Water Quality Criteria Report for Bifenthrin

Updated Report

Prepared by:
Tessa L. Fojut, Ph.D.
Central Valley Regional Water Quality Control Board

Updated May 2015

Original Report

Prepared for the Central Valley Regional Water Quality Control Board by:

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Original March 2010

Disclaimer

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Note on the Updated Report

1 The original report (March 2010) was prepared by the listed updated in May 2015 by CRWQCB-CVR staff in order to include The updates to the report were not prepared by or reviewed by UC original report was unchanged; the sections that include updates 8 Data Reduction, 9 Acute Criterion Calculation, 10 Chronic Species, 14.1 Bifenthrin Criteria Summary

Assumptions, Limitations and Uncertainties, 15.2 Comparison to National Standard Methods, and 15.3 Final Bifenthrin Criteria Statement. The recently generated toxicity data included in the update led to changes in the final criteria. In order to compare the original report and criteria to the updated report and criteria, the original report will remain available at: http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/central_valley_pesticides/criteria_method/index.shtml.

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List of acronyms and abbreviations

ACR	Acute-to-Chronic Ratio
APHA	American Public Health Association
ASTM	American Society for Testing and Materials
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BMF	Biomagnification Factor
CAS	Chemical Abstract Service
CDFG	California Department of Fish and Game
CDPR	California Department of Pesticide Regulation
CDWR	California Department of Water Resources
CSIRO	Commonwealth Scientific and Industrial Research Organization, Australia
CVRWQCB	Central Valley Regional Water Quality Control Board
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
EC_x	Concentration that affects x% of exposed organisms
FDA	Food and Drug Administration
FT	Flow-through test
GMAV	Genus Mean Acute Value
IC_x	Inhibition concentration; concentration causing *x*% inhibition
ICE	Interspecies Correlation Estimation
IUPAC	International Union of Pure and Applied Chemistry
K	Interaction Coefficient
K_H	Henry's law constant
K_{ow}	Octanol-Water partition coefficient
K_p or K_d	Solid-Water partition coefficient
LC_x	Concentration lethal to *x*% of exposed organisms
LD_x	Dose lethal to *x*% of exposed organisms
LL	Less relevant, Less reliable study
LOEC	Lowest-Observed Effect Concentration
LOEL	Lowest-Observed Effect Level
LR	Less relevant, Reliable study
MATC	Maximum Acceptable Toxicant Concentration
N	Not relevant or Not reliable study
n/a	Not applicable
NOAEL	No-Observed Adverse Effect Level
NOEC	No-Observed Effect Concentration
NR	Not reported
OC	Organic Carbon
OECD	Organization for Economic Co-operation and Development
PBO	Piperonyl butoxide
QSAR	Quantitative Structure Activity Relationship
pK_a	Acid dissociation constant

RL	Relevant, Less reliable study
RR	Relevant and Reliable study
S	Static test
SMAV	Species Mean Acute Value
SMCV	Species Mean Chronic Value
SPME	Solid-phase Microextraction
SR	Static renewal test
SSD	Species Sensitivity Distribution
TES	Threatened and Endangered Species
TIE	Toxicity Identification Evaluation
US	United States
USEPA	United States Environmental Protection Agency

2 Introduction

A new methodology for deriving freshwater water quality criteria for the protection of aquatic life was developed by the University of California, Davis (TenBrook et al. 2009a). The need for a new methodology was identified by the California Central Valley Regional Water Quality Control Board (CVRWQCB 2006) and findings from a review of existing methodologies (TenBrook & Tjeerdema 2006, TenBrook et al. 2009b). This new methodology is currently being used to derive aquatic life criteria for several pesticides of particular concern in the Sacramento River and San Joaquin River watersheds. The methodology report (TenBrook et al. 2009a) contains an introduction (Chapter 1); the rationale of the selection of specific methods (Chapter 2); detailed procedures for criteria derivation (Chapter 3); and a chlorpyrifos criteria report (Chapter 4). This criteria report for bifenthrin describes, section by section, the procedures used to derive criteria according to the UC-Davis methodology. Also included are references to specific sections of the methodology procedures detailed in Chapter 3 of the report so that the reader can refer to the report for further details (TenBrook et al. 2009a). The bifenthrin water quality criteria were updated in 2015 to include additional data generated since the original report released in 2010.

3 Basic Information

Chemical: Bifenthrin (Figure 1)

CAS: (2-methyl[1,1'-biphenyl]-3-yl)methyl (1*R*,3*R*)-rel-3-[(1*Z*)-2-chloro-3,3,3-trifluoro-1-propenyl]-2,2-dimethylcyclopropanecarboxylate
IUPAC: 2-methyl-3-phenylbenzyl (1*RS*)-cis-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropanecarboxylate

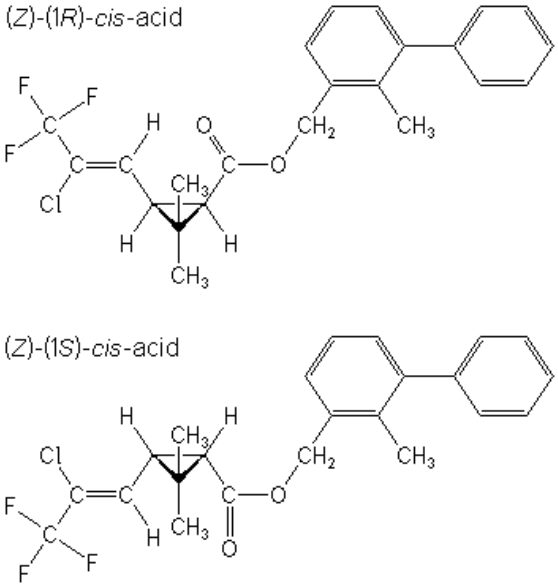

Figure 1 Structure of bifenthrin and stereoisomers (Wood 2008)

Chemical Formula: $C_{23}H_{22}ClF_3O_2$

CAS Number: 82657-04-3

CDPR Chem Code: 2300

Classification: EPA Class C Carcinogen (EXTOXNET 1995)

Trade names: Bifenthrin, bifenthrine, Bifentrin, Bifentrina, Biflex, Biphenthrin, Brigade, Capture, Cyclopropanecarboxylic acid, FMC 54800, FMC 54800 Technical, Talstar, Tarstar, DeterMite, Biphenate, Torant (with Clofentezine), Zipak (with Amitraz) (EXTOXNET 1995, FMC Corp. 2007, Kegley et al. 2008)

4 Physical-Chemical Data

Molecular Weight
422.87 (EXTOXNET 1995, Laskowski 2002)

Density
1.26 g/mL (FOOTPRINT 2010)
1.212 g/mL at 25°C (Meister 2002)
Geomean: **1.24 g/mL**

Water Solubility
1 µg/L (Tomlin 2000)
1 µg/L (FOOTPRINT 2010)
Geomean: **1 µg/L**

Melting Point
Liquid at room temperature
68-70.6 °C (EXTOXNET 1995)
69.3 °C (FOOTPRINT 2010)
Geomean: **69.3 °C**

Logistic Octanol-Water Partition Coefficient (Log K_{ow})
7.48 (slow-stir method - preferred, Dix 2014)
6.00 (Hansch et al. 1995, recommended by Sangster Research Laboratories 2007)
5.56 using HPLC (Donovan & Pescatore 2002)
6.4 (Laskowski 2002)
7.3 at 20 °C calculated (FOOTPRINT 2010)
Recommended: **7.48**

Dissociation Coefficient (K_d)
390 (Surprenant 1988)
9,300- 18,900 (Xu et al. 2007)
1,400-15,100 (Yang et al. 2006a)
8,600-24,400 (Yang et al. 2006b)

Organic Carbon-Water Adsorption Coefficient (K_{oc})

Limited to data from studies that used a batch equilibrium experimental design with natural sediment and measured the freely dissolved aqueous concentrations. All units are L/kg.

4,049,394	Chickering 2014
3,682,730	Chickering 2014
4,952,213	Chickering 2014
1,720,000	Yang et al. 2006b
628,571	Yang et al. 2006b
11,571,429	Yang et al. 2006b
1,794,118	Yang et al. 2006b
1,330,000	Cui & Gan 2013
1,200,000	Cui & Gan 2013
990,000	Cui & Gan 2013
98,000	Cui & Gan 2013
5,470,000	Cui & Gan 2013

Median K_{oc}: 1,757,059 L/kg

Median log K_{oc}: **6.24**

Vapor Pressure

1.80E-07 mm Hg at 25^{o}C (Tomlin 1994, Laskowski 2002)

1.81E-07 mm Hg at 25^{o}C (Meister 2002)

Geomean: **1.81E-07 mm Hg**

Henry's Constant (K_H)

7.2×10^{-3} atm m^3 mol^{-1} (Laskowski 2002)

7.74×10^{-5} Pa m^3 mol^{-1}, at 25 ^{o}C (FOOTPRINT 2010)

4.10×10^{-2} dimensionless, at 20 ^{o}C (FOOTPRINT 2010)

Half-life

anaerobic soil degradation:	425 d (Laskowski 2002)
anaerobic soil degradation:	179.5 d (Kegley et al. 2008)
aerobic soil degradation:	96 d (Laskowski 2002)
aerobic soil degradation:	123.0 d (Kegley et al. 2008)
sediment:	8-17 mo at 20^{o}C (Gan et al. 2005)
soils:	44-47 mo at 25^{o}C (Baskaran et al. 1999)
hydrolysis:	stable (Laskowski 2002)
photolysis, water:	408 d (Laskowski 2002)
photolysis, soil:	96.9 d (Laskowski 2002)

Bioconcentration Factors

Table 1 Bioconcentration factors (BCF) for bifenthrin
FT: flow-through; S: static; R: Recirculating. Values are on a wet weight basis and are not lipid normalized.

Species	BCF	Exposure Type	Reference
Lepomis machrochirus[1]	6090	FT, 42 d	Surprenant 1986
Lepomis machrochirus[2]	8720	FT, 42 d	Surprenant 1986
Lepomis machrochirus[3]	2140	FT, 42 d	Surprenant 1986
Pimephales promelas[1]	21,000-28,000	FT, Life Cycle	McAllister 1988
Pimephales promelas[4]	83-4900	FT, Life Cycle	McAllister 1988
Pimephales promelas[5]	530-10,000	FT, Life Cycle	McAllister 1988
Pimephales promelas[6]	6000	FT	McAllister 1988
Pimephales promelas	45-63	R, 21 d	Surprenant 1988
Daphnia magna	~ 1000-4600	S, 24 h	Yang et al. 2006a
Daphnia magna[7]	~ 1200-2600	S, 24 h, w/ sediment	Yang et al. 2006a
Daphnia magna	270-440	R, 21 d	Surprenant 1988
Asellus sp.	71-82	R, 21 d	Surprenant 1988
Asellus sp.	120-180	R, 21 d, w/ soil	Surprenant 1988
Corbicula	41-74	R, 21 d	Surprenant 1988
Corbicula	92-140	R, 21 d, w/ soil	Surprenant 1988

[1]whole body, [2]viscera, [3]fillet, [4]<48h embryos, [5]96h embryos, [6]14d larvae, [7] with suspended solids (0-200 mg/L)

5 Mode of Action and Toxicity

Pyrethroids affect the nervous system and induce paralysis in insects. More specifically, these compounds prevent sodium and potassium channels in the neuronal membranes from closing, causing over-excitation of neurons. The site of toxic action is very similar to that for DDT (Miller & Salgado 1985). Aquatic organisms are inherently more sensitive to pyrethroid pesticides than their terrestrial counterparts (Siegfried 1993), due to the effect of pyrethroids on Na^+ ATPase, an enzyme crucial to osmoregulation (Clark & Matsumura 1982).

Pyrethroids are chiral compounds consisting of multiple stereoisomers. The commercial formulations of bifenthrin are made up of 1*R*-*cis*-BF and 1*S*-*cis*-BF isomers (Figure 1). The 1*R*-*cis* enantiomer was the only enantiomer in *cis*-BF showing acute toxicity against *Ceriodaphnia dubia* (Liu et al. 2005a, b). Additionally, it was found that the 1*S*-*cis* enantiomer was preferentially degraded over the 1*R*-*cis* enantiomer, so the more toxic isomer was also more persistent in this case (Liu et al. 2005a, b).

In addition to acute toxicity, pyrethroids can induce sublethal toxicity such as altered behavior, reduced growth, immune system effects, endocrine reproductive effects, histopathological effects, as well as biochemical responses. Such sublethal effects may cause changes in predation avoidance, competition, learning and other characteristics that can affect survival and reproductive success (Werner & Moran 2008). Direct links of these effects to survival are difficult to establish. However, these effects likely contribute to negative effects on survival, growth, or reproduction, which

are measured in standard chronic toxicity tests. Solomon et al. (2001) compiled toxicity data available for several pyrethroids and found acute-to-chronic ratios (ACRs) of 2 - 425 for pyrethroids in a variety of species. The large ACRs were not just for fish. Using the data for *Daphnia magna*, calculated ACRs for cypermethrin, tralomethrin, and λ-cyhalothrin were around 100, while those for cyfluthrin, fenvalerate/esfenvalerate, permethrin, and fenpropathrin were around 5. Chronic toxicity data for sensitive species is needed to derive fully protective criteria for pyrethroids.

6 Environmental and Metabolic Fate

Bifenthrin, a third-generation synthetic pyrethroid, has greater photostability and enhanced insecticidal activity in comparison to older formulations (Mokry & Hoagland 1990). Bifenthrin is non-polar and has a strong affinity for soil particles and organic matter as represented by its high organic carbon (OC)-water adsorption partition coefficient (K_{OC}; section 4). The strong sorption to soils and the low water solubility would seem to confine these compounds to areas of use. However, they are able to move with runoff into surface streams by moving with suspended sediments and dissolved organic matter (DOM; Gan et al. 2005, Weston et al. 2004). The toxicity of pyrethroids to wildlife may be mitigated by their high affinity for suspended particulates (Hill 1989, Muir et al. 1985), and likewise toxicity during laboratory testing may be reduced due to surface adherence (Froelich et al. 1984).

A study of bifenthrin and three other pyrethroids by Bondarenko et al. (2006), which examined the time-dependence of pyrethroids distributed in the freely dissolved, DOM, and solid phases, found only a small percentage of these compounds in the freely-dissolved portion of several samples. In addition, there was a significant difference between the amounts of freely-dissolved bifenthrin in the sample after 9 days, when compared with the same fraction after 30 days, suggesting that bifenthrin takes a long time to reach equilibrium within an aquatic system (Bondarenko et al. 2006).

Bifenthrin is stable in water and has a relatively long half-life in soils and sediments (section 4). Long persistence was observed for bifenthrin under both aerobic and anaerobic conditions, and the half-life ranged from 8 to 17 months at 20 °C (Gan et al. 2005). Although pyrethroids are prone to cleavage at their ester linkage (Bradbury & Coats 1989, Tyler et al. 2000), upon binding to particulate matter the microbial degradation slows significantly and the half-life increases (Lee et al. 2004).

7 Human and Wildlife Dietary Values

There are no FDA action levels for bifenthrin (USFDA 2000). There are no food tolerances for fish, but there are food tolerances for meat of cattle, goat, hogs, horses, and sheep at 0.5 ppm (USEPA 2006a).

Wildlife toxicity values (dietary) for animals with significant food sources in water

For mallard ducklings, Fletcher (1983a) reported an eight day dietary LC_{50} value of 1280 mg/kg feed. No ducklings died from the lowest dose, the 312 mg/kg feed, but these ducklings weighed less than the control ducklings. An acute study that monitored ducks for 21 days after a single dose of pure bifenthrin (not in feed) found no effects (Fletcher 1983b). Using the highest dose the NOEC would be 2150 mg/kg body weight for adult mallards (Fletcher 1983b). Roberts et al. (1986) observed no indication of reproductive impairment in mallards after they were fed a diet spiked with bifenthrin at three doses (25, 50, 75 mg/kg feed). Roberts et al. (1986) reported a NOEC of 75 mg/kg feed, but this likely an underestimated NOEC value because it is the highest dose and no toxicity was observed.

8 Ecotoxicity Data

Approximately 40 original studies on the effects of bifenthrin on aquatic life were identified and reviewed. In the review process, many parameters are rated for documentation and acceptability for each study, including, but not limited to: organism source and care, control description and response, chemical purity, concentrations tested, water quality conditions, and statistical methods (see Tables 3.6, 3.7, 3.8 in TenBrook et al. 2009a). Single-species effects studies that were rated relevant (R) or less relevant (L) according to the method were summarized in the data summary sheets. Information in these summaries was used to evaluate each study for reliability using the rating systems described in the methodology (Tables 3.7 and 3.8, section 3-2.2, TenBrook et al. 2009a), to give a reliability rating of reliable (R), less reliable (L), or not reliable (N). Copies of completed summaries for all studies are included in Appendix B of this report. Bifenthrin studies deemed irrelevant from an initial screening were not summarized (e.g., studies involving rodents or *in vitro* exposures). All data rated as acceptable (RR) or supplemental (RL, LR, LL) for criteria derivation are summarized in Table 2, Table 3, Table 4,

Table **5**, and

Table **6**. Acceptable studies rated as RR are used for numeric criteria derivation, while supplemental studies rated as RL, LR or LL are used for evaluation of the criteria to check that they are protective of particularly sensitive species and threatened and endangered species. These considerations are reviewed in sections 13.1 and 13.3 of this report, respectively. Studies that were rated not relevant (N) or not reliable (RN or LN) were not used for criteria derivation.

Using the data evaluation criteria (section 3-2.2, TenBrook et al. 2009a), nine acute toxicity studies, yielding twenty-one toxicity values from eight taxa, were judged reliable and relevant (RR; Tables 2 and 3). Two chronic toxicity studies, yielding four toxicity values from two taxa, were judged reliable and relevant (RR; Table 4 and

Table **5**). Eleven studies were rated RL, LL, or LR and were used as supplemental information for evaluation of the derived criteria in Sections 13.1 and 13.3 (

Table **6**).

Eleven mesocosm, microcosm and ecosystem (field and laboratory) studies were identified and reviewed. Four of these studies were rated R or L and were used as supporting data in section 13.2 (Table 7). Three relevant studies of bifenthrin effects on wildlife were identified and reviewed for consideration of bioaccumulation in section 14.1.

9 Data Reduction

Multiple toxicity values for bifenthrin for the same species were reduced into one species mean acute toxicity value (SMAV) or one species mean chronic value (SMCV) according to procedures described in the methodology (section 3-2.4, TenBrook et al. 2009a). Acceptable acute and chronic data that were reduced, and the reasons for their exclusion, are shown in Table 3 and

Table **5**, respectively. Reasons for reduction of data included: data from flow-through tests in which concentrations were measured were available for the same species, more sensitive endpoints were available for the same test and more appropriate or more sensitive test durations were available for the same test. The final acute and chronic data sets are shown in Table 2 and Table 4, respectively. The final acute data set contains eight SMAVs, and the final chronic data set contains four SMCVs.

10 Acute Criterion Calculation

At least five acceptable acute toxicity values were available and fulfilled the five taxa requirements of the species sensitivity distribution (SSD) procedure (section 3-3.1, TenBrook et al. 2009a). The five taxa requirements are a warm water fish, a fish in the family Salmonidae, a planktonic crustacean, a benthic crustacean, and an insect. The log-logistic SSD procedure (section 3-3.2.2, TenBrook et al. 2009a) was used for the acute criterion calculation because there were not more than eight acceptable acute toxicity values available in the bifenthrin data set (Table 2). The eight SMAVs in the acceptable data set (Table 2) were plotted in a histogram (Figure **2**). The data do not appear to be bimodal, but there does appear to be a gap between the lowest data point and the peak bin. The log-logistic SSD procedure was used to derive 5th percentile values (median and lower 95% confidence limit), as well as 1st percentile values (median and lower 95% confidence limit). The median 5th percentile value is recommended for use in criteria derivation by the methodology because it is the most robust of the distributional estimates (section 3-3.2, TenBrook et al. 2009a). Comparing the median estimate to the lower 95% confidence limit of the 5th percentile values, it can be seen that the first significant figures of the two values are different (0.0016419 vs. 0.0000240 µg/L). Because there is uncertainty in the first significant digit, the final criterion will be reported with one significant digit (section 3-3.2.6, TenBrook et al. 2009a).

The ETX 1.3 Software program (Aldenberg 1993) was used to fit a log-logistic distribution to the data set, which is plotted with the acute values in Figure **3**. This distribution provided a satisfactory fit (Appendix A: Fit test calculations) according to the fit test described in section 3-3.2.4 of TenBrook et al. (2009a). No significant lack of fit was found ($\chi^2_{2n} = 0.1247$) using the fit test based on cross validation and Fisher's combined test (section 3-3.2.4, TenBrook et al. 2009a), indicating that the data set is valid for criteria derivation.

Log-logistic distribution
HC5 Fitting Parameter Estimates: $\alpha = -0.7777$, β (median) = 0.6816, β (lower 95% CI) = 1.305.

5th percentile, 50% confidence limit: 0.001642 µg/L
5th percentile, 95% confidence limit: 0.0000240 µg/L
1st percentile, 50% confidence limit: 0.000123 µg/L
1st percentile, 95% confidence limit: 0.0000002 µg/L

Recommended acute value = 0.001642 µg/L (median 5th percentile value)

Acute criterion = Recommended acute value ÷ 2
= 0.001642 µg/L ÷ 2
= 0.0008209 µg/L

Acute criterion = 0.0008 µg/L
= 0.8 ng/L

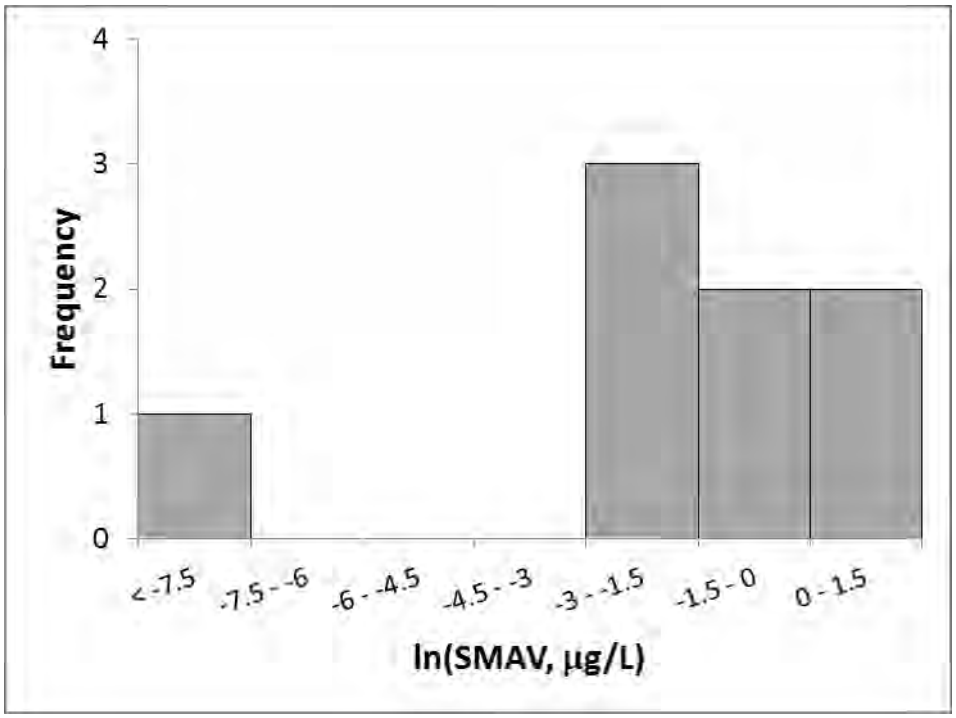

Figure 2 Histogram of acceptable bifenthrin acute data.

