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DEPARTMENT OF FISH AND GAME

HAZARD ASSESSMENT OF THE SYNTHETIC PYRETHROID INSECTICIDES BIFENTHRIN, CYPERMETHRIN, ESFENVALERATE, AND PERMETHRIN TO AQUATIC ORGANISMS IN THE SACRAMENTO-SAN JOAQUIN RIVER SYSTEM

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PREFACE

The California Department of Fish and Game (CDFG) is responsible for the protection and management of fish and wildlife. The CDFG protects fish and wildlife from pesticide hazards through consultation with the California Environmental Protection Agency's Department of Pesticide Regulation (CDPR) Pesticide Registration and Evaluation Committee. The State Water Resources Control Board and the Regional Water Quality Control Boards also protect fish and wildlife by promulgating and enforcing water quality standards for pesticides and other toxic materials. In recognition of the need for applicable environmental standards for fish and wildlife, CDPR contracted with the CDFG to assess the effects of pesticides on fish and wildlife and to facilitate development of water quality criteria to protect aquatic organisms.

This document is the twelfth in a series of pesticide hazard assessments. Hazard assessments have also been prepared for the herbicides molinate and thiobencarb; for the insecticides methyl parathion, carbofuran, chlorpyrifos, diazinon, methidathion, methomyl, dimethoate, carbaryl, and malathion; and for the fungicides benomyl, captan, chlorothalonil, maneb, and ziram.

Hazard Assessment of the Synthetic Pyrethroid Insecticides Bifenthrin, Cypermethrin, Esfenvalerate, and Permethrin to Aquatic Organisms in the Sacramento-San Joaquin River System

by

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SUMMARY

Available freshwater and saltwater toxicity data were reviewed for the pyrethroids bifenthrin, cypermethrin, esfenvalerate, and permethrin.

Nine tests on the acute and chronic toxicity of bifenthrin to aquatic animals were reviewed and evaluated. Due to insufficient data, no freshwater or saltwater water quality criteria (WQC) were developed. Three of the eight taxa required for a calculation of a freshwater Final Acute Value (FAV) were available. The most acutely sensitive freshwater species tested was the rainbow trout *Oncorhynchus mykiss* with a Genus Mean Acute Value (GMAV) of 0.15 µg/L bifenthrin. Three tests on saltwater species were available. The most acutely sensitive saltwater species tested was the mysid *Mysidopsis bahia* with a GMAV of 0.00397 µg/L bifenthrin. No monitoring data were available for bifenthrin in the Sacramento-San Joaquin River system.

Forty-six tests on the acute and chronic toxicity of cypermethrin to aquatic animals were reviewed and evaluated. Seven of the eight required taxa were available for calculation of a freshwater FAV. The most acutely sensitive freshwater species tested was the amphipod *Hyallela azteca* with a GMAV of 0.0053 µg/L cypermethrin. The interim freshwater FAV for cypermethrin was 0.003 µg/L and the interim freshwater Criterion Maximum Concentration (CMC) was 0.002 µg/L. Five of the eight required taxa of saltwater organisms were available. No saltwater WQC were developed. The most acutely sensitive saltwater species tested was the grass shrimp *Palaemonetes pugio* with a GMAV of 0.016 µg/L cypermethrin. No monitoring data were available for cypermethrin in the Sacramento-San Joaquin River system.

Ten tests on the acute and chronic toxicity of esfenvalerate to aquatic animals were reviewed and evaluated. Due to insufficient data, no freshwater or saltwater WQC were developed. Four of the eight required taxa were available for calculation of a freshwater FAV for esfenvalerate. The most acutely sensitive freshwater species tested was the rainbow trout *Oncorhynchus mykiss*

with a GMAV of 0.26 µg/L esfenvalerate. None of the eight required taxa of saltwater organisms were available for esfenvalerate. No monitoring data were available for esfenvalerate in the Sacramento-San Joaquin River system.

Sixty-nine tests on the acute and chronic toxicity of permethrin to aquatic animals were reviewed and evaluated. Seven of the eight required taxa were available for calculation of a freshwater FAV. The most acutely sensitive freshwater species tested was the mayfly *Hexagenia bilineata* with a GMAV of 0.10 µg/L permethrin. The interim freshwater FAV for permethrin was 0.059 µg/L and the interim CMC was 0.03 µg/L. All eight of the required taxa were available for the calculation of a saltwater FAV. The most acutely sensitive saltwater species was the stone crab *Menippe mercenaria* with a GMAV of 0.018 µg/L permethrin. The saltwater FAV for permethrin was 0.0021 µg/L and the CMC was 0.001 µg/L. Chronic criteria for permethrin could not be calculated due to lack of toxicity data. Monitoring data for the San Joaquin River system found one occurrence of permethrin (0.013 µg/L) out of 142 samples taken during one year.

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LIST OF ABBREVIATIONS

ACR	Acute-to-Chronic Ratio
ASTM	American Society of Testing and Materials
CCC	Criterion Continuous Concentration
CDFG	California Department of Fish and Game
CDHS	California Department of Health Services
CMC	Criterion Maximum Concentration
CDPR	(California) Department of Pesticide Regulation
USEPA	(US) Environmental Protection Agency
FACR	Final Acute Chronic Ratio
FAV	Final Acute Value
FCV	Final Chronic Value
FPV	Final Plant Value
FRV	Final Residue Value
GMAV	Genus Mean Acute Value
LOEC	Lowest Observable Effect Concentration
MATC	Maximum Acceptable Toxicant Concentration
NOEC	No Observable Effect Concentration
SMAV	Species Mean Acute Value
USGS	U.S. Geological Survey
WQC	Water Quality Criteria

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INTRODUCTION

Hazards from bifenthrin, cypermethrin, esfenvalerate, and permethrin to aquatic life in the Sacramento-San Joaquin River system could not be evaluated because of the lack of monitoring data for these synthetic pyrethroids. However, potential toxic effects of these compounds were assessed using available aquatic toxicity tests and environmental fate information. Toxicity tests were evaluated for conformance with specific criteria adapted from the U.S. Environmental Protection Agency (USEPA 1985) and the American Society for Testing and Materials (ASTM 1992, 1996). Although toxicity tests were not required to comply with all criteria, tests were rejected if they did not observe fundamental ASTM (1992, 1996) procedures. These include: test results reported as LC_{50}, EC_{50}, NOEC or LOEC; tests having at least one control; control survival in acute tests at or above ninety percent; at least five test concentrations; acceptable mortality range; and testing materials containing a high percentage of active ingredient (technical grade or better). The California Department of Fish and Game's (CDFG) hazard assessments are based on data from accepted tests and procedures adapted from USEPA (1985) guidelines (Appendix A).

The U.S. Geological Survey (USGS) monitored for permethrin in the San Joaquin River system during a one-year study. A single detection of 0.013 µg/L was found above the 0.005 µg/L reporting limit from the 142 samples taken (USGS 1998). The USGS, the Central Valley Regional Water Quality Control Board, and the California Department of Pesticide Regulation (CDPR) have not monitored surface water in the Sacramento-San Joaquin River System specifically for bifenthrin, cypermethrin and esfenvalerate. However, bifenthrin has been found in surface water, sediment, and fish tissue in Orange County during monitoring of pesticides used to eradicate the Red Imported Fire Ant (CDPR memoranda 1999-2000; CDFG unpublished data). Use of bifenthrin for eradication of Red Imported Fire Ant does not reflect normal use patterns.

BIFENTHRIN

Use and Environmental Fate

Bifenthrin is a synthetic pyrethroid compound used as an insecticide and acaricide on cotton, greenhouse ornamentals, alfalfa, melons and other crops (CDPR 1990-1998). From 1991 to 1998, the reported use of bifenthrin in California ranged from 9,360 to 57,245 pounds per year (Table 1; CDPR 1990-1998).

Table 1. Bifenthrin, cypermethrin, esfenvalerate, and permethrin use in California (in lbs.), 1990-1998.[a]

Year	Bifenthrin	Cypermethrin	Esfenvalerate	Permethrin
1990	NA[b]	92,682	15,808	133,965
1991	9,360	60,728	32,191	137,686
1992	55,518	74,042	30,975	172,168
1993	57,245	59,206	30,250	192,488
1994	37,354	56,529	31,605	252,653
1995	46,864	93,855	41,817	308,850
1996	21,272	104,708	38,420	335,160
1997	15,054	112,632	37,742	324,598
1998	22,805	139,416	35,577	371,231

[a] California Department of Pesticide Regulation Pesticide Use Reports 1990-1998.
[b] NA= No data available for this year.

Bifenthrin is highly insoluble in water with a solubility of 0.1 mg/L (Table 2; EXTOXNET). Bifenthrin has a hydrolysis $t_{1/2}$ of >30 days (FMC 1983) and a photolysis $t_{1/2}$ of 276 to 416 days (USEPA 1999a). It is extremely immobile in soil, particularly in soils with large amounts of organic matter, clay, and silt (EXTOXNET). The adsorption coefficient (k_{oc}) is 240,000 (Wauchope et al. 1992). Bifenthrin has a $t_{1/2}$ in soil of 7 days to 8 months depending on soil type and the amount of air in the soil (EXTOXNET).

Table 2. Physical and chemical properties of bifenthrin, cypermethrin, esfenvalerate and permethrin.

	Hydrolysis $t_{1/2}$	Photolysis	Solubility in H_2O (mg/L)	Soil $t_{1/2}$	Mobility in Soil
Bifenthrin	>30 d	276 – 416 d	0.1	7 d – 8 mo	low
Cypermethrin	>50 d	>100 d	0.01	4 d – 8 wk	low
Esfenvalerate	21 d	21 d	<0.3	15 d – 3 m	low
Permethrin	2.5 d	4.6 d	0.2	30 – 38 d	low

Bifenthrin tends to bioconcentrate in fish. Whole-body bioconcentration factor (BCF) values for fathead minnow *Pimephales promelas* in water were 21,000 and 28,000X in 0.0037 µg/L for 127 and 254 days, respectively (McAllister 1988).

The California Department of Health Services (CDHS) and the United States Environmental Protection Agency (USEPA) have not set action levels for bifenthrin in drinking water (A. Milea, CDHS pers. comm., USEPA 1999b).

Bifenthrin has not been monitored in the Sacramento – San Joaquin River System. However, as part of a federally and state mandated program for the eradication of the Red Imported Fire Ant in Orange County, water samples were collected and analyzed for bifenthrin (Table 3). The sites where bifenthrin was detected contain primarily nursery runoff water. This use of bifenthrin does not reflect normal use patterns.

Table 3. Bifenthrin detections in the Red Imported Fire Ant Monitoring Study (CDPR memoranda 1999-2000).

Site	Date	Bifenthrin (in µg/L)
Central Irvine Channel at Bryan St.	5/21/99	1.67
Central Irvine Channel at Bryan St.	6/25/99	0.249
Drain at Bee Canyon and Portola Parkway	10/27/99	0.478
Central Irvine Channel at Bryan St.	12/9/99	0.629
Drain at Bee Canyon and Portola Parkway	12/9/99	3.12
Hines Channel	1/17/00	0.549
Drain at Bee Canyon and Portola Parkway	1/17/00	0.689
Hines Channel	1/25/00	3.79
Hines Channel	1/25/00	2.06
Hines Channel	1/25/00	1.35
Hines Channel	1/25/00	0.319
Hines Channel	1/25/00	2.45
Hines Channel	1/25/00	1.93
Drain at Bee Canyon and Portola Parkway	1/25/00	2.57
Drain at Bee Canyon and Portola Parkway	1/25/00	2.67
Drain at Bee Canyon and Portola Parkway	1/25/00	0.792
Drain at Bee Canyon and Portola Parkway	1/25/00	1.4
Drain at Bee Canyon and Portola Parkway	1/25/00	1.8
Drain at Bee Canyon and Portola Parkway	1/25/00	1.24
Marshburn Slough at Irvine Blvd.	1/25/00	1.77
Marshburn Slough at Irvine Blvd.	1/25/00	2.27
Marshburn Slough at Irvine Blvd.	1/25/00	5.3
Marshburn Slough at Irvine Blvd.	1/25/00	1.95
Marshburn Slough at Irvine Blvd.	1/25/00	2.06
Marshburn Slough at Irvine Blvd.	1/25/00	1.57
Hines Channel	2/24/00	1.08
Drain at Bee Canyon and Portola Parkway	2/24/00	1.94
Marshburn Slough at Irvine Blvd.	2/24/00	0.365
Arroyo Trabuco at Oso Parkway	2/23/00	0.0952
Hines Channel	3/28/00	2.3
Drain at Bee Canyon and Portola Parkway	3/28/00	0.433
Hines Channel	4/19/00	0.673
Drain at Bee Canyon and Portola Parkway	4/19/00	0.467
Hines at Weir	5/24/00	0.499
El Modeno	5/24/00	0.977

Sediment samples near and downstream of nurseries that were treated with bifenthrin as a part of the Red Imported Fire Ant eradication program were analyzed for bifenthrin. The concentration of bifenthrin in sediment near a nursery was 355 µg/kg, dry weight. Approximately nine miles downstream of registered nurseries, the concentration of bifenthrin in sediment was 17 µg/kg, dry weight (CDFG unpublished data). Fish were sampled at five sites downstream of the nurseries. Bifenthrin was detected in fish at one site at 11.8 µg/kg (fresh weight, whole fish) (CDFG unpublished data).

