Water Quality Criteria Report for Cypermethrin

Phase III: Application of the pesticide water quality criteria methodology

Prepared for the Central Valley Regional Water Quality Control Board

Tessa L. Fojut, Ph.D.,
Rebecca Mulligan,
and
Ronald S. Tjeerdema, Ph.D.

Department of Environmental Toxicology
University of California, Davis

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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
CA	Concentration Addition
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
IA	Independent Action
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
NEC	No-effect concentration
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

1. 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 cypermethrin 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).

2. Basic information

Chemical: Cypermethrin (Fig. 1)

CAS: cyano(3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate

IUPAC: *RS*-α-cyano-3-phenoxybenzyl (1*RS,3RS;1RS,3SR*)-3-(2,2-dichlorvinyl)-2,2-dimethylcyclopropanecarboxylate

Chemical Formula: $C_{22}H_{19}Cl_2NO_3$

CAS Number: 52315-07-8

CA DPR Chem Code: 2171

USEPA PC Code: 109704

Trade names: Agrothrin, Ambush C, Barricade, CCN 52, Cymbush, Cyperkill, Demon, Flocord, Imperator, Kafil Super, Polytrin, Ripcord, Sherpa, Stocade, Toppel, NRDC 149, PP383, WL 43467, LE 79-600, FMC 30980, OMS 2002, FMC 45806, FMC Code 3765 (Laskowski 2002, Mackay *et al.* 2006, Tomlin 2003).

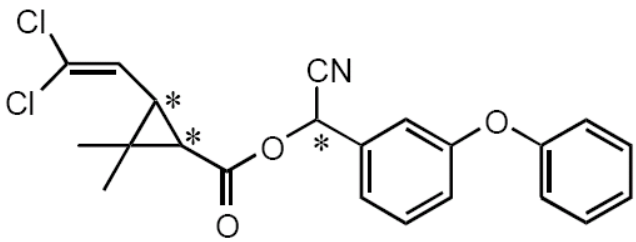

Figure 1. Structure of cypermethrin, a type II pyrethroid, asterisks indicate stereocenters.

3. Physical-chemical data

Molecular Weight
416.3 Laskowski 2002

Density
1.24 g/mL (20°C) Tomlin 2003

Water Solubility
0.004 mg/L at 20°C (mean, n=6) Laskowski 2002
0.004 mg/L at 20°C (pH 7) Tomlin 2003
Geomean: 0.004 mg/L

Melting Point
Semi-solid at room temperature (Tomlin 2003)
70°C (Mackay *et al.* 2006)
61-83°C (Tomlin 2003)
Geomean of extremes: 71.2°C

Vapor Pressure
2.0E-07 Pa (20°C, Tomlin 2003)
3.10E-09 mm Hg (4.13E-07 Pa, 25°C, Laskowski 2002)
Geomean: 2.87E-07 Pa

Organic Carbon Sorption Partition Coefficients (K_{oc})
310,000 soil adsorption (mean of 3 experiments) Laskowski 2002

Henry's constant (K_H)
3.4×10^{-7} atm m^3 mol^{-1} (0.0344478 Pa m^3 mol^{-1}) Laskowski 2002
0.020 Pa m^3 mol^{-1} Tomlin 2003
0.0195 Pa m^3 mol^{-1} Mackay *et al.* 2006
Geomean: 0.0238 Pa m^3 mol^{-1}

Log K_{ow}
6.54 Laskowski 2002

6.6 Tomlin 2003
Geomean: 6.57

Environmental Fate

Table 1. Bioconcentration factors (BCF) for cypermethrin; FT: flow-through.

Species	BCF (L/kg)	Exposure	Reference
Chironomus tentans	34-238	Static, 24 h, water-sediment system	Muir *et al.* 1985
Chlorella fusca (alga)	3,280,000	Static, 24 h	Geyer *et al.* 1984
Lepomis macrochirus	372	FT	Laskowski 2002
Oncorhynchus mykiss	821	FT	Laskowski 2002
Oncorhynchus mykiss	180-438	96 h, FT	Muir *et al.* 1994
Salmo salar	2.6-7.1	96 h, Static	McLeese *et al.* 1980

Table 2. Cypermethrin hydrolysis, photolysis, and biodegradation. NR: not reported.

	Half- life (d)	Water	Temp (°C)	pH	Reference
Hydrolysis	619	Sterile buffer	25	5	Laskowski 2002
	274	Sterile buffer	25	7	Laskowski 2002
	1.90	Sterile buffer	25	9	Laskowski 2002
	1.8	NR	25	9	Tomlin 2003
Aqueous Photolysis	30.1	Sterile buffer	NR	NR	Laskowski 2002
Aqueous Biodegradation (aerobic)	7.44 (mean of 7 values)	Natural water and sediment system	15-25	NR	Laskowski 2002

4. Human and wildlife dietary values

There are no FDA action levels for cypermethrin (USFDA 2000). There are no food tolerances for human consumption of fish, but there are food tolerances for other meat products; there are tolerances of 0.05 mg/kg for the meat, fat and meat byproducts of cattle, goat, hog, horse, and sheep in the cypermethrin reregistration eligibility decision (USEPA 2008).

We were not able to acquire any acceptable dietary toxicity values for mallard ducks in order to assess toxicity of cypermethrin to terrestrial organisms with significant food sources in water. The EPA cypermethrin reregistration eligibility decision (USEPA 2008) reports a 5-d dietary LC_{50} of >2645 mg/kg feed and a reproductive NOEC of >50 mg/kg. No effects were reported in these studies at the highest concentrations tested, thus, definitive toxicity values could not be determined. It appears that cypermethrin has extremely low toxicity to birds.

5. Ecotoxicity data

Approximately 108 original studies on the effects of cypermethrin on aquatic life were identified and reviewed. In the review process, many parameters were 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 (Table 3.6) were summarized in 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. Cypermethrin 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 Tables 3 – 9, found at the end of this report. 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 12 and 14 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), 8 acute toxicity studies, yielding 31 toxicity values, were judged reliable and relevant (RR; Tables 3 and 4). One chronic toxicity study, yielding two toxicity values, was judged reliable and relevant (RR; Tables 6 and 7). Eighteen acute and seven chronic studies were rated RL, LL, or LR and were used as supplemental information for evaluation of the derived criteria in section 12 (Tables 5 and 9, respectively).

Fifteen mesocosm, microcosm and ecosystem (field and laboratory) studies were identified and reviewed using Table 3.9 (TenBrook *et al.* 2009a). Seven of these studies were rated reliable (R) or less reliable (L) and were used as supporting data in section 13 to evaluate the derived criteria to ensure that they are protective of ecosystems (Table 9).

6. Data reduction

Multiple toxicity values for cypermethrin for the same species were reduced to 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 Tables 4 and 7, respectively. Reasons for reduction of data included: flow-through tests are preferred over static tests and more appropriate or more sensitive test durations were available for the same test. The final acute and chronic data sets are shown in Tables 3 and 6, respectively. The final acute data set contains 14 SMAVs, and the final chronic data set contains one SMCV.

7. 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 from the family Salmonidae, a planktonic crustacean, a benthic crustacean, and an insect. Acute values were plotted in a histogram (Figure 2); the data do not appear to be bimodal.

The Burr Type III SSD procedure (section 3-3.2.1, TenBrook *et al.* 2009a) was used for the acute criterion calculation because more than eight acceptable acute toxicity values were available in the cypermethrin data set (Table 3). The Burr Type III SSD procedure was used to derive the median 5th percentile and the median 1st percentile. The software could not provide lower 95% confidence limits for the 1st or 5th percentiles. The median 5th percentile is recommended for use in criteria derivation because it is the most robust of the distributional estimates (section 3-3.2, TenBrook *et al.* 2009a).

Burr III distribution
Fit parameters: b=1.10987; c=3.3645; k=0.174896 (likelihood=3.690953)

5th percentile, 50% confidence limit: 0.006828 μg/L
1st percentile, 50% confidence limit: 0.000443 μg/L

Recommended acute value = 0.006828 μg/L (median 5th percentile)

Acute criterion = acute value ÷ 2
= 0.006828 μg/L ÷ 2
= 0.003414 μg/L

Acute criterion = 0.003 μg/L
= 3 ng/L

The fit of the Burr III distribution from the BurrliOZ software (CSIRO 2001) is shown in Figure 3. This distribution did *not* provide a satisfactory fit (χ^2_{2n} = 0.000014; see Appendix A) according to 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 not valid for criteria derivation. The data set does not appear to be bimodal and the data set was

checked for erroneous data as proscribed by the method (section 3-3.2.5, TenBrook *et al.* 2009a). Instead, the log-logistic distribution was fit to the entire data set because it is less likely to over-fit the data set.