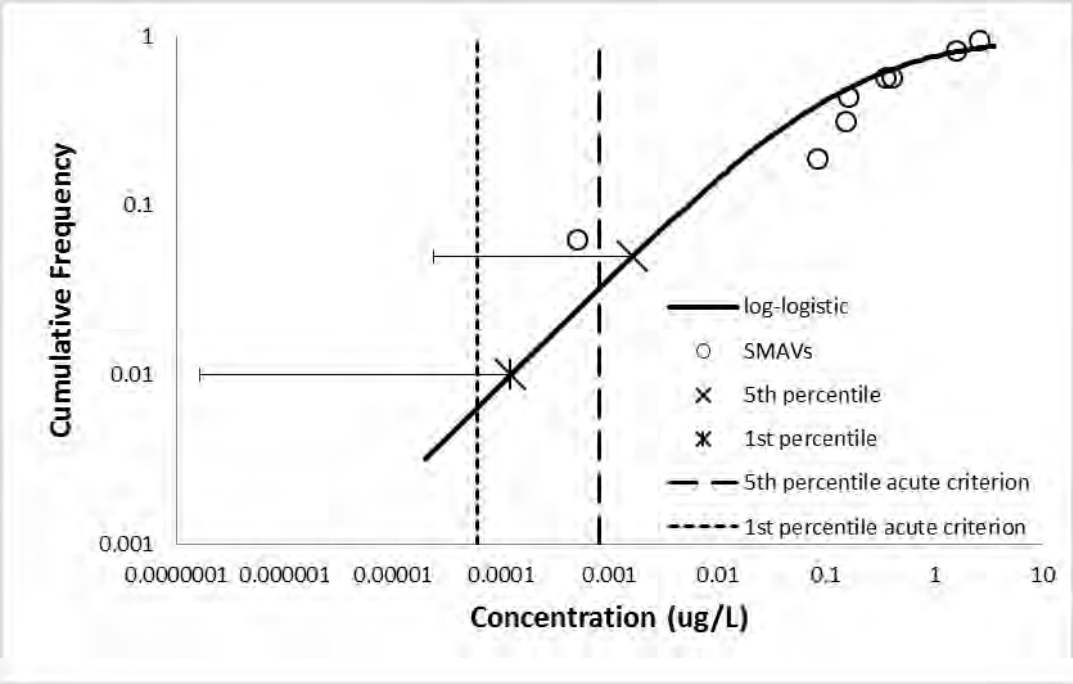

Figure 3 The fit of the log-logistic species sensitivity distribution to the acute data set. The median 5th percentile acute value with the lower 95% confidence limit and the median 1st percentile acute value with the lower 95% confidence limit are each displayed. The acute water quality criteria calculated with the median 5th percentile and median 1st percentile values are displayed as vertical lines.

11 Chronic Criterion Calculation

Chronic toxicity values from fewer than five different families were available, thus the acute-to-chronic ratio (ACR) procedure was used to calculate the chronic criterion (section 3-4.2, TenBrook et al. 2009a). Four SMCVs are in the acceptable (rated RR) data set (Table 4), satisfying three of the five taxa requirements (section 3-3.1, TenBrook et al. 2009a): warm water fish (*Pimephales promelas),* planktonic crustacean (*Ceriodaphnia dubia* and *Daphnia magna)*, and benthic crustacean (*Hyalella azteca*).

None of these chronic toxicity values could be paired with an appropriate corresponding acute toxicity value in order to calculate an ACR. The acute toxicity value for *Pimephales promelas* was conducted using a static test, which is inappropriate for determining a fish ACR (section 3-4.2.1, TenBrook et al. 2009a). There are acute toxicity values for the other three species, but the tests do not provide appropriate corresponding values for an ACR because the tests were not performed in the same laboratory or in the same dilution water (section 3-4.2.1, TenBrook et al. 2009a).

Salt-water data in the supplemental data set (

Table **6**) contained acute and chronic toxicity values for a mysid (*Americamysis bahia* – formerly *Mysidopsis bahia)*, however the acute study was conducted in full seawater (30 ppt salinity), whereas the chronic studies were conducted in estuarine water (20 ppt salinity). These are not appropriates corresponding toxicity values for an ACR, because the tests were not performed in the same dilution water (section 3-4.2.1, TenBrook et al. 2009a).

Because an ACR cannot be calculated with the available data, the chronic criterion was calculated with the default ACR. The default ACR of the UCDM (TenBrook et al. 2009) was updated by Fojut et al. (2014) to include additional pesticide data sets, specifically for the pyrethroids cyfluthrin and λ-cyhalothrin. The updated default ACR calculated by Fojut et al. (2014) is 11.4. The chronic criterion was calculated using the recommended acute value and the default ACR value as follows:

Chronic criterion = Recommended acute value ÷ ACR
= 0.001642 μg/L ÷ 11.4
= 0.000144 μg/L

Chronic criterion = 0.0001 μg/L
= 0.1 ng/L

12 Water Quality Effects

12.1 Bioavailability

Although bifenthrin and other pyrethroids are not very soluble in water, aquatic organisms are very sensitive to pyrethroids and toxicity does occur. Several ecosystem and field studies are reviewed in section 13.2 that point to bifenthrin as the cause of toxicity in surface waters in the California Central Valley. This toxicity is believed to occur primarily from the fraction of the compound that is dissolved in the water, not from the compound that is associated with the particulate phase. Bioavailability of bifenthrin to organisms in the water column was demonstrated by Surprenant (1988). Bifenthrin from spiked soil samples was available at concentrations sufficient to cause toxicity to aquatic organisms (such as *Daphnia magna)* that were housed in a separate container from the sediment, but shared the same recirculating water (however, there was no filtration to prevent dissolved particles from moving, so particles could have been involved in the exposure).

Several studies suggest that the binding of bifenthrin to suspended solids and DOM will make the bound fraction unavailable and thus nontoxic to aquatic organisms. Yang et al. (2006a) found uptake of ^{14}C-labeled bifenthrin by *Daphnia magna* decreased with increasing suspended solids concentration, and that the organism uptake was closely mimicked by solid-phase microextraction (SPME) method using polydimethylsiloxane fibers. Regression analysis suggested that the portion of the pesticide sorbed to particles was unavailable to organisms in the 24-hr study period. In a complimentary study by Yang et al. (2006b), bifenthrin LC_{50} values for *Ceriodaphnia*

dubia were five times higher when 200 mg/L of suspended sediment was added compared to the sediment-free tests. Xu et al. (2007) tested bifenthrin toxicity to *Chironomus tentans* in 10-d sediment exposures with three types of sediment. The researchers reported bifenthrin LC_{50} values for five phases: bulk sediment, OC-normalized sediment, bulk porewater, dissolved organic carbon (DOC)-normalized porewater, and the freely dissolved bifenthrin. The LC_{50} values in each of the five phases varied greatly, and varied between sediments for all phases tested except the freely dissolved, indicating that toxicity of the freely dissolved phase is independent of site-specific characteristics. The LC_{50} values based on the freely dissolved concentrations (0.048-0.053 μg/L) were approximately an order of magnitude lower than those based on bulk porewater concentrations that included DOC (0.314-0.608 μg/L). These studies suggest that the freely dissolved concentration will be the most accurate predictor of toxicity and that bound bifenthrin was unavailable to the studied organisms.

As a counterpoint, equilibrium partitioning would suggest that as organisms take up bifenthrin, more bifenthrin will desorb from particles, so the fraction absorbed to solids is likely not completely unavailable. Although more bifenthrin could desorb from particles, the dissolved concentration should be constant if the system has reached a steady-state. Benthic organisms, such as *Hyalella azteca* may be at greater risk because of their exposure to porewater and close proximity to sediments.

Additionally, the role of dietary exposure on bioavailability of pyrethroids has not been considered. In the test with *Ceriodaphnia dubia* and *Daphnia magna*, organisms were not fed during the test duration (Yang et al. 2006a, 2006b). Organisms living in contaminated waters may also be ingesting food with sorbed hydrophobic compounds that can be desorbed by digestive juices (Mayer et al. 2001). The effects of dietary exposure may also be species-specific, depending on typical food sources; some species may have greater interaction with particles, increasing their exposure. Palmquist et al. (2008) examined the effects due to dietary exposure of the pyrethroid esfenvalerate on three aqueous insects with different feeding functions: a grazing scraper (*Cinygmula reticulata* McDunnough), an omnivore filter feeder (*Brachycentrus americanus* Banks), and a predator (*Hesperoperla pacifica* Banks). The researchers observed adverse effects in *C. reticulata* and *B. americanus* after feeding on esfenvalerate-laced food sources and that none of the three insects avoided the contaminated food. The effects included reduced growth and egg production of *C. reticulata* and abandonment and mortality in *B. americanus*. These limited studies indicate that ingestion may be an important exposure route, but it is not currently possible to incorporate this exposure route into criteria compliance assessment.

Section 3-5.1 of the methodology (TenBrook et al. 2009a) suggests that if studies indicate that fewer than three phases of the pesticide (sorbed to solids, sorbed to dissolved solids, or freely dissolved in the water) are bioavailable that compliance may be based on the concentration in the bioavailable phase(s). The studies above suggest that the freely dissolved fraction of bifenthrin is the primary bioavailable portion of bifenthrin, and that this concentration is the best indicator of toxicity. The studies above suggest that the freely dissolved fraction of bifenthrin is the primary bioavailable

portion, and that this concentration is the best indicator of toxicity, thus, it is recommended that the freely dissolved fraction of bifenthrin be directly measured or calculated based on site-specific information for compliance assessment. Whole water concentrations are also valid for criteria compliance assessment, and may be used at the discretion of environmental managers, although the bioavailable fraction may be overestimated with this method.

The most direct way to determine compliance would be to measure the bifenthrin concentration in the dissolved phase to determine the total bioavailable concentration. SPME has shown to be the best predictor of pyrethroid toxicity in several studies (Bondarenko *et al*. 2007, Bondarenko & Gan 2009, Hunter et al. 2008, Xu et al. 2007, Yang et al. 2006a, 2006b, 2007). Bondarenko & Gan (2009) report a method detection limit of 1.0 ng/L for bifenthrin. If method detection limits for the SPME method are not satisfactory compared to the criteria, this method may not be able to be used for criteria compliance; if detection limits of a given testing facility are shown to be satisfactory, the SPME method is valid for criteria compliance.

Filtration of sediments is another option. Glass fiber filters with a nominal pore size of 0.7 μm or 0.45 μm are often used to remove the suspended sediments or both suspended sediments and DOM, but the filters can interfere with the detection of hydrophobic contaminants. Gomez-Gutierrez et al. (2007) found that adsorption to filters was positively correlated with the log K_{ow} and solubility values of the compounds, and that on average 58% of the one pyrethroid tested (a 50 ng/L solution of permethrin) was lost on the filter. House and Ou (1992) also tested several filter materials and found that glass fiber filters had the lowest losses of pyrethroids at 5-20%. This loss may be critical for determining compliance at environmental concentrations, thus syringe filters are not recommended for sample handling. However, the U.S. Geological Survey (USGS) has developed a filtration sample handling method specifically for pyrethroids (Hladik et al. 2009). This method involves filtering water through a diaphragm pump, with equipment made from specified materials and flow rates, and for the least losses samples should be filtered in the field. Approximately 3-5% of pyrethroids were lost to surface association in the filtration apparatus, which is considered minimal and acceptable by USGS.

Alternately, the following equation can be used to translate total bifenthrin concentrations measured in whole water to the associated dissolved bifenthrin concentrations:

$$C_{dissolved} = \frac{C_{total}}{1 + ((K_{OC} \cdot [SS]) / foc) + (K_{DOC} \cdot [DOC])} \quad (1)$$

where: $C_{dissolved}$ = concentration of chemical in dissolved phase (μg/L);
C_{total} = total concentration of chemical in water (μg/L);
K_{OC} = OC-water partition coefficient (L/kg);
[*SS*] = concentration of suspended solids in water (kg/L);
f_{oc} = fraction of OC in suspended sediment in water;

[*DOC*] = concentration of dissolved organic carbon in water (kg/L);
K_{DOC} = OC-water partition coefficient (L/kg) for DOC.

To determine compliance by this calculation, site-specific data are necessary, including: K_{OC}, K_{DOC}, the concentration of suspended solids, the concentration of DOC, and the fraction of OC in the suspended solids. If all of these site-specific data, including the partition coefficients, are not available, then this equation should not be used for compliance determination. Site-specific data are required because the sorption of bifenthrin to suspended solids and DOM depends on the physical and chemical properties of the suspended solids resulting in a range of K_{OC} values (section 4).

The freely dissolved bifenthrin concentration is recommended for determination of criteria compliance because the literature suggests that the freely dissolved concentrations are the most accurate predictor of toxicity. Environmental managers may choose an appropriate method for determination of the concentration of freely dissolved bifenthrin, or they may also choose to base compliance on whole water concentrations.

12.2 Mixtures

Bifenthrin often occurs in the environment with other pyrethroid pesticides (Werner & Moran 2008), and the presence of chemicals in surface waters is ubiquitous. All pyrethroids have the same general toxicological mode of action, and several studies have demonstrated that the toxicity of pyrethroid mixtures is additive and is well-predicted by the concentration addition model (Barata et al. 2006, Brander et al. 2009, Trimble et al. 2009). Overall, the concentration addition model should be used by following either the toxic unit or relative potency factor approach to determine criteria compliance when multiple pyrethroids are present. Definitions of additivity, synergism, antagonism, and non-additivity are available in the literature (Lydy and Austin 2004) and more detailed descriptions of mixture models can be found in the methodology (section 3-5.2, TenBrook et al. 2009a).

Callinan et al. (2012) tested pyrethroid mixtures with *Hyalella azteca* in aqueous exposures in the following binary combinations: type I-type I (bifenthrin-permethrin), type I-type II (bifenthrin-cyfluthrin, bifenthrin-lambda-cyhalothrin, permethrin-cyfluthrin, and permethrin-lambda-cyhalothrin) and type II-type II (cyfluthrin-lambda-cyhalothrin). These combinations were tested in 4-day exposures, and two of the combinations were also tested in 10-day chronic exposures. Both the concentration addition and the independent action models were fit to the observed toxicity data and the fits were compared with several statistical analyses. One way of comparing the fits indicated that all combinations of pyrethroids were additive following the concentration addition model. Another way of comparing the results indicated that there was slight antagonism in two of the pyrethroid combinations (bifenthrin-cyfluthrin and permethrin-cyfluthrin), but only in the 4-day tests, not in the 10-day test.

To examine if pyrethroid mixture toxicity is additive with a comprehensive study design, Trimble et al. (2009) performed sediment toxicity tests with *Hyalella azteca* in three binary combinations: type I-type I (permethrin-bifenthrin), type II-type II (cypermethrin-λ-cyhalothrin), and type I-type II (bifenthrin-cypermethrin). The toxicity of these combinations were predicted with the concentration addition model, with model deviations within a factor of two, indicating that in general, pyrethroid mixture toxicity is additive.

Studies with pyrethroids not including bifenthrin have also demonstrated approximately additive toxicity. Barata et al. (2006) investigated the effects of a lambda-cyhalothrin – deltamethrin mixture on mortality and feeding in *Daphnia magna.* Most of the observed effects for survival were within a factor of two of the effects predicted by the concentration addition model. The researchers observed slight antagonism in several of the mixtures and they attributed this to a few unexpected extreme values for joint survival effects. Brander et al. (2009) tested mixture toxicity of cyfluthrin and permethrin and found that the combined toxicity was nearly additive. Although the binary mixture demonstrated slight antagonism, additivity was demonstrated when piperonyl butoxide (PBO) was added. Brander et al. (2009) offered several explanations for the observed antagonism between the two pyrethroids. Permethrin is a type I pyrethroid, and cyfluthrin is a type II pyrethroid, and type II pyrethroids might be able to outcompete type I pyrethroids for binding sites, which is known as competitive agonism; or binding sites may be saturated, so that complete additivity is not observed. They also note that cyfluthrin is metabolized more slowly than permethrin, so cyfluthrin can bind longer. PBO may remove this effect because the rate of metabolism of both pyrethroids is reduced in the presence of PBO. The additivity of pyrethroid mixture toxicity has not been clearly defined in the literature, and in fact, antagonism has been observed, thus the concentration addition method is not recommended for use when multiple pyrethroids are found in a sample.

Piperonyl butoxide is commonly added to pyrethroid insecticide treatments because it is known to increase the toxic effects of pyrethroids (Weston et al. 2006). Brander et al. (2009) observed *Hyalella azteca* LC_{50} values decreased by a factor of 2 or 3.5 when a nonlethal concentration of PBO was mixed with cyfluthrin or permethrin, respectively. No interaction coefficients (K) have been derived with relevant species to describe synergism between bifenthrin and PBO. Consequently, it is not possible to quantify this non-additive toxicity and there is no accurate way to account for this interaction in compliance determination.

No studies on aquatic organisms were found in the literature that could provide a quantitative means to consider mixtures of bifenthrin with other classes of pesticides. However, several studies have been published that examine the interactive nature of bifenthrin with other pesticides and pesticide synergists in order to more effectively reduce a target pest or limit target insect resistance. The response of aquatic organisms, especially arthropods, may be comparable to the response of these targeted species (Werner & Moran 2008).

Several studies have used two similar methods to calculate the level of interaction between mixtures of bifenthrin. While their indexes do not provide a way to determine the toxicity of environmental mixtures, they provide information about the qualitative interaction. Bifenthrin toxicity to the diamondback moth (*Plutella xylostella*) was synergized by emamectin and spinosad, and were additive with those of chlorpyrifos and indoxacarb (Attique et al. 2006). Chlorpyrifos-methyl, another organophosphate pesticide, synergized effects of bifenthrin on the mosquito (*Anopheles gambiae,* Bonnet et al. 2004). Bifenthrin toxicity to the two-spotted spider mite (*Tetranychus urticae)* was synergized by acephate, amitraz, chlordimeform, profenofos, s,s,s-tributyl phosphorotrithionate, and dimethoate (Bynum et al. 1990, Bynum et al. 1997). In the Banks grass mite (*Oligonychus pratensis)* amitraz and s,s,s-tributyl phosphorotrithionate were synergistic (Bynum et al. 1997, Bynum & Archer 2002), while results with PBO varied from slightly synergistic to antagonistic (Bynum et al. 1997, Bynum & Archer 2002). It should also be noted that significant differences in response were observed between two closely related species tested in these studies (Bynum et al. 1997), which indicates that closely related aquatic organisms may also display a highly varied response to the same mixture of pesticides.

The silkworm, *Bombyx mori* (L.), a non-target organism, was exposed to leaves treated with a binary mixture of OP insecticides (dichlorvos and phoxim) and pyrethroid insecticides (permethrin, tetramethrin, bifenthrin, and ethofenprox), and experienced additive toxicity from the combination of pesticides (Zhang et al. 2008).

Although there are many examples of non-additive toxicity for bifenthrin and other chemicals, a multispecies interaction coefficient is not available for any chemical with bifenthrin, and therefore the concentrations of non-additive chemicals cannot be used for criteria compliance (section 3-5.2.2, TenBrook et al. 2009a).

12.3 Temperature, pH, and Other Water Quality Effects

Temperature, pH, and other water quality effects on the toxicity of bifenthrin were examined to determine if any effects are described well enough in the literature to incorporate into criteria compliance (section 3-5.3, TenBrook et al. 2009a). Temperature has been found to be inversely proportional to the aquatic toxicity and bioavailability of pyrethroids (Miller & Salgado 1985, Werner & Moran 2008). In fact, the increase of toxicity of pyrethroids with decreasing temperature has been used to implicate pyrethroids as the source of toxicity in environmental samples (Phillips et al. 2004). The inverse relationship between temperature and pyrethroid toxicity is likely due to the increased sensitivity of an organism's sodium channels at low temperatures (Narahashi et al. 1998).

The toxicity of sediments contaminated with pyrethroids (often bifenthrin) was more than twice as toxic when tested at 18 ˚C compared to 23 ˚C (Weston et al. 2008). Weston et al. (2008) used a toxicity identification evaluation (TIE) procedure to determine the effect of temperature reduction (18 vs. 23˚C) on toxicity of a particular environmental sediment sample to *Hyalella azteca*. These results are not directly applicable for use in water quality criteria compliance because they were sediment

exposures, and used environmental samples, instead of an exposure to a pure compound. This study does indicate that the enhanced toxic effects of pyrethroids at lower temperatures may not be as accurately represented by the results of typical laboratory toxicity tests, which tend to be run at warmer temperatures, 20-23 ˚C (USEPA 1996a, USEPA 1996b, USEPA 2000), than those of the habitats of coldwater fishes, about 15 ˚C or lower (Sullivan et al. 2000). In studies that used topical exposures (more relevant to spray application exposure to target a pest), the difference in toxicity can increase by a factor of about 1.5 to a factor of 10, in the temperature range of about 10 to 27 ˚C (Kumaraguru & Beamish 1981, Punzo 1993, Schnitzerling 1985).

Unfortunately, there are limited data using aquatic exposures with relevant species, making it unfeasible to quantify the relationship between the toxicity of bifenthrin and temperature for water quality criteria at this time (section 3-5.3, TenBrook et al. 2009a). No studies on bifenthrin were found that examined the effects of pH or other water quality parameters on toxicity, thus, there is no way to incorporate any of these parameters into criteria compliance.

