tolerant dicot, NOAEL | 0.57 lb/acre | Section 4.3.2.5.2 |
| Foliar | Sensitive | Sensitive monocot, $EC_{50}$ | 0.007 lb/acre | Section 4.3.2.5.1 |
| | Tolerant | Tolerant dicot, NOAEL | 0.76 lb/acre | Section 4.3.2.5.2 |
| **Aquatic Animals** | | | | |
| **Acute** | | | | |
| Amphibians | Sensitive | No information | N/A | Section 4.3.3.2 |
| | Tolerant | No information | N/A | |
| Fish | Sensitive | Fathead minnow NOAEC | 0.203 mg/L | Section 4.3.3.1 |
| | Tolerant | Trout NOAEC | 0.68 mg/L | |
| Invertebrates | Sensitive | Oyster embryo NOAEC | 0.048 mg/L | Section 4.3.3.3 |
| | Tolerant | *Daphnia magna* NOAEC | 1.07 mg/L | Section 4.3.3.3 |
| **Longer-term** | | | | |
| Amphibians | Sensitive | No information | N/A | Section 4.3.3.2 |
| | Tolerant | No information | N/A | |
| Fish | Sensitive | Fathead minnow NOAEC | 0.20 mg/L | Section 4.3.3.1 |
| | Tolerant | No data | N/A | Section 4.3.3.1 |
| Invertebrates | Sensitive | Shrimp NOAEC | 0.0148 mg/L | Section 4.3.3.3 |
| | Tolerant | *Daphnia magna* NOAEC | 0.085 mg/L | Section 4.3.3.3 |
| **Aquatic Plants** | | | | |
| Algae | Sensitive | *P. subcapitata* $LC_{50}\div20$ | 0.001 mg/L | Section 4.3.3.4.1 |
| | Tolerant | *S. obliquus* $LC_{50}\div20$ | 1.14 mg/L | Section 4.3.3.4.1 |
| Macrophytes | Sensitive | Not identified. | N/A | Section 4.3.3.4.2 |
| | Tolerant | Lemna NOAEC | 327 mg/L | Section 4.3.3.4.2 |

**Table 34: Risk Characterization for Non-Accidental Exposures in Mammals (3 applications)**

All values given as Hazard Quotients.

| Item | Receptor | Central | Lower | Upper |
|---|---|---|---|---|
| **Acute** | | | | |
| **Fruit** | | | | |
| | Small mammal (20g) | 0.2 | 2E-02 | 0.6 |
| | Larger Mammal (400g) | 4E-02 | 5E-03 | 0.1 |
| | Large Mammal (70 kg) | 2E-02 | 3E-03 | 8E-02 |
| **Broadleaf Foliage** | | | | |
| | Small mammal (20g) | 0.8 | 7E-02 | 4 |
| | Larger Mammal (400g) | 0.2 | 2E-02 | 0.9 |
| | Large Mammal (70 kg) | 1E-01 | 9E-03 | 0.5 |
| **Tall Grass** | | | | |
| | Small mammal (20g) | 0.6 | 6E-02 | 3 |
| | Larger Mammal (400g) | 0.1 | 1E-02 | 0.8 |
| | Large Mammal (70 kg) | 8E-02 | 8E-03 | 0.4 |
| **Short Grass** | | | | |
| | Small mammal (20g) | **1.4** | 0.1 | 7 |
| | Larger Mammal (400g) | 0.3 | 3E-02 | **1.7** |
| | Large Mammal (70 kg) | 0.2 | 2E-02 | 1.0 |
| **Surface Water** | | | | |
| | Small mammal (20g) | 5E-05 | 5E-06 | 5E-04 |
| | Larger Mammal (400g) | 4E-05 | 4E-06 | 4E-04 |
| | Canid (5 kg) | 3E-05 | 3E-06 | 3E-04 |
| | Large Mammal (70 kg) | 2E-05 | 2E-06 | 2E-04 |
| **Insects** | | | | |
| | Small mammal (20g) | 0.2 | 2E-02 | **1.0** |
| | Larger Mammal (400g) | 4E-02 | 4E-03 | 0.2 |
| **Small mammal** | | | | |
| | Canid (5 kg) | 2E-02 | 6E-03 | 3E-02 |
| **Fish** | | | | |
| | Large Mammalian Carnivore (70 kg) | 5E-03 | 5E-05 | 0.2 |
| | Canid (5 kg) | 6E-03 | 6E-05 | 0.3 |
| **Chronic** | | | | |
| **Fruit** | **Lowest Residue Rates** | | | |
| | Small mammal (20g) | **3** | 0.4 | **12** |
| | Larger Mammal (400g) | 0.7 | 8E-02 | **3** |
| | Large Mammal (70 kg) | 0.4 | 5E-02 | **1.6** |
| **Broadleaf Foliage** | | | | |
| | Small mammal (20g) | **14** | **1.2** | **82** |
| | Larger Mammal (400g) | **3** | 0.3 | **19** |
| | Large Mammal (70 kg) | **1.8** | 0.2 | **11** |
| **Tall Grass** | | | | |
| | Small mammal (20g) | **11** | 1.0 | **67** |
| | Larger Mammal (400g) | **3** | 0.2 | **15** |
| | Large Mammal (70 kg) | **1.5** | 0.1 | **9** |
| **Short Grass** | **Highest Residue Rate** | | | |
| | Small mammal (20g) | **26** | **2** | **146** |
| | Larger Mammal (400g) | **6** | 0.6 | **33** |
| | Large Mammal (70 kg) | **3** | 0.3 | **19** |
| **Surface Water** | | | | |
| | Small mammal (20g) | 1E-03 | 1E-04 | 1E-02 |
| | Larger Mammal (400g) | 1E-03 | 1E-04 | 1E-02 |
| | Canid (5 kg) | 9E-04 | 9E-05 | 9E-03 |
| | Large Mammal (70 kg) | 7E-04 | 7E-05 | 7E-03 |
| **Fish** | | | | |
| | Large Mammalian Carnivore (70 kg) | 0.1 | 1E-03 | **7** |
| | Canid (5 kg) | 0.2 | 2E-03 | **10** |

Source: Attachment 3, Worksheet G02a.
See Attachment 1, Worksheet G02a, for one application and
Attachment 2, Worksheet G02a, for two applications.

See Section 4.4.2.1 for discussion.

**Table 35: Risk Characterization for Non-Accidental Exposure in Birds (3 applications)**
All values given as Hazard Quotients.

| Item | Receptor | Central | Lower | Upper |
|---|---|---|---|---|
| **Acute** | | | | |
| **Fruit** | | | | |
| | Small bird (10g) | 1E-02 | 2E-03 | 5E-02 |
| | Large Bird (4 kg) | 2E-03 | 2E-04 | 6E-03 |
| **Broadleaf Foliage** | | | | |
| | Small bird (10g) | 8E-02 | 7E-03 | 0.4 |
| | Large Bird (4 kg) | 9E-03 | 8E-04 | 5E-02 |
| **Tall Grass** | | | | |
| | Small bird (10g) | 6E-02 | 6E-03 | 0.3 |
| | Large Bird (4 kg) | 7E-03 | 7E-04 | 4E-02 |
| **Short Grass** | | | | |
| | Small bird (10g) | 0.1 | 1E-02 | 0.7 |
| | Large Bird (4 kg) | 2E-02 | 2E-03 | 8E-02 |
| **Water** | | | | |
| | Small bird (10g) | 4E-06 | 4E-07 | 4E-05 |
| | Large Bird (4 kg) | 6E-07 | 6E-08 | 5E-06 |
| **Insects** | | | | |
| | Small bird (10g) | 2E-02 | 2E-03 | 1E-01 |
| **Small mammal** | | | | |
| | Carnivorous bird (640 g) | 1E-03 | 3E-04 | 2E-03 |
| **Fish** | | | | |
| | Fish-eating bird (2.4 kg) | 3E-04 | 3E-06 | 2E-02 |
| **Chronic** | | | | |
| **Fruit** | | | | |
| | Small bird (10g) | **1.2** | 0.1 | **5** |
| | Large Bird (4 kg) | 0.1 | 2E-02 | 0.6 |
| **Broadleaf Foliage** | | | | |
| | Small bird (10g) | **7** | 0.6 | **39** |
| | Large Bird (4 kg) | 0.7 | 7E-02 | **4** |
| **Tall Grass** | | | | |
| | Small bird (10g) | **5** | 0.5 | **32** |
| | Large Bird (4 kg) | 0.6 | 5E-02 | **4** |
| **Short Grass** | | | | |
| | Small bird (10g) | **12** | **1.2** | **69** |
| | Large Bird (4 kg) | **1.4** | 0.1 | **8** |
| **Water** | | | | |
| | Small bird (10g) | 5E-04 | 5E-05 | 5E-03 |
| | Large Bird (4 kg) | 7E-05 | 7E-06 | 7E-04 |
| **Fish** | | | | |
| | Fish-eating bird (2.4 kg) | 4E-02 | 4E-04 | **2** |

Source: Attachment 3, Worksheet G02b.
See Attachment 1, Worksheet G02b, for one application and
Attachment 2, Worksheet G02b, for two applications.
See Section 4.4.2.2 for discussion.

**Table 36: Risk Characterization for Sensitive Species of Terrestrial Arthropods**

**Hazard Quotient based on LD$_{50}$ of 0.004 lb a.e./acre**

| Distances downwind in feet [0 feet = direct spray] | Aerial | High Boom Ground Broadcast | Low Boom Ground Broadcast | Backpack |
|---|---|---|---|---|
| Direct Spray | **80** | **80** | **80** | **80** |
| 25 | **18** | **8** | **3** | 0.7 |
| 50 | **14** | **4** | **1.4** | 0.3 |
| 100 | **8** | **2.0** | 0.8 | 0.2 |
| 300 | **2** | 0.6 | 0.3 | 8E-02 |
| 500 | **1.5** | 0.3 | 0.2 | 5E-02 |
| 900 | 1.0 | 0.1 | 9E-02 | 2E-02 |

**Hazard Quotients based on LD$_{50}$ of 0.13 lb a.e./acre**

| Distances downwind in feet [0 feet = direct spray] | Aerial | High Boom Ground Broadcast | Low Boom Ground Broadcast | Backpack |
|---|---|---|---|---|
| Direct Spray | **2** | **2** | **2** | **2** |
| 25 | 0.5 | 0.3 | 9E-02 | 2E-02 |
| 50 | 0.4 | 0.1 | 4E-02 | 1E-02 |
| 100 | 0.2 | 6E-02 | 2E-02 | 6E-03 |
| 300 | 8E-02 | 2E-02 | 9E-03 | 2E-03 |
| 500 | 5E-02 | 1E-02 | 5E-03 | 1E-03 |
| 900 | 3E-02 | 4E-03 | 3E-03 | 8E-04 |

Source: Worksheet G10 of Attachments 1 to 3.
See Section 4.4.2.4.2 for discussion.

**Table 37: Risk Characterization for Fish**

All values given as Hazard Quotients.

| Applications | Type | Central | Lower | Upper |
|---|---|---:|---:|---:|
| **Accidental** | | | | |
| All | Sensitive | **3** | 0.3 | **25** |
| | Tolerant | **1.1** | 0.1 | **9** |
| **Other Acute** | | | | |
| One | Sensitive | 3E-02 | 3E-03 | 0.3 |
| | Tolerant | 9E-03 | 9E-04 | 0.1 |
| Two | Sensitive | 5E-02 | 5E-03 | 0.6 |
| | Tolerant | 2E-02 | 2E-03 | 0.2 |
| Three | Sensitive | 7E-02 | 7E-03 | 0.7 |
| | Tolerant | 2E-02 | 2E-03 | 0.2 |
| **Chronic** | | | | |
| One | Sensitive | 1E-02 | 1E-03 | 0.1 |
| | Tolerant | N/A[1] | N/A[1] | N/A[1] |
| Two | Sensitive | 2E-02 | 2E-03 | 0.3 |
| | Tolerant | N/A[1] | N/A[1] | N/A[1] |
| Three | Sensitive | 3E-02 | 3E-03 | 0.3 |
| | Tolerant | N/A[1] | N/A[1] | N/A[1] |

[1] Not available because of the lack of toxicity data in a clearly tolerant species.

Source: Attachments 1 through 3, Worksheet G03.
See Section 4.4.3.1 for discussion.

**Table 38: Risk Characterization for Aquatic Invertebrates**

All values given as Hazard Quotients.

| Applications | Type | Central | Lower | Upper |
|---|---|---|---|---|
| **Accidental** | | | | |
| All | Sensitive | **15** | **1.5** | **121** |
| | Tolerant | 0.7 | 7E-02 | **5** |
| **Other Acute** | | | | |
| One | Sensitive | 0.1 | 1E-02 | **1.5** |
| | Tolerant | 6E-03 | 6E-04 | 7E-02 |
| Two | Sensitive | 0.2 | 2E-02 | **3** |
| | Tolerant | 1E-02 | 1E-03 | 0.1 |
| Three | Sensitive | 0.3 | 3E-02 | **3** |
| | Tolerant | 1E-02 | 1E-03 | 0.1 |
| **Chronic** | | | | |
| One | Sensitive | 0.2 | 2E-02 | **1.8** |
| | Tolerant | 3E-02 | 3E-03 | 0.3 |
| Two | Sensitive | 0.3 | 3E-02 | **3** |
| | Tolerant | 5E-02 | 5E-03 | 0.6 |
| Three | Sensitive | 0.4 | 4E-02 | **4** |
| | Tolerant | 8E-02 | 8E-03 | 0.8 |

Source: Attachments 1 through 3, Worksheet G03.
See Section 4.4.3.3 for discussion.

**Table 39: Risk Characterization for Algae**

All values given as Hazard Quotients.

| Applications | Type | Central | Lower | Upper |
|---|---|---|---|---|
| **Accidental** | | | | |
| All | Sensitive | **719** | **73** | **5,829** |
| | Tolerant | 0.6 | 6E-02 | **5** |
| **Other Acute** | | | | |
| One | Sensitive | **6** | 0.6 | **74** |
| | Tolerant | 6E-03 | 6E-04 | 6E-02 |
| Two | Sensitive | **12** | **1.2** | **131** |
| | Tolerant | 1E-02 | 1E-03 | 0.1 |
| Three | Sensitive | **16** | **1.6** | **150** |
| | Tolerant | 1E-02 | 1E-03 | 0.1 |
| **Chronic** | | | | |
| One | Sensitive | **2** | 0.2 | **27** |
| | Tolerant | 2E-04 | 2E-04 | 2E-02 |
| Two | Sensitive | **4** | 0.4 | **51** |
| | Tolerant | 4E-03 | 4E-04 | 4E-02 |
| Three | Sensitive | **6** | 0.6 | **64** |
| | Tolerant | 6E-03 | 6E-04 | 6E-02 |

Source: Attachments 1 through 3, Worksheet G03.
See Section 4.4.3.4.1 for discussion.

**Table 40: Risk Characterization for Aquatic Macrophytes**

| Applications | Type | Central | Lower | Upper |
|---|---|---|---|---|
| **Accidental** | | | | |
| All | Sensitive | | | |
| | Tolerant | 2E-03 | 2E-04 | 2E-02 |
| **Other Acute** | | | | |
| One | Sensitive | N/A[1] | N/A[1] | N/A[1] |
| | Tolerant | 2E-05 | 2E-06 | 2E-04 |
| Two | Sensitive | N/A[1] | N/A[1] | N/A[1] |
| | Tolerant | 4E-05 | 4E-06 | 4E-04 |
| Three | Sensitive | N/A[1] | N/A[1] | N/A[1] |
| | Tolerant | 5E-05 | 5E-06 | 5E-04 |
| **Chronic** | | | | |
| One | Sensitive | N/A[1] | N/A[1] | N/A[1] |
| | Tolerant | 7E-06 | 7E-07 | 8E-05 |
| Two | Sensitive | N/A[1] | N/A[1] | N/A[1] |
| | Tolerant | 1E-05 | 1E-06 | 2E-04 |
| Three | Sensitive | N/A[1] | N/A[1] | N/A[1] |
| | Tolerant | 2E-05 | 2E-06 | 2E-04 |

[1] Not available because of the lack of toxicity data in a clearly
sensitive species.

Source: Attachments 1 through 3, Worksheet G03.
See Section 4.4.3.4.2 for discussion.

**Fluazifop-P-butyl and Fluazifop-P (Free Acid)**
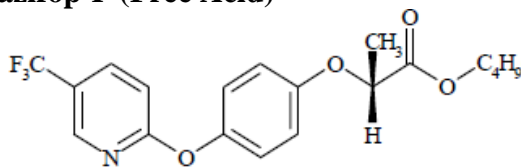


**Fluazifop-P-butyl ([R] enantiomer of fluazifop-P-butyl)**
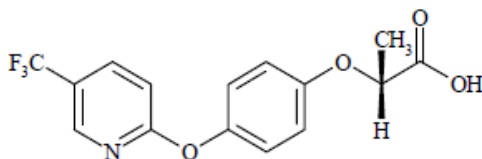


**Fluazifop-P ([R] enantiomer of fluazifop)**

**Major Environmental Metabolites**
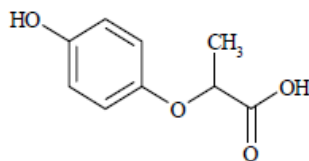


**2-(4-hydroxyphenoxy) propionic acid (Compound III metabolite)**
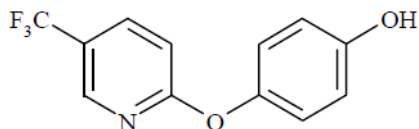


**2-(4-hydroxyphenoxy)-5-trifluoromethylpyridine (Compound IV metabolite)**
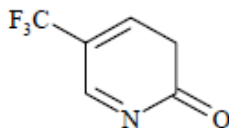


**5-trifluoromethyl-2-pyridone (Compound X metabolite)**

**Figure 1: Structure of Fluazifop-P-butyl and Major Environmental Metabolites**

Sources: U.S. EPA/OPP/HED 2004a.b,c; U.S. EPA/OPP/EFED 2008

See Section 2.2 for general discussion of enantiomers.
See Section 3.1.15.1 for discussion of metabolites.

## Estimated Agricultural Use for Fluazifop, 2009
### EPest-Low

Estimated use on agricultural land, in pounds per square mile

- < 0.0067
- 0.0067 - 0.0536
- 0.0537 - 0.2121
- 0.2122 - 0.7224
- > 0.7225
- No estimated use

## Use by Year and Crop

Estimated use in million pounds

- Other
- Pasture and hay
- Orchards and grapes
- Rice
- Vegetables and fruit
- Cotton
- Wheat
- Soybeans
- Corn
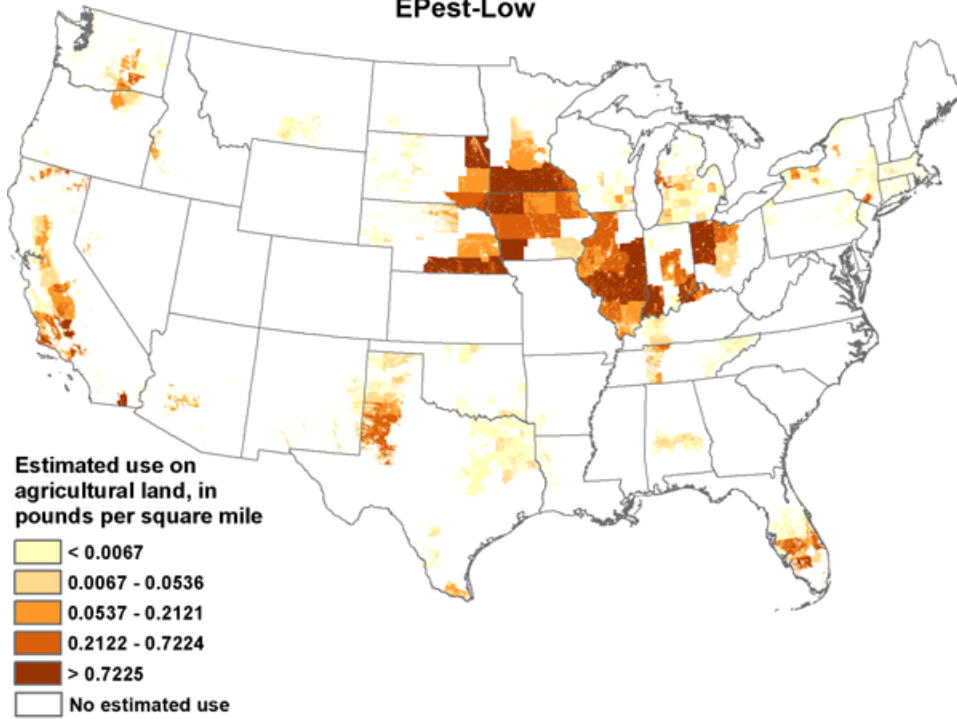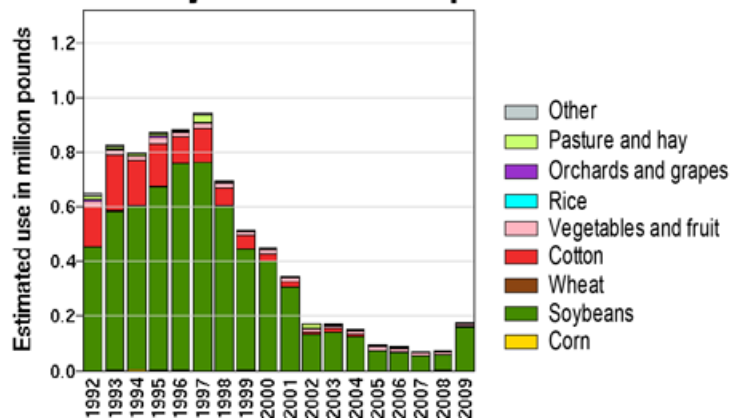
**Figure 2: Lower Bound Estimated Agricultural Use of Fluazifop-P-butyl for 2009**

Source: USGS(2013)
See Section 2.5 for discussion.