Log-logistic distribution

HC_5 Fitting Parameter Estimates: α = -0.6601, β (median) = 0.4199, β (lower 95% CI) = 0.6768

5th percentile, 50% confidence limit: 0.0126904 µg/L
5th percentile, 95% confidence limit: 0.0022237 µg/L
1st percentile, 50% confidence limit: 0.0025723 µg/L
1st percentile, 95% confidence limit: 0.0001698 µg/L

Recommended acute value = 0.0126904 µg/L (median 5th percentile)
Acute criterion = Recommended acute value ÷ 2
= 0.0126904 µg/L ÷ 2
= 0.0063452 µg/L

Acute criterion = 0.006 µg/L
= 6 ng/L

The log-logistic distribution was fit to the acute data set using the ETX 1.3 software program (Aldenberg 1993) and is also shown in Figure 3. The log-logistic distribution provided a satisfactory fit (see Appendix A) according to the fit test. No significant lack of fit was found (χ^2_{2n} = 0.3002) using a 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. The final criterion is reported with one significant digit because there is variability in the first digit of the 5th percentile values generated in the fit test (see Appendix A), as described in section 3-3.2.6 (TenBrook *et al.* 2009a).

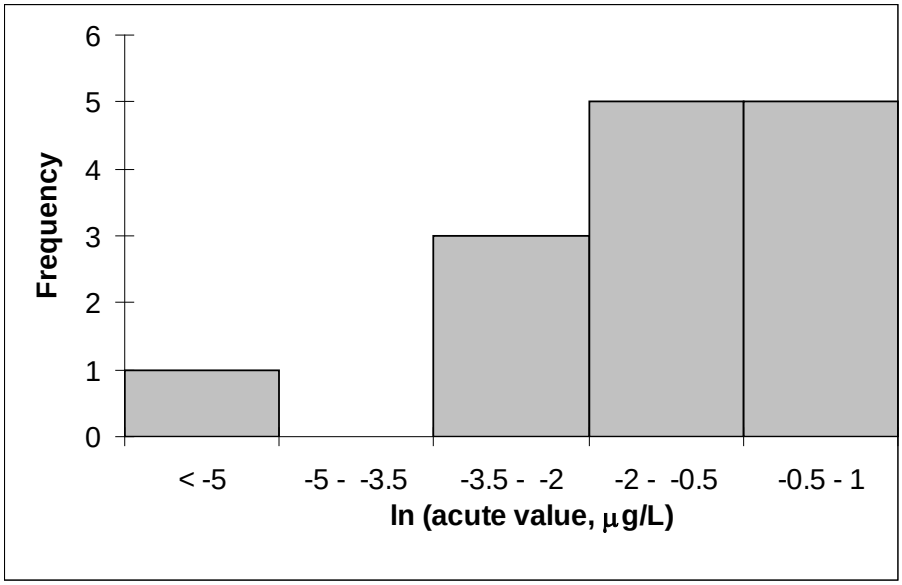

Figure 2. Histogram of the natural log of the cypermethrin species mean acute values.

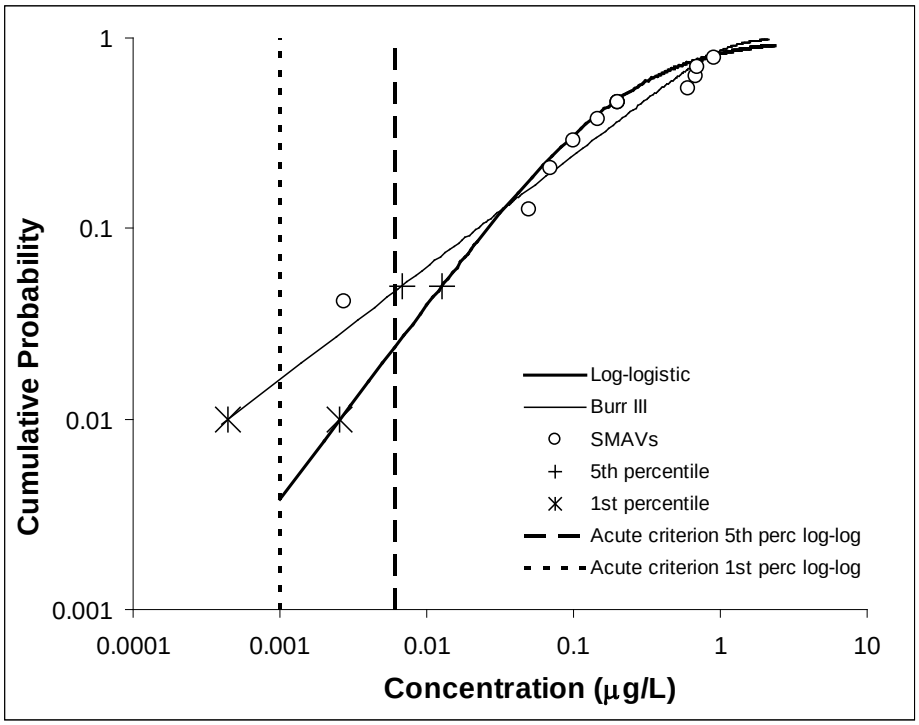

Figure 3. The fit of the Burr Type III and log-logistic distributions plotted with the species mean acute values (SMAVs), acute values, and acute criteria.

8. Chronic criterion calculation

Chronic toxicity values from fewer than five different families were available, thus the acute-to-chronic ratio (ACR) method was used to calculate the chronic criterion (section 3-4.2, TenBrook *et al.* 2009a). There is one SMCV in the acceptable (rated RR) data set (Table 6), satisfying one of the five taxa requirements (section 3-3.1, TenBrook *et al.* 2009a): a warm water fish (*Pimephales promelas).*

The *Pimephales promelas* chronic data could not be paired with appropriate RR acute data, nor were any acceptable saltwater paired acute and chronic toxicity values. Because there are no appropriate paired data, ACRs cannot be calculated from measured data, thus the default ACR of 12.4 was used (section 3-4.2.3, TenBrook *et al.* 2009a). The default ACR of 12.4 is equal to the 80th percentile of the multispecies ACRs available in eight pesticide criteria reports (section 2-3.2.5.3, TenBrook *et al.* 2009a). This is the same procedure used by the USEPA to derive a default ACR in the Water Quality Guidance for the Great Lakes System (Host *et al.* 1995, USEPA 2003).

The recommended chronic criterion was calculated using the acute median 5th percentile and the final multi-species ACR as follows:

<u>Recommended:</u>
Chronic criterion = acute median 5th percentile ÷ ACR

= 0.0126904 μg/L ÷ 12.4
= 0.00102342 μg/L

Chronic criterion = 0.001 μg/L
= 1 ng/L

The chronic criterion is rounded to one significant figure because it was calculated with the acute value, so the same rounding used for the acute criterion was also used for the chronic criterion.

9. Bioavailability

Although cypermethrin and other pyrethroids are not very soluble in water, aquatic organisms are very sensitive to pyrethroids and toxicity does occur. Pyrethroids have been identified as a cause of toxicity in surface waters in the California Central Valley (Phillips *et al.* 2007, Weston *et al.* 2009a, Weston and Lydy 2010). This toxicity is believed to occur primarily from the fraction of the compound that is dissolved in the water, not from the fraction that is associated with the particulate phase.

Several studies suggest that the binding of cypermethrin and other pyrethroids to suspended solids, dissolved organic carbon (DOC), sediment, or plant matter will make the bound fraction unavailable and thus nontoxic to aquatic organisms. Yang *et al.* (2006b) found that toxicity of cypermethrin to *Ceriodaphnia dubia* decreased with increasing suspended sediment concentration, and that toxicity was well-predicted by a solid-phase microextraction (SPME) method using polydimethylsiloxane fibers. Another study demonstrated that particulates and DOC decreased the uptake and bioconcentration of cypermethrin in rainbow trout (Muir *et al.* 1994). Uptake of cypermethrin by *Chironomus dilutus* was measured by Muir *et al.* (1985) in aquatic exposures with either sand, silt or clay and they found that uptake was most highly correlated to the dissolved concentration of cypermethrin in porewater, compared to concentrations in the sediment or whole water. They reported that sorption to sediments, suspended solids, and DOC, and hydrolysis all reduced bioavailability of pyrethroids. Lajmanovich *et al.* (2003) reported reduced mortality of tadpoles (*Physalaemus biligonigerus*) when aquatic ferns were planted in test aquaria compared to aquaria with no ferns present. The authors measured aqueous concentrations of cypermethrin and concentrations decreased more rapidly when ferns were present, presumably due to sorption of cypermethrin to fern surfaces. There are many studies on pyrethroids, not necessarily including cypermethrin, that also demonstrate decreased toxicity of pyrethroids in the presence of sediment, DOC, and other natural sorbents (Day 1991, DeLorenzo *et al.* 2006, Hunter *et al.* 2008, Smith & Lizotte 2007, Xu *et al.* 2007). These studies indicate that the freely dissolved concentration will be the most accurate predictor of toxicity and that bound cypermethrin was unavailable to the organisms that were studied.