Toxicity to Aquatic Animals

Seven tests on the acute toxicity of bifenthrin to aquatic animals were evaluated (Appendix B). Six of the tests were accepted (Table B-1) and one was not (Table B-5).

Genus Mean Acute Values (GMAVs) for bifenthrin were calculated using data from accepted acute toxicity tests and were ranked in ascending order (Tables 4 and 5). Freshwater bifenthrin GMAVs ranged from 0.15 µg/L for the rainbow trout *Oncorhynchus mykiss* to 1.6 µg/L for the cladoceran

Daphnia magna (Table 4). Three acute toxicity tests were available for saltwater species. Saltwater bifenthrin GMAVs ranged from 0.00397 µg/L for the mysid *Mysidopsis bahia* to 17.8 µg/L for the sheepshead minnow *Cyprinodon variegates* (Table 5).

Table 4. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on bifenthrin with freshwater species.

Rank	GMAV (µg/L)	Organism	Species
1	0.15[a]	Rainbow trout	*Oncorhynchus mykiss*
2	0.35[a]	Bluegill	*Lepomis macrochirus*
3	1.6[a]	Cladoceran	*Daphnia magna*

[a]LC_{50} value from one toxicity test on this species.

Table 5. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on bifenthrin with saltwater species.

Rank	GMAV (µg/L)	Organism	Species
1	0.00397[a]	Mysid	*Mysidopsis bahia*
2	0.29[a]	Eastern oyster	*Crassostrea virginica*
3	17.8[a]	Sheepshead minnow	*Cyprinodon variegatus*

[a]LC_{50} value from one toxicity test on this species.

The USEPA (1985) guidelines recommend that eight freshwater taxa are used to derive a freshwater Final Acute Value (FAV) and eight saltwater taxa are used to derive a saltwater FAV. As acceptable data were only available for three of the freshwater and three of the saltwater taxa, neither the freshwater or saltwater FAV could be calculated for bifenthrin. The freshwater and saltwater FAVs for bifenthrin may be calculated when data are available for the remaining five freshwater (Table 6) and five saltwater (Table 7) taxa recommended by the USEPA.

Both chronic tests available for bifenthrin were accepted (Table C-1). Both tests used the fathead minnow *Pimephales promelas*. As chronic values were only available for one species and acute criteria were not calculated, chronic criteria could not be calculated for bifenthrin. The MATC values fore *P. promelas* were 0.067 and 0.351 µg/L.

Table 6. Eight taxa of freshwater aquatic animals recommended by USEPA (1985) for use in deriving the freshwater FAV, representative species for which bifenthrin acute toxicity data were available, and suggested species to provide the necessary data.

Taxon	Available Species	Suggested Species
1. One Salmonid	Rainbow Trout	----------------[b]
2. Another family in class Osteichthyes	Bluegill	----------------
3. Another family in phylum Arthropoda or Chordata	N/A[a]	Fathead minnow
4. One family not in phylum Arthropoda or Chordata	N/A	Rotifer
5. One insect family or any phylum not already represented	N/A	Stonefly
6. One planktonic crustacean	Cladoceran	----------------
7. One benthic crustacean	N/A	Amphipod
8. One insect	N/A	Midge

[a]N/A = Species not available.
[b]Species was available

Table 7. Eight taxa of saltwater aquatic animals recommended by USEPA (1985) for use in deriving the saltwater FAV, representative species for which bifenthrin acute toxicity data were available, and suggested species to provide the necessary data.

Taxon	Available Species	Suggested Species
1, 2. Two families in phylum Chordata	Sheepshead minnow N/A[a]	----------------[b] Atlantic silverside
3. One family not in phylum Arthropoda or Chordata	Eastern oyster	----------------
4, 5, 6. Three other families not in phylum Chordata	N/A	Dungeness crab Blue crab Grass shrimp
7. A mysid or penaeid	Mysid	----------------
8. One other family not already represented	N/A	Rotifer

[a]N/A = Species not available.
[b]Species was available.

Toxicity to Aquatic Plants

A Final Plant Value (FPV) could not be calculated, as no data were available to analyze the toxicity of bifenthrin to aquatic plants. Because bifenthrin is an insecticide it is likely that toxicity to aquatic plants would not be greater than toxicity to aquatic animals, but more data are needed before this can be concluded.

Hazard Assessment

USEPA (1985) methods for establishing a FAV, a Final Chronic Value (FCV), a Criterion Maximum Concentration (CMC) and a Criterion Continuous Concentration (CCC) could not be followed because sufficient acute and chronic toxicity data were not available (Appendix A). Acceptable studies were available for three of the eight freshwater and three of the eight saltwater taxa recommended by the USEPA (1985). Acceptable acute tests on five more freshwater (Table 6) and five more saltwater (Table 7) taxa are needed to calculate freshwater and saltwater criteria. In order to calculate freshwater and saltwater FCVs, paired acute-chronic tests are needed for fish and invertebrates. Calculation of the freshwater FCV requires paired acute-chronic tests from a fish, an invertebrate, and an acutely sensitive freshwater species. Calculation of the saltwater FCV requires paired acute-chronic tests from a fish, an invertebrate, and an acutely sensitive saltwater species. As bifenthrin has a tendency to bioconcentrate in fish and has moderate toxicity to birds and mammals (LD_{50} value of 70 mg/kg for male rats; EXTOXNET), more data should be collected in order to calculate the Final Residue Value (FRV). The FRV may be important in determining the CCC.

The lowest currently available reporting limit for bifenthrin in water is 0.05 µg/L (B. Ehn, FMC, pers. comm). The lowest GMAV for bifenthrin is 0.00397 µg/L and the lowest Maximum Acceptable Toxicant Concentration (MATC) is 0.06 µg/L. The current reporting limit for bifenthrin may not be sensitive enough to detect acutely or chronically toxic concentrations in surface waters.

CYPERMETHRIN

Use and Environmental Fate

Cypermethrin is a synthetic pyrethroid compound used as an insecticide. Most of the reported use in California is for structural pest control with smaller amounts used on cotton, fruit, and vegetable crops (CDPR 1990-1998). From 1990 to 1998, the reported use of cypermethrin in California ranged from 56,529 to 139,416 pounds per year (Table 1; CDPR 1990-1998).

Cypermethrin is highly insoluble in water with a solubility of 0.01 mg/L and will adsorb to soil particles making groundwater contamination unlikely (EXTOXNET). At normal ambient temperatures and pH values, cypermethrin has a hydrolysis $t_{1/2}$ value of greater than 50 days and a photolysis $t_{1/2}$ value of greater than 100 days (Table 2; EXTOXNET). Cypermethrin is highly immobile in soil with a k_{oc} of 100,000 (Wauchope et al. 1992). The $t_{1/2}$ values for cypermethrin range from 4 days to 8 weeks under aerobic conditions depending on soil type (Table 2; EXTOXNET).

The CDHS and the USEPA have not set action levels for cypermethrin in drinking water (A. Milea, CDHS pers. comm., USEPA 1999b).

BCF values for rainbow trout fry ranged from 443X to 832X in different types of water with an average concentration of 80 ng/L (Muir et al. 1994).

Toxicity to Aquatic Animals

Forty-five tests on the acute toxicity of cypermethrin to aquatic animals were evaluated (Appendix B). Twenty-eight tests were accepted (Table B-2) and seventeen tests were not accepted (Table B-6).

GMAVs for cypermethrin were calculated using data from accepted acute toxicity tests and were ranked in ascending order (Tables 8 and 9). Freshwater cypermethrin GMAVs ranged from 0.0053 µg/L for the amphipod *Hyallela azteca* to 1.78 µg/L for the bluegill *Lepomis macrochirus* (Table 8). Five acute toxicity tests were available for saltwater organisms. The saltwater GMAVs for cypermethrin ranged from 0. 016 µg/L for the grass shrimp *Palaemonetes pugio* to 370 µg/L for the eastern oyster *Crassostrea virginica* (Table 9).

Table 8. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on cypermethrin with freshwater species.

Rank	GMAV (µg/L)	Organism	Species
1	0.0053[a]	Amphipod	*Hyallela azteca*
2	0.0069[a]	Midge	*Chironomus riparius*
3	0.008[a]	Isopod	*Asellus aquaticus*
4	0.016[b]	Mayfly	*Cloeon dipterum*
5	0.4[a]	Cyprinid	*Scardinius erythrophthalmus*
6	0.68[b]	Cladoceran	*Daphnia magna*
7	0.75[b]	Rainbow trout	*Oncorhynchus mykiss*
8	1.0[b]	Carp	*Cyprinius carpio*
9	1.78[a]	Bluegill	*Lepomis macrochirus*

[a] LC_{50} value from one toxicity test on this species.
[b] Species Mean Acute Value (geometric mean of values from several toxicity tests on this species); Individual values are listed in Table B-2.

Table 9. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on cypermethrin with saltwater species.

Rank	GMAV (μg/L)	Organism	Species
1	0.016[a]	Grass shrimp	*Palaemonetes pugio*
2	0.036[a]	Pink shrimp	*Penaeus duorarum*
3	1.81[b]	Sheepshead minnow	*Cyprinodon variegatus*
4	7.0[a]	Mysid	*Mysidopsis bahia*
5	370[a]	Eastern oyster	*Crassostrea virginica*

[a] LC_{50} value from one toxicity test on this species.
[b]Species Mean Acute Value (geometric mean of values from several toxicity tests on this species); Individual values are listed in Table B-2.

The USEPA has assembled a working group to evaluate the potential for sediment toxicity from synthetic pyrethroids (M. Rexrode, USEPA, pers. comm. 1999b). The working group investigated the environmental fate, bioavailability and toxicity of cypermethrin in three sediment types. Ten-day acute toxicity tests on sediment containing cypermethrin were performed using the midge *Chironomus tentans* and the amphipod *Hyallela azteca*. Ten-day LC_{50} values ranged from 14.2 to 37.4 μg/kg cypermethrin for *C. tentans* and 3.1 to 21.1 μg/kg cypermethrin for *H. azteca*. These studies indicate that, although cypermethrin binds rapidly to sediment and suspended particulate matter, it remains biologically available.

The USEPA (1985) guidelines recommend that eight freshwater taxa are used to derive a freshwater Final Acute Value (FAV) and eight saltwater taxa are used to derive a saltwater FAV. Acceptable data were available for seven of the recommended freshwater taxa (Table 10) and five of the recommended saltwater taxa (Table 11). An interim freshwater FAV of 0.003 μg/L was calculated for cypermethrin. As the remaining freshwater taxon will likely be either a rotifer or a snail, neither of which tend to be sensitive to insecticides, it is unlikely to significantly change the FAV. Saltwater FAV could not be calculated because of the lack of data, but may be calculated when data for the remaining three taxa are available.

As only one chronic test was available and accepted, no chronic criteria were calculated. The MATC value for the fathead minnow *Pimephales promelas* was 0.24 μg/L.

Table 10. Eight taxa of freshwater aquatic animals recommended by USEPA (1985) for use in deriving the freshwater FAV, representative species for which cypermethrin acute toxicity data were available, and suggested species to provide the necessary data.

Taxon	Available Species	Suggested Species
1. One Salmonid	Rainbow trout	--------------[b]
2. Another family in class Osteichthyes	Bluegill	---------------
3. Another family in phylum Arthropoda or Chordata	Carp	--------------
4. One family not in phylum Arthropoda or Chordata	N/A	Rotifer
5. One insect family or any phylum not already represented	Midge	-------------
6. One planktonic crustacean	Cladoceran	---------------
7. One benthic crustacean	Isopod	---------------
8. One insect	Mayfly	---------------

[a]N/A = Species not available.
[b] Species was available.