196

## Estimated Agricultural Use for Fluazifop , 2009

### EPest-High



**Estimated use on agricultural land, in pounds per square mile**

- < 0.0067
- 0.0067 - 0.0536
- 0.0537 - 0.2121
- 0.2122 - 0.7224
- > 0.7225
- No estimated use

## Use by Year and Crop



Legend:
- Other
- Pasture and hay
- Orchards and grapes
- Rice
- Vegetables and fruit
- Cotton
- Wheat
- Soybeans
- Corn
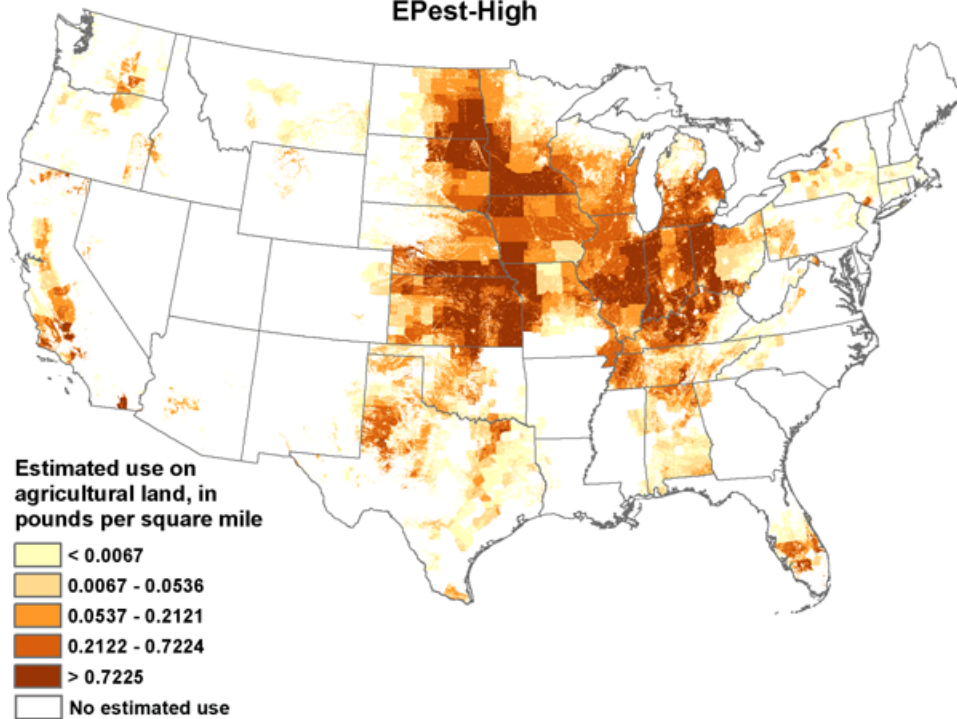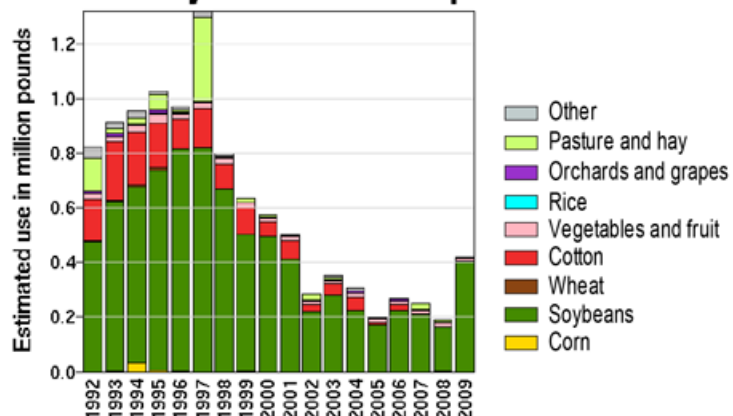
**Figure 3: Upper Bound Estimated Agricultural Use of Fluazifop-P-butyl for 2009**

Source: USGS (2013)
See Section 2.5 for discussion.
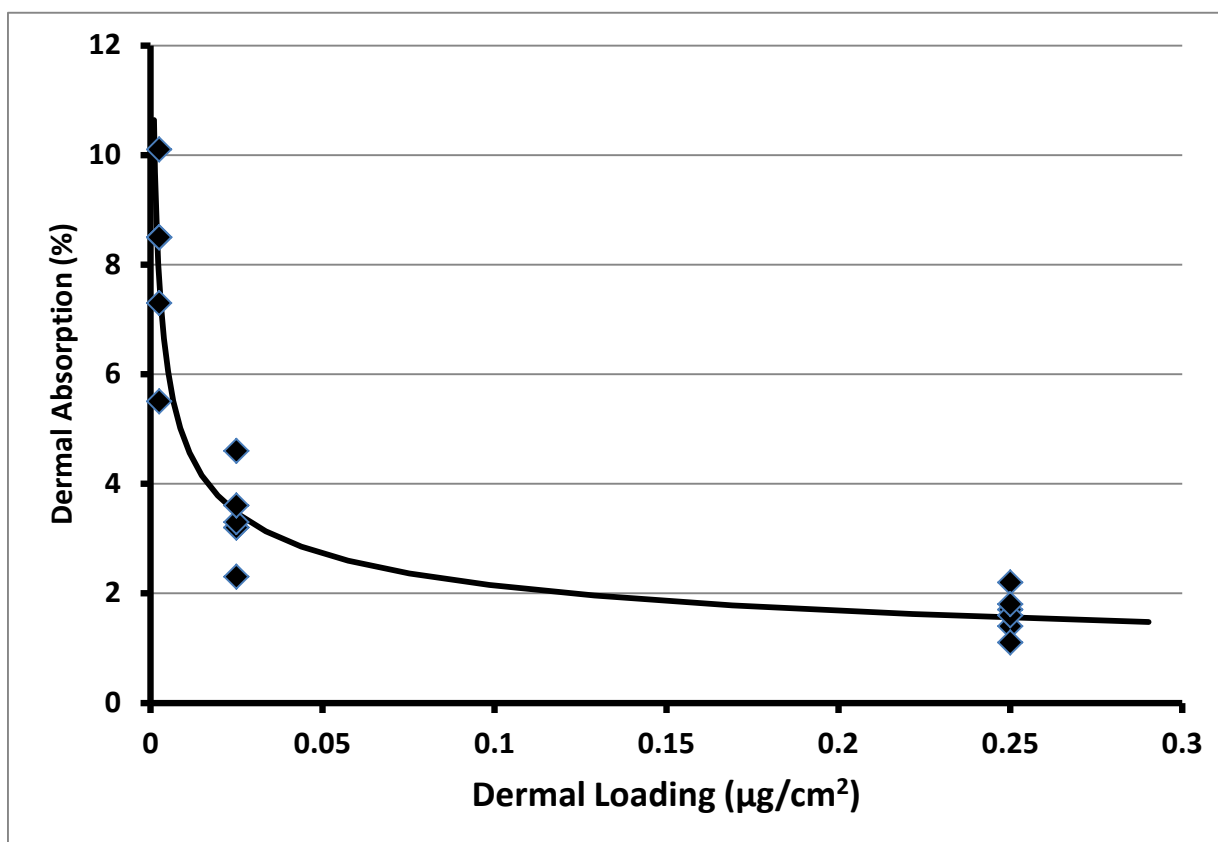
**Figure 4: Relationship of Dermal Absorption to Dermal Loading**

Data from Ramsey et al. 1992 as summarized in Table 9.
See Section 3.1.3.2.1 for discussion.

Note: The relationship of dermal absorption (Abs) to dermal loading (L) fits the following exponential function:   $Abs = 0.96L^{-0.348}$  ($r^2 = 0.91$, $p = 9 \times 10^{-10}$).
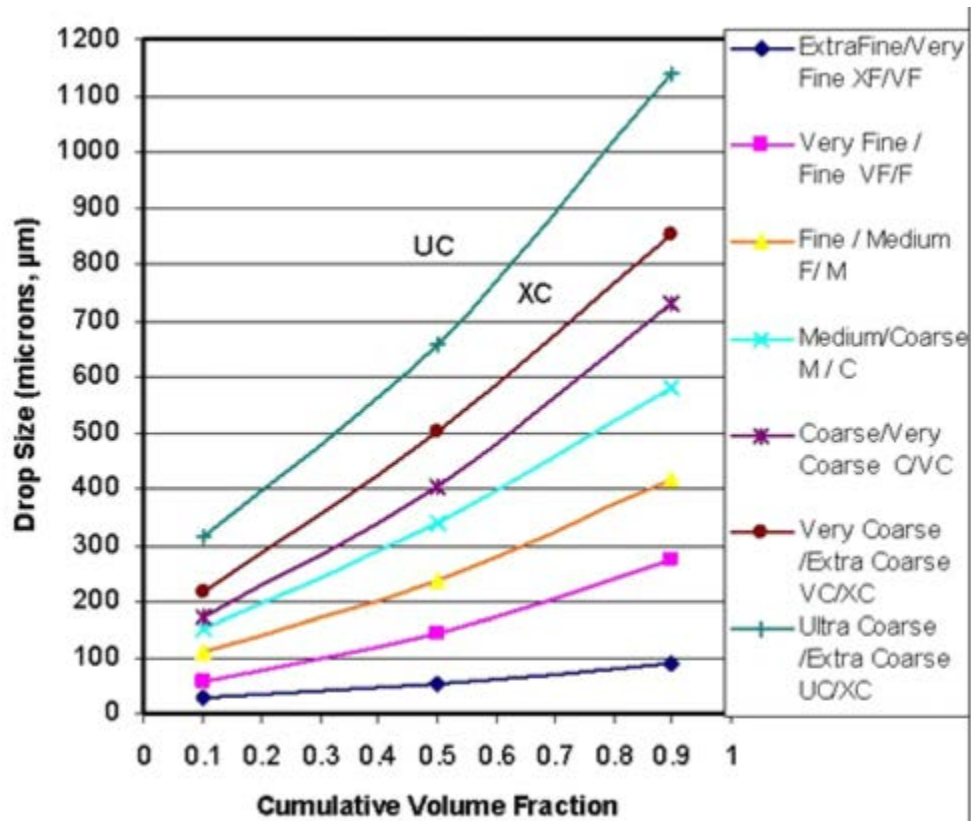
**Figure 5: Sample Reference Graph for Droplet Size Classification**

Source: ASABE (American Society of Agricultural and Biological Engineers) 2013.
Available at: http://www.asabe.org/media/107792/s572_figure_1.jpg.

See Section 3.1.3.2.1 for discussion.
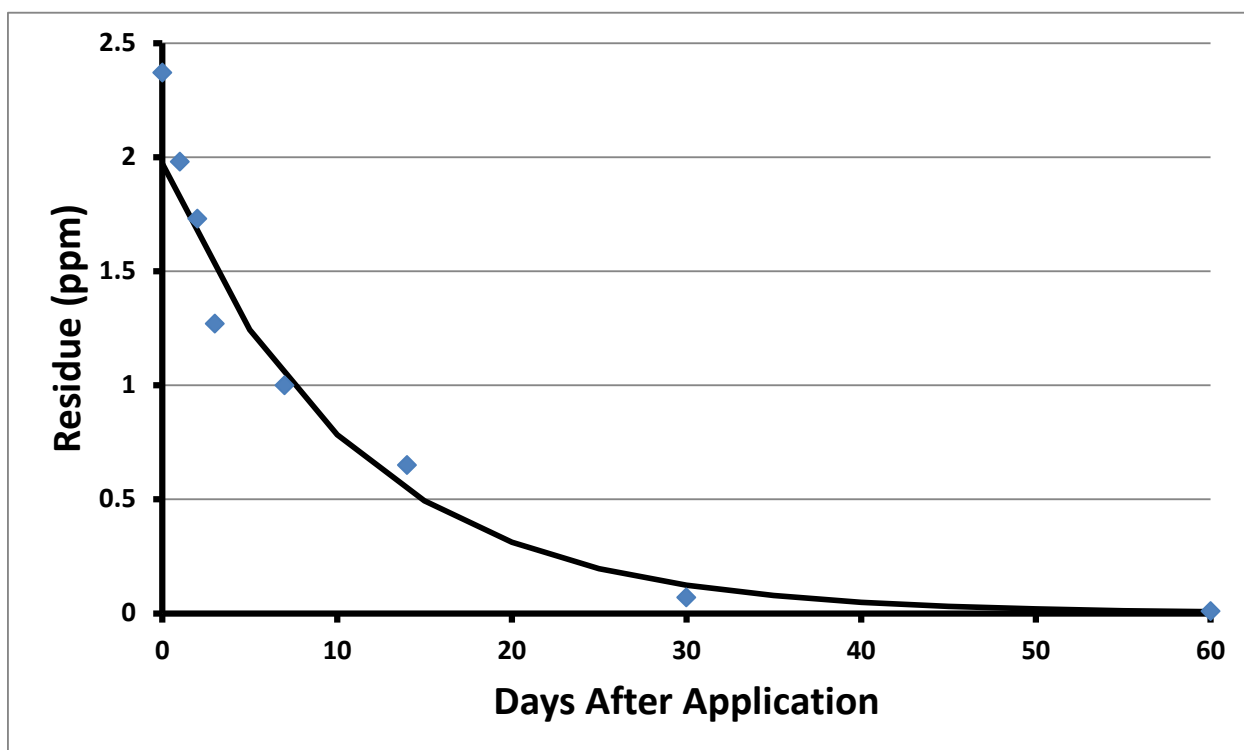
**Figure 6: Residues on soybean foliage from Kulshrestha et al. (1995)**

Note: Data fit a standard first-order decay function ($r^2$=0.981, $p$=2.07x10$^{-6}$) yielding a half-life of 7.51 (6.60-8.71) days.

See Section 3.2.3.7 for discussion.

**Appendix 1: Toxicity to Mammals.**

**MRID studies from U.S. EPA/OPP HED 2004a unless otherwise specified.**

**The summaries in this appendix are initially summarized from U.S. EPA/OPP/HED 2004a, Tables 4.1a and 4.1b with little modification.  Elaborations are made for some studies based on other information in U.S. EPA/OPP HED 2004a or information taken from U.S. EPA/OPP/HED 2011a (most recent RA) and U.S. EPA/OPP/HED 2004d (Report of Hazard Identification Assessment committee).**

**The Agency documents appear to express the doses and other measures of exposure as a.i. rather than mg a.e.  This is discussed further in the dose/response assessment (Section 3.3).  No a.i. to a.e. transformations are made in this appendix.**

**For the subchronic, chronic and reproduction studies, daily doses in mg/kg bw/day for dietary concentrations are taken directly from the U.S. EPA summaries.**

**A1 Table 1: Acute Oral LD$_{50}$ Values**

| Species | Compound | Response | Reference |
|---|---|---|---|
| **Gavage** | | | |
| Mice | Fluazifop-P-butyl (NOS) | LD$_{50}$: >2000 mg/kg bw | EFSA 2012 , p. 30 |
| Rats | Fluazifop-butyl, PP009, 97.2% | Acute LD$_{50}$<br>Males: 1940 (1193-2758) mg/kg<br>Females: 2653 (1764-3625) mg/kg<br>Toxicity Category III | MIRD 00162439, 1983 |
| Rats | Fluazifop-P-butyl, PP005, 93.7% and 86.3% | Acute LD$_{50}$<br>Males: 3680 mg/kg<br>Females: 2451 mg/kg<br>Toxicity Category III | MRID 00162440, 1984<br>Also cited in FOA/WHO 2000 and EFSA 2012 (females only) |

Appendix 1: Toxicity to mammals *(continued)*

| Species | Compound | Response | Reference |
|---|---|---|---|
| **Gavage** | | | |
| Rats, Wistar, male | Fluazifop acid, 92.2%, at doses of 0, 56, 112, 223, 446 and 891 mg/kg/day for 7 days. | Significant increases in liver palmitoyl-CoA oxidation at doses greater than 56 mg/kg bw. Significant and dose-related increases in catalase activity and relative liver weight at all doses. (Table 2 of paper) | Kostka et al. 2002 |
| Rats, Wistar, male | Fluazifop acid, 92.2%, dose of 446 mg/kg bw/day for up to 14 days | Increase in thymidine incorporation after single dose. No effect on liver cell mitoses. Transient increase in binuclear hepatocytes   from Day 2 to Day 7. (Table 3 of paper) | Kostka et al. 2002 |
| Rats, Wistar, male | Fluazifop acid, 92.2%, single doses of 0, 223, 446, and 891 mg/kg bw | Significant increases in liver DNA synthesis, and the number of binuclear hepatocytes.  No significant increase in mitoses. (Table 4 of paper) | Kostka et al. 2002 |
| Rats, Wistar, male | Fluazifop acid, 92.2%, 446 mg/kg bw/day for 14 days. | Significant increase in liver peroxisomes on Day 4 and thereafter. Significant increase in liver weight on Day 2 and thereafter. Reduced body weight gain from Day 7 to Day 14. | Kostka et al. 2002 |
| Rats, Wistar, M/F, 10/sex/dose. | Fluazifop-butyl, doses of  0, 4, 20, 100 and 500 mg/kg/day, 5 d/w, for 2 weeks. | 500 mg/kg: Signs of toxicity (piloerection, reduced motor activity, retinal pallor, and a prone or hunched posture) with mortality in 2 animals (sacrificed *in extemis*) evidenced liver necrosis. 100 mg/kg: Increase in absolute and relative liver weights in male rats. | U.S. EPA/OTS 1992c |
| **Dietary** | | | |
| Mice, male, C57B1/6J | Fluazifop-butyl, dietary concentration of 2500 ppm for 10 days. | Increase in liver weight (about 2x controls) as well as cytochrome P450 ($\approx$1.6x controls). | Krijt et al. 1993 |

**Note on Kostka et al. 2002:** No signs for liver pathology in any of the above studies.  Other than decreases in body weight at 446 and 891 mg/kg bw, no overt signs of toxicity or changes in food and water consumption were noted.

See Section 3.1.4 for general discussion.

Appendix 1: Toxicity to mammals *(continued)*

**A1 Table 2: Subchronic and Chronic Toxicity Studies**

Summaries from U.S. EPA/OPP/HED 2011a unless otherwise specified.

| Organism | Agent/Exposure | Response | MRID, Study Date, Classification |
|---|---|---|---|
| Dogs | Fluazifop-butyl, 90 days<br>Doses: 0, 5, 25, 125/250 mg/kg/day | NOAEL = 25 mg/kg/day<br>LOAEL = 125/250 mg/kg/day based on multiple pathologies in 3 dogs (2 males and 1 female) killed at 1 month dosed at 250 mg/kg/day.<br>Also seen were body weight loss gut lesions, severe eye lesions and hepatotoxicity.<br>In remaining surviving dogs dosed at 125 mg/kg/day , mild to equivocal liver lesions were seen. | MRID 00093821 1980, Acceptable |
| Dogs | Fluazifop-butyl<br>Doses: 0, 5, 25, 125 mg/kg/day for 1 year. | NOAEL = 5 mg/kg/day<br>LOAEL = 25 mg/kg/day based on marginally increased incidence adrenal fatty vacuolation & increased incidence of thymic involution and at 125 mg/kg/day death of 4/6 males and 2/6 females, eye, gastrointestinal tract lesions, adrenal and bone marrow pathology and thymic involution. | **MRID 00131462, 00131463, 92067018, (1982), Acceptable** |
| Hamsters | Fluazifop-P-butyl, 90 days<br>M: 0, 19.5, 78.3 or 291.9 mg/kg/day<br>F: 0, 19.9, 79.0 or 319.6 mg/kg/day<br><br>**Working Note: This study appears to be a dietary exposure study but the dietary concentrations are not specified in U.S. EPA/OPP/HED 2011a or other documents.** | NOAEL = M/F: 78.3/79.0 mg/kg/day<br>LOAEL = M/F: 291.9/319.6 mg/kg/day based on decreased body weight/body weight gain and food efficiency in males and evidence of liver toxicity; centrilobular eosinophilia/loss of glycogen in males and females. | MRID 46082902, 2001, Acceptable |
| Hamsters | Fluazifop-P-butyl , 80 weeks<br>Dietary Conc: 200, 750, 3000 ppm<br>M: 0, 12.5, 47.4,193.6 mg/kg/day<br>F; 0, 12.1, 45.5, 181.4 mg/kg/day | NOAEL = M/F 12.5/12.1 mg/kg/day<br>LOAEL = 47.5/45.5 mg/kg/day based on based on increased incidence of males with reduced sperm, testicular degeneration, eye cataract changes, liver inflammation and gall stones and in females, increased incidence of ovarian stroma cell/sex chord hyperplasia.<br>High Dose Group: Slight increase in brain weights.<br>No evidence of carcinogenicity | MRID 4534501, 46082905, (2001), Acceptable |
| Rats | Fluazifop-butyl, 90 days<br>Dietary Conc: 0, 10, 100, 2000  ppm<br>M: 0, 0.7, 7.1, 144.5 mg/kg/day<br>F; 0, 0.8, 8.0, 161.9 mg/kg/day | NOAEL=0.7 mg/kg/day<br>LOAEL=7.1 mg/kg/day based on liver and kidney histopathology | MRID 00093820 , 1980, Acceptable |

Appendix 1: Toxicity to mammals *(continued)*

| Organism | Agent/Exposure | Response | MRID, Study Date, Classification |
|---|---|---|---|
| Rats | Fluazifop-P-butyl, 90 days<br>Dietary Conc: 0, 10, 100, 2000 ppm<br>M: Doses not specified.<br>F; 0, 0.5, 5, 100 mg/kg/day | NOAEL=0.5 mg/kg/day<br>LOAEL=5 mg/kg/day based on decreased spleen weight and decreased hematological parameters in males.<br>Dose related testicular weight decrement and cholesterol depression were also seen.<br>2000 ppm : Slight increase in brain weights (2.9%) in female rats. | MRID 46158402, 1985, Acceptable |
| Rats, Wistar, 60/sex/group.<br><br>Interim sacrifice, 10/group at 52 weeks. | Fluazifop-butyl, 94.8%, 106 w (M) or 107 weeks (F). [See note below for clarification of study duration.]<br>Dietary Conc.: 0, 2, 10, 80, 250 ppm<br>M: 0, 0.10, 0.51, 4.15, 12.3 mg/kg/day<br>F: 0, 0.13, 0.65, 5.2, 16.0 mg/kg/day | NOAEL =M/F 0.51/5.2 mg/kg/day 10 ppm males, 80 ppm females<br>LOAEL =M/F 4.15/16.0 mg/kg/day based on increased mortality and nephropathy exacerbated by respiratory stress, and in females possible increased basal and/or follicular/luteal cysts.<br><br>No evidence of carcinogenicity. | MRID 41563703, (1985), Acceptable |

**Note on MRID 41563703**: In various sections of U.S. EPA/OPP/HED (2004d, 2011a) the duration of this study is given as 106 and 107 days. These are clearly typographical errors. While these errors are repeated at the start of the detailed discussion of this study in U.S. EPA/OPP/HED (2011a, Section 4.5.3.1, p. 24), the remainder of this section clearly indicates that the duration of the study was 106 weeks for males and 107 weeks for females, which are relatively standard durations for chronic studies in rats.

See Section 3.1.5 for discussion.

