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.

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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℃+32
centimeters	inches	0.3937
cubic meters (m^3)	liters (L)	1,000
Fahrenheit	centigrade	0.556℉-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 ($\mu g/cm^2$)	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

Fluazifop-P-butyl is a post-emergent 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 to support an assessment of the environmental consequences of using 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.

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, 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.

All indications from the Forest Service are that the most common method of application for fluazifop-P-butyl, which has not been used before in Forest Service programs, will involve either directed foliar (e.g., spot treatment) 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 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.

Human Health

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 greater than 1 is defined as the level of concern—i.e., the exposure exceeds the level of concern. For the human health risk assessment, 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 ground broadcast 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 expressed in U.S. EPA/OPP/HED (2011a). The central estimate of the HQ for backpack workers (HQ=2), however, modestly exceeds the level of concern. U.S. EPA/OPP/HED (2011a) does 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 treated vegetation following forestry applications of fluazifop-P-butyl. 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.

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

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

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 terrestrial arthropods.

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 the toxicity of fluazifop-P-butyl to reptiles and 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 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

fluazifop and *fluazifop-butyl* are also used when a statement is made that applies equally to the enantiomers.

Also following the convention used in U.S. EPA/OPP/HED (2004a) as well as the great preponderance of the literature on fluazifop and fluazifop-butyl, *fluazifop-P* is used rather than the equivalent term *[R] fluazifop* for both the acid and the ester. The origin of and rationale for the *-P* notation as a convention to designate the [R] stereoisomer is not clear; however, this convention is used almost universally in the literature for fluazifop-P as well as similar herbicides such as quizalofop-P (e.g., Mallory-Smith and Retzinger 2003).

1.1.2. Available Reviews

As noted above, the current document is a scoping/screening level risk assessment and relies heavily on existing reviews, which is not the case in a full Forest Service risk assessment. Table 2 summarizes the reviews identified to date on the toxicity and environmental fate of fluazifop-P-butyl and related compounds. In an attempt to ensure that the most recent U.S. EPA/OPP reviews were identified, Freedom of Information Act (FOIA) requests were submitted to the U.S. EPA (EPA-HQ-2013-009201, EPA-HQ-2013-010361). In response, U.S. EPA provided the most recent human health risk assessment (U.S. EPA/OPP/HED 2011a) and most recent ecological risk assessments (U.S. EPA/OPP/EFED 2008, 2010a).

In terms of the human health risk assessment, the available reviews on fluazifop-P-butyl clearly support the development of a screening level risk assessment. The U.S. EPA's Office of Pesticide Programs has prepared several human health risk assessments on fluazifop-P-butyl that are extremely detailed (e.g., U.S. EPA/OPP/HED 2004a; 2005a; 2011a). In addition, these EPA risk assessments are supported by several additional documents that address special topics relating to both potential health effects (U.S. EPA/OPP/HED 2004b,c) as well as exposure (U.S. EPA/OPP/HED 2010c,e). These EPA documents are the basis for the information used in the human health risk assessment presented in Section 3. Information from these EPA documents is supplemented by several recent reviews from Europe (EFSA 2012; European Commission 2011a), a summary of registrant studies by the California EPA (CalEPA 2002) and a published review by one of the developers of fluazifop-P-butyl (Ishihara Sangyo Kaisha 1990). All of these reviews focus on registrant-submitted studies, which are classified as Confidential Business Information (CBI) and are not publically available. Accordingly, the full studies were not available for the conduct of the current risk assessment. Nonetheless, the EPA risk assessments and related documents, supplemented by the other reviews noted above, provide a robust and credible summary of the registrant studies relating to human health effects.

The available reviews on the ecological effects of fluazifop-P-butyl also support the development of a screening level risk assessment. As noted above, the U.S. EPA provided two recent ecological risk assessments on fluazifop-P-butyl (U.S. EPA/OPP/EFED 2008, 2010a). The most recent document, however, provides only a brief and cursory summary of the registrant-submitted studies and would not, in itself, be sufficient in support of a screening level assessment. The 2008 document, however, is a standard and complete U.S. EPA/OPP/EFED ecological risk assessment and is sufficient to support a screening level ecological risk assessment. A limitation in U.S. EPA/OPP/EFED (2008) risk assessment, however, is that the summaries of acute toxicity studies for several groups of organisms (e.g., fish and aquatic

invertebrates) report LC_{50} values but not NOAECs. As discussed further in Section 4, the Forest Service prefers to use NOAECs rather than LC_{50} values for risk characterizations.

The limitation in the data summaries provided in U.S. EPA/OPP/EFED (2008) is addressed, at least partially, using ECOTOX, an ECOTOXicology Database available at http://cfpub.epa.gov/ecotox/. This database contains reasonably detailed albeit tabular summaries of several registrant-submitted studies on the toxicity of fluazifop-P-butyl and related compounds to several groups of organisms—e.g., fish, aquatic invertebrates, aquatic plants, birds, and nontarget plants. Information from ECOTOX is supplemented by information from Pesticide Ecological Effects Database (U.S. EPA/OPP 2005b) which provides additional details on studies summarized in ECOTOX. The information from the ECOTOX databases is considered reliable and is used directly in the current Forest Service risk assessment.

ECOTOX (2013) also contains summaries of open literature publications. As discussed below, the open literature studies were obtained for the current risk assessment. While ECOTOX summaries of open literature studies are not used directly, they provide a measure of quality assurance for the discussion of the open literature studies.

A recent review by the European Food Safety Commission (EFSA 2012) contains information on the ecological effects of fluazifop-P-butyl. Some of the study summaries from this review are detailed and are used in the current risk assessment to supplement the data from ECOTOX (2013). Other reviews (European Commission 2011b; Tomlin 2004) are less detailed and are used only to ensure that all relevant information has been identified.

The publication by Nishiuchi and Asano (1979) is a compendium of toxicity values on several pesticides including fluazifop-P-butyl. This article is written in Japanese but is summarized in ECOTOX. As noted in Table 2, data from Nishiuchi and Asano (1979) has been rejected by the U.S. EPA/OPP in several risk assessments on the California Red-legged Frog (e.g., U.S. EPA/OPP 2009b) because control groups were not used in the study. Data from the compendia by Nishiuchi and Asano (1979) are discussed in Section 4.1 as appropriate but are not used quantitatively in this risk assessment.

In the U.S. EPA registration review program, pesticide registrations are reviewed on a 15-year cycle. According to U.S. EPA/OPP (2013a), the EPA will not be opening a docket on the registration review of fluazifop-P-butyl until 2015. Thus, the EPA's registration review documents are not available for the current risk assessment.

A scoping/screening level risk assessment on clethodim was recently prepared for the Forest Service (SERA 2013a). While fluazifop-P-butyl is an aryloxyphenoxy propionate herbicide and clethodim is a cyclohexanedione herbicide, both classes of herbicides share a similar mechanism of action—i.e., the inhibition of acetyl coenzyme-A carboxylase (ACCase) activity. Consequently, and in the interest of economy, some of the discussions of mechanism of action and related literature in SERA (2013a) are incorporated into the current document on fluazifop-P-butyl.

1.1.3. Scoping of Open Literature

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

1.1.3.1. Human Health Effects

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

1.1.3.2. Terrestrial Plants

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

1.1.3.3. Other Terrestrial Species

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

applications of fluazifop-P-butyl. The worksheets in these workbooks provide the detail for the exposure estimates and hazard quotients cited in the body of the document. Documentation for the use of these workbooks is presented in SERA (2011b).

The EXCEL workbooks are an integral part of the risk assessment. The worksheets contained in these workbooks are designed to isolate the numerous calculations from the risk assessment narrative. In general, all calculations of exposure scenarios and quantitative risk characterizations are derived and contained in the worksheets. In these worksheets as well as in the text of this risk assessment, the hazard quotient is calculated as the ratio of the estimated exposure to a toxicity value, typically a no adverse effect level or concentration (i.e., NOAEL or NOAEC). Both the rationale for the calculations and the interpretation of the hazard quotients are contained in this risk assessment document.

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).

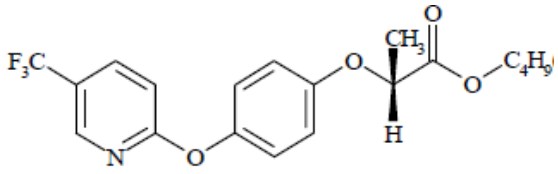
Because fluazifop-P-butyl has not been used previously in Forest Service programs, the impact of its use by the Forest Service relative to agricultural use cannot be assessed directly. Based on use statistics from California, however, it appears that agricultural uses of fluazifop-P-butyl are much greater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

2.2. Chemical Description and Commercial Formulations

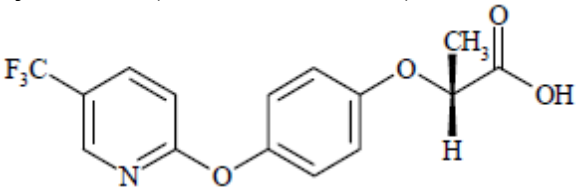
2.2.1. Chemical Structures and Stereochemistry

Most Forest Service risk assessments do not require an elaborate discussion of chemical structure; however, fluazifop-P-butyl is atypical because of issues associated with stereochemistry and metabolites. Table 1 provides an overview of the major chemical structures discussed in this section, and the relevance of these structures to the risk assessment is discussed below.

Fluazifop-P-butyl is the common name for butyl (R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy] propanoate:

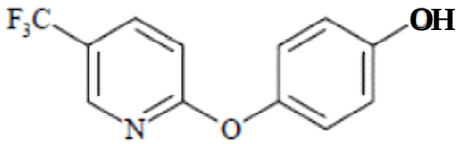


Fluazifop-P-butyl is the butyl alcohol ($HO\text{-}CH_2\text{-}CH_2\text{-}CH_3$) ester of fluazifop-P,

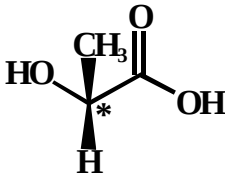


which is more formally referred to as (R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl] oxy] phenoxy] propanoic acid following CAS naming conventions.

Fluazifop-P is also an ester – i.e., the ester of 4-((5-(trifluoromethyl)-2-pyridinyl)oxy)-phenol [CAS No. 69045-85-8]



with (R)-2-hydroxypropionic acid,



which is more commonly referred to as [R]-lactic acid.

The 2-carbon in lactic acid (marked above with an asterisk) has four different substituents, including a hydrogen, a hydroxyl group (OH), a methyl group (CH_3), and a carboxylic acid group (COOH). The 2-carbon of lactic acid is referred to as *chiral*, indicating the compound can form nonsuperimposable mirror images (i.e., enantiomers) which are often referenced as the left-handed [S] enantiomer and right-handed [R] enantiomer. The triangular thick lines in the above illustration of [R]-lactic acid are a convention to indicate that methyl and hydrogen substituents

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

fluazifop-P, which is much more persistent than fluazifop-P-butyl. For the risk characterization, concentrations or doses in units of a.i. are converted to units of a.e. by multiplying the a.i. value by the ratio of the molecular weight of fluazifop-P acid (327.26 g/mole) to the molecular weight of fluazifop-P-butyl (383.37 g/mole)–i.e., 327.26 g a.i./mole ÷ 383.37 g a.e./mole ≈ 0.85364 a.e/a.i. For the sake of clarity, it is noted that considerations of stereochemistry do not impact a.i. (fluazifop-P-butyl) to a.e. (fluazifop-P) conversions.

Selected chemical and physical properties of fluazifop-P-butyl are summarized in Table 4, and the chemical and physical properties of fluazifop-P are summarized in Table 5. In terms of practical impact on the risk assessment, the most significant differences between fluazifop-P-butyl and fluazifop-P concern lipophilicity and persistence. Fluazifop-P-butyl has a high octanol-water partition coefficient (K_{ow} ≈31,600); whereas, fluazifop-P has a much lower K_{ow} of 0.16 at a neutral pH. The much higher lipophilicity of fluazifop-P-butyl relative to fluazifop-P is also reflected in binding to soil. Estimates of k_{oc} values for fluazifop-P-butyl range from 3000 to nearly 6000 (Table 4); whereas, the k_{oc} for fluazifop-P is only about 8.3 (Table 5). Although these properties might suggest a low potential for transport following applications to soil, the reality is that fluazifop-P-butyl is rapidly hydrolyzed to fluazifop-P, and, as indicated in Table 4, the soil hydrolysis of fluazifop-P occurs in only a few hours (U.S. EPA/OPP/HED 2004a, p. 11). As discussed in Section 3.1.3.1, a similar pattern is observed in mammalian studies in which both [RS] fluazifop-butyl and fluazifop-P-butyl are rapidly metabolized to fluazifop-P via ester hydrolysis.

In the Tier 2 environmental fate modeling for applications of fluazifop-P-butyl, the U.S. EPA/OPP/EFED (2004d) elected to use the environmental fate data on fluazifop-P rather than explicitly model the conversion the fluazifop-P-butyl to fluazifop-P. Given the rapidity in the degradation of fluazifop-P-butyl to fluazifop-P, this is a sensible approach. A similar approach is taken in the current Forest Service risk assessment, as detailed in Section 3.2.3.4.

2.2.3. Commercial Formulations

Formulations of fluazifop-P-butyl listed at www.greenbook.net are summarized in Table 6 and include Fusilade DX (Syngenta), Fusilade II, Turf and Ornamental Herbicide (Syngenta), Ornamec 170 Grass Herbicide (PBI/Gordon Corporation), and Ornamec Over-the-top (PBI/Gordon Corporation). Of these herbicides, only Fusilade DX is labeled specifically for Christmas tree plantings, nursery beds, and seedling establishment—i.e., uses that may be relevant to Forest Service programs. As noted in Table 6, applications of Fusilade DX to conifers are not permitted in California; however, U.S. EPA/OPP has issued a Special Local Needs Label for applications of Fusilade DX in California to control grasses in wilderness areas. Fusilade II is specifically labeled for applications to rights-of-way, and the Forest Service has indicated that some programs may include fluazifop-P applications to rights-of-way—e.g., power lines, pipelines, roadsides (Bakke 2013).

In addition to www.greenbook.net, there are many sources of information on pesticides formulations—e.g., http://iaspub.epa.gov, http://www.cdms.net/LabelsMsds, and http://www.cdpr.ca.gov/docs/label/. For example, the pesticide data base maintained by the Pesticide Action Network lists 52 active formulations of fluazifop-P-butyl, many of which include other active ingredients in addition to fluazifop-P-butyl. It is beyond the scope of the current Forest Service risk assessment to consider all commercially available formulations of

fluazifop-P-butyl, and doing so would serve little purpose because pesticide formulations are constantly being developed and/or changed, particularly for pesticides that are off patent. In addition, Forest Service risk assessments do not generally address formulations that contain more than one active ingredient. In considering formulations with multiple active ingredients, the Forest Service uses an EXCEL application, WorksheetMaker (SERA 2011b), which has been adapted to allow for the assessment of either mixture formulations or tank mixtures. Consequently, formulations of fluazifop-P-butyl that also contain other active ingredients are not considered further in this risk assessment.

Based on the above considerations, the current Forest Service risk assessment focuses on Fusilade DX as a representative formulation of fluazifop-P-butyl. This focus, however, is not intended to be exclusive. Other formulations of fluazifop-P-butyl are available commercially, and new formulations of fluazifop-P-butyl may become available at some point in the future. The Forest Service may elect to use other formulations of fluazifop-P-butyl registered for applications relevant to forestry. If other formulations are used in Forest Service programs, however, attempts should be made to identify information on the inerts in the formulations (discussed further below) as well as the toxicity of the formulations to ensure that the formulation under consideration is comparable to the formulations explicitly designated in Table 4.

One exception to the inclusion of other formulations of fluazifop-P-butyl is Fusilade Max. As discussed in Section 4.1.2.4.1, available data suggest that Fusilade Max is more toxic than technical grade fluazifop-P-butyl or other formulations of fluazifop-P-butyl to the honey bee. Furthermore, studies from European literature suggest that Fusilade Max may be toxic to other terrestrial arthropods at application rates as low as 0.005 lb a.e./acre (Section 4.1.2.4.2). In the absence of other data, studies with Fusilade Max are sometimes used in this risk assessment. This approach should be regarded as conservative (i.e., protective).

Pesticide formulations contain other ingredients, sometimes referred to as *inerts*, and the identity of the other ingredients is typically classified as proprietary or Confidential Business Information (CBI). U.S. EPA/OPP (2010c, p. 5-14) encourages but does not require the disclosure of most inerts on product labels. One exception, however, involves petroleum distillates, xylene or xylene range aromatic solvents at ≥10% (U.S. EPA/OPP (2010c, p. 5-7), which must be specified on product label. All of the formulations listed in Table 6 contain other ingredients that are specified as petroleum distillates, hydrocarbons, and/or xylene range aromatic solvents.

Table 6 includes information on the density and pH of the formulations taken from the Material Safety Data Sheets (MSDS) for the formulations. Differences in such characteristics of pesticide formulations are important to risk assessments in that the differences may be related to differences in inerts that are used in the different formulations. The density, pH, and other characteristics (e.g., % a.i.) of the two Syngenta formations, Fusilade DX and Fusilade II, are essentially identical.

Table 7 provides a more detailed summary of the other ingredients in the formulations listed in Table 6 based on the MSDS for the formulations. As illustrated in Table 7, different suppliers 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

factor of 0.854 a.e/a.i. (Section 2.2.2), these application rates correspond to approximately 0.08 to 0.32 lb a.e./acre.

The maximum cumulative seasonal application rate is 3 applications of 24 ounces per acre with a minimum application interval of 14 days. This corresponds to a maximum labeled seasonal or cumulative application rate of 1.125 lb a.i./acre [3 applications x 24 oz./acre/application x 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. = 0.9603451 lb a.e./acre].

The current Forest Service risk assessment explicitly considers three application scenarios: one application at 0.375 lb a.i./acre, two applications at 0.375 lb a.i./acre with a 14-day application interval and three applications at 0.375 lb a.i./acre with 14-day application intervals. 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). The exposure scenarios are detailed in EXCEL workbooks provided as attachments to the current risk assessment—i.e., Attachment 1 for a single application, Attachment 2 for two applications, and Attachment 3 for three applications.

In addition to application rates, application volumes, meaning the number of gallons of pesticide solution applied per acre, have an impact on the estimates of potential risk. The extent to which a formulation of fluazifop-P-butyl is diluted prior to application primarily influences dermal and direct spray scenarios, both of which depend on 'field dilution' (i.e., the concentration of fluazifop-P-butyl in the applied spray). In all cases, the higher the concentration of herbicide (i.e., equivalent to the lower dilution of the herbicide), the greater is the risk. As summarized in Table 6, the recommended application volumes for fluazifop-P-butyl formulations range from 5 to 40 gallons/acre for ground applications (with a minimum volume of 10 gallons/acre for dense grass) and 5 to 10 gallons/acre for aerial applications.

In the EXCEL workbooks that accompany this risk assessment, the range of application volumes is taken as 5 to 40 gallons per acre to encompass the application volumes that could be used in both aerial and ground applications. The central estimate of the application volume is taken as 20 gallons/acre, the minimum ground application volume for dense grass.

The selection of application rates and dilution volumes in this risk assessment is intended to reflect plausible estimates of potential exposures. In the assessment of specific program activities, the application rates and volumes can be changed in Worksheet A01 of the EXCEL workbooks that accompany this risk assessment (Attachments 1 and 2) to reflect the rates and volumes actually used in a particular Forest Service program or project.

2.5. Use Statistics

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

Information on the agricultural use of pesticides is compiled by the U.S. Geological Survey (USGS) (http://water.usgs.gov/nawqa/pnsp/usage/maps/). The USGS (2013) reports estimated uses as fluazifop rather than fluazifop-P-butyl. As noted in the EPA Tolerance Reassessment for fluazifop-P-butyl (U.S. EPA/OPP 2005a, p. 2), fluazifop-P-butyl is currently the only form of fluazifop registered as a pesticide. Consequently, the use data for fluazifop reported by USGS (2013) must apply to fluazifop-P-butyl. Nonetheless, it is unclear whether the USGS (2013) is reporting the use data in units of fluazifop-P-butyl (a.i.) or in units of fluazifop-P (a.e.).

The agricultural use of fluazifop-P-butyl in 2009 (the most recent year for which data are available from USGS) is estimated by the USGS (2013) to range from about 200,000 lbs (Figure 2) to somewhat over 400,000 lbs (Figure 3). The greatest use of fluazifop-P-butyl is in the central United States running from North Dakota to Kansas and eastwards to Michigan and Kentucky. Based on use data by crop (also summarized in Figure 2 and Figure 3), fluazifop-P-butyl is currently used almost exclusively on soybeans. The temporal pattern in the use of fluazifop-P-butyl is noteworthy with a sharp decrease in use from a maximum of about 1.3 million pounds in 1997 to as little as 0.1 million pounds in 2008.

Detailed pesticide use statistics are compiled by the state of California. The use statistics from California for 2011, the most recent year for which statistics are available, indicate that a total of about 9073.64 pounds of fluazifop-P-butyl were used in California (CDPR 2013, p. 340). The major use relevant to Forest Service programs appears to be rights-of-way management (about 801 lbs or 8.8% of total use in California). Based on these use statistics from California, agricultural uses of fluazifop-P-butyl are much greater than uses related to forestry. CDPR (2013, p. 339) does report that a total of 8.38 lbs of fluazifop-butyl (presumably relating to the mixture of the [RS] enantiomers were also applied in 2011. As noted in U.S. EPA/OPP/HED (2004a, p. 5), the registration for fluazifop-butyl (the enantiomer mixture) has been cancelled. While somewhat speculative, it seems likely that this application of the [RS] enantiomers involved an older stock which was acquired prior to the cancellation of the registration for fluazifop-butyl.

The relevance of the California statistics to the current Forest Service risk assessment is not clear. As indicated in Table 6, Fusilade DX is not labeled for applications to conifers as well as other nonbearing crops in California (Fusilade DX label SCP 1070A-L5A 0513, 4026127, p. 32) but the U.S. EPA issued a Special Local Needs label for applications of Fusilade DX in California for the control of grasses in wilderness areas.

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 38µM (≈14.5 mg/L). As discussed in Section 4.1.2.5, an ED_{50} of about 1-3 µM (≈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.

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

3.1.3. Pharmacokinetics and Metabolism

Pharmacokinetics concerns the behavior of chemicals in the body, including their absorption, distribution, alteration (metabolism), and elimination as well as the rates at which these processes occur. This section of the risk assessment addresses the pharmacokinetic processes involved in fluazifop-butyl exposure, including a general discussion about metabolism (Section 3.1.3.1), with a focus on the kinetics of absorption (Section 3.1.3.2) and excretion (Section 3.1.3.3). Absorption kinetics, particularly the kinetics of dermal absorption, is important to this risk assessment because many of the exposure scenarios (Section 3.2) involve dermal exposure. Rates of excretion are generally used in Forest Service risk assessments to evaluate the likely body burdens associated with repeated exposure.

In addition to the general consideration about how fluazifop-butyl behaves in the body, another consideration is the behavior of fluazifop-P-butyl in the environment and the extent to which the metabolism of fluazifop-butyl in the environment must be considered quantitatively in the risk assessment. The consideration of environmental metabolites is discussed in Section 3.1.15.1.

3.1.3.1. Metabolism

For pesticide registration, the U.S. EPA/OPP generally requires a relatively standard metabolism study in rats in which the compound is administered by both intravenous and oral routes. The information available on the metabolism of fluazifop-butyl, however, is more extensive. As summarized in U.S. EPA/OPP/HED (2011a), the EPA reviewed one standard metabolism study with fluazifop-butyl in rats, a metabolism study in dogs with fluazifop-butyl and a metabolism study in hamsters with fluazifop-P-butyl. The metabolism studies in rats, hamsters, and dogs reviewed in U.S. EPA/OPP/HED (2011a) indicate that fluazifop-butyl and fluazifop-P-butyl are rapidly metabolized to fluazifop acid. Other than the hydrolysis of fluazifop-butyl to fluazifop, no further metabolism of fluazifop-butyl is noted in human studies (Clark et al. 1993; Woollen 1993). In terms of potential differences in risks associated with fluazifop-butyl relative to fluazifop-P-butyl, it is important to note that fluazifop[S] is rapidly converted to fluazifop[R] – i.e., the enantiomer of fluazifop-P-butyl. Thus, exposures to fluazifop-butyl—i.e., a mixture of the [R] and [S] enantiomers—are essentially identical to exposures to fluazifop-P-butyl. Both types of exposures will involve the formation of fluazifop[R]. As discussed in the following sections of this hazard identification, there appears to be no difference in effects of fluazifop-butyl, compared with fluazifop-P-butyl.

In addition to these studies on experimental mammals, several metabolism studies with fluazifop-butyl are available in the open literature, including studies in humans. McCracken and coworkers (McCracken et al. 1990, 1992, 1993a) demonstrated that fluazifop-butyl is metabolized to fluazifop acid by microsomal and cytosol fractions from the liver, lung, and skin of rats as well as by red blood cells and plasma. As noted in Section 3.1.2, fluazifop-butyl is a substrate for cytochrome P450, and metabolism by microsomes would be expected. The metabolism of fluazifop-butyl by cytosol fractions (which do not contain substantial amounts of cytochrome P450) suggest that esterases in addition to cytochrome P450 are involved in the 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

with urine samples collected for up to 216 hours after dermal dosing. The results from the dermal absorption study from Ramsey et al. (1992) are summarized in Table 9 of the current risk assessment. The average dermal absorption decreased with increasing dose—i.e., about 8% in the 2 mg dose group, 3.6% in the 20 mg dose group, and 1.6% in the 200 mg dose group.

As discussed by Kissel (2010), a decrease in the proportion of the absorbed dose with increasing dermal loading—i.e., mg of agent per cm^2 of skin—is common for many chemicals. As noted in Table 9, the loadings associated with the doses of 2, 20, and 200 mg are 0.0025, 0.025, and 0.25 mg/cm^2. As illustrated in Figure 4, the decrease in the percent dermal absorption (Abs%) with increasing dermal loading (L) follows an exponential relationship:

$$Abs\% = 0.96L^{-0.348} \quad (1)$$

U.S. EPA/OPP/HED (2011a, pp. 15) and U.S. EPA/OPP/HED (2004d, p. 20-21) summarize a similar study, which may be a partial submission of the high and low dose portions of the study by Ramsey et al. (1992). The EPA summaries indicate that groups of six individuals were exposed to fluazifop-butyl at doses of 2 or 200 mg over a skin surface of 800 cm^2. U.S. EPA/OPP/HED (2004d, p. 20-21) notes that the study authors (NOS) report an absorption factor of 8% is reported for the low dose group and a factor of 1.6% is reported for the high dose group. Based on a reanalysis of the data, the EPA derived somewhat different absorption rates—i.e., 9% for the low dose group and 2% for the high dose group. Documentation of EPA's reanalysis of the data, however, was not identified during the conduct of this risk assessment.

The only other data available on the dermal absorption of fluazifop-butyl in humans is from the occupational exposure study by Chester and Hart (1986). This study, which is discussed in greater detail in Section 3.2.2.1, examined occupational exposures of groups of backpack workers and ground spray workers during applications of fluazifop-butyl. Based on estimates of the total dose deposited on the skin of the workers and the amounts of fluazifop-butyl excreted in their urine, Chester and Hart (1986, Table IV, p. 148) estimate the dermal absorption at 1.3 (0.4 to 1.8) % for backpack workers and 11 (0.2 to 56) % for ground spray workers. Based on individual data provided in Table II of Chester and Hart (1986, p.148), the one worker with an estimated dermal absorption of 56% is a clear outlier. All other workers had estimates of dermal absorption in the range of 0.2% to 11%. The basis for estimates of dermal absorption rates given by Chester and Hart (1986) are not detailed, and this paper is clearly focused on estimating absorbed doses for the two groups of workers rather than dermal absorption rates.

In the absence of information on first-order dermal absorption rates, quantitative structure activity relationships (QSAR) are used to estimate these rates (SERA 2011a, Section 3.1.3.2.2, Equation 3). As detailed in Worksheet B03b of Attachments 1, 2, and 3, the QSAR methods estimate a dermal absorption rate of about 0.0024 (0.00084 – 0.0070) $hour^{-1}$ based on a K_{ow} value of 31,600 and a molecular weight of 383.37 g/mole (Table 4). These properties are within the range of values on which the algorithm is based—i.e., K_{ow} values ranging from 0.0015 to 3,000,000 and molecular weights ranging from 60 to 400 g/mole. The QSAR method is based exclusively on dermal absorption data from studies in humans using a skin loading of 0.004 mg/cm^2 (i.e., Feldmann and Maibach 1969, 1970, 1974).

Based on the dermal absorption data reviewed by U.S. EPA/OPP/HED (2004a, 2011a) as discussed above, the EPA elected to use two dermal absorption factors: *2% for high exposures and 9% for low exposures* (U.S. EPA/OPP/HED 2011a, p. 5). The EPA does not quantify or specify the definitions of high and low exposures. In practice, the EPA exposure scenarios involving dermal exposure appear to be based solely on the 9% dermal absorption factor. As noted in U.S. EPA/OPP/HED (2011a, p. 9): *Given this, use of the 9% factor in combination with high levels of exposure would result in a conservative estimate of risk.*

Forest Service risk assessments typically do not use absorption factors analogous to those used by U.S. EPA, because Forest Service risk assessments include accidental exposure scenarios involving exposure periods from 1 minute to 1 hour (Section 3.2.2.2). As an alternative and as noted above, dermal absorption rate coefficients (k_a) are derived based on the following equation:

$$\ln \frac{M_t}{M_0} = Ln(1-P) = -k_a t$$
$$k_a = \frac{\ln(1-P)}{t} \qquad (2)$$

where P is the proportion absorbed, M_0 is the amount applied and M_t is the amount unabsorbed at time, t, after application. In practice, the analysis involves the regression of the natural log of the proportion of the compound unabsorbed against time and k_a is estimated from the slope of the regression.

As discussed above and illustrated in Figure 4, there is a clear inverse relationship between dermal loading and absorption, which is not uncommon. In such cases, the k_a used in the risk assessment is based on dermal loadings that are most representative of the exposure scenarios considered in the risk assessment. As discussed further in Section 3.2.2.2 (accidental dermal exposures) and detailed in the attachments that accompany this risk assessment (i.e., Worksheets C03a and C03b), the dermal loadings in exposure scenarios based on first-order dermal absorption are about 0.015 (0.008 to 0.06) mg/cm^2. These loadings are most similar to the 0.025 mg/cm^2 mid-dose exposure group from Ramsey et al. (1992), as summarized in Table 9.

In addition to the exposure scenarios based directly on first-order dermal absorption rate coefficients, first-order dermal absorption rate coefficients are also used to adjust the occupational exposure rates (mg/kg bw per lb handled) used in the worker exposure assessment for backpack applications. The details of this method are given in SERA (2013b). As discussed further in Section 3.3.2, an occupational exposure study involving backpack applications of fluazifop-butyl (Chester and Hart 1986, p. 148, Table IV) reports dermal loadings of 0.036 (0.025 to 0.051) µg/cm^2 [i.e., dermal exposures of 209 (138-294) mg over a 5800 cm^2 skin surface area]. Again, these dermal loadings are most similar to the mid-dose group (0.025 mg/cm^2 skin loading) from the study by Ramsey et al. (1992). As detailed in Table 10, the 90% confidence interval—i.e., the lower 5% bound and upper 95% bound—for the percent absorption from the mid-dose group in Ramsey et al. (1992) is about 3.4% (2.8% to 4%).

As indicated in Equation 2 above, the estimate of the k_a requires an estimate of the duration of exposure (t). This is somewhat problematic for the study by Ramsey et al. (1992) because the

skin was washed at 8 hours following exposure but the individuals did not shower for 24 hours after exposure. As noted by Ramsey et al. (1992), washing the skin surface only removed about 50% of the fluazifop-butyl. Assuming that the remainder of the compound was effectively removed by showering at 24 hours, the functional duration of exposure is estimated at 16 hours [8 hours + (24 hours – 8 hours) * 0.5]. Based on this period of functional exposure, the k_a for fluazifop-butyl in the mid-dose group from the study by Ramsey et al. (1992) is 0.00233 (0.00173 to 0.00254) $hour^{-1}$.

The central estimate of 0.00233 $hour^{-1}$ from Ramsey et al. (1992) is almost identical to the central estimate of about 0.0024 $hour^{-1}$from QSAR discussed above and detailed in Worksheet B03b in the attachments to this risk assessment. The confidence interval from Ramsey et al. (1992)—i.e., 0.00173 to 0.00254 $hour^{-1}$), however, is much narrower than that from the QSAR algorithm (i.e., 0.00084 – 0.0070 $hour^{-1}$). Given the high variability in the estimates of dermal absorption from Chester and Hart (1985, Table IV, p. 148), it seems more prudent and protective to use the estimates of k_a from the QSAR algorithm. Consequently, for the current Forest Service risk assessment, the first-order dermal absorption rate coefficients are taken as 0.0024 (0.00084 – 0.0070) $hour^{-1}$.

3.1.3.2.2. Zero-Order Dermal Absorption

Exposure scenarios involving the assumption of zero-order dermal absorption require an estimate of dermal permeability (K_p) in units of cm/hour. No experimental estimates of a K_p for fluazifop-butyl have been identified. Several estimates of dermal absorption rates, in units of $\mu g/cm^{-2}\ h^{-1}$, are reported in the literature (e.g., Auton et al. 1994; Chester and Hart 1985; Hilton et al. 1984). While these types of measurements can be used to estimate a K_p (i.e., by dividing by the concentration of the compound in the exposure media), the studies in the open literature are not designed for this purpose and do not involve essentially constant concentrations—i.e., where the amount of fluazifop-butyl clearly saturates absorption.

In the absence of experimental data, Forest Service risk assessments generally use a QSAR algorithm developed by the EPA (U.S. EPA/ORD 1992, 2007). This approach is discussed in further detail in SERA (2011a, Section 3.1.3.2.1). As with the algorithm for estimating the first-order dermal absorption rate constant, the EPA algorithm is based on molecular weight and K_{ow} (U.S. EPA/ORD 1992, 2007). The molecular weight and K_{ow} values used for estimating the K_p are identical to those used in the estimate of the first-order dermal absorption rate constants (i.e., a 31,600 and a molecular weight of 383.37 g/mole).

The EPA algorithm is derived from an analysis of 95 organic compounds with K_{ow} values ranging from about 0.0056 to 309,000 and molecular weights ranging from approximately 30 to 770 (U.S. EPA/ORD 1992, 2007). These ranges of K_{ow} and molecular weight values encompass the estimates of the corresponding values for fluazifop-butyl.

Details of the implementation of the algorithms are given in Worksheet B03a in the EXCEL workbooks for fluazifop-butyl (Attachments 1, 2 and 3). Using the EPA algorithm results in an estimated dermal permeability (K_p) of about 0.012 (0.006 to 0.026) cm/hour.

3.1.3.3. Excretion

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

$$\frac{X_{N\,Dose}}{X_{1Dose}} = \frac{(1-\left(e^{-kt^*}\right)^N)}{1-e^{-kt^*}} \quad (3)$$

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

$$\frac{X_{Inf}}{X_1} = \frac{1}{1-e^{-kt^*}} \quad (4)$$

Whole-body half-lives are most appropriate for estimating steady-state body burdens.

As reviewed by U.S. EPA/OPP/HED (2011a), fluazifop-butyl is excreted rapidly and primarily (80%-92%) in the urine. Similar excretion patterns are reported in the open literature (Auton et al. 1993b, 1994; Chester and Hart 1986; Ramsey et al. 1992; Rawlings et al. 1994a; Woollen et al. 1991). The prevalence of urinary excretion is true for most weak acids. U.S. EPA/OPP/HED (2011a, p. 15) summarizes a kinetic study in three male volunteers in which an oral dose of fluazifop-butyl (0.07 mg/kg bw) was completely excreted within 4 to 6 days. Based on the EPA description, this study appears to be identical to Woollen et al. (1991) which reports urinary eliminations half-lives of 14 (9-21) hours. The study also summarizes a pharmacokinetic study in dogs with a similar urinary half-life of about 20 hours.

The urinary half-lives of 14 (9-21) hours corresponds to first-order urinary excretion rate coefficients (k_e) of about 1.2 (0.83 to 1.8) day^{-1}. When these rate coefficients are substituted into the above equation for the plateau principle (Eq. 4), the estimated plateau for fluazifop-butyl is about 1.4 (1.2 to 1.8). In other words, over very prolonged periods of exposure, the maximum increase in the body burden of fluazifop-butyl should be less than a factor of 2.

3.1.4. Acute Oral Toxicity

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

The acute toxicity studies in mammals are summarized in Appendix 1, Table A1-1. The acute oral LD_{50} values for fluazifop-butyl (one study in rats) and fluazifop-P-butyl (one study in rats and one study in mice) are summarized in Appendix 1, Table A1-1. The studies in rats provide definitive LD_{50} values, and the LD_{50} in mice is indefinite—i.e., expressed as >2000 mg/kg bw. The definitive LD_{50} values for rats span a range of about 1.9—i.e., from the LD_{50} of 1940 mg/kg bw for fluazifop-butyl in male rats to the LD_{50} of 3680 mg/kg bw for fluazifop-P-butyl in male rats. Based on these studies, U.S. EPA/OPP/HED (2011a) classifies fluazifop-butyl and fluazifop-P-butyl as Category III for acute oral toxicity.

Based on the acute LD_{50} studies, no systematic differences are apparent between male and female rats; furthermore, the one study for which confidence intervals are available (MRID 00162439) indicates that the differences between male and female rats are not statistically significant. No substantial differences are apparent between the toxicity of fluazifop-butyl and fluazifop-P-butyl. As discussed in Section 3.1.3.1, fluazifop[S] is rapidly converted to fluazifop[R]; thus, no differences in the toxicity of fluazifop-butyl (a mixture of [R] and [S] enantiomer) and fluazifop-P-butyl (the [R] enantiomer) would be expected.

In addition to the standard acute LD_{50} assays, two acute toxicity studies are available in the open literature (Kostka et al. 2002; Krijt et al. 1993) and one unpublished acute toxicity study that is not covered in the literature from U.S. EPA/OPP was submitted to the U.S. EPA's Office of Toxic Substances (U.S. EPA/OTS 1992c). These studies are also summarized in Appendix 1, Table A1.

The study by Kostka et al. (2002) involved gavage dosing of male rats with fluazifop acid for up to 14 days with doses ranging from 56 to 891 mg/kg bw. Decreases in body weight with no change in food or water consumption were noted at doses of 446 and 891 mg/kg bw. As noted in Section 3.1.2 and discussed further in Section 3.1.5, decreased body weight is the most common observation in toxicity studies on fluazifop-butyl and fluazifop-P-butyl. The paper by Kostka et al. (2002) is focused primarily on the effects of fluazifop on the liver. The doses associated at decreased body weight (i.e., 446 and 891 mg/kg bw) were also associated with substantial increases in liver weight (30% to 40%), which is also an endpoint commonly observed in studies on fluazifop-butyl and fluazifop-P-butyl. Slight increases in liver weight (i.e., about 15%) along with changes in biochemical parameters (e.g., increased catalase activity) were observed at doses as low as 56 mg/kg bw. This observation is noteworthy because the acute RfD for fluazifop-butyl is based on a NOEL of 50 mg/kg bw/day from a developmental study in rats (Section 3.3). The proximity of the dose of 56 mg/kg bw associated with liver effects in the study by Kosta et al. (2002) is not of substantial concern. As discussed in Section 3.1.2, increases in liver weight as well as other biochemical parameters appear to be related to the induction of cytochrome P450 which is generally considered to be an adaptive response to compounds that are metabolized by cytochrome P450.

The multiple dose study in rats summarized by Krijt et al. (1993) as well as the dietary study by Krijt et al. (1993) observed increases in liver weight. Krijt et al. (1993) noted that the increase in liver weight (about a factor of 2) was accompanied by a similar increase (about a factor of 1.6) in cytochrome P450 activity. Both of these studies involved doses substantially in excess of no-effect levels used in the dose-response assessment (Section 3.3).