Table 11. Eight taxa of saltwater aquatic animals recommended by USEPA (1985) for use in deriving the saltwater FAV, representative species for which cypermethrin acute toxicity data were available, and suggested species to provide the necessary data.

Taxon	Available Species	Suggested Species
1, 2. Two families in phylum Chordata	Sheepshead minnow	-----------------[b]
	N/A[a]	Atlantic silverside
3. One family not in phylum Arthropoda or Chordata	Eastern oyster	-----------------
4, 5, 6. Three other families not in phylum Chordata	Pink shrimp	-----------------
	Grass shrimp	-----------------
	N/A	Blue crab
7. A mysid or penaeid	Mysid	------------------
8. One other family not already represented	N/A	Rotifer

[a]N/A = Species not available.
[b] Species was available.

Toxicity to Aquatic Plants

A FPV could not be calculated, as no data were available to analyze the toxicity of cypermethrin to aquatic plants. Because cypermethrin is an insecticide, it is likely that toxicity to aquatic plants would not be greater than toxicity to aquatic animals, but more data is needed before this can be concluded.

Hazard Assessment

An interim freshwater FAV of 0.003 µg/L was calculated for cypermethrin. Acceptable studies were available for seven of the eight freshwater and five of the eight saltwater taxa recommended by USEPA (1985). The interim freshwater CMC for cypermethrin was 0.002 µg/L. In order to calculate freshwater and saltwater FCVs, paired acute-chronic tests are needed for fish and invertebrates. Calculation of the freshwater FCV requires paired acute-chronic tests from a fish, an invertebrate, and an acutely sensitive freshwater species. Calculation of the saltwater FCV requires paired acute-chronic tests from a fish, an invertebrate, and an acutely sensitive saltwater species.

No monitoring data were available for cypermethrin in the Sacramento-San Joaquin River system. The lowest currently available reporting limit for cypermethrin in water is 0.1 µg/L (A. Mekebri CDFG, pers. comm.). The lowest GMAV for cypermethrin is 0.008 µg/L. This is lower than the 0.1 µg/L reporting limit. Therefore, the current reporting limit for cypermethrin is not sensitive enough to detect acutely or chronically toxic concentrations in surface waters.

ESFENVALERATE

Use and Environmental Fate

Esfenvalerate is a synthetic pyrethroid compound used as an insecticide on vegetable crops, fruit trees and nuts (EXTOXNET). From 1990 to 1998, the reported use of esfenvalerate in California ranged from 15,808 to 41,817 pounds per year (Table 1; CDPR 1990-1998). Esfenvalerate is highly insoluble in water with a solubility of less than 0.3 mg/L (EXTOXNET). The hydrolysis $t_{1/2}$ and the photolysis $t_{1/2}$ values for esfenvalerate are approximately 21 days each (Table 2; EXTOXNET). Its soil $t_{1/2}$ is 15 days to 3 months, depending on conditions (Table 2; EXTOXNET). It is relatively immobile in soil with a K_{oc} of 5,300 (Wauchope et al. 1992).

Esfenvalerate contains the ss-isomer of the naturally occurring pyrethroid fenvalerate, which is the most toxic stereoisomer (Materna et al. 1995). Fenvalerate is used as an insecticide mostly for structural pest control with reported use ranging from 19,926 to 34,068 pounds per year from 1990 to 1997 (CDPR 1990-1997). In 1998, only 3,239 pounds of fenvalerate were used (CDPR 1998). Fenvalerate use appears to be declining. Toxicity data for fenvalerate were also reviewed; however, as insufficient data exists to evaluate the relative toxicity of the two compounds, fenvalerate data were not reported.

Neither the CDHS nor the USEPA has set action levels for esfenvalerate in drinking water (A. Milea, CDHS, pers. comm., USEPA 1999b).

Esfenvalerate has a moderate tendency to bioconcentrate. The BCF value for esfenvalerate in the carp *Cyprinus carpio* was 334X to 3,650X in an average concentration of 0.04 µg/L with 68 to 74% depurated in 14 days (Ohshima and Mikami 1991).

Toxicity to Aquatic Animals

Nine tests on the acute toxicity of esfenvalerate to aquatic animals were evaluated (Appendix B). Eight tests were accepted (Table B-3), one test was not accepted (Table B-7).

Genus Mean Acute Values (GMAVs) for esfenvalerate were calculated using data from accepted acute toxicity tests and were ranked in ascending order (Table 12). Freshwater GMAVs for esfenvalerate ranged from 0.26 µg/L for the rainbow trout *Oncorhynchus mykiss* to 4.57 µg/L for the leopard frog *Rana* sp.

Table 12. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on esfenvalerate with freshwater species.

Rank	GMAV (µg/L)	Organism	Species
1	0.26[a]	Rainbow trout	*Oncorhynchus mykiss*
2	0.28[b]	Bluegill	*Lepomis macrochirus*
3	0.39[b]	Cladoceran	*Daphnia magna*
4	4.57[b]	Leopard frog	*Rana* spp.

[a] LC_{50} value from one toxicity test on this species.
[b] Species Mean Acute Value: geometric mean of values from several toxicity tests on this species. Individual values are listed in Table B-3.

One chronic test on the toxicity of esfenvalerate was evaluated and accepted (Table C-1). The MATC for esfenvalerate to bluegill *Lepomis macrochirus* was 0.02 μg/L. As chronic values were only available for one species and acute criteria were not calculated, chronic criteria could not be calculated for esfenvalerate.

The USEPA (1985) guidelines recommend that eight freshwater taxa are used to derive a freshwater Final Acute Value (FAV) and eight saltwater taxa are used to derive a saltwater FAV (Tables 13 and 14). Only four of the recommended freshwater taxa and none of the recommended saltwater taxa were available for esfenvalerate. Therefore, no freshwater or saltwater criteria could be calculated for esfenvalerate.

Table 13. Eight taxa of freshwater aquatic animals recommended by USEPA (1985) for use in deriving the freshwater FAV, representative species for which esfenvalerate acute toxicity data were available, and suggested species to provide the necessary data.

Taxon	Available Species	Suggested Species
1. One Salmonid	Rainbow trout	--------------[a]
2. Another family in class Osteichthyes	Bluegill	-------------
3. Another family in phylum Arthropoda or Chordata	Leopard frog	-------------
4. One family not in phylum Arthropoda or Chordata	N/A[b]	Rotifer
5. One insect family or any phylum not already represented	N/A	Stonefly
6. One planktonic crustacean	Cladoceran	---------------
7. One benthic crustacean	N/A	Amphipod
8. One insect	N/A	Mayfly

[a] Species was available.
[b]N/A = Species not available.

Table 14. Eight taxa of saltwater aquatic animals recommended by USEPA (1985) for use in deriving the saltwater FAV, representative species for which esfenvalerate acute toxicity data were available, and suggested species to provide the necessary data.

Taxon	Available Species	Suggested Species
1, 2. Two families in phylum Chordata	N/A[a] N/A	Sheepshead minnow Longnose killifish
3. One family not in phylum Arthropoda or Chordata	N/A	Eastern oyster
4, 5, 6. Three other families not in phylum Chordata	N/A	Dungeness crab Blue crab Grass shrimp
7. A mysid or penaeid	N/A	Mysid
8. One other family not already represented	N/A	Rotifer

[a]N/A = Species not available.

Toxicity to Aquatic Plants

A FPV could not be calculated, as no data were available to analyze the toxicity of esfenvalerate to aquatic plants. Because esfenvalerate is an insecticide, it is likely that toxicity to aquatic plants would not be greater than toxicity to aquatic animals.

Hazard Assessment

For esfenvalerate, acceptable tests were available for only four of the eight freshwater and none of the eight saltwater taxa recommended by USEPA (1985). Toxicity data are required for four freshwater and eight saltwater taxa before acute criteria can be generated. No chronic toxicity data were available for esfenvalerate.

No monitoring data were available for esfenvalerate in the Sacramento-San Joaquin River system. The lowest currently available reporting limit for esfenvalerate in water is 0.05 μg/L (G. Shan, U.C. Davis, pers. comm.). The lowest GMAV for esfenvalerate is 0.26 μg/L. The reporting limit is lower than all available toxicity values. Therefore, the reporting limit for esfenvalerate appears sensitive enough to detect acutely toxic concentrations in surface waters.

PERMETHRIN

Use and Environmental Fate

Permethrin is a synthetic pyrethroid compound used as an insecticide and acaricide. The majority of its reported use in California is for structural pest control with smaller quantities being used on fruit, vegetable and nut crops (CDPR 1990-1998). From 1990 to 1998, the reported use of permethrin in California ranged from 133,965 to 371,231 pounds per year (Table 1; CDPR 1990-1998). Permethrin is highly insoluble in water with a solubility of 0.2 mg/L (Table 2; EXTOXNET). The hydrolysis $t_{1/2}$ of permethrin occurs in 2.5 days and the photolysis $t_{1/2}$ in 4.6 days (Table 2; EXTOXNET). Permethrin is highly immobile in soil with a k_{oc} of 100,000 (Wauchope et al. 1992). Its soil $t_{1/2}$ is 30 to 38 days depending on conditions (Table 2; EXTOXNET).

The CDHS and the USEPA have not set action levels for permethrin in drinking water (A. Milea, CDHS pers. comm., USEPA 1999b).

Permethrin has a moderate tendency to bioconcentrate in biota. The BCF value for the midge larvae *Chironomus tentans* in cis-permethrin was 261X and 135X in trans-permethrin (Muir et al. 1985). Permethrin contains a proportion of 60 to 40 trans to cis isomers, respectively (Windholz 1983). In the eastern oyster *Crassostrea virginica* the BCF value was 1,900X (Schimmel et al. 1983). For rainbow trout fry *Oncorhynchus mykiss*, the BCF values ranged from 1,330X to 2,480X in different treatments (Muir et al. 1994). For 30-d old bluegill *Lepomis macrochirus* and fathead minnow *Pimephales promelas*, the BCF values were 3,000X and 20,000X, respectively (EG&G Bionomics 1977a).

Toxicity to Aquatic Animals

Sixty-seven tests on the acute toxicity of permethrin to aquatic animals were evaluated (Appendix B). Thirty-nine tests were accepted (Table B-4) and twenty-eight tests were not accepted (Table B-8).

Genus Mean Acute Values (GMAVs) for permethrin were calculated using data from accepted acute toxicity tests and were ranked in ascending order (Tables 15 and 16). Freshwater permethrin GMAVs ranged from 0.10 μg/L for the mayfly *Hexagenia bilineata* to 17 μg/L for the Atlantic salmon *Salmo salar* (Table 15). Nine acute toxicity tests were available for saltwater organisms. The saltwater GMAVs for permethrin ranged from 0.018 μg/L for the stone crab *Menippe mercenaria* to 536 μg/L for the eastern oyster *Crassostrea virginica* (Table 16).

Table 15. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on permethrin with freshwater species.

Rank	GMAV (µg/L)	Organism	Species
1	0.10[a]	Mayfly	*Hexagenia bilineata*
2	0.17[a]	Amphipod	*Gammarus pseudolimnaeus*
3	0.31[b]	Cladoceran	*Daphnia magna*
4	0.56[a]	Midge	*Chironomus plumosus*
5	3.2[a]	Brook trout	*Salvelinus fontinalis*
6	4.1[c]	Salmonid	*Oncorhynchus kisutch* (SMAV 3.2) *Oncorhynchus mykiss* (SMAV 5.18)
7	4.8[b]	Fathead minnow	*Pimephales promelas*
8	6.2[b]	Channel catfish	*Ictalurus punctatus*
9	6.57[b]	Bluegill	*Lepomis macrochirus*
10	17[a]	Atlantic salmon	*Salmo salar*

[a] LC_{50} value from one toxicity test on this species.
[b]Species Mean Acute Value: geometric mean of values from several toxicity tests on this species. Individual values are listed in Table B-4.
[c]Genus Mean Acute Value (geometric mean of values from toxicity tests on several species in this genus); Individual values are listed in Table B-4.

Table 16. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on permethrin with saltwater species.