Appendix 1: Toxicity to mammals *(continued)*

**A1 Table 3: Reproductive and Developmental Studies**

Data from U.S. EPA/OPP/HED 2010a, supplemented with information from U.S. EPA/OPP/HED 2004d (referenced here as HazID).

| Species | Exposure | Response | MRID(s), (Year), Classification |
|---------|----------|----------|----------------------------------|
| **Developmental** | | | |
| Rabbits (New Zealand White) | Fluazifop-butyl Doses: 0, 10, 30, 90 mg/kg/day. | Maternal<br>NOAEL=30 mg/kg/day<br>LOAEL=90 mg/kg/day based on abortions.<br>HazID: A nominal absolute liver (13%) and relative liver weight (9%) increase was seen at 90 mg/kg/day.<br><br>Developmental<br>NOAEL=30 mg/kg/day<br>LOAEL=90 mg/kg/day based on nominal increases in delayed ossification, total litter loss, abortions, small fetuses, cloudy eyes all above mean or range of historical controls. | MRID 00088856, 92067049, 92067021, (1981), Acceptable |
| Rabbits (New Zealand White) | **Fluazifop-P-butyl** Doses: 0, 2, 10, 50 mg/kg/day. | Maternal<br>NOAEL=10 mg/kg/day<br>LOAEL=50 mg/kg/day based death, abortions and body weight loss. HazID (p. 11) notes a decrease in appetite but food conversion efficiency is not discussed.<br><br>Developmental<br>NOAEL=10 mg/kg/day<br>LOAEL=50 mg/kg/day based on increased incidence of 13$^{th}$ rib and delayed ossification in sternebrae 2. | MRID 46082904, (1993), Acceptable |
| Rats (Sprague Dawley) | Fluazifop-butyl Doses: 0, 10, 50, and 200 mg/kg/day<br><br>Based on U.S. EPA/OPP 2011a, p. 68 | Maternal<br>NOAEL = 200 mg/kg/day<br>LOAEL = None.<br><br>Developmental<br>NOAEL=None<br>LOAEL=10 mg/kg/day based on delayed ossification.<br><br>Malformations<br>NOAEL = 50 mg/kg/day<br>LOAEL = 200 mg/kg/day based on diaphragmatic hernias. | MRIDs 00088857, 92067047, (1981), Acceptable<br><br>**This study is the basis for the acute RfD derived by U.S. EPA/OPP/HED (2011a).** |

Appendix 1: Toxicity to mammals *(continued)*

| Species | Exposure | Response | MRID(s), (Year), Classification |
|---|---|---|---|
| Rats (Sprague Dawley) | Fluazifop-butyl Doses: 0, 1.0, 5.0, 10, 200 mg/kg/day | Maternal NOAEL=200 mg/kg/day. LOAEL=None based on maternal weight decrement partially explained by gravid urine weight decrement.<br><br>Developmental NOAEL=1 mg/kg/day. LOAEL=5 mg/kg/day based on fetal weight decrement and increased incidence of small fetuses and delayed ossification.<br><br>Malformations NOAEL= 10 mg/kg/day LOAEL=200 mg/kg/day based on increased incidence of diaphragmatic hernia. | MRID 00088858, 92067048, 92967020 , (1981), Acceptable |
| Rats (Wistar) | **Fluazifop-P-butyl** Doses: 0, 0.5, 1.0, 20, 300 mg/kg/day. | Maternal NOAEL=20 mg/kg/day LOAEL= 300 mg/kg/day based on body weight gain decrement. Body weight gain decreased by 19% and food conversion efficiency decreased 13% [HazID, p. 18].<br><br>Developmental NOAEL=1.0 mg/kg/day LOAEL=20 mg/kg/day based on delayed ossification in skull bones, cervical arches and centrum in fetuses and litters and delayed ossification in the manus and pes. | MRID 46158401 (1991), Acceptable |
| Rats (Wistar) | **Fluazifop-P-butyl** Doses: 0, 2, 5 or 100 mg/kg/day | Maternal NOAEL=100 mg/kg/day LOAEL= None based no maternal toxicity.<br><br>Developmental NOAEL=2.0 mg/kg/day LOAEL=5.0 mg/kg/day based on based on dose related delayed ossification in skull bones [occipital and parietal] in fetuses and litters. | MRID 46082903, (1989), Acceptable<br><br><span style="color:red">**This study is used for the occupational short-term (1-30 days) assessment derived by U.S. EPA/OPP/HED (2011a).**</span> |
| Rats (Wistar) | Fluazifop-P-butyl Doses: 0, 2, 5 or 100 mg/kg/day | Maternal NOAEL=100 mg/kg/day LOAEL= None based on no toxic effects<br><br>Developmental NOAEL=2.0 mg/kg/day LOAEL=5.0 mg/kg/day based on delayed ossification in skull bones, sternebrae bipartite, sternebrae and calcenum unossifided in fetuses and litters. | MRID 46082013, (1990), Acceptable |

Appendix 1: Toxicity to mammals *(continued)*

| Species | Exposure | Response | MRID(s), (Year), Classification |
|---|---|---|---|
| **Reproduction** | | | |
| Rats, Wistar, 15 males and 30 females per group. | Fluazifop-butyl, 94.8%, batch/lot P14 Conc.: 0, 10, 80, 250 ppm M: 0, 0.74, 5.8, 21.7 mg/kg/day F: 0, 0.88, 7.1, 17.5 mg/kg/day<br><br>Durations: Parental: 100 days F1: 120 days F2: to weaning.<br><br>Details taken from U.S. EPA/OPP/ HED 2004a, pp. 40-41. | Parental/Systemic<br>NOAEL = M/F 0.74/7.1 mg/kg/day<br>LOAEL = M/F 5.8/ 21.7 mg/kg/day based on decreased spleen weights in males and increased absolute and relative liver and kidney weights and geriatric nephropathy in females.<br>**Working Note: The LOAEL for females should probably be 17.5 mg/kg bw/day.**<br>HazID (p. 13) notes that weight of P0 adult females was significantly increased (7%) at Week 14 in the high dose group. *The body weight increases in females may have been incidental or related to the significant absolute and relative increased kidney weight and slight increase in geriatric nephropathy found at termination at 250 ppm.*<br><br>Offspring<br>NOAEL = 7.1 mg/kg/day<br>LOAEL = 21.7 mg/kg/day based on pup viability in F1 and F2 pups during lactational days 1, 4, 11, 18 & 25 and decreased F2 pup weight on lactational day 25.<br>HazID (p. 13) notes that weight of F1 adult females was significantly increased (10%) at Week 17.<br><br>Reproductive<br>NOAEL = M/F 0.74/0.88mg/kg/day<br>LOAEL = M/F 5.8/7.1 mg/kg/day based on decreased absolute and relative testes and epididymal weights in males and decreased pituitary and uterine weights in females. Sperm counts not available. | MRID 00088859, 92067050, (1981), Acceptable<br><br>**This study is the basis for the chronic RfD derived by U.S. EPA/OPP/HED (2011a).**<br><br>**This study is also used in U.S. EPA/OPP/ EFED (2008, p. 74) but a NOAEL of 14.8 ppm is cited. This appears to be the NOAEL in female rats corrected for a.e. [17.5 x 0.854 = 14.945.]** |
| Unclear | Not detailed. | Fertility and overall reproductive performance was not impaired in the reproduction toxicity studies; the parental and offspring NOAELs are 0.8 mg/kg bw per day, whereas the reproductive NOAEL is 7mg/kg bw per day. | EFSA 2012, p. 7 |

207

Appendix 1: Toxicity to mammals *(continued)*

| Species | Exposure | Response | MRID(s), (Year), Classification |
|---|---|---|---|
| Rats | Fluazifop-butyl, dosing not detailed. | NOAEL (parental and offspring): 0.8 mg/kg bw/day. Reproductive NOAEL: 7 mg/kg bw/day Adverse effects specified as decreased testes and epididymis weight in parental generation, extended gestation period and reduced litter sizes. Offspring: Increased liver and kidney weight; decreased, spleen, , testes and uterine weights. Doses associated with LOAELs are not specified. | EFSA 2012, p. 31 |

Appendix 1: Toxicity to mammals *(continued)*

**A1 Table 4: Skin Irritation and Sensitization Studies**

Source: U.S. EPA/OPP/HED 2011a unless otherwise specified.

| Species | Exposure | Response | Reference |
|---|---|---|---|
| **Skin Irritation** | | | |
| N.S. | N.S. | Non-irritating. | EFSA 2012 , p. 30 |
| Rabbit | Fluazifop-butyl PP009; 93.3%, 79ILK8/056 | Mild erythema at 72 hours. Toxicity Category IV | MRID 00088853, 1979 |
| Rabbit | Fluazifop-P-butyl PP005, 86.3%, CTL/P/856 | Slight irritation, cleared within 72 hours. Toxicity Category IV | MRID 00162441, 1983 |
| **Skin Sensitization** | | | |
| N.S. | N.S. | **Sensitizing** `Working Note: EFSA 2012 provides no documentation but this information is consistent with statements on the MSDSs for two Fusilade formulations.  See the discussion in Section 3.1.11.2.` | EFSA 2012 , p. 30 |
| Guinea pig | N.S. | Not a sensitizer. | FAO/WHO 2000, p. 16 |
| Guinea pig | Fluazifop-butyl PP009; 99.6%, 80/ILK026/349 | Not a skin sensitizer. | MRID 00088854, 1980 |
| Guinea pig | Fluazifop-P-butyl PP005, 99.6%, 80/ILK026/349 | Not a skin sensitizer. | MRID 00162441, 1983 |

Appendix 1: Toxicity to mammals *(continued)*

**A1 Table 5: Eye Irritation Studies**

Source: U.S. EPA/OPP/HED 2011a unless otherwise specified.

| Species | Exposure | Response | Reference |
|---------|----------|----------|-----------|
| N.S. | N.S. | Non-irritating. | EFSA 2012 , p. 30 |
| Rabbit | Fluazifop-butyl PP009; 93.3%, 79/ILK9/068 | Non-irritating Toxicity Category IV EPA/OPP/HED (2011a, p. 59) | MRID 00088855, 1979 |
| Rabbit | Fluazifop-P-butyl PP005, 86.3%, CTL/P/856 | Mild irritation, cleared within 3 days. Toxicity Category IV EPA/OPP/HED (2011a, p. 59) | MRID 00162441, 1983 |

**A1 Table 6: Acute and Repeated Dose Dermal Toxicity**

Source: U.S. EPA/OPP/HED 2011a unless otherwise specified.

| Species | Exposure | Response | Reference |
|---------|----------|----------|-----------|
| **Acute** | | | |
| Rats | Fluazifop-P-butyl (NOS) | $LD_{50}$: >2110 mg/kg bw | EFSA 2012 , p. 30 FAO/WHO 2000, p. 16 |
| Rabbits | Fluazifop-butyl, PP009, 97.2%, 2 mL/L | Acute $LD_{50}$ >2000 mg/kg Toxicity Category III | MRID 00162439, 1983 |
| Rabbits | Fluazifop-P-butyl, PP005, 93.7% and 86.3% | Acute $LD_{50}$ >2000 mg/kg Toxicity Category III | MRID 00162440, 1984 |
| **Repeated Dose** | | | |
| Rabbits, New Zealand White, 5 abraded and 5 unabraded per sex per group. | Fluazifop-butyl, 99.6%, Applied to the shaved skin for 6 hours/day, 5 days/week over 21-days. Doses: 0, 100, 500, 2000 mg/kg/day. | NOAEL = 100 mg/kg/day LOAEL = 500 mg/kg/day based on death in 1 male. 2000 mg/kg/day: 4/10 males and 5/10 females died or were sacrificed in extemis between Days 6 and 10. Pathologic changes in kidney suggestive of kidney damage. Several other clinical changes in animals that died or were sacrificed. No differences noted in dermal or systemic effects between abraded and unabraded groups. | MRID 00093819, 1980, Acceptable Summary from U.S. EPA/OPP/HED 2004a. |

Appendix 1: Toxicity to mammals *(continued)*

**A1 Table 7: Acute Inhalation Toxicity**

<div align="center">Source: U.S. EPA/OPP/HED 2004a unless otherwise specified.</div>

| Species | Exposure | Response | Reference |
|---|---|---|---|
| Rats | Fluazifop-P-butyl (NOS), nose only, 4 hours | $LD_{50}$: >5.2 mg/L | EFSA 2012 , p. 30 FAO/WHO 2000, p. 16 |
| Rats | Fluazifop-butyl PP009, 97%, 79/ISK034/387 | $LC_{50}$ > 2.3 mg/L x 4 h (particle size 43% with <5 µm) $LC_{50}$ > 4.37 mg/L x 4 h (particle size 83% with <10 µm) Toxicity Category III | MRID 46082901, and 41563701, 1979 |
| Rats | Mixture of 24.6% fluazifop-P-butyl and 7.0% fenoxyprop-P-ethyl Fluazifop-P-butyl, PP005, 24.6%, CTL/P/3331 | $LC_{50}$ > 1.7 mg/L x 4 h<br><br>Information on fenoxyprop-P-ethyl from U.S. EPA/OPP/HED 2004a, p. 21. Working Note: This study is used in U.S. EPA/OPP/HED (2011a) to classify fluazifop-P-butyl as Category III.  The above 1979 inhalation study on fluazifop-butyl is not cited in U.S. EPA/OPP/HED (2011a). | MRID 41917904, 1991 |

Appendix 1: Toxicity to mammals *(continued)*

**A1 Table 8: Toxicity Information from MSDSs of Fusilade Formulations**

| Endpoint | Fusilade DX[1] | Fusilade II[1] |
|---|---|---|
| Oral $LD_{50}$ (rats) | >5000 mg/kg bw (>1225 mg a.i./kg bw) | >5000 mg/kg bw (>1225 mg a.i./kg bw) |
| Dermal $LD_{50}$ (rabbits) | >2000 mg/kg bw (>490 mg a.i./kg bw) | >2000 mg/kg bw (>490 mg a.i./kg bw) |
| Inhalation $LC_{50}$ (animal not available) | 0.54 mg/L x 4 hours | 0.54 mg/L x 4 hours |
| Eye contact (rabbit) | Slightly irritating | Slightly irritating |
| Skin contact (rabbit) | Moderately irritating | Moderately irritating |
| Skin sensitization | Repeated and/or prolonged contact may cause skin sensitization. | Repeated and/or prolonged contact may cause skin sensitization. |

[1] MSDSs specify that doses are given in units of formulation. Both formulations contain 24.5% a.i. The units in a.i. are given in parentheses.

**Appendix 2: Toxicity to Birds**

**Working Note: Unless otherwise indicated, study summaries are taken from ECOTOX and U.S. EPA/OPP/EFED 2008. Studies for which DERs were available are specified in the reference column with a standard Author(s), Year citation and the term *Syngenta DER01* in brackets.**

Tables start on next page.

**Appendix 2**: Toxicity to Birds *(continued)*

**A2 Table 1: Acute Oral/Gavage Toxicity to Birds**

| Agent Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| Mallard duck (*Anas platyrhynchos*), NOS | Fluazifop-butyl, 93.4% purity, *administered via gavage or capsule** with 14 day post-dosing observation.. | ECOTOX $LD_{50}$ >5000 mg/kg bw NOEL = 5000 mg/kg bw EPA/OPP $LD_{50}$ >4270 mg a.e./kg bw NOEL: 4270 mg a.e./kg bw | MRID 00131457, 1982, Acceptable U.S. EPA/OPP/ EFED 2008, , Table 3-7 and Appendix C. ECOTOX 2013 |
| **Fluazifop-P-butyl** | | | |
| Mallard duck (*Anas platyrhynchos*), 5 males and 5 females | P009 (Fluazifop-P-butyl), 97% purity, single gavage dose of 17,280 mg/kg bw (15 mL) without carrier. | No mortality but vomiting in "the majority" of the dosed animals. Vomiting not observed in control animals. | Ross et al. 1979 [Syngenta DER01] EPA Classification: Invalid due to vomiting and uncertainty in retained dose. |
| Mallard duck (*Anas platyrhynchos*), 16-weeks-old., ≈ 1 kg at test initiation, 5M/5F per dose group. | Fluazifop-P-butyl, 95.8% purity, *administered via gavage or capsule** for 14 days. DER clarifies the dosing as a single gavage dose in corn oil with a 14 day observation period. Doses: 0, 500, 1000, 2000, 3000, 4000 mg/kg bw. | ECOTOX $LD_{50}$ >3528 mg/kg bw NOEL = 3528 mg/kg bw EPA/OPP $LD_{50}$ >4301 mg a.e./kg bw NOEL: 3528 mg a.e./kg bw DER No mortality or signs of toxicity at any dose. No abnormalities on post-mortem. DER verifies the NOAEL of 3528 mg a.i./kg given above. DER (p. 7) provides individual body weights and food consumption. | MRID 40829201 in U.S. EPA/OPP/EFED 2008, Table 3-7 and Appendix C. Acceptable ECOTOX 2013 Roberts 1985 [Syngenta DER01] |
| Mallard duck, NOS | Fluazifop-P-butyl, 0, 506, 1030, 2010, 3030 or 3960 mg a.i./kg bodyweight | $LD_{50}$ >3960 mg a.i./kg bw NOEC: 3960 mg a.i./kg bw Above values correspond to: $LD_{50}$ >3,382 mg a.e./kg bw NOEC: 3,382 mg a.i./kg bw | FAO/WHO 2000 |

**A2 Table 2: Acute Dietary Toxicity to Birds**

| Agent<br>Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| Mallard duck (*Anas platyrhynchos*), 15-days-old, 10 birds/dose (sexes not specified). | Fluazifop-butyl, 99.6% purity, ad libitum in diet for 5 days with 3 day recovery period.<br><br>Concentrations: 0, 6554, 8192, 10,240, 12,800, 16,000, 20,000, and 25,000 ppm. | ECOTOX<br>   $LC_{50}$ >25,000 ppm<br>   NOEL = 6522 ppm<br>EPA/OPP<br>   $LC_{50}$ >21,348 ppm (a.e.)<br>DER<br>   Dose-related decrease in body weight and food consumption. Nearly total rejection of food in first 2 days. Only the two lower dose groups consumed food at half of the control rate on Days 4 and 5. *…test material is probably relatively non-toxic…* at two lower concentrations.<br>`Working Note: DER does`<br>`not give body weights`<br>`or food consumption.` | MRID 00087481, 1980, Supplemental EPA/OPP/EFED 2008, Appendix C.<br><br>ECOTOX 2013<br><br>Ross et al. 1980a [Syngenta DER01] |
| Ring-necked pheasant (*Phasianus colchicus*), 13 days old. | Fluazifop-butyl (PP009), 99.6% purity, ad libitum in diet for 8 days. | $LC_{50}$ = 18,500 ppm<br>NOEL = 8192 ppm<br>Above values correspond to:<br>   $LC_{50}$ = 15,799 ppm (a.e.)<br>   NOEL = 6996 ppm (a.e.) | ECOTOX 2013 |
| Ring-necked pheasant (*Phasianus colchicus*), 13 days old, 10 birds/dose (sexes not specified). | Fluazifop-butyl, 99.6%, 8 days. Concentrations: 6554, 8192, 10,240, 12,800, 16,000, 20,000, and 25,000 ppm.<br>5 day treatment and 3 day recovery period.<br>Dieldrin as positive control. | EPA/OPP<br>   $LC_{50}$= 20,767 ppm a.i. (≈17,735 ppm a.e.) [reanalysis of reported $LC_{50}$]<br>DER<br>   $LC_{50}$ = 18,500 (15,400 – 22,200) ppm a.i.<br>   Food consumption in treated birds not significantly different from controls.<br>   Values for food consumption and body weights not given in DER.<br>   NOAEL not given in DER. | MRID 00087482, 1982, Acceptable<br><br>Used by U.S. EPA/OPP/EFED (2008, Table 4-4, p. 73 and p. 192) for acute risk characterization. An $LC_{50}$ of 20,769 ppm is cited.<br><br>Ross et al. 1980a [Syngenta DER01] |

**Appendix 2**: Toxicity to Birds *(continued)*

| Agent<br>Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-P-butyl** | | | |
| Bobwhite quail (*Colinus virginianus*), 11-days-old | Fluazifop-P-butyl, 95.8% purity, ad libitum in diet for 8 days. | ECOTOX<br>$LC_{50}$ >5230 ppm<br>NOEL = 2980 ppm<br>EPA/OPP<br>$LC_{50}$ >4,460 ppm (a.e.)<br>NOAEL: 2,545 ppm (a.e.) | MRID 40859401, 1985, Acceptable EPA/OPP/EFED 2008, Appendix C. ECOTOX 2013 |
| Bobwhite quail (*Colinus virginianus*), 11-days-old | Fluazifop-P-butyl, 89.09% purity, ad libitum in diet for 8 days.<br><br>Concentrations: 0, 440, 653, 1090, 1820, 2980, or 5320 ppm diet (FAO/WHO 2000). | ECOTOX<br>$LC_{50}$ >5230 ppm<br>NOEL = 2980 ppm<br>EPA/OPP<br>$LC_{50}$ >4,460 ppm (a.e.) | MRID 40859401, 1985, Acceptable EPA/OPP/EFED 2008, Appendix C. ECOTOX 2013<br><br>Also cited in FAO/WHO 2000 |
| Mallard duck (*Anas platyrhynchos*), 9-days-old | Fluazifop-butyl, 95% purity, ad libitum in diet for 8 days.<br><br>Concentrations: 0, 412, 667, 1140, 1880, 3080, or 4850 ppm diet (FAO/WHO 2000) | ECOTOX<br>$LC_{50}$ >4850 ppm<br>NOEL <1040 ppm<br>EPA/OPP<br>$LC_{50}$ >4,142 ppm (a.e.)<br>NOEAL: 4,142 ppm (a.e.) | MRID 40851401, 1985, Acceptable. EPA/OPP/EFED 2008, Appendix C.<br><br>ECOTOX 2013<br><br>Also cited in FAO/WHO 2000 |

**A2 Table 3: Reproductive and Subchronic Toxicity to Birds**

| Agent Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| Mallard duck (*Anas platyrhynchos*), early life stage, A total of 39 male and 91 female wild caught birds. | Fluazifop-butyl, 99.6% purity, dietary administration for 23 weeks.<br><br>Concentrations: 0, 5, 50 ppm (FAO/WHO 2000 and DER)<br><br>Food consumption as proportion of bw:<br><br>| Dose (ppm) | Initial | Final |<br>|---|---|---|<br>| 0 | 0.110 | 0.133 |<br>| 5 | 0.105 | 0.139 |<br>| 10 | 0.104 | 0.125 |<br><br>Food consumption and body weights not statistically significantly different.<br>Average of initial and final proportion of food for high dose is 0.1145. | ECOTOX<br>  LOEC: >50 ppm<br>  NOEL: >50 ppm<br>EPA<br>  NOAEL ≥43 ppm (a.e.)<br><br>DER<br>  Some mortality in adults but not attributed to treatment.<br>  No statistically significant ($p<0.05$) differences in any parameters.<br><br>Estimated NOAEL:<br>  4.9 mg a.e./kg bw [43 mg a.e./kg food x 0.1145 g food/g bw ≈ 4.9235 mg a.e./kg bw] | MRID 00093801, 1981, Supplemental. EPA/OPP/EFED 2008, Appendix C.<br><br>ECOTOX 2013<br><br>Also cited in FAO/WHO 2000.<br><br>Roberts et al. 1981a [Syngenta DER01]<br>DER indicates a Core Classification |
| Bobwhite quail (*Colinus virginianus*), early life stage | Fluazifop-butyl, 99.6% purity, dietary administration for 31 weeks.<br><br>Concentrations: 0, 5, 50 ppm (FAO/WHO 2000 and DER)<br><br>Food consumption as proportion of bw:<br><br>| Dose (ppm) | Initial | Final |<br>|---|---|---|<br>| 0 | 0.0524 | 0.123 |<br>| 5 | 0.0521 | 0.0991 |<br>| 10 | 0.0582 | 0.0942 |<br><br>Food consumption and body weights not statistically significantly different.<br>Average of initial and final proportion of food for high dose is 0.0762. | ECOTOX<br>  LOEC (repro) >50 ppm<br>  NOEL >50 ppm<br>EPA<br>  NOAEL ≥43 ppm (a.e.)<br>DER<br>  Some mortality in adults but not attributed to treatment.<br>  No statistically significant ($p<0.05$) differences in any parameters.<br>  Transient (1st 6 weeks) and statistically insignificant ($p>0.05$) decrease in eggs laid in 50 ppm group.<br><br>Estimated NOAEL:<br>  3.3 mg a.e./kg bw [43 mg a.e./kg food x 0.0762 g food/g bw ≈ 3.2766 mg a.e./kg bw] | MRID 00093802, 1981, Supplemental. EPA/OPP/EFED 2008, Appendix C.<br><br>ECOTOX 2013<br><br>Also cited in FAO/WHO 2000<br><br>Roberts et al. 1981b [Syngenta DER01]<br>DER indicates a Core Classification |