In addition to information from the open literature and EPA documents, the Material Safety Data Sheets (MSDS) for formulations of fluazifop-P-butyl contain some information on the toxicity of the formulations—i.e., acute oral and dermal LD_{50} values, an acute inhalation LC_{50} value, and information on eye and skin irritation as well as dermal sensitization. The U.S. EPA/OPP requires that these assays are conducted on each distinct formulation of a pesticide product (U.S. EPA/OPP 2010c). Information on these assays is summarized in Appendix 1 (Table A1-8) for Fusilade DX and Fusilade II. That the information for Fusilade DX is identical to the information for Fusilade II suggests that U.S. EPA/OPP viewed the two formulations as sufficiently similar to one another that only one set of formulation toxicity studies was conducted. The oral LD_{50} values for these formulations are discussed in this section, and data from the other assays are discussed in the appropriate sections below.

The MSDS for both Fusilade DX and Fusilade II report indefinite oral LD_{50} values of >5000 mg/kg bw for the rat. The indefinite LD_{50} values (i.e., values reported as greater than a specific value) indicate that an LD_{50} could not be calculated and that the highest dose tested, in this case 5000 mg/kg bw, caused less than 50% mortality. Both MSDSs clearly indicate that the toxicity values are based on assays of the formulation and not a.i. and that the units of the toxicity values are given as the formulation. Both formulations contain 24.5% fluazifop-P-butyl. Thus, the acute oral LD_{50} of >5000 mg formulation/kg bw corresponds to >1225 mg a.i./kg bw.

As discussed above, U.S. EPA/OPP/HED (2011a) reports definitive LD_{50} values for the rat that range from 1940 mg a.i./kg bw to 3680 mg/kg bw for fluazifop-butyl and fluazifop-P-butyl. All of these LD_{50} values for fluazifop-P-butyl and fluazifop-butyl are above the formulation LD_{50} when expressed in units of a.i. Because the formulation LD_{50} is indefinite, the interpretation of the relationship between the formulation LD_{50} and the LD_{50} values for fluazifop-butyl and fluazifop-P-butyl is limited. The most that can be asserted is that these studies 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 formulation. Information on the other ingredients in the fluazifop-P-butyl formulations is discussed further in Section 3.1.14.2.

3.1.5. Subchronic or Chronic Systemic Toxic Effects

As discussed in SERA (2011a, Section 3.1.5), *subchronic* and c*hronic* are somewhat general terms which refer to studies involving repeated dosing. Some repeated dose studies are designed to detect specific toxic endpoints, like reproductive and neurological effects. Except for some comments in this subsection on general signs of toxicity, these more specialized studies are discussed in subsequent subsections of this hazard identification. The focus of this subsection is toxicity studies designed to detect more general signs of systemic toxicity and to quantify no-observable-effect levels (NOAELs) for the identified endpoints as well as levels associated with adverse effects—i.e., lowest-observed-effect-levels (LOAELS).

The subchronic and chronic toxicity studies on fluazifop-butyl and fluazifop-P-butyl are summarized in Appendix 1 (Table A1-2), and an overview of these studies is given in Table 11. Since no subchronic or chronic toxicity studies are published in the open literature, all of the toxicity studies relevant to the current risk assessment were submitted to the U.S. EPA/OPP in support of the registration of fluazifop-P-butyl. The summaries of these studies given in 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,

does address concerns for the impact of fluazifop-P-butyl on immune function based on the standard toxicity studies (U.S. EPA/OPP/HED 2011a, p. 17). The most relevant observations are those associated with effects on the thymus, spleen weights, bone marrow, and lymphatic tissue at the 25 and 125 mg/kg bw/day doses in the chronic study on dogs (MRIDs MRID 00131462, 00131463, 92067018). While these effects are all suggestive of a potential impact on immune function, the EPA discussion notes that the colony of dogs used in this study may have had pre-existing health issues that contributed to the responses to fluazifop-P-butyl. In addition, the interpretation of the results is compromised by several other issues associated with comparisons between the control and exposed groups. Furthermore, the EPA notes the lack of any endpoints associated with immune function in the chronic studies in rats as well as the subchronic study in dogs.

As with neurotoxicity, recent changes to pesticide regulations (40 CFR § 158) now require immunotoxicity assays as a condition for pesticide registration (U.S. EPA/OPP/HED 2011a, p. 17). These requirements, however, were not in effect when fluazifop-P-butyl was registered. As discussed above, fluazifop-P-butyl will undergo registration review starting in 2015, and studies specific to the assessment of immune suppression may be conducted as part of this process.

3.1.8. Effects on Endocrine System

Assessments of the direct effects of chemicals on endocrine function are most often based on mechanistic studies on estrogen, androgen, or thyroid hormone systems (i.e., assessments on hormone synthesis, hormone receptor binding, or post-receptor processing). The U.S. EPA has developed a detailed approach to the assessment of potential endocrine disruptors (U.S. EPA 2014). As part of this effort, U.S. EPA/OPP has developed a battery of screening assays for endocrine disruption which can be found at: http://www.epa.gov/ocspp/pubs/frs/publications/Test_Guidelines/series890.htm. Fluazifop-P-butyl, however, was not among the compounds listed to be screened in these assays (U.S. EPA/OPP/HED 2011a).

Notwithstanding the above, both U.S. EPA/OPP/HED (2011a, p. 28) and the earlier report from the EPA Hazard Identification Assessment Committee (U.S. EPA/OPP/HED 2004d, p. 33) indicate that *in vitro* assays were conducted on both fluazifop-P-butyl and *acid metabolites* (NOS) using recombinant yeast strains sensitive to human estrogen or androgen receptors. Both documents indicate that no estrogen or androgen activities were noted. Details of these studies and references to MRID study numbers, however, are not provided in either of the EPA documents. Based on these summaries, it is not clear if additional testing for endocrine activity will be required as part of the registration review for fluazifop-P-butyl.

In terms of functional effects that have important public health implications, effects on endocrine function could be expressed as diminished or abnormal reproductive performance. This issue is 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.

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

3.1.9.2. Reproduction Studies

Multi-generation reproduction studies typically involve dietary exposures of a group of rats or mice referred to as the *parental generation* or P_1. Male and female animals are selected from this group and mated. Exposure of the female continues through gestation and after delivery. Offspring from the parental generation, typically referred to as F_1, are then continued on dietary exposure through sexual maturity. The F_1 offspring are mated (and then referred to as the P2 generation) producing an F_2 generation. This is the basic design of a "2-generation" study, although variations on this design are sometimes used, and occasionally the study is carried over to a third generation. Multi-generation reproduction studies typically focus on effects on reproductive capacity—i.e., the number of young produced and their survival.

As detailed in Appendix 1, Table A1-3, U.S. EPA/OPP/HED (2004a,d; 2011a) summarizes the results of a 2-generation reproduction study in rats (MRID 00088859, 92067050). In this study, rats were exposed to fluazifop-butyl in the diet at concentrations of 0, 10, 80, or 250 ppm. The durations of the exposures varied by generation—i.e., 100 days for the parental generation, 120 days for the F_1 generation, and up until weaning for the F_2 generation. No adverse effects were noted for any animals (parental or offspring) at the 10 ppm exposure level. In the mid-dose group, effects were noted in both males from the parental generation and offspring. Parental males evidenced a decrease in spleen weights. Males from the F_1 and F_2 generations evidenced a decrease in absolute and relative testes and epididymal weights. Female offspring evidenced decreases in pituitary and uterine weights. In the high-dose group, parental females evidenced increases in liver and kidney weights as well as geriatric nephropathy. The EPA documents do not describe the geriatric nephropathy in detail; however, it probably indicates changes in the kidney typically seen in older animals.

As discussed further in Section 3.3 (Dose-Response Assessment), the chronic RfD for fluazifop-P-butyl is based on the low dose group NOAEL for parental males and offspring using an estimated dose of 0.74 mg/kg bw/day with a corresponding LOAEL of 5.8 mg/kg bw/day (U.S. EPA/OPP 2011a). This approach is somewhat unusual in that chronic RfDs are typically based on chronic feeding studies unless the NOAEL from the reproduction study is below the NOAEL from the standard chronic feeding study. As discussed in Section 3.1.5 and summarized in Appendix 1 (Table A1-2), the chronic feeding study in rats yielded a NOAEL of 0.51 mg/kg bw/day for males and 5.2 mg/kg/day for females with corresponding LOAELs of 4.15 mg/kg bw/day for males and 16 mg/kg bw/day for females. As with the reproduction study, the 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.

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

3.1.14.2. Adjuvants

As summarized in Table 6, adjuvants, including nonionic surfactants, methylated seed oils, or vegetable oil concentrates are recommended for the Fusilade DX and Fusilade II formulations. These adjuvants are commonly used with herbicides to improve efficacy. Product labels recommend the use of nonionic surfactants at a concentration of 0.25% v/v, methylated seed oil, vegetable oil at a concentration of 1% (v/v), or other commercially available adjuvants.

Although methylated seed oils and vegetable oil concentrates are somewhat vague terms, there is no basis for asserting that these adjuvants are likely to enhance the toxicity of fluazifop-P-butyl to humans. Several seed and vegetable oils are approved food additives (Clydesdale 1997); moreover, many vegetable and fruit oils are classified as *minimal risk inerts* (U.S. EPA/OPPTS 2009). Nonionic surfactants comprise a large and complex group of materials (e.g., Kosswig 1994). In the absence of mammalian studies regarding the potential toxicity of fluazifop-P-butyl in combination with various nonionic surfactants, it is not possible to generalize about potential hazards to human health. As discussed further in the ecological risk assessment, some nonionic surfactants are much more toxic than fluazifop-P-butyl to aquatic species (Section 4.1.3.5).

3.1.15. Impurities and Metabolites

3.1.15.1. Metabolites

As discussed in Section 3.1.3.1, metabolism studies in mammals as well as humans indicate that fluazifop-butyl and fluazifop-P-butyl are rapidly hydrolyzed to fluazifop-P (i.e., primarily the fluazifop[R] enantiomer). With the exception of conjugation reactions, however, fluazifop[R] enantiomer is not further metabolized, at least, in detectable quantities.

In the environment, however, fluazifop-P is extensively metabolized, and the major metabolites are 2-(4-hydroxyphenoxy) propionic acid (a.k.a. Metabolite III), 2-(4-hydroxyphenoxy)-5-trifluoromethylpyridine (a.k.a. Metabolite IV), and 5-trifluoromethyl-2-pyridone (a.k.a. Metabolite X). The structures of these compounds are given in the lower section of Figure 1. The analysis in U.S. EPA/OPP/HED (2004c) focuses exclusively on a discussion of the environmental metabolites and residue chemistry of fluazifop-P-butyl. U.S. EPA/OPP/HED (2004c) indicates that no toxicity data were available on these metabolites. Following standard practice, U.S. EPA/OPP/HED (2004c, p. 4) recommends that the major environmental metabolites should be considered to be as toxic as the parent compound. In practical terms, this amounts to using input parameters for exposure models (e.g., environmental half-lives) adjusted to encompass fluazifop-P (the acid) as well as the major environmental metabolites. This recommendation as well as the input parameters selected in U.S. EPA/OPP exposure assessments for fluazifop-P-butyl are discussed further in the exposure assessment (Section 3.2).

For some exposure scenarios, like the consumption of contaminated fruit or broadleaf vegetation (Section 3.2.3.7), there is a concern that the estimates of exposure may not adequately encompass exposures to metabolites of fluazifop-P acid. These instances are noted and

emphasized in the exposure assessment (Section 3.2) and discussed further in the risk characterization (Section 3.4).

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

3.1.15.2. Impurities

There is no information in the published literature or the summaries of registrant-submitted studies from EPA documents (Table 2) concerning the impurities in fluazifop-P-butyl. Nonetheless, virtually no chemical synthesis yields a totally pure product. As summarized in Appendix 1, the reported levels of purity of fluazifop-P-butyl in mammalian toxicology studies range from about 86% to over 99%. Thus, up to 14% of technical grade fluazifop-P-butyl may consist of impurities. Registrants disclose the nature of impurities in their formulations to the U.S. EPA; however, the identities of the impurities are not disclosed to the public, because that information may provide insight into the manufacturing process, which is considered proprietary and is protected under FIFRA (Section 10). Proprietary information on the identities of these impurities was not available for the preparation of the current Forest Service risk assessment.

To some extent, concern for impurities in technical grade fluazifop-P-butyl is reduced because most of the existing toxicity studies were conducted with the technical grade product or formulated products. Thus, any toxic impurities present in the technical grade product are likely to be encompassed by the available toxicity studies.

3.1.16. Toxicological Interactions

In terms of the mechanism of action, fluazifop-P is a weak acid excreted predominantly in the urine. Many weak acids, both naturally occurring and man-made, are excreted in the urine via active transport processes in the kidney (e.g., Schnermann and Sayegh 1998). Thus, it is likely that fluazifop-P, the major metabolite of fluazifop-P-butyl in humans (Section 3.1.3.1), would influence and would be influenced by other weak acids excreted by the kidney. These influences, however, would be significant only at relatively high doses that saturated the active transport processes involved in the excretion of weak acids by the kidney.

As discussed in Section 3.1.2, fluazifop-butyl is a substrate for cytochrome P450 which is involved in the hydrolysis of fluazifop-butyl to fluazifop acid prior to excretion. Cytochrome P450 is a variable set of enzymes that are both induced by and involved in the metabolism of many naturally occurring as well as man-made compounds (e.g., Coon 2005). Thus, exposures to other compounds that serve as inducers or substrates for cytochrome P450 could impact the metabolism or excretion of fluazifop-P-butyl. In the absence of other information, the impact that these interactions might have on the toxicity of fluazifop-P-butyl cannot be further characterized. Like kidney excretion, metabolic reactions involving cytochrome P450 are

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

3.2. EXPOSURE ASSESSMENT

3.2.1. Overview

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

3.2.2. Workers

3.2.2.1. General Exposures

3.2.2.1.1. Standard Estimates

As described in SERA (2011a), worker exposure rates are expressed in units of mg of absorbed dose per kilogram of body weight per pound of chemical handled. Based on analyses of several different pesticides using a variety of application methods, exposure rates are estimated for three different types of applications: directed foliar (backpack), boom spray (hydraulic ground spray), and aerial. The worker exposure rates are summarized in Table 13 of the current Forest Service risk assessment. The worker exposure rates in Table 13 are taken from a recent update and reevaluation of the methods used to estimate worker exposure (SERA 2013b). All exposure rates are based on biomonitoring studies of worker exposures during pesticide applications.

As discussed further in Section 3.2.3.1.1 (Likelihood and Magnitude of Exposure), most exposure scenarios included in the current risk assessment are accompanied by estimates of variability and/or uncertainty and are expressed as a central value (most likely exposure) as well as estimates of the upper and lower bounds of exposure. The revised worker exposure rates from SERA (2013b) are elaborated to include both 95% confidence intervals as well as 95% prediction intervals. As discussed in SERA (2013b), the 95% confidence intervals should be interpreted as the region defining ranges of average exposures in groups of workers. The 95% prediction intervals should be interpreted as the region in which most exposures for individual workers may occur.

Another elaboration in the new worker exposure methods involves the adjustment for exposure rates in backpack workers based on differences in dermal absorption. As Section 4.2.1.1 of SERA (2013b) explains, different exposure rates are based on data for backpack workers applying glyphosate, 2,4-D, and triclopyr BEE. In developing backpack worker exposure rates

for another pesticide, one of these three rates is selected based on the first-order dermal absorption rate coefficients for these pesticides and the pesticide under consideration. As discussed in Section 3.1.3.2.1, the central estimate of the first-order dermal absorption rate coefficient for fluazifop-P-butyl is taken as 0.0024 $hour^{-1}$. This estimate is based on quantitative structure-activity relationships detailed in Worksheet B03b of Attachments 1, 2, and 3 and is supported by and is virtually identical to the estimated first-order dermal absorption rate coefficient of 0.00233 $hour^{-1}$ derived from the dermal absorption study in humans by Ramsey et al. (1992).

The first-order dermal absorption rate coefficient of 0.0024 $hour^{-1}$is only modestly higher than the corresponding coefficient of 0.0021 $hour^{-1}$ for triclopyr BEE as discussed in SERA (2013b). Following the approach detailed in SERA (2013b, Equation 22), the exposure rates for triclopyr BEE derived in SERA (2013) are multiplied by the adjustment factor of about 1.14 [0.0024 $hour^{-1}$ ÷ 0.0021 $hour^{-1}$ ≈ 1.14286]—i.e., the coefficient for fluazifop-P-butyl divided by the coefficient for triclopyr BEE—and the central estimate of the exposure rate for backpack workers applying fluazifop-P-butyl is estimated at 0.011 with 95% confidence intervals of 0.0008 to 0.015 and 95% prediction intervals of 0.00023 to 0.069 mg/kg bw/day per lb a.i. handled. Details of these calculations are provided in Worksheet C01a-Sup of Attachments 1, 2, and 3.

In addition to the application rate and absorbed dose rate, the other factor affecting worker exposure is the number of acres per day that a worker will treat. Estimates of the number of acres per day that a worker might treat are also given in Table 13. These values are based on treatment rates used in several Forest Service Environmental Impact Statements (USDA/Forest Service 1989a,b,c).

Based on the above methods and the maximum single application rate of 0.32 lb a.e./acre, the estimates of worker exposures are given in Worksheets C01a (backpack directed foliar applications), C01b (ground broadcast applications), and C01c (aerial applications) of Attachment 1, 2, and 3. The specific estimates are discussed further in Section 3.2.2.1.4 and compared to estimates from U.S. EPA/OPP/HED (2011a) and the worker exposure study of Chester and Hart (1986).

3.2.2.1.2. EPA Estimates

As discussed in SERA (2013b, Section 1.1), the U.S. EPA uses deposition-based methods rather than the absorption-based methods used in Forest Service risk assessments. The deposition-based methods typically use the Pesticide Handlers Exposure Database (PHED 1995). U.S. EPA/OPP summarized surrogate exposures from PHED for 37 exposures scenarios, involving mixer-loaders, flaggers, and applicators, for several different types of formulations (e.g., liquid, granular, and wettable powders) applied with ground or aerial equipment (Keigwin 1998). Using the estimates of deposited dose and concentration of the pesticide in air, the absorbed dose for workers can be calculated if estimates are available on absorption rates for inhalation and dermal exposure. Table 14 provides an overview, adopted from Keigwin (1998), of the standard exposure rates used by the U.S. EPA.

The specific worker exposure assessments derived in the most recent EPA human health risk assessment are given in Table 8 and 9 of U.S. EPA/OPP/HED (2011a). Typically, the EPA

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

$$MOE = \frac{NOAEL}{Exposure} \tag{5}$$

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

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

A more noteworthy discrepancy, however, is a statement made in EPA's discussion of the worker exposure assessments: "…*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*" (U.S. EPA/OPP/HED 2011a, p. 48). The discussion then references Tables 8 and 9 of the EPA risk assessment. The lower bound dose noted in U.S. EPA/OPP/HED (2011a) is consistent with the higher reported doses and MOEs in Tables 8 and 9 of the EPA risk assessment. The upper bound dose of 0.07 mg/kg bw/day, however, would be associated with an MOE of only about 11 using the chronic NOAEL of 0.74 mg/kg bw/day [0.74 mg/kg bw ÷ 0.07 mg/kg bw/day ≈ 10.571] or an MOE of about 29 using the subchronic NOAEL of 2 mg/kg bw [2 mg/kg bw ÷ 0.07 ≈ 28.57]. Both of these MOEs would be substantially less than the acceptable margin of exposure (MOE = 100) used in U.S. EPA/OPP/HED (2011a, Section 4.4.4.1, p. 21). The EPA document notes that none of the worker exposures exceeds the Agency's level of concern: *In 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 ÷ 0.00091 ≈ 4.615] and a factor of about 3.7 for aerial applications [0.0037 ÷ 0.00099 ≈ 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 ÷ 0.00099 ≈ 13.13] and the prediction intervals span a factor of 7000 [0.35 ÷ 0.00005 = 7000] for the ground spray workers. Thus, given the variability

among average exposure noted in different worker exposure studies as well as the variability among individual workers, differences of a factor of 4 or 5 are not remarkable.

The above comparison of the exposure assessments from EPA/OPP/HED (2011a) to the assessments based on the methods in SERA (2013b) is somewhat distorted by differences in underlying assumptions. As detailed in U.S. EPA/OPP/HED (2011a, Table 9, p. 50), the worker exposure assessments are based on the assumption that aerial applications involve treating 350 acres and ground spray applications involve treating 80 acres. As summarized in Table 13 of the current risk assessment, the estimates from SERA (2013b) are based on standard assumptions used in all Forest Service risk assessments: aerial operations may involve treating 490 (240-800) acres and ground spray operations may involve treating 112 (66-168) acres. In Table 15, the values given in braces {} under the EPA column are adjusted to use the same number of acres as the central estimates from SERA (2013). Based on this more appropriate comparison, the differences between the SERA (2013) and EPA estimates are reduced—i.e., a factor of 3.5 for ground spray [0.0042 ÷ 0.0012 = 3.5] and 2.6 for aerial applications [0.0037 ÷ 0.0014 ≈ 2.643].

While the estimates of worker exposures using the methods from SERA (2013b) are somewhat higher than those from U.S. EPA/OPP/HED (2011a), the estimates from SERA (2013b) are somewhat lower than those from the worker exposure study with fluazifop-butyl (Chester and Hart 1986). Based on the central estimates of exposure, the doses from Chester and Hart (1986) are higher than the estimated doses using the methods from SERA (2013b) by a factor of about 1.7 for both backpack applications [0.03 ÷ 0.018 ≈ 1.67] and ground spray applications [0.007 ÷ 0.0042 ≈ 1.67]. Again, however, given the high variability in worker exposure estimates, differences of a factor of about 2 are inconsequential. This comparison, however, is not to imply that the study by Chester and Hart (1986) should be viewed as strong support for the estimates using the methods from SERA (2013). As noted in Section 3.2.2.1.3, Chester and Hart (1986) do not provide information on the amount of fluazifop-butyl that the workers applied. Notwithstanding this reservation, the study by Chester and Hart (1986) presumably involved typical backpack and ground spray operations. The relative concordance of the worker exposures from Chester and Hart (1986) with the estimates from SERA (21013b), which are based on typical Forest Service applications, are at least moderately supportive of the exposure estimates based on the methods in SERA (21013b).

Given the relative concordance of the study by Chester and Hart (1986) with the estimates based on the standard methods used in Forest Service risk assessments (SERA 2013b) as well as the modest differences between the estimates from U.S. EPA/OPP/HED (2011a) and the standard SERA (2013b) methods, the current risk assessment estimates worker exposures using the SERA (2013b) methods—i.e., the worker exposures in the last column of Table 15. While the central estimates of exposure do not differ remarkably from those in U.S. EPA/OPP/HED (2011a), the EPA only provides central estimates and does not provide estimates of variability. As discussed further in Section 3.4.2 (Risk Characterization for Workers), the upper bounds associated with worker exposures have a substantial impact on the characterization of potential risks.

3.2.2.2. Accidental Exposures

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

Quantitative exposure and dose-response assessments for skin and eye irritation are not developed in this or other Forest Service risk assessments; however, these effects are considered qualitatively in the risk characterization (Section 3.4.2).

Generally, dermal exposure is the predominant route of exposure for pesticide applicators (Ecobichon 1998; van Hemmen 1992), and accidental dermal exposures are considered quantitatively in all Forest Service risk assessments. The two types of dermal exposures modeled in the risk assessments include direct contact with a pesticide solution and accidental spills of the pesticide onto the surface of the skin. In addition, two exposure scenarios are developed for each of the two types of dermal exposure, and the estimated absorbed dose for each scenario is expressed in units of mg chemical/kg body weight. Both sets of exposure scenarios are summarized in Worksheet E01 of the EXCEL workbooks that accompany this risk assessment—i.e., Attachments 1, 2 and 3. Additionally, Worksheet E01 references other worksheets in which the calculations of each exposure assessment are detailed.

Exposure scenarios involving direct contact with solutions of fluazifop-P-butyl are characterized either by immersion of the hands in a field solution for 1 minute or wearing pesticide contaminated gloves for 1 hour. The assumption that the hands or any other part of a worker's body will be immersed in a chemical solution for a prolonged period of time may seem unreasonable; however, it is possible that the gloves or other articles of clothing worn by a worker may become contaminated with a pesticide. For these exposure scenarios, the key assumption is that wearing gloves grossly contaminated with a chemical solution is equivalent to immersing the hands in the solution. In both cases, the chemical concentration in contact with the skin and the resulting dermal absorption rate are essentially constant.

For the scenarios involving contaminated gloves, the assumption of zero-order absorption kinetics is appropriate—i.e., the concentration of the pesticide in solution is constant or nearly so. For these types of exposures, the rate of absorption is estimated based on a zero-order dermal absorption rate (K_p). Details regarding the derivation of the K_p value for fluazifop-P-butyl are provided in Section 3.1.3.2.2.

The amount of the pesticide absorbed per unit time depends directly on the concentration of the chemical in solution. For terrestrial applications, the current risk assessment uses an application volume of 20 gallons/acre with a range of 5 to 40 gallons/acre, which encompasses the potential range of application volumes used in ground and aerial applications (Section 2.4). At an application rate of 0.32 lb a.e./acre, the estimated concentrations in a field solution are 1.9 mg a.e./mL with a range of 0.96 to 7.7 mg a.e./mL (Worksheet A01 in the attachments).

The details of the accidental dermal exposure scenarios involving first-order absorption consist of spilling a chemical solution on to the lower legs or spilling a chemical solution on to the hands, at least some of which adheres to the skin. The absorbed dose is then calculated as the product of the amount of chemical on the skin surface (i.e., the amount of liquid per unit surface area multiplied by the surface area of the skin over which the spill occurs and the chemical concentration in the liquid), the first-order absorption rate coefficient, and the duration of exposure. The first-order dermal absorption rates coefficients (k_a) are derived in 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

assessments are given in the detailed calculation worksheets in the EXCEL workbook (Worksheets D01a–D11).

For fluazifop-P-butyl, a standard set of exposure assessments used in all Forest Service risk assessments for broadcast applications are considered. As summarized in Worksheet E03, the kinds of exposure scenarios developed for the general public include acute accidental, acute non-accidental, and longer-term or chronic exposures. The accidental exposure scenarios assume that an individual is exposed to the compound of concern either during or shortly after its application. Non-accidental exposures involve dermal contact with contaminated vegetation as well as the consumption of contaminated fruit, vegetation, water, or fish. The longer-term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, or fish. All of the non-accidental exposure scenarios are based on levels of exposure to be expected following a single application (Attachment 1), two applications (Attachment 3) or three applications (Attachment 3) of fluazifop-P-butyl at 0.32 lb a.e./acre with an application interval of 14 days for the multiple applications. The upper bounds of the exposure estimates for the non-accidental scenarios involve conservative assumptions intended to reflect exposure for the MEI (*Most Exposed Individual*). The impact of lower application rates of fluazifop-P-butyl on the risk characterization is discussed in Section 3.4.

The nature of the accidental exposure scenarios is intentionally extreme. The non-accidental, acute exposure scenarios are intended to be conservative but plausible, meaning that it is not unreasonable to assume that the magnitude of exposures in the non-accidental exposure scenarios could occur in the routine use of fluazifop-P-butyl. This interpretation does not extend to the longer-term exposure scenarios. The longer-term exposure scenarios essentially assume that an individual will consume either treated vegetation, fruits, or water from a treated area every day over a prolonged period of time. Despite its unlikelihood, this exposure scenario warrants consideration. As discussed further in Section 3.4.3, this scenario is an important consideration in the interpretation of hazard quotients associated with longer-term exposures to contaminated vegetation.

3.2.3.2. Direct Spray

Direct sprays involving ground applications are modeled in a manner similar to accidental spills for workers (Section 3.2.2.2). In other words, it is assumed that the individual is sprayed with a solution containing the compound and that an amount of the compound remains on the skin and is absorbed by first-order kinetics. Two direct spray scenarios are given, one for a young child (D01a) and the other for a young woman (D01b).

For the young child, it is assumed that a naked child is sprayed directly during a ground broadcast application and that the child is completely covered (that is, 100% of the surface area of the body is exposed). This scenario is intentionally extreme. As discussed in Section 3.2.3.1.1, the upper limits of this exposure scenario are intended to represent the *Extreme Value* upper limits of exposure for the *Most Exposed Individual* (MEI).

The exposure scenario involving the young woman (Worksheet D01b) is somewhat less extreme. In this scenario, it is assumed that the lower legs and feet of a woman are accidentally sprayed with a pesticide. The choice of a young woman rather than an adult male in this scenario is common to many of the exposure assessments and relates to concerns for both the *Most Exposed*

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

3.2.3.3. Dermal Exposure from Contaminated Vegetation

In this exposure scenario, it is assumed that fluazifop-P-butyl is sprayed on to vegetation and that a young woman comes in contact with sprayed vegetation or other contaminated surfaces at some period after the spray operation (Worksheet D02). For these exposure scenarios, some estimates of dislodgeable residue (a measure of the amount of the chemical that could be freed from the vegetation) and the rate of transfer of the chemical from the contaminated vegetation to the surface of the skin must be available.

As detailed in Durkin et al. (1995), dermal transfer rates are reasonably consistent for numerous pesticides, and the methods and rates derived in Durkin et al. (1995) are used as defined in Worksheet D02. The topic of dislodgeable residues is not addressed in the available literature on fluazifop-P-butyl, which leads to uncertainty. For this exposure scenario, a default dislodgeable residue rate of 0.1 of the nominal application rate is used. The uncertainties associated with this exposure scenario do not have a substantial impact on the risk assessment. As detailed in Section 3.4.3 (Risk Characterization for the General Public), hazard quotients for this scenario are far below the level of concern.

The exposure scenario assumes a contact period of 1 hour and further assumes that the chemical is not effectively removed by washing for 24 hours. Other approximations used in this exposure scenario include estimates of body weight, skin surface area, and first-order dermal absorption 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

Ultra Coarse (>650 µm). While somewhat speculative, it seems reasonable to suggest that the labeled recommendation to avoid the use of "flood type" sprays would deal with VMDs of >500 µm which would not typically be used in Forest Service applications.

The distinction between fine and coarse droplet sizes applies only to aerial and ground broadcast applications. Drift from backpack applications are always modeled using coarse droplet sizes (SERA 2011b).

U.S. EPA typically uses a 2-meter-deep pond to develop exposure assessments. If such a pond is directly sprayed with fluazifop-P-butyl at an application rate of 0.32 lb a.e./acre, the peak concentration in the pond would be about 0.036 mg a.e./L (Worksheet B04c1 and B04c2). This concentration is more than 16 times less than the upper bound of the peak concentration of 5.8 mg a.e./L after the accidental spill (Section 3.2.3.4.1, Worksheets B04a) [5.8 mg a.e./L ÷ 0.36 mg a.e./L ≈ 16.111].

Worksheets B04c1 (fine droplets) and B04c2 (coarse droplets) also model concentrations in a small pond at distances of from 25 to 900 feet down wind based on standard values adapted from AgDrift for the different terrestrial broadcast application methods considered in this risk assessment (SERA 2011b). Based on these estimates, fluazifop-P-butyl concentrations in a small pond contaminated by drift from an application made 25 feet upwind would be about 0.0003 mg a.e./L for backpack applications (coarse droplets). For broadcast applications, the concentrations at 25 feet downwind would range from about 0.001 mg a.e./L (low boom ground applications) to 0.008 mg a.e./L (aerial) using fine droplets (Worksheet B04c1) and about 0.0004 mg a.e./L (low boom ground applications) to 0.005 mg a.e./L (aerial) using coarse droplets (Worksheet B04c2).

Similar calculations can be made for scenarios involving a stream contaminated either by direct spray or drift (Worksheets B04d1 and B04d2). For this scenario, the resulting water concentrations depend on the surface area of the stream and the rate of water flow in the stream. The stream modeled in Gleams-Driver simulations (Section 3.2.3.4.3) is about 6 feet wide (1.82 meters), and it is assumed that the pesticide is applied along a 1038-foot (316.38 meters) length of the stream with a flow rate of 710,000 L/day. Using these values, the concentration in stream water after a direct spray is estimated at about 0.03 mg a.e./L. For backpack applications, the concentration in a small stream that is 25 feet downwind is estimated at about 0.0002 mg a.e./L. For broadcast applications, the concentrations at 25 feet downwind would range from about 0.001 mg a.e./L (low boom ground applications) to 0.007 mg a.e./L (aerial) using fine droplets (Worksheet B04d1) and about 0.0003 mg a.e./L (low boom ground applications) to 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

assessment (Section 3.2.3.4.3). To estimate concentrations of a pesticide in ambient water as part of a screening level risk assessment, the U.S. EPA typically uses Tier 1 screening models (e.g., GENEEC, FIRST, and SCIGROW). For more refined and extensive risk assessment, the Agency will typically use PRZM/EXAMS, a more Tier 2 modeling system. The U.S. EPA/OPP typically models pesticide concentrations in water at the maximum labeled rate. All of the concentrations given in Table 19 involved applications at 0.32 lb a.e./acre, identical to the maximum rate used in the GLEAMS-Driver simulations and with one exception (U.S. EPA/OPP/EFED 2008) involved three applications. As also noted in Table 19, EPA used application intervals of 14 to 21 days.

The highest concentrations estimated in the EPA assessments involved the application of the FIRST model—i.e., a peak concentration of about 53 ppb and a longer-term concentration of about 11 ppb. This is to be expected in the Tier 1 models, which are intended to be extremely conservative. The PRZM/EXAMS modeling resulted in lower estimates of both peak concentrations—i.e., about 1.35 to 33.4 ppb—and longer-term concentrations—i.e., about 0.7 to 6.84 ppb.

Excluding the results from the FIRST model, the midpoint of the range of peak concentrations from the EPA assessments is about 17.4 ppb [(1.35 + 33.4) ÷ 2 ≈ 17.375]. This concentration is not substantially different from the central estimate of the peak concentration (16 ppb) from the GLEAMS-Driver simulations for a small pond involving three applications of fluazifop-P-butyl. The midpoint of the range for longer-term concentrations from the EPA assessments is about 3.8 ppb [(0.74 + 6.84) ÷ 2 ≈ 3.79], which is only modestly below the average concentration of 6.53 ppm from the GLEAMS-Driver simulations.

The upper bound estimates from the GLEAMS-Driver simulations, however, are substantially higher than the peak concentrations modeled by EPA. For three applications, the peak concentration from GLEAMS-Driver for a small pond is 150 ppb, which is a factor of about 5 higher than the peak concentration reported by EPA [150 ÷ 33.4≈ 4.491]. For the longer-term concentrations, the upper bound from GLEAMS-Driver is about 61 ppb, which is a factor of about 9 higher than the upper bound from the EPA modeling [61.4 ÷ 6.84 ≈ 8.977].

The comparisons of the EPA and Gleams-Driver results for fluazifop-P-butyl are similar to many other comparisons noted in other Forest Service risk assessments. Because Gleams-Driver is applied to numerous site/soil combinations and because 100 simulations are conducted for each site/soil combination, the upper bound values from Gleams-Driver often exceed the concentrations obtained from either the Tier 2 PRZM/EXAMS modeling or the more conservative Tier 1 modeling from EPA. Because the overall intent of Gleams-Driver is to estimate both central estimates and uncertainty bounds associated with the central estimates, the conservative Tier I models from EPA typically yield concentrations higher than the central estimate from Gleams-Driver. All of these patterns are evident in the surface water modeling for fluazifop-P-butyl.

3.2.3.4.5. Monitoring Data

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

or at least some estimate of the regional use of the compound. No such studies are available for fluazifop-P-butyl. One publication (Coupe et al. 1998) that specifically focuses on this type of assessment—i.e., the relationship of pesticide use to surface water contamination—provides data on the use of fluazifop in the Mississippi delta but does not provide information on the detection of fluazifop in surface water.

The highest detected concentration of fluazifop-P-butyl in surface water is 0.2 µg/L from a river in Spain (Martinez et al. 2000, Table 4, p. 477). Similar concentrations are reported in FANPP (2013a)—i.e., 0.06 to 0.17 µg/L—for surface water in California. Much lower concentrations of about 0.0041 µg/L are reported for a stream in Northern Ireland (Scott and McConvey 2005). Fluazifop-butyl was not detected in Danish ground water at a detection limit of 0.004 µg/L (Spliid and Koppen 1998) and was not detected in Italian rainwater (Trevisan et al. 1993). Because none of these studies provide information on applications of fluazifop-P-butyl, they are not useful in assessing the credibility of the surface water modeling for fluazifop-P-butyl.

In the interest of completeness, it is noted that very low air concentrations of fluazifop-P-butyl (i.e., 0.02 to 0.007 ng/m^3) were detected in an agricultural area in Canada (White et al. 2006). As discussed in Section 3.1.13, the lowest reported 4-hour inhalation LC_{50} for fluazifop-P-butyl is 0.54 mg/L. This LC_{50} is equivalent to 540 mg/m^3, which is in turn equivalent to 540,000,000 ng/m^3. This concentration is a factor of 27 billion times greater than the peak concentration of 0.02 ng/m3 reported by White et al. (2006).

3.2.3.4.6. Concentrations in Water Used for Risk Assessment

The concentrations of fluazifop-P-butyl in water used in the current risk assessment are summarized in Table 20. The concentrations are specified as water contamination rates (WCRs)—i.e., the concentrations in water expected at a normalized application rate of 1 lb 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 of all of the modeling efforts, units of exposure are expressed as ppb or µg/L, as a matter of convenience, for an application rate of 0.32 lb a.e./acre. In Table 20, however, ppb is converted to mg/L (ppm) because mg/L is the unit of measure used in the EXCEL workbooks for contaminated water exposure scenarios in both the human health and ecological risk assessments. The water contamination rates are entered in Worksheet B04Rt in Attachment 1 (single application), Attachment 2 (two applications with a 14-day application interval) and Attachment 3 (three applications with 14-day application intervals). The values in Worksheet B04Rt are linked to the appropriate scenario-specific worksheets in the EXCEL workbooks and the concentrations are adjusted to an application rate of 0.32 lb a.e./acre.

These water contamination rates are based on the GLEAMS-Driver modeling discussed in Section 3.2.3.4.3. The GLEAMS-Driver modeling is reasonably consistent with the FIRST and PRZM/EXAMS modeling as discussed in Section 3.2.3.4.4 and summarized in Table 19. As summarized in Table 19, the Gleams-Driver simulations of the small pond are somewhat higher than those for a small stream. Consequently, the Gleams-Driver simulations for the small pond are used to derive the Water Contamination Rates given in Table 20.

Like most of the estimates provided in this risk assessment, the water contamination rates given in Table 20 are expressed as the central estimate with associated lower and upper bounds. The 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

ecological risk assessment (Section 4.2.2), only broadleaf vegetation and fruit are used in the human health risk assessment.

For longer-term exposures, the time-weighted-average concentrations are estimated using the initial pesticide concentration, the half-life on vegetation, the number of applications, and the application interval. These calculations are detailed in Worksheet B05a (fruit) and Worksheet B05b) for broadleaf vegetation. In these worksheets, the half-lives are identical to those used in the Gleams-Driver modeling—i.e., a central estimate of 7.5 days with a range of 6.6 to 8.7 days.

In the study by Kulshrestha et al. (1995), technical grade fluazifop-P-butyl (85.6% purity) was applied to soybean at a rate of 0.5 kg/ha (≈0.446 lb a.i./acre) and residues on the soybean foliage were sampled for up to 90 days after exposure. The residues were assayed as fluazifop-P acid derivatized to the methyl ester using gas liquid chromatography. Kulshrestha et al. (1995) report a half-life of 7.9 days with a correlation coefficient of 0.96 ($r^2 \approx 0.92$) but do not report a confidence interval on this estimate. Consequently, the mean residues data reported in Kulshrestha et al. (1995, Table 2, p. 279) were reanalyzed using the standard exponential decay model. While the authors report residues for up to 90 days, residues at 90 days were below the limits of detection. Thus, only the data from the day of application to 60 days after application were used in the reanalysis. Details of this reanalysis are given in Worksheet B06 of the attachments to this risk assessment.

As illustrated in Figure 6, the mean residue data are well fit using a standard first-order decay function ($r^2=0.981$, $p=2.07 \times 10^{-6}$) yielding a half-life of 7.51 with a 95% confidence interval of 6.60-8.71 days. The modest difference between the half-life reported by Kulshrestha et al. (1995) and the half-life from the reanalysis is probably attributable to the use of the individual data in the study and the use of mean estimates in the reanalysis. For the current risk assessment, a half-life of 7.51 days with a 90% confidence interval of 6.60-8.71 days is used in order to consider, to the extent possible, the variability in the data.