13 Comparison of ecotoxicity data to derived criteria

13.1 Sensitive Species

The derived criteria are compared to toxicity values for the most sensitive species in both the acceptable (RR) and supplemental (RL, LR, LL) data sets to ensure that these species will be adequately protected (section 3-6.1, TenBrook et al. 2009a). The lowest species mean acute value in the data sets rated RR, RL, LR, or LL is 0.5 ng/L for *Hyalella azteca* (Table 2). The derived acute criterion of 0.8 ng/L is a factor of 1.6 above this toxicity value, and does not appear to be protective of this sensitive species. This toxicity value was from a flow-through test and was calculated based on measured concentrations and thus meets the guidance in the method for adjusting the criterion (section 3-6.1, TenBrook et al. 2009a). The median 1st percentile estimate is recommended to derive the acute criterion, in order to be protective of this sensitive species. The acute criterion is calculated as follows:

Recommended acute value = 0.000123 µg/L (median 1st percentile value)

Acute criterion = Recommended acute value ÷ 2
= 0.000123 µg/L ÷ 2
= 0.0000615 µg/L

Acute criterion = 0.00006 µg/L
= 0.06 ng/L

The ACR method for chronic criterion calculation uses the recommended acute value (section 3-4.2, TenBrook et al. 2009), thus, the chronic criterion is also re-calculated with the median 1st percentile value as follows:

Chronic criterion = recommended acute value ÷ ACR
= 0.000123 μg/L ÷ 11.4
= 0.0000107 μg/L

Chronic criterion = 0.00001 μg/L
= 0.01 ng/L

The recommended chronic criterion (0.01 ng/L) is below the lowest SMCV in the data set rated RR (Table 4 and Table 5), which is a MATC of 1.1 ng/L for *Hyalella azteca,* and below the lowest reported toxicity value in the supplemental data set (rated RL, LR, or LL (Table 6), which is a LOEC of 1 ng/L for *Hyalella azteca.* These data indicate that the recommended chronic criterion is protective of all sensitive species in the data set.

13.2 Ecosystem and Other Studies

The derived criteria are compared to acceptable laboratory, field, or semi-field multispecies studies (rated R or L) to determine if the criteria will be protective of ecosystems (section 3-6.2, TenBrook et al. 2009a). Eleven mesocosm, microcosm and ecosystem (field and laboratory) studies were identified and rated for reliability according to the methodology (Table 3.9, TenBrook et al. 2009a). Four of these studies were rated as reliable (R) or less reliable (L); all of the studies rated R or L are listed in Table 7. Some of the studies that rated as not reliable (N) are not discussed in this report (Giddings et al. 2001, Hendley et al. 2001, Maund et al. 2001, Travis & Hendley 2001). Several bifenthrin mesocosm tests were carried out with bifenthrin in the sediments, but bifenthrin was also measured in the water column. These studies simulate real world conditions, in which most of the bifenthrin would likely be bound to sediment.

Hoagland et al. (1993) examined the effects of sediment-associated bifenthrin alone and in combination with atrazine using tanks containing natural plankton assemblages and bluegill. The number of cladocerans (*Bosmina*), cyclopoid copepodids and copepods was reduced after 7 days at a concentration as low as 20 to 60 ng/L bifenthrin, while bluegill suffered 33% mortality at 3150 ng/L. Drenner *et al*. (1993) investigated the effect of sediment-associated bifenthrin on gizzard shad and plankton in outdoor tank mesocosms. Eight day LC_{50} values for gizzard shad ranged from 207 - 521 ng/L (based on water concentrations 1 hour after sediment spiked with bifenthrin was added). In the same mesocosms, there was a significant decrease in copepod density and an increase in rotifer density.

Surprenant (1988) conducted experiments with soil that was spiked with 0.1 to 1 mg/kg bifenthrin in clean dilution water. Organisms were exposed to water only via circulation though different chambers for 21 days. *Daphnia magna* survival was significantly affected at 0.59 μg/L of bifenthrin. Survival of *Asellus sp*. was affected at

bifenthrin concentrations of 0.30 μg/L and above. No toxic effects were seen in *Pimephales promelas* at 1.86 μg/L in water, and no toxic effects were seen in *Corbicula sp*. at 2.58 μg/L and below.

In these three studies (Drenner et al. 1993, Hoagland et al. 1993, Surprenant 1988) the toxic effects reported are all from concentrations above the derived bifenthrin chronic criterion of 0.01 ng/L. Based on these ecosystem studies, there is no evidence that the criteria will be underprotective of aquatic ecosystems.

To assess possible effects of bifenthrin field applications, Sherman (1989) documented extensive surveys of the aquatic organisms in two experimental ponds from 1986-1988, as well as *in situ* bioassays using *Daphnia magna* and *Pimephales promelas* exposures to spray drift and runoff. In the summer of 1986, ten weekly applications of a commercial formulation of bifenthrin, Capture 2.0, were sprayed on to agricultural fields at a rate of twice the then current label maximum (0.1 lbs/acre). These fields drained into nearby Hagan's Pond, which was a little over 3 acres in size. Observed toxic effects were compared to data from a reference pond 19 km to the north. The post application follow-up studies continued through August of 1987 and again in the summer of 1988, monitoring for recovery.

Of the zooplankton, calanoid copeopods were clearly affected, while cladocerans showed some bifenthrin related effects. The survival and reproduction of ramshorn snail were negatively affected. Macroinvertebrates reduced in both density and number, but showed recovery. The bioassays with *Daphnia magn*a and *Pimephales promelas* showed significant toxic effects and recovery. Phytoplankton, caged shrimp and crayfish exposed showed no clear effects. Mussels were unaffected and fish suffered no acute affects. There was a gizzard shad die off in the winter of 1987-88, but this seems to have not been bifenthrin related, as it did not correlate well to high concentrations of bifenthrin. Unfortunately the concentrations of bifenthrin cannot be directly tied to the observed effects. Average pond concentrations fluctuated from slightly above 1 ng/L to almost 10 ng/L from the summer of application until the next summer. The highest concentrations occurred in the summer of treatment, but overall there was not a clear temporal pattern as high concentrations were also observed in February and March of 1987, even though spraying ended in August of 1986 (see also Figure 1 in Palmieri 1988). The report also notes that herbicides and fertilizers were also applied during the study period. Since the concentrations that caused toxicity are not clear, this study cannot be used to judge if the derived criteria will be protective.

Several recent studies on the toxicity of pyrethroid mixtures, inclusive of bifenthrin, have been performed by Donald Weston and colleagues at the University of California, Berkeley. These studies do not rate as high quality field or mesocosm studies by the methodology (section 3-6.2 and Table 3.9, TenBrook et al. 2009a) because they are not controlled exposures, but use environmental samples that could contain many chemicals. However, these studies are summarized here because they provide evidence that bifenthrin is bioavailable and present at concentrations toxic to aquatic life in several areas of the California Central Valley. They also utilize TIEs that

use several lines of evidence to identify the agents causing toxicity in samples, and the methodology does not have a rating scheme or parameter for TIE data.

Weston et al. (2005) collected sediments from creeks near residential areas of Roseville, CA. Almost half of the sampled sites (9 of 21), caused >90 % mortality to the *Hyalella azteca*. Bifenthrin, a common ingredient in lawn-care products, was implicated as the primary cause of toxicity, followed by cyfluthrin and cypermethrin. Another study, performed in 2006, confirmed that residential high pyrethroid use, particularly of bifenthrin, was causing significant toxicity in urban creeks. This study found that most samples colleted from creeks in a variety of Sacramento area locations were lethal to *Hyalella azteca* in lab tests, while the highest mortality occurred in samples from housing subdivisions (Amweg et al. 2006). Bifenthrin has also been implicated in toxicity in creeks that catch agriculture runoff. Sediment samples collected from six sites along a six kilometer stretch of Del Puerto Creek all caused >70% mortality in toxicity tests with *Hyalella azteca.* Bifenthrin was identified as the primary contributor to toxicity in nearly all sites at which toxicity was observed (Weston et al. 2008). These results demonstrate toxicity at environmental concentrations, but unfortunately none of these studies included associated water concentrations of bifenthrin to compare with the derived criteria in this report.

13.3 Threatened and Endangered Species

The derived criteria are compared to measured toxicity values for threatened and endangered species (TES), as well as to predicted toxicity values for TES, to ensure that they will be protective of these species (section 3-6.3, TenBrook et al. 2009a). Current lists of state and federally listed threatened and endangered animal species in California were obtained from the California Department of Fish and Game web site (http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/TEAnimals.pdf; CDFG 2008). Only one of the listed animals is represented in the acute or chronic toxicity data set, steelhead trout (*Oncorhynchus mykiss)*, with an LC_{50} of 0.15 µg/L. No threatened or endangered species are listed in the supplemental data set (

Table **6**).

Some of the listed species are represented in the acute toxicity data set by members of the same family or genus. *Oncorhynchus mykiss* and *Pimephales promelas* can serve as surrogates in estimates for other species in the same family using the USEPA interspecies correlation estimation website (WEB-ICE v. 2.0; Raimondo et al. 2007). Unfortunately, the bifenthrin toxicity values were out of range of the values used to develop the model for most of the available species. Only a value of 0.252 μg/L could be estimated for Coho salmon *(Oncorhynchus kisutch).* Other estimations could be made more generally for the families of Salmonidae and Cyprinidae. These estimates are 0.237 μg/L for Salmonidae to 0.307 μg/L for Cyprinidae and are shown with the listed endangered species of that family in Table 8.

No single species plant studies were found in the literature for use in criteria derivation, so no estimation could be made for plants on the state or federal endangered, threatened or rare species lists. In a pond study, phytoplankton were unaffected by bifenthrin (Sherman 1989). However, bifenthrin seemed to be beneficial in some instances and harmful in others, as reported in a mesocosm study that monitored primary productivity, green algae, chlorophyll, and other endpoints for photosynthetic organisms (Hoagland et al. 1993). Based on the mode of action, plants should be relatively insensitive to bifenthrin and the calculated bifenthrin criteria should be protective of aquatic plants.

The lowest toxicity value, from either experimental or estimated datasets, for a threatened or endangered species is the experimental LC_{50} value of 0.15 μg/L for *Oncorhynchus mykiss* that was used in bifenthrin criteria derivation calculation. Therefore, based on the available data and the estimated values for animals, there is no evidence that the calculated acute and chronic bifenthrin criteria will be underprotective of threatened or endangered species. However, it is important to note that this assessment lacks chronic data and any data for crustaceans and insects, which would be the most sensitive species in the acute criterion data set for bifenthrin. No data were found for effects of bifenthrin on federally endangered crustaceans or insects, or acceptable surrogates (i.e., in the same family).

14 Harmonization with other environmental media

14.1 Bioaccumulation

Bioaccumulation was assessed to ensure that the derived criteria will not lead to unacceptable levels of bifenthrin in food items (section 3-7.1, TenBrook et al. 2009a). Bifenthrin has a mean log K_{ow} of 6.0 and a molecular weight of 422.87 (section 4), which indicates its bioaccumulative potential (section 3-7.1, TenBrook et al. 2009a). No biomagnification factor (BMF) values were found in the literature for bifenthrin. Bioaccumulation of bifenthrin has been measured in several studies (Table 1), which are briefly summarized here. The bioconcentration Factor (BCF) in fish varied from 45 to 28,000 depending on the age of the fish and if the analysis was based on residues in

the whole body or just the portion that a human might consume (fillet). A 1986 study that examined the elimination of bifenthrin from the bluegill found that it is very slowly eliminated from tissues. After 42 days of depuration, fish tissue concentrations of bifenthrin were reduced by about half (Surprenant 1986). A recent study with *Daphnia magna* found that the Bioaccumulation Factor (BAF) varies greatly with differing concentrations of suspended sediments. BAFs in *Daphnia magna* ranged from 1000 to 4,600. As the concentration of suspended sediments was increased (0-200 mg/L), the associated BAF values decreased to 1,000 to 2,600 times (Yang et al. 2006a).

To check that these criteria are protective of terrestrial wildlife that may consume aquatic organisms, a BAF will be used to estimate the water concentration that would roughly equate to a reported toxicity value for consumption of fish by terrestrial wildlife. These calculations are further described in section 3-7.1 of the methodology (TenBrook et al. 2009a). The BAF of a given chemical is the product of the BCF and a BMF, such that BAF=BCF*BMF. For a conservative estimate, the BCF value of 28,000 L/kg for whole fish will be used (McAllister 1988, Table 1). A default BMF value of 10 is used, based on the log K_{ow} of bifenthrin (Table 3.17, TenBrook et al. 2009a). An oral predator NOEC value of 75 mg/kg feed is used (Roberts et al. 1986), although toxicity was not observed at any of the three doses tested (25, 50, 75 mg/kg), making this likely an underestimated NOEC value. This dose will be used because there were effects seen at the lowest dose (312 mg/kg feed) in a mallard duckling study by Fletcher (1983a).

$$NOEC_{water} = \frac{NOEC_{oral\_predator}}{BCF_{food\_item} * BMF_{food\_item}}$$

Mallard:
$$NOEC_{water} = \frac{75\,^{mg}/_{kg}}{28{,}000\,^{L}/_{kg} * 10} = 0.000267\,^{mg}/_{L} = 0.267\,^{\mu g}/_{L} = 267\,^{ng}/_{L}$$

To check that these criteria are protective of humans that may consume aquatic organisms, a BAF will be used to estimate the water concentration that would roughly equate to a limit for human food consumption. An appropriate BAF was not available in the data set. The BCF value of 2140 L/kg for fish fillet (Surprenant 1986, Table 1) and a default BMF are used to approximate a BAF. There are no tolerance or FDA action levels for fish tissue (USFDA 2000), but there are food tolerances for meat of cattle, goat, hogs, horses, and sheep at 0.5 ppm (USEPA 2006a). This value can be used to roughly estimate if bioconcentration could cause bifenthrin concentrations in fish tissues to be of concern to human health.

Human:
$$NOEC_{water} = \frac{0.5\,^{mg}/_{kg}}{2{,}140\,^{L}/_{kg} * 10} = 0.0000234\,^{mg}/_{L} = 0.0234\,^{\mu g}/_{L} = 23\,^{ng}/_{L}$$

In this example, the derived chronic criterion of 0.01 ng/L is below the estimated water concentrations of concern for wildlife and humans by over four orders of magnitude.

Therefore, adhering to the derived bifenthrin criteria should not conflict with other efforts to protect wildlife or human health from bifenthrin exposure.

14.2 Harmonization with Air and Sediment Criteria

This section addresses how the maximum allowable concentration of bifenthrin might impact life in other environmental compartments through partitioning (section 3-7.2, TenBrook et al. 2009a). However, there are no federal or state sediment or air quality standards for bifenthrin (CARB 2005, CDWR 1995, USEPA 2006b, USEPA 2006c) to enable this kind of extrapolation. For biota, the limited data on bioconcentration or biomagnification of bifenthrin was addressed in the bioaccumulation section (section 14.1).

15 Bifenthrin Criteria Summary

15.1 Assumptions, Limitations and Uncertainties

The assumptions, limitations and uncertainties involved in criteria derivation should be available to inform environmental managers of the accuracy and confidence in the derived criteria (section 3-8.0, TenBrook et al. 2009a). Chapter 2 of the methodology discusses these points for each section as different procedures were chosen, such as the list of assumptions associated with using a SSD (section 2-3.1.5.1), and reviews the assumptions in section 2-7.0 (TenBrook et al. 2009a). This section summarizes any data limitations that affected the procedure used to determine the final bifenthrin criteria. The different calculations of distributional estimates included in section 10 of this report may be used to consider the uncertainty in the resulting acute criterion.

For bifenthrin, the major limitation was lack of data in the chronic toxicity data set. Two of five taxa requirements were not met (a salmonid and an insect), which precluded the use of a SSD; therefore, an ACR was used to derive the chronic criterion. Since no acceptable ACRs were available for bifenthrin in the literature, the default value of 11.4 was used (Fojut et al. 2014). Uncertainty cannot be quantified for the chronic criterion because it was derived using an ACR, not an SSD.

Another concern that could not be accounted for quantitatively with the acute and chronic criteria is the increase in toxicity from lower temperatures. Most of the toxicity data were from tests performed at standard temperature, usually around 20 ˚C. However, many streams in the California Central Valley often have lower water temperatures. If colder water bodies are impacted by concentrations of bifenthrin, it may be appropriate to apply an additional safety factor to the bifenthrin criteria for those areas, to ensure adequate protection. A rough factor of two could be estimated from a study by Weston et al. (2008), however, a study relating temperature to toxicity of bifenthrin in multiple species, including *Hyalella azteca,* would be ideal to derive such an adjustment factor. We do not recommend an additional safety factor to account for temperature effects at this time, but environmental managers may want to consider

this application if the criteria do not appear to be protective of organisms in a colder water body. If aquatic exposure data for multiple species demonstrating temperature effects becomes available in the future, a regression equation describing the effect should be incorporated into criteria compliance.

Although greater than additive effects have been observed for mixtures of pyrethroids and PBO, there is insufficient data to account for this interaction for compliance determination. This is a significant limitation because formulations that contain both pyrethroids and PBO are now available on the market. When additional highly rated data is available, the criteria should be recalculated to incorporate new research.

15.2 Comparison to National Standard Methods

This section is provided as a comparison between the UC-Davis methodology for criteria calculation (TenBrook et al. 2009a) and the current USEPA (1985) national standard. The following example bifenthrin criteria were generated using the USEPA 1985 methodology with the data set generated in this bifenthrin criteria report.

The USEPA acute methods have three additional taxa requirement beyond the five required by the SSD procedure of the UC-Davis methodology (section 3-3.1, TenBrook et al. 2009a). They are:

1. A third family in the phylum Chordata (e.g., fish, amphibian);
2. A family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca);
3. A family in any order of insect or any phylum not already represented.

Two out of the three of these additional requirements are met as follows:

1. The other fish /amphibian requirement is met with data from fathead minnow.
2. This requirements not met because all data are from organisms in the phylum Arthropoda or Chordata.
3. This requirement is met because *Chironomus dilutus* (family: Diptera) is from a different family than *Procloeon sp.* (family Ephemeroptera).

Strictly speaking, the USEPA methodology cannot be used to calculate an acute criterion for bifenthrin. However, since the California Department of Fish and Game have used data sets that met only seven of eight requirements in the USEPA methodology, this will be done here.

Using the log-triangular calculation (following the USEPA 1985 guidelines) and the bifenthrin data set from Table 2 containing eight species values, the following criterion was calculated (Note: USEPA methodology uses *genus* mean acute values, while *species* mean acute values are used in this methodology and are reported in Table 2. Since there is only one species from each genus in Table 2, this final data set would be the same in both schemes.):

Example Acute value (5^{th} percentile value) = 0.0001179 μg/L

Example Acute Criterion = acute value ÷ 2
= 0.0001179 μg/L ÷ 2
= 0.00005896 μg/L

= 0.000059 μg/L
= 0.059 ng/L

According to the USEPA (1985) method, the criterion is rounded to two significant digits. The example acute criterion derived according to the US EPA methodology is approximately equal to the acute criterion derived using the UC-Davis methodology of 0.06 ng/L, with the difference being the number of significant figures.

For the chronic criterion, the bifenthrin data set only has data from four species, which are not enough for use in a SSD by either method. The USEPA 1985 methodology contains a similar ACR procedure as in the methodology used in this criteria report, to be used when three acceptable ACRs are available. For cases in which three acceptable ACRs are not available, the USEPA methodology does not have a default ACR or alternative procedure. Since no acceptable ACR could be calculated with the bifenthrin data set, no chronic criterion can be calculated using the USEPA 1985 methodology.

15.3 Final Bifenthrin Criteria Statement

The final criteria statement is:

Aquatic life in the Sacramento River and San Joaquin River basins should not be affected unacceptably if the four-day average concentration of bifenthrin does not exceed 0.00001 μg/L (0.01 ng/L) more than once every three years, on the average, and if the one-hour average concentration of bifenthrin does not exceed 0.00006 μg/L (0.06 ng/L) more than once every three years on the average. Mixtures of bifenthrin and other pyrethroids should be considered in an additive manner (see Mixtures section 12.2).

Although the criteria were derived to be protective of aquatic life in the Sacramento and San Joaquin Rivers, these criteria would be appropriate for any freshwater ecosystem in North America, unless species more sensitive than are represented by the species examined in the development of these criteria are likely to occur in those ecosystems.

The final acute criterion was derived using the log-logistic SSD procedure (section 10) and the acute data used in criteria calculation are shown in Table 2. The chronic criterion was derived by use of a default ACR (section 11); chronic data rated RR are shown in Table 4. The acute and chronic criteria were adjusted downward to be

protective of the most sensitive species in the data sets, *Hyalella azteca*, and the calculation for those adjustments are shown in section 13.1.

To date, there are no USEPA water quality criteria for bifenthrin. The California Department of Fish and Game (CDFG) composed a risk assessment report for synthetic pyrethroids (Siepmann & Holm 2000). CDFG concluded that there was insufficient data to calculate criteria for bifenthrin using the USEPA (1985) methods. The CDFG report is concluded by reporting the lowest acute and chronic toxicity values found. The lowest genus mean acute value (GMAV) for bifenthrin was 3.97 ng/L for *Americamysis bahia* (formerly *Mysidopsis bahia*) and the lowest MATC was 60 ng/L for *Pimephales promelas*. The acute and chronic criteria generated using the UC Davis method are below the lowest acute and chronic toxicity values from the CDFG report and therefore should be protective of these species. Solomon et al. (2001) performed a probabilistic risk assessment with pyrethroids. Saltwater and freshwater toxicity data were combined so the lowest toxicity value in the data set was 3.8 ng/L (for mysid, a saltwater species). The 5th percentile value for bifenthrin, based on a log-normal distribution, was also 3.8 ng/L, although much of the author's discussion centered on the 10th percentile as the protective limit, which was 15 ng/L for bifenthrin. For compounds that had larger toxicity data sets, separate analyses were performed for freshwater and saltwater data. Differences were found especially for invertebrates, which suggested that the risk to freshwater and saltwater organisms should be assessed separately.

The derived criteria appear to be protective considering bioaccumulation, ecosystem level toxicity and threatened and endangered species as discussed above in the report, but the criteria calculations should be updated whenever new data is available.

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Data Tables

Table 2 Final acute toxicity data set for bifenthrin
All studies were rated Relevant and Reliable (RR) and were conducted at standard temperature. Values in bold are species mean acute values. Est: toxicity values were calculated based on estimated concentrations (calculated from the recovery of some concentrations), Meas: toxicity values were calculated based on measured concentrations, Nom: toxicity values were calculated based on nominal concentrations. S: static, SR: static renewal, FT: flow-through.