**Appendix 3: Toxicity to Terrestrial Invertebrates.**

**Unless otherwise indicated, MRID study summaries taken from ECOTOX and U.S. EPA/OPP/EFED 2008, Appendix C.  See Section 4.1.2.4.3 for a discussion of other studies from the open literature.**
**Studies for which DERs were available are specified in the reference column with a standard Author(s), Year citation and the term *Syngenta DER01* in brackets.**

**The tables start on the following page.**

**A3 Table 1: Standard Toxicity Studies in Bees**

| Agent ROUTE Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| **ORAL** | | | |
| Honey bee (*Apis mellifera*), adult, 10 bees/dose | Fluazifop-butyl, **technical grade**, 48 hour observation period.  Toxicity values given for 24 hours.<br><br>Doses: 0, 5, 10, 20, 50, and 100 µg a.i./bee | ECOTOX<br> $LD_{50}$ = 180 µg/bee<br> NOEL <180 µg/bee<br>EPA/OPP<br> 24-h $LD_{50}$: 154 µg a.e./bee<br> NOAEL: < 154 µg a.e./bee.<br>DER<br> No effects on bees at up to 100 µg a.i./bee. | MRID 00093809,1979, Acceptable.<br><br>ECOTOX 2013<br><br>Smailes and Wilkinson 1979 [Syngenta DER01] |
| Honey bee (*Apis mellifera*), adult 10 bees/dose | Fluazifop-butyl formulation, **25 EC**, 48 hour observation period.  Toxicity values given for 24 hours.<br><br>Doses: 0, 5, 10, 20, 50, 100, and 200 µg  a.i./bee | ECOTOX<br> $LD_{50}$ >195 µg/bee<br> NOEL = 100 µg/bee<br>EPA/OPP<br> 24-h $LD_{50}$: >166 µg a.e./bee<br> Est. NOAEL:  85.4 µg a.e./bee.<br>DER<br> No effects on bees at up to 100 µg a.i./bee. | MRID 00093809, 1979, Acceptable.<br><br>ECOTOX 2013<br><br>Smailes and Wilkinson 1979 [Syngenta DER01] |
| **CONTACT** | | | |
| Honey bee (*Apis mellifera*), adult | Fluazifop-butyl, **technical grade**, **topical.** 48 hour observation period.  Toxicity values given for 24 hours.<br><br>Doses: 0, 5, 10, 20, 50, 100, and 200 µg a.i./bee | ECOTOX<br> $LD_{50}$ >240 µg/bee<br> NOEL = 195 µg/bee<br>EPA/OPP<br> 24-h $LD_{50}$: >205 µg a.e./bee<br>Est. NOAEL:  167 µg a.e./bee.<br>DER<br>No effect on bees at doses up to 200 µg a.i./bee. | MRID 00093809, 1979, Acceptable.<br><br>ECOTOX 2013<br><br>Smailes and Wilkinson 1979 [Syngenta DER01] |
| Honey bee (*Apis mellifera*), adult | Fluazifop-butyl formulation, **25 EC**, 48 hour observation period.  Toxicity values given for 24 hours.<br><br>Doses: 0, 5, 10, 20, 50, 100, and 200 µg  a.i./bee | ECOTOX<br> $LD_{50}$ >95 µg/bee<br> NOEL = 95 µg/bee<br>EPA/OPP<br> 24-h $LD_{50}$: >81 µ a.e./bee<br> NOAEL:  81µg a.e./bee.<br>DER<br> No effect on bees at doses up to 200 µg a.i./bee.<br>**Working Note: The summary in the DER is not consistent with the summary in U.S. EPA/OPP/EFED (2008). The DER does not give dose-response data.** | MRID 00093809, 1979, Acceptable.<br><br>ECOTOX 2013<br><br>Smailes and Wilkinson 1979 [Syngenta DER01] |

Appendix 3: Toxicity to Terrestrial Invertebrates (*continued*)

| Agent<br>ROUTE<br>Species | Exposure | Response | Reference |
|---|---|---|---|
| Honey bee (*Apis mellifera*), adult | Fluazifop-butyl formulation, 13.8 % a.i., **topical** application for 24 hours. | ECOTOX<br>   $LD_{50}$ = 63 µg/bee<br>   NOEL >200 µg/bee<br>EPA/OPP<br>   24-h $LD_{50}$: 54 µg a.e./bee<br><br>**See note at end of table.** | MRID 00162453, 1984, Acceptable.<br><br>ECOTOX 2013 |
| **Fluazifop-P-butyl** | | | |
| **Oral** | | | |
| Honey bee | Fluazifop-P-butyl | $LD_{50}$ >200 µg/bee | EFSA 2012 |
| Honey bee | Fusilade Max (EC 125 g/L) | $LD_{50}$: 382 µg a.e./bee | EFSA 2012 |
| **CONTACT** | | | |
| Honey bee | Fluazifop-P-butyl | $LD_{50}$ >200 µg/bee | EFSA 2012 |
| Honey bee | Fusilade Max (EC 125 g/L) | $LD_{50}$: >100 µg a.e./bee | EFSA 2012 |

Working Note on MRID 00162453: The reported NOAEL of 200 µg/bee in ECOTOX does not make sense given the reported $LD_{50}$ of 63 µg/bee.
  Link to ECOTOX at:
  http://www.ipmcenters.org/Ecotox/Details.cfm?RecordID=574
  A printout of this link is in the Scans directory with a file name of **MRID 00162453 Honey Bee Assay**.
  This study is not used in the current risk assessment.
The formulation (13.8% a.i.) corresponds to Fusilade Max but not to a formulation that would be used in Forest Service programs and the $LD_{50}$ of 62 µg/bee is not used in the current risk assessment.

**Note: Many of the above toxicity values have the same MRID number – i.e., MRID 00093809.  This is not unusual as registrants may include several studies in one submission.**

Appendix 3: Toxicity to Terrestrial Invertebrates (*continued*)

**A3 Table 2: Toxicity to Other Terrestrial Arthropods**

| Species | Exposure | Response[1] | Reference |
|---|---|---|---|
| **Chelicerata (e.g., spiders, mites)** | | | |
| Arachnida, Araneae: Lycosidae *Pardosa* sp. (spider), adult | YF7662 125g/L EC formulation, Soil, 6 d, 1875 g a.e./ha [≈1.67 lb a.e./acre]. | 40% mortality<br>No impact on predation. | EFSA 2012 |
| Acarina: Phytoseiidae *Typhlodromus pyri* (predatory mite), NOS | Fusilade Max (EC 125 g/L), 0.75, 1.5 and 3 L/ha. | Mortality ($LR_{50}$[2]) 5.6 g a.s../ha **[0.004 lb a.e./acre as discussed in Section 4.1.2.4.2]** | EFSA 2012, p. 70 |
| *Typhlodromus pyri* (predatory mite), nymphs | Fusilade Max (EC 125 g/L), on leaves, duration given as "7 d + 7d". | <table><tr><td>Dose (g a.e./ha)</td><td>Mortality (%)</td></tr><tr><td>15</td><td>12</td></tr><tr><td>200</td><td>44</td></tr><tr><td>375</td><td>60</td></tr></table> $LR_{50}$ = 174 g a.s./ha [≈0.13 lb a.e./acre]<br><br>Summary specifies an 8% adverse effect on reproduction at 15 g a.s./ha [≈0.011 lb a.e./acre].<br><br>`See note on Typhlodromus pyri at end of table.` | EFSA 2012, p. 70 |
| **Insects** | | | |
| Coleoptera: Carabidae *Poecilus cupreus* (ground beetle) | YF7662 125 g/L EC formulation, soil, 6 d, 1875 g a.e./ha. [≈1.67 lb a.e./acre] | No mortality.<br>12% adverse effect on predation. | EFSA 2012 |
| Coleoptera: Coccinellidae *Adalia bipunctata* (ladybug) | 0.5 kg/ha fluazifop-P-butyl, Fusilade EC formulation. ≈0.38 lb a.e./acre | Classified as "harmless" based on the criteria of <30% mortality.<br>Detailed responses not reported. | Hautier et al. 2005 |
| Coleoptera: Carabidae *Bembidion lampros* (carabid beetle) | 0.5 kg/ha fluazifop-P-butyl, Fusilade EC formulation. ≈0.38 lb a.e./acre | Classified as "harmless" based on the criteria of <30% mortality.<br>Detailed responses not reported. | Hautier et al. 2005 |
| Diptera: Syrphidae *Episyrphus balteatus* (hoverfly), larva | YF7662A 125 g/L, EC formulation, Seedling, larvae development, 20 d, , 375 g a.e./ha [0.33 lb a.e./acre] | No mortality.<br>3% adverse effect on reproduction. | EFSA 2012 |
| Hymenoptera: Aphidiinae *Aphidius rhopalosiphi* (parasitic wasp), NOS | Fusilade Max (EC 125 g/L) | Mortality ($LR_{50}$[2]) 177 g a.s./ha **[≈0.137 lb a.e./acre]** | EFSA 2012 |
| *Aphidius rhopalosiphi* (parasitic wasp), adult | YF7662A 125 g/L EC formulation Seedling, 2 d + 15 d | 375 g a.s../ha [≈0.28 lb a.e./acre]: No mortality but a 25% adverse impact on parasitism. | EFSA 2012 |
| *Aphidius rhopalosiphi* (parasitic wasp), adult | Fusilade Max (EC125 g/L) | Mortality ($LR_{50}$[2]) 375 g a.e./ha [0.33 lb a.e./acre] | EFSA 2012 |

Appendix 3: Toxicity to Terrestrial Invertebrates (*continued*)

| Species | Exposure | Response[1] | Reference |
|---|---|---|---|
| Neuroptera: Chrysopidae *Chrysoperla carnea* (lacewing), larvae | Fusilade Max (EC 125 g/L) Leaves, larvae development, 20 d, 1000 g a.e./ha (0.892 lb a.e./acre) | 19% mortality 6% adverse effect on reproduction. | EFSA 2012 |

[1] Table A3-2 summarizes several studies from EFSA (2012).  The exposures are not described in detail.  The descriptions under the Exposure column are taken directly from the EFSA (2012) report, pp. 70-71. Commentary from other sections of EFSA (2012) is added to the above table.

[2] LR50 is a European term for *50% lethal response*.

Note on *Typhlodromus pyri studies*: *The in-field risk to non-target arthropods (Typhlodromus pyri and Aphidius rhopalosiphi) was assessed as high at the first tier according to the guidance SETAC (2001). Extended laboratory studies on T. pyri were submitted and the magnitude of effects (60%) was slightly above the recommended trigger (i.e.50%). However, the off-field risk was assessed as low and, based on the residue decline and the time of application, the experts concluded that* **recovery in the treated field area for the most sensitive species may occur within one year**. (EFSA 2012, p. 12).  **See Section 4.1.2.4.2 for additional discussion.**

Appendix 3: Toxicity to Terrestrial Invertebrates (*continued*)

All studies are field studies unless otherwise specified.

| Order: Family Species | Exposure | Response | Reference |
|---|---|---|---|
| Coleoptera: Coccinellidae Mexican bean beetles (*Epilachna varivestis*) | Fluazifop-butyl (Fusilade NOS), 0.56 kg a.i./ha (0.427 lb a.e./acre) on soybeans and lima beans | Reduced pupal wet weights (≈8%) for beetles feeding on soybean but not lima bean. Reduction in dry weights (≈5%) not significant. No substantial changes in reproduction. An increase in egg production with treatment. | Agnello et al. 1986a |
| Coleoptera: Chrysomelidae Bean Leaf Beetle (*Cerotoma trifurcata*) | Fluazifop-butyl (Fusilade NOS) at 0.56 kg a.i./ha (0.427 lb a.e./acre) on soybeans beans | Increase in beetle populations. | Agnello et al. 1986c |
| Hymenoptera : Apidae Bumblebee (*Bombus* species NOS) | Fluazifop-P-butyl (Fusilade Max) at 0.095 kg a.i./ha (≈0.072 lb a.e./acre) applied to wildflowers for grassy weed suppression. Observations of bumblebee populations over a 3 year period. | Significant increase in bumblebee abundance correlated to increase in wildflower abundance. | Blake et al. 2011b |
| Hymenoptera: Trichogrammatidae Parasitic wasp (*Trichogramma pretiosum*) | Fluazifop (NOS) at 0.125 kg/ha to soybeans. Cannot make a.e. conversion. | No effect on number of eggs, larvae, and pupae. Very few details given. | De Fretas Bueno et al. 2008 |
| Lepidoptera: Noctuidae Soybean looper (*Pseudoplusia includens*, a.k.a. *Chrysodeixis includens*) larvae | Fluazifop-butyl (Fusilade NOS) at 0.56 kg a.i./ha (0.427 lb a.e./acre) on soybeans beans | A modest (8%) but statistically significant decrease in larval longevity (13.8 days vs 15.0 in controls). Authors suggest that the impact could be secondary to the effect of fluazifop-P-butyl on the soybeans. | Agnello et al. 1986b |

Appendix 3: Toxicity to Terrestrial Invertebrates (*continued*)

| Order: Family Species | Exposure | Response | Reference |
|---|---|---|---|
| Lepidoptera: Lycaenidae Puget Blue butterfly (*Icaricia icarioides blackmorei*), larvae | Fusilade (24.5% a.i. NOS, consistent with Fusilade DX and Fusilade II) Applied at maximum labelled rate (sparse details) to lupine with and without a nonionic surfactant (Preference). Mesocosm study – i.e., insect and plants. Larvae observed every 2 days through pupation. Observations on adults shortly after emergence.<br><br>**Application rate is not explicitly stated. This is a U.S. publication and the maximum rate was presumably 0.32 lb a.e./acre.** | Earlier emergence of pupae in treatments with herbicide alone and herbicide with surfactant. (Figure 2 of paper).<br><br>Increases in survival with herbicide, surfactant, as well as herbicide with surfactant (Figure 1b of paper). | Russell and Schultz 2010<br><br>Working Note: This study does not demonstrate a d/r relationship. |
| Lepidoptera: Noctuidae Corn Earworm (*Heliothis zea*), larvae | Fluazifop-butyl (Fusilade NOS) at 0.56 kg a.i./ha (0.427 lb a.e./acre) on soybeans beans | Initial but transient decrease in populations followed by increase. Authors speculated that initial decrease could be a repellent affect. | Agnello et al. 1986c |
| Lepidoptera: Pieridae Small Cabbage White butterfly (*Pieris rapae*) | Fusilade (24.5% a.i. NOS, consistent with Fusilade DX and Fusilade II) Applied at maximum labelled rate (sparse details) to mustard plants with and without a nonionic surfactant (Preference). Mesocosm study – i.e., insect and plants. Larvae observed every 2 days through pupation. Observations on adults shortly after emergence.<br><br>Application rate is not explicitly stated. This is a U.S. publication and the maximum rate was presumably 0.32 lb a.e./acre. | Increase in survival with surfactant alone but a 21% decrease in survival herbicide and surfactant (*p*<0.001).<br><br>Reduction in wing surface area (≈10%) and pupal weights (≈6%) in herbicide with surfactant group (Table 1 of paper). Authors suggest a possible secondary effect due to impact on plant. | Russell and Schultz 2010<br><br>Working Note: This study does not demonstrate a d/r relationship. |

| Order: Family Species | Exposure | Response | Reference |
|---|---|---|---|
| Lepidoptera: Rhopalocera suborder Butterflies, mixed, , populations | Fluazifop-P-butyl (Fusilade Max) at 0.125 kg a.i./ha (≈0.092 lb a.e./acre) applied to wildflowers for grassy weed suppression with and without ground scarification. Observations on butterflies and wildflowers over a two year period, four times per year between May and September. | Significant increase in butterfly abundance, species richness, and diversity with herbicide and scarification. A slight and statistically insignificant decrease in abundance with herbicide and no scarification. The effects on butterflies appear to be secondary to effects on wildflowers. | Blake et al. 2011a |
| Mixed soil macroarthropods | Fluazifop-butyl (NOS), 0.56 kg a.i./ha (≈0.42 lb a.e./acre) | No effects reported. `Working Note: Very few details on fluazifop-butyl exposures or effects. The paper focuses on other herbicides.` | House et al. 1987 |

Appendix 3: Toxicity to Terrestrial Invertebrates (*continued*)

**A3 Table 4: Studies on Earthworms**

| Species | Exposure | Response | Reference |
|---------|----------|----------|-----------|
| *Eisenia foetida* | Fluazifop-butyl, 14 days | $LC_{50}$: > 1000 mg a.s./kg soil (dry weight)<br>Working Note: Notation appears to indicate a corrected value of >500 mg a.s./kg soil. | EFSA 2012 |
| *Eisenia foetida* | Metabolite X (5-trifluoromethyl-2-pyridone), 14-days | $LC_{50}$: > 1000 mg a.s./kg soil (dry weight) | EFSA 2012 |
| *Eisenia foetida* | Field study with fluazifop-butyl (as a 25% w/v EC formulation) at rates up to 5 kg a.s./ha (3.8 lb a.e./acre). | No adverse effects | EFSA 2012 |

**Appendix 4: Toxicity to Terrestrial Plants**

Unless otherwise specified, all application rates are in units of a.i. rather than a.e.   Most entries
follow metric units (kg/ha) because metric units are used extensively in the open literature.
Conversions to English units are handled in the dose-response assessment (Section 4.3.2.5).

**A4 Table 1: Monocots Greenhouse Toxicity Studies, Pre-Emergence**

| Form | Exposure | Species[1] | Response | Reference |
|---|---|---|---|---|
| **Fluazifop-butyl** | | | | |
| Fluazifop-butyl | 0.1 kg/ha | Corn, sorghum, and shattercane | About 50% to 90% growth reduction. | Buhler and Burnside 1984b |
| Fluazifop-butyl | 0.3 kg/ha | Corn, sorghum, and shattercane | 100% growth reduction | Buhler and Burnside 1984b |
| **Fluazifop-butyl** | **0.035 kg/ha.** | **Goosegrass, crabgrass, and giant foxtail.** | **73% to 95% control [Table 2 in paper].** | **Derr et al. 1985c** |
| **Fluazifop-P-butyl** | | | | |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Orchard grass (*Dactylis glomerata*) | Significant toxicity based on emergence (decrease), visual damage, the biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Red fescue (*Festuca rubra*) | Significant toxicity based on emergence (decrease), visual damage, the biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max 10.4 (a.s.) at 1 m (2.77% drift) | Barnyard grass (*Echinochloa crus-galli*) | 37.1 g a.e./ha: 50% inhibition of emergence | EFSA 2012 |
| Fluazifop-P-butyl | Fusilade (212g/L) and Fusilade Forte (128 g/L) at ≈0.84 kg/ha | *Austrostipa elegantissima* and *Ehrharta calycina* | No emergence when planted on surface or with seeds planted at 10 mm and 20 mm. See Appendix B of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade (212g/L) and Fusilade Forte (128 g/L) at ≈0.84 kg/ha | *Anigozanthos manglesii* and *Conostylis candicans* [Haemodoraceae] | No significant effects. See Appendix B of paper. | Rokich et al. 2009 |

[1] All species are members of the Poaceae family unless otherwise specified in brackets [].

**A4 Table 2: Dicots Greenhouse Toxicity Studies – Pre-Emergence**

| Form | Exposure | Species | Response | Reference |
|------|----------|---------|----------|-----------|
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Yarrow (*Achillea millefolium*) | No signs of phytotoxicity or effect on biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Knapweed (*Centaurea nigra*) | No signs of phytotoxicity or effect on biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Bedstraw (*Galium verum*) | No signs of phytotoxicity or effect on biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Oxeye daisy (*Leucanthemum vulgare*) | No signs of phytotoxicity or effect on biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Birdfoot deervetch (*Lotus corniculatus*) | NOAEC: Significant increase in biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Buckhorn plantain (*Plantago lanceolata*) | No signs of phytotoxicity or effect on biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Sorrel (*Rumex acetosa*) | NOAEC: Dose-related increase in emergence. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Red campion (*Silene dioica*) | No signs of phytotoxicity or effect on biomass. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Red clover (*Trifolium pratense*) | Weak (<5%) response and only at the highest rate based on chlorosis and necrosis of leaves. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade (212g/L) and Fusilade Forte (128 g/L) at ≈0.84 kg/ha | *Banksia menziesii, Hardenbergia comptoniana, Kunzea ericifolia* | No statistically significant herbicide impact on emergence or radicle length when planted at depths of 0 (surface), 10 mm, and 20 mm.  See Appendix B of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade (212g/L) and Fusilade Forte (128 g/L) at ≈0.84 kg/ha | *Eucalyptus gomphocephala* | No emergence at 20 mm depth with Fusilade Forte with greater emergence relative to control with Fusilade.<br>No substantial effects on emergence for surface seeds or seeds planted at 10 mm.<br>See Appendix B of paper. | Rokich et al. 2009 |