Rank	GMAV (µg/L)	Organism	Species
1	0.018[a]	Stone crab	*Menippe mercenaria*
2	0.04[b]	Mysid	*Mysidopsis bahia*
3	0.22[a]	Pink shrimp	*Penaeus duorarum*
4	2.2[a]	Atlantic silverside	*Menidia menidia*
5	2.39[a]	Fiddler crab	*Uca pugilator*
6	5.5[a]	Striped mullet	*Mugil cephalus*
7	7.8[a]	Sheepshead minnow	*Cyprinodon variegatus*
8	536[a]	Eastern oyster	*Crassostrea virginica*

[a] LC_{50} value from one toxicity test on this species.
[b]Species Mean Acute Value (geometric mean of values from several toxicity tests on this species); Individual values are listed in Table B-4.

The USEPA (1985) guidelines recommend that eight freshwater taxa are used to derive a freshwater Final Acute Value (FAV) and eight saltwater taxa are used to derive a saltwater FAV. Seven of the eight freshwater taxa were available (Table 17). The remaining taxon will likely be either a rotifer or a snail, neither of which tends to be sensitive to insecticides. Usually, the four lowest GMAVs are the most significant determinants in calculating a FAV. The four lowest freshwater GMAVs for permethrin were for the mayfly *Hexagenia bilineata*, the amphipod *Gammarus pseudolimnaeus*, the cladoceran *Daphnia magna*, and the midge *Chironomus plumosus*. The interim freshwater FAV for permethrin is 0.059 µg/L. A final freshwater FAV for permethrin may be calculated when data are available for the remaining category recommended by the USEPA. All of the eight saltwater taxa recommended by the USEPA (1985) were available (Table 18). The four lowest GMAVs for saltwater organisms were for the stone crab *Menippe mercenaria*, the mysid *Mysidopsis bahia*, the pink shrimp *Penaeus duorarum*, and the Atlantic silverside *Menidia menidia*. The saltwater FAV for permethrin was 0.0021 µg/L.

Two chronic tests on the toxicity of permethrin were reviewed and one was accepted. The MATC of permethrin to the sheepshead minnow *Cyprinodon variegatus* was 15 µg/L. As only one chronic value was available, no chronic criterion was calculated.

Table 17. Eight taxa of freshwater aquatic animals recommended by USEPA (1985) for use in deriving the freshwater FAV, representative species for which permethrin acute toxicity data were available, and suggested species to provide the necessary data.

Taxon	Available Species	Suggested Species
1. One Salmonid	Rainbow trout	-------------[b]
2. Another family in class Osteichthyes	Bluegill	-------------
3. Another family in phylum Arthropoda or Chordata	Fathead minnow	-------------
4. One family not in phylum Arthropoda or Chordata	N/A[a]	Rotifer
5. One insect family or any phylum not already represented	Midge	-------------
6. One planktonic crustacean	Cladoceran	-------------
7. One benthic crustacean	Amphipod	-------------
8. One insect	Mayfly	-------------

[a]N/A = Species not available.
[b] Species was available.

Table 18. Eight taxa of saltwater aquatic animals recommended by USEPA (1985) for use in deriving the saltwater FAV, representative species for which permethrin acute toxicity data were available, and suggested species to provide the necessary data.

Taxon	Available Species	Suggested Species
1, 2. Two families in phylum Chordata	Sheepshead minnow Atlantic silverside	-----------------[a] -----------------
3. One family not in phylum Arthropoda or Chordata	Eastern oyster	-----------------
4, 5, 6. Three other families not in phylum Chordata	Stone crab Pink shrimp Fiddler crab	----------------- ----------------- -----------------
7. A mysid or penaeid	Mysid	-----------------
8. One other family not already represented	Striped mullet	-----------------

[a] Species was available.

Toxicity to Aquatic Plants

A FPV could not be calculated as no data were available to analyze the toxicity of permethrin to aquatic plants. Because permethrin is an insecticide, it is not likely that aquatic plants have a greater sensitivity than aquatic animals but more data is needed before this can be concluded.

Hazard Assessment

Acceptable tests were available for seven of the eight freshwater (Table 17) and all of the eight saltwater (Table 18) taxa recommended by USEPA (1985). The data suggest that invertebrates may be more sensitive than fish to permethrin. An interim freshwater FAV was calculated, but a test on the remaining taxon is required to complete the final FAV.

The interim freshwater FAV for permethrin was 0.059 µg/L and the interim CMC was 0.03 µg/L. The saltwater FAV for permethrin was 0.0021 µg/L and the CMC was 0.001 µg/L. USEPA (1985) methods for establishing a freshwater or saltwater CCC could not be followed because sufficient chronic toxicity data were not available.

Permethrin was detected at 0.013 µg/L in the San Joaquin River system at Vernalis in one of 142 samples taken by the USGS (1998).

The lowest currently available reporting limit for permethrin in water is 0.005 µg/L (USGS 1998). The lowest freshwater GMAV available for permethrin was 0.26 µg/L. The reporting limit appears sufficient to detect acute toxicity.

CONCLUSIONS AND RECOMMENDATIONS

Aquatic Toxicity

Interim acute freshwater CMC values were calculated for cypermethrin and permethrin, and a saltwater CMC was calculated for permethrin. Insufficient freshwater and saltwater acute toxicity data were available to calculate CMC values for bifenthrin and esfenvalerate and insufficient saltwater acute toxicity data were available for cypermethrin. Insufficient chronic toxicity data for any of the four pyrethroids were available to calculate CCC values. Paired acute and chronic tests should be run on freshwater and saltwater organisms for all four pyrethroids (Tables 19 and 20). Once additional studies become available, the CDFG may reassess the hazards posed by these pyrethroids to aquatic organisms.

Table 19. Summary of eight taxa of freshwater aquatic animals recommended by USEPA (1985) for use in deriving the freshwater FAV, and suggested species to provide the necessary data.

Taxon	*Suggested Species*	*No Acceptable Tests Available For:*
1. One Salmonid	Rainbow trout	--------------[a]
2. Another family in class Osteichthyes	Bluegill	------------
3. Another family in phylum Arthropoda or Chordata	Fathead minnow	bifenthrin
4. One family not in phylum Arthropoda or Chordata	Rotifer	bifenthrin, cypermethrin, esfenvalerate, permethrin
5. One insect family or any phylum not already represented	Midge	bifenthrin, esfenvalerate
6. One planktonic crustacean	Cladoceran	------------
7. One benthic crustacean	Amphipod	bifenthrin, esfenvalerate
8. One insect	Stonefly	bifenthrin, esfenvalerate

[a] Species was available.

Table 20. **Summary of eight taxa of saltwater aquatic animals recommended by USEPA (1985) for use in deriving the saltwater FAV, and suggested species to provide the necessary data.**

Taxon	Suggested Species	No Acceptable Tests Available For:
1. Two families in phylum Chordata	Sheepshead minnow	esfenvalerate
2.	Longnose killifish	bifenthrin, cypermethrin, esfenvalerate
3. One family not in phylum Arthropoda or Chordata	Eastern oyster	esfenvalerate
4. Three other families not in phylum Chordata	Dungeness crab	bifenthrin, esfenvalerate
5.	Blue crab	bifenthrin, cypermethrin, esfenvalerate
6.	Grass shrimp	bifenthrin, esfenvalerate
7. A mysid or penaeid	Mysid	esfenvalerate
8. One other family not already represented	Rotifer	bifenthrin, cypermethrin, esfenvalerate

[a] Species was available.

Water Column Monitoring

With the exception of monitoring for permethrin in the San Joaquin River by USGS, none of the pyrethroids have been monitored for in the Sacramento-San Joaquin River system (Table 21). Monitoring should be initiated to help assess hazards posed by bifenthrin, cypermethrin, esfenvalerate and permethrin to aquatic organisms. Current reporting limits for esfenvalerate and permethrin appear sensitive enough to detect acute toxicity. The current reporting limits for bifenthrin and cypermethrin are not low enough to detect acute toxicity. It remains uncertain if current reporting limits are capable of detecting chronically toxic concentrations of the pyrethroids.

Table 21. **Assessment of acute toxicity (values in μg/L) for bifenthrin, cypermethrin, esfenvalerate and permethrin to freshwater and saltwater organisms.**

Pyrethroid	Lowest Freshwater GMAV	Freshwater CMC	Lowest Saltwater GMAV	Saltwater CMC	Reporting Limit	Current Monitoring Program?	Number Freshwater Tests Needed	Number Saltwater Tests Needed
Bifenthrin	0.15	—	0.00397	—	0.05	No	5	5
Cypermethrin	0.0053	0.003[a]	0.016	—	0.1	No	1	3
Esfenvalerate	0.26	—	—	—	0.05	No	4	8
Permethrin	0.10	0.03[a]	0.018	0.001	0.005	No	1	0

[a] Interim value

Sediment Toxicity, Mobility and Monitoring

The pyrethroids, particularly bifenthrin, are largely immobile in soil and are highly insoluble in water. Because of the high affinity for sediment and low solubility in water, the synthetic pyrethroids have the potential to accumulate in sediment and may cause sediment toxicity to some organisms. The

USEPA has assembled a working group to evaluate the potential for sediment toxicity from synthetic pyrethroids (M. Rexrode, USEPA, pers. comm. 1999b). Studies analyzed by the working group indicated that, although cypermethrin binds rapidly to sediment and suspended particulate matter, it remains biologically available to cause toxicity.

Sediment samples taken from sites downstream of heavy bifenthrin usage contained concentrations of bifenthrin from 17 to 355 µg/kg (CDFG unpublished data).

More study is needed to further evaluate ecological impacts of pyrethroid residues in sediment. Monitoring should focus on the mobility, persistence, and toxicity of pyrethroids in sediment.

Bioconcentration

These pyrethroids, particularly bifenthrin, show a tendency to bioconcentrate in aquatic organisms. Further study may be needed to evaluate any potential ecological impacts of bioconcentration if water quality and sediment monitoring indicate presence of synthetic pyrethroids.

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APPENDIX A. Procedure Used By the California Department of Fish and Game to Prepare Hazard Assessments.

The California Department of Fish and Game (CDFG) Pesticides Investigations Unit assesses the hazard of pesticides to aquatic organisms. The hazard assessment procedure includes evaluation of toxicity studies, establishment of the Water Quality Criterion (WQC) and assessment of potential hazards.

Acute and chronic toxicity data are obtained from studies published in scientific literature and laboratory reports required by the U.S. Environmental Protection Agency for pesticide registration. The CDFG evaluates the quality of these data by evaluating the tests for compliance with standards (ASTM 1992, 1996) for test type, method, design, species and for water quality standards and toxicant monitoring and maintenance. Although a study need not comply with every standard, tests are rejected if they do not observe certain fundamental procedures or if several important standards are not met. Studies are also rejected if they do not contain sufficient information to be properly evaluated and the necessary information cannot be obtained from the researcher.

Acute toxicity data from acceptable tests on freshwater and saltwater organisms are used to determine a Final Acute Value (FAV). The USEPA (1985) guidelines recommend eight categories of saltwater organisms for deriving freshwater and saltwater FAVs. Generally, these categories of organisms are available, commonly used, and testing procedures are outlined

The FAV is calculated as follows:

1. Species Mean Acute Values (SMAV) are calculated as the geometric mean of LC_{50} and EC_{50} values from all accepted toxicity tests performed on that species.
2. Genus Mean Acute Values (GMAV) are calculated as the geometric mean of all SMAVs for each genus.
3. The GMAVs are ranked (R) from "1" for the lowest to "N" for the highest. Identical GMAVs are arbitrarily assigned successive ranks.
4. The cumulative probability (P) is calculated for each GMAV as R/ (N+1).
5. The four GMAVs with cumulative probabilities closest to 0.05 are selected. If fewer than 59 GMAVs are available, these will always be the four lowest GMAVs.
6. The FAV is calculated using the selected GMAVs and cumulative probabilities (P), as follows:

$$S^2 = \frac{\Sigma\,[\,(\ln GMAV^2)\,] - [\,(\Sigma\,(\ln GMAV)\,)^2/4]}{\Sigma\,(P) - [\,(\Sigma\,(\sqrt{P})\,)^2/4]}$$

$$L = [\Sigma\,(\ln GMAV) - S\,(\Sigma\,(\sqrt{P})\,)\,]/4$$

$A = S(\sqrt{0.05}) + L$

$FAV = e^{A}$

Chronic toxicity data from acceptable tests on freshwater and saltwater organisms are used to determine a Final Chronic Value (FCV). If data are available for the eight taxa, the FCV is calculated using the same procedure as described for the FAV. If sufficient data are not available, the following procedure is used:

1. Chronic values are obtained by calculating the geometric mean of the NOEC and the LOEC values from accepted chronic toxicity tests.