Species	Common Identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC_{50}/EC_{50} (µg/L)	Reference
Ceriodaphnia dubia	Cladoceran	Daphniidae	SR	Est	97.8%	96 h	24.0-24.7	Mortality	<24 h	0.078	Guy 2000a
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Meas	99%	96 h	22	Mortality	<24 h	0.39	Qin et al. 2011
Ceriodaphnia dubia	Cladoceran	Daphniidae	S	Nom	97.0%	48 h	25	Mortality	<24 h	0.142	Wheelock et al. 2004
Ceriodaphnia dubia										**0.16**	GEOMEAN
Chironomus dilutus (formerly *C. tentans*)	Midge	Chironomidae	S	Nom	100.0%	96 h	23 ± 1	Mortality	3rd instar	**2.615**	Anderson et al. 2006
Daphnia magna	Cladoceran	Daphniidae	FT	Nom	88.4%	48 h	20-21	Mortality	<24 h	**1.6**	Surprenant 1983
Hyalella azteca	Amphipod	Hyalellidae	FT	Meas	93.6%	96 h	23 ± 1	Mortality	9 d	**0.00050**	Bradley 2013
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Nom	88.4%	96 h	21-22	Mortality	2.5 g, 8 mm	**0.35**	Hoberg 1983a
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	96 h	11-12	Mortality	1.0 g, 46 mm	**0.15**	Hoberg 1983b
Pimephales promelas	Fathead minnow	Cyprinidae	S	Meas	96.2%	96 h	25 ± 1	Mortality	40 d, 0.059g	0.21	McAllister 1988
Pimephales promelas	Fathead minnow	Cyprinidae	SR	Est	97.8%	96 h	24.0-24.5	Mortality	8 d, 0.0039-0.0052g	0.78	Guy 2000b
Pimephales promelas										**0.405**	GEOMEAN
Procloeon sp	Mayfly	Baetidae	S	Nom	100.0%	48 h	23 ± 1	Mortality	0.5-1.0 cm	**0.0843**	Anderson et al. 2006

Table 3 Acceptable acute toxicity data for bifenthrin excluded in data reduction process
All studies were rated relevant and reliable (RR). S: static, FT: flow-through.

Species	Common Identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC_{50}/ EC_{50} (µg/L)	Reference	Reason for exclusion
Hyalella azteca	Amphipod	Hyalellidae	S	Nom	100.0%	96 h	23 ± 1	Mortality	7-14 d	0.0093	Anderson et al. 2006	1
Hyalella azteca	Amphipod	Hyalellidae	SR	Est	98%	96 h	23 ± 1	Mortality	7-14 d	0.0027	Weston & Jackson 2009	1
Hyalella azteca	Amphipod	Hyalellidae	SR	Est	98%	96 h	23 ± 1	Mortality	7-14 d	0.0073	Weston & Jackson 2009	1
Hyalella azteca	Amphipod	Hyalellidae	SR	Est	98%	96 h	23 ± 1	Mortality	7-14 d	0.0080	Weston & Jackson 2009	1
Hyalella azteca	Amphipod	Hyalellidae	SR	Est	98%	96 h	23 ± 1	Mortality	7-14 d	0.0082	Weston & Jackson 2009	1
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Nom	88.4%	48 h	21-22	Mortality	2.5 g, 58 mm	0.65	Hoberg 1983a	2
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Nom	88.4%	72 h	21-22	Mortality	2.5 g, 58 mm	0.44	Hoberg 1983a	2
Lepomis macrochirus	Bluegill	Centrarchidae	FT	Nom	88.4%	144 h	21-22	Mortality	2.5 g, 58 mm	0.3	Hoberg 1983a	2
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	24 h	11-12	Mortality	1.0 g, 46 mm	6.2	Hoberg 1983b	2
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	48 h	11-12	Mortality	1.0 g, 46 mm	0.34	Hoberg 1983b	2
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	72 h	11-12	Mortality	1.0 g, 46 mm	0.2	Hoberg 1983b	2
Oncorhynchus mykiss	Rainbow trout	Salmonidae	FT	Nom	88.4%	120 h	11-12	Mortality	1.0 g, 46 mm	0.1	Hoberg 1983b	2

Reasons for exclusion

1. Data from a flow-through test in which concentrations were measured are available.
2. A more sensitive or more appropriate test duration was available for the same test.

Table 4 Final chronic toxicity data set for bifenthrin
All studies were rated relevant and reliable (RR). SR: static renewal; FT: flow-through.

Species	Common Identifier	Test type	Meas/ Nom	Chemical	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference
Ceriodaphnia dubia	Cladoceran	SR	Meas	99%	6-8 d	23	Growth	9-14 d	288	432	353	Deanovic et al. 2013
Ceriodaphnia dubia	Cladoceran	SR	Meas	99%	6-8 d	23	Growth	9-14 d	179	288	227	Deanovic et al. 2013
Ceriodaphnia dubia									227	353	**283**	GEOMEAN
Daphnia magna	Cladoceran	FT	Meas	97.0%	21 d	19-22	Reproduction	< 24 h	0.0013	0.0029	**0.0019**	Burgess 1989 MRID 41156501
Hyalella azteca	Amphipod	SR	Meas	99%	10 d	23	Growth	9-14 d	0.0006	0.002	**0.0011**	Deanovic et al. 2013
Pimephales promelas	Fathead minnow	FT	Meas	96.2%	92 d	25	Mortality	< 48 h	0.040	0.090	**0.060**	McAllister 1988 MRID 40791301

Table 5 Acceptable chronic toxicity data for bifenthrin excluded in data reduction process
All studies were rated relevant and reliable (RR). SR: static renewal; FT: flow-through.

Species	Common Identifier	Test type	Meas/ Nom	Chemical	Duration	Temp (^{o}C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference	Reason for exclusion
Ceriodaphnia dubia	Cladoceran	SR	Meas	99%	6-8 d	23	Mortality	9-14 d	288	432	353	Deanovic et al. 2013	1
Ceriodaphnia dubia	Cladoceran	SR	Meas	99%	6-8 d	23	Mortality	9-14 d	179	288	227	Deanovic et al. 2013	1
Daphnia magna	Cladoceran	FT	Meas	97.0%	21 d	19-22	Time to 1st brood	< 24 h	0.0029	0.0076	0.0047	Burgess 1989	1
Daphnia magna	Cladoceran	FT	Meas	97.0%	21 d	19-22	Length	< 24 h	0.0029	0.0076	0.0047	Burgess 1989	1
Hyalella azteca	Amphipod	SR	Meas	99%	10 d	23	Mortality	9-14 d	0.002	0.003	0.0024	Deanovic et al. 2013	1
Hyalella azteca	Amphipod	SR	Meas	99%	10 d	23	Mortality	9-14 d	0.001	0.003	0.0017	Deanovic et al. 2013	1

Reasons for exclusion
1. More sensitive or equally sensitive endpoint available from same test

Table 6 Supplemental studies excluded from bifenthrin criteria derivation (rated less relevant and/or less reliable: RL, LR, or LL)
S: static, SR: static renewal; FT: flow-through.

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/ size	LC_{50}/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating/ Reason
Americamysis bahia	Mysid shrimp	FT	Meas	88%	96 h	21.5-21.6	Mortality	< 24 h	0.00397	-----	Barrows 1986b	LR 3
Americamysis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.5-25.7	Survival, F1	< 24 h	-----	0.00125	Boeri & Ward 1991	LR 3
Americamysis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.5-25.7	Reproduction, young per female	< 24 h	-----	0.00343	Boeri & Ward 1991	LR 3
Americamysis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.5-25.7	Growth, F1 length	< 24 h	-----	0.00125	Boeri & Ward 1991	LR 3
Americamysis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.1-25.8	Survival F1,	< 24 h	-----	0.0025	Ward & Boeri 1991	LR 2, 3
Americamysis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.1-25.8	Young per female,	< 24 h	-----	0.0025	Ward & Boeri 1991	LR 2, 3
Americamysis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.1-25.8	F1 length,	< 24 h	-----	0.0025	Ward & Boeri 1991	LR 1, 3
Americamysis bahia	Mysid shrimp	FT	Meas	96.5%	28 d	23.1-25.8	Sublethal effects	< 24 h	-----	0.0025	Ward & Boeri 1991	LR 2, 3
Ceriodaphnia dubia	Cladoceran	S	Nom	96%	96 h	20	Mortality	< 20 h	0.144	-----	Liu et al. 2005a, 2005b	RL 2, 5
Ceriodaphnia dubia	Cladoceran	S	Nom	98%	96 h	21	Mortality	< 24 h	0.05	-----	Yang et al. 2006b	RL 5
Ceriodaphnia dubia	Cladoceran	SR	Meas	99%	6-8 d	23	Mortality	9-14 d	345	-----	Deanovic et al. 2013	RR 6
Ceriodaphnia dubia	Cladoceran	SR	Meas	99%	6-8 d	23	Mortality	9-14 d	266	-----	Deanovic et al. 2013	RR 6
Ceriodaphnia dubia	Cladoceran	SR	Meas	99%	6-8 d	23	Growth	9-14 d	EC25: 245	-----	Deanovic et al. 2013	RR 6

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/ size	LC_{50}/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating/ Reason
Ceriodaphnia dubia	Cladoceran	SR	Meas	99%	6-8 d	23	Growth	9-14 d	EC25: 232	-----	Deanovic et al. 2013	RR 6
Cheumatopsyche spp. & *Hydropsyche* spp.	Caddisfly	S	Nom	94%	24 h	20	Mortality	Larvae	7.2	-----	Siegfried 1993	RL 5
Crassostrea virginica	Eastern oyster	FT	Meas	88%	96 h	24	Reduced shell growth	31-50 mm height	> 2.15	-----	Ward 1986a	LR 3, 4
Crassostrea virginica	Eastern oyster	FT	Meas	88%	96 h	26	Reduced shell growth	36-50 mm height	> 99.7	-----	Ward 1986b	LR 3, 4
Cyprinodon variegatus	Sheepshead minnow	FT	Meas	88%	96 h	19.9-22.3	Survival	9 wk	17.8	-----	Barrows 1986a	LR 3
Daphnia magna	Cladoceran	FT	Meas	10.4%	48 h	19-21	Survival	≤ 24 h	0.11	-----	Hoberg et al. 1985	LR 1
Daphnia magna	Cladoceran	FT	Meas	10.4%	21 d	19-21	Survival	≤ 24 h	-----	0.01929	Hoberg et al. 1985	LR 1
Daphnia magna	Cladoceran	FT	Meas	10.4%	21 d	19-21	Reproduction	≤ 24 h	-----	0.0014	Hoberg et al. 1985	LR 1
Daphnia magna	Cladoceran	SR	Nom	99.5%	21 d	22	# of young/female	<24 h	-----	0.014	Wang et al. 2009	RL 2, 5
Daphnia magna	Cladoceran	SR	Nom	99.5%	21 d	22	Average brood size	<24 h	-----	0.014	Wang et al. 2009	RL 2, 5
Daphnia magna	Cladoceran	SR	Nom	99.5%	21 d	22	# of first brood/female	<24 h	-----	0.014	Wang et al. 2009	RL 2, 5
Daphnia magna	Cladoceran	SR	Nom	99.5%	21 d	22	Days to first brood	<24 h	-----	0.028	Wang et al. 2009	RL 2, 5
Daphnia magna	Cladoceran	SR	Nom	99.5%	21 d	22	Longevity	<24 h	0.031	0.014	Wang et al. 2009	RL 2, 5
Enellagma spp. & *Ishnura* spp.	Damselfly	S	Nom	94%	24 h	20	Mortality	Nymph	1.1	-----	Siegfried 1993	RL 5

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/ size	LC_{50}/EC_{50} (µg/L)	MATC (µg/L)	Reference	Rating/ Reason
Heptageniidae spp.	Mayfly	S	Nom	94%	24 h	20	Mortality	Nymph	2.3	-----	Siegfried 1993	RL 2, 5
Hyalella azteca	Amphipod	SR	Meas	99%	10 d	23	Mortality	9-14 d	-----	LOEC: 0.001	Deanovic et al. 2013	LR 4
Hydrophilus spp.	Diving beetle	S	Nom	94%	24 h	20	Mortality	Adult	5.4	-----	Siegfried 1993	RL 5
Simulium vittatum	Blackfly	S	Nom	94%	24 h	20	Mortality	Larvae	1.3	-----	Siegfried 1993	RL 5

Reasons for Rating
1. Low chemical grade
2. Control response not reported or not acceptable
3. Not freshwater
4. No toxicity value calculated
5. Low reliability score6. Does not fit definition for acute or chronic test

Table 7 Acceptable multispecies field, semi-field, laboratory, microcosm, mesocosm studies
R= reliable; L= less reliable.

Reference	Habitat	Rating
Drenner et al. (1993)	Outdoor tank mesocosm	R
Hoagland et al. (1993)	Outdoor tank mesocosm	R
Sherman (1989)	Outdoor ponds	R
Surprenant (1988)	Indoor laboratory microcosm	R

Table 8 Laboratory bifenthrin LC_{50} values for threatened or endangered species and predicted values Predicted values from WEB-ICE (Raimondo et al. 2007).

Species	Common Name	Family	LC_{50} (µg/L)	Surrogate
Lab determined values for endangered species				
Oncorhynchus mykiss	Steelhead	Salmonidae	0.15	None - experimental value
Predicted based on species specific model				
Oncorhynchus kisutch	Coho salmon	Salmonidae	0.252	*Oncorhynchus mykiss*
Predicted with the family based model for Salmonidae				
Oncorhynchus clarki	Coho salmon	Salmonidae	0.237	*Oncorhynchus mykiss*
Oncorhynchus mykiss	Steelhead	Salmonidae	0.237	*Oncorhynchus mykiss*
Oncorhynchus tshawytscha	Chinook salmon	Salmonidae	0.237	*Oncorhynchus mykiss*
Predicted with the family based model for Cyprinidae				
Gila elegans	Bonytail chub	Cyprinidae	0.307	*Pimephales promelas*
Ptychocheilus lucius	Colorado squawfish	Cyprinidae	0.307	*Pimephales promelas*

Appendix A: Fit test calculations

Bifenthrin all SMAVs	Omit one 1	2	3	4	5	6	7	8
0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
0.0843	0.0843		0.0843	0.0843	0.0843	0.0843	0.0843	0.0843
0.15	0.15	0.15		0.15	0.15	0.15	0.15	0.15
0.16	0.16	0.16	0.16		0.16	0.16	0.16	0.16
0.35	0.35	0.35	0.35	0.35		0.35	0.35	0.35
0.405	0.405	0.405	0.405	0.405	0.405		0.405	0.405
1.6	1.6	1.6	1.6	1.6	1.6	1.6		1.6
2.615	2.615	2.615	2.615	2.615	2.615	2.615	2.615	

Omitted point, xi:	0.0005	0.0843	0.15	0.16	0.35	0.405	1.6	2.615
median 5th percentile Log-logistic	0.0399	0.002145	0.001089	0.001078	0.00099597	0.000989	0.001063	0.001163
percentile	0.02	38.76	48.23	49.3	62.18	64.49	83.31	88.34
F-i(xi)	0.0002	0.3876	0.4823	0.493	0.6218	0.6449	0.8331	0.8834
1-F(xi)	0.9998	0.6124	0.5177	0.507	0.3782	0.3551	0.1669	0.1166
Min of F-i(xi) or 1-F(xi)	0.0002	0.3876	0.4823	0.493	0.3782	0.3551	0.1669	0.1166
p_i =2(min)	0.0004	0.7752	0.9646	0.986	0.7564	0.7102	0.3338	0.2332

p_i	$\ln(p_i)$	Fisher test statistic: -2*Sum of ln (pi)	X^2_{2n}
0.0004	-7.8240	22.6066	0.1247
0.7752	-0.2546		
0.9646	-0.0360		
0.9860	-0.0141		
0.7564	-0.2792		
0.7102	-0.3422		
0.3338	-1.0972		
0.2332	-1.4559		

$X^2 > 0.05$ so the distribution does not have a significant lack of fit for the bifenthrin acute data set

if $X^2 < 0.05$ significant lack of fit

if $X^2 > 0.05$ fit (no significant lack of fit)

Appendix B: Data summary sheets

Appendix B1: Acceptable data rated RR
Appendix B2: Supplemental data rated RL, LR, or LL
Appendix B3: Unused data rated N

Abbreviations used in this appendix:

n/a = Not Applicable
NC = Non Calculable
NR = Not Reported

Unused lines were deleted from tables

Within each section, studies are listed in alphabetical order by species name, when there are multiple summaries for one species, they are listed in alphabetical order by author.

Appendix B1: Studies rated RR

Appendix B1: Studies rated RR

Toxicity Data Summary

Ceriodaphnia dubia

Deanovic LA, Markiewicz D, Stillway M, Fong S, Werner I. 2013. Comparing the effectiveness of chronic water column tests with the crustaceans *Hyalella azteca* (Order: Amphipoda) and *Ceriodaphnia dubia* (Order: Cladocera) in detecting toxicity of current-use insecticides. Environmental Toxicology and Chemistry 32(3):707-712.

Relevance
Score: 100
Rating: R

Reliability
Score: 87
Rating: R

	Deanovic et al. 2013	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	US EPA 2002	
Phylum/subphylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Family native to North America?	Yes	
Age/size at start of test/growth phase	9-14 days	
Source of organisms	Lab cultures	In-house
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Not reported	
Test vessels randomized?	Not reported	
Test duration	6-8 d (time to produce a 3rd brood)	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	Synthetic water: 0% Filtered ambient water: 0%	
Effect 2	Reproduction (# of neonates)	
Control response 2	Synthetic water: 17.7 (SE=2.15) Filtered ambient water: 16.1 (SE=1.25)	
Temperature	23 $\pm$ 1^{o}C	
Test type	Static renewal	80% renewed every 24

	Deanovic et al. 2013	***C. dubia***
Parameter	**Value**	**Comment**
		h
Photoperiod/light intensity	16 h light: 8 h dark	
Dilution water	1) Synthetic water (deionized water amended to be moderately hard water) 2) Filtered (1.0 μm) ambient water from Sacramento-San Joaquin Delta (previously tested as nontoxic)	
pH	Measured at t_0 and t_{final} within acceptable range throughout test. Not reported.	Amended to 7.9
Hardness	Not reported	
Alkalinity	Not reported	
Conductivity	Measured at t_0 and t_{final} within acceptable range throughout test. Not reported.	Amended to 900 uS/cm
Dissolved Oxygen	4.9-8.9 mg/L	60-100% saturation
DOC	Synthetic water: Filtered ambient water:	
Feeding	Yes, 1 mL of a mixture of yeast, organic alfalfa, & trout chow at initiation and every other day after water renewals	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	Synthetic water: 47-81% Filtered ambient water: 77-100%	
Toxicity values calculated based on nominal or measured concentrations?	Measured	
Chemical method documented?	Yes, GC-ECD	EPA method 8081B
Concentration of carrier (if any) in test solutions	$\leq$ 0.05% methanol	
Concentration 1 Nom; Meas (ng/L)	Synthetic water: 1.0; 0.6 Filtered ambient water: 1; not detected	4 reps, 10/rep
Concentration 2 Nom; Meas (ng/L)	Synthetic water: 4; 2.0	4 reps, 10/rep

	Deanovic et al. 2013	***C. dubia***
Parameter	**Value**	**Comment**
	Filtered ambient water: 2.0; not detected	
Concentration 3 Nom; Meas (ng/L)	Synthetic water: 8; 3.0 Filtered ambient water: 4; 1.0	4 reps, 10/rep
Concentration 4 Nom; Meas (ng/L)	Synthetic water: 16; 8.0 Filtered ambient water: 8; 3.0	4 reps, 10/rep
Concentration 5 Nom; Meas (ng/L)	Synthetic water: not tested Filtered ambient water: 16; 6.0	4 reps, 10/rep
Control	Solvent & dilution water	4 reps, 10/rep
LC_{50} (95% CI) (ng/L)	Synthetic water: 345 (323-353) Filtered ambient water: 266 (233-323)	Method: Best fit of linear regression, nonlinear regression, or linear interpolation
EC_{25} (95% CI) (ng/L)	Synthetic water: 245 (203-302) Filtered ambient water: 232 (212-263)	
NOEC (ng/L)	Mortality Synthetic water: 288 Filtered ambient water: 179 Growth Synthetic water: 288 Filtered ambient water: 179	Method: Fisher's exact test, t-tests, or Wilcoxon tests p: not reported MSD: value not reported, but within acceptable range
LOEC (ng/L)	Mortality Synthetic water: 432 Filtered ambient water: 288 Growth Synthetic water: 432 Filtered ambient water: 288	Same as above
MATC (GeoMean NOEC,LOEC) (ng/L)	Mortality Synthetic water: 353 Filtered ambient water: 227 Growth Synthetic water: 353 Filtered ambient water: 227	
% of control at NOEC	Mortality Synthetic water: 90% Filtered ambient water: 90% Growth Synthetic water:	

	Deanovic et al. 2013	***C. dubia***
Parameter	**Value**	**Comment**
	11.3/17.7=64% Filtered ambient water: 17.2/16.1= 107%	
% of control at LOEC	Mortality Synthetic water: 0% Filtered ambient water: 60% Growth Synthetic water: 0/17.7= 0% Filtered ambient water: 9.0/16.1= 56%	

Notes:

U.S. Environmental Protection Agency. 2002. Short-term methods for measuring the chronic toxicity of effluents and receiving waters to freshwater organisms, 4th ed. EPA/821/R-02/013. Washington, DC.

Reliability points taken off for:
Documentation: Hardness (2), Alkalinity (2), Conductivity (2), pH (3), Significance level (2). Total: 100-11=89

Acceptability: Measured concentrations within 20% of nominal (4), Carrier solvent (4), Organisms randomized (1), Hardness (2), Alkalinity (2), Random design (2). Total: 100-15=85

Reliability score: mean(89, 85)=87

Appendix B1: Studies rated RR

Toxicity Data Summary

Ceriodaphnia dubia

Study: Guy D. 2000a. Aquatic Toxicology laboratory Report P-2161-2. Bifenthrin with cladoceran *Ceriodaphnia dubia* in an acute definitive test. California Department of Fish and Game, Aquatic Toxicology Lab, Elk Grove, CA.

Relevance
Score: 100
Rating: R

Reliability
Score: 86.5
Rating: R

Reference	**Guy 2000a**	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	ASTM /EPA	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Family in North America?	Yes	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	In house culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	100% survival in solvent and dilution water controls	
Temperature	24.0 -24.7 ^{o}C	
Test type	Static w/ 48 h renewal	
Photoperiod/light intensity	16:8 light:dark	
Dilution water	NR	
pH	8.04-8.38	
Hardness	138-168 mg/L	
Alkalinity	152-184 mg/L	
Conductivity	328-447 µs/cm	
Dissolved Oxygen	7.74-8.36 mg/L	

Reference	**Guy 2000a**	***C. dubia***
Parameter	**Value**	**Comment**
Feeding	No	
Purity of test substance	97.8 %	
Concentrations measured?	No - estimated	
Measured is what % of nominal?	85% estimated from spikes	
Chemical method documented?	No	
Concentration of carrier (if any) in test solutions	0.0016 mL/L (acetone)	
Nominal and estimated (Est) concentrations (divided by a factor derived from recovery of spiked water samples on day 0 and day 2		
Concentration 1 Nom/Est (µg/L)	0.05/0.036	4 reps and 5 neonates per rep
Concentration 2 Nom/Est (µg/L)	0.1/0.036	4 reps and 5 neonates per rep
Concentration 3 Nom/Est (µg/L)	0.2/0.091	4 reps and 5 neonates per rep
Concentration 4 Nom/Est (µg/L)	0.4/0.153	4 reps and 5 neonates per rep
Concentration 5 Nom/Est (µg/L)	0.8/0.392	4 reps and 5 neonates per rep
Concentration 6 Nom/Est (µg/L)	1.6/0.861	4 reps and 5 neonates per rep
Controls	Water only and a solvent (acetone) control	4 reps and 5 neonates per rep
LC_{50} (95% Confidence interval) (µg/L)	0.078 (0.056-0.13)	Linear interpolation

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Dilution water source (3), Hypothesis tests (8)

Acceptability: Meas. Concentrations 20% Nom (4), Dilution water source acceptable (2), Hypothesis tests (3)

Toxicity Data Summary

Ceriodaphnia dubia

Study: Qin G, Presley SM, Anderson TA, Gao W, Maul JD. 2011. Effects of predator cues on pesticide toxicity: Toward and understanding of the mechanism of the interaction. Environ Toxicol Chem 30:1926-1934.