**A4 Table 3: Monocots Greenhouse Toxicity Studies, Post-Emergence**

*All species are members of the Poaceae family unless otherwise indicated in [].*

| Form | Exposure | Species | Response | Reference [1] |
|---|---|---|---|---|
| **Fluazifop (NOS)** | | | | |
| Fluazifop NOS. | Foliar | Foxtail | $ED_{50}$ (shoot dry matter): 0.04 kg/ha | Beckie and Morrison 1993 |
| **Fluazifop –P** | | | | |
| Fluazifop-P | Foliar spray, 14-28 g/ha. | Yellow foxtail | 24 to 78 % control by 21 DAT (Table 1). No substantial enhanced control with adjuvants (petroleum oil, soybean oil, or methylated seed oil. | Bohannan and Jordan 1995 |
| Fluazifop-P | Foliar spray | Ryegrass | $ED_{50}$: 19.8 g a.i./ha | Leys et al. 1988 |
| Fluazifop-P | Foliar spray | Wild oats | $ED_{50}$: 35.2 g a.i./ha | |
| Fluazifop-P | Foliar spray | Paradoxa grass | $ED_{50}$: 32.5 g a.i./ha | |
| Fluazifop-P | Foliar spray | Barley grass | $ED_{50}$: 24.7 g a.i./ha | |
| Fluazifop-P | Foliar spray | Great brome | $ED_{50}$: 32.1 g a.i./ha | |
| **Fluazifop – butyl** | | | | |
| Fluazifop-butyl | Foliar spray, 0.125 and 1.0 kg/ha | Quackgrass | Substantial and dose-related inhibition of growth. | Chandrasena and Sagar 1986a |
| Fluazifop-butyl | Foliar, 0.15 lb/ac | Colonial bentgrass, ryegrass, bluegrass | High levels of visual damage by 15 weeks after application. | Cisar and Jagschitz 1984a |
| Fluazifop-butyl | Foliar, 0.15 lb/ac | Red fescue | Little visual damage by 15 weeks after application. | Cisar and Jagschitz 1984a |
| Fluazifop-butyl | Postemergence at 0.035 and 0.070 kg/ha. | Goosegrass, crabgrass, and giant foxtail.. | Nearly 100% control of goosegrass. 57% to 100% control of other grasses depending on timing of application. | Derr et al. 1985c |
| Fluazifop-butyl | Foliar, 0.25 and 1 kg/ha | 13 species of Gramineae | Complete kill | Haga et al. 1987 |
| Fluazifop-butyl | Foliar, 0.25 and 1 kg/ha | 2 species of Gramineae: *Imperata cylindrica* and *Miscanthus sinensis*. | Moderate damage at lower rate and severe damage (9/10) at higher rate. | Haga et al. 1987 |
| Fluazifop-butyl | Foliar, 0.25 and 1 kg/ha | 2 species of **Cyperaceae** | Minimal damage (1/10) | Haga et al. 1987 |
| Fluazifop-butyl | Foliar, 0.25 and 1 kg/ha | Commelina communis (**Cyperaceae**) | Minimal damage (1/10) | Haga et al. 1987 |
| Fluazifop-butyl | Foliar, 0.25 and 1 kg/ha | *Allium cepa* (**Liliaceae**), onion | Minimal damage (1/10) | Haga et al. 1987 |
| Fluazifop-butyl | Foliar, 0.25 and 1 kg/ha | *Colocasia esculenta* (**Araceae**) | Minimal damage (1/10) | Haga et al. 1987 |
| Fluazifop-butyl | Foliar, 0.084, to 0.84 kg/ha | Bermudagrass, Quackgrass, and wirestem muhly. | Dose-related increase in control based on visual observations at 28 DAT. Substantial inhibition of shoot regrowth. | Hicks and Jordan 1984 |

| Form | Exposure | Species | Response | Reference [1] |
|------|----------|---------|----------|---------------|
| Fluazifop-butyl | Foliar: 0.038, 0.066, 0.094, or 0.188 kg/ha | African couchgrass | Reduction in dry shoot (≈40-60%) and dry rhizomes (≈66-78%) weights at higher doses. Only transient and mild effects at lowest dose. | Kabanyoro 2001 |
| **Fluazifop –P-butyl** | | | | |
| Fluazifop-P-butyl | Fusilade Max: 0. 0.09375, 0.1875, and 0.75 kg/ha | Orchard grass (*Dactylis glomerata*) | Severe and progressive damage (chorosis) from Day 3 to Day 21 at all doses. | Blake et al. 2012 |
| Fluazifop-P-butyl | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Red fescue (*Festuca rubra*) | No temporal relationship but chlorosis, leaf curl and leaf necrosis at high dose. | Blake et al. 2012 |
| Fluazifop-P-butyl | Two Fusilade formulations at 0.42, 0.84, 1.69, and 3.4 kg/ha | *Austrostipa elegantissima*, 3-4 months old | Dose-related decrease in plant height (max of ≈50%) and dose-related decrease in visual damage. See Appendix D of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade Forte formulations at 1.69 kg/ha | *Austrostipa elegantissima*, 4-5 months old | Reduction in plant height (≈33%) following foliar and soil application. See Appendix E of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Two Fusilade formulations at 0.42, 0.84, 1.69, and 3.4 kg/ha | *Avena fatua* 3-4 months old | Dose-related but modest decrease in plant height (max of ≈12%). See Appendix D of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade Forte formulations at 1.69 kg/ha | *Avena fatua* 4-5 months old | Severe visual damage and reduced plant height (max ≈38%) following foliar and soil application. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Two Fusilade formulations at 0.42, 0.84, 1.69, and 3.4 kg/ha | *Anigozanthos manglesii* [Haemodoraceae], 3-4 months old | Reduced plant height (max of ≈40%) but not dose-related. See Appendix D of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade Forte formulations at 1.69 kg/ha | *Anigozanthos manglesii* [Haemodoraceae], 5-6 months old | Modest reduction in height (20% max) following **foliar and soil** application. See Appendix E of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Two Fusilade formulations at 0.42, 0.84, 1.69, and 3.4 kg/ha | *Sowerbaea laxiflora* and *Thysanotus manglesianus* [Anthericacae] 3-4 months old | No adverse effects. See Appendix D of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade Forte formulations at 1.69 kg/ha | *Sowerbaea laxiflora* [Anthericacae] 4-5 months old | Severe visual damage and reduced plant height (max ≈34%) following foliar and soil application. See Appendix E of paper. | Rokich et al. 2009 |

| Form | Exposure | Species | Response | Reference [1] |
|---|---|---|---|---|
| Fluazifop-P-butyl | Fusilade Forte formulations at 1.69 kg/ha | *Thysanotus manglesianus* [Anthericacae] 4-5 months old | No effect on plant height. Visual damage (leaf burn with some drop) **following soil but not foliar** application. See Appendix E of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade Max, Foliar | Corn (*Zea mays*) | 9.1 g a.e./ha: 50% inhibition of growth | EFSA 2011 |
| **Fusilade Max Blank** | | | | |
| Fusilade Max Blank | Fusilade Max with no a.i.: 0.90375, 0.1875, and 0.75 kg/ha | Orchard grass (Dactylis glomerata) | Blank cause some toxicity but mild compared to control. | Blake et al. 2012 |

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

**A4 Table 4: Dicots Greenhouse Toxicity Studies – Post-Emergence**

| Form | Exposure | Species | Response | Reference |
|---|---|---|---|---|
| **Fluazifop (NOS)** | | | | |
| Fluazifop (RS) | 0.28 kg/ha, foliar, greenhouse | Collards, cucumber, okra, Snapbean, and tomato. | No effect | Boucounis et al. 1998 |
| Fluazifop (RS) | 0.56 kg/ha, foliar, greenhouse | Collard and tomato. | No effect | Boucounis et al. 1998 |
| Fluazifop (RS) | 0.56 kg/ha, foliar, greenhouse | Cucumber | 34% reduction in stem length | Boucounis et al. 1998 |
| Fluazifop (RS) | 0.56 kg/ha, foliar, greenhouse | Okra | 8% reduction in fresh weight ($p<0.05$) | Boucounis et al. 1998 |
| Fluazifop (RS) | 0.56 kg/ha, foliar, greenhouse | Snapbean | Stem diameter reduced by 10% ($p<0.05$) | Boucounis et al. 1998 |
| **Fluazifop-P** | | | | |
| Fluazifop-P | Foliar: 0.42, 0.84, and 1.68 kg/ha | Lamb's ear | Some damage (scored 11-23) over a 3 to 11 week period. | Talbert et al. 1996 |
| **Fluazifop-butyl** | | | | |
| Fluazifop-butyl | 6 kg/ha, greenhouse | Soybean | 6 kg/ha: only a 4% reduction in growth.  See entries for dicots above for contrast. | Buhler and Burnside 1984b |
| Fluazifop-butyl | Foliar, 0.25 and 1 kg/ha | 14 species from 9 families | No damage | Haga et al. 1987 |
| Fluazifop-butyl | Foliar: 210 g/ha | *Vernonia galamensis* | No damage | Posenberg 1997 |
| **Fluazifop-P-butyl** | | | | |
| Fluazifop-P-butyl | Yarrow (*Achillea millefolium*) | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | No effects. | Blake et al. 2012 |
| Fluazifop-P-butyl | Knapweed (*Centaurea nigra*) | Fusilade Max: 0. 09375, 0.1875, and 0.75 kg/ha | No effects. | Blake et al. 2012 |
| Fluazifop-P-butyl | Bedstraw (*Galium verum*) | Fusilade Max: 0. 09375, 0.1875, and 0.75 kg/ha | Dose-related but transient chlorosis and damage to the growing points at Day 3. Damage only at highest dose on days 7-21. | Blake et al. 2012 |
| Fluazifop-P-butyl | Oxeye daisy (*Leucanthemum vulgare*) | Fusilade Max: 0. 09375, 0.1875, and 0.75 kg/ha | Visible damage only at highest dose and only on Day 3. | Blake et al. 2012 |
| Fluazifop-P-butyl | Birdfoot deervetch (*Lotus corniculatus*) | Fusilade Max: 0. 09375, 0.1875, and 0.75 kg/ha | Visible damage (leaf curl/distortion, chlorosis and damage to growing points) only at highest dose and only on Days 3 and 7. | Blake et al. 2012 |

| Form | Exposure | Species | Response | Reference |
|---|---|---|---|---|
| Fluazifop-P-butyl | Buckhorn plantain (*Plantago lanceolata*) | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Damage (leaf curl/distortion, chlorosis, reduced vigor and leaf necrosis) on Days 3 to 21. Damage most severe on Day 3. | Blake et al. 2012 |
| Fluazifop-P-butyl | Sorrel (*Rumex acetosa*) | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Damage (leaf curl/distortion, chlorosis, reduced vigor and leaf necrosis) on Days 3 to 21. Phytotoxicity scores elevated from Day 3 to Day 21. | Blake et al. 2012 |
| Fluazifop-P-butyl | Red campion (*Silene dioica*) | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | No temporal relationship but signs of chlorosis, leaf curl and leaf necrosis marked at highest dose. | Blake et al. 2012 |
| Fluazifop-P-butyl | **Red clover** (*Trifolium pratense*) | Fusilade Max: 0.09375, 0.1875, and 0.75 kg/ha | Visible damage (chlorosis) substantial but declining from Day 3 to Day 21. Damage significantly different from controls on Days 7 and 17 at all doses. No significant difference, however, at lowest rate on Days 3 and 21. | Blake et al. 2012 |
| Fluazifop-P-butyl | Two Fusilade formulations at 0.42, 0.84, 1.69, and 3.4 kg/ha | *Acacia lasiocarpa* and *Banksia menziesii*, 3-4 months old | No adverse effects. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade Forte formulations at 1.69 kg/ha | *Acacia lasiocarpa* (shrub), 4-5 months old | No effect following foliar exposure. Soil exposures caused visual leaf damage. See Appendix E of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Two Fusilade formulations at 0.42, 0.84, 1.69, and 3.4 kg/ha | *Eucalyptus gomphocephala* (Tuart tree), 3-4 months old | Dose-related decrease in plant height (max ≈35%) and modest visual damage (leaf burn) See Appendix D of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Two Fusilade formulations at 0.42, 0.84, 1.69, and 3.4 kg/ha | *Euphorbia terracina*, 3-4 months old | No effect on height but visual signs of damage (leaf burn and drop). See Appendix D of paper. | Rokich et al. 2009 |
| Fluazifop-P-butyl | Fusilade Forte formulations at 1.69 kg/ha | *Eucalyptus gomphocephala* and *Euphorbia terracina*, 4-5 months old | No effects following foliar or soil exposure. | Rokich et al. 2009 |
| **Fusilade Max Blank** | | | | |
| Fusilade Max Blank | Bedstraw (*Galium verum*) | Adjuvants at rates comparable to studies with a.i. | High dose blank caused progressive damage from Day 3 to Day 7 but not damage thereafter. | Blake et al. 2012 |
| Fusilade Max Blank | Buckhorn plantain (*Plantago lanceolata*) | Adjuvants at rates comparable to studies with a.i. | Formulation and blank about equally toxic at low dose. Formulation much more toxic at high dose. | Blake et al. 2012 |

| Form | Exposure | Species | Response | Reference |
|---|---|---|---|---|
| Fusilade Max Blank | Sorrel (***Rumex acetosa***) | Adjuvants at rates comparable to studies with a.i. | High dose blank caused about damage about half as severe as the high dose formulation. | Blake et al. 2012 |
| Fusilade Max Blank | Red campion (***Silene dioica***) | Adjuvants at rates comparable to studies with a.i. | High dose blank was about equally toxic to high dose formulation on Day 3 but the blank was less toxic on Day 7. | Blake et al. 2012 |
| Fusilade Max Blank | Red clover (***Trifolium pratense***) | Adjuvants at rates comparable to studies with a.i. | High dose blank less toxic than high dose formulation on Days 3, 7, and 21 and equitoxic on Day 14. | Blake et al. 2012 |

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

**A4 Table 5: Ferns Greenhouse Toxicity Studies, Post-Emergence**

| Form | Exposure | Species | Response | Reference |
|---|---|---|---|---|
| Fluazifop-butyl | Foliar, 0.25 and 1 kg/ha | Pteridophyte: *Pteridium aqulinum*, *Osmunda japonica*, and *Equisetum arvenuse* | No damage | Haga et al. 1987 |

**A4 Table 6: Field Studies with Fluazifop**

| Target Weed Species[2] | Non-target Crop[2] | Form[1]: Application Rate[3] | Observations [No report of nontarget/crop damage unless otherwise stated.] | Reference |
|---|---|---|---|---|
| Bermudagrass [M] and several dicots | Onion [M] | f-b: Unclear | About 50% control for Bermuda grass and about 26% control for broadleaf weeds [Table 1]. | Abdel-Aai and El-Haroun 1990 |
| Barnyard grass | Mungbean | flz: 0.75 to 1 kg/ha | About 55.3 to 66.4% control. | Balyan and Malik 1991 |
| Mixed | Four legumes | f-b: 0.25 kg/ha | No effect on monocot or dicot weeds. | Belander and Winch 1985 |
| Mixed | Wildflowers | f-P-b: Fusilade Max, 0.125 kg/ha | Increase in wildflower abundance and species richness. Also positive impact on butterfly abundance. | Blake et al. 2011a |
| Mixed | Wildflower | f-P-b: Fusilade Max, ≈0.094 kg/ha | Significant increase in wildflower cover. Also positive impact on number of bumblebees. | Blake et al. 2011b |
| Mixed | *Festuca ovina*, Sheep fescue [M - Poaceae] | f-P-b: Fusilade 2000, 1.12 kg/ha | Minor decrement in crop quality (score of 3.5 vs 3.9 in weeded control). | Calkins et al. 1996 0=dead 5=excellent |
| Mixed | Miniature dwarf bearded iris [M - Iridaceae] | f-P-b: Fusilade 2000, 1.12 kg/ha | Relatively severe damage to crop (score of 1.7 vs 3.5 in weeded control) | Calkins et al. 1996 0=dead 5=excellent |
| Mixed | After dark daylily [M- Xanthor-rhoeaceae] | f-P-b: Fusilade 2000, 1.12 kg/ha | Relatively pronounced damage to crop (score of 2.6 vs 3.3 in weeded control) | Calkins et al. 1996 0=dead 5=excellent |
| Mixed | Young love daylily [M- Xanthor-rhoeaceae] | f-P-b: Fusilade 2000, 1.12 kg/ha | No adverse effect on crop (score of 3.8 vs 3 in weeded control). | Calkins et al. 1996 0=dead 5=excellent |
| Mixed | Plantain lily (*Hosta lancifolia*) [M-Asparagaceae] | f-P-b: Fusilade 2000, 1.12 kg/ha | No adverse effect on crop (score of 3.2 vs 3.4 in weeded control). | Calkins et al. 1996 0=dead 5=excellent |

| Target Weed Species[2] | Non-target Crop[2] | Form[1]: Application Rate [3] | Observations [No report of nontarget/crop damage unless otherwise stated.] | Reference |
|---|---|---|---|---|
| Mixed | Siberian iris [**M-Iridaceae**] | f-P-b: Fusilade 2000, 1.12 kg/ha | No substantial adverse effect on crop (score of 3.7 vs 3.5 in weeded control). | Calkins et al. 1996 0=dead 5=excellent |
| Mixed grassy weeds | Corn [**M - Poaceae**] | flz: 1 to 13.4 g/ha | Visual signs of injury to corn with slight decrease in yield at 8 g/ha and higher in applications to 70- to 80-cm corn. | Chernicky and Slife 1986 |
| NS | Bentgrass and bluegrass [**M - Poaceae**] | f-b: 0.125 lb/ac with COC 1% | Some injury over 11 week observation period. Most pronounced with bentgrass | Cisar and Jagschitz 1984a |
| Smooth crabgrass | Bentgrass and bluegrass, and red fescue [**M-Poaceae**] | f-b: 0.0375 and 0.075 lb/ac with COC 1% | Moderate (36-60% control with minimal injury to lawns. | Cisar and Jagschitz 1984b |
| Quackgrass | Strawberries | f-b: 1.6 kg a.i./ha x 5 | Eradication of quackgrass. No damage to strawberries. | Clay et al. 1990 |
| Quackgrass | Strawberries | f-b: 0.25 kg a.i./ha x 2 | Poor (50%) control. | Doohan et al. 1986 |
| Crabgrass | Strawberries | f-b: 0.30 kg a.i./ha x 2 | Good (>90%) control. | Doohan et al. 1986 |
| Large crabgrass | None | f-b: 0.56 kg a.i./ha | Significant reduction (36%) in crabgrass dry weight | Ennis and Ashley 1984 |
| Crabgrass, goosegrass, and pigweed [**D**] | Baby's Breath | f-p-b: 0.28 kg/ha | Efficacy to grasses not quantified. No effect on crop. | Gilreath 1987 |
| African couchgrass | Cotton | f-b: 0.138, 0.162, 0.188 kg/ha | Good (79-96%) control at 35 DAT. No remarkable dose-response relationship. | Kabanyoro 2001 |
| Barley grass and Great brome | None | flz-P: 63, 94, and 125 a.i./ha | Ap. Rate / % Control; 63 / 38.2-48.5; 94 / 55.7-75; 125 / 61.5-72.8 | Beys et al. 1998 |
| Mixed broadleaves and grasses | Alfalfa | f-b: 0.25 and 0.5 kg/ha | Seed yields of alfalfa lower at 0.5 kg/ha in the year following treatment. This data is not in Table 4 of paper. Alfalfa tolerance characterized in paper as "excellent". Grass control 67% at lower rate and 89% at higher rate. | Malik and Waddington 1990 |
| N.S. | Daylily [M-Xanthorrhoeaceae], Phlox, Red Hot Poker [M-Xanthorrhoeaceae], yarrow | f-p-b: 0.19 lb a.i./acre as Fusilade | No visual signs of damage. | Skroch et al. 1990 |

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

| Target Weed Species[2] | Non-target Crop[2] | Form[1]: Application Rate [3] | Observations [No report of nontarget/crop damage unless otherwise stated.] | Reference |
|---|---|---|---|---|
| Green foxtail, large crabgrass, yellow foxtail, giant foxtail, and Japanese millet | None | flz: 0.07 to 0.28 kg/ha | Generally dose-related control but variable among years (Table 1). Differences in sensitivity: green foxtail > large crabgrass > yellow foxtail > giant foxtail >Japanese millet. | Smeda and Putnam 1990 |
| N.S | Rice [M - Poaceae] | f-b: 0.11 and 0.22 kg a.e./ha over 4 years | A modest (9 to 16%) reduction in rice yield in 3rd year at lower rate and 2nd and 3rd year at higher rate. No effect on seed germination or weights. | Street and Snipes 1987 |
| Large crabgrass and goosegrass | Gaillardia plumme (*Gaillardia pulchella* ?) | flz-P: 0.84 and 1.68 kg/ha. | Transient and slight injury (leaf curl) to crop with recovery by 21 DAT. Excellent control (NOS) of weeds). Injury confirmed with container experiment without weeds. | Talbert et al. 1995 |
| Green foxtail, wild oat | Flax | flz-P: 0.125 kg/ha. | Significant (p<0.05) and substantial reduction in weed biomass. Significant increase in crop biomass on 1 of 2 years. No effects on crop. | Wall 1994 |
| Perennial ryegrass | Yellow rattle | flz-P-b (Fusilade 250EW): 0.125 kg/ha | Over a 2 year period, no impact on species richness. Reduction in grasses but only in Year 1. Increase in dicots but not yellow rattle. | Westbury et al. 2008 |

[1] Abbreviations used in table:
    f-b: fluazifop-butyl
    f-P-b: fluazifop-P-butyl
    flz: fluazifop (not otherwise specified)
    flz-P: fluazifop-P
[2] Unless otherwise specified, all target weeds are monocots [M] and all nontarget crops are dicots [D]. Monocots are also designated with the family to which the monocot belongs..
[3] Application rates as reported in publication.