It can also be noted that bound pyrethroids can continue to desorb into the water column for long periods of time because pyrethroids have long equilibration times (~30 d, Bondarenko *et al.* 2006) and environmental systems are not likely at true equilibrium.

The fraction of chemical that is potentially available to an organism is known as the bioaccessible fraction, and it has been linked to biological effects (Semple *et al.* 2004, You *et al.* 2011). Benthic organisms, such as *Hyalella azteca*, may be at greater risk because of their exposure to porewater and close proximity to sediments where dissolved concentrations may persist.

Additionally, the role of dietary exposure on bioavailability of pyrethroids has not been considered. Organisms living in contaminated waters are also 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*. Stratton and Corke (1981) tested toxicity of permethrin to *Daphnia magna* with and without feeding of algae, and found that mortality at 24 h was significantly increased when daphnids were fed, although mortality at 48 h was not affected. The authors propose that permethrin may have been ingested by the daphnids if it was sorbed on the algal cells, and caused increased toxicity, although the same effect was not seen when bacteria were provided as a food source. 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, then compliance may be based on the concentration in the bioavailable phase(s). The studies above suggest that the freely dissolved fraction of cypermethrin is the primary bioavailable phase, and that this concentration is the best indicator of toxicity, thus, it is recommended that the freely dissolved fraction of cypermethrin be directly measured or calculated based on site-specific information for compliance assessment. If environmental managers choose to measure whole water concentrations for criteria compliance assessment, the bioavailable fraction will likely be overestimated.

The most direct way to determine compliance would be to measure the cypermethrin concentration in the dissolved phase to determine the total bioavailable concentration. Solid-phase microextraction only measures the freely dissolved concentration and 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 2.0 ng/L for cypermethrin, which is above both the adjusted acute and

chronic criteria (see section 12 below). Li *et al.* (2009) report a method detection limit of 1.0 ng/L for cypermethrin using SPME, so lower detection levels may be possible as analytical techniques progress. Analytical detection limits may create a problem for criteria compliance because it is possible that cypermethrin could be present in toxic amounts, yet be below the detection limit so that an excursion is not identified. Filtration of particles 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 dissolved organic matter, 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 tested pyrethroid (50 ng/L solution of permethrin) was lost on the filter. This loss may be critical for determining compliance at environmental concentrations.

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

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

where:
$C_{dissolved}$ = concentration of chemical in dissolved phase (μg/L);
C_{total} = total concentration of chemical in water (μg/L);
K_{OC} = organic carbon-water partition coefficient (L/kg);
$[SS]$ = concentration of suspended solids in water (kg/L);
f_{oc} = fraction of organic carbon in suspended sediment in water;
$[DOC]$ = concentration of dissolved organic carbon in water (kg/L);
K_{DOC} = organic carbon-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 organic carbon 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 cypermethrin to suspended solids and dissolved organic matter depends on the physical and chemical properties of the suspended solids. Such physical-chemical properties can vary both spatially and temporally, further complicating measurement of these properties and subsequent assessment of bioavailability using site-specific partition coefficients.

The freely dissolved cypermethrin 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 cypermethrin, or they may also choose to base compliance on whole water concentrations.

10. Mixtures

Cypermethrin often occurs in the environment with other pyrethroid pesticides (Trimble *et al.* 2009, Werner & Moran 2008), and the presence of chemicals in surface waters is ubiquitous. All pyrethroids have the same 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). 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).

To examine if pyrethroid mixture toxicity is additive, 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.

Piperonyl butoxide (PBO) is commonly added to pyrethroid insecticide treatments because it is known to increase the toxic effects of pyrethroids (Weston *et al.* 2006). Many studies have demonstrated that the addition of PBO at a concentration that would be nonlethal on its own, increases the toxicity of pyrethroids (Brander *et al.* 2009, Hardstone *et al.* 2007, Kasai *et al.* 1998, Paul *et al.* 2006, Singh & Agarwal 1986, Xu *et al.* 2005). Rodriguez *et al.* (2005) tested cypermethrin toxicity to mosquitoes (*Aedes aegypti*) with and without PBO and reported an interaction coefficient (K) of 31.8 with a pyrethroid-resistant mosquito strain, but a K of 0.2 with a pyrethroid-susceptible strain, indicating antagonism rather than synergism. Because there is not enough data to calculate a multispecies interaction coefficient for cypermethrin and PBO, there is no accurate way to account for this interaction in compliance determination.

Norgaard & Cedergreen (2010) tested the toxicity of α-cypermethrin in binary combinations with six fungicides with *Daphnia magna* and found that equitoxic mixtures of the fungicides and α-cypermethrin demonstrated synergism with Ks ranging from 1.4-27. They also tested toxicity ratios of 75:25 and 25:75 with each fungicide and α-cypermethrin combination and reported Ks of 0.41-37 for these combinations. Another study also presents evidence that fungicides and cypermethrin, often found in combination in wood preservatives, are highly toxic to aquatic invertebrates and demonstrate synergism (Adam *et al.* 2009). The thiocarbamate pesticide cartap appears to be antagonistic when combined with cypermethrin as no toxicity was observed in tests with *Daphnia magna* and *Oryzias latipes* when the concentrations of each chemical tested in combination were higher than the reported EC/LC_{50} values for the single chemicals (Kim *et al.* 2008). Gartenstein *et al.* (2006) tested cypermethrin in binary combinations with diflubenzuron and diazinon with brine shrimp (*Artemia salina*). Synergism was demonstrated for both binary combinations, but the combination of all three compounds produced an antagonistic effect.

No studies on aquatic organisms were found in the literature that could provide a quantitative means to consider mixtures of cypermethrin with other classes of pesticides. Although there are examples of non-additive toxicity for cypermethrin and other chemicals, a multispecies interaction coefficient is not available for any chemical with cypermethrin, and therefore the concentrations of non-additive chemicals cannot be used for criteria compliance (section 3-5.2.2, TenBrook *et al.* 2009a).

11. Temperature, pH, other water quality effects

Temperature, pH, and other water quality effects on the toxicity of cypermethrin 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, Weston *et al.* 2009b). 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 toxicities of six aqueous pyrethroids (cypermethrin, permethrin, fenvalerate, *d*-phenothrin, flucythrinate, and bioallethrin) were 1.33- to 3.63-fold greater at 20 ˚C compared to 30 ˚C for mosquito larvae (Cutkomp and Subramanyam 1986). No other aqueous toxicity studies were identified that tested cypermethrin, but temperature effects have been demonstrated with several other pyrethroids (Harwood *et al.* 2009, Kumaraguru and Beamish 1981). 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).

The toxicity of sediments contaminated with pyrethroids (including cypermethrin) was more than twice as toxic when tested at 18 ˚C compared to 23 ˚C (Weston *et al.* 2009b). Weston *et al.* (2009b) 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.

Unfortunately, there are limited data demonstrating increased toxicity at lower temperatures using aquatic exposures with relevant species, making it unfeasible to quantify the relationship between the toxicity of cypermethrin and temperature for water quality criteria at this time (section 3-5.3, TenBrook *et al.* 2009a). While there are no studies about the effects of pH on cypermethrin toxicity, it is likely that there is reduced risk at high pH levels because the hydrolysis half-life of cypermethrin is < 2 days at pH 9

(Table 2). Several studies that examined the effects of DOC and suspended solids on cypermethrin toxicity are discussed in the bioavailability section 9 above. No other studies on cypermethrin were identified 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.

12. 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 derived acute criterion (0.006 μg/L) is higher than one SMAV in the RR acute data set, 0.0027 μg/L for *Hyalella azteca* (Table 3). The *Hyalella azteca* SMAV is the geometric mean of four values, three from a study in which concentrations were measured (Weston & Jackson 2009), all of which are lower than the acute criterion of 0.006 μg/L. There are also acute data for the freshwater prawn *Palaemonetes argentinus* (0.002-0.0031 μg/L) and *Daphnia magna* (0.0006-0.002 μg/L) that are below the acute criterion from studies that rated LL and RL, respectively (Table 5). Thus, it is recommended that the next lowest estimate from the species sensitivity distribution should be used to derive the criteria in order to be protective of all species represented in the data set. The next lowest estimate is the median 1st percentile from the log-logistic distribution, and the acute and chronic criteria are calculated as follows:

1st percentile, 50% confidence limit: 0.0025723 μg/L

Recommended acute value = 0.0025723 μg/L (median 1st percentile)

Acute criterion = Recommended acute value ÷ 2
= 0.0025723 μg/L ÷ 2
= 0.00128615 μg/L

Adjusted acute criterion = 0.001 μg/L
= 1 ng/L

There is still one datum in the supplemental data set that is below the adjusted acute criterion (96-h EC_{50}=0.6 ng/L for *Daphnia magna*), but this toxicity value was not based on measured concentrations, and this species is represented in the RR data set with a SMAV that indicates it is protected by the adjusted acute criterion.