2. Acute-Chronic ratios (ACR) are calculated for each chronic value for which at least one corresponding acute value is available. Whenever possible, the acute test (s) should be part of the same study as the chronic test.

3. The Final ACR (FACR) is calculated as the geometric mean of all mean ACRs available for both freshwater and saltwater species.

4. FCV = FAV / FACR.

Plant toxicity data from algae or aquatic vascular plants are used to determine a Final Plant Value (FPV). The FPV is the lowest result from a test with a biologically important endpoint.

The USEPA guidelines specify that a WQC consists of two concentrations, the Criterion Maximum Concentration (CMC) and the Criterion Continuous Concentration (CCC). The CMC is equal to one-half the FAV. The CCC is equal to the lowest of three values: the FCV, the FPV, or the Final Residue Value (FRV). The FRV is intended to prevent pesticide concentrations in recreational or commercially important species from affecting marketability because of excedence of applicable action levels and to protect important resident species (USEPA 1985).

The WQC is stated as follows: (freshwater / saltwater) aquatic organisms should not be affected unacceptably if the four-day average concentration of (pesticide) does not exceed (CCC value) and if the one-hour average concentration does not exceed (CMC value) more than once every three years on the average (USEPA 1985).

Hazard assessment is an iterative process by which new data are evaluated to refine the WQC. Hazard assessments frequently recommend additional toxicity tests with sensitive native species and commonly used test organisms listed by ASTM.

APPENDIX B. Abstracts of Accepted and Unaccepted Acute Toxicity Tests Reviewed for Hazard Assessment.

Accepted acute toxicity tests- *The following tests used accepted test methods.*

ABC (1980a)- In 1980, a 96-h flow-through acute toxicity test was performed by Analytical Bio-Chem Laboratories in Columbia, Missouri with technical grade permethrin on mayfly nymphs *Hexagenia bilineata*. Five concentrations and controls were tested. Water quality parameters and mortality/survival values were within acceptable testing range. The 96-h LC_{50} for *H. bilineata* was 0.10 µg/L.

Baer (1992a) – In 1992, a 48-h acute static toxicity test was performed by Haskell Laboratory for Toxicology and Industrial Medicine in Newark, Delaware on technical grade esfenvalerate (98.6%) with <24-h cladoceran *Daphnia magna*. Seven concentrations and water and solvent controls were tested in replicate. Water quality parameters during the test were: temperature of 19.6 to 19.9°C; pH of 7.3 to 7.4; dissolved oxygen of 8.7 to 8.8 mg/L; and hardness of 78 mg/L as $CaCO_3$. Control survival was 100% and mortality range was acceptable. The 48-h EC_{50} for *D. magna* was 0.24 µg/L.

Battelle (1986a) – In 1986, a 96-h acute flow-through test was performed by Battelle Ocean Sciences and Technology Department in Duxbury, Massachusetts on technical grade bifenthrin (88%) with juvenile sheepshead minnow *Cyprinodon variegatus*. Five concentrations and solvent and water controls were tested in replicate. Water quality parameters during the test were: temperature of 19.9 to 22.3°C; pH of 7.80 to 7.97; dissolved oxygen of >72% saturation, and salinity of 32.5 to 33.0 $^{o}/_{oo}$. Control survival was 95 to 100% and mortality range was acceptable. The 96-h LC_{50} for *C. variegatus* was 17.8 µg/L.

Battelle (1986b) – In 1986, a 96-h acute flow-through test was performed by Battelle Ocean Sciences and Technology Department in Duxbury, Massachusetts on technical grade bifenthrin (100%) with <24-h mysid *Mysidopsis bahia*. Five concentrations and solvent and water controls were tested in replicate. Water quality parameters during the test were: temperature of 21.0 to 21.8°C; pH of 7.69 to 7.97; dissolved oxygen of >74% saturation, and salinity of 29.5 to 31.0 $^{o}/_{oo}$. Control survival was 95 to 100% and mortality range was acceptable. The 96-h LC_{50} for *M. bahia* was 0.00397 µg/L.

Cripe (1994)- In 1994, 96-ha static acute toxicity test was performed by the USEPA Environmental Research Laboratory in Gulf Breeze, Florida on technical grade permethrin (99.99%) with <24-h mysid *Mysidopsis bahia*. Five concentrations and a water and solvent control were tested in replicate. Water quality parameters during the test were: temperature of 24.5 to 25.5°C; pH of 7.8 to 8.1; dissolved oxygen of 5.9 mg/L; and salinity of 25$^{o}/_{oo}$. Mortality range was acceptable and control survival was above 90%. The 96-h LC_{50} values for *M. bahia* was 0.095 µg/L.

EG&G Bionomics (1983a) – In 1983, a 120-h acute flow-through test was performed by EG&G Bionomics Aquatic Toxicology Laboratory in Wareham, Massachusetts on technical grade bifenthrin (100%) with rainbow trout *Oncorhynchus mykiss*. Five concentrations and solvent and water controls were tested in replicate. Water quality parameters during the test were: temperature of 11 to 12°C; pH of 7.1 to 7.2; dissolved oxygen of 8.8 to 9.7 mg/L; and hardness of 28 to 30 mg/L as $CaCO_3$. Control survival was 100% and mortality range was acceptable. The 96-h LC_{50} for *O. mykiss* was 0.15 µg/L.

EG&G Bionomics (1983b) – In 1983, a 144-h acute flow-through test was performed by EG&G Bionomics Aquatic Toxicology Laboratory in Wareham, Massachusetts on technical grade bifenthrin (100%) with bluegill *Lepomis macrochirus*. Five concentrations and solvent and water controls were tested in replicate. Water quality parameters during the test were: temperature of 22 to 23°C; pH of 7.0 to 7.5; dissolved oxygen of 7.2 to 8.9 mg/L; and hardness of 28 to 30 mg/L as $CaCO_3$. Control survival was 100% and mortality range was acceptable. The 96-h LC_{50} for *L. macrochirus* was 0.35 µg/L.

EG&G Bionomics (1983c) – In 1983, a 48-h acute flow-through test was performed by EG&G Bionomics Aquatic Toxicology Laboratory in Wareham, Massachusetts on technical grade bifenthrin (100%) with <24-h cladoceran *Daphnia magna*. Five concentrations and solvent and water controls were tested in replicate. Water quality parameters during the test were: temperature of 20°C; pH of 8.2 to 8.3; dissolved oxygen of 80 to 90% saturation; and hardness of 160 to 190 mg/L as $CaCO_3$. Control survival was 100% and mortality range was acceptable. The 48-h LC_{50} for *D. magna* was 1.6 µg/L.

Envirosystems (1991a)-In 1991, a 48-h acute toxicity test was performed by Envirosystems Division Resource Analysts Inc., Hampton, New Hampshire on technical grade cypermethrin with <24-h cladoceran *Daphnia magna*. Six concentrations and water controls were tested in replicate. Water temperature during the test was 19 to 21°C. Control survival was 100% and mortality range was acceptable. The 48-h LC_{50} for *D. magna* was 0.134 µg/L.

Envirosystems (1991b) –In 1991, a 96-h flow-through acute toxicity test was performed by Envirosystems Division Resource Analysts Inc. in Hampton, New Hampshire on technical grade cypermethrin with <24-h mysid *Mysidopsis bahia*. Five concentrations and water controls were tested in replicate. Water salinity was 17 ‰ and the pH 7.8 to 8.0. Control survival was 90 to 100% and mortality range was acceptable. The 96-h LC_{50} for *M. bahia* was 7.0 µg/L.

ESE (1990a)- In 1990, a 96-h flow-through acute toxicity test was performed by Environmental Science and Engineering, Inc. in Gainesville, Florida with technical grade cypermethrin on 30-59-d sheepshead minnow *Cyprinodon variegatus*. Five concentrations and a water and solvent control were tested in replicate. Water quality parameters during the test were: temperature of 20 to 22°C; pH of 7.9 to 8.3; dissolved oxygen of $\geq$ 6.0 mg/L; and salinity of 20 ‰. Control survival was 100% and mortality range was acceptable. The 96-h LC_{50} for *C. variegatus* was 3.42 µg/L.

ESE (1990b)- In 1990, a 96-h flow-through acute toxicity test was performed by ESE, in Gainesville, Florida with technical grade cypermethrin on 91-d sheepshead minnow *Cyprinodon variegatus*. Five concentrations and a water and solvent control were tested in replicate. Water quality parameters during the test were: temperature of 20 to 24°C; pH of 8.1 to 8.3; dissolved oxygen of 5.0 to 8.1 mg/L; and salinity of 22 ‰. Control survival was 100% and mortality range was acceptable. The 96-h LC_{50} for *C. variegatus* was 2.37 µg/L.

ESE (1990c)- In 1990, a 96-h flow-through acute toxicity test was performed by ESE in Gainesville, Florida with technical grade cypermethrin on 60-d rainbow trout *Oncorhynchus mykiss*. Five concentrations and a water and solvent control were tested in replicate. Water quality parameters during the test were: temperature of 12 to 13°C; pH of 7.8 to 8.0; and hardness of 269 mg/L as $CaCO_3$. Control survival was 100% and mortality range was acceptable. The 96-h LC_{50} for *O. mykiss* was 0.69 µg/L.

ESE (1990d)- In 1990, a 96-h flow-through acute toxicity test was performed by ESE in Gainesville, Florida on technical grade cypermethrin with 83-d rainbow trout *Oncorhynchus mykiss*. Five concentrations and a water and solvent control were tested in replicate. Water quality parameters during the test were: temperature of 11.0 to 12.2°C; pH of 7.9 to 8.1; and dissolved oxygen of 8.4 to 10.6 mg/L. Control survival was 100% and the mortality range was acceptable. The 96-h LC_{50} for *O. mykiss* was 0.90 µg/L.

Fairchild et al. (1992) – In 1990, 96-h and 48-h static acute toxicity tests were performed by the U.S. Fish and Wildlife Service Laboratory in Columbia, Missouri on esfenvalerate (84%) with bluegill *Lepomis macrochirus* and <24-h cladoceran *Daphnia magna*. Five concentrations and solvent controls were tested. Water quality parameters were measured daily and found to be acceptable. Control survival was acceptable. The 96-h LC_{50} for *L. macrochirus* was 0.31 µg/L and the 48-h LC_{50} for *D. magna* was 0.27 µg/L.

FMC (1977)- In 1977, a 96-h static bioassay was performed on technical grade permethrin with bluegill *Lepomis macrochirus* and rainbow trout *Oncorhynchus mykiss*. Eight to ten concentrations and water and solvent controls were tested. Water quality parameters, control survival and mortality range were not given but are assumed to be acceptable. The 96-h LC_{50} for both *L. macrochirus* and *O. mykiss* was 3.2 µg/L.

Forbis et al. (1985a)- In 1985, a 96-h static acute toxicity test was performed by Analytical Bio-Chemistry Laboratories, Inc. in Columbia, Missouri on technical grade esfenvalerate (98.8%) with 41 mm rainbow trout *Oncorhynchus mykiss*. Five concentrations and a water control were tested in replicate. Water quality parameters during the test were: temperature of 11°C; pH of 7.1 to 7.7; dissolved oxygen of 7.9 to 8.7 mg/L; and hardness of 40 to 45 mg/L as $CaCO_3$. Control survival was 100% and mortality range was acceptable. The 96-h LC_{50} for *O. mykiss* was 0.26 µg/L.

Forbis et al. (1985b)- In 1985, 96-h static acute toxicity tests were performed by Analytical Biochemical Laboratories, Inc. in Columbia, Missouri on technical grade esfenvalerate (98.8%) with 25 mm bluegill sunfish *Lepomis macrochirus*. Five concentrations and a water control were tested in replicate. Water quality parameters during the test were: temperature of 22°C; pH of 7.0 to 7.6; dissolved oxygen of 4.4 to 8.7 mg/L; and hardness of 40 to 45 mg/L as $CaCO_3$. Control survival was 100% and mortality range was acceptable. The 96-h LC_{50} for *L. macrochirus* was 0.26 µg/L.