**Appendix 5: Toxicity to Fish.**

**Data taken from ECOTOX and U.S. EPA/OPP/EFED 2008 unless otherwise specified.  ECOTOX gives values in a.i.  The EFED risk assessment gives values in a.e. using a conversion factor of 0.854 a.e./a.i.  The EFED risk assessment does not report NOAEC values for acute exposures.  NOAEC's reported in ECOTOX are converted to units of a.e.  Studies for which DERs were available are specified in the reference column with a standard Author(s), Year citation and the term *Syngenta DER01* in brackets.**

**A5 Table 1: Acute Toxicity to Freshwater Fish**

| Chemical Form Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| Nile tilapia (*Oreochromis niloticus*), >2-week-old fingerling, approx. 1 inch | Fluazifop-butyl, 100% purity, in static system for 48 hours.<br><br>Solvent = 2-propanone (acetone) | $LC_{50}$ = 0.29 ppm  (a.i.)<br> Equiv. to 0.25 ppm (a.e.)<br><br>This study is not discussed in U.S. EPA/OPP/EFED (2008). Nonetheless, the report $LC_{50}$ is very close to the $LC_{50}$ of 0.32 ppm (a.e.) for MRID 00093808. | Tejada et al. 1994<br><br>(Also cited in ECOTOX 2013) |
| Fathead minnow (*Pimephales promelas*), <24-hours-old.<br>15 fish/dose. | Fluazifop-butyl, 90.2% purity for 96 hours in static system.<br><br>Nominal Concentrations: 0, 0.098, 0.16, 0.27, 0.45, and 0.75 mg a.i./L. | ECOTOX<br> $LC_{50}$ = 0.37 ppm (a.i.)<br> NOEL = 0.27 ppm (a.i.)<br>EFED<br> $LC_{50}$ = 0.32 ppm (a.e.)<br>NOAEC = 0.23 ppm (a.e.)<br>DER<br> NOAEC based on 1/15 mortality in mid-dose group after 96-hours.<br> Slope: 10.65<br> $LC_{50}$ = 0.37 ppm (a.i.) with 95% confidence interval of 0.32-0.44 ppm (a.i.)<br>The $LC_{50}$ of 0.32 ppm (a.e.) is used in U.S. EPA/OPP/EFED (2008, Table 4-1, pp. 58-59) for calculating RQs for freshwater fish. | MRID 00093808, 1981, Supplemental<br><br>ECOTOX 2013<br><br>Wilson et al. 1981 [Syngenta DER01] |

Appendix 5: Toxicity to fish *(continued)*

| Chemical Form Species | Exposure | Response | Reference |
|---|---|---|---|
| Bluegill (*Lepomis macrochirus*), 4.13 g. 20 fish/dose | Fluazifop-butyl, 98.6% purity for 96 hours in flow-through system.<br><br>Nominal Concentrations: 0.36, 0.77, 1.07, and 1.6 mg a.i./L. | ECOTOX<br>    $LC_{50}$ = 0.53 ppm<br>    NOEL = 0.36 ppm<br>EFED<br>    $LC_{50}$ = : 0.45 ppm (a.e.)<br>NOEL = 0.31 ppm (a.e.)<br>DER<br>    $LC_{50}$ = 0.53 ppm (a.i.) with 95% confidence interval of 0.36-0.77 mg a.i./L.<br>    No signs of toxicity at 0.36 mg a.i./L.  At higher concentrations, signs of toxicity included … *loss of balance, quiescence, and sane spiraling.*<br>Working Note: NOAEC based on both lack of mortality and lack of overt signs of toxicity.  After 96 hours, all fish at the 0.77 mg/L concentration and above were dead. | MRID 00087485, 1981, Acceptable<br><br>ECOTOX 2013<br><br>Hill et al. 1981 [Syngenta DER01] |
| Carp (*Cyprinus carpio*) | Fluazifop-butyl (NOS), 96 hours | $LC_{50}$ = 1.31 ppm  [≈1.12 ppm (a.e.)] | FAO/WHO 2000 EFSA 2012 |
| Rainbow trout (*Oncorhynchus mykiss*), NOS | Fluazifop-butyl, 93.7% purity for 96 hours in flow-through system.<br><br>Test concentrations: 1.3-1.54 ppm | ECOTOX<br>    $LC_{50}$ = 1.41 ppm<br>    NOEL = 0.8 ppm<br>EFED<br>    $LC_{50}$ = 1.2 ppm (a.e.)<br>    Slope: 15.2<br>NOEL = 0.68 ppm (a.e.) | MRID 00131458, 1983, Supplemental<br><br>ECOTOX 2013<br><br>Also cited in FAO/WHO 2000 EFSA 2012 |
| **Fluazifop Acid** | | | |
| Rainbow trout (*Oncorhynchus mykiss*), 6.2 g | Fluazifop-butyl, 98% purity for 96 hours in static system.<br><br>Test concentrations: 108-127 ppm | ECOTOX<br>    $LC_{50}$ = 117 ppm<br>    NOEL = 96 ppm<br>EFED<br>    $LC_{50}$ = 99.9 ppm (a.e.)<br>NOEL = 82.0 ppm (a.e.) | MRID 00087483, 1981, Acceptable<br><br>ECOTOX 2013<br><br>EFSA 2012 |

Appendix 5: Toxicity to fish *(continued)*

| Chemical Form Species | Exposure | Response | Reference |
|---|---|---|---|
| **Formulations** | | | |
| Bluegill (*Lepomis macrochirus*), 3.31 g | Fluazifop-butyl, 25.8% formulation for 96 hours in flow-through system.<br><br>Test concentrations:<br>2.32-3.07 ppm<br>(2320-3070 µg/L) | ECOTOX<br>$LC_{50}$ = 2.67 ppm<br>NOEL = 1.51 ppm<br>EFED<br>$LC_{50}$ = : 2.28 ppm (a.e.)<br>NOEL = 1.29 ppm (a.e.) | MRID 00087486, 1981, Acceptable<br><br>ECOTOX 2013 |
| Rainbow trout (*Oncorhynchus mykiss*), 2.2 g | Fluazifop-butyl, 25.8% formulation for 96 hours in flow-through system.<br><br>Test concentrations:<br>4.4-5.4 ppm<br>(4400-5400 µg/L) | ECOTOX<br>$LC_{50}$ = 4.9 ppm<br>NOEL = 0.4 ppm<br>EFED<br>$LC_{50}$ = 4.2 ppm (a.e.)<br>NOEL = 0.34 ppm (a.e.) | MRID 00087484, 1981, Acceptable<br><br>ECOTOX 2013 |
| Rainbow trout (*Oncorhynchus mykiss*) | Fusilade Max (EC 125 g/L) | 1.6 mg a.i./L<br>[≈1.37 a.e./L] | EFSA 2012 |
| **Metabolite X** | | | |
| Rainbow trout (*Oncorhynchus mykiss*) | Purity not specified | $LC_{50}$ = 240 ppm (nominal) | EFSA 2012 |

**Note on MRID 00087483: This study is cited in U.S. EPA/OPP/EFED (2008) and ECOTOX as being conducted with Fluazifop-butyl, 98% purity. This is an error. EFSA (2012) indicates that this study was conducted on fluazifop acid and this has been confirmed by Syngenta (Henry 2014).**

**A5 Table 2: Acute Toxicity to Saltwater Fish**

| Species | Exposure | Response | Reference |
|---|---|---|---|
| Sheepshead minnow (*Cyprinodon variegatus*), 0.37 g | Fluazifop-butyl (**25EC formulation**), 25.4% a.i. for 96 hours in flow-through system.<br><br>Test concentration: 9-13 ppm | ECOTOX<br>  $LC_{50}$ = 11 ppm<br>  NOEL = 3 ppm<br>EFED<br>  $LC_{50}$ = 9.4 ppm (a.e.)<br>  Slope = 13.2<br>NOEL = 2.56 ppm (a.e.) | Accession No.[1]: ACC070630, 1981, Acceptable<br><br>ECOTOX 2013 |
| Sheepshead minnow (*Cyprinodon variegatus*), 0.57 g 20 fish/group | Fluazifop-butyl (Fusilade 4E formulation), 46.8% a.i. for 96 hours in flow-through system.<br><br>Nominal Concentrations: 1.7, 3, 5.5, 9.8, 15.7, and 25.7 mg/L. | ECOTOX<br>  $LC_{50}$ = 8.04 ppm<br>  NOEL = not reported.<br>EFED<br>  $LC_{50}$ = 6.86 ppm (a.e.)<br>  Slope: 10.1<br>DER<br>  $LC_{50}$ = 8.1 ppm formulation<br>`Working Note:`<br>`  Correcting for the`<br>`  formulation to a.e.`<br>`  conversion, the`<br>`  correct LC`$_{50}$` is:`<br>  $LC_{50}$ = 3.24 ppm (a.e.) | MRID 00152173, 1985, Acceptable<br><br>ECOTOX 2013<br><br>Hill et al. 1985 [Syngenta DER01] |
| Sheepshead minnow (*Cyprinodon variegatus*), 0.57 g 20 fish/group | Blank Formulation of Fusilade 4E formulation, no a.i., for 96 hours in flow-through system.<br><br>Fusilade blank: 1.7, 9.6, and 29.8 mg/L. | DER<br>  $LC_{50}$ = 10.4 ppm formulation<br>The formulation blank caused no mortality at lowest concentration, 40% mortality at mid concentration, and 100% mortality at highest concentration.<br>*Comparison of the results for Fusilade 4E and the Fusilade blank indicated the solvent used in the formulation was a major contributing factor to the toxicity determined in the study* (DER, p. 5). | Hill et al. 1985 [Syngenta DER01] |

Note on MRID 00152173: The summary given in ECOTOX and the summary given in the DER appear to express concentrations as formulation and not as a.i. Based on the DER, there clearly were problems with solubility and the measured concentrations were much lower than the nominal concentrations.
The DER notes the following: *Because of the solubility problem experienced with the technical material, this study will be considered as acceptable in fulfilling the EEB requirement for an LC50 on the technical even though the formulation was utilized. Registration of different formulations will require submission of additional data.*

[1] Accession numbers were used by the U.S. EPA prior to adopting MRID numbers.

Appendix 5: Toxicity to fish *(continued)*

**A5 Table 3: Early Life Stage (Chronic) Toxicity to Fish**

| Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| Fathead minnow (*Pimephales promelas*), 0.37g 60 embryos per replicate, 2 replicates/dose. | Fluazifop-butyl, 90.2% purity for 30 days in flow-through system. Mean measured concentrations: 3.3, 24.3, 51.2, 103, and 238 µg a.i./L with 38.7 µg/L solvent control. Solvent not specified in DER. | ECOTOX   NOEC = 0.238 ppm (a.i.)   LOEC: >0.238 ppm (a.i.) EFED   NOEC = >0.203 ppm (a.e.) DER   DER gives classification of Core.   At highest dose, decrease in mean body weights (≈6% and 18% in replicates) with respect to untreated control. This effect not noted in solvent control (15% increase and ≈9.3 % decrease in replicates). No effects at lower concentrations. | MRID 00093808, 1981, Supplemental ECOTOX 2013 Wilson et al. 1981 [Syngenta DER01] |
| **Fluazifop-P-butyl** | | | |
| Fathead minnow (*Pimephales promelas*) | Fluazifop-P-butyl, 28 days, flow-through, early life stage | NOEC: 0.077 mg/L NOEC based on hatching, survival, and growth. | EFSA 2012 FAO/WHO 2000 |
| **Fluazifop-P Acid** | | | |
| Fathead minnow (*Pimephales promelas*) | Fluazifop-P acid, no details of study given. | NOEC: 1.46 mg/L NOEC based on hatching, survival, and growth. | EFSA 2012 |

**General Working Note: None of the early life stage studies appear to have observed adverse effects at the highest concentration tested. Such effects (if noted) would probably be reported in the summaries from U.S. EPA/OPP/EFED (2008), EFSA 2012, and FAO/WHO 2000.**

**Working Note on MRID 00093808: This early life stage NOEC is virtually identical to the NOAEC from the fry $LC_{50}$ study (MRID 00093808, 1981). Note that the MRID numbers are identical and both acute and chronic studies were summarized in the same DER. The NOEC of 0.203 ppm (a.e.) is used in U.S. EPA/OPP/EFED (2008, Table 4-2, pp. 70-71) for calculating chronic RQs for freshwater fish.**
**A handwritten note on the DER indicates that raw data was available and these data support the NOAEC of 0.238 ppm (a.i.).**

**Appendix 6: Toxicity to Aquatic Invertebrates.**

**Data taken from ECOTOX and U.S. EPA/OPP/EFED 2008 unless otherwise specified. ECOTOX gives values in a.i. The EFED risk assessment gives values in a.e. using a conversion factor of 0.854 a.e./a.i. The EFED risk assessment does not report NOAEC values for acute exposures. NOAEC's reported in ECOTOX are converted to units of a.e. Studies for which DERs were available are specified in the reference column with a standard Author(s), Year citation and the term *Syngenta DER01* in brackets.**

**A6 Table 1: Acute Toxicity to Freshwater Aquatic invertebrates**

| Form<br>Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| Water flea (*Daphnia magna*), <24-hours-old | Fluazifop-butyl, 97.8% purity, for 48 hours in static system. | ECOTOX<br>  $EC_{50}$ = 281.2 ppm  (a.i.)<br>  NOEL = 97 ppm<br>EFED 2008, p. 190<br>  $EC_{50}$ = 240 ppm (a.e.)<br>NOAEC: 82.8 ppm (a.e.) | MRID 00087490, 1981, Acceptable<br><br>ECOTOX 2013 |
| **Fluazifop-P-butyl** | | | |
| Water flea (*Daphnia magna*), <24-hours-old | Fluazifop-P-butyl (RS 1:1 enantiomer, RS11), 11% a.i., for 48 hours in static system. | ECOTOX<br>  $EC_{50}$ = 553.9 ppm<br>  NOEL = 192 ppm<br>EFED<br>  $EC_{50}$ = 473 ppm (a.e.)<br>NOAEC: 162 ppm (a.e.) | MRID 00162452, 1983, Supplemental<br><br>ECOTOX 2013 |
| Water flea (*Daphnia magna*), <24-hours-old | Fluazifop-P-butyl (RS 1:7 enantiomer, RS71), 71% purity, for 48 hours in static system. | ECOTOX<br>  $EC_{50}$ = 545.6 ppm)<br>  NOEL = 298 ppm<br>EFED<br>  $EC_{50}$ = 466 ppm (a.e.)<br>NOAEC: 254 ppm (a.e.) | MRID 00162452, 1983, Supplemental<br><br>ECOTOX 2013 |
| Water flea (*Daphnia magna*), <24-hours-old | Fluazifop-P -butyl (RS 1:14 enantiomer, RS14), 14% purity, for 48 hours in static system. | ECOTOX<br>  EC50 = 412.4 ppm<br>  NOEL = 162 ppm<br>EFED<br>  $EC_{50}$ = 352 ppm (a.e.)<br>NOAEC: 138 ppm (a.e.) | MRID 00162452, 1983, Supplemental<br><br>ECOTOX 2013 |

Appendix 6: Toxicity to Aquatic Invertebrates *(continued)*

| Form<br>Species | Exposure | Response | Reference |
|---|---|---|---|
| Water flea (*Daphnia magna*) | Fluazifop-P-butyl (NOS) | $EC_{50} > 1$ mg/L | FAO/WHO 2000 |
| Water flea (*Daphnia magna*) | Fluazifop-P-butyl (NOS) | $EC_{50} > 0.62$ mg/L | EFSA 2012 |
| Water flea (*Daphnia magna*), 12-hours-old | Fluazifop-P-butyl (PP009), 94.8% a.i., 48 hours, static<br><br>DER: Two separate assays at concentrations up to 10 mg/L (Test 1) and 12.3 mg/L (Test 2). | ECOTOX<br>　$EC_{50}$ >10 ppm<br>　NOEL = 10 ppm<br>EFED<br>　48-h $EC_{50}$: 8.5 ppm (a.e.)<br>DER<br>　No effects observed at any concentration. | MRID 00087488, 1979, Acceptable<br><br>ECOTOX 2013<br><br>Getty et al. 1979 [Syngenta DER01] |
| *Biomphalaria alexandrina* (snail) Egyptian snail, vector for *Schistosoma mansoni*, cause of schistosomiasis. | Fluazifop-P-butyl, methods for toxicity studies not fully described.<br>`Working Note: Paper focuses on impact of compound on pathogen.` | $LC_{50}$: 17.6 mg/L<br>$LC_5$: 1.76 mg/L<br>Decreased glycogen content of soft tissues (NOS).<br>`Cannot determine if the concentrations are formulation, a.i., or a.e.  Not used quantitatively.` | Tantawy 2002 |
| **Formulations** | | | |
| Water flea (*Daphnia magna*), 12-hours-old | Fluazifop-butyl (PP009), 24% formulation, for 48 hours in static system. | ECOTOX<br>　$EC_{50}$ = 6.02 ppm<br>　NOEL = 1.25 ppm<br>EPA<br>　$EC_{50}$ = 5.14 ppm (a.e.)<br>NOEL = 1.07 ppm (a.e.)<br><span style="color:red">**The $LC_{50}$ of 5.14 ppm (a.e.) is used in U.S. EPA/OPP/EFED (2008, Table 4-1, pp. 58-59) is cited but not used for RQs. The lower value for the Pacific oyster is used.**</span> | MRID 00087489, 1980, Acceptable<br><br>ECOTOX 2013 |
| Water flea (*Daphnia magna*), 12-hours-old | Fluazifop-butyl (PP009), **25 EC**, 25% a.i., for 48 hours in static system. | ECOTOX<br>　$EC_{50}$ = 6.5 ppm<br>　NOEL = Not reported<br>EPA<br>　$EC_{50}$ = 5.5 ppm (a.e.)<br>DER<br>　The DER does not detail the results of the formulation assay. | MRID 00087488, 1979, Acceptable<br><br>ECOTOX 2013<br><br>Getty et al. 1979 [Syngenta DER01] |
| *Daphnia magna* | Fusilade Max (EC 125 g/L), 48 hours, static | $EC_{50}$ = 2.1 mg a.i./L<br>$EC_{50} \approx 1.79$ mg a.e./L | EFSA 2012 |
| Mayfly (*Cloeon dipterum*), nymph, 9.3 mm | Fluazifop-butyl (Fusilade, Hydrate), purity not reported, for 3, 6, 24, and 48 hours. | $LD_{50}$ >40 ppm | Nishiuchi and Asano 1979<br><br>(Cited in ECOTOX 2013) |
| **Fluazifop acid** | | | |
| *Daphnia magna* | Fluazifop acid (NOS), static | $LC_{50}$ = 240 mg a.e./L | EFSA 2012 |

Appendix 6: Toxicity to Aquatic Invertebrates *(continued)*

| Form<br>Species | Exposure | Response | Reference |
|---|---|---|---|
| **Compound X** | | | |
| *Daphnia magna* | Compound X (NOS) | $LC_{50}$ = 681 mg/L | EFSA 2012 |

Note on MRID 00162452: The summaries in ECOTOX and U.S. EPA/OPP/EFED (2008) indicate that the test material was fluazifop-butyl. Two DERs are available in the DER01 from Syngenta: Jealotts Hill Research Station 1983 and Hamer and Hill (1983). Both indicate that the test material was fluazifop acid and not fluazifop-butyl. This ambiguity does not substantially impact the current assessment because these studies are not used quantitatively.

**A6 Table 2: Acute Toxicity to Saltwater Aquatic invertebrates**

| Form<br>Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| Pacific oyster (*Crassostrea gigas*), embryo | Fluazifop-butyl (PP009), 98.6% purity, for 48 hours in flow-through system.<br><br>Test concentration: 91-105 ppb | ECOTOX<br>$\quad$ $LC_{50}$ = 0.097 ppm<br>$\quad$ NOEL = 0.056 ppm<br>EFED<br>$\quad$ $LC_{50}$ = 0.083 ppm (a.e.)<br>$\quad$ NOAEC = 0.048 ppm (a.e.)<br><br>**The $LC_{50}$ of 0.083 ppm/ 83 ppb (a.e.) is used in U.S. EPA/OPP/EFED (2008, Table 4-1, physical pp. 70-71) for deriving RQs for freshwater mollusks which are presumed to be more sensitive than daphnids. Note that this presumption is supported by the Tantawy 2002 study in Egyptian snails.** | MRID 00131460, 1982, Acceptable<br><br>ECOTOX 2013 |
| Opossum shrimp (*Americamysis bahia*), 6- to 8-days-old | Fluazifop-butyl (PP009), 98.6% purity, for 96 hours in flow-through system. | ECOTOX<br>$\quad$ $LC_{50}$ = 0.216 ppm<br>$\quad$ NOEL = 0.048 ppm<br>EFED<br>$\quad$ $LC_{50}$ = 0.184 ppm (a.e.)<br>$\quad$ NOAEC = 0.041 ppm (a.e.) | MRID 00093806, 1980, Acceptable<br><br>ECOTOX 2013 |
| **Fluazifop-P-butyl** | | | |
| Opossum shrimp (*Americamysis bahia*; a.k.a. *Mysidopsis bahia*) | Fluazifop-P-butyl, 92.2% purity for 96 hours in a flow-through system. | ECOTOX<br>$\quad$ $LC_{50}$ = 0.51 ppm<br>$\quad$ NOEL = 0.20 ppm<br>EFED<br>$\quad$ $LC_{50}$ = 0.44 ppm (a.e.)<br>$\quad$ NOAEC = 0.17 ppm (a.e.) | MRID 42543201, 1991, Acceptable<br><br>ECOTOX 2013 |
| Opossum shrimp (*Americamysis bahia*; a.k.a. *Mysidopsis bahia*), 6-8 days old, 10 per exposure level | Fluazifop-P-butyl, PP009, 98.6%<br><br>Measured Concentrations: 45.5, 85.2, 170, 361, 775 ppb a.i. | EFED<br>$\quad$ 96-hr $LC_{50}$ = 0.216 ppm (a.i.)<br>$\quad$ 96-hr $LC_{50}$ = 0.184 ppm (a.e.)<br>$\quad$ Slope: 4.6<br>DER<br>$\quad$ Consistent with summary from EFED. EFED did recalculate the $LC_{50}$ values. | MRID 00093805, 1980, Acceptable<br><br>Hollister et al. 1980/1981 [Syngenta DER01] Covers only shrimp assay and not the fiddler crab assay with the same MRID number. |
| Opossum shrimp (*Americamysis bahia*; a.k.a. *Mysidopsis bahia*), NOS | Fluazifop-P-butyl, NOS | $LC_{50}$ = 0.54 mg a.i./L<br>$\approx$0.46 mg a.e./L | EFSA 2013 |

Appendix 6: Toxicity to Aquatic Invertebrates *(continued)*

| Form Species | Exposure | Response | Reference |
|---|---|---|---|
| American or Virginia oyster (*Crassostrea virginica*), NOS | Fluazifop-P-butyl, 90% purity for 96 hours in a flow-through system. | ECOTOX<br>  $EC_{50}$ = 0.47 ppm<br>  NOEL = 0.17 ppm<br>EFED<br>  $LC_{50}$ = 0.40 ppm (a.e.)<br>NOAEC = 0.15 ppm (a.e.) | MRID 41900601, 1991, Supplemental<br><br>ECOTOX 2013 |
| American or Virginia oyster (*Crassostrea virginica*) | Fluazifop-P-butyl (NOS), flow-through | $LC_{50}$ = 0.53 mg a.i./L<br>≈0.45 mg a.e./L | EFSA 2012 |
| **Formulations** | | | |
| Fiddler crab (*Uca pugilator*), 1.5 g | Fluazifop-butyl (PP009), 25.4% a.i. for 96-hours in static system. | ECOTOX<br>  $LC_{50}$ = 4.1 ppm<br>  NOEL = 2.54 ppm<br>EFED<br>  $LC_{50}$ = 3.5 ppm (a.e.)<br>NOAEC = 2.1 ppm (a.e.) | MRID 00093806, 1980, Supplemental<br><br>ECOTOX 2013 |
| Pink **shrimp** (*Penaeus duorarum*), 0.21 g | Fluazifop-butyl (PP009), 25.4% a.i. for 96-hours in flow-through system. | ECOTOX<br>  $LC_{50}$ = 6 ppm<br>  NOEL = 3 ppm<br>EFED<br>  $LC_{50}$ = 5.1 ppm (a.e.)<br>NOAEC = 2.6 ppm (a.e.) | MRID 00093804, 1980, Acceptable<br><br>ECOTOX 2013 |

Appendix 6: Toxicity to Aquatic Invertebrates *(continued)*

**A6 Table 3: Chronic Toxicity to Aquatic invertebrates**

| Species | Exposure | Response | Reference |
|---|---|---|---|
| **Freshwater** | | | |
| Water flea (*Daphnia magna*), NOS | Fluazifop-butyl, 97.2% purity, for 21 days in flow-through<br><br>Nominal Conc.: 0, 0.1, 0.33, 1.0, and 3.0 mg/L.<br><br>Measured Concentrations: 0, 0.1, 0.25, 0.64, and 2.0 mg/L. | ECOTOX<br>  Effects on growth, reproduction, and 14-day survival were statistically significant:<br>  LOEC = 250 µg/L (growth)<br>  LOEC = 640 µg/L (reproduction and 14-day survival)<br>  NOEL = 100 µg/L (growth)<br><br>EFED<br>  21-day NOAEC 0.0854 ppm (a.e.)<br>  21-day LOAEC 0.213 ppm (a.e.)<br>DER<br>  The DER is consistent with the summary in EFED.<br>`The NOAEC of 0.0854 ppm (a.e.) is used in U.S. EPA/OPP/EFED (2008, Table 4-2, physical pp. 70-71) for calculating chronic RQs for freshwater invertebrates.` | MRID 00093807, 1981, Supplemental<br><br>ECOTOX 2013<br><br>Edwards et al. 1981 [Syngenta DER01]<br><br>The DER (prepared in 1991) notes that a new study will be required. A new study, however, has not been identified. |
| Water flea (*Daphnia magna*), NOS | Fluazifop-butyl (NOS), 21-days | Effect Concentration: 0.25 mg a.i./L ($\approx$ 0.21 mg a.e./L)<br>`Working Note: This is virtually identical to the LOAEL from MRID 00093807 and may be from the same study.` | FAO/WHO 2000 |
| **Saltwater** | | | |
| Opossum shrimp (*Americamysis bahia*; a.k.a. *Mysidopsis bahia*), NOS | Fluazifop-butyl (PP009), 98.6% purity, for 28 days in flow-through system in life cycle study.<br><br><u>Test concentration</u>: 56.2-111.9 ppb | ECOTOX<br>  $LC_{50}$ = 77.7 ppb [≈66.4 ppb a.e.]<br>  NOEL = 17.4 ppb<br><br>EFED<br>  NOEL = 0.0148 ppm (a.e.), reported as 14.8 ppb (a.e.)<br><br>`The NOAEC of 14.8 ppb (a.e.) is used in U.S. EPA/OPP/EFED (2008, Table 4-2, physical pp. 70-71) for calculating chronic RQs for saltwater invertebrates.` | MRID 00093805, 1981, Supplemental<br><br>ECOTOX 2013 |
| *Mysidopsis bahia* Opossum shrimp | Fluazifop-butyl (NOS), 28 day flow-through | Reproduction NOEC: 0.0477 mg a.i./L $\approx$ 0.041 mg a.e./L. | EFSA (2012) |