Recommended chronic criterion = acute median 1st percentile ÷ ACR
= 0.0025723 μg/L ÷ 12.4
= 0.00020744 μg/L

Adjusted chronic criterion = 0.0002 μg/L
= 0.2 ng/L

There are chronic values below the adjusted chronic criterion of 0.2 ng/L, which are MATCs of 0.00063 ng/L and 0.063 ng/L for *Daphnia magna* (Kim *et al.* 2008) that are rated RL. We do not recommend further downward adjustment of the chronic criterion because these toxicity values were calculated with nominal concentrations, and the methodology recommends that criteria should only be adjusted for sensitive species if the toxicity values were calculated with measured concentrations (section 3-6.1, TenBrook *et al.* 2009a). While criteria derivation for the protection of aquatic life does not take current method detection limits or factors other than toxicity data into account, we do recognize that this value is below any reported detection limits for this compound.

13. 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). Fifteen studies describing effects of cypermethrin on mesocosm, microcosm and model ecosystems were identified and rated for reliability according to the methodology (Table 3.9, TenBrook *et al.* 2009a). Three of the studies were rated as reliable (R; Farmer *et al.* 1995, Friberg-Jensen *et al.* 2003, Wendt-Rasch *et al.* 2003), and four were rated as less reliable (L; Crossland 1982, Lutnicka *et al.* 1999, Maund *et al.* 2009, Medina *et al.* 2004) and are used as supporting data. Eight studies rated as not reliable (N) and are not discussed in this report (Crossland *et al.* 1982, Dabrowski *et al.* 2005, Feng *et al.* 2009, Helson & Surgeoner 1986, Sherratt *et al.* 1999, Shires 1983, Stephenson *et al.* 1984, Walton *et al.* 1990). All of the studies are listed in Table 9. These studies included freshwater pond and stream micro- and mesocosms, a rice paddy, and marine environments. Two studies reported no-effect concentrations (NECs) for particular taxa groups to which the chronic criterion may be compared.

Several studies did single treatments of cypermethrin in pond mesocosms and measured the recovery of the invertebrate communities. Crossland (1982) sprayed outdoor ponds with a cypermethrin formulation at a much higher concentration (22-24 mg/L measured 1 h post-application) than is typically found in current environmental sampling. Some insects and crustaceans declined or disappeared in the 4 weeks following the treatment, but most species had re-colonized the treated pond by 10 weeks post-treatment. Farmer *et al.* (1995) sprayed pond mesocosms with one level of cypermethrin, at which *Gammarus* spp. abundance was completely eliminated, with no indication of recovery 3 months later. Unfortunately, measured concentrations were not reported in this study. Maund *et al.* (2009) performed a study with microcosm enclosures set in a pond that looked at macroinvertebrate recovery after treatment with cypermethrin at a nominal concentration of 0.070 μg/L (0.041-0.058 μg/L measured). In some microcosms, natural reinvasion was simulated by adding invertebrates to the enclosures post-treatment; in these microcosms there was general recovery of invertebrate populations in approximately 100 d. In contrast, the microcosms that received no additional organisms showed only limited recovery after 16 weeks of observation. These results indicate that

small, isolated or heavily impacted waterbodies will likely recover more slowly than waterbodies that are only partially impacted or are near other unimpacted waterbodies from which organisms can immigrate.

Friberg-Jensen *et al.* (2003) calculated cypermethrin NECs for crustaceans, copepods, and cladocerans ranging from 0.02-0.07 μg/L in enclosures set in a lake. These NECs are all significantly higher than the chronic criterion of 0.0002 μg/L. They also reported that rotifers, protozoans, bacteria, periphyton plankton, and periphytic algae all proliferated after treatment with cypermethrin in response to the decreased populations of grazers. A sister paper describing effects for the same experiment reported a NEC of 0.01 μg/L for copepod nauplii (Wendt-Rasch *et al.* 2003). This paper also reported significant changes to species composition of the aforementioned communities at nominal concentrations greater than 0.13 μg/L.

Medina *et al.* (2004) reported reduced copepods and cladocerans in marine mesocosms moored in a bay treated with 5 μg/L cypermethrin (nominal). While cladocerans recovered after 2 weeks, copepod populations remained significantly reduced at 2 weeks post-treatment.

All of these studies reported adverse effects on aquatic invertebrates, which have also been demonstrated to be the most sensitive taxon in laboratory toxicity tests compared to fish or mollusks. The tested concentrations in these studies, ranging from 0.01-24,000 μg/L, were much higher than the chronic criterion. The NECs were also much higher than the criterion, indicating the derived criterion will likely be protective of aquatic ecosystems. It should be noted that nominal or whole water measured concentrations were reported in these studies, and that the truly dissolved concentrations were likely much lower, so it is not clear how close the truly dissolved concentrations were to the chronic criterion.

14. 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 plant and animal species in California were obtained from the California Department of Fish and Game (CDFG) website (http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/TEAnimals.pdf; CDFG 2008). One California listed animal species is represented in the data set. Five Evolutionarily Significant Units of *Oncorhynchus mykiss* are listed as federally threatened or endangered throughout California. The acute data set includes a SMAV for *O. mykiss* of 0.90 μg/L, which is well above the acute criterion.

Some of the listed species are represented in the acute toxicity data set by members of the same family or genus. *Oncorhynchus mykiss* can serve as a surrogate 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). Table 10 summarizes the

results of the ICE analyses. The estimated acute toxicity values in Table 10 range from 0.980 μg/L for Coho salmon to 1.31 μg/L for all other endangered *Oncorhynchus spp.*

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. There are also no aquatic plants listed as state or federal endangered, threatened or rare species so they are not considered in this section. Based on the available data and estimated values for animals, there is no evidence that the calculated acute and chronic criteria will be underprotective of threatened and endangered species.

15. Bioaccumulation

Bioaccumulation was assessed to ensure that the derived criteria will not lead to unacceptable levels of cypermethrin in food items (section 3-7.1, TenBrook *et al.* 2009a). Cypermethrin has a log K_{ow} of 6.57 and a molecular weight of 416.3 (section 3), which indicates it has bioaccumulative potential (section 3-7.1, TenBrook *et al.* 2009a). No biomagnification factors (BMFs) were found in the literature for cypermethrin, but bioconcentration of cypermethrin has been measured in several studies (Table 1).

To check that these criteria are protective of terrestrial wildlife that may consume aquatic organisms, a bioaccumulation factor (BAF) was 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 explained in section 3-7.1 of the methodology (TenBrook *et al.* 2009a). The BAF of a given chemical is the product of the bioconcentration factor (BCF) and a BMF, such that BAF=BCF*BMF. For a conservative estimate, the highest fish BCF of 821 L/kg for *Oncorhynchus mykiss* was used (Table 1) with a default BMF of 10, which was chosen based on the log K_{ow} of cypermethrin (Table 3.15, TenBrook *et al.* 2009a). A chronic dietary NOEC for an oral predator is preferred for this calculation because it is the most realistic value for extrapolation to bioaccumulation in the environment (section 3-7.1, TenBrook *et al.* 2009a), but the only dietary toxicity value available for mallard duck was > 50 mg/kg (USEPA 2008). Although this value is not definitive, it will be used in this calculation as an approximation because no other definitive values were available and it has been demonstrated that cypermethrin is very nontoxic to mallards.

$$NOEC_{water} = \frac{NOEC_{oral_predator}}{BCF_{food_item} * BMF_{food_item}}$$

Mallard: $$NOEC_{water} = \frac{50\,{}^{mg}/_{kg}}{821\,{}^{L}/_{kg} * 10} = 0.00609\,{}^{mg}/_{L} = 6.09\,{}^{\mu g}/_{L}$$

In this example, the estimated $NOEC_{water}$ for the mallard (6.09 μg/L) is above the aqueous solubility of cypermethrin (4 μg/L). Consequently, food-web transfers would not occur because the cypermethrin concentrations required for such transfers would not occur in the environment.

16. Harmonization with air or sediment criteria

This section addresses how the maximum allowable concentration of cypermethrin 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 cypermethrin (CARB 2005, CDWR 1995, USEPA 2006a, USEPA 2006b) to enable this kind of extrapolation. For biota, the limited data on bioconcentration or biomagnification of cypermethrin was addressed in the bioaccumulation section (section 15).

17. 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 there is a review of 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 cypermethrin criteria.

There was enough highly rated acute cypermethrin data to use a SSD to calculate the acute criterion, but there was a significant lack of fit of the Burr Type III SSD to the acute data set, thus the log-logistic distribution was fit to the data set instead. The lack of fit of the Burr Type III SSD appeared to be related to the large spread between the lowest toxicity value (*Hyalella azteca* SMAV=0.0027 mg/L) and the next lowest value, because the test judged the *H. azteca* value as an outlier or error (see fit test calculations in Appendix A). The *H. azteca* SMAV is very similar to those for other pyrethroids, and is based on two different studies, so it does not appear to be an error. It is likely that if more data were calculated using measured (instead of nominal) concentrations the distribution of data would shift toward the lower end, and the *H. azteca* value would not appear to be an outlier in the distribution and allow for a satisfactory fit.