As discussed further in Section 3.4.3 (Risk Characterization for the General Public), the exposure scenarios associated with the consumption of contaminated fruit and broadleaf vegetation are a concern, particularly for longer-term exposures. As with the exposure scenarios for the consumption of contaminated fish (Section 3.2.3.5), longer-term exposures for the consumption of contaminated vegetation are likely to involve fluazifop-P acid rather than fluazifop-P-butyl, which is accounted for in the data from Kulshrestha et al. (1995). The analytical method used by Kulshrestha et al. (1995), however, does not appear to account for the possibly greater persistence of the metabolites of fluazifop-P. Thus, the use of the half-lives from the study by Kulshrestha et al. (1995) could underestimate the longer-term residues of fluazifop-P metabolites.

For longer-term exposure scenarios associated with the consumption broadleaf vegetation, the likelihood and plausibility of such exposures will be low for herbicides that are toxic to broadleaf vegetation. Fluazifop-P-butyl, however, is most toxic to true grasses but relatively nontoxic to dicots (Section 4.1.2.5.2). Thus, the phytotoxicity of fluazifop-P-butyl does not diminish 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.

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

3.4.2. Workers

The quantitative risk characterization for workers is summarized in Table 23. The HQs given in this table are taken from Worksheets E02 in Attachment 3 (three applications). Note that the HQs for workers are identical in the EXCEL workbooks for one, two, and three applications. Accidental exposure scenarios model only a single event. The general exposure scenarios assume that the worker will repeatedly apply the pesticide—i.e., a longer-term toxicity value is used. Thus, the risk to the worker remains the same, whether the worker is repeatedly applying the pesticide to the same field or applying the pesticide to different fields.

Table 23 is divided into two sections. The upper section gives the Hazard Quotients (HQs)—i.e., the estimated dose divided by the appropriate RfD or surrogate RfD, as discussed in Section 3.3. HQs are the standard numerical expression of the risk characterization used in Forest Service risk assessments with a level of concern of 1 (i.e., HQ=1). If the HQ exceeds 1, concern for potential adverse effects is triggered.

The lower section of Table 23 gives the Margins of Exposure (MOE) that correspond to the HQs. The MOE is the appropriate animal NOAEL divided by the estimated exposure. The MOE is used by the U.S. EPA/OPP with a defined level of concern. In the case of fluazifop-P-butyl, an MOE of less than 100 triggers concern.

HQs and MOEs are essentially reciprocal expressions. Assuming that the level of concern for the MOE is equal to the uncertainty factor used to derive the RfD, the MOE associated with a particular HQ is simply the uncertainty factor divided by the HQ. In the case of fluazifop-P-butyl, the EPA uses an MOE of 100 to trigger concern and the uncertainty factor used for all of the RfDs is also 100. Margins of exposure are not typically discussed explicitly in Forest Service risk assessments. An exception is made with the current risk assessment to facilitate the comparison of the risk characterization for workers offered by U.S. EPA/OPP/HED (2011a) and the risk characterization developed in the current risk assessment.

3.4.2.1. Accidental Exposures

The only accidental exposure scenario that leads to an excursion above the level of concern [HQ=1] is the upper bound of the HQ for wearing contaminated gloves for 1 hour [HQ=6]. As summarized in Table 12, the HQ for this and other accidental exposure scenarios is based on the 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 [$0.0042 \div 0.00091 \approx 4.66$] and a factor of about 4 for aerial applications [$0.0037 \div 0.00099 \approx 3.73$]. 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 [$0.0042 \div 0.0012 = 3.5$] and a factor of 2.6 for aerial applications [$0.0037 \div 0.0014 \approx 2.64$]. 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,

the use of upper bound treatment rates (i.e., acres treated per day) with upper bound exposure rates may not be realistic. This argument is not considered further in the current risk assessment which does not explicitly involve site-specific applications; nonetheless, this consideration could have merit in a specific planned application of fluazifop-P-butyl.

The characterization of risk for workers that uses both confidence and prediction intervals combined with considerations of both shorter-term and longer-term exposures and dose-severity relationships is admittedly cumbersome. In plain language, the current Forest Service risk assessment concurs with the risk characterization for workers developed in U.S. EPA/OPP/HED (2011a): Based on the central estimates of exposure, ground broadcast and aerial applications of fluazifop-P-butyl do not appear to pose risks to workers. Based on upper bound estimates of exposures, however, caution is warranted, and measures to limit or otherwise mitigate worker exposures are justified. Backpack workers may be at greater risk based on central as well as upper bound levels of exposure, particularly when workers are involved in longer-term applications. Even in shorter-term backpack applications, the central estimate of the HQ for workers (HQ=0.9) approaches a level of concern (HQ=1).

3.4.3. General Public

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

3.4.3.1. Accidental Exposures

The two general types of accidental exposure scenarios considered include dermal exposure through accidental spray and oral exposure through the consumption of contaminated water or fish following an accidental spill. Like the accidental exposure scenarios for workers, the accidental exposure scenarios for members of the general public are the same for one, two, and three applications—i.e., accidental exposures are assumed to occur only once.

None of the exposure scenarios involving dermal exposure lead to HQs that exceed the level of concern (HQ=1). The highest HQ is 0.5, the upper bound HQ for the accidental spray of naked child. The naked child scenario is intended to be extreme. While the upper bound for this exposure scenario is below the level of concern, it is worth noting that this exposure scenario covers a 1-hour exposure period. In other words, the assumption is made that the pesticide is effectively removed from the surface of the child after 1 hour. Thus, a longer period of exposure (in this example about 2.25 hours) would result in an HQ of 1, which reaches the level of concern. As with any event involving accidental exposure to a pesticide, prudent measures should be taken promptly to mitigate the exposure.

All of the HQs associated with an accidental spill exceed the level of concern (HQ=1) at least at the upper bounds of exposures. For the consumption of contaminated water by a child, the

exceedance at the upper bound of the HQ is modest (HQ=1.5). In addition, this scenario assumes that the child consumes 1 liter of water—i.e., about the amount that a child might consume over the course of a single day.

The upper bound HQs for the consumption of contaminated fish by an adult are more substantial—i.e., an upper bound HQ of 4 for members of the general public and 18 for members of subsistence populations who may consume a larger quantity of caught fish. As discussed in Section 3.3.5 (Dose-Severity Relationships), the ratio of the LOAEL to the corresponding NOAEL used to derive the acute RfD is 4—i.e., a LOAEL of 200 divided by the NOAEL of 50 mg/kg bw]. The endpoint associated with the LOAEL is the development of diaphragmatic hernias in rat offspring from a developmental study (MRIDs 00088857). In the event of an accidental spill of fluazifop-P-butyl, vigorous efforts would be justified to minimize exposures associated with the consumption of contaminated fish by members of the general public, particularly women of child-bearing age.

3.4.3.2. Acute Non-Accidental Exposures

The risk characterization for acute non-accidental exposures is relatively simple. All scenarios involving contaminated water as well as contact with contaminated vegetation are below the level of concern (HQ=1). The highest of these HQs is 0.5, and this HQ is associated with the upper bound for the consumption of contaminated fish by subsistence populations following three applications of fluazifop-P-butyl at the maximum application rate. This HQ is based on both upper bounds of estimated concentrations of fluazifop-P-butyl in water as well as upper bound estimates for the consumption of fish.

The only exposure scenario that triggers a level on concern (HQ>1) involves the consumption of contaminated broadleaf vegetation following two applications (upper bound HQ of 1.3) or three applications (HQ 1.4) of fluazifop-P-butyl. These are very modest excursions above the acute RfD. While these excursions, by definition, would not be viewed as acceptable, it is not clear that these exposures would be associated with any observable effects.

As discussed in Section 2, fluazifop-P-butyl will be used to treat grassy weeds and will not be intentionally applied to vegetation or fruits that might be consumed by humans in a treated area. While the inadvertent application of fluazifop-P-butyl to edible vegetation would not be likely in backpack (i.e., directed foliar) applications, the inadvertent application of fluazifop-P-butyl to edible vegetation seems plausible in ground broadcast applications and likely in aerial applications, if consumable vegetation is in the treated area.

3.4.3.3. Longer-term Exposures

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

As summarized in Table 25, the longer-term HQs associated with the consumption of contaminated broadleaf vegetation are much greater than the corresponding acute HQs. Based on the central estimate of exposures, the HQ reaches a level of concern following a single application (HQ=1), and exceeds the level of concern following two applications (HQ=2) and three applications (HQ=3). Based on the upper bound levels of exposure, the HQs substantially exceed the level of concern following one application (HQ=10), two applications (HQ=19), and three applications (HQ=29).

As discussed in the hazard identification (Sections 3.1.5 and 3.1.9.2), both the reproduction study on which the chronic RfD is based and the chronic toxicity study in rats indicate that males are more sensitive than females. The endpoint of concern in the reproduction study on which the RfD is based involved decreased testicular weight which was seen at a dose that was a factor of about 8 higher than the NOAEL. In the chronic toxicity study (MRID 41563703 as summarized in Appendix 1, Table A1-3), the LOAELs in male rats involved kidney damage and increased mortality which also occurred at a dose of about a factor of 8 times greater than the NOAEL [$4.15 \div 0.51 \approx 8.13$]. Thus, as discussed in Section 3.3.5 (Dose-Severity Relationships), chronic HQs in excess of 8 are a clear cause for concern.

Based on the relationships discussed above, the upper bound HQs of 10 for two applications and 19 for three applications are clearly a substantial concern. Based on the observations in rats, concerns would be higher for males than for females, and, clearly, the endpoints of concern would be considered severe—i.e., decreased testicular weight, kidney damage, and mortality.

Notwithstanding the above considerations, the results from animal studies may not be directly transferable to assessing risks in humans in both quantitative terms (i.e., the relationship of NOAELs to LOAELs) and in qualitative terms (i.e., the specific effect that might be caused in humans). While this is a general limitation in most pesticide risk assessments, and the limitation is acknowledged, animal studies are used for and are often the only source of estimating acceptable or tolerable levels of exposure in humans.

Another consideration in interpreting the exceedances in chronic exposures to contaminated vegetation involves the plausibility of the exposure scenarios. As discussed in 3.2.3.6, the exposure scenario assumes that edible vegetation is contaminated and that an individual consumes this vegetation in amounts that account for the typical consumption of vegetation by humans over a prolonged period of time. In other words, this scenario could be most relevant to subsistence populations who gather most of the vegetation that they consume from a treated area. In addition to subsistence populations, other individuals may gather wild plants regarded as delicacies (e.g., Peterson and Peterson 1977) but such individuals would often consume lesser amounts of contaminated vegetation from treated areas for a prolonged period than the estimates used in the current risk assessment. While the exposure scenarios for the longer-term consumption of contaminated vegetation may be viewed as highly conservative and perhaps limited to only a minority of the general population, this scenario is a standard in all Forest Service risk assessments for pesticides applied to vegetation, and this scenario is considered relevant by the Forest Service.

It should be noted that the types of exposure scenarios for contaminated vegetation that are routinely used in Forest Service risk assessments are not considered in pesticide risk assessments conducted by the U.S. EPA/OPP. For example, the total chronic dietary assessment for fluazifop-P-butyl from the U.S. EPA/OPP/HED (2010a, Table 6, 12) estimates doses in the range of 0.0006 to 0.007 mg/kg bw/day. For comparison, the exposure assessments for the consumption of contaminated vegetation used in the current Forest Service risk assessments are in the range of about 0.0004 to 0.06 mg/kg bw/day following one application and 0.001 to 0.18 mg/kg bw/day following three applications.

The reason for the substantial differences between EPA exposure assessments and the exposure assessments given in the current Forest Service risk assessment relates to differences in both assessment methods and underlying assumptions. As detailed in U.S. EPA/OPP/HED (2011a), the U.S. EPA uses a dietary exposure model that estimates total pesticide consumption from commercially purchased foods based on dietary patterns as well as pesticide residue data from FDA market basket surveys (e.g., Egan 2013) and the USDA Pesticide Data Program (e.g., Punzi et al. 2005). This type of exposure assessment is appropriate for a consideration of risks associated with agricultural applications for which tolerance limits are set by the EPA. Tolerance limits, however, are applicable and enforced in agricultural applications but are not applicable to forestry uses of a pesticide. This is essentially the rationale used by the Forest Service to assess dietary exposures associated with the consumption of contaminated vegetation following forestry applications.

3.4.4. Sensitive Subgroups

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

3.4.5. Connected Actions

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

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

4.1.2.2. Birds

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.

As with studies included in the human health risk assessment, the U.S. EPA/OPP uses a classification system for categorizing the acute toxicity of pesticides to various groups of nontarget species (see SERA 2011a, Table 16 with discussion in Section 4.1.2 of SERA 2011a). Based on the dietary LC_{50} values, U.S. EPA/OPP/EFED (2008, p. 11) classifies fluazifop-P-butyl as *practically nontoxic* to birds.

In addition to the standard acute toxicity studies in birds, standard reproduction studies were conducted in both mallards and quail. DERs for both of these studies were available for the conduct of the current risk assessment—i.e., the study in mallards (MRID 00093801) is Roberts et al. (1981a) and the study in quail (MRID 00093802) is Roberts et al. (1981b). These studies are summarized in Appendix 2 (Table A2-3) and less detailed summaries are given in U.S. EPA/OPP/EFED (2008) and FAO/WHO (2000). No statistically significant (p<0.05) signs of toxicity or effects on reproduction were noted at dietary concentrations of 43 ppm (a.e.). In both studies, some adult mortality was noted that was not attributed to treatment. In U.S. EPA/OPP/EFED (2008, Appendix C) both of these studies are classified as Supplemental. In the DERs, these studies are classified as Core.

4.1.2.2.2 Open Literature

The open literature on birds consists of three studies from the Hungarian literature (Varga et al. 1999; Varnagy et al. 1996, 1999). The studies by Varga et al. (1999) and Varnagy et al. (1996) both involved egg injection—i.e., pheasant eggs in the former study and chicken eggs in the latter study—using a 12.5% a.i. formulation identified as Fusilade S. Both studies noted embryo lethality. These types of studies are commonly used as screening tools to examine the potential developmental effects of chemicals. Given the route of exposure, however, these studies are not directly useful in the hazard identification.

Varnagy et al. (1999) describe a field study in pheasants involving Fusilade S (which appears to be a European formulation of fluazifop-P-butyl) in combination with Sumithion 50 EC. Sumithion is a formulation of fenitrothion, an organophosphate insecticide. Varnagy et al. (1999) monitored the concentration of these compounds in the food consumed by the pheasants. At reported concentrations of up to 2250 ppm Fusilade (presumably referring to concentrations of fluazifop-P-butyl), no deaths attributable to toxicity were noted. Because of co-exposure to the organophosphate, this study is not directly useful in the current risk assessment. Nonetheless, it seems worth noting that the functional NOAEL of 2250 ppm fluazifop-P-butyl is consistent with the standard bioassay data on birds (Section 4.1.2.2.1).

4.1.2.3. Reptiles and Amphibians (Terrestrial Phase)

No information regarding the toxicity of fluazifop-P-butyl or related compounds (Table 1) to reptiles or terrestrial-phase amphibians was identified in the open literature or in the available reviews (Table 2). Neither the database maintained by Pauli et al. (2000) nor the open literature includes information on the toxicity of fluazifop-P-butyl to reptiles or terrestrial-phase amphibians.

Risks to terrestrial phase amphibians are addressed in the EPA ecological risk assessments on fluazifop-P-butyl prepared by the Environmental Fate and Effects Division (EFED) of U.S. 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}

of >240 µg/bee for fluazifop-butyl reported by EPA/OPP/EFED (2008) is consistent with the contact LD_{50} of >200 µg/bee for fluazifop-P-butyl reported by EFSA (2012).

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

4.1.2.4.2. Toxicity to Other Terrestrial Arthropods

Information on the toxicity of fluazifop-P-butyl on terrestrial arthropods other than the honeybee is summarized in Appendix 3 (Table A3-2). This information is from the European literature. Most of the studies are reported in the review of fluazifop-P-butyl by the European Food Safety Authority (2012), which provides little experimental detail. This is also true for the open literature publication by Hautier et al. (2005), also from the European literature. All of these studies appear to be laboratory assays rather than field studies. The available field studies are discussed in the following section.

Toxicity studies are available on spiders, mites, and four orders of insects, including Coleoptera, Diptera, Hymenoptera, and Neuroptera, and all toxicity values are expressed as application rate equivalents. The only formulation specified in these studies is Fusilade Max. As noted in Section 4.1.2.4.1, Fusilade Max is a 13.7% (w/w) formulation of fluazifop-P-butyl which is not being considered for use in Forest Service programs. As also in Section 4.1.2.4.1, the toxicity data in honeybees indicates that Fusilade Max may be more toxic than the 24.5% a.i. Fusilade formulations that are being considered by the Forest Service.

There are substantial differences in the sensitivity of different arthropods to the formulations of fluazifop-P-butyl covered in the European literature. The most sensitive organism appears to be a predatory mite, *Typhlodromus pyri*. EFSA (2012, p. 70) reports an LR_{50} (a term that functionally corresponds to the LD_{50}) of 5.6 g a.s./ha. The term "a.s." is an abbreviation used in the OECD literature for "active substance" (e.g., http://www.oecd.org/env/ehs/pesticides-biocides/1944058.pdf). In the case of fluazifop-P-butyl, this term probably designates fluazifop-P-butyl itself rather than the acid equivalent. Under this assumption, the application rate of 5.6 g 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 0.854 a.e./a.i. = 0.0042659 lb a.e./acre]. This application rate is below the maximum application rate considered in the current risk assessment by a factor of over 70 [0.32 lb a.e./acre ÷ 0.0043 lb a.e./acre ≈ 74.4186].

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

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

4.1.2.4.4. Earthworms

Studies on the toxicity of fluazifop-butyl to earthworms are summarized in Appendix 3 (Table A3-4). The descriptions of all of these studies are taken from EFSA (2012). As noted previously, the summaries of the studies in EFSA (2012) are cursory. Notwithstanding this limitation, the reported toxicity data for fluazifop-butyl clearly indicate that this herbicide is not toxic to earthworms at high concentrations (i.e., LC_{50} > 1,000 mg/kg soil) and excessive application rates (up to 3.8 lb a.e./acre).

The data on earthworms also include a 14-day bioassay on 5-trifluoromethyl-2-pyridone. As illustrated in Figure 1, this environmental metabolite is referred to in the literature concerning fluazifop-butyl as Compound X or Metabolite X. The reported LC_{50} for this metabolite is identical to that for fluazifop-butyl—i.e., >1,000 mg/kg soil. While these indefinite LD_{50} values cannot be used to define relative toxicity, this report is one of the very few bioassays on a fluazifop-butyl metabolite and indicates that this metabolite does not appear to be remarkably more toxic than fluazifop-butyl. As discussed further in Section 4.1.3, Metabolite X is less toxic than fluazifop-butyl to fish, aquatic invertebrates, and algae.

4.1.2.5. Terrestrial Plants (Macrophytes)

4.1.2.5.1. Mechanism of Action

As indicated in Section 2.2, the mechanism of action involved in the phytotoxicity of fluazifop-P-butyl and other aryloxyphenoxy propionate herbicides is the inhibition of acetyl coenzyme-A carboxylase (ACCase). Based on this mechanism, fluazifop-P-butyl is categorized as a Group 1 herbicide under the system used by the Weed Science Society of America and a Class A herbicide under the system used by the Herbicide Resistance Action Committee. Other similarly classified aryloxyphenoxy propionate herbicides include clodinafop, cyhalofop-butyl, diclofop, fenoxaprop, haloxyfop, propaquizafop, and quizalofop-P. Cyclohexanedione herbicides (e.g., clethodim, alloxydim, butroxydim, cycloxydim, sethoxydim, and tralkoxydim) also act through the inhibition of ACCase (Mallory-Smith and Retzinger 2003). ACCase is a key enzyme in fatty acid metabolism and catalyzes the carboxylation of acetyl-CoA to produce malonyl-CoA (Abell 1996; Burton et al. 1989; Dotray et al. 1993; Focke and Lichtenthaler 1987; Kobek and Lichtenthaler 1990; Lichtenthaler et al. 1991; Maier et al. 1994; Rendina et al. 1990; Tong 2005). Fluazifop-P-butyl inhibits the production of chlorophyll in grass leaves, leading to chlorosis, and also inhibits the growth of grass roots (Derr et al. 1985a; Kabanyoro 2001).

Fluazifop-P-butyl is rapidly absorbed by plant leaves and then rapidly hydrolyzed to fluazifop acid, which is the phytotoxic agent (Balinova and Lalova 1992; Carr 1986a; Derr et al. 1985b). Fluazifop sensitivity differences among monocots are related to differences in the rate of absorption (Derr et al. 1985a). While fluazifop acid is highly mobile in phloem, fluazifop-butyl 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 µM [i.e., ≈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 µM (i.e., ≈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 µM 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

relatively minor damage compared with other true grasses following application rates of up to 0.18 kg a.i./ha (Blake et al. 2012; Cisar and Jagschitz 1984a). In addition to the studies summarized in Table 26, Haga et al. (1987, Table 2, p. 314) noted only moderate damage in two species of Poaceae—i.e., *Imperata cylindrica* (3/10) and *Miscanthus sinensis* (4/10) at an application rate of 0.25 kg a.i./ha). In this publication, visual damage was ranked on a scale from 0 (no damage) to 10 (complete kill). While damage to these Poaceae species was only moderate at an application rate of 0.25 kg a.i./ha, both species of Poaceae were severely damaged at an application rate of 1 kg a.i./ha.

The most remarkable tolerance in a true grass, however, is reported in the field study by Calkins et al. (1996) indicating that blue fescue (*Festuca ovina* var. *glauca*) evidenced relatively little damage following applications of fluazifop-P-butyl at 1.12 kg a.i./ha. The study by Calkins et al. (1996) is a survey involving the application of several herbicides to several species of nontarget plants for weed control. The results reported in Calkins et al. (1996) are not detailed and are expressed as signs of visual injury rated on a score from 0 (dead plants) to 5 (excellent condition). The field study appears to have been long-term with treatments repeated for 2 additional years following the initial application. When fluazifop-P-butyl was applied at a rate of 1.12 kg a.i./ha, the response of blue fescue was rated as 3.5 in the treated group relative to scores of 3.9 in both non-weeded and manually weeded control groups. In this study, blue fescue was injured by other herbicides including Goal (a formulation of oxyflurfen) and Rout (a formulation containing oxyflurfen and oryzalin). Studies to corroborate the tolerance level of fescue to fluazifop-P-butyl reported by Calkins et al. (1996) were not identified in the open literature.

4.1.2.5.2.2.2. Other Monocots

Other non-Poaceae monocots are much less sensitive than the true grasses to fluazifop-P-butyl, and the distinction between *sensitive* and *tolerant* non-Poaceae monocots is based largely on the severity of the observed responses rather than responses at different application rates.

In addition to the assays on the Poaceae discussed in the previous section, Haga et al. (1987) assayed two species of Cyperaceae (sedges) and one species each of Commelinaceae (spiderworts), Liliaceae (lilies), and Araceae (taro). At application rates of 0.25 and 1 kg a.i./ha, minimal damage (1/10) was noted. In addition, Rokich et al. (2009) noted no damage in two species of Anthericacae (3- to 4-month-old *Sowerbaea laxiflora* and *Thysanotus manglesianus*) at application rates of up to 3.4 kg a.i./ha. These observations are consistent with the field study by Calkins et al. (1996) which noted no adverse effects on lilies from the families Xanthorrhoeaceae and Asparagaceae at an application rate of up to 1.12 kg a.i./ha. While not summarized in Table 26, the tolerance of Xanthorrhoeaceae is also supported in the field study by Skroch et al. (1990) in which no adverse effects were observed in two species of Xanthorrhoeaceae from this family at lower applications rates of ≈0.2 kg a.i./ha.

At high application rates, fluazifop-P-butyl has caused adverse responses in some non-Poaceae monocots. In the study by Rokich et al. (2009), severe visual damage as well as a reduction in plant height (≈34%) was observed in 4- to 5-month-old *Sowerbaea laxiflora* (Anthericacae) following an application of 1.69 kg a.i./ha fluazifop-P-butyl. As noted above, adverse effects 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

Table A5-2: Acute Toxicity to Saltwater Fish
Table A5-3: Chronic Toxicity to Fish.

An overview of these studies is presented in Table 27, which provides a summary of LC_{50} values and NOAECs (when available) for acute toxicity studies and NOAEC and LOAEC values for the longer-term studies.

Most of the available toxicity studies on fluazifop-butyl are studies submitted to the U.S EPA and are summarized U.S. EPA/OPP/EFED (2008). As noted in Appendix 5, DERs were available on the acute toxicity studies with fluazifop-butyl in fathead minnows (MRID 00093808, Wilson et al. 1981) and bluegills (MRID 00087485, Hill et al. 1981) as well as an acute toxicity study with the Fusilade 4E formulation with sheepshead minnow (MRID 00152173, Hill 1985). A DER was also available on an early life stage study in fathead minnows (MRID 00093808, Wilson et al. 1981).

Some additional unpublished studies are summarized in FAO/WHO (2000) and EFSA (2012). Information from the open primary literature is limited to an LD_{50} in tilapia from Tejada et al. (1994) and field observations in trout (Schramm et al. 1998). The study by Tejada et al. (1994) is discussed below. The paper by Schramm et al. (1998) reports changes in liver function and morphology in brown trout from streams with detectable levels of fluazifop as well as many other contaminants. This paper cannot be used to assess the impact of fluazifop-P-butyl on trout and is not considered further in this risk assessment.

The acute toxicity data on fluazifop-butyl are reasonably consistent with all but one of the LC_{50} values ranging from 0.25 mg a.e./L (*Nile tilapia*) to 1.2 mg a.e./L (rainbow trout). One notable exception, however, is the LC_{50} of 99.9 mg a.e./L or 117 mg a.i./L (MRID 00087483) for rainbow trout from U.S. EPA/OPP/EFED (2008, p. 179). The EPA indicates that this LC_{50} was conducted on fluazifop-butyl. EFSA (2012) indicates an LC_{50} in trout of 117 mg a.e./L based on an assay using fluazifop acid. Syngenta was queried on this discrepancy and has confirmed that the entry in EFSA (2012) is correct. The rainbow trout bioassay in MRID 00087483 was conducted on fluazifop acid.

The review by EFSA (2011) also provides the only information on the toxicity of a metabolite of fluazifop-P-butyl, 5-trifluoromethyl-2-pyridone, which is referenced in the literature on fluazifop as Compound X or Metabolite X. Based on the bioassay of Compound X in rainbow trout, Compound X is less toxic than fluazifop-butyl by a factor of 200 [240 mg/L ÷ 1.2 mg a.e./L]. As with earthworms (Section 4.1.2.4.4.) and as discussed further below, Compound X is also much less toxic than fluazifop-butyl to both aquatic invertebrates (Section 4.1.3.3) and algae (Section 4.1.3.4.1).

Data are available on the toxicity of fluazifop-P-butyl formulations. Two of the studies are for unspecified 25.8% a.i. formulations (MRID 00087486; MRID 00087484) and are summarized in U.S. EPA/OPP/EFED (2008). As indicated in Table 6, the percent 25.8% a.i. in these formulations is similar to the nominal 24.5% a.i. in Fusilade DX and Fusilade II. An LC_{50} for Fusilade Max (12.5% a.i.) is also reported in EFSA (2012). The toxicity data in rainbow trout indicate that Fusilade Max is more toxic than the 25.8% a.i. formulation(s) by about a factor of 3

[4.2 mg/L ÷ 1.37 mg/L ≈ 3.066]. Nonetheless, all of the toxicity data on the fluazifop-P-butyl formulations indicate that the formulations are less toxic than fluazifop-butyl when the units of dosing are expressed in units of mg a.e./L. Hence, the inerts in these formulations do not seem to contribute to the toxicity of the formulations to fish. As discussed further in Section 4.1.3.3, the opposite pattern is seen with aquatic invertebrates—i.e., the formulations of fluazifop-butyl are much more toxic than technical grade fluazifop-butyl to aquatic invertebrates.

As noted above, a DER is available on the study with Fusilade 4E in sheepshead minnow (MRID 00152173, Hill 1985). In the EPA ecological risk assessment on fluazifop-P-butyl (U.S. EPA/OPP/EFED 2008), the LC_{50} reported for this study is 6.85 mg a.e./L. This LC_{50} appears to be based on the LC_{50} of 8.1 mg/L reported in the DER under the assumption that the units used 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, appears to express units in terms of the formulation (46.83% a.i.). Correcting for the percent a.i. in the formulation, the EC_{50} value in acid equivalents should be about 3.2 mg a.e./L [8.1 mg formulation/L x 0.4683 a.i./formulation x 0.854 a.e./a.i. ≈ 3.2394 mg a.e./L].

While not discussed in U.S. EPA/OPP/EFED (2008), the study by Hill (1985, (MRID 00152173) also assayed a formulation blank—i.e., the formulation without the a.i. As detailed in Appendix 5 (Table A5-2), the LC_{50} for the formulation blank is reported as 10.4 mg formulation/L, which is only modestly higher than the LC_{50} reported for the full formulation with the a.i.—i.e., 8.1 mg formulation/L. Based on this relationship, the discussion in the DER notes:

> *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.*
>
> Hill 1985, DER, p. 5.

As noted above and discussed further in Section 4.1.3.3, this assessment is consistent with the formulation toxicity data in aquatic invertebrates. In the absence of DERs on the other formulation studies in fish, the reporting of units in U.S. EPA/OPP/EFED (2008) for the other registrant-submitted formulation studies cannot be verified.

Several of the studies summarized in U.S. EPA/OPP/EFED (2008) report both LC_{50} values and NOECs, and some of the studies report slopes of the dose-response curves. While it is not clear if the slopes are based on common or natural logarithms of the concentrations, it is apparent that the slopes are steep and that most of the NOAECs are only modestly below the LC_{50} values, by factors of less than 4. The only exception is a formulation bioassay in rainbow trout (MRID 00087484) in which the NOAEC is a factor of about 12 below the LC_{50} [4.2 ÷ 0.34 ≈ 12.353].

Based on the LC_{50} values for fathead minnows (Table 27), the EPA classifies fluazifop-P-butyl as *Very Highly Toxic* to fish (U.S. EPA/OPP/EFED 2008, p. 43).

While no full lifespan toxicity studies are available in fish, early life stage studies are available on fluazifop-butyl (MRID 00093808), fluazifop-P-butyl (EFSA 2012; FAO/WHO 2000), and fluazifop acid (EFSA 2012). These studies report NOAECs of >0.203 mg a.e./L (fluazifop-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

Table A5-3: Chronic Toxicity to Aquatic Invertebrates

4.1.3.3.1. Acute Studies

An overview of acute toxicity studies is presented in Table 28, which provides a summary of LC_{50} values and NOAECs (when available). An overview of the chronic toxicity studies is presented in Table 29, which provides a summary of NOAEC and LOAEC values (when available).

Two studies from the open literature summarized in Appendix 6 (Table A6-1) are not included in Table 28 —i.e., Nishiuchi and Asano (1979) and Tantawy (2002). The study by Nishiuchi and Asano (1979) reports an LC_{50} of >40 ppm for a Fusilade formulation in a species of mayfly (*Cloeon dipterum*) nymphs. This study is from the Japanese literature and is published in Japanese. A translated copy of this publication was obtained for the current risk assessment. As noted in Section 1.1.2., the U.S. EPA/OPP rejected this study in several risk assessmenOts on the California Red-legged Frog (e.g., U.S. EPA/OPP 2009b) because control groups were not used in the study. While the reported indefinite LC_{50} is consistent with definitive LC_{50} values reported in *Daphnia magna* (Table 28), any indefinite LC_{50} is only minimally useful. As with the EPA risk assessments, the Nishiuchi and Asano (1979) study is not considered quantitatively in the current risk assessment. Tantawy (2002) reports an LC_{50} of 17.6 and an LC_5 of 1.76 for fluazifop-P-butyl (NOS) in *Biomphalaria alexandrina*, an Egyptian snail that is a vector for *Schistosoma mansoni*, cause of schistosomiasis. The paper by Tantawy (2002) provides few experimental details, and it cannot be determined if the LC_{50} value is reported in units of formulation, a.i., or a.e. This LC_{50} value would not have a quantitative impact on the risk assessment but would expand the class of species on which data are available. In the absence of better documentation of the units for the toxicity value, however, the paper by Tantawy (2002) is not considered useful in the hazard identification for aquatic invertebrates.

Apart from the above two studies, there are uncertainties in some of the reported LC_{50} values in Table 28. U.S. EPA/OPP/EFED (2008) reports an LC_{50} of 8.5 mg a.e./L in *Daphnia magna* (MRID 00087488). In ECOTOX, however, the LC_{50} is reported as indefinite with a value of >10 mg a.i./L (≈8.54 mg a.e./L). Given the other daphnid toxicity data on fluazifop-P-butyl, it seems likely that the definitive LC_{50} of 8.5 mg a.e./L reported in U.S. EPA/OPP/EFED (2008) should have been reported as an indefinite LC_{50}.of >8.5 mg a.e./L. In the absence of additional details on the study, however, no clearer determination can be made.

As summarized in Table 28 and detailed further in Appendix 6 (Table A6-1) a series of studies were conducted in *Daphnia magna* using 1:1, 1:7, and 1:14 blends of the [R]:[S] enantiomers. U.S. EPA/OPP/EFED (2008, Appendix C, p. 190) indicates that the test substance was fluazifop-butyl. Two DERs are available for this study (Jealotts Hill Research Station 1983; Hamer and Hill 1983), both of which indicate that the test substance was fluazifop acid rather than fluazifop-butyl. This ambiguity does not have a substantial impact on the current risk assessment because these studies are not used quantitatively.

Another issue involves the reported LC_{50} of 240 mg a.e./L for fluazifop-butyl from MRID 00087490, as summarized in U.S. EPA/OPP/EFED (2008). An identical LC_{50} of 240 mg a.e./L is reported by EFSA (2012) for fluazifop acid. The two identical LC_{50} values for fluazifop-butyl 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).

U.S. EPA/OPP/EFED (2008, p. 9) indicates that bioassays in a *Lemna* species are required for fluazifop-P-butyl. As discussed in Section 1.1.2, fluazifop-P-butyl is undergoing registration review and bioassays on *Lemna* may be required as part of this process.

As summarized in Table 30 and detailed further in Appendix 7, several algal bioassays on fluazifop-P-butyl and formulations of fluazifop-P-butyl are cited in European reviews (e.g., EFSA 2012; FAO/WHO 2000), and additional toxicity studies are published in the open literature (Felix et al. 1988; Ma 2002; Ma et al. 2002a,b, 2004, 2006; Michel et al. 2004; Perschbacher et al. 1997). Except for the paper by Perschbacher et al. (1997), which was conducted in the United States, all of these toxicity studies on algae are from the European literature (EFSA 2012; FAO/WHO 2000; Felix et al. 1988) or Chinese literature (the publications by Ma and coworkers). Perschbacher et al. (1997) used an unspecified Fusilade formulation. Studies summarized in EFSA (2012) involved technical grade fluazifop-P-butyl, fluazifop acid, 5-trifluoromethyl-2-pyridone (Metabolite X), and Fusilade Max. The studies by Ma and coworkers involved an unspecified 53% EC formulation.

4.1.3.4.1. Algae

While data are available on the toxicity of fluazifop-P-butyl and related compounds to nine different species of algae (Table 30), only *Pseudokirchneriella subcapitata* and *Navicula pelliculosa* have been assayed with more than one form of fluazifop or formulation.

Pseudokirchneriella subcapitata has been assayed using technical grade fluazifop-P-butyl, fluazifop acid, 5-trifluoromethyl-2-pyridone (Metabolite X), and Fusilade Max. While the bioassays on fluazifop-P-butyl and fluazifop acid are indefinite, they suggest that fluazifop-P-butyl may be more toxic than fluazifop acid, similar to the observations in fish (4.1.3.1) and aquatic invertebrates (4.1.3.3). Also as with fish and aquatic invertebrates, the 5-trifluoromethyl-2-pyridone metabolite of fluazifop-P-butyl appears to be much less toxic than fluazifop-P-butyl. Fusilade Max has been assayed in *Pseudokirchneriella subcapitata* with and without sediment. As noted in Table 30, the EC_{50} without sediment (0.02 mg a.e./L) is much lower than the EC_{50} with sediment (0.128 mg a.e./L). As summarized in Table 4, fluazifop-P-butyl may bind to sediment (K_{oc} values of 2010 to 5700), which may explain the apparent decrease in toxicity in a sediment/water system. Similarly, unless sterile sediment was used, the decrease in toxicity to algae could be due to the more rapid metabolism of fluazifop-P-butyl to fluazifop acid. In the absence of additional details on the design and conduct of these studies, these suppositions cannot be elaborated.

The bioassays on *Navicula pelliculosa* involved both technical grade fluazifop-P-butyl and Fusilade Max. As with *Pseudokirchneriella subcapitata*, the EC_{50} for the Fusilade formulation (0.118 mg a.e./L) is less than the EC_{50} for technical grade fluazifop-P-butyl (EC_{50} 0.44 mg a.e./L); however, the magnitude of the difference—i.e., about a factor of 4 [$0.44 \div 0.118 \approx 3.73$] —is much less than the factor of over 77 with *Pseudokirchneriella subcapitata* [$>1.54 \div 0.02 > 77$].

Most of the bioassays with the Chinese 53% EC formulation yielded EC_{50} values that are higher (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 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} (≈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., ≈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).

Based on the label instructions for fluazifop-P-butyl formulations likely to be used in Forest Service programs, the recommended concentration for nonionic surfactants is 0.25% to 0.5% v/v (Table 6). Assuming a surfactant density of 1 g/mL for illustration, 0.5% w/v corresponds to a concentration of 5000 mg/L. In order to assess potential hazard to aquatic organisms, however, the dilution of the surfactant must be considered. Three applications of fluazifop-P-butyl at a rate of 0.32 lb a.e./acre with a 14-day application interval may be taken as a reasonable example. As detailed in Attachment 3 (Worksheet B04a), the peak expected concentration of fluazifop-P-butyl in surface water would be about 0.47 mg a.e./L. If 0.5% surfactant is added to a representative formulation containing 20.09% a.e. (Table 6), the peak concentration of the surfactant in surface water would be about 0.01 mg/L [0.47 mg a.e./L x 0.5% ÷ 20.09% a.e. ≈ 0.011196 mg/L].

As discussed in the EPA ecological risk assessments on fluazifop-P-butyl (U.S. EPA/OPP 2008), the standard criterion used by U.S. EPA/OPP is a level of concern for endangered species of 0.05, meaning that the ratio of the anticipated concentration in water to the acute LC_{50} should be no greater than 0.05. Using a very toxic surfactant with an acute LC_{50} of 1 mg/L, the ratio of the anticipated concentration of the surfactant in water (0.011 mg/L) to the LC_{50} of 1 mg/L is 0.011—i.e., below the 0.05 level of concern by a factor greater than 4 [$0.05 \div 0.011 \approx 4.545$]. Thus, there is no apparent basis for asserting that the use of surfactants with fluazifop-P-butyl applications is likely to pose an acute hazard to aquatic species. The use of a relatively nontoxic surfactant (e.g., an LC_{50} of 1000 mg/L) would result in a correspondingly lower ratio and lesser assessment of potential risk.

The above discussion applies only to potential acute risks. Since a useful compendium on the longer-term toxicity of nonionic surfactants to aquatic organisms is not available, the potential for longer-term risks cannot be assessed.

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.

The initial concentrations of fluazifop-P-butyl on contaminated food items are based on the U.S. EPA/OPP (2001) adaptation of the residue rates from Fletcher et al. (1994), as summarized in Table 21. The methods of estimating the peak and time-weighted average concentrations of fluazifop-P-butyl in vegetation are identical to those used in the human health risk assessment (Section 3.2.3.7). As summarized in Table 21, fruit and short grass comprise the food commodities with the lowest pesticide residue rates (fruit) and the highest pesticide residue rates (short grass). Tall grass and broadleaf forage plants are estimated to have intermediate residue rates. For each of these four types of vegetation, both acute and longer-term exposure scenarios are developed, as detailed in Worksheet G01a for mammals and Worksheet G01b for birds, in the attachments to this risk assessment.