Relevance
Score: 100
Rating: R

Reliability
Score: 80
Rating: R

	Qin et al. 2011	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	USEPA 2002	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Family in North America?	Yes	
Age/size at start of test/growth phase	<24 h old	
Source of organisms	Laboratory cultures	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Not reported	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0%	
Temperature	22 ± 1°C	
Test type	Static	
Photoperiod/light intensity	16 h light: 8 h dark	
Dilution water	Synthetic moderately hard water	
pH	7.78-8.33	
Hardness	Not reported	
Alkalinity	Not reported	
Conductivity	310-346 uS/cm	
Dissolved Oxygen	4.70-5.66 mg/L	
Feeding	Fed 50 uL algae, 50 uL YCT	
Purity of test substance	99%	
Concentrations measured?	Yes	

	Qin et al. 2011	***C. dubia***
Parameter	**Value**	**Comment**
Measured is what % of nominal?	21-26%	
Toxicity values calculated based on nominal or measured concentrations?	Measured	
Chemical method documented?	Yes, GC-ECD	
Concentration of carrier (if any) in test solutions	0.06% acetone	
Concentration 1 Nom; Meas (µg/L)	0.1; 0.021	6 reps, 5 org/rep
Concentration 2 Nom; Meas (µg/L)	0.2; 0.052	6 reps, 5 org/rep
Concentration 3 Nom; Meas (µg/L)	0.5; meas not reported	6 reps, 5 org/rep
Concentration 4 Nom; Meas (µg/L)	1; meas not reported	6 reps, 5 org/rep
Concentration 5 Nom; Meas (µg/L)	2; meas not reported	6 reps, 5 org/rep
Control	Solvent	6 reps, 5 org/rep
LC_{50} (µg/L)	0.39 (0.29-0.49)	Method: not reported

Notes:
Reliability points taken off for:
Documentation (Table 3.7): Measured concentrations (3), Hardness (2), Alkalinity (2), Statistical methods (5), Hypothesis tests (8). 100-20=80

Acceptability (Table 3.8): Measured concentrations within 20% of nominal (4), Feeding (3), Exposure type (2), Hardness (2), Alkalinity (2), Random design (2), Statistical method (2), Hypothesis tests (3). 100-20=80

Toxicity Data Summary

Ceriodaphnia dubia

Study: Wheelock CE, Miller JL, Miller MJ, Gee SJ, Shan G, Hammock BD. 2004. Development of toxicity identification evaluation procedures for pyrethroid detection using esterase activity. Environmental Toxicology and Chemistry 23(11): 2699-2708.

Relevance
Score: 100
Rating: R

Reliability
Score: 77.5
Rating: R

Reference	**Wheelock** et al. **2004**	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	EPA	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	*dubia*	
Family in North America?	Yes	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	AQUA-Science, Davis, CA	
Have organisms been exposed to contaminants?	Probably not	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	> 90%	
Temperature	25 $\pm$ 1 ºC	
Test type	Static	
Photoperiod/light intensity	16:8, light:dark	
Dilution water	EPA moderately hard	
pH	7.4-7.8	
Hardness	80-100 mg/L	
Alkalinity	60-70 mg/L	
Conductivity	Measured but NR	
Dissolved Oxygen	Measured but NR	
Feeding	None during test	
Purity of test substance	> 97%	

Reference	**Wheelock** et al. **2004**	***C. dubia***
Parameter	**Value**	**Comment**
Concentrations measured?	No	
Measured is what % of nominal?	NR	
Chemical method documented?	NR	
Concentration of carrier (if any) in test solutions	< 1 %	
Concentration 1 Nom/Meas (µg/L)	5-7 concentrations	2-4 reps w/ 5 neonates each
Control	Water and methanol control	2-4 reps w/ 5 neonates each
LC_{50} (µg/L)	48 h: 0.142 $\pm$ 0.122	ToxCal software, but no stat method reported

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Dissolved Oxygen (4), Conductivity (2), Statistical methods identified (5), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Concentrations do not exceed 2x water solubility (4), Carrier solvent ≤ 0.5 mL/L (4), Appropriate spacing between concentrations (2), Appropriate statistical method (2), Hypothesis tests (3)

Toxicity Data Summary

Chironomus dilutus (formerly *Chironomus tentans*)

Study: Anderson BS, Phillips BM, Hunt JW, Connor V, Richard N, Tjeerdema RS. 2006. Identifying primary stressors impacting macroinvertebrates in the Salinas River (CA, USA): Relative effects of pesticides and suspended particles. Environmental Pollution 141:402-408.

Relevance
Score: 90 (No standard method)
Rating: R

Reliability
Score: 79
Rating: R

Reference	**Anderson et al. 2006**	***C. dilutus***
Parameter	**Value**	**Comment**
Test method cited	NR	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	*Chironomus*	
Species	*dilutus*	
Family in North America?	Yes	
Age/size at start of test/growth phase	3rd instar	
Source of organisms	Chesapeake Culture, Hayes, VA.	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	No	
Test duration	96 hr	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	90% survival*	
Temperature	23 ± 1 °C*	
Test type	Static	
Photoperiod/light intensity	16 light:8 dark*	
Dilution water	Well Water	
pH	NR	
Hardness	91.6 mg/L*	
Alkalinity	122.4 mg/L as $CaCO_3$*	
Conductivity	NR	

Reference	**Anderson et al. 2006**	***C. dilutus***
Parameter	**Value**	**Comment**
Dissolved Oxygen	NR	
Feeding	Not fed	
Purity of test substance	100%	
Concentrations measured?	Some were, but not used in toxicity value calculations	
Measured is what % of nominal?	36-65%	Meas. 2 reps of only some conc's
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Used 100 mg/L methanol stock	
Concentration 1 Nom/Meas (µg/L)	0.560/ 200, 364	10 reps, 1 per rep
Concentration 2 Nom/Meas (µg/L)	1.8/ 0.964, 1.110	10 reps, 1 per rep
Concentration 3 Nom/Meas (µg/L)	5/ NR	10 reps, 1 per rep
Concentration 4 Nom/Meas (µg/L)	10/ NR	10 reps, 1 per rep
Concentration 5 Nom/Meas (µg/L)	20/ NR	10 reps, 1 per rep
Control	0/ NR	10 reps, 1 per rep
LC_{50} (µg/L)	2.615	Method: Spearman-Karber

Other notes:

*Control survival, temp. variation photoperiod, and water chemistry obtained by personal communication with the testing laboratory.

Emailing author revealed typo in the article. The LC_{50} of 26 µg/L in the paper SHOULD READ 2.6 µg/L.

Reliability points taken off for:
Documentation: Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)
Acceptability: Standard method (5), Meas. Concentrations 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated (1), Dissolved oxygen (6), Conductivity (1), pH (2), Random design (2), Hypothesis tests (3)

Toxicity Data Summary

Daphnia magna

Study: Surprenant DC. 1983. Acute toxicity of FMC 54800 technical to *Daphnia magna*. Bionomics Study. FMC Study No: A83 / 986. MRID 00132537.

Relevance
Score: 100
Rating: R

Reliability
Score: 89
Rating: R

Reference	**Surprenant 1983**	***D. magna***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*magna*	
Native to	Northeastern United States	
Age/size at start of test/growth phase	< 24 hours	
Source of organisms	Laboratory culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	48 hr	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	0 %	
Temperature	20-21 ^{o}C	
Test type	Flow-through	
Photoperiod/light intensity	16 light: 8 dark	
Dilution water	EPA hard water (fortified well water)	Warham Mass. well water
pH	7.9-8.3	
Hardness	160-190 mg/L	
Alkalinity	110-130 mg/L	
Conductivity	400-600 uMhos/cm	
Dissolved Oxygen	> 5.6 mg/L	
Feeding	None	

Reference	**Surprenant 1983**	***D. magna***
Parameter	**Value**	**Comment**
Purity of test substance	88.35 %	
Concentrations measured?	No	
Measured is what % of nominal?	NR	
Chemical method documented?	No	
Concentration of carrier (if any) in test solutions	< 0.47 µL/mL	DMF
Concentration 1 Nom (µg/L)	10	4 reps, 20 org/rep
Concentration 2 Nom (µg/L)	5	4 reps, 20 org/rep
Concentration 3 Nom (µg/L)	2.5	4 reps, 20 org/rep
Concentration 4 Nom (µg/L)	1.2	4 reps, 20 org/rep
Concentration 5 Nom (µg/L)	0.60	4 reps, 20 org/rep
Control	Solvent control and dilution water	4 reps, 20 org/rep
LC_{50} (95% confidence limit) (µg/L)	48 hr: 1.6 (1.2-2.0)	Method: Moving angle average analysis

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Hypothesis tests (3)

Toxicity Data Summary

Daphnia magna

Study: Burgess D. 1989. Chronic Toxicity of 14C-FMC 54800 to Daphnia magna Under Flow-Through Test Conditions. ABC Labs. FMC #A88-2649. MRID 411565-01.

Relevance
Score: 100
Rating: R

Reliability
Score: 93.5
Rating: R

Reference	**Burgess 1989**	***D. magna***
Parameter	**Value**	**Comment**
Test method cited	USEPA/ASTM/ Organization for Economic Cooperation and Development	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*magna*	
Family in North America?	Yes	
Age/size at start of test	< 24 hours	
Source of organisms	Lab Culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated / disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Not Reported	
Test duration	21 Days	
Data for multiple times?	Raw data, but no toxicity values	
Effect 1	Survival	
Control response 1	97.5 %	
Effect 2	Length	
Control response 2	4.1 mm	
Effect 3	Time to 1st Brood	
Control response 3	8 days	
Effect 4	Reproduction	
Control response 4	4.7 young/day/adult	
Temperature	19 – 20 ºC	
Test type	Flow-Through	
Photoperiod/light intensity	16 light:8 dark, 30-70 Foot Candles	
Dilution water	Blended R.O. and well water to achieve hardness	Missouri well water

Appendix B1: Studies rated RR

Reference	**Burgess 1989**	***D. magna***
Parameter	**Value**	**Comment**
pH	7.4-7.7	
Hardness	160-180 mg/L	
Alkalinity	174-192 mg/L	
Conductivity	350-360 µmhos/cm	
Dissolved Oxygen	7.4-8.4 mg/L	
Feeding	Selenastrum suspension 3x daily + Yeast, Vitamin, Tetramin 1x daily	
Purity of test substance	97%	purified in lab
Concentrations measured?	Yes	
Measured is what % of nominal?	50-76%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Not Reported	
Concentration 1 Nom/Meas (ng/L)	0.6/0.296	4 rep/10 per rep
Concentration 2 Nom/Meas (ng/L)	1.2/0.76	4 rep/10 per rep
Concentration 3 Nom/Meas (ng/L)	2.5/1.3	4 rep/10 per rep
Concentration 4 Nom/Meas (ng/L)	5/2.9	4 rep/10 per rep
Concentration 5 Nom/Meas (ng/L)	10/7.6	4 rep/10 per rep
Control/Solvent Control	0/Unreported	4 rep/10 per rep
Reproduction		
NOEC	1.3 ng/L (reproduction)	Method: ANOVA w/Dunnett's test p: 0.05, MSD: NR
LOEC	2.9 ng/L	
MATC (GeoMean NOEC,LOEC)	1.9 ng/L	
% control at NOEC	4.5/4.7 - 96%	
% of control LOEC	2.1/4.7 - 44%	
Length		
NOEC	2.9 ng/L (length)	Method: ANOVA w/Dunnett's test p: 0.05, MSD: NR
LOEC	7.6 ng/L	
MATC (GeoMean NOEC,LOEC)	4.7 ng/L	
% control at NOEC	3.6/4.1 - 88%	
% of control LOEC	3.2/4.1 - 78%	
Time to 1st brood		
NOEC	2.9 ng/L (time to 1st brood)	Method: ANOVA w/Dunnett's test p: 0.05, MSD: NR
LOEC	7.6 ng/L	
MATC (GeoMean NOEC,LOEC)	4.7 ng/L	
% control at NOEC	NR	
% of control LOEC	NR	

Reliability points taken off for:
Documentation: Minimum significant difference (2)

Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.1 mL/L (4), Random or block design (2), Minimum significant difference (1)

Toxicity Data Summary

Hyalella azteca

Study: Anderson BS, Phillips BM, Hunt JW, Connor V, Richard N, Tjeerdema RS. 2006. Identifying primary stressors impacting macroinvertebrates in the Salinas River (CA, USA): Relative effects of pesticides and suspended particles. Environmental Pollution 141:402-408.

Relevance
Score: 90 (no Standard method)
Rating: R

Reliability
Score: 79
Rating: R

Reference	**Anderson et al. 2006**	***H. azteca***
Parameter	**Value**	**Comment**
Test method cited	NR	
Phylum	Arthropoda	
Class	Crustacea	
Order	Malacostraca	
Family	Hyalellidae	
Genus	*Hyalella*	
Species	*azteca*	
Family in North America?	Yes	
Age/size at start of test/growth phase	7-14 days	
Source of organisms	Aquatic Biosystems, FT. Collins, CO.	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	No	
Test duration	96 hours	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	97% survival*	
Temperature	23 ± 1°C*	
Test type	Static	
Photoperiod/light intensity	16 light: 8 dark*	
Dilution water	Well Water	
pH	NR	
Hardness	91.6 mg/L*	
Alkalinity	122.4 mg/L as CaCO3*	
Conductivity	NR	

Reference	**Anderson et al. 2006**	***H. azteca***
Parameter	**Value**	**Comment**
Dissolved Oxygen	NR	
Feeding	Not fed	
Purity of test substance	100%	
Concentrations measured?	Yes	
Measured is what % of nominal?	19-56%	Meas. 2 reps of only some conc's
Chemical method documented?	Some were, but not used in toxicity value calculations	
Concentration of carrier (if any) in test solutions	Used 100 mg/L methanol stock	
Concentration 1 Nom (µg/L)	0.0056	3 reps, 5 org/rep
Concentration 2 Nom/Meas (µg/L)	0.010/ 0.002, 0.005	3 reps, 5 org/rep
Concentration 3 Nom (µg/L)	0.018	3 reps, 5 org/rep
Concentration 4 Nom/Meas (µg/L)	0.032/ 0.006,0.018	3 reps, 5 org/rep
Concentration 5 Nom (µg/L)	0.056	3 reps, 5 org/rep
Control	0	3 reps, 5 org/rep
LC_{50} (µg/L)	0.0093	Method: Spearman-Karber

Other notes:

*Control survival, temp. variation and water chemistry obtained by personal communication with the testing laboratory.

Reliability points taken off for:
Documentation: Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)
Acceptability: Standard method (5), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated (1), Dissolved oxygen (6), Conductivity (1), pH (2), Random / block design (2), Hypothesis tests (3)

Toxicity Data Summary

Hyalella azteca

Bradley MJ. 2013. Bifenthrin – Acute toxicity to freshwater amphipods (*Hyalella azteca*) under flow-through conditions. Submitted to: Pyrethroid Working Group, FMC Corporation, Ewing, NJ, 08628. Performing laboratory: Smithers Viscient, 790 Main St, Wareham, MA, 02571-1037; lab project ID: Smithers Viscient Study No. 13656.6164.

Relevance	Reliability
Score: 100	Score: 92.5
Rating: R	Rating: R

	Bradley 2013	***H. azteca***
Parameter	**Value**	**Comment**
Test method cited	Smithers Viscient protocol, generally following USEPA OCSPP 850.1000, OCSPP 850.1020	There is not yet a final EPA method for this test
Phylum/subphylum	Arthropoda	
Class	Crustacea	
Order	Malacostraca	
Family	Hyalellidae	
Genus	*Hyalella*	
Species	*azteca*	
Family native to North America?	Yes	
Age/size at start of test/growth phase	9 days	
Source of organisms	In-house lab cultures	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Not reported	
Test duration	96 h	
Data for multiple times?	Yes, 24, 48, 72 h	
Effect 1	Mortality	
Control response 1	0%	
Temperature	23 $\pm$ 1 ^{o}C	
Test type	Flow-through	
Photoperiod/light intensity	16 h light: 8 h dark, 260-350 lux	
Dilution water	Laboratory well water	
pH	7.3-7.7	

	Bradley 2013	***H. azteca***
Parameter	**Value**	**Comment**
Hardness	28 mg/L $CaCO_3$	
Alkalinity	26-28 mg/L $CaCO_3$	
Conductivity	94-100 uS/cm	
Total organic carbon	1.5 mg/L	
Dissolved Oxygen	7.4-8.8 mg/L	$\geq$ 75% saturation
Feeding	1.0 mL YCT once daily	YCT: Yeast, cereal leaves, flaked fish food
Purity of test substance	93.6%	
Concentrations measured?	Yes	
Measured is what % of nominal?	100-118%	
Toxicity values calculated based on nominal or measured concentrations?	Measured	
Chemical method documented?	Yes, GC-MSD	
Concentration of carrier (if any) in test solutions	0.050 mL/L acetone	
Concentration 1 Nom; Meas (ng/L)	0.25; 0.28	2 reps, 10/rep
Concentration 2 Nom; Meas (ng/L)	0.50; 0.53	2 reps, 10/rep
Concentration 3 Nom; Meas (ng/L)	1.0; 1.0	2 reps, 10/rep
Concentration 4 Nom; Meas (ng/L)	2.0; 2.2	2 reps, 10/rep
Concentration 5 Nom; Meas (ng/L)	4.0; 4.7	2 reps, 10/rep
Control	Solvent and dilution water	2 reps, 10/rep
LC_{50} (95% CI) (ng/L)	0.50 (0.43-0.59)	Method: Trimmed Spearman-Karber estimates

Notes: Typically organisms are not fed in acute exposures, but were fed daily in this test. EPA guidance recommends feeding at day 0 and day 2 in a static 96-h water only reference-toxicant test (USEPA 2000). Because this test was flow-through with 90% renewal of overlying water every 5 h, it is unlikely the particulate or dissolved organic matter was significantly increased in the tests, and unlikely that a significant amount of test chemical was adsorbed to the food and ingested by the organisms. Thus daily feeding was considered acceptable in this test.

Reliability points taken off for:
Documentation: Hypothesis tests (8). Total: 100-8=92

Acceptability: Random design (2), Adequate replication (2), Hypothesis tests (3). Total: 100-7=93

Reliability score: mean(92, 93)=92.5

Toxicity Data Summary

Hyalella azteca

Deanovic LA, Markiewicz D, Stillway M, Fong S, Werner I. 2013. Comparing the effectiveness of chronic water column tests with the crustaceans *Hyalella azteca* (Order: Amphipoda) and *Ceriodaphnia dubia* (Order: Cladocera) in detecting toxicity of current-use insecticides. Environmental Toxicology and Chemistry 32(3):707-712.

Relevance
Score: 100
Rating: R

Reliability
Score: 87
Rating: R

	Deanovic et al. 2013	***H. azteca***
Parameter	**Value**	**Comment**
Test method cited	California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Program Plan & EPA 2000	
Phylum/subphylum	Arthropoda	
Class	Crustacea	
Order	Malacostraca	
Family	Hyalellidae	
Genus	*Hyalella*	
Species	*azteca*	
Family native to North America?	Yes	
Age/size at start of test/growth phase	9-14 days	
Source of organisms	Lab cultures	Purchased from Aquatic Research Organisms
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes (48 h acclimation from receipt)	
Animals randomized?	Not reported	
Test vessels randomized?	Not reported	
Test duration	10 d	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	Synthetic water: 3% Filtered ambient water: 0%	
Effect 2	Growth	
Control response 2	Synthetic water: 0.069 (SE=0.004)	

	Deanovic et al. 2013	***H. azteca***
Parameter	**Value**	**Comment**
	Filtered ambient water: 0.088 (SE=0.005)	
Temperature	23 ± 1°C	
Test type	Static renewal	80% renewed on days 2, 4, 6, 8
Photoperiod/light intensity	16 h light: 8 h dark	
Dilution water	3) Synthetic water (deionized water amended to be moderately hard water) 4) Filtered (1.0 μm) ambient water from Sacramento-San Joaquin Delta (previously tested as nontoxic)	
pH	Measured at t_0 and t_{final} within acceptable range throughout test. Not reported.	Amended to 7.9
Hardness	Not reported.	
Alkalinity	Not reported.	
Conductivity	Measured at t_0 and t_{final} within acceptable range throughout test. Not reported.	Amended to 900 uS/cm
Dissolved Oxygen	4.9-8.9 mg/L	60-100% saturation
DOC	Synthetic water: Filtered ambient water:	
Feeding	Yes, 1 mL of a mixture of yeast, organic alfalfa, & trout chow at initiation and every other day after water renewals	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	Synthetic water: 47-81% Filtered ambient water: 77-100%	
Toxicity values calculated based on nominal or measured concentrations?	Measured	
Chemical method documented?	Yes, GC-ECD	EPA method 8081B
Concentration of carrier (if any) in test solutions	≤ 0.05% methanol	

	Deanovic et al. 2013	***H. azteca***
Parameter	**Value**	**Comment**
Concentration 1 Nom; Meas (ng/L)	Synthetic water: 1.0; 0.6 Filtered ambient water: 1; not detected	4 reps, 10/rep
Concentration 2 Nom; Meas (ng/L)	Synthetic water: 4; 2.0 Filtered ambient water: 2.0; not detected	4 reps, 10/rep
Concentration 3 Nom; Meas (ng/L)	Synthetic water: 8; 3.0 Filtered ambient water: 4; 1.0	4 reps, 10/rep
Concentration 4 Nom; Meas (ng/L)	Synthetic water: 16; 8.0 Filtered ambient water: 8; 3.0	4 reps, 10/rep
Concentration 5 Nom; Meas (ng/L)	Synthetic water: not tested Filtered ambient water: 16; 6.0	4 reps, 10/rep
Control	Solvent & dilution water	4 reps, 10/rep
LC_{50} (95% CI) (ng/L)	Synthetic water: 2.7 (2.5-3.0) Filtered ambient water: 2.3 (1.6-4.5)	Method: Best fit of linear regression, nonlinear regression, or linear interpolation
EC_{25} (95% CI) (ng/L)	Synthetic water: 1.3 (<0.6-2.3) Filtered ambient water: 0.5 (0.4-0.7)	
NOEC (ng/L)	<u>Mortality</u> Synthetic water: 2 Filtered ambient water: 1 <u>Growth</u> Synthetic water: 0.6 Filtered ambient water: <1	Method: Either Dunnett's procedure, steel's many-one rank test, or Wilcoxon rank sum test with Bonferroni adjustment as per EPA method guidance p: not reported MSD: value not reported, but within acceptable range
LOEC (ng/L)	<u>Mortality</u> Synthetic water: 3 Filtered ambient water: 3 <u>Growth</u> Synthetic water: 2 Filtered ambient water: 1	Same as above
MATC (GeoMean NOEC,LOEC) (ng/L)	<u>Mortality</u> Synthetic water: 2.4	

	Deanovic et al. 2013	***H. azteca***
Parameter	**Value**	**Comment**
	Filtered ambient water: 1.7 Growth Synthetic water: 1.1 Filtered ambient water: Not calculable	
% of control at NOEC	Mortality Synthetic water: 103% Filtered ambient water: 97% Growth Synthetic water: 0.062/0.069= 90% Filtered ambient water: 0.089/0.088= 101%	
% of control at LOEC	Mortality Synthetic water: 36% Filtered ambient water: 33% Growth Synthetic water: 0.045/0.069= 65% Filtered ambient water: 0.055/0.088= 62.5%	

Notes:

USEPA. 2000. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Second edition. March 2000. EPA 600/R-99/064.