Another limitation in the acute criterion calculation was that not all of the data were from flow-through tests that used measured concentrations to calculate the toxicity values. Flow-through tests and measurement of concentrations are particularly important in tests with pyrethroid pesticides because they are highly sorptive. Three of the 18 acute RR data are from flow-through tests and six studies used measured concentrations, so most of the data are from static or static renewal tests that calculated the toxicity values with nominal concentrations. Using nominal concentrations and static tests can

overestimate the true exposure of test organisms, thus underestimating the toxicity of cypermethrin.

For cypermethrin, the major limitation was in the chronic toxicity data set. Four of five taxa requirements were not met (daphnid, salmonid, benthic crustacean and insect), which precluded the use of a SSD; therefore, an ACR was used to derive the chronic criterion. There were no paired toxicity data available, so the default ACR was used to calculate the chronic criterion (as specified in section 3-4.2.3, TenBrook *et al.* 2009a). It would be preferable to calculate a cypermethrin ACR solely based on measured RR data, but these data are not available at this time. 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 for criteria compliance is the increase in toxicity from lower temperatures. Half of the toxicity data were from tests performed at standard temperature (20-25 ˚C), including tests for the most sensitive species in the data set, *Hyalella azteca*. However, many streams in the California Central Valley often have lower water temperatures. If colder water bodies are impacted by concentrations of cypermethrin, it may be appropriate to apply an additional safety factor to the cypermethrin 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 aqueous toxicity of cypermethrin 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.

18. Comparison to national standard method

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 cypermethrin criteria were generated using the USEPA 1985 methodology with the data set generated in this cypermethrin criteria report.

The USEPA acute methods have three additional taxa requirement beyond the five required by the methodology used in this criteria report (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.

One out of three of these additional requirements are met as follows:

1. This requirement is not met because there are only two chordates in the data set.
2. This requirement is not met because all data are from organisms in the phylum Arthropoda or Chordata.
3. This requirement is met because there are insects from five different families.

The USEPA methodology cannot be used to calculate an acute criterion for cypermethrin because two of the eight taxa requirements are not met.

For the chronic criterion, the cypermethrin data set only has data from two 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 UC-Davis methodology, to be used when three acceptable experimental ACRs are available. As there were no experimental ACRs, and no acute value, a chronic criterion cannot be calculated for cypermethrin using the EPA method.

19. Final 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 cypermethrin does not exceed 0.0002 µg/L (0.2 ng/L) more than once every three years on the average and if the one-hour average concentration does not exceed 0.001 µg/L (1 ng/L) more than once every three years on the average. Mixtures of cypermethrin and other pyrethroids should be considered in an additive manner (see Mixtures section).

While the aim of this criteria report was to derive criteria 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 median 1st percentile of the log-logistic SSD (sections 9 and 12) and the acute data used in criterion calculation are shown in Table 3. The chronic criterion was derived by use of a default ACR (sections 10 and 12); chronic data rated RR are shown in Table 6. It is recommended that the freely dissolved cypermethrin concentration is measured for criteria compliance because this appears to be the best predictor of the bioavailable fraction (section 9).

To date, there are no established criteria for cypermethrin to which the criteria calculated in this report can be compared. Criteria for cypermethrin could not be calculated using the USEPA 1985 method because of missing taxa requirements, highlighting the need for the availability of more high quality toxicity data for cypermethrin, which would yield more robust criteria by any derivation method. 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 are available.

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Data Tables

Table 3. Final acute toxicity data set for cypermethrin. All studies were rated RR. 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/EC$_{50}$ (µg/L) (95% CI)	Reference
Aedes aegypti	Insect	Culicidae	S	Nom	>85%	24 h	18	Mortality	Larvae	**1 (0.4-4)**	Stephenson 1982
Asellus aquaticus	Crustacean	Asellidae	S	Nom	>85%	24 h	15	Mortality	3-8 mm	**0.2 (0.1-0.4)**	Stephenson 1982
Ceriodaphnia dubia	Daphnid	Daphniidae	SR	Nom	>90%	48 hr	25	Mortality	< 24 h	**0.683 ± 0.072**	Wheelock *et al.* 2004
Chaoborus crystallinus	Insect	Chaoboridae	S	Nom	>85%	24 h	15	Mortality	Larvae	**0.2 (0.03-0.4)**	Stephenson 1982
Chironomus thummi	Insect	Chironomidae	S	Nom	>85%	24 h	15	Immobility	Larvae	**0.2 (0.1-0.3)**	Stephenson 1982
Cloeon dipterum	Mayfly (Insect)	Baetidae	S	Nom	>85%	24 h	15	Mortality	Larvae	**0.6 (0.3-1)**	Stephenson 1982
Corixa punctata	Insect	Corixidae	S	Nom	>85%	24 h	15	Immobility	Adults	**0.7 (0.4-2)**	Stephenson 1982
Daphnia magna	Daphnid	Daphniidae	SR	Meas	92.3%	48 hr	20	Mortality	<24 h old	0.134 (0.114-0.157)	Ward & Boeri 1991
Daphnia magna	Daphnid	Daphniidae	FT	Nom	95.7%	48 hr	20	Mortality	<24 h old	0.1615 (0.1344-0.1917)	Wheat & Evans 1994
										0.147	
Gammarus pulex	Amphipod (Crustacea)	Gammaridae	S	Nom	>85%	24 hr	15	Mortality	3-8 mm	**0.1 (0.08-0.2)**	Stephenson 1982
Gyrinus natator	Coleoptera (Insect)	Gyrinidae	S	Nom	>85%	24 hr	15	Immobility	Adults	**0.07 (0.04-0.2)**	Stephenson 1982
Hyalella azteca	Amphipod (Crustacea)	Hyalellidae	SR	Meas	> 98%	96 h	23	Mortality	7-14 d	0.0021 (0.0017-0.0025)	Weston & Jackson 2009

Table 3. Final acute toxicity data set for cypermethrin. All studies were rated RR. 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/EC$_{50}$ (µg/L) (95% CI)	Reference
Hyalella azteca	Amphipod	Hyalellidae	SR	Meas	>98%	96 h	23	Mortality	7-14 d	0.0023 (0.0013-0.0035)	Weston & Jackson 2009
Hyalella azteca	Amphipod	Hyalellidae	SR	Meas	>98%	96 h	23	Mortality	7-14 d	0.0031 (0.0020-0.0044)	Weston & Jackson 2009
Hyalella azteca	Amphipod	Hyalellidae	SR	Nom	97.0%	96 h	23	Mortality	Adults	0.0036 (0.002-0.0049)	Hamer 1997
Hyalella azteca	GEOMEAN									**0.0027**	
Oncorhynchus mykiss	Rainbow Trout	Salmonidae	FT	Meas	91.5%	96 hr	12	Mortality	83-d old juvenile	**0.90 (0.72-1.35)**	Vaishnav & Yurk 1990
Oreochromis niloticus	Tilapia	Cichlidae	FT	Meas	98.4%	96 hr	25	Mortality	0.6-3.0 g	**2**	Stephenson *et al.* 1984
Piona carnea	Arachnid	Pionidae	S	Nom	>85%	24 h	15	Mortality	Adults	**0.05 (0.03-0.08)**	Stephenson 1982

Table 4. Excluded acute data rated RR with given reason for exclusion. S: static; SR: static renewal; FT: flow-through.

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L) (95% CI)	Reference	Reason
Aedes aegypti	Insect	S	Nom	>85%	24 h	18	Immobility	Larvae	0.03	Stephenson 1982	C
Asellus aquaticus	Crustacean	S	Nom	>85%	24 h	15	Immobility	3-8 mm	0.02	Stephenson 1982	C
Chaoborus crystallinus	Insect	S	Nom	>85%	24 h	15	Immobility	Larvae	0.03	Stephenson 1982	C
Cloeon dipterum	Mayfly (Insect)	S	Nom	>85%	24 h	15	Immobility	Larvae	0.07 (0.04-0.2)	Stephenson 1982	C
Daphnia magna	Daphnid	S	Nom	>85%	24 h	18	Mortality	< 24 h	2 (1-5)	Stephenson 1982	B
Daphnia magna	Daphnid	S	Nom	>85%	24 h	18	Immobility	< 24 h	2 (1-3)	Stephenson 1982	B,C
Gammarus pulex	Amphipod (Crustacea)	S	Nom	>85%	24 hr	15	Immobility	3-8 mm	0.04 (0.02-0.06)	Stephenson 1982	C
Oncorhynchus mykiss	Rainbow Trout	FT	Meas	91.50%	24 hr	12	Mortality	83-d old juveniles	1.74 (1.35-2.24)	Vaishnav & Yurk 1990	A
Oncorhynchus mykiss	Rainbow Trout	FT	Meas	91.50%	48 hr	12	Mortality	83-d old juveniles	1.03 (0.719-1.35)	Vaishnav & Yurk 1990	A
Oncorhynchus mykiss	Rainbow Trout	FT	Meas	91.50%	72 hr	12	Mortality	83-d old juveniles	0.95 (0.719-1.35)	Vaishnav & Yurk 1990	A
Oreochromis niloticus	Tilapia	FT	Meas	98.40%	24 hr	25	Mortality	0.6-3.0 g	4	Stephenson *et al.* 1984	A
Oreochromis niloticus	Tilapia	FT	Meas	98.40%	48 hr	25	Mortality	0.6-3.0 g	3	Stephenson *et al.* 1984	A
Piona carnea	Arachnid	S	Nom	>85%	24 hr	15	Immobility	Adults	0.02	Stephenson 1982	C

Exclusion Reasons

A. Not the most sensitive or appropriate duration
B. FT test preferred over S
C. Not the most sensitive or appropriate endpoint

Table 5. Supplemental acute data rated RL, LR, LL with given reason for rating and exclusion. S: static; SR: static renewal; FT: flow-through. NR: not reported.