Geiger et al. (1988)- In 1979 and 1980, 96-h static acute toxicity tests were performed by the Center for Lake Superior Environmental Studies in Superior, Wisconsin on technical grade permethrin (91.9%) with 31-day old fathead minnows *Pimephales promelas*. Five concentrations and a water control were tested in replicate. Water quality parameters were: temperature of 25.4 ± 0.25°C; pH of 7.1 ± 0.05;

hardness of 45.7 mg/L as $CaCO_3$; and dissolved oxygen of 7.5 mg/L. Control survival for permethrin was 100%. The mortality range was acceptable. The 96-h LC_{50} for *P. promelas* was 16.0 µg/L.

Hamer et al. (1982)– In 1982, 72-h acute toxicity tests were performed by ICI Plant Protection Division in Jealott's Hill on technical grade cypermethrin (91.5%) with 6-d cladoceran *Daphnia magna*, mayfly *Cloeon dipterum* nymphs, and 5mm isopod *Asellus aquaticus*. Two to three tests were run for each organism. Six to nine concentrations and water controls were tested. Water quality parameters during the test were not given. Control survival was 100% for *D. magna*, 90 to 100% for *C. dipterum* and 100% for *A. aquaticus*. Mortality ranges were acceptable. The 72-h LC_{50} values for *D. magna* were 1.69 µg/L, 1.32 µg/L and 1.70 µg/L; for *C. dipterum* were 0.023 µg/L and 0.006 µg/L; and for *A. aquaticus* was 0.008 µg/L. Additional toxicity tests were performed with soil in the test vessels; these values were not used.

Hutton (1987)- In 1987, a 48-h static acute toxicity test was performed by E. I. du Pont de Nemours and Company, Inc. in Newark, Delaware with technical grade ASANA (98.6% esfenvalerate) on <24-h cladoceran *Daphnia magna*. Eight concentrations and water and solvent controls were tested. Water quality parameters during the test were: temperature of 19.8 to 20.2°C; pH of 8.2 to 8.3; hardness of 177 mg/L as $CaCO_3$; and dissolved oxygen of 8.3 to 8.4 mg/L. Mortality range, and control survival were acceptable. The 48-h EC_{50} for *D. magna* was 0.90 µg/L.

ICI Americas (1977)- In 1977, 96-h and 48-h acute flow-through toxicity tests were performed on technical grade cypermethrin and permethrin with rainbow trout *Oncorhynchus mykiss*, bluegill *Lepomis macrochirus* and cladoceran *Daphnia magna*. For cypermethrin, with *O. mykiss*, the 96-h LC_{50} at 13°C, was 0.92 µg/L. The 96-h LC_{50} for cypermethrin with *L. macrochirus* was 1.78 µg/L at 23 °C. The 72-h EC_{50} for cypermethrin with *D. magna* was 0.199 µg/L at 17 °C. The 48-h EC_{50} for permethrin with *D. magna* was 0.60 µg/L.

Materna et al. (1995)- In 1995, a 96-h acute static toxicity test was performed by National Biological Service in Columbia, Missouri on technical grade esfenvalerate (85%) with leopard frog (*Rana* spp.) tadpoles. Six concentrations and water and solvent controls were tested. Water temperature was 18 and 22 °C and other water quality parameters were not given. The 96-h EC_{50} value for leopard frogs was 3.40 µg/L at 18 °C and 6.14 µg/L at 22 °C.

Mayer and Ellersieck (1986)-From 1965 to 1985, 48-h and 96-h static acute toxicity tests were performed by Columbia National Fisheries Research Laboratory of the U.S. Fish and Wildlife Service in Columbia, Missouri on technical grade permethrin (91 and 92.5%) with: first instar cladoceran *Daphnia magna*; immature amphipod *Gammarus pseudolimnaeus*; third instar midge *Chironomus plumosus*; rainbow trout *Oncorhynchus mykiss* (0.60-1.20 g); brook trout *Salvelinus fontinalis* (1.20 g); fathead minnow *Pimephales promelas* (0.60-1.0 g); channel catfish *Ictalurus punctatus* (0.70 g) and bluegill *Lepomis macrochirus* (0.50-0.70 g). A minimum of four concentrations and solvent controls were tested in replicate. Water quality parameters for *D. magna* (two tests) were: temperature of 17 and 18 °C; pH of 7.4; and hardness of 42 and 44 mg/L as $CaCO_3$. Water quality parameters for *G. pseudolimnaeus* were: temperature of 17 °C; pH of 7.4; and hardness of 42 and 44 mg/L as $CaCO_3$. Water quality parameters for *C. plumosus* were: temperature of 22 °C; pH of 7.4; and hardness of 42 and 44 mg/L as

$CaCO_3$. Water quality parameters for *O. mykiss* were: temperature of 7 to 22 °C; pH of 6.6 to 8.5; and hardness of 40-320 mg/L as $CaCO_3$. Water quality parameters for *S. fontinalis* were: temperature of 12°C; pH of 7.5; and hardness of 40 mg/L as $CaCO_3$. Water quality parameters for *P. promelas* were: temperature of 22 °C; pH of 7.1 and 7.3; and hardness of 38 and 40 mg/L as $CaCO_3$. Water quality parameters for *I. punctatus* were: temperature of 22°C; pH of 7.1; and hardness of 40 mg/L as $CaCO_3$. Water quality parameters for *L. macrochirus* were: temperature of 12 to 22 °C; pH of 6.5 to 8.5; and hardness of 38 to 320 mg/L as $CaCO_3$. The 48-h EC_{50} values and 96-h LC_{50} values for all tests can be found in Table and B-4.

Schimmel et al. (1983)- In 1983, 96-h flow-through acute toxicity tests were performed by the Environmental Research Laboratory in Gulf Breeze, Florida on technical grade permethrin (93%) with: <24-h mysid *Mysidopsis bahia*; <24-h old pink shrimp *Penaeus duorarum*; sheepshead minnow *Cyprinodon variegatus*; Atlantic silverside *Menidia menidia*; striped mullet *Mugil cephalus*; and <24-h Gulf toadfish *Ospanus beta*. Mortality range was acceptable and control survival was 100%. Water quality parameters and 96-h LC_{50} values for permethrin are reported in Table B-4.

Stephenson (1982) - In 1982, 96-h flow-through acute toxicity tests were performed by Shell Research Limited in England on cypermethrin (85 and ≥95%) with carp *Cyprinus carpio*, cyprinid *Scardinius erythrophthalmus*, and rainbow trout *Oncorhynchus mykiss*. LC50 values are listed in Table B-2.

United States Environmental Protection Agency Pesticide Ecotoxicity Database (USEPA) (1999c)- Between 1974 and 1994, flow-through and static acute toxicity tests were performed on technical grade bifenthrin, cypermethrin, esfenvalerate, and permethrin, with a variety of aquatic organisms. These tests were reviewed and determined to have followed acceptable testing procedures. Water quality parameters were not listed in the database but were found to comply with USEPA standards. LC_{50} and EC_{50} values for all tests are reported in Tables B-2and B-4.

Ward (1987) – In 1987, a 48-h acute static test was performed by Environmental Science and Engineering in Gainesville, Florida on technical grade bifenthrin (88.4%) with eastern oyster embryos *Crassostrea virginica*. Seven concentrations and seawater and solvent controls were tested in triplicate. Water quality parameters during the test were: temperature of 20 to 24°C; pH of 8.0 to 8.3; dissolved oxygen of ≥6.5 mg/L; and salinity of 19 $^0/_{00}$. Control survival and effect range were acceptable. The 48-h EC_{50} for *C. virginica* was 0.285 µg/L, based on reduction of normal larvae.

Unacceptable acute toxicity tests- The following tests used unacceptable test methods and/or produced unaccepted results.

Baer (1992b)- In 1992, a 48-h static acute toxicity test was performed by Haskell Laboratory for Toxicology and Industrial Medicine, Newark, Delaware on DPX-YB656-59 (8.4% esfenvalerate) with <24-h cladoceran *Daphnia magna*. Six concentrations and a water control were tested in replicate. Water quality parameters during the test were: temperature of 19.7 to 19.9°C; hardness of 76 mg/L as $CaCO_3$; and dissolved oxygen of 8.5 to 8.8 mg/L. Control survival, and mortality range were acceptable. The 48-h EC_{50} for *D. magna* was 5.6 μg/L. This test was not accepted because the percent of active ingredient in the formulation was too low.

Coats and O-Donnell-Jeffrey (1979) – In 1979, 24-h toxicity tests were performed by the University of Guelph in Ontario, Canada on technical grade (92-96%) and formulated (25%) permethrin and technical grade (92-96%) and formulated (40%) cypermethrin with rainbow trout *Oncorhynchus mykiss*. Four to five concentrations were tested with three to six replicates. Water quality parameters during the test were: temperature of 10°C; pH of 7.5, and hardness of 110 mg/L as $CaCO_3$. Control survival information was not given. The 24-h LC_{50} values for *O. mykiss* were 135 μg/L for technical grade permethrin; 61 μg/L for formulated permethrin; 55 μg/L for technical grade cypermethrin, and 11 μg/L for formulated cypermethrin. These values were not used because the testing duration was too short.

Cripe (1994)- In 1994, 96-h static acute toxicity tests were performed by USEPA Environmental Research Laboratory in Gulf Breeze, Florida on technical grade cypermethrin and permethrin (99.99%) with <24-h mysid *Mysidopsis bahia* and 3 to 5-d pink shrimp *Penaeus duorarum*. Five concentrations and a solvent and water control were tested in replicate. Water quality parameters during the test were: temperature of 24.5 to 25.5°C; pH of 7.8 to 8.1 for mysids and 7.5 to 7.9 for shrimp; dissolved oxygen of 5.9 mg/L for mysids and 5.6 mg/L for shrimp; and salinity of $25^{0}/_{00}$. Mortality range was acceptable and control survival was above 90% for all tests but the permethrin with *P. duorarum*. The 96-h LC_{50} values for *M. bahia* and *P. duorarum* are given in Tables B-6 and B-8. These tests were not accepted because either the percent control mortality was too high or the toxicity values were more than a factor of ten different than others for the same species.

ESE (1986)- In 1986, a 96-h flow-through acute toxicity test was performed by Environmental Science and Engineering, Inc., Gainesville, Florida on technical bifenthrin (88.35%) on adult eastern oysters *Crassostrea virginica*. Five concentrations and a water and solvent control were tested. Water quality parameters during the test were: temperature of 24°C; salinity of 34 to 35 $^{0}/_{00}$; pH from 7.5 to 8.0; and dissolved oxygen of 5.5 mg/L. Control survival was acceptable. The 96-h EC_{50} for *C. virginica* was >2.15 μg/L. This value was not accepted because the mortality range was unacceptable and there was difficulty in interpreting the results.

FMC (1984a)- In 1984, a 96-h static acute toxicity test was performed by Springborn Binomics, Incorporated in Princeton, New Jersey on FMC 45806 (30.4% cypermethrin) with bluegill *Lepomis macrochirus*. Nine concentrations and a control were tested. Water quality parameters during the tests, and mortality and control survival were not given. The 96-h LC_{50} for *L. macrochirus* was 0.20 μg/L.

Tests were also performed in soybean oil; these values were not used. This test was not accepted because the percent active ingredient was too low and control survival was not given.

FMC (1984b)- In 1984, a 48-h static acute toxicity test was performed by Springborn Binomics, Incorporated in Princeton, New Jersey on FMC 45806 (30.4% cypermethrin) with cladoceran *Daphnia magna*. Ten concentrations and control were tested. Water quality parameters during the tests, and mortality and control survival were not given. The 48-h LC_{50} for *D. magna* was 0.29 µg/L. Tests were also performed in soybean oil; these values were not used. This test was not accepted because the percent active ingredient was too low and control survival and mortality range were not given.

Glickman et al. (1982)- In 1982, a 24-h static acute toxicity test was performed on trans-permethrin (99%) with rainbow trout *Oncorhynchus mykiss*. Water quality test parameters and test concentrations were not given. The 24-h LC_{50} for *O. mykiss* was 0.018 µg/L. This test was not accepted because the duration was too short, and essential information such as control survival and mortality range was not given.

Hamer et al. (1982)- In 1982, a 72-h static acute toxicity test was performed by ICI Plant Protection Division on cypermethrin (91.5%) with isopod *Assellus aquaticus*. Two to three tests were run for the isopods. Six to nine concentrations and water controls were tested. Water quality parameters during the test were not given. Control survival was < 80% and mortality range was acceptable. The 72-h LC_{50} for *A. aquaticus* was 0.010 µg/L. This test was not accepted because the control survival was below 90%.