**Appendix 7: Toxicity to Aquatic Plants.**

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Working Note: See Section 4.1.3.4 for discussion of mesocosm study by Perschbacher et
  al. 1997.
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**A7 Table 1: Toxicity to Algae**

| Form Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-butyl** | | | |
| Plankton sp., NOS | Fusilade, 100% purity, in mesocosm study under lentic conditions for 24 and 48 hours.<br><br>Application rates:<br>0.0010, 0.010, or 0.10 a.i. kg/ha | No consistent of systematic effect on mean morning oxygen levels. Few details.<br><br>```Working Note: ECOTOX record indicates that the effects were not significant at all concentrations. This is consistent with paper.``` | Perschbacher et al. 1997 (Cited in ECOTOX 2013) |
| **Fluazifop-P-butyl** | | | |
| Green algae (*Pseudokirchneriella subcapitata*), NOS | Fluazifop-P-butyl, 81.3% purity, in static system for 4 days. | Endpoint: population abundance $EC_{50}$ >1.8 ppm (>1.54 ppm a.e.) NOEL = 0.88 ppm (0.75 ppm a.e.)<br><br>Note: The NOEL of 0.88 ppm is given only in ECOTOX 2013) | ECOTOX 2013<br><br>Also cited by FAO/WHO 2000, p. 18 and EFSA 2012, p. 65 |
| Diatom (*Navicula pelliculosa*) | Fluazifop-P-butyl (NOS) | Biomass:<br>72-h $EC_{50}$: 0.51 mg a.i./L ($\approx$0.44 mg a.e./L)<br>Growth rate:<br>72-h $EC_{50}$: 1.4 mg a.i./L (1.20 mg a.e./L) | FAO/WHO 2000, p. 18 and EFSA 2012, p. 65 |
| **Fluazifop Acid** | | | |
| Green algae (*Pseudokirchneriella subcapitata*), NOS | Fluazifop acid (NOS), 96 hour static | Cell density:<br>$EC_{50}$: >46.8 mg/L (>40.0 mg a.e./L) | EFSA 2012, p. 65 |
| **Compound X** | | | |
| Green algae (*Pseudokirchneriella subcapitata*), NOS | Compound X (NOS), 72 hour static | Biomass:<br>$EC_{50}$: 340 mg/L<br>Growth rate:<br>$EC_{50}$: 860 mg/L | EFSA 2012, p. 65 |
| **Fusilade Max** | | | |
| Green algae (*Pseudokirchneriella subcapitata*), NOS | Fusilade Max (EC125 g/L), 72 hour static | Biomass:<br>$EC_{50}$: 0.024 mg a.i./L ($\approx$0.020 mg a.e./L)<br>Growth rate:<br>$EC_{50}$: 0.088 mg a.i./L ($\approx$0.075 mg a.e./L) | EFSA 2012, p. 66 |

Appendix 7: Toxicity to Aquatic Plants *(continued)*

| Form Species | Exposure | Response | Reference |
|---|---|---|---|
| Green algae (*Pseudokirchneriella subcapitata*), NOS | Fusilade Max, 72 hour static, assay with sediment. | Biomass:<br>  $EC_{50}$: 0.15 mg a.i./L (≈0.128 mg a.e./L)<br>Growth rate:<br>  $EC_{50}$: >0.16 mg a.i./L (>≈0.137 mg a.e./L) | EFSA 2012, p. 66 |
| Diatom (*Navicula pelliculosa*) | Fusilade Max, 72 hour static | Biomass:<br>  $EC_{50}$: 0.22 mg a.i./L (≈0.188 mg a.e./L)<br>Growth rate:<br>  $EC_{50}$: 1.46 mg a.i./L (≈1.25 mg a.e./L) | EFSA 2012, p. 66 |
| **Chinese 53% EC formulation** | | | |
| *Chlorella pyrenoidosa* (green alga) | 53% EC formulation | $EC_{50}$: 15.6 mg/L (13.3 mg a.e./L) | Ma 2002; Ma et al. 2001 |
| *Chlorella pyrenoidosa* (green alga) | 53% EC formulation | EC50: 15.74 mg/L (13.4 mg a.e./L) | Ma et al. 2002a |
| *Chlorella vulgaris* (green alga) | 53% EC formulation | EC50: 21.7 mg/L (18.5 mg a.e./L) | Ma et al. 2002b |
| *Raphidocelis subcapitata* (green alga) | 53% EC formulation | EC50: 1.05 mg/L (0.89 mg a.e./L) | Ma et al. 2006 |
| *Scenedesmus obliquus* (green alga) | 53% EC formulation | EC50: 26.7 mg/L (22.8 mg a.e./L) | Ma 2002 |
| *Scenedesmus quadricauda* (green alga) | 53% EC formulation | EC50: 18.3 mg/L (15.6 mg a.e./L | Ma et al. 2004 |
| **Unspecified formulation** | | | |
| Green algae (*Dunaliella bioculata*), [no cell wall] | Fluazifop-butyl, unspecified formulation.<br>1, 10, and 100 μM (0.00327, 0.0327, 0.327 mg a.e./L)<br><br>Solvent:0.1 M sulfinyl bis (methane) | NOEC: 0.0327 mg a.e./L (population growth)<br>LOEC: 0.327 mg a.e./L (60% reduction in population growth, some cell lysis, and slow movement) | Felix et al. 1988 (Cited in ECOTOX 2013) |

Appendix 7: Toxicity to Aquatic Plants *(continued)*

**A7 Table 2: Toxicity to Aquatic Macrophytes**

| Form Species | Exposure | Response | Reference |
|---|---|---|---|
| **Fluazifop-P-butyl** | | | |
| Common duckweed (*Lemna gibba*) | Fluazifop-P-butyl (NOS), 14 days | EC$_{50}$ (growth inhibition): >1.4 mg/L (>1.2 mg a.e./L) | FAO/WHO 2000, p. 18 EFSA 2012, p. 66 |
| Lesser duckweed (*Lemna paucicostata*), 4- to 5-days-old, bilobed colony, exponential growth phase | Fluazifop-P-butyl (analytical grade) for 7 days. Purity not reported, exposure type not reported.<br><br>Solvent: acetone<br>Solvent control used | <u>Effect measurement</u>: population growth rate.<br><br>NOAEC: 1.0 mM (327 mg a.e./L). No impact on growth. (Table 2 of paper) | Michel et al. 2004 (Also cited in ECOTOX 2013) |
| **Fusilade Max** | | | |
| Common duckweed (*Lemna gibba*) | Fusilade Max (EC 125 g/L), 7 day static | EC50: >13.6 mg a.i./L (>≈11.6 mg a.e./L)<br><br>Based on yield and growth. | FAO/WHO 2000, p. 18 EFSA 2012, p. 66 |

251

One Application

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 1.35E-07 | 0 | 0 |
| | (0 - 0.00008) | (0 - 1.17E-06) | (0 - 0) |
| Dry and Temperate Location | 1.58E-06 | 0 | 0 |
| | (0 - 0.00129) | (0 - 1.54E-06) | (0 - 0) |
| Dry and Cold Location | 0.00071 | 0 | 0 |
| | (0 - 0.0063) | (0 - 0.000098) | (0 - 0) |
| Average Rainfall and Warm Location | 0.00062 | 1.99E-05 | 0 |
| | (0.000049 - 0.0161) | (6.50E-07 - 0.00156) | (0 - 6.10E-07) |
| Average Rainfall and Temperate Location | 0.0026 | 0.000112 | 0 |
| | (0.000143 - 0.0236) | (3.30E-06 - 0.00289) | (0 - 6.50E-07) |
| Average Rainfall and Cool Location | 0.00245 | 0.00009 | 0 |
| | (0.000089 - 0.0173) | (1.54E-06 - 0.00261) | (0 - 7.40E-08) |
| Wet and Warm Location | 0.0068 | 0.00063 | 2.51E-09 |
| | (0.0005 - 0.037) | (5.30E-06 - 0.0057) | (0 - 2.39E-06) |
| Wet and Temperate Location | 0.0039 | 0.000209 | 0 |
| | (0.000213 - 0.0241) | (2.56E-06 - 0.0035) | (0 - 1.11E-06) |
| Wet and Cool Location | 0.0057 | 0.00039 | 0 |
| | (0.00071 - 0.0304) | (5.20E-06 - 0.0046) | (0 - 1.34E-06) |
| | | Average of Central Values: | 0.000898 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 0.037 |
| | | Summary of Values: | 0.0009 (0 - 0.037) |

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.173 | 0.158 | 0.158 |
| | (0.172 - 0.174) | (0.157 - 0.159) | (0.157 - 0.159) |
| Dry and Temperate Location | 0.175 | 0.16 | 0.16 |
| | (0.174 - 0.178) | (0.159 - 0.162) | (0.159 - 0.162) |
| Dry and Cold Location | 0.245 | 0.223 | 0.221 |
| | (0.224 - 0.264) | (0.203 - 0.242) | (0.199 - 0.24) |
| Average Rainfall and Warm Location | 0.172 | 0.158 | 0.158 |
| | (0.171 - 0.173) | (0.156 - 0.158) | (0.156 - 0.158) |
| Average Rainfall and Temperate Location | 0.175 | 0.159 | 0.159 |
| | (0.174 - 0.176) | (0.158 - 0.16) | (0.158 - 0.16) |
| Average Rainfall and Cool Location | 0.176 | 0.16 | 0.16 |
| | (0.175 - 0.181) | (0.159 - 0.163) | (0.159 - 0.16) |
| Wet and Warm Location | 0.172 | 0.157 | 0.157 |
| | (0.167 - 0.174) | (0.154 - 0.159) | (0.146 - 0.159) |
| Wet and Temperate Location | 0.175 | 0.159 | 0.159 |
| | (0.173 - 0.175) | (0.158 - 0.16) | (0.152 - 0.16) |
| Wet and Cool Location | 0.175 | 0.16 | 0.16 |
| | (0.175 - 0.176) | (0.16 - 0.161) | (0.16 - 0.161) |
| | | Average of Central Values: | 0.1713 |
| | | 25th Percentile of Lower Bounds: | 0.1575 |
| | | Maximum Value: | 0.264 |
| | | Summary of Values: | 0.171 (0.1575 - 0.264) |

One Application
Table 3: Concentration in Top 36 Inches of Soil (ppm)

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.058 | 0.053 | 0.053 |
| | (0.057 - 0.058) | (0.052 - 0.053) | (0.052 - 0.053) |
| Dry and Temperate Location | 0.058 | 0.053 | 0.053 |
| | (0.058 - 0.059) | (0.053 - 0.054) | (0.053 - 0.054) |
| Dry and Cold Location | 0.082 | 0.075 | 0.074 |
| | (0.075 - 0.088) | (0.068 - 0.081) | (0.068 - 0.08) |
| Average Rainfall and Warm Location | 0.057 | 0.053 | 0.053 |
| | (0.057 - 0.058) | (0.052 - 0.053) | (0.052 - 0.053) |
| Average Rainfall and Temperate Location | 0.058 | 0.053 | 0.053 |
| | (0.058 - 0.059) | (0.053 - 0.054) | (0.053 - 0.054) |
| Average Rainfall and Cool Location | 0.06 | 0.055 | 0.054 |
| | (0.059 - 0.062) | (0.053 - 0.057) | (0.053 - 0.055) |
| Wet and Warm Location | 0.057 | 0.053 | 0.053 |
| | (0.056 - 0.058) | (0.052 - 0.053) | (0.052 - 0.053) |
| Wet and Temperate Location | 0.058 | 0.053 | 0.053 |
| | (0.058 - 0.06) | (0.053 - 0.054) | (0.053 - 0.053) |
| Wet and Cool Location | 0.06 | 0.054 | 0.053 |
| | (0.058 - 0.067) | (0.053 - 0.058) | (0.053 - 0.054) |
| | | Average of Central Values: | 0.0574 |
| | | 25th Percentile of Lower Bounds: | 0.053 |
| | | Maximum Value: | 0.088 |
| | | Summary of Values: | 0.057 (0.053 - 0.088) |

One Application

Table 4: Maximum Penetration into Soil Column (inches)

| Site | Clay | Loam | Sand |
|------|------|------|------|
| Dry and Warm Location | 12 | 12 | 12 |
| | (8 - 30) | (4 - 30) | (4 - 36) |
| Dry and Temperate Location | 24 | 18 | 30 |
| | (8 - 36) | (8 - 36) | (8 - 36) |
| Dry and Cold Location | 36 | 36 | 36 |
| | (24 - 36) | (24 - 36) | (30 - 36) |
| Average Rainfall and Warm Location | 36 | 36 | 36 |
| | (36 - 36) | (36 - 36) | (36 - 36) |
| Average Rainfall and Temperate Location | 36 | 36 | 36 |
| | (36 - 36) | (36 - 36) | (36 - 36) |
| Average Rainfall and Cool Location | 36 | 36 | 36 |
| | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Warm Location | 36 | 36 | 36 |
| | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Temperate Location | 36 | 36 | 36 |
| | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Cool Location | 36 | 36 | 36 |
| | (36 - 36) | (36 - 36) | (36 - 36) |
| | | Average of Central Values: | 32 |
| | | 25th Percentile of Lower Bounds: | 24 |
| | | Maximum Value: | 36 |
| | | Summary of Values: | 32 (24 - 36) |

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.0005 | 0 | 0 |
| | (0 - 0.3) | (0 - 0.005) | (0 - 0.04) |
| Dry and Temperate Location | 0.004 | 0 | 0 |
| | (0 - 5.1) | (0 - 0.016) | (0 - 0.4) |
| Dry and Cold Location | 2.34 | 0.0004 | 0.4 |
| | (0 - 18.7) | (0 - 0.7) | (0 - 13.2) |
| Average Rainfall and Warm Location | 1.54 | 0.3 | 4.8 |
| | (0.15 - 20.4) | (0.011 - 3.4) | (0.4 - 36) |
| Average Rainfall and Temperate Location | 4.4 | 1.49 | 13.9 |
| | (0.4 - 24.3) | (0.06 - 12.5) | (1.59 - 77) |
| Average Rainfall and Cool Location | 5.7 | 2.29 | 13.4 |
| | (0.9 - 26.6) | (0.17 - 10.8) | (2.22 - 69) |
| Wet and Warm Location | 10.8 | 6 | 38 |
| | (2.89 - 42) | (0.7 - 24.9) | (6.1 - 100) |
| Wet and Temperate Location | 8 | 4.6 | 30.6 |
| | (1.94 - 31) | (0.9 - 30) | (5.1 - 104) |
| Wet and Cool Location | 26.9 | 34 | 83 |
| | (15.9 - 43) | (19.7 - 63) | (54 - 135) |
| | | Average of Central Values: | 10.8 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 135 |
| | | Summary of Values: | 10.8 (0 - 135) |

**Appendix 8**: GLEAMS-Driver, Single Application (*continued*)

One Application

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 1.3E-06 | 0 | 0 |
| | (0 - 0.0009) | (0 - 0.000013) | (0 - 0.00018) |
| Dry and Temperate Location | 0.000021 | 0 | 0 |
| | (0 - 0.014) | (0 - 0.00005) | (0 - 0.002) |
| Dry and Cold Location | 0.007 | 1.6E-06 | 0.0024 |
| | (0 - 0.06) | (0 - 0.0025) | (0 - 0.12) |
| Average Rainfall and Warm Location | 0.012 | 0.006 | 0.1 |
| | (0.0011 - 0.08) | (0.0001 - 0.09) | (0.007 - 0.5) |
| Average Rainfall and Temperate Location | 0.05 | 0.03 | 0.3 |
| | (0.003 - 0.19) | (0.0007 - 0.4) | (0.03 - 1.72) |
| Average Rainfall and Cool Location | 0.08 | 0.09 | 0.6 |
| | (0.008 - 0.3) | (0.0024 - 0.5) | (0.12 - 1.84) |
| Wet and Warm Location | 0.22 | 0.31 | 1.5 |
| | (0.06 - 0.8) | (0.031 - 1.4) | (0.29 - 2.6) |
| Wet and Temperate Location | 0.3 | 0.4 | 1.24 |
| | (0.07 - 0.8) | (0.08 - 1.33) | (0.29 - 3) |
| Wet and Cool Location | 2.67 | 3 | 3.5 |
| | (1.31 - 3.5) | (2.07 - 3.9) | (2.78 - 4.9) |
| | | Average of Central Values: | 0.534 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 4.9 |
| | | Summary of Values: | 0.53 (0 - 4.9) |

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.00015 | 0 | 0 |
| | (0 - 0.09) | (0 - 0.0014) | (0 - 0.031) |
| Dry and Temperate Location | 0.0018 | 0 | 0 |
| | (0 - 1.44) | (0 - 0.01) | (0 - 0.4) |
| Dry and Cold Location | 0.8 | 0.00014 | 0.21 |
| | (0 - 6.6) | (0 - 0.31) | (0 - 10) |
| Average Rainfall and Warm Location | 1.28 | 0.7 | 11.3 |
| | (0.12 - 17.2) | (0.013 - 9.3) | (0.7 - 68) |
| Average Rainfall and Temperate Location | 4.2 | 2.37 | 30.6 |
| | (0.5 - 23.7) | (0.11 - 34) | (3.3 - 183) |
| Average Rainfall and Cool Location | 7 | 6.6 | 39 |
| | (0.9 - 22.3) | (0.19 - 39) | (7.5 - 155) |
| Wet and Warm Location | 12.4 | 18.3 | 97 |
| | (2.85 - 43) | (1.94 - 82) | (18.3 - 203) |
| Wet and Temperate Location | 9.2 | 9.2 | 64 |
| | (2.29 - 25.7) | (2.01 - 61) | (8.4 - 231) |
| Wet and Cool Location | 52 | 61 | 102 |
| | (27.8 - 77) | (39 - 89) | (67 - 184) |
| | | Average of Central Values: | 19.6 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 231 |
| | | Summary of Values: | 19.6 (0 - 231) |

One Application

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.000026 | 0 | 0 |
| | (0 - 0.029) | (0 - 0.0004) | (0 - 0.009) |
| Dry and Temperate Location | 0.0005 | 0 | 0 |
| | (0 - 0.4) | (0 - 0.0029) | (0 - 0.13) |
| Dry and Cold Location | 0.23 | 0.00004 | 0.06 |
| | (0 - 1.92) | (0 - 0.09) | (0 - 2.89) |
| Average Rainfall and Warm Location | 0.5 | 0.28 | 4.5 |
| | (0.05 - 6) | (0.006 - 4.7) | (0.3 - 29.6) |
| Average Rainfall and Temperate Location | 1.95 | 1.42 | 14.7 |
| | (0.17 - 9.1) | (0.04 - 18.9) | (1.78 - 83) |
| Average Rainfall and Cool Location | 3.2 | 3.12 | 19.2 |
| | (0.4 - 10.4) | (0.1 - 18.7) | (4.4 - 63) |
| Wet and Warm Location | 4.6 | 6.4 | 33 |
| | (1.28 - 13.2) | (0.9 - 25.8) | (6.1 - 66) |
| Wet and Temperate Location | 4.3 | 4.5 | 22.7 |
| | (1.05 - 9.4) | (0.9 - 23) | (2.8 - 77) |
| Wet and Cool Location | 27.4 | 30.2 | 19.7 |
| | (15.4 - 45) | (13.6 - 44) | (10 - 41) |
| | | Average of Central Values: | 7.48 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 83 |
| | | Summary of Values: | 7.48 (0 - 83) |

259

Two Applications

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 3.20E-07 | 0 | 0 |
| | (0 - 0.000183) | (0 - 2.89E-06) | (0 - 0) |
| Dry and Temperate Location | 3.80E-06 | 0 | 0 |
| | (0 - 0.00267) | (0 - 3.90E-06) | (0 - 0) |
| Dry and Cold Location | 0.00143 | 0 | 0 |
| | (0 - 0.0128) | (0 - 0.000198) | (0 - 0) |
| Average Rainfall and Warm Location | 0.00137 | 0.000056 | 8.00E-10 |
| | (0.000124 - 0.0215) | (1.57E-06 - 0.00258) | (0 - 7.00E-07) |
| Average Rainfall and Temperate Location | 0.0048 | 0.000277 | 0 |
| | (0.00048 - 0.0261) | (7.40E-06 - 0.005) | (0 - 6.50E-07) |
| Average Rainfall and Cool Location | 0.0042 | 0.000183 | 0 |
| | (0.00035 - 0.033) | (3.40E-06 - 0.0054) | (0 - 4.00E-07) |
| Wet and Warm Location | 0.0111 | 0.00079 | 6.70E-09 |
| | (0.00103 - 0.059) | (0.000022 - 0.0088) | (0 - 2.54E-06) |
| Wet and Temperate Location | 0.0084 | 0.00055 | 0 |
| | (0.00082 - 0.033) | (7.20E-06 - 0.0041) | (0 - 1.11E-06) |
| Wet and Cool Location | 0.0149 | 0.00121 | 0 |
| | (0.0031 - 0.058) | (2.48E-05 - 0.0097) | (0 - 2.74E-06) |
| | | Average of Central Values: | 0.001825 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 0.059 |
| | | Summary of Values: | 0.00182 (0 - 0.059) |