Reliability points taken off for:
Documentation: Hardness (2), Alkalinity (2), Conductivity (2), pH (3), Significance level (2). Total: 100-11=89

Acceptability: Measured concentrations within 20% of nominal (4), Carrier solvent (4), Organisms randomized (1), Hardness (2), Alkalinity (2), Random design (2). Total: 100-15=85

Reliability score: mean(89, 85)=87

Toxicity Data Summary

Hyalella azteca

Study: Weston DP, Jackson CJ. 2009. Use of Engineered Enzymes to Identify Organophosphate and Pyrethroid-Related Toxicity in Toxicity Identification Evaluations. Environmental Science and Technology 43:5514-5520.

Relevance
Score: 100
Rating: R

Reliability
Score: 88
Rating: R

Reference	**Weston & Jackson 2009**	***H. azteca***
Parameter	**Value**	**Comment**
Test method cited	USEPA	Modified for H. azteca
Phylum	Arthropoda	
Class	Crustacea	
Order	Malacostraca	
Family	Hyalellidae	
Genus	*Hyalella*	
Species	*azteca*	
Family in North America?	Yes	
Age/size at start of test/growth phase	7- 14 d†	
Source of organisms	Lab Culture†	Weston lab
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes†	
Animals randomized?	Yes†	
Test vessels randomized?	Yes†	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	Median control survival was 95% (range 84-100%). Median solvent control survival for the acetone carrier was 98% (84-100%)	
Effect 2	Impaired swimming*	
Control response 2	Survivors never had impaired control response	
Temperature	23 °C	
Test type	Static renewal (48 h)	
Photoperiod/light intensity	16:8 (light:dark)	
Dilution water	EPA moderately hard water,	

Reference	**Weston & Jackson 2009**	***H. azteca***
Parameter	**Value**	**Comment**
	from purified water	
pH	7.5†	
Hardness	90 mg/L as $CaCO_3$ †	
Alkalinity	60 mg/L as $CaCO_3$ †	
Conductivity	335 umhos/cm†	
Dissolved Oxygen	7.4 mg/L†	
Feeding	Yes, but appropriate	DO depletion & sorption minimized by feeding 6h prior to renewal
Purity of test substance	> 98%†	
Concentrations measured?	Yes, but not all, used recovery of some to estimate "actual" conc.	
Measured is what % of nominal?	median 114% of nominal; range 64-189%	pyrethroid conc. declined to a median of 34% of initial nominal concentration within 48 h (range <12-72%, *n* = 9).
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Acetone, < 32 µL/L	
Concentration 1 Nom (µg/L)	5-8 conc. separated by a factor of 0.5 (e.g., 20, 10, 5, 2.5, 1.3 ng/L)	3 reps, 10 org /rep †
Control	Solvent	3 reps, 10 org/rep
LC_{50} (95% confidence interval) (ng/L)	2.7 (2.1-3.3) 7.3 (6.1-8.6) 8.0 (6.8-9.4) 8.2 (7.0-9.6)	Method: Probit
EC_{50} (95% confidence interval) (ng/L)	1.9 (1.5-2.3) 3.1 (2.7-3.7) 3.5 (3.1-3.9) 3.5 (2.9-4.1)	Method: Probit

Other notes:

†Indicates information was gathered or clarified via email communication with the author Dr. Donald Weston (dweston@berkeley.edu).

*From the study: "Most impaired organisms were lying on their sides, able only to twitch one or more appendages. For those few individuals still able to swim, movement was poorly coordinated and swimming limited to only a few body lengths. Therefore, we also recorded the proportion of animals able to swim normally, with results reported as the median effective concentration (EC_{50})."

When spiking water or sediment with pesticides, samples to determine the actual pesticide concentration were taken from one concentration step in the midpoint of the range used. For the water tests, the initial water concentration was determined at time 0 and again when fresh solutions were prepared at 48 h. The two samples were either analyzed separately or as a composite. Samples were also taken of water that had been in the beakers for the maximum period (at the end of the first and second 48 h intervals, combined as a composite).

The average pyrethroid concentrations to which *H. azteca* were exposed were approximated as the nominal concentration minus one-half of the 66% nonenzymatic loss over 48 h (i.e., average actual concentration equal to 33% less than nominal). All reported water concentrations are actual values, derived from nominal concentrations adjusted by this factor.

Reliability points taken off for:
Documentation: Nominal concentrations (3), Measured concentrations (3), Hypothesis tests (8)
Acceptability: Meas. conc. w/in 20% of nom. (4), Conc. not > 2x water solubility (4), Hypothesis tests (3)

Appendix B1: Studies rated RR

Toxicity Data Summary

Lepomis macrochirus

Study: Hoberg JR. 1983a. Acute toxicity of FMC 54800 technical to bluegill (*Lepomis macrochirus*). FMC Study No: A83/987. MRID 00132536.

Relevance
Score: 100
Rating: R

Reliability
Score: 84.5
Rating: R

Reference	**Hoberg 1983a**	***L. macrochirus***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Chordata	
Class	Actinopterygii	
Order	Perciformes	
Family	Centrarchidae	
Genus	*Lepomis*	
Species	*macrochirus*	
Native to	St. Lawrence River, Great Lakes, Mississippi River	Introduced worldwide
Age/size at start of test/growth phase	2.5 (1.3-3.6) g 58 (49-64) mm	mean (range)
Source of organisms	Commercial supplier	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	14 day acclimation period
Animals randomized?	No	
Test vessels randomized?	No	
Test duration	144 hr	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	0 % at all time points	
Temperature	21-22 ^{o}C	
Test type	Flow though	
Photoperiod/light intensity	16 light:8 dark (2-20 hectolux)	
Dilution water	Well water	
pH	7.0-7.5	
Hardness	28-30 mg/L	
Alkalinity	24-28 mg/L	
Conductivity	100-140 μMhos/cm	
Dissolved Oxygen	87-94% saturation	

Reference	**Hoberg 1983a**	***L. macrochirus***
Parameter	**Value**	**Comment**
Feeding	Dry pelleted food @ 120 hr	ad libitum
Purity of test substance	88.35 %	
Concentrations measured?	No	
Measured is what % of nominal?	n/a	
Chemical method documented?	No	
Concentration of carrier (if any) in test solutions	NR	DMF
Concentration 1 Nom (µg/L)	1	2 reps /10 fish each
Concentration 2 Nom (µg/L)	0.65	2 reps /10 fish each
Concentration 3 Nom (µg/L)	0.42	2 reps /10 fish each
Concentration 4 Nom (µg/L)	0.27	2 reps /10 fish each
Concentration 5 Nom (µg/L)	0.18	2 reps /10 fish each
Control	Control and solvent control	
LC_{50} (95% confidence interval) (µg/L)	48 hr: 0.65 (0.42-1.0)	Method: Binomial probability
LC_{50} (95% confidence interval) (µg/L)	72 hr: 0.44 (0.39-0.50) 96 hr: 0.35 (0.30-0.40) 144 hr: 0.30 (0.28-0.35)	Method: Moving angle average

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Organisms randomly assigned to containers (1), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Appendix B1: Studies rated RR

Toxicity Data Summary

*Oncorhynchus mykiss (*formerly *Salmo gairdneri)*

Study: Hoberg JR. 1983b. Acute toxicity of FMC 54800 technical to rainbow trout (*Salmo gairdneri*). FMC Study No: A83/967. MRID 00132539.

Relevance
Score: 100
Rating: R

Reliability
Score: 86
Rating: R

Reference	**Hoberg 1983b**	***O. mykiss***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Vertebrae	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	*Oncorhynchus*	
Species	*mykiss*	
Native to	Canada, Alaska	
Age/size at start of test/growth phase	1.0 (0.57-1.6) g 46 (40-54) mm	mean (range)
Source of organisms	Commercial supplier	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Not reported	
Test vessels randomized?	Not reported	
Test duration	120 hr	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	0% (at all times)	
Temperature	11 - 12 ^{o}C	
Test type	Flow-through	
Photoperiod/light intensity	16 light :8 dark	
Dilution water	Well water	
pH	7.0 - 7.3	
Hardness	28-30 mg/L	
Alkalinity	24 mg/L as $CaCO_3$	
Conductivity	130-140 µMhos/cm	
Dissolved Oxygen	9.0 - 9.8 mg/L	
Feeding	None	
Purity of test substance	88.35 %	

Reference	**Hoberg 1983b**	***O. mykiss***
Parameter	**Value**	**Comment**
Concentrations measured?	No	
Measured is what % of nominal?	Not applicable	
Chemical method documented?	Not applicable	
Concentration of carrier (if any) in test solutions	Not reported	Dimethyl formamide (DMF)
Concentration 1 Nom (µg/L)	1.5	2 reps /10 fish each
Concentration 2 Nom (µg/L)	0.75	2 reps /10 fish each
Concentration 3 Nom (µg/L)	0.38	2 reps /10 fish each
Concentration 4 Nom (µg/L)	0.19	2 reps /10 fish each
Concentration 5 Nom (µg/L)	0.094	2 reps /10 fish each
Control	Control and solvent control	2 reps /10 fish each
LC_{50}	24 h: 6.2 µg/L	Method: probit analysis
LC_{50} (95% confidence interval) (µg/L)	48 h: 0.34 (0.27-0.42) 72 h: 0.20 (0.15-0.26) 96 h: 0.15 (0.15-0.26) 120 h: 0.10 (0.15-0.26)	Method: moving angle average analysis

Other notes:

Increased mortalities prevented calculation of an LC_{50} after 120hrs
Moving angle average analysis:
Peltier, W.H., and Weber, C.I. (1985). *Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms.* EPA-600/4-85-013, U.S. Environmental Protection Agency, Cincinnati, OH.

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Hypothesis tests (8)
Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Random or block design (2), Hypothesis tests (3)

Appendix B1: Studies rated RR

Toxicity Data Summary

Pimephales promelas

Study: Guy D. 2000b. Aquatic Toxicology laboratory Report P-2161-2. Bifenthrin with *Pimephales promelas* in an acute definitive test. California Department of Fish and Game, Aquatic Toxicology Lab, Elk Grove, CA.

Relevance
Score: 100
Rating: R

Reliability
Score: 85
Rating: R

Reference	**Guy 2000b**	***P. promelas***
Parameter	**Value**	**Comment**
Test method cited	ASTM /EPA	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Family in North America?	Yes	
Age/size at start of test/growth phase	8 d, dry wt: 0.0039-0.0052 g	
Source of organisms	Aquatic Resources Lab	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	100% in solvent control; 98% in dilution water cont	
Temperature	24.0 - 24.5 ^{o}C	
Test type	Static w/ 48 h renewal	
Photoperiod/light intensity	16:8 light:dark	
Dilution water	NR	
pH	8.02-8.41	
Hardness	150-162 mg/L	
Alkalinity	170-182 mg/L	
Conductivity	328-447 µs/cm	
Dissolved Oxygen	6.65-8.33 mg/L	

Reference	**Guy 2000b**	***P. promelas***
Parameter	**Value**	**Comment**
Feeding	Yes, can not determine if during test or just acclimation period	
Purity of test substance	97.8%	
Concentrations measured?	Not directly: estimated	
Measured is what % of nominal?	184 - 204% estimated from spikes	
Chemical method documented?	No (would be helpful to know since recovery abnormally high)	
Concentration of carrier (if any) in test solutions	0.0055 mL/L (acetone)	
Nominal and estimated (Est) concentrations (divided by a factor derived from recovery of spiked water samples on day 0 and day 2		
Concentration 1 Nom/Est (µg/L)	0.3/0.56	4 reps; 10 fish per rep
Concentration 2 Nom/Est (µg/L)	0.6/1.09	4 reps; 10 fish per rep
Concentration 3 Nom/Est (µg/L)	1.25/2.4	4 reps; 10 fish per rep
Concentration 4 Nom/Est (µg/L)	2.5/5.1	4 reps; 10 fish per rep
Concentration 5 Nom/Est (µg/L)	3.75/7.40	4 reps; 10 fish per rep
Concentration 6 Nom/Est (µg/L)	5 /9.18	4 reps; 10 fish per rep
Controls	Water only and a solvent (acetone) control	4 reps; 10 fish per rep
LC_{50} (95% confidence interval) (µg/L)	0.78 (0.526-0.853)	Method: Linear interpolation

Reliability points taken off for:
Documentation: Analytical method (4), Measured concentrations (3), Dilution water source (3), Hypothesis tests (8)
Acceptability: Measured concentrations within 20% nominal (4), Organism fed in acute tests (3), Dilution water source acceptable (2), Hypothesis tests (3)

Appendix B1: Studies rated RR

Toxicity Data Summary

Pimephales promelas

Study: McAllister WA. 1988. Full life cycle toxicity of ^{14}C-FMC 54800 to the fathead minnow (*Pimephales promelas*) in a flow-through system. FMC Study No: A86/2100. MRID 40791301.

Relevance
Score: 100
Rating: R

Reliability
Score: chronic 93.5, acute 87.5
Rating: R

Reference	**McAllister 1988**	***P. promelas***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	*Pimephales*	
Species	*promelas*	
Native to	North America	
Age/size at start of test/growth phase	Chronic: < 48 hr eggs Acute: 14 d old	
Source of organisms	In-house laboratory culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	Chronic: 368 days Acute: 96 h	F_0 and F_1 gen - entire life cycle
Data for multiple times?	Yes	
Acute effect 1	96 h Mortality	
Acute control response 1	0%	
Chronic effect 1	92 d F_0 Survival	
Control response 1	100%	
Effect 2-6	Number eggs / female, Number of spawns, Number of eggs, Number spawns / female, Number eggs / female, Percent egg hatch	No statistically significant responses, but trend - High variability, See Fig. 10
Other effects measured	F_0 wet weight, F_0 Hatchability, F_0 Standard length, F_1 Hatchability, F_1	No statistically significant responses found

Reference	**McAllister 1988**	***P. promelas***
Parameter	**Value**	**Comment**
	Standard length, F_1 wet weight, F_1 wet weight, F_1 Survival	
Other Effect/ info in study	Bioconcentration factor	
	> 48 hr old 83-4900X	
	96 hr old 530-10,000X	
	14 day old 6000X	0.019 µg/L conc.
	Whole body residue Adults (F_0) 21-28,000X	
Temperature	25 ± 1 °C	
Test type	Acute: static Chronic: flow-through	
Photoperiod/light intensity	Chronic: 16 light: 8 dark Acute: NR	
Dilution water	Aerated well water	
pH	Chronic: 7.8 - 8.2 Acute: 8.1-8.2	
Hardness	Chronic: 246 - 346 mg/L Acute: 270-280 mg/L	
Alkalinity	Chronic: 302 - 522 mg/L Acute: NR	
Conductivity	Chronic: 530 – 840 uMhos/cm Acute: NR	
Dissolved Oxygen	Chronic: 3.9 - 8.7 mg/L Acute: 5.2-8.7 mg/L	
Feeding	Acute - none Chronic - daily artemia	
Purity of test substance	Technical- 96.2%	^{14}C labeled
Concentrations measured? (ug/L)	Yes	
Measured is what % of nominal?	Acute: 73-88% Chronic: 53 - 146 %	
Chemical method documented?	Liquid scintillation counting	
Concentration of carrier (if any) in test solutions	max. 0.013 mL/L	Acetone
Acute test		
Concentration 1 Nom/Meas (µg/L)	0.051/0.042	10 fish per aquaria
Concentration 2 Nom/Meas (µg/L)	0.10/0.083	10 fish per aquaria
Concentration 3 Nom/Meas (µg/L)	0.20/0.17	10 fish per aquaria
Concentration 4 Nom/Meas (µg/L)	0.40/0.35	10 fish per aquaria
Concentration 5 Nom/Meas (µg/L)	0.80/0.58	10 fish per aquaria
Control	Water only + solvent	10 fish per aquaria
LC_{50} (95% confidence interval)	96 hr: 0.21 (0.16-0.28) µg/L	Method: Moving

Reference	**McAllister 1988**	***P. promelas***
Parameter	**Value**	**Comment**
		average
Chronic		
Concentration 1 Nom/Meas (µg/L)	0.0050/0.0037 ± 0.0013	Started w/ 35 eggs in 4 replicate chambers at each conc. (was F_0)
Concentration 2 Nom/Meas (µg/L)	0.0090/0.0090 ± 0.0034	
Concentration 3 Nom/Meas (µg/L)	0.019/0.019 ± 0.0062	
Concentration 4 Nom/Meas (µg/L)	0.038/0.040 ± 0.017	
Concentration 5 Nom/Meas (µg/L)	0.075/0.090 ± 0.042	
Control	Water only + solvent (acetone)	
Chronic 92 d F_0 Survival		
NOEC	0.040 µg/L	Method: ANOVA w/ Tukey's HSD p: 0.05 MSD: NR
LOEC	0.090 µg/L	
MATC (GeoMean NOEC,LOEC)	0.060 µg/L	
% of control at NOEC	Day 92: 100%	
% of control LOEC	Day 92: 54%	

Static acute tests are not good for calculating ACR for fish

Acute and chronic test run separately. Acute test is static, and is documented separately at starting on pg 168.

Reliability points taken off CHRONIC test for:
Documentation: Minimum significant difference (MSD)(2).
Acceptability: Measured concentrations within 20% Nom (4), Dissolved oxygen ≥ 60 % (6), MSD (1).

Reliability points taken off ACUTE test for:
Documentation: Alkalinity (2), Conductivity (2), Photoperiod (3), Minimum significant difference (MSD)(2).
Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Alkalinity (2), Conductivity (1), Photoperiod (2), Adequate replication (2), MSD (1).

Appendix B1: Studies rated RR

Toxicity Data Summary

Procloeon sp.

Study: Anderson BS, Phillips BM, Hunt JW, Connor V, Richard N, Tjeerdema RS. 2006. Identifying primary stressors impacting macroinvertebrates in the Salinas River (CA, USA): Relative effects of pesticides and suspended particles. Environmental Pollution 141:402-408.

Relevance
Score: 90 (no Std method)
Rating: R

Reliability
Score: 77
Rating: R

Reference	**Anderson et al. 2006**	***Procloeon sp.***
Parameter	**Value**	**Comment**
Test method cited	NR	
Phylum	Arthropoda	
Class	Insecta	
Order	Ephemeroptera	
Family	Baetidae	
Genus	*Procloeon*	
Species	NR	
Family in North America?	Yes	
Age/size at start of test/growth phase	0.5-1.0 cm	
Source of organisms	Reference station, Salinas River	
Have organisms been exposed to contaminants?	Maybe	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	No	
Test duration	48 hours	
Data for multiple times?	No	
Effect 1	Survival	
Control response 1	87% survival*	
Temperature	23 ± 1°C *	
Test type	Static	
Photoperiod/light intensity	16 light: 8 dark*	
Dilution water	Well Water	
pH	NR	
Hardness	91.6 mg/L*	
Alkalinity	122.4 mg/L as CaCO3*	
Conductivity	NR	

Reference	**Anderson et al. 2006**	***Procloeon sp.***
Parameter	**Value**	**Comment**
Dissolved Oxygen	NR	
Feeding	Not fed	
Purity of test substance	100%	
Concentrations measured?	Some were, but not used in toxicity value calculations	
Measured is what % of nominal?	55-77%	Meas. 2 reps of only some conc's
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	Used 100 mg/L methanol stock	
Concentration 1 Nom (µg/L)	0.018	3 reps, 5 org/rep
Concentration 2 Nom (µg/L)	0.032	3 reps, 5 org/rep
Concentration 3 Nom/Meas) (µg/L)	0.056/0.031, 0.043	3 reps, 5 org/rep
Concentration 4 Nom (µg/L)	0.100	3 reps, 5 org/rep
Concentration 5 Nom (µg/L)	0.180	3 reps, 5 org/rep
Concentration 6 Nom/Meas (µg/L)	0.320/0.206, 0.202	3 reps, 5 org/rep
Concentration 7 Nom (µg/L)	0.560	3 reps, 5 org/rep
Control	0	3 reps, 5 org/rep
LC_{50} (µg/L)	0.084	Method: Spearman-Karber

Other notes:

*Control survival, temp. variation and water chemistry obtained by personal communication with the testing laboratory.