Holdway and Dixon (1988)- In 1988, 96-h acute pulse exposure toxicity tests were performed on technical grade permethrin with three different ages of white sucker *Catostomus commersoni* and flagfish *Jordanella floridae*. Four concentrations and a water and solvent control were tested in replicate. For flagfish, the water quality parameters were: temperature of 25.3°C; pH of 7.96; dissolved oxygen of 8.3 mg/L and hardness of 233 mg/L as $CaCO_3$. For white sucker the parameters were: temperature of 20.5°C; pH of 8.09; dissolved oxygen of 9.0 mg/L; and hardness of 384 mg/L as $CaCO_3$. Mortality ranges, and control survival were acceptable. The 96-h PE LC_{50}'s for fed *C. commersoni* and fed *J. floridae* can be found in Table B-8. Pulse exposure tests were not used in this hazard assessment.

Jolly et al. (1978)- In 1978, static acute toxicity tests were performed in Baton Rouge, Louisiana on formulated permethrin with newly hatched and juvenile crayfish *Procambarus clarkii*, channel catfish *Ictalurus punctatus*, largemouth bass *Micropterus salmoides*, mosquitofish *Gambusia affinis*, and bullfrog tadpoles *Rana catesbeiana*. A range of concentrations and a water control were tested in replicate. Water temperature during the test was held at 24 $\pm$ 1°C. The 96-h LC_{50}'s for newly hatched *P. clarkii*, juvenile crayfish *P. clarkii*, catfish *I. punctatus*, largemouth bass *M. salmoides*, mosquitofish *G. affinis* and tadpoles *R. catesbeiana* were 0.39 µg/L, 0.62 µg/L, 1.10 µg/L, 8.50 µg/L, 15 µg/L and 7,033 µg/L, respectively. These tests were not accepted because the percent active ingredient was too low and mortality and control survival were not given.

Kent et al. (1995a)- In 1995, a 48-h static acute toxicity test was performed by Brixham Environmental Laboratories in Devon, United Kingdom on permethrin (25%) with <24-h cladoceran *Daphnia magna*. Seven concentrations and water control were tested in replicate. Water quality parameters during the test were: temperature of 20.3 to 20.5 °C; pH of 8.01 to 8.07; and dissolved oxygen of 8.6 to 9.0 mg/L. The control survival was 100% and the mortality range acceptable. The 48-h EC_{50} for *D. magna* was 0.84 μg/L. This test was not used because the percent active ingredient was too low.

Kent et al. (1995b)- In 1995, a 96-h flow-through acute toxicity test was performed by Brixham Environmental Laboratories in Devon, United Kingdom on permethrin (25%) with 39-55 mm rainbow trout *Oncorhynchus mykiss*. Six concentrations and water controls were tested in replicate. Water quality parameters during the test were: temperature of 12.0 to 12.4 °C; pH of 7.59 to 7.87; dissolved oxygen of 9.8 to 10.6 mg/L; and hardness of 40.5 to 44.3 mg/L as $CaCO_3$. The control survival was 100% and the mortality range acceptable. The 96-h LC_{50} for *O. mykiss* was 8.5 μg/L. This test was not accepted because the percent active ingredient was too low.

McLeese et al. (1980) – In 1980, 96-h static acute toxicity tests were performed by the Department of Fisheries and Oceans in St. Andrews, New Brunswick on permethrin (92.1%) with Atlantic salmon *Salmo salar*, lobster *Homarus americanus*, and shrimp *Crangon septemspinosa*. Six concentrations were tested. The temperature during testing was 10°C. Control survival information was not given. The 96-h LC_{50} values were 12 μg/L for *S. salar*, 0.73 μg/L for *H. americanus*, and 0.13 μg/L for *C. septemspinosa*. These values were not used because important information, such as control survival was not given and too few organisms per concentration were tested.

Mulla et al. (1978) – In 1976 and 1977, 48-h acute toxicity tests were performed by the University of California at Riverside on permethrin (percent active ingredient not given) with mosquitofish *Gambusia affinis*, tilapia *Tilapia mossambica*, rainbow trout *Oncorhynchus mykiss*, and pupfish *Cyprinodon macularius*. Concentrations were tested in replicate. Water quality parameters during the test were not given. Control survival information was not given. The 48-h LC_{50} values were 97.0 μg/L for *G. affinis*, 5.0 μg/L for *C. macularius*, 6.0 μg/L for *O. mykiss*, and 44.0 μg/L for *T. mossambica*. These values were not used because important information, such as control survival was not given, and the testing duration was too short.

Rice et al. (1997)- In 1996, a 48-h static acute toxicity test was performed in Ames Iowa on permethrin (88%) with 30-d old Japanese medaka *Oryzias latipes*. Five concentrations and water controls were tested in replicate. Water quality parameters during the test were: temperature of 25 $\pm$ 1°C; pH of 6.6 to 8.0; hardness of 116 to 156 mg/L as $CaCO_3$; and dissolved oxygen of 5.8 to 8.4 mg/L. The 48-h LC_{50} for *O. latipes* was 0.011 μg/L. This test was not accepted because the test organism is not a resident species in North America.

Stephenson (1982) - In 1982, 24-h static acute toxicity tests were performed by Shell Research Limited in England on cypermethrin (85 and $\geq$95%) with cladoceran *Daphnia magna*, isopod *Asellus aquaticus*, amphipod *Gammarus pulex*, mayfly *Cloeon dipterum*, beetle *Gyrinus natator*, midges *Chironomus thummi* and *Chaoborus crystallinus*, mosquito *Aedes aegypti*, hemipteran *Corixa punctata*, and hydracarina *Piona carnea*. LC50 values are listed in Table B-6. These values were not used because the testing duration was too short.

Zitko et al. (1979) – In 1979, 96-h static acute toxicity tests were performed by the Department of Fisheries and Environmental Biological Station in Saint Andrews, New Brunswick on formulated permethrin (percent active ingredient not given) with juvenile Atlantic salmon *Salmo salar* and adult lobster *Homarus americanus*. Water quality parameters during the tests were: temperature of 10°C; salinity of 30 ‰ and dissolved oxygen of 8 mg/L. The MATC values were 8.80 µg/L for *S. salar* and 7.00 µg/L for *H. americanus* These values were not used because too few organisms were tested, the percent active ingredient was not given, and no LC_{50} values were determined.

Table B-1. Values (µg/L) from accepted tests on the acute toxicity of bifenthrin to aquatic animals.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness [b]	Effect	Values µg/L (95% C.L.)	Reference
Bluegill *Lepomis macrochirus*	N/A[c]	100%	F/T	144-h	28-30	LC_{50}	0.35 (0.3-0.4)	EG&G Bionomics 1983b
Cladoceran *Daphnia magna*	<24-h	100%	F/T	48-h	160-190	LC_{50}	1.6 (1.2-2)	EG&G Bionomics 1983c
Eastern oyster *Crassostrea virginica*	embryo	88.4%	static	48-h	19 ‰	EC_{50}	0.285	Ward 1987
Mysid *Mysidopsis bahia*	<24-h	technical	F/T	96-h	30-31‰	LC_{50}	0.00397 (0.003-0.005)	Battelle 1986b
Rainbow trout *Oncorhynchus mykiss*	N/A	100%	F/T	96-h	28-30	LC_{50}	0.15 (0.1-0.2)	EG&G Bionomics 1983a
Sheepshead minnow *Cyprinodon variegatus*	juvenile	88%	F/T	96-h	33 ‰	LC_{50}	17.8 (14.7-21.8)	Battelle 1986a

[a] F/T = Flow-through
[b] Water hardness is in mg/L as CaCO3.
[c] N/A = Information not available.

Table B-2. Values (µg/L) from accepted tests on the acute toxicity of cypermethrin to aquatic animals.

Species	Life Stage	Formula	Test Method [b]	Test Length	Salinity/ Hardness [c]	Effect	Values µg/L (95% C.L.)	Reference
Amphipod *Hyallela azteca*	N/A	N/A	N/A	48-h	N/A	LC_{50}	0.0053 (0.0043-0.0065)	USEPA unpublished data
Bluegill *Lepomis macrochirus*	35-87mm	technical	F/T	96-h	N/A	LC_{50}	1.78 (1.63-1.95)	ICI Americas 1977
Carp *Cyprinus carpio*	N/A	>95%	F/T	96-h	N/A	LC_{50}	1.1 (0.6-2.8)	Stephenson 1982
Carp *Cyprinus carpio*	N/A	>95%	F/T	96-h	N/A	LC_{50}	0.9 (0.6-1.7)	Stephenson 1982
Cladoceran *Daphnia magna*	< 24-h	technical	N/A[a]	48-h	N/A	LC_{50}	0.134 (0.114-0.157)	Envirosystems 1991a
Cladoceran *Daphnia magna*	6-d	91.5%	N/A	72-h	N/A	EC_{50}	1.69 (1.16-2.87)	Hamer et al. 1982
Cladoceran *Daphnia magna*	6-d	91.5%	N/A	72-h	N/A	EC_{50}	1.32 (0.98-1.81)	Hamer et al. 1982
Cladoceran *Daphnia magna*	6-d	91.5%	N/A	72-h	N/A	EC_{50}	1.70 (1.22-2.5)	Hamer et al. 1982
Cladoceran *Daphnia magna*	1st instar	technical	F/T	72-h	N/A	EC_{50}	0.199 (0.162-0.241)	ICI Americas 1977
Cladoceran *Daphnia magna*	<24-h	91.5%	static	48-h	N/A	EC_{50}	1 (0.8-1.3)	USEPA 1999c
Cyprinid *Scardinius erythrophthalmus*	N/A	>95%	F/T	96-h	N/A	LC_{50}	0.4	Stephenson 1982
Eastern oyster *Crassostrea virginica*	spat	91.5%	F/T	96-h	N/A	EC_{50}	370 (245-556)	USEPA 1999c
Grass shrimp *Palaemonetes pugio*	adult	96%	F/T	96-h	N/A	LC_{50}	0.016 (0.13-0.19)	USEPA 1999c
Isopod *Asellus aquaticus*	1st instar	91.5%	N/A	72-h	N/A	LC_{50}	0.008 (0.005-0.02)	Hamer et al. 1982
Mayfly *Cloeon dipterum*	nymph	91.5%	N/A	72-h	N/A	EC_{50}	0.023 (0.016-0.034)	Hamer et al. 1982
Mayfly *Cloeon dipterum*	nymph	91.5%	N/A	72-h	N/A	EC_{50}	0.006 (0.004-0.009)	Hamer et al. 1982
Mayfly *Cloeon dipterum*	larvae	98.1%	F/T	96-h	N/A	LC_{50}	0.03 (0.01-0.07)	USEPA 1999c
Midge *Chironomus riparius*	1st instar	N/A		48-h	N/A	LC_{50}	0.0069 (0.0056-0.0085)	USEPA unpublished data
Mysid *Mysidopsis bahia*	<24-h	technical	F/T	96-h	17‰	LC_{50}	7.0 (5.5-9.1)	Envirosystems 1991b
Pink shrimp *Penaeus duorarum*	juvenile	91.5%	F/T	96-h	N/A	LC_{50}	0.036 (0.031-0.043)	USEPA 1999c

Table B-2 cont.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness [b]	Effect	Values µg/L (95% C.L.)	Reference
Rainbow trout *Oncorhynchus mykiss*	35-87mm	technical	F/T	96-h	N/A	LC_{50}	0.92 (0.81-1.05)	ICI Americas 1977
Rainbow trout *Oncorhynchus mykiss*	60-d	technical	F/T	96-h	269	LC_{50}	0.69 (0.60-0.82)	ESE 1990c
Rainbow trout *Oncorhynchus mykiss*	83-d	technical	F/T	96-h	N/A	LC_{50}	0.90 (0.72-1.35)	ESE 1990d
Rainbow trout *Oncorhynchus mykiss*	N/A	$\geq$95%	F/T	96-h	N/A	LC_{50}	0.5	Stephenson 1982
Rainbow trout *Oncorhynchus mykiss*	0.4 g	92.9%	F/T	101-h	N/A	LC_{50}	0.82 (0.7-0.9)	USEPA 1999c
Sheepshead minnow *Cyprinodon variegatus*	30-59-d	technical	F/T	96-h	20‰	LC_{50}	3.42 (1.87-4.07)	ESE 1990a
Sheepshead minnow *Cyprinodon variegatus*	91-d	technical	F/T	96-h	22‰	LC_{50}	2.37 (1.79-3.5)	ESE 1990b
Sheepshead minnow *Cyprinodon variegatus*	N/A	91.5%	F/T	96-h	N/A	LC_{50}	0.73 (0.48-1.9)	USEPA 1999c

[a] N/A = Information not available
[b] F/T = Flow-through
[c] Hardness expressed as mg/L $CaCO_3$

Table B-3. Values (µg/L) from accepted tests on the acute toxicity of esfenvalerate to aquatic animals.