The acute and chronic exposure scenarios are based on the assumption that 100% of the diet is contaminated, which may not be realistic for some acute exposures and seems an unlikely event in chronic exposures—i.e., animals may move in and out of the treated areas. While estimates of the proportion of the diet contaminated could be incorporated into the exposure assessment, the estimates would be an essentially arbitrary set of adjustments. The proportion of the contaminated diet is linearly related to the resulting HQs, and its impact is discussed further in the risk characterization (Section 4.4.2.1).

The estimated food consumption rates by various species of mammals and birds are based on field metabolic rates (kcal/day), which, in turn, are based on the adaptation of estimates from Nagy (1987) by the U.S. EPA/ORD (1993). These allometric relationships account for much of the variability in food consumption among mammals and birds. There is, however, variability not apparently related to body weight, which is remarkably constant among different groups of organisms (Table 3 in Nagy 1987). As discussed by Nagy (2005), the estimates from the allometric relationships may differ from actual field metabolic rates by about ±70%. Consequently, in all worksheets involving the use of the allometric equations for field metabolic rates, the lower bound is taken as 30% of the estimate and the upper bound is taken as 170% of the estimate.

The estimates of field metabolic rates are used to calculate food consumption based on the caloric value (kcal/day dry weight) of the food items considered in this risk assessment and estimates of the water content of the various foods. Estimates of caloric content are summarized in Table 22. Most of the specific values in Table 22 are taken from Nagy (1987) and U.S. EPA/ORD (1993).

Along with the exposure scenarios for the consumption of contaminated vegetation, similar sets of exposure scenarios are provided for the consumption of small mammals by either a predatory mammal (Worksheet F10a) or a predatory bird (Worksheet F10b) and the consumption of contaminated insects by a small mammal, a larger (400 g) mammal, and a small bird (Worksheets F09a-c). The residue rates for insects are taken from the U.S. EPA/OPP (2001) adaptation of the residue rates in Fletcher et al. (1994), as summarized in Table 21.

4.2.2.4. Ingestion of Contaminated Water

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

bird. Like food consumption rates, water consumption rates, which are well characterized in terrestrial vertebrates, are based on allometric relationships in mammals and birds, as summarized in Table 31. From these estimates, exposure scenarios involving the consumption of contaminated water are developed for mammals and birds for accidental spills (Worksheets F02a-f), expected peak concentrations (Worksheets F08a-f), and expected longer-term concentrations (Worksheets F16a-f) of Attachments 1, 2 and 3.

Like food consumption, water consumption in birds and mammals varies substantially with diet, season, and many other factors; however, quantitative estimates regarding the variability of water consumption by birds and mammals is not well documented in the available literature and is not considered in the exposure assessments. Nevertheless, as summarized in Table 20, the upper and lower bound estimates of concentrations of fluazifop in surface water vary substantially (i.e., by a factor of over 94 [0.047 mg/L ÷ 0.005 mg/L] for acute exposures and a factor of over 100 [0.2 mg/L ÷ 0.002] for chronic exposures). Given this degree of variability in the estimated concentrations of fluazifop in surface water, it is unlikely that a quantitative consideration of the variability in water consumption rates of birds and mammals would have a substantial impact on the risk characterization. In addition and as discussed further in Section 4.4.2.1 (risk characterization for mammals) and Section 4.4.2.2 (risk characterization for birds), exposures associated with the consumption of contaminated surface water are far below the level of concern (HQ=1). Consequently, even extreme variations on the consumption of contaminated water by mammals and birds would have no impact on the risk characterization for mammals and birds.

4.2.2.5. Consumption of Contaminated Fish

In addition to the consumption of contaminated vegetation, insects, and other terrestrial prey (Section 4.2.2.3), the consumption of contaminated fish by piscivorous species is a potentially significant route of exposure to fluazifop-P-butyl (acute exposures) and fluazifop acid (longer-term exposures). Exposure scenarios are developed for the consumption of contaminated fish after an accidental spill (Worksheets F03a-c), expected peak exposures (Worksheets F011a-c), and estimated longer-term concentrations (Worksheets F17a-c). These exposure scenarios are applied to 5 and 70 kg carnivorous mammals as well as a 2.4 kg piscivorous bird. The 70 kg carnivorous mammal is typical of a black bear (which does not actively hunt fish) but could be representative of a small or immature brown bear (*Ursus arctos*), which is an endangered species that actively feeds on fish (Reid 2006). As summarized in Table 31, the 5 kg mammal is representative of a fox, and the 2.4 kg bird is representative of a heron.

Exposure levels associated with the consumption of contaminated fish depend on the concentration of the compound in water and the bioconcentration factor for the compound in fish. The concentrations of fluazifop in water are identical to those discussed in Section 4.2.2.4. As discussed in Section 3.2.3.5, fluazifop acid is not likely to accumulate in fish, but fluazifop-P-butyl may accumulate substantially. Thus, for acute exposure scenarios, the bioconcentration factor of 120 from MRIDs 93196 and 92067035 is used and, presumably, applies to fluazifop-P-butyl. For longer-term exposure scenarios, the bioconcentration factor of 2.1 from MRID 93195 is used and, presumably, applies to fluazifop acid. As noted in Section 4.1.1, all exposures are expressed in units of fluazifop acid, regardless of the bioconcentration factor, and this conversion 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 (≈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.

4.2.4.3. Runoff and Soil Mobility

Terrestrial plant exposures associated with runoff and sediment losses from the treated site to an adjacent untreated site are summarized in Worksheet G04 of the EXCEL workbooks for fluazifop-P-butyl (Attachments 1, 2, and 3).

Any pesticide can be transported from the soil at the application site by runoff, sediment loss, or percolation. Runoff, sediment loss, and percolation are considered in estimating contamination of ambient water (Section 3.2.3.4). Only runoff and sediment loss are considered in assessing off-site soil contamination. This approach is reasonable because off-site runoff and sediment transport will contaminate the off-site soil surface and could have an impact on non-target plants. Percolation, on the other hand, represents the amount of herbicide transported below the root zone, which may affect water quality but should not affect off-site vegetation. As with the estimates of fluazifop-P-butyl in surface water, estimates of runoff and sediment losses are modeled for clay, loam, and sand at nine sites that represent different temperatures and rainfall patterns, as specified in Table 16.

The exposure scenario for runoff and sediment losses assumes that the pesticide is lost from the treated field and spread uniformly over an adjacent untreated field of the same size. This assumption is admittedly arbitrary. Much more severe exposures could occur if all of the runoff losses were distributed into a much smaller area. Conversely, lower exposures would occur if runoff losses were distributed from the treated field to a much larger area.

For fluazifop-P-butyl, the results of the standard GLEAMS modeling of runoff and sediment losses are summarized in Appendix 8 for a single application, Appendix 9 for two applications, and Appendix 10 for three applications. Note that amount of runoff and sediment loss will vary substantially with different types of climates—i.e., temperature and rainfall—as well as soils, with no or very little runoff or sediment loss anticipated in predominantly sandy soils. The input parameters used to estimate runoff and sediment losses are identical to those used in the Gleams-Driver modeling for concentrations of fluazifop-P-butyl in surface water as discussed in Section 3.2.3.4 and summarized in Table 17 (site characteristics) and Table 18 (chemical-specific input parameters).

For a single application, the runoff for fluazifop-P-butyl as a proportion of the application rate is taken as 0.0009 (0.00009 to 0.037). The central estimate and upper bound are taken directly from the Gleams-Driver modeling—i.e., the median and empirical upper 95% bound, as detailed in Appendix 8 (Table A8-1)—rounding all values to one significant place. The lower bound is effectively zero—i.e., for sandy soils regardless of temperature and rainfall rates. The lower bound value of 0.0009 is simply the central estimate divided by 10. Much lower loss rates are plausible—i.e., in areas with predominantly sandy soils, as discussed further in the risk characterization (Section 4.4.2.5.2).

For two applications, the runoff as a proportion of the application rate is taken as 0.002 (0.0002 to 0.06). For three applications, the runoff as a proportion of the application rate is taken as 0.0025 (0.00025 to 0.073). As with the single application, the central estimate and upper bound are taken directly from the Gleams-Driver modeling—i.e., the median and empirical upper 95% bound, as detailed in Appendix 9 (Table A9-1) for two applications and Appendix 10 (Table

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

4.2.4.4. Contaminated Irrigation Water

Forest Service risk assessments include this standard scenario for the use of contaminated water for irrigation. The exposure levels associated with this scenario depend on the pesticide concentration in the ambient water used for irrigation and the amount of irrigation water used. Concentrations in ambient water are based on the peak concentrations modeled in the human health risk assessment, as discussed in Section 3.2.3.4.6.

The amount of irrigation used will depend on the climate, soil type, topography, and plant species under cultivation. Thus, the selection of an irrigation rate is somewhat arbitrary. In the absence of any general approach for determining and expressing the variability of irrigation rates, the application of 1 inch of irrigation water with a range of 0.25 to 2 inches is used in this risk assessment. Details of the calculations used to estimate the functional application rates based on irrigation using contaminated surface water are provided in Worksheet G06a of the EXCEL workbooks for fluazifop-P-butyl (Attachments 1, 2 and 3).

While the labels and/or EPA documents for some herbicides specifically state that water potentially contaminated with herbicides should not be used for irrigation, no such language was identified on the product labels for Fusilade DX and Fusilade II.

4.2.4.5. Wind Erosion

Wind erosion can be a major transport mechanism for soil (e.g., Winegardner 1996), and wind erosion is also associated with the environmental transport of herbicides adsorbed to soil (Buser 1990). Wind erosion leading to off-site movement of pesticides is likely to be highly site-specific. The amount of fluazifop-P-butyl that might be transported by wind erosion depends on several factors, including application rate, depth of incorporation into the soil, persistence in the soil, wind speed, and topographical and surface conditions of the soil. Under desirable conditions—e.g., relatively deep (10 cm) soil incorporation, low wind speed, and surface conditions which inhibit wind erosion—it is unlikely that a substantial amount of fluazifop-P-butyl would be transported by wind.

For this risk assessment, the potential effects of wind erosion are estimated in Worksheet G06b in Attachments 1, 2 and 3. In this worksheet, it is assumed that fluazifop-P-butyl is incorporated into the top 1 cm of soil, which is identical to the depth of incorporation used in GLEAMS modeling (Table 18). Average soil losses are estimated to range from 1 to 10 tons/ha/year with a central estimate of 5 tons/ha/year. These estimates are based on the results of agricultural field studies which found that wind erosion may account for annual soil losses ranging from 2 to 6.5 metric tons/ha (Allen and Fryrear 1977).

As noted in Worksheet G06b, offsite losses are estimated to reach as much as 0.014% of the application rate. Larney et al. (1999), however, report that wind erosion of other herbicides could be associated with losses up to 1.5% of the nominal application rate following soil incorporation or 4.5% following surface application. This difference appears to be due to the much higher soil losses noted by Larney et al. (1999)—i.e., up to 56.6 metric tons/ha from a

fallow field. The losses reflected in Worksheet G06b may be somewhat more realistic for forest or rangeland applications, because forestry applications of herbicides are rarely made to fallow areas. As noted by Patric (1976), total soil erosion from all sources in well-managed forests is typically in the range of about 0.12-0.24 tons/ha/year [0.05 to 0.10 ton/acre/year], substantially below the range from 1 to 10 tons/ha/year used in Worksheet G06b. Thus, losses due to wind erosions following pesticide applications under forest canopies or heavily vegetated areas may be much less than the estimates used in this risk assessment.

In any event, the higher offsite losses reported by Larney et al. (1999) are comparable to exposures associated with offsite drift at distances of about 50 feet from the application site following low boom and high boom ground broadcast applications (Worksheet G05). All of the estimates for wind erosion and offsite drift are likely to vary dramatically according to site conditions and weather conditions.

4.2.5. Terrestrial Microorganisms

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

4.2.6. Aquatic Organisms

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

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).

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

4.3.2.2. Birds

4.3.2.2.1. Acute Exposures

The available toxicity studies in birds consist of standard assays submitted to the U.S. EPA/OPP in support of the registration of fluazifop-p-butyl (Section 4.1.2.2.1) as well as a few publications in the open literature (Section 4.1.2.2.2). The latter group of studies, however, is not useful for deriving toxicity values.

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 development of acute dietary risk quotients for birds (U.S. EPA/OPP/EFED 2008, p. 73, Table 4-4). As in the dose-response assessment for mammals, the Forest Service prefers to use acute NOAECs rather than LC_{50} values.

As summarized in Appendix 2 (Table A2-2), dietary NOAELs range from 2545 ppm a.e. in mallards (MRID 40859401) to 6996 ppm a.e. in pheasants (ECOTOX 2013). For the current Forest Service risk assessment, the lower NOAEL of 2545 ppm a.e. (2545 mg a.e./kg food) for mallards is used. No information is available on the food consumption during the mallard study. Taking a food consumption value of 0.42 kg food/kg body weight from an acute dietary study in mallards with aminopyralid (SERA 2007b), the dose for the mallards is taken as 1069 mg a.e./kg bw [2545 mg a.e./kg food x 0.42 kg food/kg body weight = 1068.9 mg a.e./kg bw]. Gavage dosing is more stressful to animals than dietary exposures; hence, NOAELS for gavage administration are generally lower than those for short-term dietary exposures. This is not the case with fluazifop-P-butyl.

As summarized in Appendix 2 (Table A2-1), a gavage NOAEL of about 3528 mg a.e./kg bw is available for mallards (MRID 40829201). Thus, the estimated NOAEL of 1069 mg a.e./kg bw from the dietary study may be viewed as conservative and perhaps overly so. Conversely, a concern with using default values for food consumption concerns the possible impact of fluazifop-butyl on food consumption in birds. Based on the DER for a different acute dietary study in mallards (MRID 00087481, Ross et al. 1980a), food consumption in mallards was substantially reduced at dietary concentrations of fluazifop-butyl as low as 6554 ppm (a.i.), corresponding to about 5600 ppm (a.e.). Food consumption data are not reported in the DERs or other study summaries for any of the acute dietary studies in birds. If food consumption were reduced in MRID 40829201, the dietary NOAEL expressed as mg a.e./kg bw would be underestimated.

4.3.2.2.2. Longer-term Exposures

As summarized in Appendix 2 (Table A2-3), the only longer-term studies in birds are the standard avian reproduction studies in mallards and quail, both of which yield a dietary NOAEL 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 in U.S. EPA/OPP/EFED (2008, p. 73, Table 4-4) in the development of chronic risk quotients for birds.

Based on the average of the reported food consumption and body weights for birds in the DERs for these studies, the dietary concentration of 43 mg a.e./kg food corresponds to about 4.9 mg a.e./kg bw/day for mallards and 3.3 mg a.e./kg bw/day for quail. For characterizing risks to birds associated with longer-term exposures, the somewhat lower NOAEL for quail is used in the current risk assessment.

4.3.2.3. Reptiles and Amphibians (Terrestrial Phase)

Since toxicity data are not available for terrestrial-phase reptiles or amphibians (Section 4.1.2.3), no dose-response assessment can be derived for these groups of organisms.

4.3.2.4. Terrestrial Invertebrates

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

4.3.2.4.1. Honeybee (Standard Surrogate Species)

As discussed in Section 4.1.2.4 and summarized in Appendix 3, standard oral and contact bioassays are available in honeybees. These studies are summarized in U.S. EPA/OPP/EFED 2008 (Appendix C), and additional details on NOAELs are available in ECOTOX. In the ecological risk assessment (U.S. EPA/OPP/EFED 2008, p. 73, Table 4-3), the EPA uses the acute contact LD_{50} of 63 µg a.i./bee (MRID 00162453) to estimate risk quotients for the consumption of contaminated vegetation and fruit by a terrestrial insect. As discussed in Section 4.1.2.4.1, ECOTOX indicates a NOAEL for this study of 200 µg/bee, which appears to be an error; accordingly, this NOAEL is not used in the current Forest Service risk assessment. In addition, the formulation used in this study (13.8% a.i.) corresponds to Fusilade Max but not formulations that will be used in Forest Service programs—i.e., 24.5% a.i. formulations such as Fusilade DX and Fusilade II. Consequently, the contact LD_{50} of 63 µg a.i./bee from MRID 00162453 is not used in the current Forest Service risk assessment because studies on other formulations more similar to those that might be used in Forest Service programs are available.

As with other receptors considered in the current risk assessment, the Forest Service prefers to use NOAELs rather than LD_{50} values for risk characterization (SERA 2009). For the current risk assessment, the oral NOAEL of 85.4 µg a.e./bee (MRID 00093809) for a 25% EC formulation of fluazifop-butyl is used to characterize risks associated with oral exposures. While the specific formulation used in this study is not identified, the 25% a.i. formulation is similar to formulations that might be used in Forest Service programs. Typical body weights for worker bees range from 81 to 151 mg (Winston 1987, p. 54). Taking 116 mg as an average body

weight, a dose of 85.4 µg/bee corresponds to about 736 mg a.e./kg bw [0.0854 mg a.e. ÷ 0.000116 kg ≈ 736.207 mg/kg bw].

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

4.3.2.4.2. Other Terrestrial Arthropods

In addition to the standard toxicity studies on the honeybee, additional data on terrestrial arthropods include what appear to be standard bioassays (Section 4.1.2.4.2; Appendix 3, Table A3-2) as well as field/mesocosm studies (Section 4.1.2.4.3; Appendix 3, Table A3-3). Most of the information on other terrestrial arthropods appears to have been generated after the recent EPA ecological risk assessments, (U.S. EPA/OPP/EFED 2008, 2010a), and the discussions of risks to insects in the EPA risk assessments include only the toxicity data on bees.

As discussed in Section 4.1.2.4.2, the most sensitive terrestrial arthropod (based on mortality) appears to be *Typhlodromus pyri* [Acarina: Phytoseiidae] with a reported LD_{50} of 5.6 g a.i./ha or about 0.004 lb a.e./acre (EFSA 2012). As noted in Appendix 3 (Table A3-2), this study involved Fusilade Max. As noted in the previous discussion of honeybees (Section 4.3.2.4.2), Fusilade Max appears to be more toxic than 25% a.i. formulations to the honeybee. In the absence of data on the effects of 25% a.i. formulations on *Typhlodromus pyri*, the studies on Fusilade Max from EFSA (2012) are used in the current risk assessment.

EFSA (2012) also reports another and a much higher LD_{50} of 174 g a.i./ha (≈0.13 lb a.e./acre) for *Typhlodromus pyri*. As noted in Section 4.1.2.4.2, EFSA (2012) does not discuss the discrepancy between the reported LD_{50} of 5.6 g a.i. and the much higher LD_{50} of 177 g a.i./ha (≈0.13 lb a.e./acre), presumably from the *extended laboratory studies*. The lower LD_{50} is about a factor of 74 higher than the application rate of 0.32 lb a.e./acre being considered by the Forest Service [0.32 lb a.e./acre ÷ 0.0043 lb a.e./acre ≈ 74.4186]. The higher LD_{50} is a factor of about 2.5 higher than this application rate [0.32 lb a.e./acre ÷ 0.13 lb a.e./acre ≈ 2.4615]. These differences obviously have a substantial impact on risk characterization.

The magnitude of the difference between the lower and higher LD_{50} values for *Typhlodromus 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 experiments (or sets of experiments) with *Typhlodromus pyri* are not available, the difference in the LD_{50} values between the two studies appears to be beyond the range of normal variability, and it seems likely that the two studies used different protocols. In the absence of additional information, the more relevant study cannot be identified. Consequently, the risk characterizations for potentially sensitive terrestrial insects will be based on both the lower LD_{50} 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 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 for *Aphidius rhopalosiphi* [Hymenoptera: Aphidiinae] reported in EFSA (2012).

Other species of terrestrial arthropods appear to be much more tolerant to fluazifop-P-butyl. Presumably, the increased mortality (21%) in larvae of the small cabbage white butterfly 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. ≈ 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 (≈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. ≈ 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.

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

4.3.2.6. Terrestrial Microorganisms

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

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

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

4.3.3.1.1. Acute Toxicity

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

4.3.3.1.2. Chronic Toxicity

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

(i.e., fathead minnows appear to be sensitive species based on acute toxicity studies), the longer-term NOAEC in fathead minnows is applied to sensitive species.

U.S. EPA/OPP/EFED (2008, pp. 72) uses a relative potency method to approximate a longer-term NOAEC of 4.3 mg a.e./L in sheepshead minnow. As detailed in U.S. EPA/OPP/EFED (2008, p. 23, footnote 1), this approximation involves multiplying the longer-term NOAEC in the fathead minnow by the ratio of the lowest LC_{50} in sheepshead minnows (6.86 mg a.e./L) to the corresponding LC_{50} in 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 current risk assessment. As detailed further in Section 4.4.3.1, none of the longer-term exposures in fish exceed the level of concern for the presumably sensitive species. Thus, an extrapolated elaboration for presumably tolerant species of fish is unnecessary.

4.3.3.2. Amphibians

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

4.3.3.3. Aquatic Invertebrates

4.3.3.3.1. Acute Toxicity

U.S. EPA/OPP/EFED (2008, pp. 71-72) uses an EC_{50} value of 5.14 mg a.e./L (*Daphnia magna*, MRID 00087489) for characterizing risks to sensitive species of freshwater invertebrates and an EC_{50} value of 0.083 mg a.e./L (Pacific oyster, MRID 00131460, 98.6% fluazifop-butyl) for assessing risks to sensitive species of aquatic invertebrates.

As summarized in Table 28, acute toxicity data are available on one species of freshwater invertebrate (*Daphnia magna*) and five species of saltwater/estuarine invertebrates (Pacific oyster, American oyster, fiddler crab, pink shrimp and opossum shrimp). Given the much larger number of aquatic invertebrates that might be exposed to any pesticide, Forest Service risk assessments will typically identify the most sensitive and most tolerant invertebrates on which data are available as representative of sensitive and tolerant organisms in freshwater and saltwater.

Based on the EC_{50} values, the most sensitive species is the Pacific oyster. Rather than using the 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 modestly lower NOAEC of 0.041 mg a.e./L is reported for opossum shrimp (MRID 00093806). The difference between these two NOAECs is insubstantial and preference is given to the NOAEC for the Pacific oyster both to maintain consistency with the EPA study selection and because EC_{50} values are preferable to NOAECs in ranking species sensitivities. In the absence of additional details on the studies in question—e.g., the number and spacing of concentrations tested—this approach seems reasonable.

The highest acute EC_{50} values are reported for bioassays of technical grade fluazifop-butyl and fluazifop-P-butyl in *Daphnia magna*—i.e., EC_{50} values of >200 mg a.e./L as summarized in Table 28. Unlike the case with fish, however, the available data indicate that fluazifop-P-butyl formulations are much more toxic (i.e., EC_{50} values in the range of 1.79 to 5.14 mg a.e./L) than 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.

4.4. RISK CHARACTERIZATION

4.4.1. Overview

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 (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 to 57 for a small bird and 146 for a small mammal. Following one or two applications, the central estimates of 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 are 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 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.

4.4.2. Terrestrial Organisms

4.4.2.1. Mammals

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

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

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

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

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

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

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

[200 ÷ 50]. The LOAEL is based on diaphragmatic hernias in offspring. The acute exceedances might be associated with conditions that could impair the ability of offspring to survive and/or develop normally; however, overt signs of toxicity would probably not be observed. Acute HQs at or above 4 are noted only at upper bound exposures for the small mammal consuming broadleaf vegetation (HQ=4) or short grass (HQ=7).

The acute risk characterization given above for acute exposure scenarios is not consistent with U.S. EPA/OPP/EFED (2008, p. 7) which notes that …*no acute risks are expected for mammals*. As discussed in Section 4.3.2.1, a major difference between the current Forest Service risk assessment and the EPA risk assessment is the EPA's use of an acute oral LD_{50} of 1940 mg a.i./kg bw (MIRD 00162439) for risk characterization, which is about 39 times greater than the acute NOAEL 50 mg a.i./kg bw used in the current risk assessment [1940 mg a.i./kg bw ÷ 50 mg a.i./kg bw = 38.8].

As also summarized in Table 22, the longer-term NOAEL of 0.74 mg a.i./kg bw/day is associated with a LOAEL of 5.8 mg a.i./kg bw/day, with a corresponding HQ of about 8 [5.8 mg a.i./kg bw/day ÷ 0.74 mg a.i./kg bw/day ≈ 7.838]. The chronic LOAEL is associated with decreased testes weight in male offspring. This chronic exceedance could be associated with diminished reproductive capacity. As with the acute exceedances, there would be no expectation of overt signs of toxicity.

The risk characterization for longer-term exposures discussed above is reasonably consistent with U.S. EPA/OPP/EFED (2008, p. 7) which notes that … *the chronic mammalian RQ* [risk quotient] *values exceed the Agency's LOC* [level of concern] *for all proposed uses except for mammals feeding only on fruits, pods, large insects or seeds.* The minor differences between the current risk assessment and the EPA risk assessment reflect differences in the mammalian receptors that are considered and the methods used to estimate food consumption.

As discussed in Section 4.2.2.3, the exposure assessments for mammalian wildlife assume that 100% of the diet of the receptor is contaminated. For some mammals, particularly the canid and the 70 kg mammal, this assumption might be conservative and in some cases extremely conservative for longer-term exposures if only moderate or small areas are treated with fluazifop-P-butyl. In such cases, the receptors could move in and out of the treated areas and a small proportion of the diet would be contaminated. Given the magnitude of the HQs, however, these considerations do not have a substantial impact on the risk characterization.

4.4.2.2. Birds

Table 35 gives an overview of the risk characterization for birds associated with acute and longer-term exposure scenarios following three applications of fluazifop-P-butyl. This table is taken from Worksheet G02b of Attachment 3.

As with the corresponding table for mammals (Table 34), Table 35 does not include the accidental exposure scenarios. For birds, all of the accidental exposure scenarios are below the level of concern (HQ=1). The highest accidental HQ for birds is 0.6, the upper bound HQ for the consumption of contaminated fish by a piscivorous bird.

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.

4.4.3. Aquatic Organisms

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

4.4.3.1. Fish

As summarized in Table 37, the HQs for fish are below the level of concern (HQ=1), except for the accidental exposure scenarios.

The upper bounds of the HQs for the accidental spill scenarios are 25 for sensitive species of fish and 9 for tolerant species of fish. As detailed in Worksheet B04b of the attachments to this risk assessment, the upper bound HQs are based on a water concentration of about 5.8 mg a.e./L fluazifop-P-butyl. As summarized in Table 27, the acute LC_{50} values for technical grade fluazifop-butyl and formulations of fluazifop-butyl range from about 0.25 mg a.e./L (Tejada et al. 1994) to 4.2 mg a.e./L (MRID 00087484). In the event of a serious accidental spill similar to that developed in the current risk assessment (Section 3.2.3.4.1), fish mortality would probably be observed.

For the non-accidental exposures, none of the HQs exceed the level of concern. The highest HQ is 0.7—i.e., the upper bound of the acute HQ for sensitive species of fish following three applications of fluazifop-P-butyl. There is no basis for asserting that fish will be adversely impacted due to exposures to fluazifop-P-butyl anticipated in the normal use of this herbicide in Forest Service programs.

Some of the HQs for two and three applications are identical in Table 37. This is also true for other groups of organisms discussed below. As discussed in Section 4.4.2.5.3, the identical HQs for two and three applications is an artifact of rounding—i.e., HQs below 1 are rounded to the nearest significant decimal. For example, the upper bound HQs for tolerant species of fish following two and three applications are both 0.2. The underlying value in the G03 worksheets is 0.192941176 for two applications and 0.221176471 for three applications. Other such similarities are not discussed further in the following sections for other groups of aquatic organisms; nonetheless, the differences in the underlying value can be verified by an examination of the G03 worksheet in the attachments.

4.4.3.2. Amphibians

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

4.4.3.3. Aquatic Invertebrates

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

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

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

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

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

4.4.3.4. Aquatic Plants

4.4.3.4.1. Algae

As detailed in Section 4.3.3.4.1 (the dose-response assessment for algae), the toxicity data on algae are highly variable, which may 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 of the bioassays on algae. Another limitation with the data on algae is that few NOAECs are available (Table 30). Thus, for both sensitive and tolerant species, NOAECs are estimated by dividing the EC_{50} values by a factor of 20 (SERA 2011a, Section 4.3.2, p. 98). While this procedure is a standard practice in Forest Service risk

assessments and is consistent with the approach used by U.S. EPA/OPP/EFED, the use of this method introduces additional uncertainties into the dose-response assessment, which carry over to the risk characterization.

Within the above limitations, which are substantial, the HQs for algae (Table 39) suggest that sensitive species of algae could be adversely affected by fluazifop-P-butyl based on the central estimates of the non-accidental HQs (which range from 2 to 16) and the upper bounds of the HQs (which range from 27 to 150).

The acute concentrations of fluazifop-P-butyl in water associated with the central estimates of the HQs range from about 0.0064 mg a.e./L (central estimate for one application) to 0.15 mg a.e./L (upper bound, three applications). As summarized in Table 30, the reported EC_{50} values for algae range from 0.02 to 22.8 mg a.e./L. It appears that tolerant species of algae would not be exposed to fluazifop-P-butyl at a sufficient level to cause detectable adverse effects. In some cases, however, sensitive species could be adversely affected to the extent that their populations might decrease.

The longer-term HQs for algae are associated with longer-term concentrations of fluazifop-P-butyl in water in the range from about 0.0024 mg a.e./L (central estimate for one application) to 0.064 mg a.e./L (upper bound, three applications). Only the upper bound concentrations would appear to pose a longer-term risk to sensitive species of algae. As discussed in Section 3.2.3.4.3, the concentrations of fluazifop-P-butyl in water used in the current risk assessment are based on modeling nine different locations with substantially different climates. In specific applications of fluazifop-P-butyl, site-specific modeling would be necessary to better characterize potential impacts on sensitive species of algae.

4.4.3.4.2. Macrophytes

As discussed in Section 4.3.3.4.2, toxicity data on aquatic macrophytes are limited to bioassays on *Lemna*, a monocot but not a true grass. As summarized in Table 40, all HQs for this presumably tolerant genus of aquatic plants are well-below the level of concern. The upper bound of the HQ for the accidental spill is 0.02—i.e., below the level of concern by a factor of 50. As with the risk characterization for terrestrial non-Poaceae monocots and terrestrial dicots, there is no basis for asserting that applications of fluazifop-P-butyl would adversely impact *Lemna*. By analogy to tolerant terrestrial plants, the largely benign risk characterization for *Lemna* may apply to other non-Poaceae aquatic monocots as well as aquatic dicots.

The lack of data on aquatic Poaceae monocots, however, is a concern. In the absence of toxicity data on aquatic Poaceae monocots (e.g. Crow and Hellquist 2000; Martínez-y-Pérez et al. 2007), however, this concern cannot be further elaborated.

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**

{Abdel-Aal and El-Haroun 1990} Abdel-Aal SM; El-Haroun MS. 1990. Efficiency of Some Herbicides on Weed Control and Yield of Onion (*Allium cepa*, L.). Egyptian Journal of Agronomy. 15(1-2): 35-44. [Set01 - ToxL Fluazifop Full]

{Abdel-Mallek et al. 1996} Abdel-Mallek AY; Abdel-Kader M IA; Omar SA. 1996. Effect of the Herbicide Fluazifop-Butyl on Fungal Populations and Activity in Soil. Water Air and Soil Pollution. 86 (1-4): 151-157. [Set01 - ToxL Fluazifop Full]

{Abell 1996} Abell LM. 1996. Biochemical Approaches to Herbicide Discovery: Advances in Enzyme Target Identification and Inhibitor Design. Weed Science. 44 (3): 734-742. [Toxline01 - Clethodim]

{Agnello et al. 1986} Agnello AM; Bradley J R JR; Van Duyn JW. 1986. Plant-Mediated Effects of Postemergence Herbicides on *Pseudoplusia-includens*. Journal of Agricultural Entomology. 3 (1): 61-65. [Set01 - ToxL Fluazifop Full]

{Agnello et al. 1986a} Agnello AM; Bradley J R JR; Van Duyn JW. 1986a. Plant-Mediated Effects of Postemergence Herbicides on *Epilachna-varivestis* Coleoptera Coccinellidae. Environmental Entomology. 15 (1): 216-220. [Set01 - ToxL Fluazifop Full/ ECOTOX]

{Agnello et al. 1986b} Agnello AM; Van Duyn JW; Bradley J R JR. 1986b. Influence of Postemergence Herbicides on Populations of Bean Leaf Beetle *Cerotoma-trifurcata* Coleoptera Chrysomelidae and Corn Earworm *Heliothis-zea* Lepidoptera Noctuidae in Soybeans *Glycine-max*. Journal of Economic Entomology. 79 (1): 261-265. [Set01 - ToxL Fluazifop Full]

{Alarcón-Reverte and Moss 2008} Alarcón-Reverte R; Moss SR. 2008. Resistance to ACCase-Inhibiting Herbicides in the Weed *Lolium multiflorum*. Communications in Agricultural and Applied Biological Sciences. 73(4):899-902. [Set01 - ToxL Fluazifop Full]

{Allen and Fryrear. 1977} Allen RR; Fryrear DW. 1977. Limited tillage saves soil, water, and energy. ASAE Annual Meeting, NC State Univ., Raleigh, NC. June 26-29, 1977. 14 pp. [Std]

{ASABE 2013} ASABE (American Society of Agricultural and Biological Engineers). 2013. ANSI/ASAE S572.1 W/Corr. 1 MAR2009 (R2013). Spray Nozzle Classification by Droplet Spectra. 6 pp. [Std]

{Atkinson et al. 2008} Atkinson D; Burnett F; Foster GN; Litterrick A; Mullay M; Watson CA. 2008. The Minimisation of Pesticide Residues in Food : A Review of the Published Literature. Scottish Agriculture College, West Mains Road, Edinburgh, EH9 3JG. Available at: www.food.gov.uk/multimedia/pdfs/pesticideslitreview.pdf. [Set00]

{ATSDR 1995} ATSDR (Agency for Toxic Substances and Disease Registry). 1995. Toxicological Profile for Fuel Oils. Available from U.S. Department of Health and Human Services, Public Health Service, ATSDR, Division of Toxicology. Available at: http://www.atsdr.cdc.gov/. [Set 00]

{ATSDR 1999} ATSDR (Agency for Toxic Substances and Disease Registry). 1999. Toxicological Profile for Total Petroleum Hydrocarbons (TPH). Document dated September 1999. Available from U.S. Department of Health and Human Services, Public Health Service, ATSDR, Division of Toxicology. Available at: http://www.atsdr.cdc.gov/. [Set 00]

{ATSDR 2002} ATSDR (Agency for Toxic Substances and Disease Registry). 2002. Exposure Investigation Spring Valley Neighborhood. Available at: http://www.atsdr.cdc.gov/sites/ springvalley/mar02ei.html. [Std]

{Auton et al. 1993a} Auton TR; Ramsey JD; Woollen BH. 1993a. Modeling Dermal Pharmacokinetics Using *in vitro* Data. Part I. Fluazifop-Butyl in the Rat. Human and Experimental Toxicology. 12(3):199-206. [Set01 - ToxL Fluazifop Full]

{Auton et al. 1993b} Auton TR; Ramsey JD; Woollen BH. 1993b. Modeling Dermal Pharmacokinetics Using *in vitro* Data. Part II. Fluazifop-Butyl in Man. Human and Experimental Toxicology. 12(3):207-213. [Set01 - ToxL Fluazifop Full]

{Auton et al. 1994} Auton TR; Westhead DR; Woollen BH; Scott RC; Wilks MF. 1994. A Physiologically Based Mathematical Model of Dermal Absorption in Man. Human and Experimental Toxicology. 13(1): 51-60. [Set01 - ToxL Fluazifop Full]

{Bakke 2013} Bakke D. 2013. Comments on preliminary Program Description for Fluazifop-P-butyl (SERA TR-056-05-02-01a) via email dated December 16, 2013. [FS01]

{Baldos 2009} Baldos OC. 2009. Assessment of Hydroplanting Techniques and Herbicide Tolerance of Two Native Hawaiian Groundcovers with Roadside Re-Vegetation Potential. M.S.Thesis, University of Hawaii at Manoa, HI:149 p. Available at: http://www.ctahr.hawaii.edu/defrankJ/Text%20resources/Native_Plant_Weed_Control_2007/baldos_final_MS_manuscript.pdf. [Set01 – ECOTOX – Fluazifop-P-butyl]

{Balinova and Lalova 1992} Balinova AM; Lalova MP. 1992. Translocation, Metabolism and Residues of Fluazifop-Butyl in Soybean Plants. Weed Research. 32 (2): 143-147. [Set01 - ToxL Fluazifop Full]

{Balyan and Malik 1991} Balyan RS; Malik RK. 1991. Barnyard Grass (*Echinochloa crus* Galli) Control Efficacy of Post-Emergence Herbicides with and without Surfactant in Green Gram (*Phaseolus radiatus*). Indian Journal of Agronomy. 36 (3): 354-356. [Set01 - ToxL Fluazifop Full]

{Banks and Tripp 1983} Banks PA; Tripp TN. 1983. Control of Johnsongrass (*Sorghum halepense*) in Soybeans (*Glycine max*) with Foliar-Applied Herbicides. Weed Science. 31:628-633. [Set01 – ECOTOX – Fluazifop-butyl]

{Barnwell and Cobb 1993} Barnwell P; Cobb AH. 1993. An Investigation of Aryloxyphenoxypropionate Antagonism of Auxin-Type Herbicide Action of Proton-Efflux. Pesticide Biochemistry and Physiology. 47 (2): 87-97. [Set01 - ToxL Fluazifop Full]

{Beckie and Morrison 1993} Beckie HJ; Morrison IN. 1993. Effect of Ethalfluralin and Other Herbicides on Trifluralin-Resistant Green Foxtail (*Setaria viridis*). Weed Technology. 7(1): 6-14. [Set01 – ECOTOX - Fluazifop]

{Belander and Winch 1985} Belander G; Winch JE. 1985. Herbicides for Sod-Seeding Legumes on Shallow Soil Pastures. Canadian Journal of Plant Science. 65(4): 1049-1055. [Set01 – ECOTOX – Fluazifop-butyl]

{Bell et al. 1998} Bell GA; Formstone CA; Hammond J HN; Sohm RH. 1998. The Development and Herbicidal Activity of Adjuvant-Containing Water-Dispersible Granule Formulations of Fluazifop-P-Butyl. Pesticide Science. 54 (4): 401-407. [Set01 - ToxL Fluazifop Full]

{Bewick 1986} Bewick DW. 1986. Stereochemistry of Fluazifop-Butyl Transformations in Soil. Pesticide Science. 17 (4): 349-356. [Set01 - ToxL Fluazifop Full]

{Beyer et al. 1994} Beyer WN; Connor EE; Gerould S. 1994. Estimates of Soil Ingestion by Wildlife. Journal of Wildlife Management. 58(2): 375-382. [Set02]

{Blake et al. 2011a } Blake RJ; Woodcock BA; Westbury DB; Sutton P; Potts SG. 2011a. New Tools to Boost Butterfly Habitat Quality in Existing Grass Buffer Strips. Journal of Insect Conservation. 15: 221-232. [Set03]

{Blake et al. 2011b } [Set03] Blake RJ; Woodcock BA; Westbury DB; Sutton P; Potts S. 2011b. Enhancing Habitat to Help the Plight of the Bumblebee. Pest Management Science. 67: 377-379. [Set03]

{Blake et al. 2012} Blake RJ; Westbury DB; Woodcock BA; Sutton P; Potts SG. 2012. Investigating the Phytotoxicity of the Graminicide Fluazifop-P-Butyl against Native UK Wildflower Species. Pest Management Science. 68(3):412-21. [Set01 - ToxL Fluazifop Full]

{Bohannan and Jordan 1995} Bohannan DR; Jordan TN. 1995. Effects of Ultra-Low Volume Application on Herbicide Efficacy Using Oil Diluents as Carriers. Weed Technology. 9 (4): 682-688. [SET01 - Toxline01 - Clethodim]

{Boucounis and Ogle 1985} Boucounis TG; Ogle WL. 1985. The Use of Fluazifop-Butyl in a Systematic Approach to Weed Control in Vegetable Crops. Hortscience. 20 (4): 666. [Set01 - ToxL Fluazifop Full]

{Boucounis et al. 1988} Boucounis TG; Whitwell T; Ogle WL. 1988. Growth of Five Vegetables Crops Treated with the Herbicide Fluazifop in a Greenhouse. Hortscience. 23 (4): 771. [Set01 - ToxL Fluazifop Full]