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L) (95% CI)	Reference	Rating/ Reason
Acartia tonsa	Crustacean	SR	Meas	99.5%	5 d	20	Mortality	Adults	0.1081 (0.00704-0.1461)	Barata *et al.* 2002	LL (1,2,6)
Acartia tonsa	Crustacean	SR	Meas	99.5%	48 hr	20	Mortality	Eggs	0.1288 (0.0637-0.1972)	Barata *et al.* 2002	LL (1,2,6)
Acartia tonsa	Crustacean	SR	Meas	99.5%	96 hr	20	Mortality	Nauplii (< 2d old)	0.005	Medina *et al.* 2002	LL (1,2,6)
Acartia tonsa	Crustacean	SR	Meas	99.5%	96 hr	20	Mortality	Adults	0.142	Medina *et al.* 2002	LL (1,2,6)
Acartia tonsa	Crustacean	S	Meas	99.5%	24 hr	20	Mortality	Adults	0.75	Medina *et al.* 2004	LR (2)
Aedes aegypti	Mosquito	S	Nom	94.2%	24 hr	20	Mortality	3rd instar larvae	0.16 (0.13-0.18)	Cutkomp & Subramanyam 1986	RL (1,6)
Aedes aegypti	Mosquito	S	Nom	94.2%	24 hr	30	Mortality	3rd instar larvae	0.34 (0.29-0.39)	Cutkomp & Subramanyam 1986	RL (1,6)
Americamysis bahia	Mysid Shrimp	FT	Meas	95.9%	48 hr	22	Mortality	<24 hr	0.007 (0.006-0.010)	Ward *et al.* 1992	LR (2)
Americamysis bahia	Mysid Shrimp	FT	Meas	95.9%	72 hr	22	Mortality	<24 hr	0.006 (0.006-0.007)	Ward *et al.* 1992	LR (2)
Americamysis bahia	Mysid Shrimp	FT	Meas	95.9%	96 hr	22	Mortality	<24 hr	0.005 (0.005-0.006)	Ward *et al.* 1992	LR (2)
Americamysis bahia	Mysid Shrimp	FT	Meas	92.3%	48 hr	22	Mortality	<24 hr	0.0058 (0.0039-0.0079)	Ward & Boeri 1991	LR (2)
Americamysis bahia	Mysid Shrimp	FT	Meas	92.3%	72 hr	22	Mortality	<24 hr	0.0051 (0.0048-0.0057)	Ward & Boeri 1991	LR (2)

Table 5. Supplemental acute data rated RL, LR, LL with given reason for rating and exclusion. S: static; SR: static renewal; FT: flow-through. NR: not reported.

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L) (95% CI)	Reference	Rating/ Reason
Americamysis bahia	Mysid Shrimp	FT	Meas	92.3%	96 hr	22	Mortality	<24 hr	0.0049 (0.0049-0.0054)	Ward & Boeri 1991	LR (2)
Americamysis bahia	Mysid Shrimp	S	Nom	Technical	96 hr	25	Mortality	Juveniles, < 24 h old	0.027 (0.024-0.031)	Cripe 1994	LR (2)
Americamysis bahia	Mysid Shrimp	S	Nom	Technical	96 hr	25	Mortality	Juveniles, < 24 h old	0.0128 (0.0117-0.0141)	Cripe *et al.* 1989	L,R (2)
Americamysis bahia	Mysid Shrimp	S	Nom	Technical	96 hr	25	Mortality	Juveniles, < 24 h old	0.0128 (0.0105-0.0158)	Cripe *et al.* 1989	LR (2)
Americamysis bahia	Mysid Shrimp	S	Nom	Technical	96 hr	25	Mortality	Juveniles, < 24 h old	0.0205 (0.0166-0.0252)	Cripe *et al.* 1989	LR (2)
Americamysis bahia	Mysid Shrimp	S	Nom	Technical	96 hr	25	Mortality	Juveniles, < 24 h old	0.0182 (0.0142-0.0232)	Cripe *et al.* 1989	LR (2)
Americamysis bahia	Mysid Shrimp	S	Nom	Technical	96 hr	25	Mortality	Juveniles, < 24 h old	0.0204 (0.0186-0.0225)	Cripe *et al.* 1989	LR (2)
Americamysis bahia	Mysid Shrimp	S	Nom	Technical	96 hr	25	Mortality	Juveniles, < 24 h old	0.0184 (0.0156-0.0216)	Cripe *et al.* 1989	LR (2)
Cyprinus carpio	Carp	SR	Nom	20.0%	1 hr	24	Mortality	Hatched Larvae	7.816 (2.829-33.652)	Aydin *et al.* 2005	LR (1,7)
Cyprinus carpio	Carp	SR	Nom	20.0%	24 hr	24	Mortality	Hatched Larvae	6.196 (2.481-22.897)	Aydin *et al.* 2005	LR (1,7)
Cyprinus carpio	Carp	SR	Nom	20.0%	48 hr	24	Mortality	Hatched Larvae	2.940 (1.327-8.125)	Aydin *et al.* 2005	LR (1,7)
Cyprinus carpio	Carp	SR	Nom	20.0%	72 hr	24	Mortality	Hatched Larvae	1.304 (0.612-3.389)	Aydin *et al.* 2005	LR (1,7)
Cyprinus carpio	Carp	SR	Nom	20.0%	96 hr	24	Mortality	Hatched Larvae	0.809 (0.530-1.308)	Aydin *et al.* 2005	LR (1,7)
Cyprinus carpio	Carp	FT	Meas	>85%	96 hr	10	Mortality	8-10 g	0.9 (0.6-1.7)	Stephenson 1982	LL (1,5,6)

Table 5. Supplemental acute data rated RL, LR, LL with given reason for rating and exclusion. S: static; SR: static renewal; FT: flow-through. NR: not reported.

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L) (95% CI)	Reference	Rating/ Reason
Cyprinus carpio	Carp	FT	Meas	>85%	96 hr	20-25	Mortality	8-10 g	1.1 (0.6-2.8)	Stephenson 1982	LL (1,5,6)
Cyprinodon variegatus	Sheepshead Minnow	FT	Meas	91.5%	96 hr	21	Mortality	87-107 d old juveniles	3.42 (1.87-4.07) OR 3.88 (2.41-4.61)	Chandler 1990	LR (1,2)
Daphnia magna	Daphnid	SR	Nom	99.0%	48 hr	21	Immobility	< 24 h neonates	0.10 (0.035-0.28)	Kim *et al.* 2008	RL (5,6)
Daphnia magna	Daphnid	SR	Nom	99.0%	72 hr	21	Immobility	< 24 h neonates	0.002 (0.0011-0.005)	Kim *et al.* 2008	RL (5,6)
Daphnia magna	Daphnid	SR	Nom	99.0%	96 hr	21	Immobility	< 24 h neonates	0.0006 (0.0003-0.0011)	Kim *et al.* 2008	RL (5,6)
Enellagma & *Ishnura*	Damselflies	S	Nom	99.4%	24 hr	20	Mortality	larvae	1.4 (0.92-2.0)	Siegfried 1993	RL (1,6)
Gammarus pulex	Arthropod	S	Meas	97.0%	24 hr	15	Mortality	Adults, > 6m	0.12 (0.116-0.135)	Adam *et al.* 2009	LL (1,5,6)
Gammarus pulex	Arthropod	S	Meas	97.0%	48 hr	15	Mortality	Adults, > 6m	0.11 (0.098-0.116)	Adam *et al.* 2009	LL (1,5,6)
Gammarus pulex	Arthropod	S	Meas	97.0%	72 hr	15	Mortality	Adults, > 6m	0.092 (0.084-0.103)	Adam *et al.* 2009	LL (1,5,6)
Gammarus pulex	Arthropod	S	Meas	97.0%	96 hr	15	Mortality	Adults, > 6m	0.09 (0.082-0.101)	Adam *et al.* 2009	LL (1,5,6)
Heptageniidae	Mayfly	S	Nom	99.4%	24 hr	20	Mortality	larvae	1.3 (0.78-2.1)	Siegfried 1993	RL (1,6)
Hyalella azteca	Amphipod	SR	Meas	>98%	96 hr	23	Impaired swimming	7-14 d	0.0016 (0.0014-0.0019)	Weston & Jackson 2009	LR (8)

Table 5. Supplemental acute data rated RL, LR, LL with given reason for rating and exclusion. S: static; SR: static renewal; FT: flow-through. NR: not reported.