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.304 | 0.278 | 0.278 |
| | (0.289 - 0.315) | (0.264 - 0.288) | (0.263 - 0.288) |
| Dry and Temperate | 0.33 | 0.299 | 0.299 |
| Location | (0.32 - 0.37) | (0.291 - 0.34) | (0.29 - 0.34) |
| Dry and Cold Location | 0.49 | 0.44 | 0.44 |
| | (0.44 - 0.53) | (0.4 - 0.48) | (0.4 - 0.48) |
| Average Rainfall and | 0.289 | 0.264 | 0.263 |
| Warm Location | (0.265 - 0.34) | (0.243 - 0.313) | (0.236 - 0.311) |
| Average Rainfall and | 0.32 | 0.292 | 0.291 |
| Temperate Location | (0.311 - 0.33) | (0.281 - 0.302) | (0.26 - 0.301) |
| Average Rainfall and Cool | 0.34 | 0.308 | 0.305 |
| Location | (0.33 - 0.35) | (0.298 - 0.32) | (0.276 - 0.312) |
| Wet and Warm Location | 0.281 | 0.252 | 0.233 |
| | (0.259 - 0.295) | (0.216 - 0.268) | (0.174 - 0.264) |
| Wet and Temperate | 0.32 | 0.294 | 0.283 |
| Location | (0.308 - 0.33) | (0.264 - 0.304) | (0.22 - 0.303) |
| Wet and Cool Location | 0.35 | 0.315 | 0.315 |
| | (0.34 - 0.39) | (0.311 - 0.36) | (0.306 - 0.36) |
| | | Average of Central Values: | 0.3138 |
| | | 25th Percentile of Lower Bounds: | 0.2615 |
| | | Maximum Value: | 0.53 |
| | | Summary of Values: | 0.314 (0.2615 - 0.53) |

Two Applications
Table 3: Concentration in Top 36 Inches of Soil (ppm)

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.101 | 0.093 | 0.093 |
| | (0.096 - 0.105) | (0.088 - 0.096) | (0.088 - 0.096) |
| Dry and Temperate Location | 0.109 | 0.1 | 0.1 |
| | (0.106 - 0.124) | (0.097 - 0.115) | (0.097 - 0.115) |
| Dry and Cold Location | 0.163 | 0.148 | 0.148 |
| | (0.147 - 0.175) | (0.134 - 0.161) | (0.134 - 0.159) |
| Average Rainfall and Warm Location | 0.096 | 0.088 | 0.088 |
| | (0.089 - 0.113) | (0.082 - 0.104) | (0.082 - 0.104) |
| Average Rainfall and Temperate Location | 0.108 | 0.099 | 0.098 |
| | (0.104 - 0.112) | (0.095 - 0.102) | (0.095 - 0.101) |
| Average Rainfall and Cool Location | 0.115 | 0.105 | 0.103 |
| | (0.11 - 0.122) | (0.101 - 0.111) | (0.101 - 0.107) |
| Wet and Warm Location | 0.097 | 0.089 | 0.088 |
| | (0.09 - 0.102) | (0.083 - 0.093) | (0.08 - 0.093) |
| Wet and Temperate Location | 0.109 | 0.1 | 0.099 |
| | (0.107 - 0.113) | (0.097 - 0.102) | (0.097 - 0.102) |
| Wet and Cool Location | 0.118 | 0.106 | 0.105 |
| | (0.114 - 0.132) | (0.104 - 0.119) | (0.104 - 0.119) |
| | | Average of Central Values: | 0.1061 |
| | | 25th Percentile of Lower Bounds: | 0.0895 |
| | | Maximum Value: | 0.175 |
| | | Summary of Values: | 0.106 (0.0895 - 0.175) |

Two Applications
  Table 4: Maximum Penetration into Soil Column (inches)

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 18 | 12 | 18 |
|  | (8 - 36) | (8 - 36) | (8 - 36) |
| Dry and Temperate Location | 24 | 18 | 30 |
|  | (8 - 36) | (8 - 36) | (8 - 36) |
| Dry and Cold Location | 36 | 36 | 36 |
|  | (24 - 36) | (24 - 36) | (30 - 36) |
| Average Rainfall and Warm Location | 36 | 36 | 36 |
|  | (36 - 36) | (36 - 36) | (36 - 36) |
| Average Rainfall and Temperate Location | 36 | 36 | 36 |
|  | (36 - 36) | (36 - 36) | (36 - 36) |
| Average Rainfall and Cool Location | 36 | 36 | 36 |
|  | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Warm Location | 36 | 36 | 36 |
|  | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Temperate Location | 36 | 36 | 36 |
|  | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Cool Location | 36 | 36 | 36 |
|  | (36 - 36) | (36 - 36) | (36 - 36) |
|  |  | Average of Central Values: | 32.4 |
|  |  | 25th Percentile of Lower Bounds: | 24 |
|  |  | Maximum Value: | 36 |
|  |  | Summary of Values: | 32.4 (24 - 36) |

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.0013 | 0 | 0 |
| | (0 - 0.7) | (0 - 0.011) | (0 - 0.09) |
| Dry and Temperate Location | 0.01 | 0 | 0 |
| | (0 - 8.7) | (0 - 0.04) | (0 - 1.18) |
| Dry and Cold Location | 4.7 | 0.0008 | 0.8 |
| | (0 - 38) | (0 - 1.4) | (0 - 26.6) |
| Average Rainfall and Warm Location | 4.3 | 1 | 11.6 |
| | (0.4 - 25.3) | (0.05 - 6.7) | (1 - 69) |
| Average Rainfall and Temperate Location | 8.9 | 2.61 | 25 |
| | (1.09 - 36) | (0.27 - 21.2) | (2.58 - 115) |
| Average Rainfall and Cool Location | 9.1 | 4.5 | 23.9 |
| | (2.03 - 37) | (0.4 - 19.6) | (4.7 - 121) |
| Wet and Warm Location | 15.6 | 7.5 | 51 |
| | (5.1 - 42) | (1.25 - 38) | (11.4 - 152) |
| Wet and Temperate Location | 13.2 | 8.1 | 46 |
| | (4.7 - 33) | (2.69 - 42) | (8.9 - 176) |
| Wet and Cool Location | 54 | 70 | 170 |
| | (33 - 85) | (40 - 129) | (111 - 270) |
| | | Average of Central Values: | 19.7 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 270 |
| | | Summary of Values: | 19.7 (0 - 270) |

Appendix 9: GLEAMS-Driver, Two Applications (*continued*)

Two Applications

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

| Site | Clay | Loam | Sand |
|------|------|------|------|
| Dry and Warm Location | 0.000004 | 0 | 0 |
| | (0 - 0.0021) | (0 - 0.00003) | (0 - 0.0004) |
| Dry and Temperate Location | 0.00005 | 0 | 0 |
| | (0 - 0.03) | (0 - 0.00011) | (0 - 0.006) |
| Dry and Cold Location | 0.014 | 3.1E-06 | 0.005 |
| | (0 - 0.12) | (0 - 0.005) | (0 - 0.24) |
| Average Rainfall and Warm Location | 0.04 | 0.018 | 0.25 |
| | (0.003 - 0.11) | (0.0004 - 0.23) | (0.02 - 1.17) |
| Average Rainfall and Temperate Location | 0.08 | 0.07 | 0.7 |
| | (0.012 - 0.4) | (0.0024 - 0.8) | (0.07 - 2.97) |
| Average Rainfall and Cool Location | 0.14 | 0.17 | 1.09 |
| | (0.021 - 0.6) | (0.012 - 0.9) | (0.24 - 3.6) |
| Wet and Warm Location | 0.4 | 0.5 | 2.39 |
| | (0.09 - 1.28) | (0.06 - 2.22) | (0.5 - 4.5) |
| Wet and Temperate Location | 0.7 | 0.8 | 2.21 |
| | (0.17 - 1.41) | (0.18 - 2.12) | (0.5 - 5.3) |
| Wet and Cool Location | 5.5 | 6.2 | 7.2 |
| | (2.82 - 7.1) | (4.4 - 7.9) | (5.7 - 9.9) |
| | | Average of Central Values: | 1.05 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 9.9 |
| | | Summary of Values: | 1.05 (0 - 9.9) |

Appendix 9: GLEAMS-Driver, Two Applications (*continued*)

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.0004 | 0 | 0 |
| | (0 - 0.21) | (0 - 0.005) | (0 - 0.08) |
| Dry and Temperate Location | 0.004 | 0 | 0 |
| | (0 - 2.99) | (0 - 0.021) | (0 - 1) |
| Dry and Cold Location | 1.52 | 0.00028 | 0.4 |
| | (0 - 13.4) | (0 - 0.6) | (0 - 20.1) |
| Average Rainfall and Warm Location | 3.5 | 1.86 | 26.6 |
| | (0.4 - 28.2) | (0.07 - 22) | (2.36 - 152) |
| Average Rainfall and Temperate Location | 8.1 | 4.8 | 55 |
| | (1.42 - 34) | (0.3 - 63) | (6.1 - 340) |
| Average Rainfall and Cool Location | 12.5 | 12.1 | 72 |
| | (2.29 - 45) | (0.9 - 76) | (15.2 - 288) |
| Wet and Warm Location | 18.4 | 23.3 | 156 |
| | (5.7 - 72) | (2.2 - 139) | (40 - 301) |
| Wet and Temperate Location | 17 | 16.4 | 106 |
| | (6.2 - 38) | (4 - 97) | (14.3 - 410) |
| Wet and Cool Location | 107 | 125 | 211 |
| | (58 - 158) | (79 - 201) | (138 - 370) |
| | | Average of Central Values: | 36.2 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 410 |
| | | Summary of Values: | 36.2 (0 - 410) |

Two Applications

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.00008 | 0 | 0 |
| | (0 - 0.07) | (0 - 0.0012) | (0 - 0.024) |
| Dry and Temperate Location | 0.0011 | 0 | 0 |
| | (0 - 0.9) | (0 - 0.007) | (0 - 0.3) |
| Dry and Cold Location | 0.5 | 0.00008 | 0.13 |
| | (0 - 3.9) | (0 - 0.18) | (0 - 5.8) |
| Average Rainfall and Warm Location | 1.45 | 0.8 | 11.2 |
| | (0.16 - 9.5) | (0.023 - 11.6) | (1.06 - 68) |
| Average Rainfall and Temperate Location | 4 | 2.75 | 30.3 |
| | (0.7 - 15.5) | (0.12 - 34) | (3.6 - 160) |
| Average Rainfall and Cool Location | 5 | 6.1 | 35 |
| | (0.9 - 19.1) | (0.4 - 34) | (8.6 - 122) |
| Wet and Warm Location | 7.1 | 9.5 | 55 |
| | (2.44 - 22.5) | (1.09 - 44) | (13.5 - 101) |
| Wet and Temperate Location | 7.7 | 7.4 | 37 |
| | (2.99 - 15.6) | (1.88 - 36) | (4.6 - 125) |
| Wet and Cool Location | 56 | 62 | 40 |
| | (31.2 - 92) | (27.9 - 95) | (20.2 - 84) |
| | | Average of Central Values: | 14 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 160 |
| | | Summary of Values: | 14 (0 - 160) |

Three Applications

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 6.20E-07 | 0 | 0 |
| | (0 - 0.000307) | (0 - 5.80E-06) | (0 - 0) |
| Dry and Temperate Location | 6.20E-06 | 0 | 0 |
| | (0 - 0.00267) | (0 - 0.000006) | (0 - 0) |
| Dry and Cold Location | 0.00217 | 0 | 0 |
| | (0 - 0.0195) | (0 - 0.00036) | (0 - 0) |
| Average Rainfall and Warm Location | 0.00273 | 0.000153 | 8.40E-10 |
| | (0.000256 - 0.0262) | (5.20E-06 - 0.0032) | (0 - 1.34E-06) |
| Average Rainfall and Temperate Location | 0.0063 | 0.0004 | 7.80E-10 |
| | (0.00087 - 0.0309) | (1.07E-05 - 0.005) | (0 - 6.50E-07) |
| Average Rainfall and Cool Location | 0.0051 | 0.00033 | 0 |
| | (0.00058 - 0.039) | (5.70E-06 - 0.0057) | (0 - 5.80E-07) |
| Wet and Warm Location | 0.0123 | 0.00098 | 1.84E-08 |
| | (0.00114 - 0.059) | (3.13E-05 - 0.0088) | (0 - 0.000004) |
| Wet and Temperate Location | 0.0094 | 0.00065 | 0 |
| | (0.00171 - 0.05) | (1.09E-05 - 0.0048) | (0 - 1.11E-06) |
| Wet and Cool Location | 0.0248 | 0.00219 | 8.80E-10 |
| | (0.0044 - 0.073) | (0.000056 - 0.0116) | (0 - 3.50E-06) |
| | | Average of Central Values: | 0.0025 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 0.073 |
| | | Summary of Values: | 0.0025 (0 - 0.073) |

Three Applications

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.39 | 0.35 | 0.35 |
| | (0.35 - 0.43) | (0.32 - 0.4) | (0.32 - 0.4) |
| Dry and Temperate Location | 0.45 | 0.41 | 0.41 |
| | (0.42 - 0.5) | (0.39 - 0.46) | (0.38 - 0.46) |
| Dry and Cold Location | 0.72 | 0.65 | 0.64 |
| | (0.65 - 0.77) | (0.59 - 0.71) | (0.58 - 0.7) |
| Average Rainfall and Warm Location | 0.35 | 0.32 | 0.314 |
| | (0.316 - 0.41) | (0.285 - 0.37) | (0.272 - 0.37) |
| Average Rainfall and Temperate Location | 0.43 | 0.38 | 0.37 |
| | (0.39 - 0.45) | (0.34 - 0.41) | (0.316 - 0.4) |
| Average Rainfall and Cool Location | 0.47 | 0.43 | 0.42 |
| | (0.45 - 0.5) | (0.4 - 0.45) | (0.36 - 0.44) |
| Wet and Warm Location | 0.35 | 0.311 | 0.28 |
| | (0.302 - 0.39) | (0.256 - 0.35) | (0.216 - 0.33) |
| Wet and Temperate Location | 0.45 | 0.4 | 0.38 |
| | (0.42 - 0.48) | (0.35 - 0.44) | (0.283 - 0.43) |
| Wet and Cool Location | 0.46 | 0.4 | 0.315 |
| | (0.36 - 0.5) | (0.313 - 0.45) | (0.309 - 0.41) |
| | | Average of Central Values: | 0.415 |
| | | 25th Percentile of Lower Bounds: | 0.311 |
| | | Maximum Value: | 0.77 |
| | | Summary of Values: | 0.41 (0.311 - 0.77) |

Three Applications
Table 3: Concentration in Top 36 Inches of Soil (ppm)

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.129 | 0.118 | 0.118 |
| | (0.116 - 0.144) | (0.106 - 0.133) | (0.106 - 0.132) |
| Dry and Temperate Location | 0.149 | 0.136 | 0.136 |
| | (0.141 - 0.167) | (0.129 - 0.154) | (0.128 - 0.153) |
| Dry and Cold Location | 0.239 | 0.218 | 0.217 |
| | (0.216 - 0.258) | (0.196 - 0.236) | (0.196 - 0.234) |
| Average Rainfall and Warm Location | 0.118 | 0.107 | 0.106 |
| | (0.105 - 0.136) | (0.095 - 0.124) | (0.096 - 0.124) |
| Average Rainfall and Temperate Location | 0.143 | 0.13 | 0.13 |
| | (0.132 - 0.152) | (0.121 - 0.14) | (0.121 - 0.139) |
| Average Rainfall and Cool Location | 0.16 | 0.145 | 0.143 |
| | (0.152 - 0.173) | (0.137 - 0.157) | (0.137 - 0.153) |
| Wet and Warm Location | 0.124 | 0.114 | 0.111 |
| | (0.109 - 0.136) | (0.1 - 0.125) | (0.095 - 0.121) |
| Wet and Temperate Location | 0.152 | 0.139 | 0.137 |
| | (0.144 - 0.161) | (0.132 - 0.147) | (0.131 - 0.145) |
| Wet and Cool Location | 0.169 | 0.153 | 0.148 |
| | (0.165 - 0.188) | (0.148 - 0.165) | (0.114 - 0.162) |
| | | Average of Central Values: | 0.144 |
| | | 25th Percentile of Lower Bounds: | 0.1075 |
| | | Maximum Value: | 0.258 |
| | | Summary of Values: | 0.144 (0.1075 - 0.258) |

Three Applications
  Table 4: Maximum Penetration into Soil Column (inches)

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 18 | 12 | 18 |
| | (8 - 36) | (8 - 36) | (8 - 36) |
| Dry and Temperate | 24 | 18 | 30 |
| Location | (8 - 36) | (8 - 36) | (8 - 36) |
| Dry and Cold Location | 36 | 36 | 36 |
| | (24 - 36) | (24 - 36) | (30 - 36) |
| Average Rainfall and | 36 | 36 | 36 |
| Warm Location | (36 - 36) | (36 - 36) | (36 - 36) |
| Average Rainfall and | 36 | 36 | 36 |
| Temperate Location | (36 - 36) | (36 - 36) | (36 - 36) |
| Average Rainfall and Cool | 36 | 36 | 36 |
| Location | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Warm Location | 36 | 36 | 36 |
| | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Temperate | 36 | 36 | 36 |
| Location | (36 - 36) | (36 - 36) | (36 - 36) |
| Wet and Cool Location | 36 | 36 | 36 |
| | (36 - 36) | (36 - 36) | (36 - 36) |
| | | Average of Central Values: | 32.4 |
| | | 25th Percentile of Lower Bounds: | 24 |
| | | Maximum Value: | 36 |
| | | Summary of Values: | 32.4 (24 - 36) |

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.0023 | 0 | 0 |
| | (0 - 1.23) | (0 - 0.023) | (0 - 0.2) |
| Dry and Temperate Location | 0.018 | 0 | 0 |
| | (0 - 8.7) | (0 - 0.05) | (0 - 2.05) |
| Dry and Cold Location | 7.1 | 0.0013 | 1.2 |
| | (0 - 57) | (0 - 2.15) | (0 - 40) |
| Average Rainfall and Warm Location | 5.7 | 1.66 | 19 |
| | (0.7 - 28.4) | (0.12 - 10.3) | (1.9 - 99) |
| Average Rainfall and Temperate Location | 10.2 | 3.12 | 32 |
| | (2.38 - 40) | (0.5 - 27.9) | (3.6 - 163) |
| Average Rainfall and Cool Location | 11 | 6.6 | 34 |
| | (2.98 - 43) | (1.06 - 27.7) | (6.9 - 133) |
| Wet and Warm Location | 17.7 | 9.3 | 67 |
| | (6.5 - 48) | (1.43 - 56) | (18.6 - 176) |
| Wet and Temperate Location | 17 | 12.2 | 57 |
| | (6.8 - 38) | (3.7 - 48) | (12.3 - 236) |
| Wet and Cool Location | 73 | 102 | 231 |
| | (46 - 118) | (61 - 185) | (157 - 360) |
| | | Average of Central Values: | 26.6 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 360 |
| | | Summary of Values: | 26.6 (0 - 360) |

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.000007 | 0 | 0 |
| | (0 - 0.004) | (0 - 0.00007) | (0 - 0.0013) |
| Dry and Temperate Location | 0.00008 | 0 | 0 |
| | (0 - 0.03) | (0 - 0.00018) | (0 - 0.011) |
| Dry and Cold Location | 0.021 | 0.000005 | 0.008 |
| | (0 - 0.18) | (0 - 0.008) | (0 - 0.4) |
| Average Rainfall and Warm Location | 0.06 | 0.032 | 0.4 |
| | (0.009 - 0.18) | (0.0009 - 0.4) | (0.04 - 1.83) |
| Average Rainfall and Temperate Location | 0.12 | 0.1 | 0.9 |
| | (0.03 - 0.5) | (0.005 - 1.1) | (0.12 - 3.5) |
| Average Rainfall and Cool Location | 0.2 | 0.25 | 1.63 |
| | (0.04 - 0.9) | (0.019 - 1.35) | (0.4 - 4.6) |
| Wet and Warm Location | 0.5 | 0.7 | 3.13 |
| | (0.16 - 1.9) | (0.08 - 3.3) | (1 - 6.8) |
| Wet and Temperate Location | 1 | 1.14 | 3.05 |
| | (0.3 - 1.99) | (0.29 - 2.96) | (0.9 - 7.3) |
| Wet and Cool Location | 8.2 | 9.4 | 10.6 |
| | (4.1 - 10.9) | (6.5 - 11.4) | (8.5 - 13.5) |
| | | Average of Central Values: | 1.53 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 13.5 |
| | | Summary of Values: | 1.53 (0 - 13.5) |

Appendix 10: GLEAMS-Driver, Three Applications (*continued*)

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.0007 | 0 | 0 |
|  | (0 - 0.4) | (0 - 0.009) | (0 - 0.23) |
| Dry and Temperate Location | 0.008 | 0 | 0 |
|  | (0 - 2.99) | (0 - 0.04) | (0 - 1.71) |
| Dry and Cold Location | 2.23 | 0.0005 | 0.7 |
|  | (0 - 20.4) | (0 - 1) | (0 - 30.4) |
| Average Rainfall and Warm Location | 6.6 | 3.4 | 45 |
|  | (1.22 - 29.5) | (0.15 - 39) | (3 - 288) |
| Average Rainfall and Temperate Location | 12 | 6.4 | 76 |
|  | (3.7 - 41) | (0.9 - 103) | (9.3 - 420) |
| Average Rainfall and Cool Location | 16.1 | 18.3 | 105 |
|  | (4.1 - 56) | (1.3 - 110) | (23.4 - 350) |
| Wet and Warm Location | 23.7 | 33 | 206 |
|  | (9.4 - 103) | (3.8 - 202) | (56 - 470) |
| Wet and Temperate Location | 22.8 | 22.2 | 130 |
|  | (10.8 - 55) | (6.2 - 109) | (18.5 - 450) |
| Wet and Cool Location | 161 | 190 | 284 |
|  | (88 - 249) | (118 - 273) | (199 - 440) |
|  |  | Average of Central Values: | 50.5 |
|  |  | 25th Percentile of Lower Bounds: | 0 |
|  |  | Maximum Value: | 470 |
|  |  | Summary of Values: | 50.5 (0 - 470) |

274

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

| Site | Clay | Loam | Sand |
|---|---|---|---|
| Dry and Warm Location | 0.00016 | 0 | 0 |
| | (0 - 0.09) | (0 - 0.0022) | (0 - 0.08) |
| Dry and Temperate Location | 0.0019 | 0 | 0 |
| | (0 - 0.9) | (0 - 0.013) | (0 - 0.6) |
| Dry and Cold Location | 0.7 | 0.00012 | 0.2 |
| | (0 - 5.9) | (0 - 0.28) | (0 - 8.8) |
| Average Rainfall and Warm Location | 2.59 | 1.35 | 19.2 |
| | (0.4 - 10.1) | (0.05 - 20.1) | (1.63 - 118) |
| Average Rainfall and Temperate Location | 5.6 | 3.7 | 40 |
| | (1.59 - 19.8) | (0.29 - 50) | (5.5 - 195) |
| Average Rainfall and Cool Location | 8.2 | 8.7 | 54 |
| | (1.68 - 28) | (0.6 - 52) | (12.9 - 171) |
| Wet and Warm Location | 9.9 | 11.9 | 73 |
| | (4.3 - 33) | (1.53 - 66) | (22.2 - 142) |
| Wet and Temperate Location | 10.8 | 10.3 | 48 |
| | (5 - 21.5) | (2.83 - 39) | (6.9 - 147) |
| Wet and Cool Location | 87 | 97 | 64 |
| | (47 - 143) | (45 - 146) | (30 - 141) |
| | | Average of Central Values: | 20.6 |
| | | 25th Percentile of Lower Bounds: | 0 |
| | | Maximum Value: | 195 |
| | | Summary of Values: | 20.6 (0 - 195) |