{Bradley and Hagood 2001} Bradley KW; Hagood ES. 2001. Identification of a Johnsongrass (*Sorghum halepense*) Biotype Resistant to Aryloxyphenoxypropionate and Cyclohexanedione Herbicides in Virginia. Weed Technology. 15(4): 623-627. [Set01 – ECOTOX – Fluazifop-P]

{Bromilow et al. 1990} Bromilow, RH; Chamberlain, K; Evans, AA. 1990. Physicochemical aspects of phloem translocation of herbicides. Weed Sci. 38: 305-314.[Std]

{Brudenell a et al. 1995} Brudenell a JP; Baker DA; Grayson BT. 1995. Phloem Mobility of Xenobiotics: Tabular Review of Physicochemical Properties Governing the Output of the Kleier Model. Plant Growth Regulation. 16 (3): 215-231. [Std]

{Buhler and Burnside 1984a} Buhler DD; Burnside OC. 1984a. Effect of Application Factors on Postemergence Phytotoxicity of Fluazifop-Butyl, Haloxyfop-Methyl, and Sethoxydim. Weed Science. 32 (5): 574-583. [Set01 - ToxL Fluazifop Full]

{Buhler and Burnside 1984b} Buhler DD; Burnside OC. 1984b. Herbicidal Activity of Fluazifop-Butyl, Haloxyfop-Methyl, and Sethoxydim in Soil. Weed Science. 32:824-831. [Set01 – ECOTOX – Fluazifop-butyl]

{Burden et al. 1990} Burden RS; Cooke DT; Hargreaves JA. 1990. Review: Mechanism of Action of Herbicidal and Fungicidal Compounds on Cell Membranes. Pesticide Science. 30 (2): 125-140. [Set01 - ToxL Fluazifop Full]

{Burke et al. 2006a} Burke IC; Wilcut JW; Cranmer J. 2006a. Cross-Resistance of a Johnsongrass (*Sorghum halepense*) Biotype to Aryloxyphenoxypropionate and Cyclohexanedione Herbicides. Weed Technology. 20(3): 571-575. [Set01 – ECOTOX – Fluazifop-P-butyl]

{Burke et al. 2006b} Burke IC: Thomas WE; Burton JD; Spears JF; Wilcut JW. 2006. A Seedling Assay to Screen Aryloxyphenoxypropionic Acid and Cyclohexanedione Resistance in Johnsongrass (*Sorghum halepense*). Weed Technology. 20(4): 950-955. [Set01 – ECOTOX – Fluazifop-P]

{Burton et al. 1989} Burton JD; Gronwald JW; Somers DA; Gengenbach BG; Wyse DL. 1989. Inhibition of Corn Acetyl Coenzyme a Carboxylase by Cyclohexanedione and Aryloxyphenoxypropionate Herbicides. Pesticide Biochemistry and Physiology. 34 (1): 76-85. [SET01 - Toxline01 - Clethodim]

{Buser 1990} Buser HR. 1990. Atrazine and other s-triazine herbicides in lakes and in rain in Switzerland. Environ. Sci. Technol. 24(7): 1049-1058. [Std]

{Calabrese and Baldwin. 1993} Calabrese EJ; Baldwin LA. 1993. Performing Ecological Risk Assessments. Lewis Publishers, Boca Raton, LA, pp. 12-24. [Std]

{CalEPA 2002} CalEPA (California Environmental Protection Agency). 2002. California Environmental Protection Agency, Department Of Pesticide Regulation, Medical Toxicology Branch, Summary of Toxicology Data, Fluazifop-P-Butyl. Document dated May 20, 2003. Available at: http://www.fluoridealert.org/pesticides/fluazifop-p-butyl.caepa.02.pdf. [Set00]

{Calkins et al. 1996} Calkins JB; Swanson BT; Newman DL. 1996. Weed Control Strategies for Field Grown Herbaceous Perennials. Journal of Environmental Horticulture. 14(4): 221-227. [Set01 – ECOTOX – Fluazifop-butyl]

{Carr 1986a} Carr JE. 1986a. The Uptake Translocation and Metabolism of Fluazifop-Butyl. Pesticide Science. 17(1): 58-59. [Set01 - ToxL Fluazifop Full]

{Carr 1986b} Carr JE. 1998b. Physiological effects of the herbicide fluazifop-butyl. Ph.D. Thesis, Trent Polytechnic, Nottingham Trent University. NAL unable to supply copy. [Set02 – ToxL Fluazifop Full]

{Carr et al. 1986} Carr JE; Davies LG; Cobb AH; Pallett KE. 1986. Uptake, Translocation and Metabolism of Fluazifop-Butyl in *Setaria viridis*. Annals of Applied Biology. 108 (1): 115-124. [Set01 - ToxL Fluazifop Full]

{Catanzaro et al. 1993a} Catanzaro CJ; Burton JD; Skroch WA. 1993a. Graminicide Resistance of Acetyl-CoA Carboxylase from Ornamental Grasses. Pesticide Biochemistry and Physiology. 45(2):147-153. [Set01 - ToxL Fluazifop Full]

{Catanzaro et al. 1993b} Catanzaro CJ; Skroch WA; Burton JD. 1993b. Resistance of Selected Ornamental Grasses to Graminicides. Weed Technology. 7 (2): 326-330. [Set01 - ToxL Fluazifop Full]

{CDPR 2013} CDPR (California Department of Pesticide Regulation). 2013. Summary of Pesticide Use Report Data 2011, Indexed by Chemical. Report dated June 2013. Available at: http://www.cdpr.ca.gov/docs/pur/pur11rep/chmrpt11.pdf. [Std]

{CFR 2002} CFR (Code of Federal Regulations). 2002. U.S. EPA. Code of Federal Regulations § 180.1001 Exemptions from the requirement of a tolerance. pp. 509-543. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2002-title40-vol20/pdf/CFR-2002-title40-vol20-sec180-1001.pdf. [Std]

{Chamberlain et al. 1996} Chamberlain K; Evans AA; Bromilow RH. 1996. 1-Octanol/water Partition Coefficient (Kow) and pK_a for Ionizable Pesticides Measured by a pH-Metric Method. Pesticide Science. 47(3):265-271. [Set01 - ToxL Fluazifop Full]

{Chandrasena and Sagar 1986a} Chandrasena NR; Sagar GR. 1986a. Some Factors Affecting the Performance of Fluazifop-Butyl Against *Elymus repens* (Equals *Agropyron repens*). Weed Research. 26(2):139-148. [Set01 - ToxL Fluazifop Full]

{Chandrasena and Sagar 1986b} Chandrasena NR; Sagar GR. 1986b. Uptake and Translocation of Carbon-14 Fluazifop by Quackgrass *Agropyron-repens*. Weed Science. 34 (5): 676-684. [Set01 - ToxL Fluazifop Full]

{Chandrasena and Sagar 1987} Chandrasena NR; Sagar GR. 1987. The Effect of Site Application of Carbon-14 Fluazifop on its Uptake and Translocation by Quackgrass Agropyron-repens. Weed Science. 35(4):457-462. [Set01 - ToxL Fluazifop Full]

{ChemIDplus 2013} ChemIDplus. 2013. United States National Library of Medicine. Available at: http://chem.sis.nlm.nih.gov/chemidplus/. [Std]

{Chernicky and Slife 1986} Chernicky JP; Slife FW. 1986. Effects of Sublethal Concentrations of Bentazon, Fluazifop, Haloxyfop and Sethoxydim on *Corn Zea-mays* Cultivar Pioneer-3377. Weed Science. 34 (2): 171-174. [Set01 - ToxL Fluazifop Full]

{Chester and Hart 1986} Chester G; Hart TB. 1986. Biological Monitoring of a Herbicide Applied Through Backpack and Vehicle Sprayers. Toxicology Letters. 33(1-3):137-149. [Set01 - ToxL Fluazifop Full]

{Chronopoulou et al. 2012} Chronopoulou E; Madesis P; Asimakopoulou B; Platis D; Tsaftaris A; Labrou NE. 2012. Catalytic and Structural Diversity of the Fluazifop-Inducible Glutathione Transferases from *Phaseolus vulgaris*. Planta (Springer). 235(6):1253-69. [Set01 - ToxL Fluazifop Full]

{Cisar and Jagschitz 1984a} Cisar JL; Jagschitz JA. 1984a. Turfgrass Tolerance to Post- and Preemergence Herbicides. Proceedings of the Northeast Weed Science Society. 38:298-302. [Set01 – ECOTOX – Fluazifop-butyl]

{Cisar and Jagschitz 1984b} Cisar JL; Jagschitz JA. 1984b Postemergence Control of Smooth Crabgrass in Lawn Turf. Proceedings of the Northeast Weed Science Society. 38:276-280. [Set01 – ECOTOX – Fluazifop-butyl]

{Clark 2012} Clark J. 2012. ChemGuide. Stereoisomerism – Optical Isomerism. Available at: http://www.chemguide.co.uk/basicorg/isomerism/optical.html. [Std]

{Clark et al. 1993} Clark NW; Scott RC; Blain PG; Williams FM. 1993. Fate of Fluazifop Butyl in Rat and Human Skin *in vitro*. Archives of Toxicology. 67(1):44-8. [Set01 - ToxL Fluazifop Full]

{Clarke et al. 1998} Clarke ED; Greenhow DT; Adams D. 1998. Metabolism-Related Assays and Their Application to Agrochemical Research: Reactivity of Pesticides with Glutathione and Glutathione Transferases. Pesticide Science. 54(4):385-393. [Set01 - ToxL Fluazifop Full]

{Clay et al. 1990} Clay DV; Lawrie J; Hertz LB. 1990. Effects of Repeated Applications of Fluazifop-Butyl, Haloxyfop and Sethoxydim on *Elymus repens* in Strawberries. Weed Research. 30 (6): 439-448. [Set01 - ToxL Fluazifop Full]

{Clegg 1987} Clegg BS. 1987. Gas Chromatographic Analysis of Fluazifop-Butyl Fusilade in Potatoes Soybeans and Soil. Journal of Agricultural and Food Chemistry. 35 (2): 269-273. [Set01 - ToxL Fluazifop Full]

{Clydesdale 1997} Clydesdale, FM. 1997. Food Additives: Toxicology, Regulation, and Properties. CRC Press, Boca Raton, Florida. CD-ROM Database. [Std]

{Cocker et al. 2001} Cocker KM; Northcroft DS; Coleman JO; Moss SR. 2001. Resistance to ACCase-Inhibiting Herbicides and Isoproturon in UK Populations of *Lolium multiflorum*: Mechanisms of Resistance and Implications for Control. Pest Management Science. 57(7):587-97. [Set01 - ToxL Fluazifop Full]

{Coon 2005}Coon MJ. 2005. Cytochrome P450: Nature's Most Versatile Biological Catalyst. Annual Review of Pharmacology and Toxicology. 45: 1-25. [Std]

{Coupe et al. 1998} Coupe RH; Thurman EM; Zimmerman LR. 1998. Relation of Usage to the Occurrence of Cotton and Rice Herbicides in Three Streams of the Mississippi Delta. Environmental Science and Technology. 32 (23): 3673-3680. [Set01 - ToxL Fluazifop Full]

{Crow and Hellquist 2000} Crow GE; Hellquist CB. 2000. Aquatic and Wetland Plants of Northeastern North America. 1st Edition. Volume 2: Angiosperms: Monocotyledons. University of Wisconsin Press. 464 pp. [Std]

{Daly et al. 2007} Daly GL; Lei YD; Teixeira C; Muir DCG; Wania F. 2007. Pesticides in Western Canadian mountain air and soil. Environmental Science and Technology. 41: 6020-6025. [Set02]

{Davy and Francis 1987} Davy GS; Francis PD. 1987. Separation of the Enantiomers of Fluazifop and Other 2 Phenoxypropionic Acids Using Chiral Metal Chelate Additives in Reversed-Phase High-Performance Liquid Chromatography. Journal of Chromatography. 394 (2): 323-332. [Set01 - ToxL Fluazifop Full]

{De Freitas Bueno et al. 2008} De Freitas Bueno A; De Freitas Bueno RCO; Parra JRP; Vieira SS. 2008. Effects of Pesticides Used in Soybean Crops to the Egg Parasitoid *Trichogramma pretiosum*. Ciencia Rural. 38(6): 1495-1503. [Set01 – ECOTOX – Fluazifop-butyl]

{Defrank 1990} Defrank J. 1990. The Response of Nine *Protea* Species to Spray Applications of Fluazifop-P. Tropical Pest Management. 36 (2): 145-146. [Set01 - ToxL Fluazifop Full]

{Dekker and Chandler 1985} Dekker JH; Chandler K. 1985. Herbicide Effect on the Viability of Quackgrass (*Agropyron repens*) Rhizome Buds. Canadian Journal of Plant Science. 65(4): 1057-1064. [Set01 – ECOTOX – Fluazifop-butyl]

{Derr et al. 1985a} Derr JF; Monaco TJ; Sheets TJ. 1985a. Uptake and Translocation of Fluazifop by Three Annual Grasses. Weed Science. 33 (5): 612-617. [Set01 - ToxL Fluazifop Full]

{Derr et al. 1985b} Derr JF; Monaco TJ; Sheets TJ. 1985b. Metabolites Recovered in Nutrient Solution Following Root and Shoot Application of the Butyl Ester of Carbon-14-Labeled Fluazifop. Virginia Journal of Science. 36(4):299-305. [Set01 - ToxL Fluazifop Full]

{Derr et al. 1985c} Derr JF; Monaco TJ; Sheets TJ. 1985c. Response of Three Annual Grasses to Fluazifop. Weed Science. 33 (5): 693-697. [Set01 - ToxL Fluazifop Full]

{Dick and Scott 1992} Dick IP; Scott RC. 1992. Pig Ear Skin as an *in vitro* Model for Human Skin Permeability. Journal of Pharmacy and Pharmacology. 44 (8): 640-645. [Set01 - ToxL Fluazifop Full]

{Doohan et al. 1986} Doohan DJ; Monaco TJ; Sheets TJ; Leidy RB. 1986. Residues and Efficacy and Fluazifop-Butyl in Strawberries. Weed Research. 26 (2): 89-98. [Set01 - ToxL Fluazifop Full]

{Dotray et al. 1993} Dotray PA; Ditomaso JM; Gronwald JW; Wyse DL; Kochian LV. 1993. Effects of Acetyl-Coenzyme a Carboxylase Inhibitors on Root Cell Transmembrane Electric Potentials in Graminicide-Tolerant and -Susceptible Corn (Zea mays L.). Plant Physiology (Rockville). 103 (3): 919-924. [Clethodim - SET01 - Toxline01]

{Dunning. 1993} Dunning JB. 1993. CRC Handbook of Avian Body Masses. CRC Press, Boca Raton FL, 371 pp.[Std]

{Durkin et al. 1995} Durkin PR; Rubin L; Withey J; Meylan W. 1995. Methods of assessing dermal absorption with emphasis on uptake from contaminated vegetation. Toxicol. Indust. Health. 11(1): 63-79.[Std]

{Ecobichon. 1998} Ecobichon DJ. 1998. Occupational Hazards of Pesticide Exposure – Sampling, Monitoring, Measuring. Taylor & Francis, Philadelphia, PA. 251 pp.[Std]

{ECOTOX 2013} ECOTOX 2013) ECOTOX Release 4.0. The ECOTOX (ECOTOXicology) Database. Database maintained by U.S. EPA. Available at: http://cfpub.epa.gov/ecotox/. [Std]

{Edwards et al. 1981} Edwards PJ; Brown SM; Hamer MJ; Tummon OJ; Sealey C. 1981. Fluazifop butyl: 21 Day *Daphnia magna* life-cycle study. Report Series No. R J 0209B. (unpublished study received Jan. 18, 1982 under PP 2F2630 (Accession 070630; prepared by Imperial Chemical Industries Limited, Plant Protect ion Division, submitted by ICI Americas Inc., Wilmington, Del.; CDL. MRID 00093807. [DER01]

{EFSA 2012} EFSA (European Food Safety Authority). 2012. Conclusion on the peer review of the pesticide risk assessment of the active substance fluazifop-P (evaluated variant of fluazifop-P-butyl). EFSA Journal. 10(11): 2945. 95 pp. Available at: http://www.efsa.europa.eu/en/efsajournal/pub/2945.htm. [Set00]

{EFSA 2013a} EFSA (European Food Safety Authority). 2013a. Access to the draft risk assessment report of the active substance "Fluazifop-P". Email from the European Food Safety Authority to P. Durkin dated September 13, 2013 with links to documents on fluazifop-P. [Set00]

{Egan 2013} Egan K. 2013. United States Food and Drug Administration's Total Diet Study Program. Chapter 41 in: Total Diet Studies. G.G. Moy and R.W Vannoort Eds. Springer Press. Pp. 411-417. [Std]

{El-Metwally and Shalby 2007}El-Metwally IM; Shalby SEM. 2007. Bio-remediation of Fluazifop-P-butyl herbicide contaminated soil with special reference to efficacy of some weed control treatments in Faba Bean Plants. Journal of Agriculture and Biological Sciences. 3(3): 157-165. [Set02]

{Ennis and Ashley 1984} Ennis BG; Ashley RA. 1984. Effect of Nitrogen Fertility Levels on Crabgrass Control by Several Postemergence Herbicides. Proceedings of the Northeast Weed Science Society. 38:133-135. [Set01 – ECOTOX – Fluazifop-butyl]

{EPI Suite 2011} EPI Suite. 2011. Estimation Program Interface (EPI) Suite, Version 4.1. Copyright 2000-2008 by the U.S. EPA. Available at: http://www.epa.gov/oppt/exposure/pubs/episuite.htm. [Std]

{European Commission 2011a} European Commission. 2011a. Fluazifop-P: Addendum to the Additional Report of Volume 3 B6 – Prepared to Amend the Regulation of Approval 788 / 2011. Rapporteur Member State: France. Document dated December 2011. Available at: http://www.efsa.europa.eu/en/efsajournal/pub/2945.htm via request to EFSA 2013a. [SET00]

{European Commission 2011b} European Commission. 2011b. Fluazifop-P: List of End Points (based on EPCO Manual E4 – rev. 4, September 2005). Rapporteur Member State: France. Document dated December 2011. Available at: http://www.efsa.europa.eu/en/efsajournal/pub/2945.htm via request to EFSA 2013a. [SET00]

{FANPP 2013a} FANPP (Flouride Action Network). 2013a. Fluazifop-P-butyl and Fluazifop-P. Available at: http://www.fluoridealert.org/pesticides/fluazifop-p-butyl.page.htm. [Set00]

{FANPP 2013b} FANPP (Flouride Action Network). 2013b. Fluazifop-P-butyl Adverse Effects. Available at: http://www.fluoridealert.org/pesticides/epage.fluazifop-p-butyl.htm. [Set00]

{FAO/WHO 2000} FAO/WHO (Food and Agriculture Organization/World Health Organization). 2000. Fluazifop-P-butyl , FAO Specifications and Evaluations For Plant Protection Products. Available at: http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Specs/fluazifo.pdf. [Set00]

{Feldmann and Maibach. 1969} Feldmann RJ; Maibach HI. 1969. Percutaneous penetration of steroids in man. J. Invset. Dermatol. 52: 89-94.[Std]

{Feldmann and Maibach. 1970} Feldmann RJ; Maibach HI. 1970. Absorption of some organic compounds through the skin in man. J. Invest. Dermatol. 54: 399-404.[Std]

{Feldmann and Maibach. 1974} Feldmann RJ; Maibach HI. 1974. Percutaneous penetration of some pesticides and herbicides in man. Toxicol. Appl. Pharmacol. 28: 126-132.[Std]

{Felix et al. 1988} Felix HR; Chollet R; Harr J. 1988. Use of the Cell Wall-Less Alga *Dunaliella bioculata* in Herbicide Screening Tests. Annals of Applied Biology. 113(1): 55-60. [Set01 – ECOTOX – Fluazifop-butyl]

{Fish and Wildlife Service 2012a} Fish and Wildlife Service (FWS). 2012a. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition To List the Mardon Skipper as Threatened or Endangered. Federal Register. 77(171): 54332- 54352. Docket ID: FWS-R1-ES-2012-0060. File Name: FWS-R1-ES-2012-0060-0001. Available at: http://www.regulations.gov/#!docketDetail;D=FWS-R1-ES-2012-0060. [E-Docket]

{ Fish and Wildlife Service 2012b} Fish and Wildlife Service (FWS). 2012b. Literature cited in Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition To List the Mardon Skipper as Threatened or Endangered. Docket ID: FWS-R1-ES-2012-0060. File Name: FWS-R1-ES-2012-0060-0002. Available at: http://www.regulations.gov/#!docketDetail;D=FWS-R1-ES-2012-0060. [E-Docket]

{Fletcher et al. 1994} Fletcher JS; Nellessen JE; Pfleeger TG. 1994. Literature review and evaluation of the EPA food-chain (Kenega) nomogram, an instrument for estimating pesticide residues on plants. Environ. Toxicol. Chem. 13(9):1383-1391. [Std]

{Focke and Lichtenthaler 1987} Focke M; Lichtenthaler HK. 1987. Inhibition of the Acetyl Coenzyme A Carboxylase of Barley Chloroplasts by Cycloxydim and Sethoxydim. Zeitschrift für Naturforschung C Biosciences. 42 (11-12): 1361-1363. [Clethodim - SET01 - Toxline01]

{Frigerio et al. 1987} Frigerio A; Pusino A; Gessa C. 1987. Photochemical Isomerization of Fluazifop-Butyl. Pesticide Science. 21 (3): 175-180. [Set01 - ToxL Fluazifop Full]

{Fritz et al. 2012} Fritz BJ; Hoffmann WC; Czaczyk1 Z; Bagley W; Kruger G; Henry R. 2012. Measurement and Classification Methods Using the ASAE S572.1 Reference Nozzles. Journal of Plant Protection Research. 52(4): 447-457. [Std]

{Gardner and Storey 1985} Gardner WA; Storey GK. 1985. Sensitivity of *Beauveria bassiana* to Selected Herbicides. J. Economic Entomology. 78(6): 1275-1279. [Set01 – ECOTOX – Fluazifop-butyl]

{Gennari et al. 1991} Gennari M; Negre M; Andreoni V; Ambrosoli R. 1991. Degradation of Fluazifop-Butyl by Soil Microorganisms. Walker, A. (Ed.). British Crop Protection Council Monograph, No. 47. Pesticides in Soils and Water: Current Perspectives. Symposium, Coventry, England, Uk, March 25-27, 1991 Ix+233p British Crop Protection Council: Farnham, England, UK. Illus Maps PAPER. ISBN 0-948404-51-5.; 0 (0). BIOSIS/91/24310 [Set01 - ToxL Fluazifop Full]

{Getty et al. 1979} Getty CW; Wilkinson CW; Sealey C; Riley D. 1979. PP 009: Toxicity of technical material and 25 % EC. JF6901 to first instar *Daphnia magna*. Report Series No. RS 0075 B. (Unpublished study received Dec. 9, 1981 under 11823 - EUP-27, -28, and -29; prepared by ICI Plant Protection Division, submitted by ICI Americas, Wilmington, Del.; CDL. MRID 00087488. [DER01]

{Gilreath 1987} Gilreath JP. 1987. Chemical Weed Control in *Gypsophila*. Hortscience. 22(3): 446-448. [Set01 – ECOTOX – Fluazifop-P]

{Goldring and Read 1993 }Goldring JP, Read JS. 1993. Insect acetyl-CoA carboxylase activity during the larval, pupal, and adult stages of insect development. Comparative Biochemistry and Physiology. 106:855–858. [Set03]

{Goldstein et al. 1974} Goldstein A; Aronow L; Kaman SM. 1974. Principles of Drug Action: The Basis of Pharmacology. 2nd ed. John Wiley and Sons, New York, NY. 854 p.[Std]

{Gouin et al. 2004} Gouin, T; Mackay D; Jones KC; Harner T; Meijer SN. 2004. Evidence of the "grasshopper" effect and fractionation during long-range atmospheric transport of organic contaminants. Environmental Pollution. 128: 139-148. [Set02]

{Gronwald 1991} Gronwald JW. 1991. Lipid Biosynthesis Inhibitors. Weed Science. 39 (3): 435-449. [Set01 - ToxL Fluazifop Full]

{Haga et al. 1987} Haga T; Fujikawa K-I; Sakashita N; Nishiyama R. 1987. Development of a New Herbicide Fluazifop-Butyl. Journal of Pesticide Science. 12 (2): 311-326. Japanese Language Review. [Set01 - ToxL Fluazifop Full]

{Hamer and Hill 1983} Hamer MJ; Hill IR. 1983. Fluazifop: Toxicity of Different E:S Enantiomer Ratios to First Instar *Daphnia magna*. Report Series RJ 0315B. Prepared and submitted by ICI Plant Protection Division, Bracknell, Berkshire, England. MRID No. 162452. [DER01]

{Hansel and Morris 1996} Hansel SB; Morris ME. 1996. Hepatic conjugation/deconjugation cycling pathways. Computer simulations examining the effect of Michaelis-Menten parameters, enzyme distribution patterns, and a diffusional barrier on metabolite disposition. Journal of Pharmacokinetics and Biopharmaceutics. 24(2): 219-243 [Set04]

{Harwood 1988} Harwood JL. 1988. The Site of Action of Some Selective Graminaceous Herbicides Is Identified as Acetyl Coenzyme a Carboxylase. Trends in Biochemical Science. 13 (9): 330-331. [Set01 - ToxL Fluazifop Full]

{Hautier et al. 2005} Hautier L: Jansen JP; Mabon N; Schiffers B. 2005. Selectivity Lists of Pesticides to Beneficial Arthropods for IPM Programs in Carrot - First Results. Communications in Agriculture and Applied Biological Sciences. 70(4): 547-557. [Set01 – ECOTOX – Fluazifop-butyl]

{Henry 2014} Henry K. 2014. E-mail from Kevin Henry (Ecological Risk Assessor, Syngenta, kevin.henry@syngenta.com) to Patrick Durkin (SERA Inc., sera_inc@msn.com) concerning MRID 00087483. [Syngenta]

{Herbert et al. 1997} Herbert D; Walker KA; Price LJ; Cole DJ; Pallett KE; Ridley SM; Harwood JL. 1997. Acetyl-CoA Carboxylase: a Graminicide Target Site. Pesticide Science. 50 (1): 67-71. [Set01 - ToxL Fluazifop Full]

{Hicks and Jordan 1984} Hicks CP; Jordan TN. 1984. Response of Bermudagrass (*Cynodon dactylon*), Quackgrass (*Agropyron repens*), and Wirestem Muhly (*Muhlenbergia frondosa*) to Postemergence Grass Herbicides. Weed Science. 32:835-841. [Set01 – ECOTOX – Fluazifop-butyl]

{Hill 1985} Hill RW. 1985. Fluazifop-butyl: Determination of the acute toxicity of "Fusilade" 4E to sheepshead minnow (*Cyprinodon variegatus*). (Unpublished study received February 8, 1985, under 10182-67; prepared by Brixham Laboratory, submitted by ICI Americas, Wilmington, Del.; CDL. MRID 00152173. [DER01]

{Hill et al. 1981} Hill RW; Maddock BG; Harland BJ; Pearson CR. 1981. Determination of the acute toxicity of PP009 to bluegill sunfish (*Lepomis macrochirus*) using a saturation column. Brixham Report No. B-7. (Unpublished study received Dec. 9, 1981 under 11823 - WP-27, -28, ad -29; prepared by Imperial Chemical Industries Limited, Brixham Laboratory, Freshwater Quarry, submitted by ICI Americas Inc., Wilmington, Del.; CDL MRID 00087485. [DER01]

{Hilton et al. 1994} Hilton J; Woollen BH; Scott RC; Auton TR; Trebilcock KL; Wilks MF. 1994. Vehicle Effects on *in vitro* Percutaneous Absorption Through Rat and Human Skin. Pharmaceutical Research. 11(10):1396-400. [Set01 - ToxL Fluazifop Full]

{Hoerger and Kenaga. 1972} Hoerger F; Kenaga EE. 1972. Pesticide residues on plants: Correlation of representative data as a basis for estimation of their magnitude in the environment. In: Environmental Quality and Safety, Volume I: Global Aspects of Toxicology and Technology as Applied to the Environment. F. Coulston and F. Kerte (eds.). Academic Press, New York, NY. pp. 9-28.[Std]

{Hollister et al. 1980/1981} Hollister TA; Miller AG; Shuba PJ. 1980, Revised 1981. Acute and chronic toxicity of PP009 to mysid shrimp (*Mysidopsis bahia*) . Report No. BP-80-10-182-R. (Unpublished study received Jan. 19, 1982 under PP 2F2630 (070630); prepared by EG&G Bionomics, Marine Research Laboratory, Pensacola, Florida, submitted by ICI Americas Inc., Wilmington, Del .; CDL. [DER01]

{Hopkins et al. 2009} Hopkins P; Grisso R; Wolf B; Reed T. 2009. Droplet Chart/Selection Guide. Virginia Cooperative Extension. College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University. 2 pp. Available at: http://pubs.ext.vt.edu/442/442-031/442-031_pdf.pdf. [Std]

{House et al. 1987} House GJ; Worsham AD; Sheets TJ; Stinner RE. 1987. Herbicide Effects on Soil Arthropod Dynamics and Wheat Straw Decomposition in a North Carolina USA No-Tillage Agroecosystem. Biology and Fertility of Soils . 4 (3): 109-114. [Set01 - ToxL Fluazifop Full]

{HSDB 2000} HSDB (Hazardous Substances Database). Fluazifop-Butyl. Entry last updated on March 13, 2000. Available at: http://toxnet.nlm.nih.gov. [Internet]

{Humphrey and Dykes 2008} Humphrey JAC; Dykes ES. 2008. Thermal energy conduction in a honey bee comb due to cell-heating bees. J Theoretical Biology. 250 (1): 194-208. [Std]

{ICRP 2005} ICRP (International Commission on Radiological Protection). 2005. 2005 Recommendations of the International Commission on Radiological Protection. Available at: http://www.icrp.org/docs/2005_recs_CONSULTATION_Draft1a.pdf. [Std]

{Ishihara Sangyo Kaisha 1990} Ishihara Sangyo Kaisha 1990. Summary of Toxicity Studies on Fluazifop-Butyl. Journal of Pesticide Science. 15 (2): 305-310. Available at: http://ci.nii.ac.jp/els/110001712358.pdf?id=ART0001835813&type=pdf&lang=en&host=cinii&order_no=&ppv_type=0&lang_sw=&no=1379620164&cp=. English Language Review. [Set01 - ToxL Fluazifop Full]

{Ishihara Sangyo Kaisha 2013} Ishihara Sangyo Kaisha 2013. Fluazifop-P-butyl, System grass herbicide. Document not dated. Downloaded on September 20, 2013. Available at: https://www.iskweb.co.jp/products/pdf/fluazifop-p-butyl.pdf. [Set00]

{Jealotts Hill Research Station 1983} Jealotts Hill Research Station. 1983. Toxicity of different R:S- enantiomer ratios to first instar *Daphnia magna*. Dated 5 May 1983, conducted by ICI's Jealotts Hill Research Station. EPA Accession No. 252852. [DER01]

{Jehlickov et al. 1990} Jehlickov Z; Hajslov J; Poustka J; Pudil F; Davidek J. 1990. Determination of Aryloxyphenoxypropanoic Acid Derivatives in Crops Treated with Herbicidal Sprays. Zeitschrift für Lebensmittel-Untersuchung und-Forschung . 190(5):436-40. [Set01 - ToxL Fluazifop Full]

{Kabanyoro 2001} Kabanyoro R. 2001. Responses of the Weed Digitaria abyssinica (A. Rich.) Stapf to Selective Grass Herbicides in Ugandan Cotton. Ph.D. Thesis in the Faculty of Agriculture and Biological Sciences, University of Newcastle Upon Tyne. Thesis dated January 2001. Avilable at: https://theses.ncl.ac.uk/dspace/bitstream/10443/515/1/Kabanyoro01.pdf. [Set00]

{Kah and Brown 2007a} Kah M; Brown CD. 2007a. Prediction of the Adsorption of Ionizable Pesticides in Soils. Journal of Agricultural and Food Chemistry. 55(6):2312-22. [Set01 - ToxL Fluazifop Full]

{Kah and Brown 2007b} Kah M; Brown CD. 2007b. Changes in Pesticide Adsorption with Time at High Soil to Solution Ratios. Chemosphere. 68(7):1335-43. [Set01 - ToxL Fluazifop Full]

{Kah et al. 2007} Kah M; Beulke S; Brown CD. 2007. Factors Influencing Degradation of Pesticides in Soil. Journal of Agricultural and Food Chemistry. 55(11):4487-92. [Set01 - ToxL Fluazifop Full]

{Kegley et al. 2010} Kegley SE; Hill BR; Orme S; Choi AH. 2010. PAN (Pesticide Action Network). 2010. Pesticides Database – Chemicals. Fluazifop-P-butyl - Identification, toxicity, use, water pollution potential, ecological toxicity and regulatory information. Available at: http://www.pesticideinfo.org/Detail_Chemical.jsp?Rec_Id=PC37432. [Set00]

{Keigwin 1998} Keigwin T. 1998. PHED (Pesticide Handlers Exposure Database) Surrogate Exposure Guide. Dated April 1997 with revisions in August 1998. Copy courtesy of Hank Appleton/USDA/Forest Service. 82 pp. [Std]

{Kemal and Casida 1992} Kemal C; Casida JE. 1992. Coenzyme A Esters of 2-Aryloxyphenoxypropionate Herbicides and 2-Arylpropionate Antiinflammatory Drugs Are Potent and Stereoselective Inhibitors of Rat Liver Acetyl-CoA Carboxylase. Life Science. 50(7):533-40. [Set01 - ToxL Fluazifop Full]

{Kissel 2010} Kissel JC. 2010. The mismeasure of dermal absorption. Journal of Exposure Science and Environmental Epidemiology. 21: 302–309. [Std]

{Knisel and Davis 2000} Knisel WG; Davis FM. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual. U.S. Department of Agriculture, Agricultural Research Service, Southeast Watershed Research Laboratory, Tifton, GA. Pub. No.: SEWRL-WGK/FMD-050199. Report Dated May 1, 1999 and revised August 15, 2000. 194pp. http://www.tifton.uga.edu/sewrl/Gleams/gleams_y2k_update.htm. [Std]

{Kobek and Lichtenthaler 1990} Kobek K; Lichtenthaler HK. 1990. Effect of Different Cyclohexane-1,3-Dione Derivatives on the *de novo* Fatty Acid Biosynthesis in Isolated Oat Chloroplasts. Zeitschrift für Naturforschung C Biosciences. 45 (1-2): 84-88. [Clethodim - SET01 - Toxline01]

{Koppen and Spliid 1998} Koppen B; Spliid NH. 1998. Determination of Acidic Herbicides Using Liquid Chromatography with Pneumatically Assisted Electrospray Ionization Mass Spectrometric and Tandem Mass Spectrometric Detection. Journal of Chromatography A. 803 (1-2): 157-168. [Set01 - ToxL Fluazifop Full]

{Kosswig 1994} Kosswig K. 1994. Surfactants. In: Ullmann's Encyclopedia of Industrial Chemistry. 5th Edition, Volume 25a. pp. 747-815. [Std]

{Kostka et al. 2002} Kostka G; Palut D; Ludwicki JK; Kope#263-Szlezak J; Wiadrowska B; Lembowicz K. 2002. Hepatocellular Peroxisome Proliferation and DNA Synthesis in Wistar Rats Treated with Herbicide Fluazifop. Toxicology. 178(3):221-8. [Set01 - ToxL Fluazifop Full]

{Krijt et al. 1993} Krijt J; Van Holsteijn I; Hassing I; Vokurka M; Blaauboer BJ. 1993. Effect of Diphenyl Ether Herbicides and Oxadiazon on Porphyrin Biosynthesis in Mouse Liver, Rat Primary Hepatocyte Culture and HepG2 Cells. Archives of Toxicology. 67(4):255-261. [Set01 - ToxL Fluazifop Full]

{Krijt et al. 1997} Krijt J; Vokurka M; Richert L. 1997. Letters to the Editor and Reply. Toxicology and Applied Pharmacology. 146 (1): 170-171. [Set01 - ToxL Fluazifop Full]

{Kulshrestha et al. 1992} Kulshrestha G; Singh SB; Gautam KC. 1992. Dissipation of Fluazifop-P-Butyl Herbicide in Soybean Crop. Journal of Nuclear Agriculture and Biology. 21 (3): 275. [Set01 - ToxL Fluazifop Full]

{Kulshrestha et al. 1995} Kulshrestha G; Singh SB; Gautam KC. 1995. Residues of Fluazifop-P-Butyl Following Application to Soybean. Bulletin of Environmental Contamination and Toxicology. 55 (2): 276-282. [Set01 - ToxL Fluazifop Full]

{Kurth et al. 2009} Kurth DF; Gago GM; de la Iglesia A; Lyonnet BB; Lin T-W; Morbidoni HR; Tsai S-C; Gramajo H. 2009. ACCase 6 is the essential acetyl-CoA carboxylase involved in fatty acid and mycolic acid biosynthesis in mycobacteria. Microbiology. 155(Pt 8): 2664–2675. [Clethodim - Set04]

{Larney et al. 1999} Larney FJ; Cessna AJ; Bullock MS. 1999. Herbicide transport on wind-eroded sediment. Journal of Environmental Quality. 28(5): 1412-1421. [Std]

{Leys et al. 1988} Leys AR; Plater B; Cullis B. 1988. Response of Six Temperate Annual Grass Weeds to Six Selective Herbicides. Plant Protection Quarterly. 3(4): 163-168. [Set01 – ECOTOX – Fluazifop-P]

{Lichtenthaler et al. 1991} Lichtenthaler HK; Klobek K; Retzlaff G. 1991. Effect of Cyclohexane-1 3-Diones on *De-Novo* Fatty Acid Biosynthesis in Different Forms of Isolated Plastids. Pesticide Science. 30 (4): 427-430. [Clethodim - SET01 - Toxline01]

{Luo et al. 2004 } Luo XY; Sunohara Y; Matsumoto H. 2004. Fluazifop-butyl causes memberane peroxidation in Herbicide-Susceptible Broad Leaf Weed Bristly Starbur (Acanthospermum hispidum). Pesticide Biochemistry and Physiology. 78: 93-102. [Set03]

{Ma 2002} Ma J. 2002. Differential Sensitivity to 30 Herbicides among Populations of Two Green Algae *Scenedesmus obliquus* and *Chlorella pyrenoidosa*. Bull Environ Contam Toxicol. 66(4): 536-541. [Std-Compendia]

{Ma et al. 2001} Ma J; Liang W; Xu L; Wang S; Wei Y; Lu J. 2001. Acute Toxicity of 33 Herbicides to the Green Alga Chlorella pyrenoidosa. Bull Environ Contam Toxicol. 66(4): 536-541. [Std-Compendia]

{Ma et al. 2002a} Ma J; Xu L; Wang S; Zheng R; Jin S; Huang S; Huang Y. 2002a. Toxicity of 40 Herbicides to the Green Alga *Chlorella vulgaris*. Ecotoxicol Environ Saf. 51(2): 128-132. [Std-Compendia]

{Ma et al. 2002b} Ma J; Xu L; Wang S. 2002. A Quick, Simple, and Accurate Method of Screening Herbicide Activity Using Green Algae Cell Suspension Cultures. Weed Science. 50(5): 555-559. [Set01 – ECOTOX – Fluazifop-P]

{Ma et al. 2002b} Ma J; Xu L; Wang S. 2002b. A Quick, Simple, and Accurate Method of Screening Herbicide Activity Using Green Algae Cell Suspension Cultures. Weed Science. 50(5): 555-559. [Std – Compendia]

{Ma et al. 2004} Ma J; Lin F; Wang S; Xu L. 2004. Acute Toxicity Assessment of 20 Herbicides to the Green Alga *Scenedesmus quadricauda* (Turp.) Breb. Bulletin of Environmental Contamination and Toxicology. 72(6): 1164-1171. [Std – Compendia]

{Ma et al. 2006} Ma J; Wang S; Wang P; Ma L; Chen X; Xu R. 2006. Toxicity Assessment of 40 Herbicides to the Green Alga *Raphidocelis subcapitata*. Ecotoxicology and Environmental Safety. 63(3): 456-462. [Std – Compendia]