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L) (95% CI)	Reference	Rating/ Reason
Hyalella azteca	Amphipod	SR	Meas	>98%	96 hr	23	Impaired swimming	7-14 d	0.0017 (0.0014-0.0019)	Weston & Jackson 2009	LR (8)
Hyalella azteca	Amphipod	SR	Meas	>98%	96 hr	23	Impaired swimming	7-14 d	0.0018 (0.0009-0.0026)	Weston & Jackson 2009	LR (8)
Hydrophilus spp.	Diving beetle	S	Nom	99.4%	24 hr	20	Mortality	larvae	8.3 (5.9-11)	Siegfried 1993	RL (1,6)
Hydropsyche & Chematopsyche	Caddisflies	S	Nom	99.4%	24 hr	20	Mortality	larvae	1.4 (0.81-2)	Siegfried 1993	RL (1,6)
Labeo rohita	Carp	S	Nom	98.0%	96 hr	27	Mortality	NR	5.24	Philip *et al.* 1995	LL (1,5,6)
Oncorhynchus mykiss	Rainbow Trout	FT	Meas	>98%	96 hr	12-15	Mortality	Juveniles (1.1-2.5 g, 45-60 mm or 10-30 g, 100-150 mm)	1.47 (1.20-1.75)	Davies *et al.* 1994	LR (1,5)
Oncorhynchus mykiss	Rainbow Trout	FT	Meas	>85%	96 hr	10	Mortality	1-2 g	0.5	Stephenson 1982	LL (1,5,6)
Oncorhynchus mykiss	Rainbow Trout	FT	Meas	>85%	96 hr	15	Mortality	1-2 g	0.5	Stephenson 1982	LL (1,5,6)
Oreochromis niloticus	Tilapia	FT	Meas	>85%	96 hr	25	Mortality	1-3 g	2.2	Stephenson 1982	LL (1,5,6)
Palaemonetes argentinus	Arthropod	S	Nom	25.0%	24 hr	25	Mortality	Juveniles, average wt. 0.01 ± 0.006 g	0.0031	Collins & Cappello 2006	LL (1,5,6)
Palaemonetes argentinus	Arthropod	S	Nom	25.0%	48 hr	25	Mortality	Juveniles, average wt. 0.01 ± 0.006 g	0.00275	Collins & Cappello 2006	LL (1,5,6)
Palaemonetes argentinus	Arthropod	S	Nom	25.0%	72 hr	25	Mortality	Juveniles, average wt. 0.01 ± 0.006 g	0.0025	Collins & Cappello 2006	LL (1,5,6)

Table 5. Supplemental acute data rated RL, LR, LL with given reason for rating and exclusion. S: static; SR: static renewal; FT: flow-through. NR: not reported.

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L) (95% CI)	Reference	Rating/ Reason
Palaemonetes argentinus	Arthropod	S	Nom	25.0%	96 hr	25	Mortality	Juveniles, average wt. 0.01 ± 0.006 g	0.002	Collins & Cappello 2006	LL (1,5,6)
Paratya australiensis	Arthropod	FT	Meas	>98%	12 hr	12-15	Mortality	0.05-0.15 g	0.09 (0.06-0.12)	Davies *et al.* 1994	LL (1,5,6)
Penaeus duorarum	Pink Shrimp	S	Nom	Technical	96 hr	25	Mortality	3-5 day old post larvae	0.11 (0.089-0.13)	Cripe 1994	LR (2)
Pseudaphritus urvillii	Fish	FT	Meas	>98%	96 hr	12-15	Mortality	Juveniles (6-30 g, 95-160 mm)	2.19 (1.80-2.65)	Davies *et al.* 1994	LL (1,5,6)
Salmo trutta	Brown trout	FT	Meas	>85%	96 hr	15	Mortality	5-8 g	1.2	Stephenson 1982	LL (1,5,6)
Scardinius erythrophthalmus	Common rudd	FT	Meas	>85%	96 hr	15	Mortality	8-10 g	0.4	Stephenson 1982	LL (1,5,6)
Trichodactylus borellianus	Freshwater crab	S	Nom	25.0%	24 hr	25	Mortality	Adults & Juveniles	0.0119 (0.0071-0.0234)	Veronica & Collins 2003	LL (3,6,7)
Trichodactylus borellianus	Freshwater crab	S	Nom	25.0%	48 hr	25	Mortality	Adults & Juveniles	0.0119 (0.0071-0.0234)	Veronica & Collins 2003	LL (3,6,7)
Trichodactylus borellianus	Freshwater crab	S	Nom	25.0%	72 hr	25	Mortality	Adults & Juveniles	0.0104 (0.0054-0.0249)	Veronica & Collins 2003	LL (3,6,7)
Trichodactylus borellianus	Freshwater crab	S	Nom	25.0%	96 hr	25	Mortality	Adults & Juveniles	0.0097 (0.0049-0.0231)	Veronica & Collins 2003	LL (3,6,7)

Exclusion Reasons

1. Not a standard method
2. Saltwater

Table 5. Supplemental acute data rated RL, LR, LL with given reason for rating and exclusion. S: static; SR: static renewal; FT: flow-through. NR: not reported.

Species	Common Identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC$_{50}$ (µg/L) (95% CI)	Reference	Rating/ Reason

3. Family not found in N. America
4. Unacceptable control response/response not reported
5. Control response not described
6. Low reliability score
7. Low chemical purity/purity not reported
8. Endpoint not linked to survival/growth/reproduction

95% CI: 95% confidence interval

Table 6. Final chronic toxicity data set for cypermethrin. All studies were rated RR. S: static; SR: static renewal; FT: flow-through. NR: not reported

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference
Pimephales promelas	Fathead minnow	FT	Meas	93.1%	60 d	25	Mortality	<48 hr	0.077	0.15	**0.11**	Tapp *et al.* 1988

Table 7. Acceptable reduced chronic data rated RR with reason for exclusion given below. S: static; SR: static renewal; FT: flow-through. NR: not reported

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference	Reason for exclusion
Pimephales promelas	Fathead minnow	FT	Meas	93.1%	30 d	25	Mortality	<48 hr	0.077	0.15	0.11	Tapp *et al.* 1988	A

Reasons for Exclusion

A. Later time point available

Table 8. Supplemental chronic toxicity data from studies rated RL, LR, or LL. S: static; SR: static renewal; FT: flow-through. NR: not reported, NC: not calculable.

Species	Test type	Meas /Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/ size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L) (95% CI)	Reference	Rating/ Reason
Acartia tonsa	SR	Meas	99.5%	32 d	20°C	Clutch size	<24 h	0.0893	0.2593	0.1522	Barata *et al.* 2002	LL (1,2,6)
Acartia tonsa	S	Meas	99.5%	1 hr exp. 144 hr obs.	20°C	Male survival	Adults	0.7	2.2	1.24	Medina *et al.* 2004	LR (2)
Americamysis bahia	FT	Meas	98.0%	28 d	26.1	Mortality	< 24 h	0.000781	0.001976	0.00124	Wheat 1993	LR (2)
Americamysis bahia	FT	Meas	98.0%	28 d	26.1	Growth	< 24 h	0.000781	0.001976	0.00124	Wheat 1993	LR (2)
Cyprinus carpio	SR	Nom	20.0%	96 hr	24	Larval mortality	eggs	< 0.0001	0.0001	--	Aydin *et al.* 2005	LR (1,3)
Daphnia magna	SR	Nom	99%	21 d	21	young/ female	< 24 h, neonates	0.0000002	0.000002	**0.00000063**	Kim *et al.* 2008	RL (6)
Daphnia magna	SR	Nom	99%	21 d	21	brood/ female	< 24 h, neonates	0.00002	0.0002	6.32E-05	Kim *et al.* 2008	RL (6)
Daphnia magna	SR	Nom	99%	21 d	21	brood/ female	7 d juveniles	0.02	0.2	0.0632	Kim *et al.* 2008	RL (6)
Daphnia magna	SR	Nom	99%	21 d	21	young/ female	7 d juveniles	0.00002	0.0002	6.32E-05	Kim *et al.* 2008	RL (6)
Lymnaea acuminata	S	Nom	NR	96 hr	23 ± 0.8°C	Number of eggs	Adults	<4.0	4	NA	Tripathi & Singh 2004	LL (1,3,6)

Table 8. Supplemental chronic toxicity data from studies rated RL, LR, or LL. S: static; SR: static renewal; FT: flow-through. NR: not reported, NC: not calculable.