Reliability points taken off for:
Documentation: Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)
Acceptability: Standard method (5), Measured concentrations within 20% nominal (4), Organisms randomly assigned to containers (1), Organisms properly acclimated (1), Dissolved oxygen (6), Conductivity (1), pH (2), Random / block design (2), Hypothesis tests (3), prior contaminant exposure? (4)

Appendix B2: Studies rated RL, LR, LL

Toxicity Data Summary

Americamysis bahia (formerly *Mysidopsis bahia*)

Study: Barrows ME. 1986b. Acute toxicity of FMC 54800 to mysid shrimp *Mysidopsis bahia*. FMC Study No: A85-1875. EPA MRID: 00163102, or 470271-039

Relevance
Score: 85 (saltwater)
Rating: L

Reliability
Score: 89.5
Rating: R

Reference	**Barrows 1986b**	***A. bahia***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Arthropoda	
Class	Malacostraca	
Order	Mysida	
Family	Mysidae	
Genus	*Americamysis*	Formerly *Mysidopsis*
Species	*bahia*	*bahia*
Found in North America?	Yes, Gulf of Mexico, FL coast	15-30 ppt waters
Age/size at start of test/growth phase	<24 hours	
Source of organisms	Laboratory culture	
Have organisms been exposed to contaminants?	no	
Animals acclimated and disease-free?	yes	
Animals randomized?	yes	
Test vessels randomized?	yes	
Test duration	96 hours	
Data for multiple times?	yes	
Effect 1	mortality 96 hrs	
Control response 1	0%, 5% mortality	Control, solvent control
Temperature	21.5-21.6 ^{o}C	
Test type	Flow-through	
Photoperiod/light intensity	16:8	
Dilution water	Duxbury Bay (Mass) seawater	30.5-31.0 ppt
pH	7.82-7.86	
Hardness	(30.5-31.0 ppt)	
Alkalinity	NR	
Conductivity	(30.5-31.0 ppt)	

Reference	**Barrows 1986b**	***A. bahia***
Parameter	**Value**	**Comment**
Dissolved Oxygen	5.6-6.6 mg/L, ≥74%	
Feeding	None	
Purity of test substance	88.35% (stated in appendix)	
Concentrations measured?	no	
Measured is what % of nominal?	77-117 %	
Chemical method documented?	Liquid scintillation counting	
Concentration of carrier (if any) in test solutions	0.27 mL/L	acetone
Concentration 1 Nom/Meas (µg/mL)	0.050/ 439	2 reps, 10 per rep
Concentration 2 Nom/Meas (µg/mL)	0.025/ 0.0192	2 reps, 10 per rep
Concentration 3 Nom/Meas (µg/mL)	0.0125/ 0.0115	2 reps, 10 per rep
Concentration 4 Nom/Meas (µg/mL)	0.00625/ 0.00731	2 reps, 10 per rep
Concentration 5 Nom/Meas (µg/mL)	0.00312/ 0.00248	2 reps, 10 per rep
Control	Solvent and water only	2 reps, 10 per rep
LC_{50}	3.97 ng/L (3.09-4.97) (0.00397 µg/L)	Method not specified

Reliability points taken off for:
Documentation: Alkalinity (2), Minimum significant difference (2), % of control at NOEC and/or LOEC (2), point estimates (8)
Acceptability: Measured concentrations within 20% Nom (4), Alkalinity (2), Minimum significant difference (1)

Toxicity Data Summary

Americamysis bahia (Formerly *Mysidopsis bahia*)

Study: Boeri RL, Ward TJ. 1991. Life Cycle Toxicity of Bifenthrin to the mysid, *Mysidopsis bahia*. FMC # A90-3318. MRID 42338801

Relevance
Score: 85 (saltwater Species)
Rating: L

Reliability
Score: 87.5
Rating: R

Reference	**Boeri & Ward 1991**	***A. bahia***
Parameter	**Value**	**Comment**
Test method cited	USEPA, 1985,1988	
Phylum	Arthropoda	
Class	Crustacea	
Order	Mysida	
Family	Mysidae	
Genus	*Americamysis*	Formerly *Mysidopsis*
Species	*bahia*	*bahia*
Family in North America?	Yes	
Age/size at start of test/growth phase	<24 hours	
Source of organisms	Aquatic Research Organisms Division of Resource Analysts, Inc.	Hampton, NH.
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	28 Days	
Data for multiple times?	Raw Data Only	
Effect 1	Survival, F1	
Control response 1	Pooled Control: 92.5%	
Effect 2	Reproduction, young per female	
Control response 2	7.0, 7.5 young /day	For Control, Solvent Control
Effect 3	Growth: F1 length	
Control response 3	8.6 ± 0.1 mm	
Temperature	23.5-25.7°C	
Test type	Chronic Flow Through	

Reference	**Boeri & Ward 1991**	***A. bahia***
Parameter	**Value**	**Comment**
Photoperiod/light intensity	16:8 l/d, 12μEs^{-1}m^{-2}	
Dilution water	20% seawater	
pH	7.2-9.5	
Hardness	NR	
Alkalinity	NR	
Conductivity	20-21 ppt	
Dissolved Oxygen	>6.8 mg/L	
Feeding	Artemia salina nauplii, 2x daily	
Purity of test substance	96.5 %	
Concentrations measured?	yes	
Measured is what % of nominal?	42-152%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	0.1 ml/L Acetone	
Concentration 1 Nom/Meas (ng/L)	0.79/1.2	8 rep/40 per
Concentration 2 Nom/Meas (ng/L)	1.4/1.3	8 rep/40 per
Concentration 3 Nom/Meas (ng/L)	2.8/1.6	8 rep/40 per
Concentration 4 Nom/Meas (ng/L)	5.6/2.5	8 rep/40 per
Concentration 5 Nom/Meas (ng/L)	11.3/4.7	8 rep/40 per
Control	0/0.98	8 rep/40 per
Solvent Control	0/0.98	8 rep/40 per
NOEC (ng/L)	Survival of F1 gen.: 1.2 Length: 1.2 Reproduction: 2.5	Method:ANOVA w/Dunnett's test p:0.05 MSD: NR
LOEC (ng/L)	Survival of F1 gen.: 1.3 Length: 1.3 Reproduction: 4.7	Same as above
MATC (GeoMean NOEC,LOEC) (ng/L)	Survival of F1 gen.: 1.25 Length: 1.25 Reproduction: 3.43	
% control at NOEC	NR	
% of control LOEC	NR	

Other notes: There is a trend of decreased reproduction starting at 1.3 ng/L (similar to other endpoints), but it is not statistically significant until higher concentrations (see Tables 3 and 6)

Sublethal effects MATC = 4.7ng/L (lethargy, erratic swimming)
Number of young per female MATC = 4.7ng/L

Reliability points taken off for:
Documentation: Alkalinity (2), Statistical methods identified (5), Hypothesis tests (8)\

Acceptability: Measured concentrations within 20% Nom (4), Alkalinity (2), Appropriate statistical method (2), Hypothesis tests (3)

Toxicity Data Summary

Ceriodaphnia dubia

Study: Liu W, Gan J, Lee S, Werner I. 2005a. Isomer selectivity in aquatic toxicity and biodegradation of bifenthrin and permethrin. Environmental Toxicology & Chemistry 24: 1861-1866.

Same data as reported in Liu et al. 2005b.

Relevance
Score: 92.5 (control response not reported)
Rating: R

Reliability
Score: 60
Rating: L

Reference	**Liu et al. 2005a**	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Arthropoda / Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	Ceriodaphnia	
Species	dubia	
In North America	Yes	
Age/size at start of test/growth phase	<20 hrs old	
Source of organisms	Commercial supplier*	*info obtained from Liu et al. 2005b
Have organisms been exposed to contaminants?	Probably not	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 hr	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	NR	
Temperature	NR	
Test type	Static	
Photoperiod/light intensity	NR	
Dilution water	USEPA Moderately hard water	
pH	NR	
Hardness	NR	

Reference	**Liu et al. 2005a**	***C. dubia***
Parameter	**Value**	**Comment**
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	Not during exposure	
Purity of test substance	96%	
Concentrations measured?	NR	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes, but it was not used to measure concentrations in the toxicity tests.	
Concentration of carrier (if any) in test solutions	0.08%	Acetone
Concentrations (nominal) (µg/L)	0-0.6	4 rep /5 org ea.
Control	Solvent control	4 rep /5 org ea.
LC50 (µg/L)	0.144	Method: probit

Notes:
*info obtained from Liu et al. 2005b

Liu W, Gan J, Schlenk D, Jury WA. 2005b. Enantioselectivity in environmental safety of current chiral insecticides. Proceedings of the National Academy of Sciences, 102:701-706.

Reliability points taken off for:
Documentation: Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Temperature (4), Conductivity (2), pH (3), Photoperiod (3), Hypothesis tests (8).

Acceptability: Control response (9), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated/disease free (1), Hardness (2), Alkalinity (2), Dissolved Oxygen (6), Temperature acceptable (3), Temperature not held to $\pm$ 1^{o}C (3), Conductivity (1), pH (2), Photoperiod (2), Number of concentrations (3), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3).

Toxicity Data Summary

Ceriodaphnia dubia

Study: Liu W, Gan J, Schlenk D, Jury WA. 2005b. Enantioselectivity in environmental safety of current chiral insecticides. Proceedings of the National Academy of Sciences, 102:701-706.

Same data as reported in Liu et al. 2005a.

Relevance
Score: 92.5 (control response not reported)
Rating: R

Reliability
Score: 60
Rating: L

Reference	**Liu et al. 2005b**	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Arthropoda / Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	Ceriodaphnia	
Species	dubia	
In North America	Yes	
Age/size at start of test/growth phase	<20 hrs old	
Source of organisms	Commercial supplier	Aquatic Biosystems (Fort Collins, CO)
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 hr	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	NR	
Temperature	NR	
Test type	Static	
Photoperiod/light intensity	NR	
Dilution water	USEPA Moderately hard water*	*info. From Liu et al. 2005a
pH	NR	
Hardness	NR	

Reference	**Liu et al. 2005b**	***C. dubia***
Parameter	**Value**	**Comment**
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	None during test*	*info. From Liu et al. 2005a
Purity of test substance	96%	
Concentrations measured?	NR	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes, but not used for the toxicity tests.	
Concentration of carrier (if any) in test solutions	0.08%	Acetone
Concentrations (nominal) (µg/L)	0-0.6*	4 rep /5 org ea.
Control	Solvent control*	4 rep /5 org ea.
LC_{50} (µg/L)	0.144 $\pm$ 0.017	Method: probit

Notes:
*info. From Liu et al. 2005a

Liu W, Gan J, Lee S, Werner I. 2005a. Isomer selectivity in aquatic toxicity and biodegradation of bifenthrin and permethrin. Environmental Toxicology & Chemistry 24: 1861-1866.

Reliability points taken off for:
Documentation: Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Temperature (4), Conductivity (2), pH (3), Photoperiod (3), Hypothesis tests (8).

Acceptability: Control response (9), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated/disease free (1), Hardness (2), Alkalinity (2), Dissolved Oxygen (6), Temperature acceptable (3), Temperature not held to $\pm$ 1°C (3), Conductivity (1), pH (2), Photoperiod (2), Number of concentrations (3), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3).

Toxicity Data Summary

Ceriodaphnia dubia

Study: Yang WC, Spurlock F, Liu WP, Gan JY. 2006b. Inhibition of aquatic toxicity of pyrethroid insecticides by suspended sediment. *Environ Toxicol Chem* 25:1913-1919.

Relevance
Score: 92.5 (control type not described)
Rating: R

Reliability
Score: 66
Rating: L

Data summarized for only for treatment of added suspended solids

Reference	**Yang et al. 2006b**	***C. dubia***
Parameter	**Value**	**Comment**
Test method cited	EPA	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Ceriodaphnia*	
Species	dubia	
Family in North America?	Yes	
Age/size at start of test/growth phase	<24 h	
Source of organisms	Aquatic Biosystems	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	no	
Effect 1	mortality	
Control response 1	= or > 90% survival	
Temperature	21 +/- 1 C	
Test type	Static	
Photoperiod/light intensity	16: 8 light: dark	
Dilution water	EPA moderately hard water	
pH	NR	
Hardness	Recipe given-can calculate	96 mg NaHCO3/L
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	None during test	
Purity of test substance	98%	

Reference	**Yang et al. 2006b**	***C. dubia***
Parameter	**Value**	**Comment**
Concentrations measured?	Not for this test	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes, but not used for this test	
Concentration of carrier (if any) in test solutions	About 0.4mL /L acetone	
Concentration 1 Nom (µg/L)	0.4	4 Reps, 5 per rep
Concentration 2 Nom (µg/L)	0.2	4 Reps, 5 per rep
Concentration 3 Nom (µg/L)	0.1	4 Reps, 5 per rep
Concentration 4 Nom (µg/L)	0.05	4 Reps, 5 per rep
Concentration 5 Nom (µg/L)	0.02	4 Reps, 5 per rep
Concentration 6 Nom (µg/L)	0.01	4 Reps, 5 per rep
Control	Not described	4 Reps, 5 per rep
LC_{50} (µg/L)	0.05 (0.043 -0.057)	Method not stated, only that ToxCalc soft ware was used

Reliability points taken off for:
Documentation: Control type (8), Analytical method (4), Measured concentrations (3), Alkalinity (2), Dissolved oxygen (4), Conductivity (2), pH (3), Statistical methods identified (5), Hypothesis tests (8).

Acceptability: Control appropriate (6), Measured concentrations within 20% Nom (4), Organisms randomly assigned to test containers (1), Alkalinity (2), Dissolved oxygen (6), Conductivity (1), pH (2), Random or block design (2), Appropriate statistical method (2), Hypothesis tests (3).

Toxicity Data Summary

Crassostrea virginica

Study: Ward GS. 1986a. Acute toxicity of FMC 54800 technical on new shell growth of the eastern oyster (*Crassostrea virginica*). FMC Study No: A86-2083. MRID 470271-040. or EPA no:00136103

Relevance
Score: 70 (saltwater, no toxicity values)
Rating: L

Reliability
Score: 81.5
Score: R

Reference	**Ward 1986a**	***C. virginica***
Parameter	**Value**	**Comment**
Test method cited	EPA and in house protocol	
Phylum/subphylum	Mollusca	
Class	Bivalvia	
Order	Ostreoida	
Family	Ostreidae	
Genus	Crassostrea	
Species	virginica	
Native to	North America (east coast)	
Age/size at start of test/growth phase	31-50 mm height	
Source of organisms	commercial supplier	
Have organisms been exposed to contaminants?	no	
Animals acclimated and disease-free?	yes	
Animals randomized?	yes	
Test vessels randomized?	yes	
Test duration	96 hours	
Data for multiple times?	no	
Effect 1	Reduced shell growth	
Control response 1	3.15mm, 3.68mm for control. Solvent control	Shell growth
Temperature	24 ^{o}C	
Test type	Flow-trough	
Photoperiod/light intensity	16:8	
Dilution water	unfiltered seawater, from Marineland, FL	34-35 ppt
pH	7.5 - 8.0	
Hardness	34-35 ppt salinity	
Alkalinity	NR	
Conductivity	34-35 ppt salinity	
Dissolved Oxygen	> 5.5 mg/L	
Feeding	Plankton available in unfiltered water	

Reference	**Ward 1986a**	***C. virginica***
Parameter	**Value**	**Comment**
Exposure	aqueous	
Purity of test substance	88.35%	technical grade
Concentrations measured?	Yes	
Measured is what % of nominal?	26-122%	
Chemical method documented?	HPLC	
Concentration of carrier (if any) in test solutions	0.05 mL/L	acetone
Concentration 1 Nom/Meas (µg/L)	0.30 / 0.0781	20 per concentration, (assume 1 rep)
Concentration 2 Nom/Meas (µg/L)	0.59 / 0.721	
Concentration 3 Nom/Meas (µg/L)	1.18 / 0.393	
Concentration 4 Nom/Meas (µg/L)	2.37 / 1.09	
Concentration 5 Nom/Meas (µg/L)	4.74 / 2.15	
Control	Seawater and solvent control	
EC_{50}	Cannot calculate, authors suggest >2.15 µg/L	
NOEC	NR	
LOEC	NR	
MATC (GeoMean NOEC,LOEC)	NR	96 h test
% control at NOEC	NR	
% of control LOEC	NR	

See also Ward 1986b for rating sheet

Problems:
Concentrations decreased over the 4 day test, even though test was flow-thru (w/ diluter system)

Only the highest (2.15 ug/L) and the lowest (0.078 ug/L) concentrations were statistically different than the control, so interrupted dose-response

Reliability points taken off for:
Documentation: Alkalinity (2), Hypothesis tests (8), Point estimates (8)
Acceptability: Measured concentrations within 20% Nom (4), Organism fed (3), Alkalinity (2), random or block design (2), Adequate replication (2), Hypothesis tests (3), Point estimates (3)

Toxicity Data Summary

Crassostrea virginica

Study: Ward GS. 1986b. Acute toxicity of FMC 54800 technical on new shell growth of the eastern oyster (*Crassostrea virginica*). FMC Study No: A86-2203. MRID 40266501

Relevance
Score: 70 (Saltwater, no toxicity values)
Rating: L

Reliability
Score: 79.5
Rating: R

Reference	**Ward 1986b**	***C. virginica***
Parameter	**Value**	**Comment**
Test method cited	In house protocol and USEPA	
Phylum/subphylum	Mollusca	
Class	Bivalvia	
Order	Ostreoida	
Family	Ostreidae	
Genus	Crassostrea	
Species	virginica	
Native to	North America (east coast)	
Age/size at start of test/growth phase	36-50 mm height	
Source of organisms	commercial supplier	
Have organisms been exposed to contaminants?	no	
Animals acclimated and disease-free?	yes	
Animals randomized?	yes	
Test vessels randomized?	yes	
Test duration	96 hours	
Data for multiple times?	no	
Effect 1	Reduced shell growth	
Control response 1	2.77, 2.26 mm, in control and solvent control	shell growth
Temperature	26 $\pm$ 1 ^{o}C	
Test type	Flow Thru	
Photoperiod/light intensity	16:8	
Dilution water	unfiltered seawater	35-36 ppt, from Marineland, Fl,
pH	7.0 - 7.8	
Hardness	35-36 ppt salinity	
Alkalinity	NR	
Conductivity	35-36 ppt salinity	
Dissolved Oxygen	> 3.4 mg/L	

Reference	**Ward 1986b**	***C. virginica***
Parameter	**Value**	**Comment**
Feeding	Phytoplankton in unfiltered sea water, also water supplemented with corn starch to maximize growth	
Exposure	aqueous	
Purity of test substance	88.35%	technical grade
Concentrations measured?	Yes	
Measured is what % of nominal?	7.4-44%	dramatically decreased over the 4 days, but flow thru
Chemical method documented?	HPLC	
Concentration of carrier (if any) in test solutions	0.06 mL/L	acetone
Concentration 1 Nom/Meas (µg/L)	130/32.1	20 per concentration, (assume 1 rep)
Concentration 2 Nom/Meas (µg/L)	216/95.7	
Concentration 3 Nom/Meas (µg/L)	360/71.5	
Concentration 4 Nom/Meas (µg/L)	600/99.7	
Concentration 5 Nom/Meas (µg/L)	1000/73.9	
Control	Water only and solvent	
EC_{50} (µg/L)	96 hr: > 99.7 estimated, actual EC_{50} could not be determined, no clear dose-response relationship	
NOEC (µg/L)	96 hr Meas: 71.5 96 hr Nom: 600	
LOEC; indicate calculation method	96 hr Meas: 73.9 96 hr Nom: 360	
MATC (GeoMean NOEC,LOEC)	NR	ACUTE Data only (96 hr values)
% control at NOEC	+16 @ 71.5 ug/L +& @ 95.7 ug/L	
% of control LOEC	24% reduction @ 99.7ug/L 13% reduction @ 73.9ug/L	

Problem with study:
Concentrations (measured every 2 days) dramatically decreased over the 4 days, some problem with diluted described that slowed flow, resulting in lower concentrations.
No clear dose-response relationship, control has 23% more growth than solvent control

Reliability points taken off for:
Documentation: Alkalinity (2), Hypothesis tests (8), Point estimates (8)
Acceptability: Measured concentrations within 20% Nom (4), Concentrations do not exceed 2x water solubility (4), Organism fed (3), Alkalinity (2), random or block design (2), Adequate replication (2), Hypothesis tests (3), Point estimates (3)

Toxicity Data Summary

Cyprinodon variegatus

Study: Barrows ME. 1986a. Acute toxicity of FMC 54800 to sheepshead minnow (*Cyprinodon variegatus*). FMC Study No: A85-1874. EPA no: 00163101, or MRID 470 271-038

Relevance
Score: 85 (saltwater)
Rating: L

Reliability
Score: 88
Rating: R

Reference	**Barrows 1986a**	***C. variegatus***
Parameter	**Value**	**Comment**
Test method cited	ASTM	
Phylum/subphylum	Chordata	
Class	Actinopterygii	
Order	Cyprinodontiformes	
Family	Cyprinodontidae	
Genus	Cyprinodon	
Species	variegatus	
Native to	North & South America	
Age/size at start of test/growth phase	9 weeks, juveniles	
Source of organisms	laboratory culture	
Have organisms been exposed to contaminants?	no	
Animals acclimated and disease-free?	yes	
Animals randomized?	yes	
Test vessels randomized?	yes	
Test duration	96 hr	
Data for multiple times?	Yes- raw data in appendix	
Effect 1	96 hr mortality	
Control response 1	0 % mortality	In both solvent control and control
Temperature	32.5-33 ^{o}C	
Test type	Flow-through	
Photoperiod/light intensity	16:8	
Dilution water	Duxbury Bay seawater (Mass)	in raw data says filtered seawater
pH	7.80 - 7.97	
Hardness	30.5-31.0 ppt salinity	
Alkalinity	NR	
Conductivity	30.5-31.0 ppt salinity	
Dissolved Oxygen	>72% saturation	
Feeding	None	

Reference	**Barrows 1986a**	***C. variegatus***
Parameter	**Value**	**Comment**
Purity of test substance	88.35 % technical	
Concentrations measured? (µg/L)	yes	
Measured is what % of nominal?	106 - 145 %	
Chemical method documented?	liquid scintillation count	
Concentration of carrier (if any) in test solutions	0.28 mL/L	acetone
Concentration 1 Nom/Meas (µg/L)	60/ 63.4	2 reps, 10 per rep
Concentration 2 Nom/Meas (µg/L)	30/ 31.7	2 reps, 10 per rep
Concentration 3 Nom/Meas (µg/L)	15/ 17.2	2 reps, 10 per rep
Concentration 4 Nom/Meas (µg/L)	7.5/ 10.9	2 reps, 10 per rep
Concentration 5 Nom/Meas (µg/L)	3.8/ 5.24	2 reps, 10 per rep
Control	Control and solvent control	2 reps, 10 per rep
LC50 96h	17.8 (14.7-21.8) ug/L	Moving average
NOEC;	(Not applicable- 96 hr values)	
LOEC; indicate calculation method	NR	
MATC (GeoMean NOEC,LOEC)	NR	
% control at NOEC	NR	
% of control LOEC	NR	

Reliability points taken off for:
Documentation: Alkalinity (2), Hypothesis tests (8)
Acceptability: Measured concentrations within 20% Nom (4), Alkalinity (2), Temperature not held to $\pm$ 1^{o}C (3), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Daphnia magna

Study: Hoberg, J., Nicholson, R.B., Grandy, K., Surprenant, D.C. 1985. The Chronic Toxicity of 14C-FMC 54800 to Daphnia magna Under Flow-Through Conditions. FMC # 84-1256. MRID 40275401 (Raw data in MRID 470286-025/00163139)

Relevance
Score: 85 (low chemical purity)
Rating: L

Reliability
Score: 89, both acute & chronic
Rating: R

Reference	**Hoberg et al. 1985**	***D. magna***
Parameter	**Value**	**Comment**
Test method cited	EPA 1975, Lab Established protocol	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*magna*	
Family in North America?	Yes	
Age/size at start of test/growth phase	≤24 Hours	
Source of organisms	Lab Culture	
Have organisms been exposed to contaminants?	Probably not	
Animals acclimated and disease-free?	Not Specified	
Animals randomized?	Yes	
Test vessels randomized?	Not Reported	
Test duration	21 Days	
Data for multiple times?	Raw Data	
Effect 1	Survival	
Control response 1	100% Control and Solvent Control	
Effect 4	Reproduction	
Control response 4	Control: 58 young/ adult Solvent C.: 60 young/ adult	
Temperature	19 – 21 ºC	
Test type	Chronic Flow-Through	
Photoperiod/light intensity	3-6 Hectolux 16:8 l/d	
Dilution water	Fortified Well Water	
pH	7.8-8.3	
Hardness	160-180	
Alkalinity	110-130	
Conductivity	400-600 µmhos/cm	

Reference	**Hoberg et al. 1985**	***D. magna***
Parameter	**Value**	**Comment**
Dissolved Oxygen	> 60 %	
Feeding	5 ml Yeast, 2 ml Ankistrodesmus 3x daily, 2x daily weekends	
Purity of test substance	10.36%	
Concentrations measured?	Yes	
Measured is what % of nominal?	54%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	20 mL/L	
ACUTE		
Concentration 1 Nom/Meas (µg/L)	0.58 /0.48	4 rep/5 per rep
Concentration 2 Nom/Meas (µg/L)	0.29 /0.20	4 rep/5 per rep
Concentration 3 Nom/Meas (µg/L)	0.14/ 0.12	4 rep/5 per rep
Concentration 4 Nom/Meas (µg/L)	0.072/ 0.064	4 rep/5 per rep
Concentration 5 Nom/Meas (µg/L)	0.036/ 0.025	4 rep/5 per rep
Control	Solvent and dilution water	4 rep/5 per rep both
CHRONIC		
Concentration 1 Nom/Meas (µg/L)	0.0025/0.00095	4 rep/20 per
Concentration 2 Nom/Meas (µg/L)	0.0050/0.0022	4 rep/20 per
Concentration 3 Nom/Meas (µg/L)	0.010/0.0051	4 rep/20 per
Concentration 4 Nom/Meas (µg/L)	0.020/0.012	4 rep/20 per
Concentration 5 Nom/Meas (µg/L)	0.040/0.031	4 rep/20 per
Control	Solvent and dilution water	4 rep/20 per both
LC_{50} (95% confidence interval) (µg/L)	0.11 (0.094-0.13)	Method: Moving average angle analysis
NOEC (µg/L)	Reproduction: 0.00095 Survival: 0.012	Method: ANOVA w/Dunnett's test p: 0.05 MSD: NR
LOEC (µg/L)	Reproduction: 0.0022 Survival: 0.031	Interrupted dose-response -repro
MATC (GeoMean NOEC,LOEC) (µg/L)	Reproduction: 0.0014 Survival: 0.019	
% control at NOEC/LOEC	NR	

Acute Test run first, the results were used to determine the concentrations for the chronic test run after.
Reliability points taken off for:
Documentation: Minimum significant difference (2), % of control at NOEC/ LOEC (2).
Acceptability: Purity (10), Measured concentrations within 20% Nom (4), Carrier solvent too high (4), Organisms acclimated and disease free (1), Random or block design (2), Minimum significant difference (2).