{Maier et al. 1994} Maier A; Golz A; Lichtenthaler HK; Meyer N; Retzlaff G. 1994. Studies on the Effect of Different Cyclohexane-1,3-Diones on *De-Novo* Fatty Acid Biosynthesis in *Poaceae*. Pesticide Science. 42 (3): 153-161. [Clethodim - SET01 - Toxline01]

{Malik nd Waddington 1990} Malik N; Waddington J. 1990. Alfalfa (*Medicago sativa*) Seed Yield Response to Herbicides. Weed Technology. 4:63-67. [Set01 – ECOTOX – Fluazifop-butyl]

{Mallory-Smith and Retzinger 2003} Mallory-Smith CA; Retzinger J. 2003. Revised Classification of Herbicides by Site of Action for Weed Resistance Management Strategies. Weed Technology. 17: 605-619. [Std]

{Martinez et al. 2000} Martinez RC; Gonzalo ER; Fernandez Laespada ME; Roman FJSS. 2000. Evaluation of surface-and ground-water pollution due to herbicides in agricultural areas of Zamora and Salamanca (Spain). Journal of Chromatography A. 869: 471-480. [Set02]

{Martínez-y-Pérez et al. 2007} Martínez-y-Pérez JL; Mejía-Saulés T; Sosa V; 2007. Phylogenetic relationships of Luziola (Poaceae: Oryzeae) and related genera from aquatic habitats. Canadian Journal of Botany. 84(12): 1753-1770. [Set05]

{McLaren/Hart 1995} McLaren/Hart (McLaren/Hart Environmental Engineering Corporation). 1995. Use of the Registered Aquatic Herbicide Fluridone (SONAR) and the Use of the Registered Aquatic Herbicide Glyphosate (Rodeo and Accord) in the State of New York, prepared by McLaren/Hart Environmental Engineering Corporation for DowElanco and Monsanto. Report (447 pp.) dated January 10, 1995. Available at: http://nysl.nysed.gov/uhtbin/cgisirsi/EkOsIswy8Y/NYSL/297230031/523/3643. [Std]

{McCracken et al. 1990} McCracken NW; Blain PG; Williams FM. 1990. Distribution of Esterases in the Rat. Human and Experimental Toxicology. 9 (5): 335. [Set01 - ToxL Fluazifop Full]

{McCracken et al. 1992 } McCracken NW; Blain PG; Williams FM. 1992. Xenobiotic metabolizing esterases in human liver and blood. British Journal of Clinical Pharmacology. 34: 160-?? [Set03]

{McCracken et al. 1993a} McCracken NW; Blain PG; Williams FM. 1993a. Nature and Role of Xenobiotic Metabolizing Esterases in Rat Liver, Lung, Skin and Blood. Biochemical Pharmacology. 45 (1): 31-36. [Set01 - ToxL Fluazifop Full]

{McCracken et al. 1993b} McCracken NW; Blain PG; Williams FM. 1993b. Peripheral Esterases in the Rat: Effects of Classical Inducers. Chemico-Biological Interactions. 87(1-3):183-5. [Set01 - ToxL Fluazifop Full]

{McCracken et al. 1993c} McCracken NW; Blain PG; Williams FM. 1993c. Human Xenobiotic Metabolizing Esterases in Liver and Blood. Biochemical Pharmacology. 46 (7): 1125-1129. [Set01 - ToxL Fluazifop Full]

{Messersmith and Adkins 1995} Messersmith CG; Adkins SW. 1995. Integrating Weed-Feeding Insects and Herbicides for Weed Control. Weed Technology. 9 (1): 199-208. [Set01 - ToxL Fluazifop Full]

{Michel et al. 2004} MichelA; Johnson RD; Duke SO; Scheffler BE. 2004. Dose-Response Relationships Between Herbicides with Different Modes of Action and Growth of *Lemna paucicostata*: An Improved Ecotoxicological Method. Environmental Toxicology and Chemistry. 23(4): 1074-1079. [Set01 – ECOTOX – Fluazifop-butyl]

{Michitte et al. 2003} Michitte P; Espinoza N; De Prado R. 2003. Cross-Resistance to ACCase Inhibitors of Lolium *multiflorum*, *Lolium perenne* and *Lolium rigidum* Found in Chile. Communications in Agricultural and Applied Biological Sciences. 68(4 Pt A):397-402. [Set01 - ToxL Fluazifop Full]

{Mills and Simmons 1998} Mills MS; Simmons ND. 1998. Assessing the Ground-Water Contamination Potential of Agricultural Chemicals: A Flexible Approach to Mobility and Degradation Studies. Pesticide Science. 54(4): 418-434. [Set01 - ToxL Fluazifop Full]

{Miyazaki 1997} Miyazaki A. 1997. Progress and Prospects of Optically Active Pesticides. Journal of Pesticide Science. 22 (2): 136-155. [Set01 - ToxL Fluazifop Full]

{More et al. 2012} More PM; Antre RV; Shelke TT; Mutha MM; Badr SM; Eisa HM; Kore PV. 2012. Docking Studies of Benzimidazole Derivatives as Coenzyme-A Carboxylase (ACCase) Inhibitor. Open Access Scientific Reports. http://dx.doi.org/10.4172/scientificreports.439. [Clethodim - Set04]

{Moss et al. 2003} Moss SR; Cocker KM; Brown AC; Hall L; Field LM. 2003. Characterization of Target-Site Resistance to ACCase-Inhibiting Herbicides in the Weed *Alopecurus myosuroides* (Black-Grass). Pest Management Science. 59(2):190-201. [Set01 - ToxL Fluazifop Full]

{Mousa 1982} Mousa M. 1982. Mitotic Inhibition and Chromosomal Aberrations Induced by Some Herbicides in Root Tips of *Allium cepa*. Egyptian Journal of Genetics and Cytology. 11 (2): (Recd1983)193-208. [Set01 - ToxL Fluazifop Full]

{Muller and Buser 1997}Muller MD; Buser H. 1997. Conversion reactions of various phenyoxyalkanoic acid herbicides in soil. 1. Enantiomerization and enantioselective degradation of the chiral 2-phenyoxypropionic acid herbicides. Environmental Science and Technology. 31: 1953-1959. [Set02]

{Mutch et al. 1990} Mutch E; Blain PG; Williams FM. 1990. Esterase Activity in Rat Hepatocytes. Human and Experimental Toxicology. 9 (5): 346-347. [Set01 - ToxL Fluazifop Full]

{Nagy 1987} Nagy KA. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecol. Monogr. 57: 111-128. [Std-Allom]

{Nagy 2005} Nagy KA. 2005. Field metabolic rate and body size. Journal of Experimental Biology. 208: 1621-1625. [Std-Allom]

{Nalewaja and Skrzypczak 1986} Nalewaja JD; Skrzypczak GA. 1986. Absorption and Translocation of Fluazifop with Additives. Weed Science. 34 (4): 572-576. [Set01 - ToxL Fluazifop Full]

{Nalewaja et al. 1986} Nalewaja JD; Skrzypczak GA; Gillespie GR. 1986. Absorption and Translocation of Herbicides with Lipid Compounds. Weed Science. 34 (4): 564-568. [Set01 - ToxL Fluazifop Full]

{Negre et al. 1988} Negre M; Gennari M; Cignetti A; Zanini E. 1988. Degradation of Fluazifop-Butyl in Soil and Aqueous Systems. Journal of Agricultural and Food Chemistry. 36 (6): 1319-1322. [Set01 - ToxL Fluazifop Full]

{Negre et al. 1993} Negre M; Gennari M; Andreoni V; Ambrosoli R; Celi L. 1993. Microbial Metabolism of Fluazifop-Butyl. Journal of Environmental Science and Health - Part B: Pesticides, Food Contaminants, and Agricultural Wastes. 28(5):545-576. [Set01 - ToxL Fluazifop Full]

{Nishiuchi and Asano 1979} NishiuchiY; Asano K. 1979. Toxicity of Agricultural Chemicals to Some Freshwater Organisms – 59. Suisan Zoshoku (Aquaculture). 27(1): 48-55. Review in Japanese Language. [Set01 – ECOTOX – Fluazifop-butyl]

{NMFS 2012} National Marine Fisheries Service (NMFS). 2012. Draft Biological Opinion Environmental Protection Agency Registration of Pesticides Oryzalin, Pendimethalin, Trifluralin. Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2008-0654-0455. [E-Docket]

{Norris and Kogan 2000} Norris RF; Kogan M. 2000. Weed Science. Interactions between weeds, arthropod pests, and their natural enemies in managed ecosystems. 48(1): 94-158. [Set01 - Sundry]

{Ozhan et al. 2005} Ozhan G; Ozden S; Alpertunga B. 2005. Determination of Commonly Used Herbicides in Surface Water Using Solid-Phase Extraction and Dual-Column HPLC-DAD. Journal of Environmental Science and Health - Part B: Pesticides, Food Contaminants, and Agricultural Wastes. 40(6):827-40. [Set01 - ToxL Fluazifop Full]

{Page et al. 1994} Page RA; Okada S; Harwood JL. 1994. Acetyl-CoA Carboxylase Exerts Strong Flux Control Over Lipid Synthesis in Plants. Biochimica et Biophysica Acta. 1210 (3): 369-372. [Set01 - ToxL Fluazifop Full]

{Patric 1976} Patric JH. 1976. Soil Erosion in the Eastern Forest. Journal of Forestry. 74(10): 671-677. [Std]

{Patumi et al. 1987} Patumi M; Marucchini C; Businelli M; Vischetti C. 1987. An Analytical Method for the Determination of Fluazifop-Butyl and Fluazifop Residues in Soil. Pesticide Science. 21 (3): 193-202. [Set01 - ToxL Fluazifop Full]

{Pauli et al. 2000} Pauli BD; Perrault JA; Money SL. 2000. RATL: A Database of Reptile and Amphibian Toxicology Literature. National Wildlife Research Centre 2000, Canadian Wildlife Service, Environmental Conservation Branch, Technical Report Series Number 357. Available at: http://dsp-psd.communication .gc.ca/Collection/CW69-5-357E.pdf. [Std]

{Payne-Sturges et al. 2004} Payne-Sturges DC; Burke TA; Breysse P; Diener-WestD; Buckley T. 2004. Personal Exposure Meets Risk Assessment: A Comparison of Measured and Modeled Exposures and Risks in an Urban Community. Environmental Health Perspectives. 112(5): 589-598. [Std]

{Perschbacher et al. 1997} Perschbacher PW; Stone N; Ludwig GM; Guy C B JR. 1997. Evaluation of Effects of Common Aerially-Applied Soybean Herbicides and Propanil on the Plankton Communities of Aquaculture Ponds. Aquaculture. 157 (1-2): 117-122. [Set01 - ToxL Fluazifop Full and ECOTOX]

{Peterson and Peterson 1977} Peterson LA; Peterson RT. 1977. A Field Guide to Edible Wild Plants: Eastern and central North America. The Peterson Field Guide Series, No. 23. Houghton Mifflin Company, Boston, Mass. ISBN 0-395-20445-3. [Std]

{PHED Task Force. 1995} PHED Task Force. 1995. PHED: The Pesticide Handlers Exposure Database. Version 1.1. Health Canada, U.S. Environmental Protection Agency, and American Crop Protection Association.[Std]

{Plowman et al. 1980} Plowman RE; Stonebridge WC; Hawtree JN. 1980. Proceedings of the 1980 British Crop Protection Conference - Weeds : (15th British Weed Control Conference), 17-20 Nov. 1980, Brighton, Eng.; [comps. C. Wheeler, J. Holroyd, Programme Committee, ARC Weed Research Organ.]. [Croydon, Surrey] : British Crop Protection Council, [1980]. Proc Br Crop Prot Conf. p. 29-37. [Set00]

{Polcaro et al. 1999} Polcaro CM; Marra C; Desiderio C; Fanali S. 1999. Stereoselective Analysis of Acid Herbicides in Natural Waters by Capillary Electrophoresis. Electrophoresis. 20(12):2420-4. [Set01 - ToxL Fluazifop Full]

{Punzi et al. 2005} Punzi JS; Lamont M; Haynes D; Epstein RL. 2005. USDA Pesticide Data Program. Outlooks on Pest Management. June 2005, pp. 131-137. [Std]

{Qin and Gan 2007}Qin S; Gan J. 2007. Abiotic enantiomerization of permethrin and cypermethrin: effects of organic solvents. Journal of Agricultural and Food Chemistry. 55: 5734-5739. [Set02]

{Qin et al. 2006} Qin S; Budd R; Bondarenko S; Liu W; Gan J. 2006. Enantioselective degradation and chiral stability of pyrethroids in soil and sediment. Journal of Agricultural and Food Chemistry. 54: 5040-5045. [Set02]

{Quaranta et al. 2009} Quaranta A; Bellantuono V; Cassano G: Lippe C. 2009. Why Amphibians Are More Sensitive than Mammals to Xenobiotics. PLoS ONE. 4: (11): 1-4. [Std]

{Ramsey et al. 1992} Ramsey JD; Woollen BH; Auton TR; Batten PL; Leeser JE. 1992. Pharmacokinetics of Fluazifop-Butyl in Human Volunteers. II: Dermal Dosing. Human and Experimental Toxicology. 11(4):247-54. [Set01 - ToxL Fluazifop Full]

{Ramsey et al. 1994} Ramsey JD; Woollen BH; Auton TR; Scott RC. 1994. The Predictive Accuracy of *in vitro* Measurements for the Dermal Absorption of a Lipophilic Penetrant (Fluazifop-Butyl) Through Rat and Human Skin. Fundamental and Applied Toxicology. 23 (2): 230-236. [Set01 - ToxL Fluazifop Full]

{Rawlings et al. 1994a} Rawlings JM; Provan WM; Wilks MF; Batten PL. 1994a. Comparison of Two Methods for Determining the Toxicokinetics of Fluazifop-Butyl after Intravenous Dosing in Rats. Human and Experimental Toxicology. 13 (2): 123-129. [Set01 - ToxL Fluazifop Full]

{Rawlings et al. 1994b} Rawlings JM; Hilton J; Trebilcock KL; Woollen BH; Wilks MF. 1994b. Effect of Dosing Vehicle on the Dermal Absorption of Fluazifop-Butyl and Fomesafen in Rats *in vivo*. Fundamental and Applied Toxicology. 23(1): 93-100 [Set01 - ToxL Fluazifop Full]

{Reichle et al. 1973} Reichle DE, Goldstein RA; Van Hook RI; Dodson DJ. 1973. Analysis of Insect Consumption in a Forest Canopy. Ecology. 54: 1076-1084. [Insect Consump]

{Reid 2006} Reid FA. 2006. A Field Guide to Mammals of North America North of Mexico. Fourth Edition. The Peterson Field Guide Series. Houghton Mifflin Company, Boston MA. 570 pp. [Std]

{Rendina et al. 1990} Rendina AR; Craig-Kennard AC; Beaudoin JD; Breen MK. 1990. Inhibition of Acetyl Coenzyme A Carboxylase by Two Classes of Grass-Selective Herbicides. Journal of Agricultural and Food Chemistry. 38 (5): 1282-1287. [Clethodim - SET01 - Toxline01]

{Rick et al. 1987} Rick SK; Slife FW; Banwart WL. 1987. Adsorption of Selective Grass Herbicides by Soils and Sediments. Weed Science. 35 (2): 282-288. [Set01 - ToxL Fluazifop Full]

{Roberts 1985} Roberts NL. 1985. The Acute Oral Toxicity of Fluazifop-p-butyl to the Mallard Duck. Laboratory Project ID CTL/P/1375. Performed by Huntingdon Research Center, Huntington, Cambridgeshire, England. Submitted by ICI Americas Inc., Wilmington, DE. EPA MRID No. 40829201. [DER01]

{Roberts et al. 1981a} Roberts NL; Phillips CNK; Woodhouse RN; Chanter DO; McCallister A. 1981a. The effect of dietary inclusion of fluazifop butyl on reproduction of mallard duck. Test No. ISK/ICI/286/8144. (Unpublished study received Jan. 18, 1982 under Petition No. 2F2630 070630; prepared by Huntington Research Centre, Huntington, England, submitted by I C I Americas Inc., Wilmington, Del.; CDL. MRID 00093801. [DER01]

{Roberts et al. 1981b} Roberts NL; Phillips CNK; Almond RA; Chanter DO; McCallister A. 1981b. Fluazifop butyl: The effect of dietary inclusion on reproduction of bobwhite quail. Test No. ISK/ICI/287/81209. (Unpublished study received Jan. 18, 1982 under Petition No. 2F2630070630; prepared by Huntington Research Centre, Huntington, England, submitted by ICI Americas Inc., Wilmington, Del .; CDL. MRID 00093802. [DER01]

{Rokich et al. 2009 } Rokich DP; Harma J; Turner SR; Sadler RJ; Tan BH. 2009. Fluazifop-p-butyl herbicide: Implications for Germination, emergence and Growth of Australian Plant Species. Biological Conservation. 142: 850-869. [Set03]

{Rosenberg 1997} Rosenberg RJ. 1997. Herbicide Tolerance by *Vernonia* Grown in the Temperate Zone. Industrial Crops and Products. 6(2): 89-96. [Set01 – ECOTOX - Fluazifop]

{Ross et al. 1979} Ross DB; Roberts NL; Phillips C . 1979. The acute oral toxicity (LD_{50}) of PP009 to the mallard duck. Test No. ISK/ICI/283/79104. (Unpublished study received Dec. 9, 1981 under 11823-EUP-27, -28, and -29; prepared by Huntington Research Centre, Huntington , England, submitted by ICI Americas Inc., Wilmington, Del.; CDL. [DER01]

{Ross et al. 1980a} Ross DB; Roberts NL; Phillips C; Woodhouse RN. 1980a. The subacute dietary toxicity (LC_{50}) of PP009 to the mallard duck. Test No. ISK/ICI WL 284179835. (Unpublished study received Dec. 9, 1981 under 11823-EUP-27, -28, and -29; prepared by Huntington Research Centre, Huntington, England, submitted by I C I Americas Inc., Wilmington, Del . ; CDL. MRID 92067-003 (Summary Report) and MRID 00087481 (Study Report). [DER01]

{Ross et al. 1980b} Ross DB; Roberts NL; Phillips C. Woodhouse NR. 1980. The subacute dietary toxicity (LC_{50}) of PP009 to the ring-necked pheasant. Test No. ISK/ICI WL 285/79834. (Unpublished study received Dec. 9, 1981 under 11823-EUP-27, -28, and -29; prepared by Huntington Research Centre, Huntington, England, submitted by ICI Americas Inc., Wilmington, Del. CDL. MRID 00087482. [DER01]

{Russell and Schultz 2010} Russell C; Schultz CB. 2010. Effects of grass-specific herbicides on butterflies: an experimental investigation to advance conservation efforts. Journal of Insect Conservation. 14:53-63. [Set01 – FWS 2012a]

{Sapundzhieva and Kuzmanova 1987} Sapundzhieva K; Kuzmanova J. 1987. Effect of Fluazifop-Butyl on Soil Microflora. Pochvozn Agrokhim Rastit Zasht. 22 (6): 35-38. In Russian with English abstract. [Set01 - ToxL Fluazifop Full]

{Schnermann and Sayegh 1998} Schnermann JB; Sayegh SI. 1998. Kidney Physiology. Chapter 9: Organic Substances, Organic anions and cations. pp.122-127. Lippincott-Ravin Publishers, Philadelphia and New York. [Std]

{Schramm et al. 1998} Schramm M; Mueller E; Triebskorn R. 1998. Brown Trout (*Salmo trutta* F. Fario) Liver Ultrastructure as a Biomarker for Assessment of Small Stream Pollution. Biomarkers. 3 (2): 93-108. [Set01 - ToxL Fluazifop Full]

{Scott and McConvey 2005} Scott G; McConvey P. 2005. Regional Groundwater Monitoring Network Northern Ireland. Review of 2005 Monitoring Data. Environmental and Heritage Service, Lis burn. Available at: http://www.doeni.gov.uk/niea/groundwater_2005_report.pdf. [Set02]

{Sellers et al. 2007}Sellers RS; Morton D; Michael B; Roome N; Johnson JK; Yano BL; Perry R; Schafer K. 2007. Society of Toxicologic Pathology Position Paper: OrganWeight Recommendations for Toxicology Studies. Toxicologic Pathology. 35: 751-755. [Std]

{SERA 2001} SERA (Syracuse Environmental Research Associates, Inc.). 2001. Sethoxydim [Poast]-Human Health and Ecological Risk Assessment, Final Report, SERA TR 01-43-01-01c, Report dated October 31, 2001. Prepared under USDA Forest Service BPA: WO-01-3187-0150, Purchase Order No.: 43-3187-1-0035. Available at: http://www.fs.fed.us/foresthealth/pesticide/risk.shtml. [Set00]

{SERA 2007a} SERA (Syracuse Environmental Research Associates, Inc.). 2007a. Gleams-Driver User Guide (Version 1.8). SERA TR 07-52-05-08a. Report dated December 31, 2007. Available at: www.sera-inc.com. [Std]

{SERA 2007b} SERA (Syracuse Environmental Research Associates, Inc.). 2007b. Aminopyralid Human Health and Ecological Risk Assessment – FINAL REPORT with Annotated Bibliography. SERA TR-052-04-04a. Report dated June 27, 2007. Available at: http://www.fs.fed.us/foresthealth/pesticide/risk.shtml. [Std]

{SERA 2009} SERA (Syracuse Environmental Research Associates, Inc.). 2009. Technical Comparison of EPA, BLM and Forest Service Pesticide Risk Assessments, Final Report. SERA TR-052-19-02. Report dated July 29, 2009. Available at: http://www.fs.fed.us/foresthealth/pesticide/pdfs/SERA_TR-052-19-02_Risk_Comparison.pdf. [Std]

{SERA 2011a} SERA (Syracuse Environmental Research Associates, Inc.). 2011a. Preparation of Environmental Documentation and Risk Assessments, SERA TP 11-23-01-012, ATT-3 and SERA MD-2011-01b. Document dated November 11, 2011 with minor editorial modifications on February 11, 2012. Syracuse Environmental Research Associates, Inc., Fayetteville, NY. Available at www.sera-inc.com. [Std]

{SERA 2011b} SERA (Syracuse Environmental Research Associates, Inc.). 2011b. WorksheetMaker Version 6.00, User Guide. SERA TR-052-20-01b. Document dated December 21, 2011. Syracuse Environmental Research Associates, Inc., Fayetteville, NY. Available at www.sera-inc.com. [Std]

{SERA 2011c} SERA (Syracuse Environmental Research Associates, Inc.). 2011c. Memorandum on Release of Gleams-Driver 1.9.3. Memo dated November 6, 2011. Available at: www.sera-inc.com. [Std]

{SERA 2011d} SERA (Syracuse Environmental Research Associates, Inc.). 2011d. Triclopyr, Human Health and Ecological Risk Assessment, Final Report. Available at: http://www.fs.fed.us/foresthealth/pesticide/risk.shtml. [Std]

{SERA 2013a} SERA (Syracuse Environmental Research Associates, Inc.). 2013a. Scoping/Screening Level Risk Assessment on Clethodim, SERA TR-056-05-01-01a, report dated November 24, 2013. Prepared under USDA Forest Service Contract AG-3187-C-12-0009, Order No.: AG-3187-D-13-0232. [Set00]

{SERA 2013b} SERA (Syracuse Environmental Research Associates, Inc.). 2013b. Reassessment of Worker Exposure Rates – Corrected and Revised Final Report. SERA TR-052-30-03a. Document dated October 13, 2013. Syracuse Environmental Research Associates, Inc., Fayetteville, NY. Available at: http://www.fs.fed.us/foresthealth/pesticide/risk.shtml. [Std]

{Sesline and Jackson 1994} Sesline DH; Jackson RJ. 1994. The Effects of Prenatal Exposure to Pesticides. Prenatal Exposure to Toxicants: Developmental Consequences. (The Johns Hopkins Series in Environmental Toxicology) pp. 233-48. DART/TER/94000863. IB - 0-8018-4704-4. [Set01 - ToxL Fluazifop Full]

{Sibley 2000} Sibley DA. 2000. The Sibley Guide to Birds. National Audubon Society, Chanticleer Press Edition. Alfred A. Knopf Inc., New York. 545 pp. [Std]

{Skroch et al. 1990} Skroch WA; Catanzaro CJ; Yonce MH. 1990. Response of Nine Herbaceous Flowering Perennials to Selected Herbicides. Journal of Environmental Horticulture . 8 (1): 26-28. [Set01 - ToxL Fluazifop Full]

{Smailes and Wilkinson 1979} Smailes JM; Wilkinson W. 1979. PP009 : Laboratory Determination of the Acute Oral and Contact Toxicity to Honeybees of Technical Material and 25% Emulsifiable Concentrate Formulation. ICI Plant Protection Division Report No. RJ 0094B (November 1979). In EPA Accession No. 070631. [DER01]

{Smeda and Putnam 1990} Smeda RJ; Putnam AR. 1990. Influence of Temperature, Rainfall, Grass Species, and Growth Stage on Efficacy of Fluazifop. Weed Technology. 4 (2): 349-355. [Set01 - ToxL Fluazifop Full]

{Smeda et al. 1997} Smeda RJ; Snipes CE; Barrentine WL. 1997. Identification of Graminicide-Resistant Johnsongrass (*Sorghum halepense*). Weed Science. 45 (1): 132-137. [SET01 - Toxline01]

{Smith 1987} Smith AE. 1987. Persistence Studies with the Herbicide Fluazifop-Butyl in Saskatchewan Soils Under Laboratory and Field Conditions. Bulletin of Environmental Contamination and Toxicology. 39(1):150-5. [Set01 - ToxL Fluazifop Full]

{Spliid and Koppen 1998} Spliid NH; Koppen B. 1998. Occurrence of Pesticides in Danish Shallow Ground Water. Chemosphere. 37 (7): 1307-1316. [Set01 - ToxL Fluazifop Full]

{Spliid et al. 2006} Spliid NH; Helweg A; Heinrichson K. 2006. Leaching and Degradation of 21 Pesticides in a Full-Scale Model Biobed. Chemosphere. 65(11):2223-32. [Set01 - ToxL Fluazifop Full]

{Street and Snipes 1987} Street JE; Snipes CE. 1987. Susceptibility of Rice *Oryza-sativa* to Various Postemergence Grass Herbicides. Weed Science. 35 (5): 686-690. [Set01 - ToxL Fluazifop Full]

{Svenson et al. 1985} Svenson SE; Witte WT; Crater D. 1985. Phytotoxicity Evaluation of Fluazifop-P-Butyl Experimental Herbicide on 22 Species of Woody Ornamentals. Hortscience. 20 (4): 659. [Set01 - ToxL Fluazifop Full]

{Talbert et al. 1995} Talbert RE; Tierney MJ; Burgos NR; Strebe TA; Kitt MJ. 1995. Field Evaluation of Herbicides on Small Fruit, Vegetable and Ornamental Crops, 1995. Research series (Arkansas Agricultural Experiment Station) No. 447. 53 p. [Set01 – ECOTOX – Fluazifop-P-butyl]

{Talbert et al. 1996} Talbert RE; Tierney MJ; Burgos NR; Strebe TA; Curless JK; Miesner J. 1996. Field Evaluation of Herbicides on Small Fruit, Vegetable and Ornamental Crops, 1995. Research series (Arkansas Agricultural Experiment Station) No. 452. 38 p. 1503. [Set01 – ECOTOX – Fluazifop-P-butyl]

{Tantawy 2002} Tantawy AA. 2002. Effect of Two Herbicides on Some Biological and Biochemical Parameters of *Biomphalaria alexandrina*. Journal of the Egyptian Society of Parasitology. 32(3):837-47. [Set01 - ToxL Fluazifop Full]

{Tejada et al. 1994} Tejada AW; Bajet CM; Magbauna MG; Gambalan NG; Araez LC; Magallona ED. 1994. Toxicity of Pesticides to Target and Non-Target Fauna of the Lowland Rice Ecosystem. B.Widianarko, K.Vink, and N.M.Van Straalen (Eds.), Environmental Toxicology in South East Asia, VU Univ.Press, Amsterdam, Netherlands. pp. 89-103. [Set01 – ECOTOX – Fluazifop-butyl]

{Teske et al. 2002} Teske ME; Bird SL; Esterly DM; Ray SL; Perry SG. 2002. A User's Guide for AgDRIFT 2.0.05: A Tiered Approach for the Assessment of Spray Drift. Continuum Dynamics, Inc. Public Use Version. C.D.I. Report No. 01-02. Report dated January 2002. Available, with executable model at: http://www.agdrift.com/ [Std]

{Tomlin 2004a} Tomlin C. 2004a. The e-Pesticide Manual, Thirteenth Edition, Crop Protection Publications; British Crop Protection Council. Entry for fluazifop-P-butyl. Available at: http://www.bcpcbookshop.co.uk. [Std]

{Tomlin 2004b} Tomlin C. 2004b. The e-Pesticide Manual, Thirteenth Edition, Crop Protection Publications; British Crop Protection Council. Entry for fluazifop-butyl. Available at: http://www.bcpcbookshop.co.uk. [Std]

{Tong 2005} Tong L. 2005. Acetyl-coenzyme A carboxylase: crucial metabolic enzyme and attractive target for drug discovery. Cellular and Molecular Biology. 62(16):1784-803. [Clethodim-Set03]

{Trebilcock et al. 1994} Trebilcock KL; Heylings JR; Wilks MF. 1994. *In vitro* Tape Stripping as a Model for *in vivo* Skin Stripping. Toxicology In Vitro. 8(4):665-7. [Set01 - ToxL Fluazifop Full]

{Trevisan et al. 1993} Trevisan M; Montepiani C; Ragozza L; Bartoletti C; Ioannilli E; Del Rea AM. 1993. Pesticides in Rainfall and Air in Italy. Environmental Pollution. 80 (1): 31-39. [Set01 - ToxL Fluazifop Full]

{Tu et al. 2001} Tu M; Hurd C; Randall JM. 2001. Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas. Nature Conservancy. Available at: http://www.invasive.org/gist/handbook.html. [Std]

{U.S. EPA 2014} U.S. EPA (U.S. Environmental Protection Agency). 2014. U.S. Environmental Protection Agency Endocrine Disruptor Screening Program, Comprehensive Management Plan. Jointly developed by the Office of Chemical Safety and Pollution Prevention and the Office of Water. Available at: http://www.epa.gov/endo/pubs/EDSP_Comprehesive_Management%20Plan_%20021414_f.pdf. [Std]

{U.S. EPA/OCSPP 2013} U.S. EPA/OCSPP (U.S. Environmental Protection Agency/ Office of Chemical Safety and Pollution Prevention). 2013. OCSPP Harmonized Test Guidelines. OPPTS Harmonized Test Guidelines - Master List. Last Updated February, 2013. Available at: http://www.epa.gov/ocspp/pdfs/OCSPP-TestGuidelines_MasterList.pdf. [Std]

{U.S. EPA/OPP 2011b} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2011b. Fluazifop-P-butyl; Pesticide Tolerances. Federal Register. 76(22): 5696-5704. EPA Document Name: EPA-HQ-OPP-2009-0980-0004. Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2009-0980-0004. [E-Docket]

{U.S. EPA/OPP 2007a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2007a. Authorization to open Docket EPA-HQ-OPP-2007-0151: Special Docket of old risk assessments and related documents moved from Agency's reregistration chemical status web pages. Document dated May 21, 2007. Available at: http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2007-0151. [Set00]

{U.S. EPA/OPP 2007b} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2007b. Fenoxaprop-p-ethyl Summary Document Registration Review: Initial Docket. Document dated August 29, 2007. Available at: http://www.epa.gov/oppsrrd1/registration_review/fenoxaprop/. [Set00]

{U.S. EPA/OPP 2008a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2008d. Reregistration Eligibility Decision for Naphthalene. EPA 738-R-07-010. Report dated September 12, 2008. Available at: http://www.epa.gov/pesticides/reregistration/REDs/naphthalene-red.pdf. [Set00]

{U.S. EPA/OPP 2009a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2009a. Fluazifop-P-butyl; Pesticide Tolerances. Federal Register. 74(41): 9367-9373. EPA Document Name: EPA-HQ-OPP-2008-0066-0003. E-Docket No. EPA–HQ–OPP–2008–0066 Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2008-0066-0003. [E-Docket]

{U.S. EPA/OPP 2010a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2010a. Pesticide Products; Registration Applications. Federal Register. 75(48): 11884-11886. Syngenta Application. EPA Document Name: EPA-HQ-OPP-2009-0833-0003. E-Docket No. EPA–HQ–OPP–2009–0833. Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2009-0833-0003. [E-Docket]

{U.S. EPA/OPP 2010b} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2010b. Notice of Receipt of Several Pesticide Petitions Filed for Residues of Pesticide Chemicals in or on Various Commodities; Correction. Federal Register. 75(46): 11173-11174. EPA Document Name: EPA-HQ-OPP-2009-0980-0003.pdf. Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2009-0980-0003. [FOIA01]

{U.S. EPA/OPP 2010c} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2010c. Label Review Manual. Updated August 2010. Available at: http://www.epa.gov/oppfead1/labeling/lrm/. [Std]

{U.S. EPA/OPP 2011a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2011a. Fluazifop-P-butyl; Pesticide Tolerances. Federal Register. 76(188): 59906-59908. EPA Document Name: EPA-HQ-OPP-2009-0980-0005.pdf. Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2010-0849-0003. [E-Docket]

{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]

{U.S. EPA/OPP 2013b} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2013b. Registration Review: Summary of Planned Schedule for Opening Registration Review Dockets by Fiscal Year 2012 to 2015, Revised July 9, 2013. Available at: http://www.epa.gov/oppsrrd1/registration_review/fy12-fy15-schedule-summary.pdf. [Set00]

{U.S. EPA/OPP 2013c} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2013c. Occupational Pesticide Handler Unit Exposure Surrogate Reference Table. Document dated March 2013. Available at: http://www.epa.gov/pesticides/science/handler-exposure-table.pdf. [Set00]

{U.S. EPA/OPP/EFED 2001} U.S. EPA/OPP/EFED (U.S. Environmental Protection Agency/Office of Pesticide Programs/Environmental Fate and Effects Division). 2001. Ecological Risk Assessor Orientation Package, Draft Version August 2001, Environmental Fate and Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency, Washington, D.C. [Std]

{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]

{U.S. EPA/OPP/EFED 2004a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Environmental Fate and Effects Division). 2004a. Tier 2 Drinking Water Assessment for Fluazifop-P-butyl and its Major Degradate Fluazifop-acid. Report dated June 20, 2004. Available at: http://www.fluoridealert.org/pesticides/fluazifop-p-b.opp-2004-0347-0012.pdf. [Set00]

{U.S. EPA/OPP/EFED 2005a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs). 2005. Pesticide Ecological Effects Database, Guidance Manual. Document updated October 26, 2005. Available at: http://www.ipmcenters.org/Ecotox/DatabaseGuidance.pdf. [Std]

{U.S. EPA/OPP/EFED 2008} U.S. EPA/OPP/EFED (U.S. Environmental Protection Agency/Office of Pesticide Programs/Environmental Fate and Effects Division). 2008. Ecological Risk Assessment Addressing the Proposed Registration of Fluazifop-p-butyl for New Uses on Peanuts and Dry Beans and Amended Uses on Soybeans. Report dated August 28, 2008. 208 pp. Copy courtesy of U.S. EPA/OPP in response to FOIA EPA-HQ-2013-010361. [FOIA02]

{U.S. EPA/OPP/EFED 2009a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Environmental Fate and Effects Division). 2009a. Appendix H – Biography of ECOTOX Papers – to the Risks of Methidathion Use to Federally Threatened California Red-legged Frog. Available at: http://www.epa.gov/espp/litstatus/effects/redleg-frog/#methidathion. [E-Docket]

{U.S. EPA/OPP/EFED 2010a} U.S. EPA/OPP/EFED (U.S. Environmental Protection Agency/Office of Pesticide Programs/Environmental Fate and Effects Division). 2010a. Ecological Risk Assessment Addressing the Proposed Registration of Fluazifop-p-butyl for New Uses on Bananas, Plantains, Citrus, Grapes, and Sugarbeets. Report dated September 23, 2010. 126 pp. Copy courtesy of U.S. EPA/OPP in response to FOIA EPA-HQ-2013-010361. [FOIA02]

{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]

{U.S. EPA/OPP/HED 2004c} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Health Effects Division). 2004c. Fluazifop-P-butyl. Report of the Metabolism Assessment Review Committee. Report dated July 8, 2004. Available at: http://www.fluoridealert.org/pesticides/fluazifop-p-b.opp-2004-0347-0010.pdf. [Set00]

{U.S. EPA/OPP/HED 2004d} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Health Effects Division). 2004d. Fluazifop-P-butyl. Report of the Hazard Identification Review Committee. Report dated June 8, 2004. Available at: http://www.epa.gov/pesticides/chem_search/hhbp/R100705.pdf .[Set00]

{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]

{U.S. EPA/OPP/HED 2005a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Health Effects Division). 2005a. Report of the Food Quality Protection Act (FQPA) Tolerance Reassessment Progress and Risk Management Decision (TRED) for Fluazifop-P-butyl. EPA 738-R-05-005. Document dated September, 2005. Available at: http://www.epa.gov/oppsrrd1/REDs/fluazifop_tred.pdf. [Set00]

{U.S. EPA/OPP/HED 2010a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Health Effects Division). 2010a. Fluazifop-p- Butyl Acute and Chronic Aggregate Dietary (Food and Drinking Water) Exposure and Risk Assessment for the Section 3 Registration Action to add uses on Banana, Plantains, Citrus, Grapes, Potato and Sugar beet. Document dated August 9, 2010. EPA Document Name: EPA-HQ-OPP-2009-0980-0008.pdf. Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2009-0980-0008. [FOIA01]

{U.S. EPA/OPP/HED 2010b} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs Health Effects Division). 2010b. Fluazifop-P-Butyl. Request for the Registration of a Reduced Pre-Harvest Interval for Application of the Venture L End-Use Product on Imported Potatoes. Summary of Analytical Chemistry and Residue Data. Document dated August 31, 2010. 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]

{U.S. EPA/OPP/HED 2011a} U.S. EPA/OPP (U.S. Environmental Protection Agency/Office of Pesticide Programs/Health Effects Division). 2011a. Revised Fluazifop-P-Butyl. Amended Human Health Risk Assessment to Support Use on Bananas, Citrus, Grapes, Sugar Beets, and the Establishment of a Tolerance on Imported Potatoes. EPA Document Name: EPA-HQ-OPP-2009-0980-0003.pdf. Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2009-0980-0005. [FOIA01]

{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]

{U.S. EPA/OPPTS 2009} U.S. EPA/OPPTS (U.S. Environmental Protection Agency/Office of Pollution Prevention and Toxic Substances). 2009. Inert Ingredients Eligible for FIFRA 25(b) Pesticide Products. Last Updated March 3, 2009. Available at: http://www.epa.gov/opprd001/inerts/section25b_inerts.pdf. [Std]

{U.S. EPA/ORD 1992} U.S. EPA/ORD (U.S. Environmental Protection Agency/Office of Research and Development). 1992. Dermal Exposure Assessment: Principles and Applications. EPA/600/8-91/011B. Interim Report. Exposure Assessment Group, Office of Health and Environmental Assessment, Washington, DC. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=12188 [Std]

{U.S. EPA/ORD 1993} U.S. EPA/ORD (U.S. Environmental Protection Agency/Office of Research and Development). 1993. Wildlife Exposure Factors Handbook. Volumes 1 and 2. EPA/600/R-93/187a,b. Pagination not continuous. NTIS PB94-174778 and PB94-174779. Available at: http://rais.ornl.gov/homepage. [Std]

{U.S. EPA/ORD 2007} U.S. EPA/ORD (U.S. Environmental Protection Agency/Office of Research and Development). 2007. Dermal Exposure Assessment: A Summary of EPA Approaches. EPA/600/R-07/040F. Report dated September 2007. Available at http://www.epa.gov/ncea. [Std]

{U.S. EPA/OTS 1992a} U.S. EPA/OTS (U.S. Environmental Protection Agency/Office of Toxic Substances). 1992a. Initial Submission: 13 Week Dietary Toxicity Study with PP009 [Fluazifop-butyl, CAS # 69806-50-4] In Rats (Final Report) with Cover Letter Dated 08/28/92. Abstract only from TOXLINE, EPA/OTS; Doc #88-920006943. This is MRID 00093820 and is summarized in U.S. EPA/OPP/HED 2011a. [Set01 - Toxline]