Species	Test type	Meas /Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/ size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L) (95% CI)	Reference	Rating/ Reason
Lymnaea acuminata	S	Nom	NR	96 hr	23 ± 0.8°C	Number of eggs hatched	Adults	<4.0	4	NA	Tripathi & Singh 2004	LL (1,3,6)
Lymnaea acuminata	S	Nom	NR	14 d	23 ± 0.8°C	Survival of Hatchlings	Adults	<4.0	4	NA	Tripathi & Singh 2004	LL (1,3,6)
Lymnaea acuminata	S	Nom	NR	21 d	23 ± 0.8°C	Survival of Hatchlings	Adults	<4.0	4	NA	Tripathi & Singh 2004	LL (1,3,6)
Lymnaea acuminata	S	Nom	NR	28 d	23 ± 0.8°C	Survival of Hatchlings	Adults	<4.0	4	NA	Tripathi & Singh 2004	LL (1,3,6)
Oncorhynchus mykiss	FT	Meas	>98%	10 d	12-15 °C	Hepatic GST activity	Juv (1.1-2.5 g, 45-60 mm or 10-30 g, 100-150 mm)	0.49	0.87	0.65	Davies *et al.* 1994	LR (1,4,5)

Exclusion Reasons

1. Not a standard method
2. Saltwater
3. Low chemical purity or purity not reported
4. Endpoint not linked to growth, reproduction or survival (Section 3-2.1.3)
5. Control response not reported/not acceptable
6. Low reliability score
7. Inappropriate test duration (Section 3-2.1.1)

Table 9. Acceptable multispecies field, semi-field, laboratory, microcosm, mesocosm studies; R= reliable; L= less reliable.

Reference	Habitat	Rating
Crossland 1982	Outdoor ponds	L
Crossland *et al.* 1982	Outdoor ponds and streams	N
Dabrowski *et al.* 2005	Indoor stream microcosm	N
Farmer *et al.* 1995	Outdoor pond mesocosms	R
Feng *et al.* 2009	Submerged in Tongan Bay, China	N
Friberg-Jensen *et al.* 2003	Outdoor pond enclosures	R
Helson & Surgeoner 1986	Outdoor simulated pools and natural pools	N
Lutnicka *et al.* 1999	Artificial river systems	L
Maund *et al.* 2009	Pond microcosms	L
Medina *et al.* 2004	Marine mesocosms	L
Sherratt *et al.* 1999	Outdoor mesocosms	N
Shires 1983	Outdoor pond enclosures	N
Stephenson *et al.* 1984	Rice paddies	N
Walton *et al.* 1990	Outdoor ponds	N
Wendt-Rasch *et al.* 2003	Outdoor pond enclosures	R

Table 10. Threatened, Endangered, or Rare Species Predicted values by ICE.

Surrogate		Predicted	
Species	**LC_{50} (µg/L)**	**Species**	**LC_{50} (µg/L)**
Rainbow trout (*Oncorhynchus mykiss)*	0.90	Chinook salmon *(O. tshawytscha)*	1.31
		Coho salmon (*O. kisutch)*	0.980
		Paiute cutthroat trout (*O. clarki seleniris)*	1.31
		Greenback cutthroat trout (*O. c. stomias*)	1.31
		Gila trout (*O. gilae*)	1.31
		Chum salmon (*O. keta*)	1.31
		Sockeye salmon (*O. nerka*)	1.31

Appendix A

Fit test calculations

1) Burr III distribution
2) Log-logistic distribution

1) Fit test for Burr III distribution

Omit one

SMAVs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0027		0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027
0.05	0.05		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.070	0.070	0.070		0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
0.100	0.100	0.100	0.100		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.147	0.147	0.147	0.147	0.147		0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147
0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	0.2	0.2
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6		0.6	0.6	0.6	0.6	0.6
0.683	0.683	0.683	0.683	0.683	0.683	0.683	0.683	0.683	0.683		0.683	0.683	0.683	0.683
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7		0.7	0.7	0.7
0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9		0.9	0.9
1	1	1	1	1	1	1	1	1	1	1	1	1		1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	

1) Fit test for Burr III distribution

Omitted point, xi:	0.0027	0.05	0.07	0.1	0.147	0.2	0.2	0.2	0.6	0.683	0.7	0.9	1	2
median 5th percentile	0.057708	0.009	0.0082	0.0074	0.0066	0.006	0.006	0.006	0.0052	0.006	0.0063	0.0077	0.0077	0.000633
	6.00205E-09													
percentile	99.999999993998	85.6	81.71	76.72	70.16	63.92	63.92	63.92	31.13	24.76	23.52	14.73	11.97	1.51
F-i(xi)	0.99999999994	0.856	0.8171	0.7672	0.7016	0.6392	0.6392	0.6392	0.3113	0.2476	0.2352	0.1473	0.1197	0.0151
1-F(xi)	0.00000000006	0.144	0.1829	0.2328	0.2984	0.3608	0.3608	0.3608	0.6887	0.7524	0.7648	0.8527	0.8803	0.9849
Min of F-i(xi) or 1-F(xi)	0.0000000000600	0.144	0.1829	0.2328	0.2984	0.3608	0.3608	0.3608	0.3113	0.2476	0.2352	0.1473	0.1197	0.0151
p_i =2(min)	0.0000000001200	0.288	0.3658	0.4656	0.5968	0.7216	0.7216	0.7216	0.6226	0.4952	0.4704	0.2946	0.2394	0.0302

1) Fit test for Burr III distribution

		Fisher test statistic	
p_i	$\ln(p_i)$	-2*Sum of ln (pi)	X^2_{2n}
0.0000	-22.8432	70.8712	0.00001405
0.2880	-1.2448		
0.3658	-1.0057		
0.4656	-0.7644		
0.5968	-0.5162		
0.7216	-0.3263		
0.7216	-0.3263		
0.7216	-0.3263		
0.6226	-0.4739		
0.4952	-0.7028		
0.4704	-0.7542		
0.2946	-1.2221		
0.2394	-1.4296		
0.0302	-3.4999		

0.00001405 < 0.05 so the distribution does not fit the cypermethrin acute data set

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

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

2) Fit test for log-logistic distribution

Omit one

SMAVs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0027		0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027
0.05	0.05		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.070	0.070	0.070		0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
0.100	0.100	0.100	0.100		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.147	0.147	0.147	0.147	0.147		0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147
0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	0.2	0.2
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6		0.6	0.6	0.6	0.6	0.6
0.683	0.683	0.683	0.683	0.683	0.683	0.683	0.683	0.683	0.683		0.683	0.683	0.683	0.683
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7		0.7	0.7	0.7
0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9		0.9	0.9
1	1	1	1	1	1	1	1	1	1	1	1	1		1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	

2) Fit test for log-logistic distribution

Omitted point, xi:	0.0027	0.05	0.07	0.1	0.147	0.2	0.2	0.2	0.6	0.683	0.7	0.9	1	2
median 5th percentile	0.0432	0.0137	0.0128	0.0129	0.0115	0.0112	0.0112	0.0112	0.0107	0.0108	0.0108	0.0109	0.0110	0.0117
percentile	0.080	16.48	22.51	29.37	39.56	47.62	47.62	47.62	74.84	77.47	77.95	82.51	84.23	92.73
F-i(xi)	0.0008	0.1648	0.2251	0.2937	0.3956	0.4762	0.4762	0.4762	0.7484	0.7747	0.7795	0.8251	0.8423	0.9273
1-F(xi)	0.9992	0.8352	0.7749	0.7063	0.6044	0.5238	0.5238	0.5238	0.2516	0.2253	0.2205	0.1749	0.1577	0.0727
Min of F-i(xi) or 1-F(xi)	0.0008	0.1648	0.2251	0.2937	0.3956	0.4762	0.4762	0.4762	0.2516	0.2253	0.2205	0.1749	0.1577	0.0727
p_i =2(min)	0.0016	0.3296	0.4502	0.5874	0.7912	0.9524	0.9524	0.9524	0.5032	0.4506	0.441	0.3498	0.3154	0.1454

2) Fit test for log-logistic distribution

		Fisher test statistic	
p_i	$\ln(p_i)$	-2*Sum of ln (pi)	X^2_{2n}
0.0016	-6.4378	31.3870	0.30016816
0.3296	-1.1099		
0.4502	-0.7981		
0.5874	-0.5320		
0.7912	-0.2342		
0.9524	-0.0488		
0.9524	-0.0488		
0.9524	-0.0488		
0.5032	-0.6868		
0.4506	-0.7972		
0.441	-0.8187		
0.3498	-1.0504		
0.3154	-1.1539		
0.1454	-1.9283		

0.3 > 0.05, indicating that there is not a significant lack of fit of the distribution to the cypermethrin acute data set

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

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