Toxicity Data Summary

Daphnia magna

Study: Wang C, Chen F, Zhang Q, Fang Z. 2009. Chronic toxicity and cytotoxicity of synthetic pyrethroid cis-bifenthrin. Journal of Environmental Science-China, 21, 1710-1715.

Relevance
Score: 92.3 (Control not described)
Rating: R

Reliability
Score: 69
Rating: L

Reference	**Wang et al. 2009**	***D. magna***
Parameter	**Value**	**Comment**
Test method cited	OECD 1998	
Phylum	Arthropoda	
Class	Crustacea	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*magna*	
Family in North America?	Yes	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Laboratory culture	Institute of Environmental Science, Zhejiang University
Have organisms been exposed to contaminants?	Probably not	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	21 d	
Data for multiple times?	No	
Effect 1	Number of young/female	
Control response 1	91.6 (SD=16.61)	
Effect 2	Average brood size	
Control response 2	7.5 (SD=1.65)	
Effect 3	Number of first brood/female	
Control response 3	12.4 (SD=3.6)	
Effect 4	Days to first brood	
Control response 4	6.2 (SD=0.63)	
Effect 5	Longevity (d)	
Control response 5	20.5 (SD=1.33)	
Effect 6	Length (cm)	
Control response 6	5.1 (SD=0.29)	

Reference	**Wang et al. 2009**	***D. magna***
Parameter	**Value**	**Comment**
Temperature	22 ±1 °C	
Test type	Static renewal, 48 h renewal	
Photoperiod/light intensity	12L:12D	
Dilution water	M4 medium (OECD 1998)	
pH	NR	
Hardness	NR	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	Feeding in tests NR	
Purity of test substance	99.5%	
Concentrations measured?	No	
Measured is what % of nominal?	n/a	
Toxicity values calculated based on nominal or measured concentrations?	Nominal	
Chemical method documented?	n/a	
Concentration of carrier (if any) in test solutions	Ethanol, $\leq$ 0.008%	
Concentration 1 Nom/Meas (µg/L)	0.005	10 reps, #/rep NR
Concentration 2 Nom/Meas (µg/L)	0.01	10 reps, #/rep NR
Concentration 3 Nom/Meas (µg/L)	0.02	10 reps, #/rep NR
Concentration 4 Nom/Meas (µg/L)	0.04	10 reps, #/rep NR
Concentration 5 Nom/Meas (µg/L)	0.08	10 reps, #/rep NR
Control	Not described	10 reps, #/rep NR
EC_{50} (µg/L)	Longevity: 0.031 Reproduction: 0.019	Method: non-linear regression
NOEC (µg/L)	Longevity: **0.01** # of 1st brood/female: **0.01** Average brood size: **0.01** # of young/female: **0.01** Days to 1st brood: 0.02 Length: 0.04	Method: one-way ANOVA p: < 0.05 MSD: NR
LOEC(µg/L)	Longevity: **0.02** # of 1st brood/female: **0.02** Average brood size: **0.02** # of young/female: **0.02** Days to 1st brood: 0.04 Length: > 0.04	Same as above
MATC (GeoMean NOEC,LOEC) (µg/L)	Longevity: **0.014** # of 1st brood/female: **0.014** Average brood size: **0.014** # of young/female: **0.014**	
% of control at NOEC	Longevity: 94%	

Reference	**Wang et al. 2009**	***D. magna***
Parameter	**Value**	**Comment**
	# of 1st brood/female: 90% Average brood size: 95% # of young/female: 92% Days to 1st brood: 98% Length: 75%	
% of control at LOEC	Longevity: 81% # of 1st brood/female: 72% Average brood size: 69% # of young/female: 52% Days to 1st brood: 126%	

Notes:

Reliability points taken off for:
Documentation: Control type (8), Analytical method (4), Measured concentrations (3), Hardness (2), Alkalinity (2), Dissolved oxygen (4), Conductivity (2), pH (3), Minimum significant difference (2).
Acceptability: Control description (6), Measured concentrations within 20% of nominal (4), Organisms randomized (1), Organisms/rep (2), Feeding (3), Hardness (2), Alkalinity (2), Dissolved oxygen (6), Conductivity (1), pH (2), Random design (2), Minimum significant difference (1).

Toxicity Data Summary

Oncorhynchus mykiss

Study: Riar N, Crago J, Jiang W, Maryoung LA, Gan J, Schlenk D. 2013. Effects of salinity acclimation on the endocrine disruption and acute toxicity of bifenthrin in freshwater and euryhaline strains of *Oncorhynchuss mykiss.* Environ Toxicol Chem 32:2779-2785.

Relevance
Score: 90
Rating: R

Reliability
Score: 72.5
Rating: L

*No standard method (10)

	Riar et al. 2013	***O. mykiss***
Parameter	**Value**	**Comment**
Test method cited	None cited	
Phylum	Chordata	
Class	Osteichthyes	
Order	Salmoniformes	
Family	Salmonidae	
Genus	*Oncorhynchus*	
Species	*mykiss*	
Family in North America?	Yes	
Age/size at start of test/growth phase	Rainbow trout: Juvenile (mean length 9.3 ± 1.0 cm, mean body wt 10.6 ± 3.4 g) Steelhead trout: Juvenile (mean length 9.6 ± 1.5 cm, mean body wt 10.6 ± 3.4 g)	
Source of organisms	Purchased from fish hatcheries	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes, 2 week acclimation	Rainbow trout and steelhead were each acclimated to freshwater, 8 g/L and 17 g/L salinity
Animals randomized?	Not reported	
Test vessels randomized?	Not reported	
Test duration	14 d	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0%	
Temperature	11-12 ± °C	
Test type	Static renewal, renewed	

	Riar et al. 2013	***O. mykiss***
Parameter	**Value**	**Comment**
	every 48 h	
Photoperiod/light intensity	14 h light: 10 h dark	
Dilution water	Filtered tap water	
pH	Not reported	
Hardness	Not reported	
Alkalinity	Not reported	
Conductivity	Not reported	
Dissolved Oxygen	Not reported	
Feeding	Fed every 48 h	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	25-71%	
Toxicity values calculated based on nominal or measured concentrations?	Measured	
Chemical method documented?	Yes, GC-ECD	
Concentration of carrier (if any) in test solutions	0.01% ethanol	
Concentration 1 Nom; Meas (µg/L)	Rainbow trout 0.1; 0.025 Steelhead trout 0.1; 0.030	3 reps, 5 org/rep
Concentration 2 Nom; Meas (µg/L)	Rainbow trout 1.5; 1.072 Steelhead trout 1.5; 0.608	3 reps, 5 org/rep
Control	Solvent (<0.005 ug/L)	3 reps, 5 org/rep
NOEC	Rainbow trout (freshwater): 0.025	Method: ANOVA p: <0.05 MSD: not reported
LOEC	Rainbow trout (freshwater): 1.072	Same as above
MATC (GeoMean NOEC,LOEC)	Rainbow trout (freshwater): 0.16	
% of control at NOEC	90%	
% of control at LOEC	45%	

Notes: No significant effects were observed for the steelhead trout in any water type, and no significant effects were observed for rainbow trout in either of the euryhaline waters.

Reliability points taken off for:
Documentation (Table 3.7): Hardness (2), Alkalinity (2), Dissolved oxygen (4), Conductivity (2), pH (3), Minimum significant difference (2), Point estimates (8). 100-23=77

Acceptability (Table 3.8): No standard method (5), Measured concentrations within 20% of nominal (4), Organisms randomized (1), Hardness (2), Alkalinity (2), Dissolved oxygen (6), Conductivity (1), pH (2), Number of concentrations (3), Random design (2), Minimum significant difference (1), Point estimates (3). 100-32=68

Appendix B2: Studies rated RL, LR, LL

Toxicity Data Summary

Simulium vitattum - Blackfly
Cheumatopsyche spp. & *Hydropsyche* spp. - Caddisfly
Heptageniidae spp. - Mayfly
Enellagma spp. & *Ishnura* spp. - Damselfly
Hydrophilus spp. - Water scavenger beetle

Siegfried BD. 1993. Comparative toxicity of pyrethroid insecticides to terrestrial and aquatic insects. Environmental Toxicology and Chemistry 12: 1683-1689.

AQUATIC exposures only, TOPICAL exposures not summarized here

Relevance	Reliability
Score: 90 (no std method)	Score: 63.5
Rating: R	Rating: L

Reference	**Siegfried 1993**	**Various insects**
Parameter	**Value**	**Comment**
Test method cited	No standard method cited	
Phylum/subphylum	Arthropoda	
Class	Insecta	
Order	Diptera, Trichoptera, Ephemeroptera, Odonata, Coleoptera	
Family	various	
Genus	*Simulium, Hydropsyche, Ishnura, Enellagma, Hydrophilus, Cheumatopsyche, Heptageniidae*	Terrestrial insects tested in this study were not included here.
Species	*vitattum*, others unidentified	
Native to	Nebraska, USA	
Age/size at start of test/growth phase	Larva (Black fly & Caddisfly), nymph (Mayfly & Damselfly), adult (beetles)	
Source of organisms	Collected from field, Lancaster County, NE	Various ponds and lakes
Have organisms been exposed to contaminants?	Yes-probably	Collected from environment
Animals acclimated and disease-free?	Acclimated-72 h	Health status not determined
Animals randomized?	NR	
Test vessels randomized?	NR	

Reference	**Siegfried 1993**	**Various insects**
Parameter	**Value**	**Comment**
Test duration	24 hours	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	< 10 mortality, except black flies 14%, mayflies 16%	
Temperature	20 ^{o}C	
Test type	Acute Static	
Photoperiod/light intensity	24 hr dark	
Dilution water	states only 'distilled'	
pH	NR	
Hardness	NR	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	None	
Purity of test substance	94%	
Concentrations measured?	NR	
Measured is what % of nominal?	NR	
Chemical method documented?	NR	
Concentration of carrier (if any) in test solutions	states diluted in water	
Concentrations (µg/L)	NR, at least three concentrations used	3 reps, 5-10 insects per rep
Control	Acetone	
LC_{50} (µg/L)	Black fly 1.3 Caddisfly 7.2 Mayfly 2.3 Damselfly 1.1 Diving beetle 5.4	Method: probit

Reliability points taken off for:
Documentation: Analytical method (4), Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)

Acceptability: Acceptable standard method (5), Measured concentrations within 20% Nom (4), No prior contaminant exposure (4), Organisms randomly assigned to containers (1), Dilution water source (2), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Temperature not held to $\pm$ 1^{o}C (3), Conductivity (2), pH (3), Adequate number of concentrations (3), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3).

Appendix B3: Studies rated RN, LN, N

Toxicity Data Summary

Aedes albopictus

Study: Arshad AJK, Xue R-D. 1995. Comparative toxicity of selected larvicides and insect growth regulators to a Florida laboratory population of *Aedes albopictus*. Journal of the American Mosquito Control Association, 11:72-76.

Relevance
Score: 82.5 (No std method, Control response)
Rating: L

Reliability
Score: 55.5
Rating: N

Reference	**Ali & Xue 1995**	***A. albopictus***
Parameter	**Value**	**Comment**
Test method cited	Ref to Mulla et al. 1982	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Culicidae	
Genus	*Aedes*	
Species	*albopictus*	
Family in North America?	Yes (non native? Pest/invasive?)	
Age/size at start of test/growth phase	Late 4th instar	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	no	
Animals acclimated and disease-free?	yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	24 h	
Data for multiple times?	NR	
Effect 1	mortality	
Control response 1	NR	
Temperature	26 $\pm$ 2 ^{o}C	
Test type	static	
Photoperiod/light intensity	14 h L: 10 h D	
Dilution water	tap	
pH	NR	
Hardness	NR	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	once	

Reference	**Ali & Xue 1995**	***A. albopictus***
Parameter	**Value**	**Comment**
Purity of test substance	93.7%	
Concentrations measured?	No	
Measured is what % of nominal?	NR	
Chemical method documented?	NR	
Concentration of carrier (if any) in test solutions	1mL/100mL	
Concentration 1 Nom/Meas (μg/L)	4-9 conc	3 Reps and 20 organisms per rep, test repeated 3x
Control	solvent	3 Reps and 20 organisms per rep, test repeated 3x
LC_{50} (95% confidence interval) (μg/L)	5.2 (4.5-6.0)	Method: Log-dose-probit
LC_{90} (95% confidence interval) (μg/L)	17.5 (14.3-22.4)	Method: Log-dose-probit

Reliability points taken off for:
Documentation: Analytical method (4), Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)

Acceptability: Acceptable standard method (5), Control response (9), Measured concentrations within 20% Nom (4), Concentrations do not exceed 2x water solubility (4), Carrier solvent ≤ 0.5 mL/L (4), Appropriate age/size (3), Organisms randomly assigned to containers (1), Feeding (3), Dilution water source (2), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Temperature not held to $\pm$ 1°C (3), Conductivity (2), pH (3), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Ceriodaphnia dubia
Daphnia magna

Study: Mokry, LE & Hoagland KD. 1990. Acute toxicities of five synthetic pyrethroid insecticides to *Daphnia magna* and *Ceriodaphnia dubia*. Environmental Toxicology & Chemistry 9 (8): 1045-1051.

Relevance
Score: 67.5 (purity-25.4 %, no std method, control response NR)
Rating: N

Toxicity Data Summary

Chironomus dilutus

Study: Ding Y, Landrum PF, You J, Harwood AD, Lydy MJ. 2012. Use of solid phase microextraction to estimate toxicity: Relating fiber concentrations to body residues – Part II. Environ Toxicol Chem 31:2168-2174.

Relevance	Reliability
Score: 85*	Score: not rated
Rating: N	Rating: not rated

*Toxicity values are reported in this study, but they are reported in terms of body residue, not aqueous concentrations, and thus are not compatible with toxicity data used in the UCDM, therefore the study is rated not relevant (N).

Toxicity Data Summary

Crassostrea virginica

Study: Ward GS. 1987. Acute toxicity of FMC 54800 technical to embryos and larvae of the eastern oyster (*Crassostrea virginica*). FMC Study No: A87-2264. MRID 40383501

Relevance
Score: 85 (saltwater)
Rating: N – all concentrations tested > 2x water solubility

Toxicity Data Summary

Culex pipiens quinquefasciatus

Hardstone MC, Leichter C, Harrington LC, Kasai S, Tomita T, Scott JG. 2008. Corrigendum to ‘‘Cytochrome P450 monooxygenase-mediated permethrin resistance confers limited and larval specific cross-resistance in the southern house mosquito, *Culex pipiens quinquefasciatus*.” *Pest Biochem Physiol* 91:191-191.

and

Original article:
Hardstone MC, Leichter C, Harrington LC, Kasai S, Tomita T, Scott JG. 2007. Cytochrome P450 monooxygenase-mediated permethrin resistance confers limited and larval specific cross-resistance in the southern house mosquito, Culex pipiens quinquefasciatus. *Pest Biochem Physiol* 89:175.

Relevance
Rating: N → not aqueous exposures

Study reports LC_{50}s of 3.5 and 5.2 μg/L for susceptible and resistant strains but these were not aqueous exposures.

From the methods section:
"Adult mosquito bioassays were conducted in glass jars (230 ml, internal surface area of 180 cm2) treated with 1 ml of insecticide solution (or 1 ml of acetone for controls), which was evenly coated on the inner walls."

Toxicity Data Summary

Culex quinquefasciatus

Study: Halliday WR Georghiou GP. 1985. Cross-resistance and dominance relationships of pyrethroids in a permethrin-selected strain of *Culex quinquefasciatus (*Diptera: Culicidae). Journal of Economic Entomology, 78:127-1232.

Relevance
Score: 82.5 (No std method, Control not described)
Rating: L

Reliability
Score: 47
Rating: N

Reference	**Halliday & Georghiou 1985**	***C. quinquefasciatus***
Parameter	**Value**	**Comment**
Test method cited	Ref Georghiou 1966	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Culicidae	
Genus	*Culex*	
Species	*quinquefasciatus*	
Family in North America?	Yes	
Age/size at start of test/growth phase	4th instar	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	24 h	
Data for multiple times?	no	
Effect 1	mortality	Susceptible and resistant strains tested
Control response 1	$\leq$ 15%	
Temperature	NR	
Test type	static	
Photoperiod/light intensity	NR	
Dilution water	tap	
pH	NR	
Hardness	NR	
Alkalinity	NR	

Reference	**Halliday & Georghiou 1985**	***C. quinquefasciatus***
Parameter	**Value**	**Comment**
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	NR	
Purity of test substance	'Technical' no%	
Concentrations measured?	NR	
Measured is what % of nominal?	NR	
Chemical method documented?	NR	
Concentration of carrier (if any) in test solutions	10mL/L	
Concentration 1 Nom/Meas (μg/L)	4 levels, but concentrations not reported	4 reps and 20 organisms per rep
Control	yes	
LC_{50} (μg/L)	Susceptible: 2.1 Resistant: 39.0	Method: probit

Reliability points taken off for:
Documentation: Control Type (8), Analytical method (4), Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Temperature (4), Conductivity (2), pH (3), Photoperiod (3) Hypothesis tests (8)

Acceptability: Standard method (5), Control appropriate type (6), Meas. Concentrations 20% Nom (4), Concentrations do not exceed 2x water solubility (4), Carrier solvent ≤ 0.5 mL/L (4), Appropriate age/ size (3), Organisms randomly assigned to containers (1), Dilution water (2), Hardness (2), Alkalinity (2), Dissolved Oxygen (6), Temperature (6), Conductivity (1), pH (2), Photoperiod (2), Adequate number of concentrations (3), Appropriate spacing between concentrations (2), Random / block design (2), Hypothesis tests (3)

Toxicity Data Summary

Cyprinodon variegates
Palaemonetes pugio

Harper, HE, Pennington, PL, Hoguet, J and Fulton, MH. 2008. Lethal and sublethal effects of the pyrethroid, bifenthrin, on grass shrimp (*Palaemonetes pugio*) and sheepshead minnow (*Cyprinodon variegatus*). Journal of Environmental Science and Health, Part B, 43:6, 476 - 483.

Relevance - Mortality
Score: 67.5 (saltwater, no std method, Control response NR)
Rating: N

Relevance - Sublethal effects (not summarized)
Score: 52.5 (saltwater, no std method, Control response NR, endpoint not relevant)
Rating: N

Toxicity Data Summary

Daphnia magna

Study: Liu W, Gan J, Schlenk D, Jury WA. 2005b. Enantioselectivity in environmental safety of current chiral insecticides. Proceedings of the National Academy of Sciences, 102:701-706.

Relevance
Score: 85 (control not described, response not reported)
Rating: L

Reliability
Score: 50.5
Rating: N

Reference	**Liu et al. 2005b**	***D. magna***
Parameter	**Value**	**Comment**
Test method cited	USEPA	
Phylum/subphylum	Arthropoda / Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	*Daphnia*	
Species	*magna*	
In North America	Yes	
Age/size at start of test/growth phase	adults	
Source of organisms	Commercial supplier	Aquatic Biosystems (Fort Collins, CO)
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	NR	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 hr	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	NR	
Temperature	NR	
Test type	Static	
Photoperiod/light intensity	NR	
Dilution water	NR	
pH	NR	
Hardness	NR	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	

Reference	**Liu et al. 2005b**	***D. magna***
Parameter	**Value**	**Comment**
Feeding	NR	
Purity of test substance	96%	
Concentrations measured?	NR	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes, but not used for the toxicity tests.	
Concentration of carrier (if any) in test solutions	0.08%	Acetone
Concentrations (nominal) (µg/L)	NR	4 rep /5 org ea.
Control	Not described	4 rep /5 org ea.
LC_{50} (µg/L)	0.175 ± 0.030	Method: probit

Notes:

Reliability points taken off for:
Documentation: Control type (8), Nominal concentrations (3), Measured concentrations (3), Dilution water (3), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Temperature (4), Conductivity (2), pH (3), Photoperiod (3), Hypothesis tests (8).

Acceptability: Control description (6), Control response (9), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated/disease free (1), Dilution water (2), Hardness (2), Alkalinity (2), Dissolved Oxygen (6), Temperature acceptable (3), Temperature not held to ± 1°C (3), Conductivity (1), pH (2), Photoperiod (2), Number of concentrations (3), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3).