{U.S. EPA/OTS 1992b} U.S. EPA/OTS (U.S. Environmental Protection Agency/Office of Toxic Substances). 1992b. Initial Submission: Teratology Study With Fluazifop Butyl in Rats with Cover Letter Dated 08/28/92. Abstract only from TOXLINE, EPA/OTS; Doc #88-920007020. This is summarized in U.S. EPA/OPP/HED 2011a as MRID 0008857, 92067047, p. 60. [Set01 - Toxline]

{U.S. EPA/OTS 1992c} U.S. EPA/OTS (U.S. Environmental Protection Agency/Office of Toxic Substances). 1992c. Initial Submission: 14 Day Subacute Oral Toxicity Study with PP009 [Fluazifop-butyl, CAS # 69806-50-4] in Rats with Cover Letter Dated 08/28/92. Abstract only from TOXLINE, EPA/OTS; Doc #88-920007017. [Set01 - Toxline]

{USDA/ARS 1995} USDA/ARS (U.S. Department of Agriculture Agricultural Research Station). 1995. ARS Pesticide Properties Database. Entry for fluazifop-P-butyl dated May 1995. Available at: http://www.ars.usda.gov/Services/docs.htm?docid=14147. [Std]

{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]

{USDA/FS. 1989b} USDA/FS (U.S. Department of Agriculture/Forest Service). 1989b. Draft Environmental Impact Statement: Vegetation Management in the Ozark/Ouachita Mountains, Management Bulletin R8-MB-23, dated June, 1989. 499 pp. [Std]

{USDA/FS. 1989c} USDA/FS (U.S. Department of Agriculture/Forest Service). 1989c. Final Environmental Impact Statement: Vegetation Management in the Appalachian Mountains, Management Bulletin R8-MB-38, dated July, 1989. 1104 pp. [Std]

{USDA/NSERL 2005} USDA/NSERL (United States Department of Agriculture/National Soil Erosion Research Laboratory). 2004. Cligen Weather Generator, expanded and improved by USDA Agricultural Research Service and U. S. Forest Service. Available at: http://horizon.nserl.purdue.edu/Cligen/. [Std]

{USGS 2013} USGS (U.S. Geological Survey). 2013. Pesticide National Synthesis Project. Pesticide Use Maps. Maps up to 2009. Entry for Fluazifop. Available at: http://water.usgs.gov/nawqa/pnsp/usage/maps . [Std]

{van Hemmen. 1992} van Hemmen JJ. 1992. Agricultural pesticide exposure data bases for risk assessment. Rev. Environ. Contam. Toxicol. 126: 1-85.[Std]

{Varga et al. 1999} Varga T; Hlubik I; Varnagy L; Budai P; Moln R E. 1999. Embryonic Toxicity of Insecticide Sumithion 50 EC and Herbicide Fusilade S in Pheasants After Individual Or Combined Administration. Acta Veterinaria Hungarica. 47(1):123-8. [Set01 - ToxL Fluazifop Full]

{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]

{Varnagy et al. 1999} Varnagy L; Budai P; Zaj K A; Varga T; Moln R E. 1999. Model Field Study of Sumithion 50 EC and Fusilade S on Pheasants. Acta Veterinaria Hungarica. 47(2):271-7. [Set01 - ToxL Fluazifop Full]

{VinZant 2013} VinZant K. 2013. Comments from Katie VinZant (Botanist/BAER Coordinator, Angeles National Forest, Arcadia, CA) on preliminary Program Description for Clethodim (SERA TR-056-05-01-01a) via email from David Bakke dated September 24, 2013. [FS01]

{Waldbauer 1968} Waldbauer GP. 1968. The consumption and utilization of food by insects. Advan Insect Physiol. 5: 229-288. [Std]

{Walker et al. 1988a} Walker KA; Ridley SM; Harwood JL. 1988a. Effects of the Selective Herbicide Fluazifop on Fatty Acid Synthesis in Pea (*Pisum sativum*) and Barley (*Hordeum vulgare*). Biochemical Journal. 254 (3): 811-818. [Set01 - ToxL Fluazifop Full]

{Walker et al. 1988b} Walker KA; Ridley SM; Lewis T; Harwood JL. 1988b. Fluazifop, a Grass-Selective Herbicide Which Inhibits Acetyl-CoA Carboxylase in Sensitive Plant Species. Biochemical Journal. 254(1):307-10. [Set01 - ToxL Fluazifop Full]

{Wall 1994} Wall DA. 1994. Fluazifop-P Tank-Mixtures with Clethodim for Annual Grass Control in Flax (*Linum usitatissimum*). Weed Technology. 8 (4): 673-678. [SET01 - Toxline01 - Clethodim]

{Wang et al. 2005} Wang P; Jiang RS; Qui J; Wang QX; Wang P; Zhou ZQ. 2005. Stereoselective degradation of ethofumesate in turfgrass and soil. Pesticide Biochemistry and Physiology. 82: 197-204. [Set02]

{Westbury and Dunnett 2008 } Westbury DB; Dunnett NP. 2008. The promotion of grassland forb abundance: a chemical or biological solution. Basic and Applied Ecology. 9: 653-662. [Set03]

{White et al. 2006} White LM; Ernst WR; Julien G; Garron C; Leger M. 2006. Ambient Air Concentrations of Pesticides Used in Potato Cultivation in Prince Edward Island, Canada. Pest Management Science. 62(2):126-36. [Set01 - ToxL Fluazifop Full]

{Wigfield and Lanouette 1993} Wigfield YY; Lanouette M. 1993. Supercritical Fluid Extraction of the Fortified Residues of Fluazifop-P-Butyl (Fusilade II) and its Major Metabolite, Fluazifop-P, in Onions. Journal of Agricultural and Food Chemistry. 41 (1): 84-88. [Set01 - ToxL Fluazifop Full]

{Williams et al. 1990} Williams FM; Mutch E; Blain PG. 1990. Rat Hepatocytes Uptake and Hydrolysis of Xenobiotics. Biochemical Society Transactions. 18 (6): 1217. [Set01 - ToxL Fluazifop Full]

{Wilson et al. 1981} Wilson BF; LeBlanc GA; Petrocelli SR; Bentley RA. 1981. The toxicity of PP009 to fathead minnow (*Pimephales promelas*) embyros and larvae. Report No. BW-81-2-813. (Unpublished study received Jan. 18, 1982 under Petition No. 2F2630 (Accession No. 070630); prepared by EG&G Bionomics, Aquatic Toxicology Laboratory, Wareham, Massachusetts; submitted by ICI Americas Inc., Wilmington, Del. [DER01]

{Wimmer et al. 1993} Wimmw MJ; Smith RK; Wallinga DI; Toney SR; Faber DC; Miracle JE; Carnes JT; Rutherford AB. 1993. Persistence of Diflubenzuron on Appalachian Forest Leaves after Aerial Application of Dimilin. J Agric Food Chem. 41: 2184-2190. [Std]

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

{Winston 1987} Winston ML. 1987. The Biology of the Honey Bee. Harvard University Press, Cambridge, MA. ISBN 0-674-07409-2 280 pp. [Std]

{Womac 2000} Womac AR. 2000. Quality Control of Standardized Reference Spray Nozzles. Transactions of the ASAE (American Society of Agricultural Engineers). 43(1): 47-56. [Std]

{Wood 2013} Wood A. 2013. Compendium of Pesticide Common Names. Justis Publishing Limited, London, United Kingdom. Available at: http://www.alanwood.net/pesticides/. [Std]

{Woollen 1993} Woollen BH. 1993. Biological Monitoring for Pesticide Absorption. Annals of Occupational Hygiene. 37(5):525-40. [Set01 - ToxL Fluazifop Full]

{Woollen et al. 1991} Woollen BH; Hart TB; Batten PL; Laird WJD; Davies DS; Dollery CT. 1991. Oral Pharmacokinetics of Fluazifop-Butyl in Human Volunteers. Human and Experimental Toxicology. 10(1): 39-43 [Set01 - ToxL Fluazifop Full]

{Xu et al. 2008} Xu C; Wang J; Liu W; Sheng GD; Tu Y; Ma Y. 2008. Separation and aquatic toxicity of enantiomers of the pyrethroid insecticide Lambda-cyhalothrin. Environmental Toxicology and Chemistry 27: 17 4-181. [Set02]

{Yu et al. 2007} Yu Q; Collavo A; Zheng MQ; Owen M; Sattin M; Powles SB. 2007. Diversity of Acetyl-Coenzyme A Carboxylase Mutations in Resistant *Lolium* Populations: Evaluation Using Clethodim. Plant Physiology. 145(2):547-58. [SET01 - Toxline01 - Clethodim]

{Zidan et al. 2002} Zidan ZH; Ragab FM; Mohamed KH. 2002. Molluscicidal Activities of Certain Pesticide and Their Mixtures against *Biomphalaria alexandrina*. Journal of the Egyptian Society of Parasitology. 32(1):285-96. [Set01 - ToxL Fluazifop Full]

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

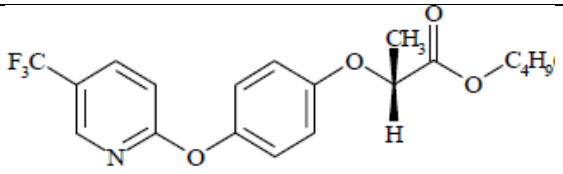
Topic	Citations[1]
Human Health	
Dermal Absorption	Auton et al. 1993a,b, 1994; Clark et al. 1993; Dick and Scott 1992; Hilton et al. 1994; Ramsey et al. 1994; Rawlings et al. 1994b; Trebilcock et al. 1994;
Mechanism	Kemal and Casida 1992; Kostka et al. 2002; Krijt et al. 1993, 1997;
Metabolism	McCracken 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	$C_{19}H_20F_3NO_4$	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

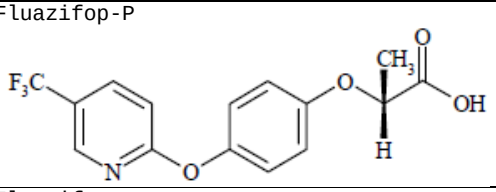
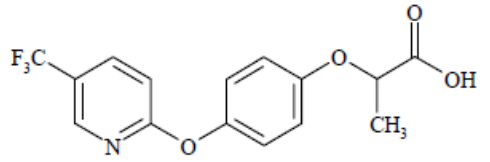
Item	Value	Reference[1]
Hydrolysis	DT_{50} (days) / pH at 25°C: >30 / 5; 78 / 7; ≈1.2 [29 hrs] / 9	Tomlin 2004
	Stable at pH 4 and 7. Half-life of 2.5 days at pH 9.	Negre et al. 1998
K_{ow}	≈31,600 [logP = 4.5] (20 °C)	Tomlin 2004; U.S. EPA/OPP 2004a, MRID 92067999; EFSA 2012
Molecular weight (g/mole)	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
	3×10^{-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. 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) 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: Initial phase (to 14 day): 6.2 to 7.2 days 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) Note: This appears to be for fluazifop and 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

<table>
<tr><th>Item</th><th>Value</th><th>Reference</th></tr>
<tr><td></td><td>Identifiers</td><td></td></tr>
<tr><td>Common name:</td><td>Fluazifop-P</td><td>Tomlin 2004</td></tr>
<tr><td>CAS Name</td><td>(R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl] oxy]phenoxy]propanoic acid</td><td>Tomlin 2004</td></tr>
<tr><td>CAS No.</td><td>83066-88-0</td><td>Tomlin 2004</td></tr>
<tr><td>IUPAC Name</td><td>(R)-2-[4-(5-trifluoromethyl-2-pyridyloxy) phenoxy]propionic acid</td><td>Tomlin 2004</td></tr>
<tr><td>Mechanistic group</td><td>WWSA Group 1/HRAC Class A: Inhibitors of acetyl CoA carboxylase (ACCase)</td><td>Mallory-Smith and Retzinger 2003</td></tr>
<tr><td>Chemical Group</td><td>Aryloxyphenoxy propionate</td><td>Mallory-Smith and Retzinger 2003</td></tr>
<tr><td>Molecular formula</td><td>$C_{15}H_{12}F_3NO_4$</td><td>Tomlin 2004</td></tr>
<tr><td>Smiles Code</td><td>n1cc(C(F)(F)F)ccc1Oc2ccc(OC(C)C(=O)O)cc2</td><td>EPI-Suite 2011</td></tr>
<tr><td>Structure (resolved [R] stereo- isomer)</td><td>Fluazifop-P
  </td><td>U.S. EPA/OPP 2004b, Table 3</td></tr>
<tr><td>Structure (racemic, without stereochemistry)</td><td>Fluazifop
  </td><td>U.S. EPA/OPP 2004b, Table 3</td></tr>
<tr><td></td><td>Chemical Properties(1)</td><td></td></tr>
<tr><td>Form</td><td>Pale yellow, glass-like material</td><td>Tomlin 2004</td></tr>
<tr><td>Henry’s Law Constant</td><td>3 x 10^{-7} Pa m^3 mol^{-1} (calc.)</td><td>Tomlin 2004</td></tr>
<tr><td>Hydrolysis</td><td>Stable at pH 5 to 9 at 25°C</td><td>Tomlin 2004</td></tr>
<tr><td></td><td>78 days at pH 7</td><td>U.S. EPA/OPP 2004a, p. 11</td></tr>
<tr><td>Kow</td><td><table><tr><th>pH (20°C)</th><th>≈Kow</th><th>Log Kow</th></tr><tr><td>2.6</td><td>1260</td><td>3.1</td></tr><tr><td>7</td><td>0.16</td><td>-0.8</td></tr></table>Note: These appear to be measured values.</td><td>Tomlin 2004</td></tr>
<tr><td></td><td>≈1510 [Log Kow = 3.18]
Note: This measured value is probably at acidic pH. See above from Tomlin 2004.</td><td>EPI-Suite 2011</td></tr>
<tr><td></td><td>≈1510 [Log Kow = 3.18]
Cited as measured value.</td><td>Chamberlain et al. 1996</td></tr>
<tr><td>MW (g/mole)</td><td>327.3</td><td>Tomlin 2004</td></tr>
<tr><td></td><td>327.26</td><td>EPI-Suite 2011</td></tr>
<tr><td>pKa</td><td>2.8</td><td>U.S. EPA/OPP 2003a, Table 2, MRID 41900604</td></tr>
<tr><td></td><td>3.22 [specified as fluazifop]</td><td>Chamberlain et al. 1996</td></tr>
<tr><td></td><td>2.98 [fluazifop-P]</td><td>Kah and Brown 2007b; Kah et al 2007</td></tr>
<tr><td>Vapor pressure</td><td>7.9 x 10^{-4} mPa (20 °C)</td><td>Tomlin 2004</td></tr>
</table>

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

Source: www.Greeenbook.net

Formulation, Supplier, EPA Registration Number	Composition/ Characteristics[1]	Application Information, Methods and Rates[2]
Fusilade DX Syngenta EPA Reg. No. 100-1070 EPA SLN No. CA-110010	24.5% a.i. on label and MSDS. (20.09 % a.e.) 2 lbs. a.i./gallon (1.708 lbs a.e./gallon) 75.5% inerts, *Contains petroleum distillates.* Density: 0.9807 g/ml @ 68°F (20°C) pH: 6.2 (1% w/w dilution in deionized water)	Relevant Labeled Uses: Conifers – Christmas tree plantings, nursery beds, and seedling establishment. A**pplication 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. 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. Maximum Seasonal Rate: 1.125 lb a.i./acre/season [3 applications of 24 oz/day] Minimum Application Interval: 14 days Adjuvants: COC or NIS 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. NIS with 75% surface active agent at 0.25%-0.5% v/v for ground application. 1 pt./acre for aerial application. Application Volumes Ground Application: 5-40 gals./acre, minimum of 20 gals/acre for dense grass. Aerial Application: 5-10 gal./acre.
Fusilade II, Turf and Ornamental Herbicide. Syngenta EPA Reg. No. 100-1084 Cannot be used in Nassau and Suffolk Counties in NY.	24.5% a.i. on label and MSDS. (20.09 % a.e.) 2 lbs. a.i./gallon (1.708 lbs a.e./gallon) 75.5% inerts, *Contains petroleum hydrocarbons.* Density: 0.98 g/ml @ 68°F (20°C) 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.** 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. Maximum Seasonal Rate: None specified for conifers. Adjuvants: COC or NIS 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. NIS with 75% surface active agent at 0.25%-0.5% v/v for ground application. 1 pt./acre for aerial application. Application Volumes Ground Application: 5-40 gals./acre, minimum of 20 gals/acre for dense grass. Aerial Application: 5-10 gal./acre.

Formulation, Supplier, EPA Registration Number	Composition/ Characteristics[1]	Application Information, Methods and Rates[2]
Ornamec 170 Grass Herbicide PBI/Gordon Corporation EPA Reg. No. 2217-751	1.7% a.i. on label and MSDS. 0.125 lb. a.i./gallon (0.107 lb a.e./gallon) 98.3% inerts, *Contains petroleum distillates.* Density: 7.44 lbs./gal. Specific gravity: 0.89037 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. 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. Maximum Seasonal Rate: 1.1 lbs. a.i./acre/season. Adjuvants: None specified. Application Volumes Ground Application: N.S. Spray to coverage but not to runoff. Aerial Application: N/A
Ornamec Over-the-top PBI/Gordon Corporation EPA Reg. No. 2217-728	6.75% a.i. on label and MSDS. 0.5 lbs. a.i./gallon (0.427 lb a.e./gallon) 93.25% inerts, *Contains petroleum distillates, xylene or xylene range aromatic solvent.* Density: 7.43 lbs./gal. Specific gravity: 0.89121 pH: N.S.	Relevant Labeled Uses: Control of grasses in non-crop areas with ornamentals, trees, shrubs, and ground cover. **No specific forestry applications.** Application rates: 64-96 oz./acre (0.25–0.375 lb. a.i./acre). Maximum Seasonal Rate: N.S. Adjuvants: Nonionic surfactant with at least 75% surface wetting agent at 0.25% v/v. Application Volumes Ground Application: Minimum of 30 gallons/acre. 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)	Naphthalene	N.S.	<5%
24.5% a.i., 75.5% total inerts	Petroleum distillates, light paraffinic	N.S.	N.S.
	Petroleum Solvent	N.S.	N.S
Fusilade II (Syngenta)	Naphthalene	N.S.	<5%
24.5% a.i. 75.5% total inerts	Petroleum distillates, light paraffinic	N.S.	N.S.
	Petroleum Solvent	N.S.	N.S
Ornamec 170 (PBI Gordon)	1,2,4-trimethylbenzene	95636	9.0%
1.7% a.i.	Ethyl benzene	100414	1.7%
98.3% total inerts	Petroleum solvent	64742956	11.3%
	Xylenes	1330207	0.9%
Ornamec Over-the-top	1,2,4-trimethylbenzene	95636	9.6%
(PBI Gordon)	Ethyl benzene	100414	2.0%
6.75% a.i.	Petroleum solvent	64742956	13.6%
93.25% total inerts	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] **50** [6]	10[5] 200	00088857
Rats	200	N/A[3]	1[5] 10	5[5] 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.

See Appendix 1, Table A1-3 for details.
See Section 3.1.9 for discussion.

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 **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.

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) ≥ 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 Agent	LC_{50} (mg a.e./L)[1]	NOAEC (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 [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 [Slope=10.1]	1.92	MRID 00087486
Rainbow trout, 25.8% formulation	4.2 [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, Agent	NOAEC (mg a.e./L)	LOAEC (mg a.e./L)	Reference
Fathead minnow, fluazifop-butyl	>0.203	N/A	MRID 00093808
Fathead minnow fluazifop-P-butyl	0.07	N/A	EFSA 2012; FAO/WHO 2000
Fathead minnow 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}÷20	0.001 mg/L	Section 4.3.3.4.1
	Tolerant	*S. obliquus* LC_{50}÷20	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.

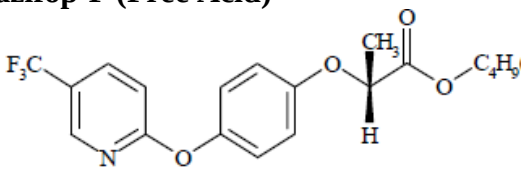
Table 40: Risk Characterization for Aquatic Macrophytes

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

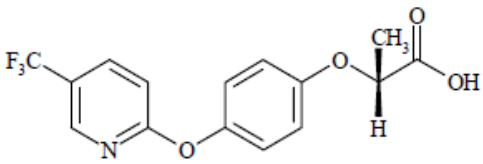
[1] Not available because of the lack of toxicity data in a clearly sensitive species.

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

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

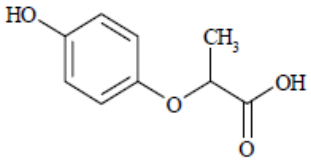


Fluazifop-P-butyl ([R] enantiomer of fluazifop-P-butyl)

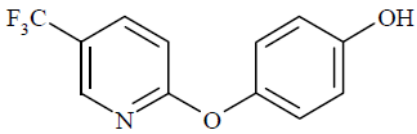


Fluazifop-P ([R] enantiomer of fluazifop)

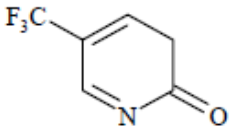
Major Environmental Metabolites



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



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

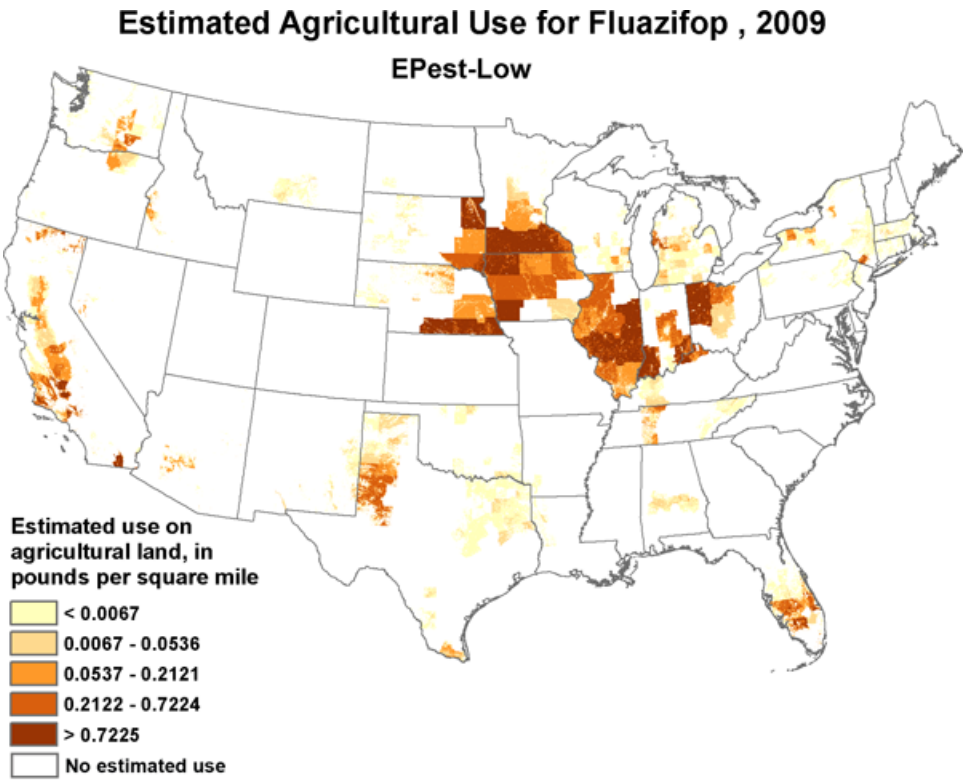


5-trifluoromethyl-2-pyridone (Compound X metabolite)

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.



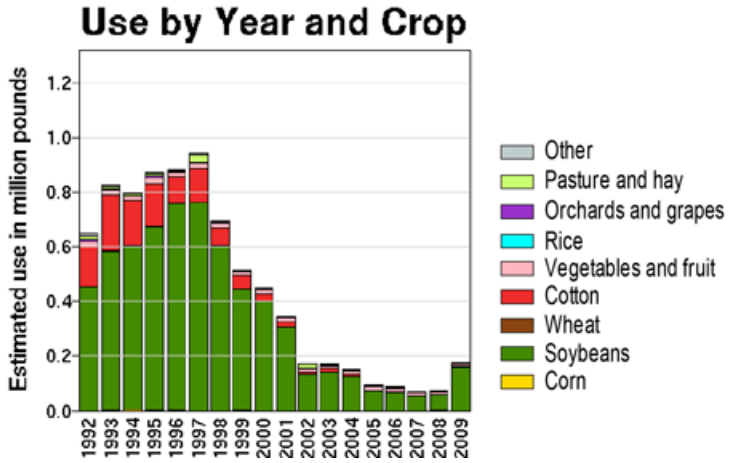


Figure 2: Lower Bound Estimated Agricultural Use of Fluazifop-P-butyl for 2009

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

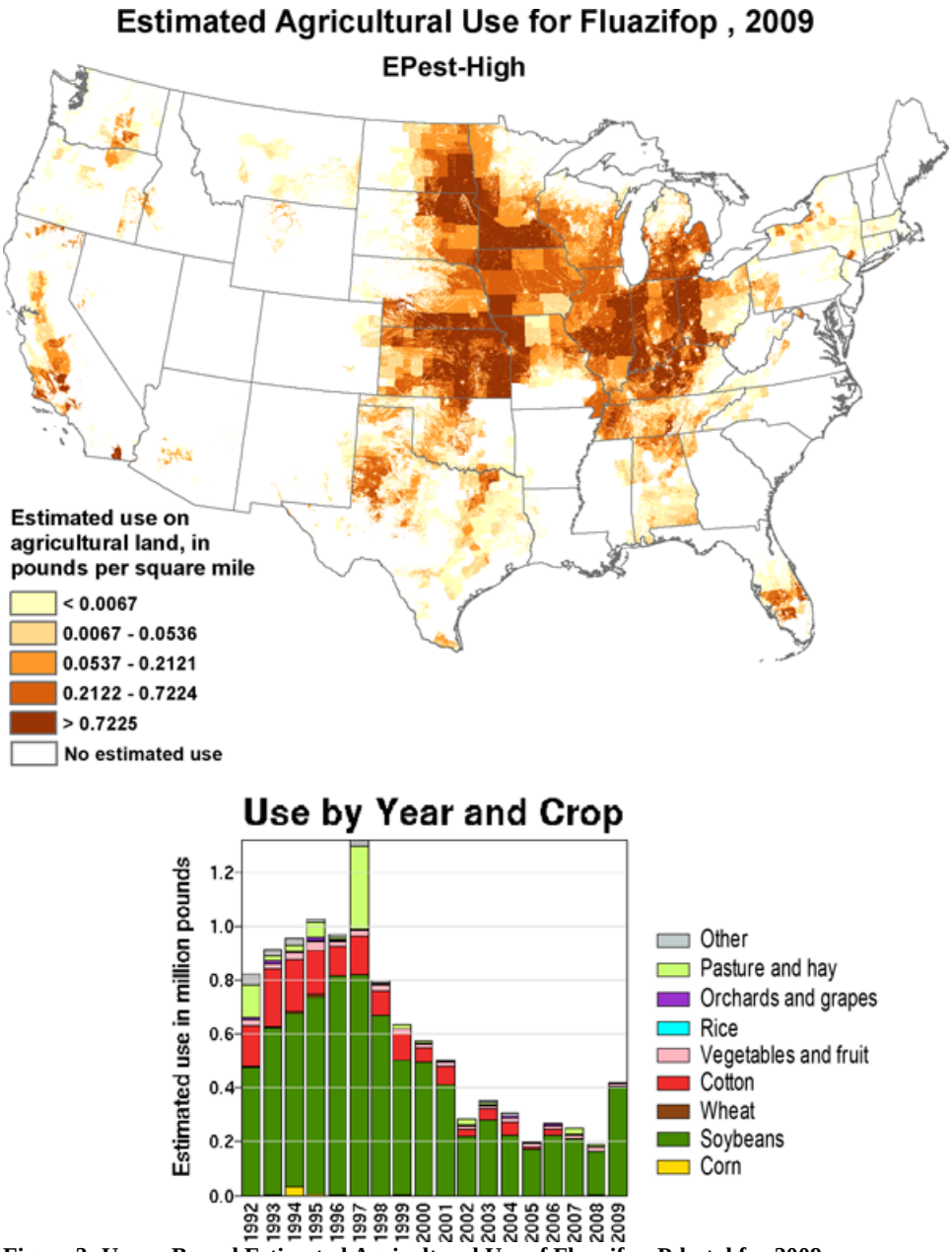


Figure 3: Upper Bound Estimated Agricultural Use of Fluazifop-P-butyl for 2009

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

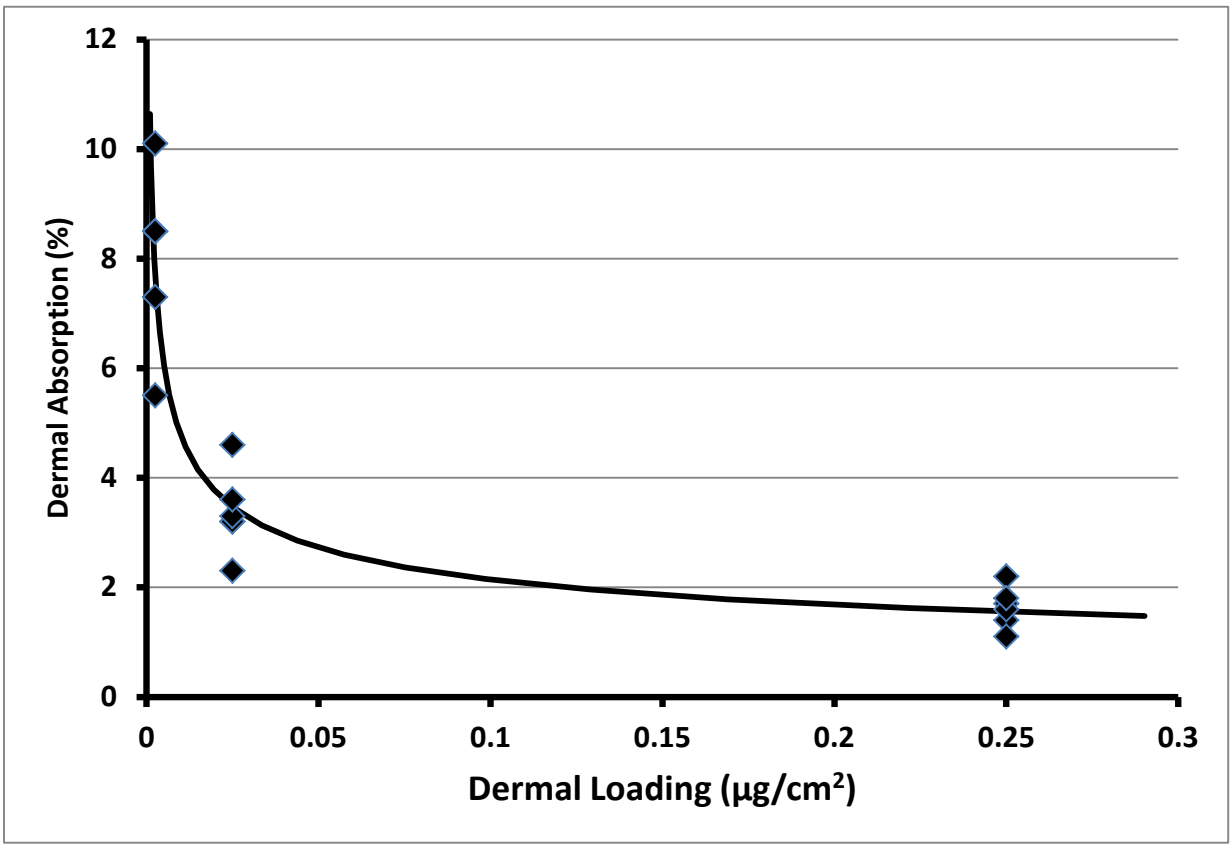


Figure 4: Relationship of Dermal Absorption to Dermal Loading

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: $Abs = 0.96L^{-0.348}$ ($r^2 = 0.91$, $p = 9x10^{-10}$).

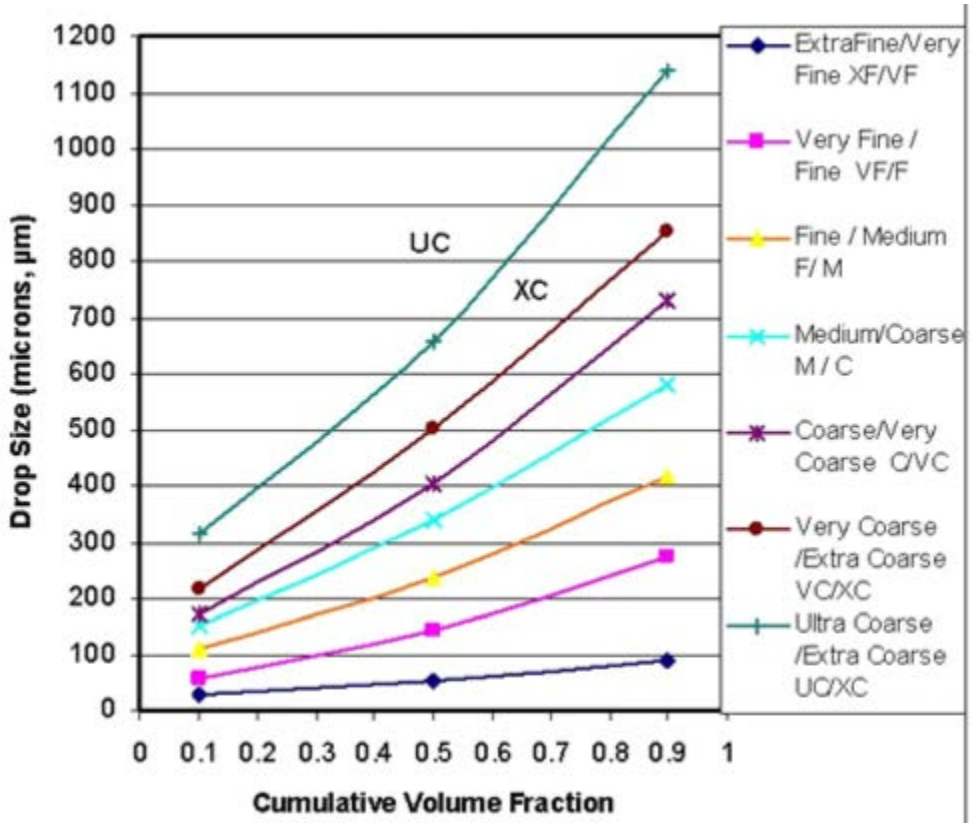


Figure 5: Sample Reference Graph for Droplet Size Classification

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.

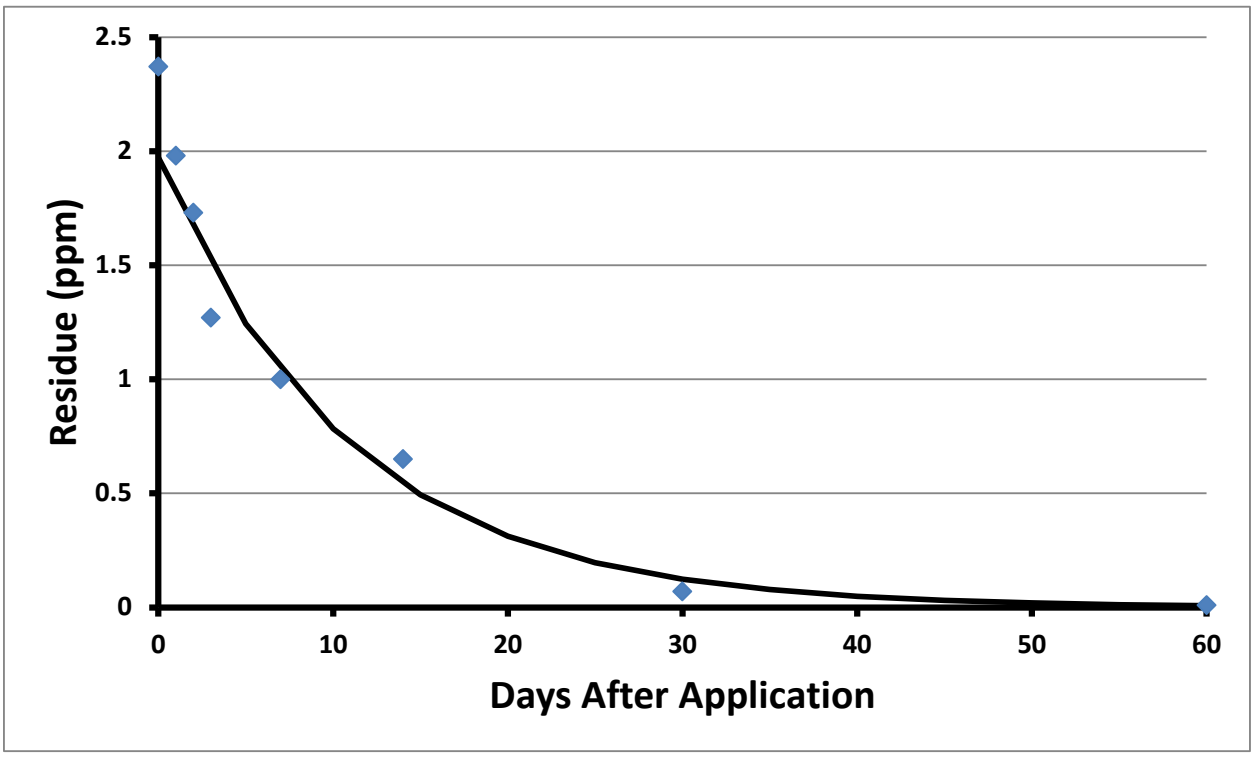


Figure 6: Residues on soybean foliage from Kulshrestha et al. (1995)

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} Males: 1940 (1193-2758) mg/kg Females: 2653 (1764-3625) mg/kg Toxicity Category III	MIRD 00162439, 1983
Rats	Fluazifop-P-butyl, PP005, 93.7% and 86.3%	Acute LD_{50} Males: 3680 mg/kg Females: 2451 mg/kg Toxicity Category III	MRID 00162440, 1984 Also cited in FOA/WHO 2000 and EFSA 2012 (females only)

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 (≈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.

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 Doses: 0, 5, 25, 125/250 mg/kg/day	NOAEL = 25 mg/kg/day 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. Also seen were body weight loss gut lesions, severe eye lesions and hepatotoxicity. In remaining surviving dogs dosed at 125 mg/kg/day , mild to equivocal liver lesions were seen.	MRID 00093821 1980, Acceptable
Dogs	Fluazifop-butyl Doses: 0, 5, 25, 125 mg/kg/day for 1 year.	NOAEL = 5 mg/kg/day 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 M: 0, 19.5, 78.3 or 291.9 mg/kg/day F: 0, 19.9, 79.0 or 319.6 mg/kg/day **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 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 Dietary Conc: 200, 750, 3000 ppm M: 0, 12.5, 47.4,193.6 mg/kg/day F; 0, 12.1, 45.5, 181.4 mg/kg/day	NOAEL = M/F 12.5/12.1 mg/kg/day 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. High Dose Group: Slight increase in brain weights. No evidence of carcinogenicity	MRID 4534501, 46082905, (2001), Acceptable
Rats	Fluazifop-butyl, 90 days Dietary Conc: 0, 10, 100, 2000 ppm M: 0, 0.7, 7.1, 144.5 mg/kg/day F; 0, 0.8, 8.0, 161.9 mg/kg/day	NOAEL=0.7 mg/kg/day LOAEL=7.1 mg/kg/day based on liver and kidney histopathology	MRID 00093820 , 1980, Acceptable

Organism	Agent/Exposure	Response	MRID, Study Date, Classification
Rats	Fluazifop-P-butyl, 90 days Dietary Conc: 0, 10, 100, 2000 ppm M: Doses not specified. F; 0, 0.5, 5, 100 mg/kg/day	NOAEL=0.5 mg/kg/day LOAEL=5 mg/kg/day based on decreased spleen weight and decreased hematological parameters in males. Dose related testicular weight decrement and cholesterol depression were also seen. 2000 ppm : Slight increase in brain weights (2.9%) in female rats.	MRID 46158402, 1985, Acceptable
Rats, Wistar, 60/sex/group. 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.] Dietary Conc.: 0, 2, 10, 80, 250 ppm M: 0, 0.10, 0.51, 4.15, 12.3 mg/kg/day 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 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. 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.

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 NOAEL=30 mg/kg/day LOAEL=90 mg/kg/day based on abortions. HazID: A nominal absolute liver (13%) and relative liver weight (9%) increase was seen at 90 mg/kg/day. Developmental NOAEL=30 mg/kg/day 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 NOAEL=10 mg/kg/day 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. Developmental NOAEL=10 mg/kg/day LOAEL=50 mg/kg/day based on increased incidence of 13th 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 Based on U.S. EPA/OPP 2011a, p. 68	Maternal NOAEL = 200 mg/kg/day LOAEL = None. Developmental NOAEL=None LOAEL=10 mg/kg/day based on delayed ossification. Malformations NOAEL = 50 mg/kg/day LOAEL = 200 mg/kg/day based on diaphragmatic hernias.	MRIDs 00088857, 92067047, (1981), Acceptable **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. 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. 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]. 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. 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 **This study is used for the occupational short-term (1-30 days) assessment derived by U.S. EPA/OPP/HED (2011a).**
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 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 unossified in fetuses and litters.	MRID 46082013, (1990), Acceptable

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 Durations: Parental: 100 days F1: 120 days F2: to weaning. Details taken from U.S. EPA/OPP/ HED 2004a, pp. 40-41.	Parental/Systemic NOAEL = M/F 0.74/7.1 mg/kg/day 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. **Working Note: The LOAEL for females should probably be 17.5 mg/kg bw/day.** 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.* Offspring NOAEL = 7.1 mg/kg/day 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. HazID (p. 13) notes that weight of F1 adult females was significantly increased (10%) at Week 17. Reproductive NOAEL = M/F 0.74/0.88mg/kg/day 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 **This study is the basis for the chronic RfD derived by U.S. EPA/OPP/HED (2011a).** **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

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

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

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.

A1 Table 7: Acute Inhalation Toxicity

Source: U.S. EPA/OPP/HED 2004a unless otherwise specified.

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 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

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.

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 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. Concentrations: 0, 6554, 8192, 10,240, 12,800, 16,000, 20,000, and 25,000 ppm.	ECOTOX LC_{50} >25,000 ppm NOEL = 6522 ppm EPA/OPP LC_{50} >21,348 ppm (a.e.) DER 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. **Working Note: DER does not give body weights or food consumption.**	MRID 00087481, 1980, Supplemental EPA/OPP/EFED 2008, Appendix C. ECOTOX 2013 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 NOEL = 8192 ppm Above values correspond to: LC_{50} = 15,799 ppm (a.e.) 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. 5 day treatment and 3 day recovery period. Dieldrin as positive control.	EPA/OPP LC_{50}= 20,767 ppm a.i. (≈17,735 ppm a.e.) [reanalysis of reported LC_{50}] DER LC_{50} = 18,500 (15,400 – 22,200) ppm a.i. Food consumption in treated birds not significantly different from controls. Values for food consumption and body weights not given in DER. NOAEL not given in DER.	MRID 00087482, 1982, Acceptable 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. Ross et al. 1980a [Syngenta DER01]

Appendix 2: Toxicity to Birds *(continued)*

Agent 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 LC_{50} >5230 ppm NOEL = 2980 ppm EPA/OPP LC_{50} >4,460 ppm (a.e.) 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. Concentrations: 0, 440, 653, 1090, 1820, 2980, or 5320 ppm diet (FAO/WHO 2000).	ECOTOX LC_{50} >5230 ppm NOEL = 2980 ppm EPA/OPP LC_{50} >4,460 ppm (a.e.)	MRID 40859401, 1985, Acceptable EPA/OPP/EFED 2008, Appendix C. ECOTOX 2013 Also cited in FAO/WHO 2000
Mallard duck (*Anas platyrhynchos*), 9-days-old	Fluazifop-butyl, 95% purity, ad libitum in diet for 8 days. Concentrations: 0, 412, 667, 1140, 1880, 3080, or 4850 ppm diet (FAO/WHO 2000)	ECOTOX LC_{50} >4850 ppm NOEL <1040 ppm EPA/OPP LC_{50} >4,142 ppm (a.e.) NOEAL: 4,142 ppm (a.e.)	MRID 40851401, 1985, Acceptable. EPA/OPP/EFED 2008, Appendix C. ECOTOX 2013 Also cited in FAO/WHO 2000

A2 Table 3: Reproductive and Subchronic Toxicity to Birds

<table>
<tr><th>Agent
Species</th><th>Exposure</th><th>Response</th><th>Reference</th></tr>
<tr><td>Fluazifop-butyl</td><td></td><td></td><td></td></tr>
<tr><td>Mallard duck (Anas platyrhynchos), early life stage,
A total of 39 male and 91 female wild caught birds.</td><td>Fluazifop-butyl, 99.6% purity, dietary administration for 23 weeks.

Concentrations: 0, 5, 50 ppm (FAO/WHO 2000 and DER)

Food consumption as proportion of bw:
<table><tr><th>Dose (ppm)</th><th>Initial</th><th>Final</th></tr><tr><td>0</td><td>0.110</td><td>0.133</td></tr><tr><td>5</td><td>0.105</td><td>0.139</td></tr><tr><td>10</td><td>0.104</td><td>0.125</td></tr></table>Food consumption and body weights not statistically significantly different.
Average of initial and final proportion of food for high dose is 0.1145.</td><td>ECOTOX
LOEC: >50 ppm
NOEL: >50 ppm
EPA
NOAEL ≥43 ppm (a.e.)

DER
Some mortality in adults but not attributed to treatment.
No statistically significant ($p<0.05$) differences in any parameters.

Estimated NOAEL:
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]</td><td>MRID 00093801, 1981, Supplemental. EPA/OPP/EFED 2008, Appendix C.

ECOTOX 2013

Also cited in FAO/WHO 2000.

Roberts et al. 1981a [Syngenta DER01]
DER indicates a Core Classification</td></tr>
<tr><td>Bobwhite quail (Colinus virginianus), early life stage</td><td>Fluazifop-butyl, 99.6% purity, dietary administration for 31 weeks.

Concentrations: 0, 5, 50 ppm (FAO/WHO 2000 and DER)

Food consumption as proportion of bw:
<table><tr><th>Dose (ppm)</th><th>Initial</th><th>Final</th></tr><tr><td>0</td><td>0.0524</td><td>0.123</td></tr><tr><td>5</td><td>0.0521</td><td>0.0991</td></tr><tr><td>10</td><td>0.0582</td><td>0.0942</td></tr></table>Food consumption and body weights not statistically significantly different.
Average of initial and final proportion of food for high dose is 0.0762.</td><td>ECOTOX
LOEC (repro) >50 ppm
NOEL >50 ppm
EPA
NOAEL ≥43 ppm (a.e.)
DER
Some mortality in adults but not attributed to treatment.
No statistically significant ($p<0.05$) differences in any parameters.
Transient (1st 6 weeks) and statistically insignificant ($p>0.05$) decrease in eggs laid in 50 ppm group.

Estimated NOAEL:
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]</td><td>MRID 00093802, 1981, Supplemental. EPA/OPP/EFED 2008, Appendix C.

ECOTOX 2013

Also cited in FAO/WHO 2000

Roberts et al. 1981b [Syngenta DER01]
DER indicates a Core Classification</td></tr>
</table>

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. Doses: 0, 5, 10, 20, 50, and 100 µg a.i./bee	ECOTOX LD_{50} = 180 µg/bee NOEL <180 µg/bee EPA/OPP 24-h LD_{50}: 154 µg a.e./bee NOAEL: < 154 µg a.e./bee. DER No effects on bees at up to 100 µg a.i./bee.	MRID 00093809,1979, Acceptable. ECOTOX 2013 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. Doses: 0, 5, 10, 20, 50, 100, and 200 µg a.i./bee	ECOTOX LD_{50} >195 µg/bee NOEL = 100 µg/bee EPA/OPP 24-h LD_{50}: >166 µg a.e./bee Est. NOAEL: 85.4 µg a.e./bee. DER No effects on bees at up to 100 µg a.i./bee.	MRID 00093809, 1979, Acceptable. ECOTOX 2013 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. Doses: 0, 5, 10, 20, 50, 100, and 200 µg a.i./bee	ECOTOX LD_{50} >240 µg/bee NOEL = 195 µg/bee EPA/OPP 24-h LD_{50}: >205 µg a.e./bee Est. NOAEL: 167 µg a.e./bee. DER No effect on bees at doses up to 200 µg a.i./bee.	MRID 00093809, 1979, Acceptable. ECOTOX 2013 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. Doses: 0, 5, 10, 20, 50, 100, and 200 µg a.i./bee	ECOTOX LD_{50} >95 µg/bee NOEL = 95 µg/bee EPA/OPP 24-h LD_{50}: >81 µ a.e./bee NOAEL: 81µg a.e./bee. DER No effect on bees at doses up to 200 µg a.i./bee. **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. ECOTOX 2013 Smailes and Wilkinson 1979 [Syngenta DER01]

Agent ROUTE Species	Exposure	Response	Reference
Honey bee (*Apis mellifera*), adult	Fluazifop-butyl formulation, 13.8 % a.i., **topical** application for 24 hours.	ECOTOX LD_{50} = 63 µg/bee NOEL >200 µg/bee EPA/OPP 24-h LD_{50}: 54 µg a.e./bee **See note at end of table.**	MRID 00162453, 1984, Acceptable. 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.

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 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".	Dose (g a.e./ha) / Mortality (%): 15 / 12; 200 / 44; 375 / 60 LR_{50} = 174 g a.s./ha [≈0.13 lb a.e./acre] Summary specifies an 8% adverse effect on reproduction at 15 g a.s./ha [≈0.011 lb a.e./acre]. **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. 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. 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. 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. 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

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.**

A3 Table 3: Field and Mesocosm Studies on Arthropods

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

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. **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). Increases in survival with herbicide, surfactant, as well as herbicide with surfactant (Figure 1b of paper).	Russell and Schultz 2010 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. 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). 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 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

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) 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. No substantial effects on emergence for surface seeds or seeds planted at 10 mm. 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

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

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

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

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

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

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

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

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

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
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. Solvent = 2-propanone (acetone)	LC_{50} = 0.29 ppm (a.i.) Equiv. to 0.25 ppm (a.e.) **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 (Also cited in ECOTOX 2013)
Fathead minnow (*Pimephales promelas*), <24-hours-old. 15 fish/dose.	Fluazifop-butyl, 90.2% purity for 96 hours in static system. Nominal Concentrations: 0, 0.098, 0.16, 0.27, 0.45, and 0.75 mg a.i./L.	ECOTOX LC_{50} = 0.37 ppm (a.i.) NOEL = 0.27 ppm (a.i.) EFED LC_{50} = 0.32 ppm (a.e.) NOAEC = 0.23 ppm (a.e.) DER NOAEC based on 1/15 mortality in mid-dose group after 96-hours. Slope: 10.65 LC_{50} = 0.37 ppm (a.i.) with 95% confidence interval of 0.32-0.44 ppm (a.i.) **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 ECOTOX 2013 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. Nominal Concentrations: 0.36, 0.77, 1.07, and 1.6 mg a.i./L.	ECOTOX LC_{50} = 0.53 ppm NOEL = 0.36 ppm EFED LC_{50} = : 0.45 ppm (a.e.) NOEL = 0.31 ppm (a.e.) DER LC_{50} = 0.53 ppm (a.i.) with 95% confidence interval of 0.36-0.77 mg a.i./L. 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*. 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 ECOTOX 2013 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. Test concentrations: 1.3-1.54 ppm	ECOTOX LC_{50} = 1.41 ppm NOEL = 0.8 ppm EFED LC_{50} = 1.2 ppm (a.e.) Slope: 15.2 NOEL = 0.68 ppm (a.e.)	MRID 00131458, 1983, Supplemental ECOTOX 2013 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. Test concentrations: 108-127 ppm	ECOTOX LC_{50} = 117 ppm NOEL = 96 ppm EFED LC_{50} = 99.9 ppm (a.e.) NOEL = 82.0 ppm (a.e.)	MRID 00087483, 1981, Acceptable ECOTOX 2013 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. Test concentrations: 2.32-3.07 ppm (2320-3070 µg/L)	ECOTOX LC_{50} = 2.67 ppm NOEL = 1.51 ppm EFED LC_{50} = : 2.28 ppm (a.e.) NOEL = 1.29 ppm (a.e.)	MRID 00087486, 1981, Acceptable ECOTOX 2013
Rainbow trout (*Oncorhynchus mykiss*), 2.2 g	Fluazifop-butyl, 25.8% formulation for 96 hours in flow-through system. Test concentrations: 4.4-5.4 ppm (4400-5400 µg/L)	ECOTOX LC_{50} = 4.9 ppm NOEL = 0.4 ppm EFED LC_{50} = 4.2 ppm (a.e.) NOEL = 0.34 ppm (a.e.)	MRID 00087484, 1981, Acceptable ECOTOX 2013
Rainbow trout (*Oncorhynchus mykiss*)	Fusilade Max (EC 125 g/L)	1.6 mg a.i./L [≈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. Test concentration: 9-13 ppm	ECOTOX LC_{50} = 11 ppm NOEL = 3 ppm EFED LC_{50} = 9.4 ppm (a.e.) Slope = 13.2 NOEL = 2.56 ppm (a.e.)	Accession No.[1]: ACC070630, 1981, Acceptable 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. Nominal Concentrations: 1.7, 3, 5.5, 9.8, 15.7, and 25.7 mg/L.	ECOTOX LC_{50} = 8.04 ppm NOEL = not reported. EFED LC_{50} = 6.86 ppm (a.e.) Slope: 10.1 DER LC_{50} = 8.1 ppm formulation Working Note: Correcting for the formulation to a.e. conversion, the correct LC_{50} is: LC_{50} = 3.24 ppm (a.e.)	MRID 00152173, 1985, Acceptable ECOTOX 2013 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. Fusilade blank: 1.7, 9.6, and 29.8 mg/L.	DER LC_{50} = 10.4 ppm formulation The formulation blank caused no mortality at lowest concentration, 40% mortality at mid concentration, and 100% mortality at highest concentration. *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.

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 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 EC_{50} = 281.2 ppm (a.i.) NOEL = 97 ppm EFED 2008, p. 190 EC_{50} = 240 ppm (a.e.) NOAEC: 82.8 ppm (a.e.)	MRID 00087490, 1981, Acceptable 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 EC_{50} = 553.9 ppm NOEL = 192 ppm EFED EC_{50} = 473 ppm (a.e.) NOAEC: 162 ppm (a.e.)	MRID 00162452, 1983, Supplemental 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 EC_{50} = 545.6 ppm) NOEL = 298 ppm EFED EC_{50} = 466 ppm (a.e.) NOAEC: 254 ppm (a.e.)	MRID 00162452, 1983, Supplemental 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 EC50 = 412.4 ppm NOEL = 162 ppm EFED EC_{50} = 352 ppm (a.e.) NOAEC: 138 ppm (a.e.)	MRID 00162452, 1983, Supplemental ECOTOX 2013

Appendix 6: Toxicity to Aquatic Invertebrates *(continued)*

Form 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 DER: Two separate assays at concentrations up to 10 mg/L (Test 1) and 12.3 mg/L (Test 2).	ECOTOX EC_{50} >10 ppm NOEL = 10 ppm EFED 48-h EC_{50}: 8.5 ppm (a.e.) DER No effects observed at any concentration.	MRID 00087488, 1979, Acceptable ECOTOX 2013 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. Working Note: Paper focuses on impact of compound on pathogen.	LC_{50}: 17.6 mg/L LC_{5}: 1.76 mg/L Decreased glycogen content of soft tissues (NOS). 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 EC_{50} = 6.02 ppm NOEL = 1.25 ppm EPA EC_{50} = 5.14 ppm (a.e.) NOEL = 1.07 ppm (a.e.) **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.**	MRID 00087489, 1980, Acceptable ECOTOX 2013
Water flea (*Daphnia magna*), 12-hours-old	Fluazifop-butyl (PP009), **25 EC**, 25% a.i., for 48 hours in static system.	ECOTOX EC_{50} = 6.5 ppm NOEL = Not reported EPA EC_{50} = 5.5 ppm (a.e.) DER The DER does not detail the results of the formulation assay.	MRID 00087488, 1979, Acceptable ECOTOX 2013 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 EC_{50} ≈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 (Cited in ECOTOX 2013)
Fluazifop acid			
Daphnia magna	Fluazifop acid (NOS), static	LC_{50} = 240 mg a.e./L	EFSA 2012

Form 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 Species	Exposure	Response	Reference
Fluazifop-butyl			
Pacific oyster (*Crassostrea gigas*), embryo	Fluazifop-butyl (PP009), 98.6% purity, for 48 hours in flow-through system. Test concentration: 91-105 ppb	ECOTOX LC_{50} = 0.097 ppm NOEL = 0.056 ppm EFED LC_{50} = 0.083 ppm (a.e.) NOAEC = 0.048 ppm (a.e.) **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 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 LC_{50} = 0.216 ppm NOEL = 0.048 ppm EFED LC_{50} = 0.184 ppm (a.e.) NOAEC = 0.041 ppm (a.e.)	MRID 00093806, 1980, Acceptable 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 LC_{50} = 0.51 ppm NOEL = 0.20 ppm EFED LC_{50} = 0.44 ppm (a.e.) NOAEC = 0.17 ppm (a.e.)	MRID 42543201, 1991, Acceptable 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% Measured Concentrations: 45.5, 85.2, 170, 361, 775 ppb a.i.	EFED 96-hr LC_{50} = 0.216 ppm (a.i.) 96-hr LC_{50} = 0.184 ppm (a.e.) Slope: 4.6 DER Consistent with summary from EFED. EFED did recalculate the LC_{50} values.	MRID 00093805, 1980, Acceptable 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 ≈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 EC_{50} = 0.47 ppm NOEL = 0.17 ppm EFED LC_{50} = 0.40 ppm (a.e.) NOAEC = 0.15 ppm (a.e.)	MRID 41900601, 1991, Supplemental ECOTOX 2013
American or Virginia oyster (*Crassostrea virginica*)	Fluazifop-P-butyl (NOS), flow-through	LC_{50} = 0.53 mg a.i./L ≈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 LC_{50} = 4.1 ppm NOEL = 2.54 ppm EFED LC_{50} = 3.5 ppm (a.e.) NOAEC = 2.1 ppm (a.e.)	MRID 00093806, 1980, Supplemental ECOTOX 2013
Pink **shrimp** (*Penaeus duorarum*), 0.21 g	Fluazifop-butyl (PP009), 25.4% a.i. for 96-hours in flow-through system.	ECOTOX LC_{50} = 6 ppm NOEL = 3 ppm EFED LC_{50} = 5.1 ppm (a.e.) NOAEC = 2.6 ppm (a.e.)	MRID 00093804, 1980, Acceptable ECOTOX 2013

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 Nominal Conc.: 0, 0.1, 0.33, 1.0, and 3.0 mg/L. Measured Concentrations: 0, 0.1, 0.25, 0.64, and 2.0 mg/L.	ECOTOX Effects on growth, reproduction, and 14-day survival were statistically significant: LOEC = 250 µg/L (growth) LOEC = 640 µg/L (reproduction and 14-day survival) NOEL = 100 µg/L (growth) EFED 21-day NOAEC 0.0854 ppm (a.e.) 21-day LOAEC 0.213 ppm (a.e.) DER The DER is consistent with the summary in EFED. **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 ECOTOX 2013 Edwards et al. 1981 [Syngenta DER01] 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 (≈ 0.21 mg a.e./L) 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. Test concentration: 56.2-111.9 ppb	ECOTOX LC_{50} = 77.7 ppb [≈66.4 ppb a.e.] NOEL = 17.4 ppb EFED NOEL = 0.0148 ppm (a.e.), reported as 14.8 ppb (a.e.) **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 ECOTOX 2013
Mysidopsis bahia Opossum shrimp	Fluazifop-butyl (NOS), 28 day flow-through	Reproduction NOEC: 0.0477 mg a.i./L ≈ 0.041 mg a.e./L.	EFSA (2012)

Appendix 7: Toxicity to Aquatic Plants.

Working Note: See Section 4.1.3.4 for discussion of mesocosm study by Perschbacher et al. 1997.

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. Application rates: 0.0010, 0.010, or 0.10 a.i. kg/ha	No consistent of systematic effect on mean morning oxygen levels. Few details. 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.) Note: The NOEL of 0.88 ppm is given only in ECOTOX 2013)	ECOTOX 2013 Also cited by FAO/WHO 2000, p. 18 and EFSA 2012, p. 65
Diatom (*Navicula pelliculosa*)	Fluazifop-P-butyl (NOS)	Biomass: 72-h EC_{50}: 0.51 mg a.i./L (≈0.44 mg a.e./L) Growth rate: 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: 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: EC_{50}: 340 mg/L Growth rate: 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: EC_{50}: 0.024 mg a.i./L (≈0.020 mg a.e./L) Growth rate: EC_{50}: 0.088 mg a.i./L (≈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: EC_{50}: 0.15 mg a.i./L (≈0.128 mg a.e./L) Growth rate: 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: EC_{50}: 0.22 mg a.i./L (≈0.188 mg a.e./L) Growth rate: 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. 1, 10, and 100 µM (0.00327, 0.0327, 0.327 mg a.e./L) Solvent:0.1 M sulfinyl bis (methane)	NOEC: 0.0327 mg a.e./L (population growth) 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)

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. Solvent: acetone Solvent control used	Effect measurement: population growth rate. 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) Based on yield and growth.	FAO/WHO 2000, p. 18 EFSA 2012, p. 66

Appendix 8: GLEAMS-Driver, Single Application

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	1.58E-06	0	0
Location	(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	0.00062	1.99E-05	0
Warm Location	(0.000049 - 0.0161)	(6.50E-07 - 0.00156)	(0 - 6.10E-07)
Average Rainfall and	0.0026	0.000112	0
Temperate Location	(0.000143 - 0.0236)	(3.30E-06 - 0.00289)	(0 - 6.50E-07)
Average Rainfall and Cool	0.00245	0.00009	0
Location	(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	0.0039	0.000209	0
Location	(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	0.175	0.16	0.16
Location	(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	0.172	0.158	0.158
Warm Location	(0.171 - 0.173)	(0.156 - 0.158)	(0.156 - 0.158)
Average Rainfall and	0.175	0.159	0.159
Temperate Location	(0.174 - 0.176)	(0.158 - 0.16)	(0.158 - 0.16)
Average Rainfall and Cool	0.176	0.16	0.16
Location	(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	0.175	0.159	0.159
Location	(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 (0.057 - 0.058)	0.053 (0.052 - 0.053)	0.053 (0.052 - 0.053)
Dry and Temperate Location	0.058 (0.058 - 0.059)	0.053 (0.053 - 0.054)	0.053 (0.053 - 0.054)
Dry and Cold Location	0.082 (0.075 - 0.088)	0.075 (0.068 - 0.081)	0.074 (0.068 - 0.08)
Average Rainfall and Warm Location	0.057 (0.057 - 0.058)	0.053 (0.052 - 0.053)	0.053 (0.052 - 0.053)
Average Rainfall and Temperate Location	0.058 (0.058 - 0.059)	0.053 (0.053 - 0.054)	0.053 (0.053 - 0.054)
Average Rainfall and Cool Location	0.06 (0.059 - 0.062)	0.055 (0.053 - 0.057)	0.054 (0.053 - 0.055)
Wet and Warm Location	0.057 (0.056 - 0.058)	0.053 (0.052 - 0.053)	0.053 (0.052 - 0.053)
Wet and Temperate Location	0.058 (0.058 - 0.06)	0.053 (0.053 - 0.054)	0.053 (0.053 - 0.053)
Wet and Cool Location	0.06 (0.058 - 0.067)	0.054 (0.053 - 0.058)	0.053 (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	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
		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 - 0.3)	0 (0 - 0.005)	0 (0 - 0.04)
Dry and Temperate Location	0.004 (0 - 5.1)	0 (0 - 0.016)	0 (0 - 0.4)
Dry and Cold Location	2.34 (0 - 18.7)	0.0004 (0 - 0.7)	0.4 (0 - 13.2)
Average Rainfall and Warm Location	1.54 (0.15 - 20.4)	0.3 (0.011 - 3.4)	4.8 (0.4 - 36)
Average Rainfall and Temperate Location	4.4 (0.4 - 24.3)	1.49 (0.06 - 12.5)	13.9 (1.59 - 77)
Average Rainfall and Cool Location	5.7 (0.9 - 26.6)	2.29 (0.17 - 10.8)	13.4 (2.22 - 69)
Wet and Warm Location	10.8 (2.89 - 42)	6 (0.7 - 24.9)	38 (6.1 - 100)
Wet and Temperate Location	8 (1.94 - 31)	4.6 (0.9 - 30)	30.6 (5.1 - 104)
Wet and Cool Location	26.9 (15.9 - 43)	34 (19.7 - 63)	83 (54 - 135)
		Average of Central Values:	10.8
		25th Percentile of Lower Bounds:	0
		Maximum Value:	135
		Summary of Values:	10.8 (0 - 135)

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	0.000021	0	0
Location	(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	0.012	0.006	0.1
Warm Location	(0.0011 - 0.08)	(0.0001 - 0.09)	(0.007 - 0.5)
Average Rainfall and	0.05	0.03	0.3
Temperate Location	(0.003 - 0.19)	(0.0007 - 0.4)	(0.03 - 1.72)
Average Rainfall and Cool	0.08	0.09	0.6
Location	(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	0.3	0.4	1.24
Location	(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 - 0.09)	0 (0 - 0.0014)	0 (0 - 0.031)
Dry and Temperate Location	0.0018 (0 - 1.44)	0 (0 - 0.01)	0 (0 - 0.4)
Dry and Cold Location	0.8 (0 - 6.6)	0.00014 (0 - 0.31)	0.21 (0 - 10)
Average Rainfall and Warm Location	1.28 (0.12 - 17.2)	0.7 (0.013 - 9.3)	11.3 (0.7 - 68)
Average Rainfall and Temperate Location	4.2 (0.5 - 23.7)	2.37 (0.11 - 34)	30.6 (3.3 - 183)
Average Rainfall and Cool Location	7 (0.9 - 22.3)	6.6 (0.19 - 39)	39 (7.5 - 155)
Wet and Warm Location	12.4 (2.85 - 43)	18.3 (1.94 - 82)	97 (18.3 - 203)
Wet and Temperate Location	9.2 (2.29 - 25.7)	9.2 (2.01 - 61)	64 (8.4 - 231)
Wet and Cool Location	52 (27.8 - 77)	61 (39 - 89)	102 (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	0.0005	0	0
Location	(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	0.5	0.28	4.5
Warm Location	(0.05 - 6)	(0.006 - 4.7)	(0.3 - 29.6)
Average Rainfall and	1.95	1.42	14.7
Temperate Location	(0.17 - 9.1)	(0.04 - 18.9)	(1.78 - 83)
Average Rainfall and Cool	3.2	3.12	19.2
Location	(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	4.3	4.5	22.7
Location	(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)

Appendix 9: GLEAMS-Driver, Two Applications

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	3.80E-06	0	0
Location	(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	0.00137	0.000056	8.00E-10
Warm Location	(0.000124 - 0.0215)	(1.57E-06 - 0.00258)	(0 - 7.00E-07)
Average Rainfall and	0.0048	0.000277	0
Temperate Location	(0.00048 - 0.0261)	(7.40E-06 - 0.005)	(0 - 6.50E-07)
Average Rainfall and Cool	0.0042	0.000183	0
Location	(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	0.0084	0.00055	0
Location	(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 (0.289 - 0.315)	0.278 (0.264 - 0.288)	0.278 (0.263 - 0.288)
Dry and Temperate Location	0.33 (0.32 - 0.37)	0.299 (0.291 - 0.34)	0.299 (0.29 - 0.34)
Dry and Cold Location	0.49 (0.44 - 0.53)	0.44 (0.4 - 0.48)	0.44 (0.4 - 0.48)
Average Rainfall and Warm Location	0.289 (0.265 - 0.34)	0.264 (0.243 - 0.313)	0.263 (0.236 - 0.311)
Average Rainfall and Temperate Location	0.32 (0.311 - 0.33)	0.292 (0.281 - 0.302)	0.291 (0.26 - 0.301)
Average Rainfall and Cool Location	0.34 (0.33 - 0.35)	0.308 (0.298 - 0.32)	0.305 (0.276 - 0.312)
Wet and Warm Location	0.281 (0.259 - 0.295)	0.252 (0.216 - 0.268)	0.233 (0.174 - 0.264)
Wet and Temperate Location	0.32 (0.308 - 0.33)	0.294 (0.264 - 0.304)	0.283 (0.22 - 0.303)
Wet and Cool Location	0.35 (0.34 - 0.39)	0.315 (0.311 - 0.36)	0.315 (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	0.109	0.1	0.1
Location	(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	0.096	0.088	0.088
Warm Location	(0.089 - 0.113)	(0.082 - 0.104)	(0.082 - 0.104)
Average Rainfall and	0.108	0.099	0.098
Temperate Location	(0.104 - 0.112)	(0.095 - 0.102)	(0.095 - 0.101)
Average Rainfall and Cool	0.115	0.105	0.103
Location	(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	0.109	0.1	0.099
Location	(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	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)

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 - 0.7)	0 (0 - 0.011)	0 (0 - 0.09)
Dry and Temperate Location	0.01 (0 - 8.7)	0 (0 - 0.04)	0 (0 - 1.18)
Dry and Cold Location	4.7 (0 - 38)	0.0008 (0 - 1.4)	0.8 (0 - 26.6)
Average Rainfall and Warm Location	4.3 (0.4 - 25.3)	1 (0.05 - 6.7)	11.6 (1 - 69)
Average Rainfall and Temperate Location	8.9 (1.09 - 36)	2.61 (0.27 - 21.2)	25 (2.58 - 115)
Average Rainfall and Cool Location	9.1 (2.03 - 37)	4.5 (0.4 - 19.6)	23.9 (4.7 - 121)
Wet and Warm Location	15.6 (5.1 - 42)	7.5 (1.25 - 38)	51 (11.4 - 152)
Wet and Temperate Location	13.2 (4.7 - 33)	8.1 (2.69 - 42)	46 (8.9 - 176)
Wet and Cool Location	54 (33 - 85)	70 (40 - 129)	170 (111 - 270)
		Average of Central Values:	19.7
		25th Percentile of Lower Bounds:	0
		Maximum Value:	270
		Summary of Values:	19.7 (0 - 270)

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	0.00005	0	0
Location	(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	0.04	0.018	0.25
Warm Location	(0.003 - 0.11)	(0.0004 - 0.23)	(0.02 - 1.17)
Average Rainfall and	0.08	0.07	0.7
Temperate Location	(0.012 - 0.4)	(0.0024 - 0.8)	(0.07 - 2.97)
Average Rainfall and Cool	0.14	0.17	1.09
Location	(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	0.7	0.8	2.21
Location	(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)

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 - 0.21)	0 (0 - 0.005)	0 (0 - 0.08)
Dry and Temperate Location	0.004 (0 - 2.99)	0 (0 - 0.021)	0 (0 - 1)
Dry and Cold Location	1.52 (0 - 13.4)	0.00028 (0 - 0.6)	0.4 (0 - 20.1)
Average Rainfall and Warm Location	3.5 (0.4 - 28.2)	1.86 (0.07 - 22)	26.6 (2.36 - 152)
Average Rainfall and Temperate Location	8.1 (1.42 - 34)	4.8 (0.3 - 63)	55 (6.1 - 340)
Average Rainfall and Cool Location	12.5 (2.29 - 45)	12.1 (0.9 - 76)	72 (15.2 - 288)
Wet and Warm Location	18.4 (5.7 - 72)	23.3 (2.2 - 139)	156 (40 - 301)
Wet and Temperate Location	17 (6.2 - 38)	16.4 (4 - 97)	106 (14.3 - 410)
Wet and Cool Location	107 (58 - 158)	125 (79 - 201)	211 (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 - 0.07)	0 (0 - 0.0012)	0 (0 - 0.024)
Dry and Temperate Location	0.0011 (0 - 0.9)	0 (0 - 0.007)	0 (0 - 0.3)
Dry and Cold Location	0.5 (0 - 3.9)	0.00008 (0 - 0.18)	0.13 (0 - 5.8)
Average Rainfall and Warm Location	1.45 (0.16 - 9.5)	0.8 (0.023 - 11.6)	11.2 (1.06 - 68)
Average Rainfall and Temperate Location	4 (0.7 - 15.5)	2.75 (0.12 - 34)	30.3 (3.6 - 160)
Average Rainfall and Cool Location	5 (0.9 - 19.1)	6.1 (0.4 - 34)	35 (8.6 - 122)
Wet and Warm Location	7.1 (2.44 - 22.5)	9.5 (1.09 - 44)	55 (13.5 - 101)
Wet and Temperate Location	7.7 (2.99 - 15.6)	7.4 (1.88 - 36)	37 (4.6 - 125)
Wet and Cool Location	56 (31.2 - 92)	62 (27.9 - 95)	40 (20.2 - 84)
		Average of Central Values:	14
		25th Percentile of Lower Bounds:	0
		Maximum Value:	160
		Summary of Values:	14 (0 - 160)

Appendix 10: GLEAMS-Driver, Three Applications

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	6.20E-06	0	0
Location	(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	0.00273	0.000153	8.40E-10
Warm Location	(0.000256 - 0.0262)	(5.20E-06 - 0.0032)	(0 - 1.34E-06)
Average Rainfall and	0.0063	0.0004	7.80E-10
Temperate Location	(0.00087 - 0.0309)	(1.07E-05 - 0.005)	(0 - 6.50E-07)
Average Rainfall and Cool	0.0051	0.00033	0
Location	(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	0.0094	0.00065	0
Location	(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 - 0.43)	0.35 (0.32 - 0.4)	0.35 (0.32 - 0.4)
Dry and Temperate Location	0.45 (0.42 - 0.5)	0.41 (0.39 - 0.46)	0.41 (0.38 - 0.46)
Dry and Cold Location	0.72 (0.65 - 0.77)	0.65 (0.59 - 0.71)	0.64 (0.58 - 0.7)
Average Rainfall and Warm Location	0.35 (0.316 - 0.41)	0.32 (0.285 - 0.37)	0.314 (0.272 - 0.37)
Average Rainfall and Temperate Location	0.43 (0.39 - 0.45)	0.38 (0.34 - 0.41)	0.37 (0.316 - 0.4)
Average Rainfall and Cool Location	0.47 (0.45 - 0.5)	0.43 (0.4 - 0.45)	0.42 (0.36 - 0.44)
Wet and Warm Location	0.35 (0.302 - 0.39)	0.311 (0.256 - 0.35)	0.28 (0.216 - 0.33)
Wet and Temperate Location	0.45 (0.42 - 0.48)	0.4 (0.35 - 0.44)	0.38 (0.283 - 0.43)
Wet and Cool Location	0.46 (0.36 - 0.5)	0.4 (0.313 - 0.45)	0.315 (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 (0.116 - 0.144)	0.118 (0.106 - 0.133)	0.118 (0.106 - 0.132)
Dry and Temperate Location	0.149 (0.141 - 0.167)	0.136 (0.129 - 0.154)	0.136 (0.128 - 0.153)
Dry and Cold Location	0.239 (0.216 - 0.258)	0.218 (0.196 - 0.236)	0.217 (0.196 - 0.234)
Average Rainfall and Warm Location	0.118 (0.105 - 0.136)	0.107 (0.095 - 0.124)	0.106 (0.096 - 0.124)
Average Rainfall and Temperate Location	0.143 (0.132 - 0.152)	0.13 (0.121 - 0.14)	0.13 (0.121 - 0.139)
Average Rainfall and Cool Location	0.16 (0.152 - 0.173)	0.145 (0.137 - 0.157)	0.143 (0.137 - 0.153)
Wet and Warm Location	0.124 (0.109 - 0.136)	0.114 (0.1 - 0.125)	0.111 (0.095 - 0.121)
Wet and Temperate Location	0.152 (0.144 - 0.161)	0.139 (0.132 - 0.147)	0.137 (0.131 - 0.145)
Wet and Cool Location	0.169 (0.165 - 0.188)	0.153 (0.148 - 0.165)	0.148 (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 - 1.23)	0 (0 - 0.023)	0 (0 - 0.2)
Dry and Temperate Location	0.018 (0 - 8.7)	0 (0 - 0.05)	0 (0 - 2.05)
Dry and Cold Location	7.1 (0 - 57)	0.0013 (0 - 2.15)	1.2 (0 - 40)
Average Rainfall and Warm Location	5.7 (0.7 - 28.4)	1.66 (0.12 - 10.3)	19 (1.9 - 99)
Average Rainfall and Temperate Location	10.2 (2.38 - 40)	3.12 (0.5 - 27.9)	32 (3.6 - 163)
Average Rainfall and Cool Location	11 (2.98 - 43)	6.6 (1.06 - 27.7)	34 (6.9 - 133)
Wet and Warm Location	17.7 (6.5 - 48)	9.3 (1.43 - 56)	67 (18.6 - 176)
Wet and Temperate Location	17 (6.8 - 38)	12.2 (3.7 - 48)	57 (12.3 - 236)
Wet and Cool Location	73 (46 - 118)	102 (61 - 185)	231 (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	0.00008	0	0
Location	(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	0.06	0.032	0.4
Warm Location	(0.009 - 0.18)	(0.0009 - 0.4)	(0.04 - 1.83)
Average Rainfall and	0.12	0.1	0.9
Temperate Location	(0.03 - 0.5)	(0.005 - 1.1)	(0.12 - 3.5)
Average Rainfall and Cool	0.2	0.25	1.63
Location	(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	1	1.14	3.05
Location	(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)

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 - 0.4)	0 (0 - 0.009)	0 (0 - 0.23)
Dry and Temperate Location	0.008 (0 - 2.99)	0 (0 - 0.04)	0 (0 - 1.71)
Dry and Cold Location	2.23 (0 - 20.4)	0.0005 (0 - 1)	0.7 (0 - 30.4)
Average Rainfall and Warm Location	6.6 (1.22 - 29.5)	3.4 (0.15 - 39)	45 (3 - 288)
Average Rainfall and Temperate Location	12 (3.7 - 41)	6.4 (0.9 - 103)	76 (9.3 - 420)
Average Rainfall and Cool Location	16.1 (4.1 - 56)	18.3 (1.3 - 110)	105 (23.4 - 350)
Wet and Warm Location	23.7 (9.4 - 103)	33 (3.8 - 202)	206 (56 - 470)
Wet and Temperate Location	22.8 (10.8 - 55)	22.2 (6.2 - 109)	130 (18.5 - 450)
Wet and Cool Location	161 (88 - 249)	190 (118 - 273)	284 (199 - 440)
		Average of Central Values:	50.5
		25th Percentile of Lower Bounds:	0
		Maximum Value:	470
		Summary of Values:	50.5 (0 - 470)

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 - 0.09)	0 (0 - 0.0022)	0 (0 - 0.08)
Dry and Temperate Location	0.0019 (0 - 0.9)	0 (0 - 0.013)	0 (0 - 0.6)
Dry and Cold Location	0.7 (0 - 5.9)	0.00012 (0 - 0.28)	0.2 (0 - 8.8)
Average Rainfall and Warm Location	2.59 (0.4 - 10.1)	1.35 (0.05 - 20.1)	19.2 (1.63 - 118)
Average Rainfall and Temperate Location	5.6 (1.59 - 19.8)	3.7 (0.29 - 50)	40 (5.5 - 195)
Average Rainfall and Cool Location	8.2 (1.68 - 28)	8.7 (0.6 - 52)	54 (12.9 - 171)
Wet and Warm Location	9.9 (4.3 - 33)	11.9 (1.53 - 66)	73 (22.2 - 142)
Wet and Temperate Location	10.8 (5 - 21.5)	10.3 (2.83 - 39)	48 (6.9 - 147)
Wet and Cool Location	87 (47 - 143)	97 (45 - 146)	64 (30 - 141)
		Average of Central Values:	20.6
		25th Percentile of Lower Bounds:	0
		Maximum Value:	195
		Summary of Values:	20.6 (0 - 195)