Species	Life Stage	Formula	Test Method	Test Length	Salinity/ Hardness [a]	Effect	Values µg/L (95% C.L.)	Reference
Bluegill *Lepomis macrochirus*	N/A[b]	84%	static	96-h	N/A	LC_{50}	0.31 (0.25-0.40)	Fairchild et al. 1992
Bluegill *Lepomis macrochirus*	N/A[b]	98.8%	static	96-h	40-45	LC_{50}	0.26 (0.20-0.36)	Forbis et al. (1985b)
Cladoceran *Daphnia magna*	<24-h	98.6%	static	48-h	78	EC_{50}	0.24	Baer 1992a
Cladoceran *Daphnia magna*	<24-h	98.6%	static	48-h	177	EC_{50}	0.90 (0.7-0.116)	Hutton 1987
Cladoceran *Daphnia magna*	<24-h	84%	static	48-h	N/A	LC_{50}	0.27 (0.19-0.42)	Fairchild et al. 1992
Leopard frog *Rana* spp.	tadpole	85%	static	96-h	N/A	EC_{50}	3.40	Materna et al. 1995
Leopard frog *Rana* spp.	tadpole	85%	static	96-h	N/A	EC_{50}	6.14	Materna et al. 1995
Rainbow trout *Oncorhynchus mykiss*	41mm	98.8%	static	96-h	40-45	LC_{50}	0.26	Forbis et al. 1985a

[a] Water hardness is in mg/L as CaCO3.
[b] N/A = Information not available.

Table B-4. Values (µg/L) from accepted tests on the acute toxicity of permethrin to aquatic animals.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness [b]	Effect	Values (95% C.L.)	Reference
Amphipod *Gammarus pseudolimnaeus*	immature	91%	static	96-h	42	LC_{50}	0.17 (0.11-0.27)	Mayer & Ellersieck 1986
Atlantic salmon *Salmo salar*	N/A	technical	static	96-h	N/A	LC_{50}	17 (13-24)	USEPA 1999c
Atlantic silverside *Menidia menidia*	N/A	93%	F/T	96-h	25‰	LC_{50}	2.2 (1.2-6.4)	Schimmel et al. 1983
Bluegill *Lepomis macrochirus*	N/A	91%	static	96-h	38	LC_{50}	5.0 (3.1-7.9)	Mayer & Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	91%	static	96-h	39	LC_{50}	4.5 (3.6-5.6)	Mayer & Ellersieck 1986

Table B-4. cont.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness [b]	Effect	Values (95% C.L.)	Reference
Bluegill *Lepomis macrochirus*	N/A	91%	static	96-h	39	LC_{50}	8.0 (6-10.8)	Mayer & Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	91%	static	96-h	39	LC_{50}	7.1 (5.5-9.2)	Mayer & Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	91%	static	96-h	44	LC_{50}	5.6 (4.1-7.7)	Mayer & Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	91%	static	96-h	44	LC_{50}	7.6 (5.7-10.2)	Mayer & Ellersieck 1986
Bluegill Lepomis macrochirus	N/A	91%	static	96-h	44	LC_{50}	7.2 (5.5-9.4)	Mayer & Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	95.7%	static	96-h	N/A	LC_{50}	2.52 (1.88-3.36)	USEPA 1999c
Bluegill *Lepomis macrochirus*	N/A	100%	static	96-h	N/A	LC_{50}	6.1 (5.1-7.3)	USEPA 1999c
Bluegill *Lepomis macrochirus*	0.70	91%	static	96-h	40	LC_{50}	13.0 (10-16.9)	Mayer & Ellersieck 1986
Bluegill *Lepomis macrochirus*	0.70	91%	static	96-h	320	LC_{50}	6.2 (4.4-8.8)	Mayer & Ellersieck 1986
Bluegill *Lepomis macrochirus*	N/A	technical	static	96-h	N/A	LC_{50}	3.2	FMC 1977
Bluegill *Lepomis macrochirus*	1 g	94.4%	static	96-h	N/A	LC_{50}	13.3	USEPA 1999c
Bluegill *Lepomis macrochirus*	1 g	91.4%	static	96-h	N/A	LC_{50}	13.5	USEPA 1999c
Brook trout *Salvelinus fontinalis*	1.20 g	92.5%	static	96-h	40	LC_{50}	3.2 (2.2-4.8)	Mayer & Ellersieck 1986
Channel catfish *Ictalurus punctatus*	0.70 g	91%	static	96-h	40	LC_{50}	7.2 (5.7-9)	Mayer & Ellersieck 1986
Channel catfish *Ictalurus punctatus*	N/A	technical	static	96-h	N/A	LC_{50}	5.4 (3.9-7.4)	USEPA 1999c
Cladoceran *Daphnia magna*	12-h	95.7%	static	96-h	N/A	EC_{50}	0.039 (0.025-0.006)	USEPA 1999c
Cladoceran *Daphnia magna*	1st instar	technical	F/T	48-h	N/A	EC_{50}	0.60 (0.53-0.671)	ICI Americas 1977
Cladoceran *Daphnia magna*	N/A	technical	static	48-h	N/A	EC_{50}	0.32 (0.24-0.44)	USEPA 1999c
Cladoceran *Daphnia magna*	1st instar	91%	static	48-h	42	EC_{50}	1.26 (0.63-2.49)	Mayer & Ellersieck 1986
Coho salmon *Oncorhynchus kisutch*	N/A	technical	static	96-h	N/A	LC_{50}	3.2 (2.2-4.8)	USEPA 1999c
Eastern oyster *Crassostrea virginica*	N/A	95.7%	F/T	96-h	N/A	EC_{50}	536	USEPA 1999c
Fathead minnow *Pimephales promelas*	0.60 g	91%	static	96-h	38	LC_{50}	2.3 (1.4-3.7)	Mayer & Ellersieck 1986
Fathead minnow *Pimephales promelas*	31-d	91.9 %	static	96-h	45.7	LC_{50}	16.0 (8.71-29.6)	Geiger et al. 1988
Fathead minnow *Pimephales promelas*	N/A	technical	static	96-h	N/A	LC_{50}	3 (1-9)	USEPA 1999c
Fiddler crab *Uca pugilator*	N/A	95.7%	static	96-h	N/A	LC_{50}	2.39 (1.82-3.25)	USEPA 1999c
Mayfly *Hexagenia bilineata*	nymph	technical	F/T	96-h	N/A	LC_{50}	0.1	ABC 1980a
Midge *Chironomus plumosus*	3rd instar	91%	static	48-h	42	EC_{50}	0.56 (0.18-1.65)	Mayer & Ellersieck 1986
Mysid *Mysidopsis bahia*	<24-h	93%	F/T	96-h	22.6‰	LC_{50}	0.02 (0.017-0.024)	Schimmel et al. 1983
Mysid *Mysidopsis bahia*	<24-h	99.99%	static	96-h	25‰	LC_{50}	0.095 (0.0.077-0.12)	Cripe 1994

Table B-4. cont.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness [b]	Effect	Values (95% C.L.)	Reference
Pink shrimp *Penaeus duorarum*	N/A	93%	F/T	96-h	25‰	LC_{50}	0.22 (0.06-0.79)	Schimmel et al. 1983
Rainbow trout *Oncorhynchus mykiss*	0.70 g	91%	static	96-h	44	LC_{50}	4.1 (3.2-5.2)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	0.80 g	91%	static	96-h	40	LC_{50}	2.9 (2-4.2)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	0.80 g	91%	static	96-h	40	LC_{50}	4.1 (3.2-5.3)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	0.80 g	91%	static	96-h	40	LC_{50}	6.0 (4.9-7.4)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	1.10 g	91%	static	96-h	40	LC_{50}	6.3 (5.2-7.6)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	1.10 g	91%	static	96-h	40	LC_{50}	7.0 (5.5-8.9)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	1.10 g	91%	static	96-h	40	LC_{50}	8.2 (6.3-10.)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	0.70 g	91%	static	96-h	40	LC_{50}	4.2 (3.5-5)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	0.70 g	91%	static	96-h	320	LC_{50}	5.2 (3.8-7.1)	Mayer & Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	N/A	technical	static	96-h	N/A	LC_{50}	3.2	FMC 1977
Rainbow trout *Oncorhynchus mykiss*	N/A	100%	static	96-h	N/A	LC_{50}	9.8 (7.7-12.6)	USEPA 1999c
Sheepshead minnow *Cyprinodon variegatus*	N/A	93%	F/T	96-h	22.1‰	LC_{50}	7.8 (6.2-10)	Schimmel et al. 1983
Stone crab *Menippe mercenaria*	larva	93%	static	96-h	N/A	EC_{50}	0.018 (0.01-0.03	USEPA 1999c
Striped mullet *Mugil cephalus*	N/A	93%	F/T	96-h	19‰	LC_{50}	5.5 (4.1-7.4)	Schimmel et al. 1983

[b] Water hardness is in mg/L as CaCO3.
[c] This tested the effect of low oxygen (53% saturation).
[d] N/A = Information not available.

Table B-5. Values (µg/L) from unaccepted test on the acute toxicity of bifenthrin to aquatic animals.

Species	Life Stage	Formula	Test Method [a]	Test Length	Effect	Values µg/L (95% C.L.)	Reference	Test Deficiencies [b]
Eastern oyster *Crassostrea virginica*	adult	88.35%	F/T	96-h	EC_{50}	> 2.15	ESE 1986	1

[a] F/T = Flow-through
[b] 1 = mortality range unacceptable
[c] N/A = Information not available.

Table B-6. Values (µg/L) from unaccepted tests on the acute toxicity of cypermethrin to aquatic animals.

Species	Life Stage	Formula	Test Method [a]	Test Length	Effect	Values µg/L (95% C.L.)	Reference	Test Deficiencies [b]
Amphipod Gammarus pulex	3-8 mm	85%	static	24-h	EC_{50}	0.04 (0.02-0.06)	Stephenson 1982	1
Beetle *Gyrinus natator*	adult	85%	static	24-h	EC_{50}	0.07 (0.04-0.2)	Stephenson 1982	1
Bluegill *Lepomis macrochirus*	N/A	30.4%	static	96-h	LC_{50}	0.2 (0.14-0.28)	FMC 1984a	2, 3, 4
Cladoceran *Daphnia magna*	<24-h	85%	static	24-h	EC_{50}	2 (1-3)	Stephenson 1982	1
Cladoceran *Daphnia magna*	N/A	30.4%	static	48-h	LC_{50}	0.29 (0.1-0.48)	FMC 1984b	2, 3, 4
Hemipteran *Corixa punctata*	adult	85%	static	24-h	EC_{50}	0.7 (0.4-2)	Stephenson 1982	1
Hydracarina *Piona carnea*	adult	85%	static	24-h	EC_{50}	0.02	Stephenson 1982	1
Isopod *Asellus aquaticus*	1st instar	91.5%	N/A	72-h	LC_{50}	0.009 (0.5-0.2)	Hamer et al. 1982	2
Isopod *Asellus aquaticus*	3-8 mm	85%	static	24-h	EC_{50}	0.02	Stephenson 1982	1
Mayfly *Cloeon dipterum*	larvae	85%	static	24-h	EC_{50}	0.07 (0.04-0.2)	Stephenson 1982	1
Midge *Chironomus thummi*	larvae	85%	static	24-h	EC_{50}	0.2 (0.1-0.3)	Stephenson 1982	1
Midge *Chaoborus flavicans*	larvae	85%	static	24-h	EC_{50}	0.03	Stephenson 1982	1
Mosquito *Aedes aegypti*	larvae	85%	static	24-h	EC_{50}	0.03	Stephenson 1982	1
Mysid *Mysidopsis bahia*	< 24-h	99.99%	static	96-h	LC_{50}	0.027 (0.024-0.031)	Cripe 1994	5
Pink shrimp *Penaeus duorarum*	3-5-d	99.99%	static	96-h	LC_{50}	11	Cripe 1994	5
Rainbow trout *Oncorhynchus mykiss*	fingerling	92-96%	static	24-h	LC_{50}	55	Coats and O'Donnell-Jeffrey 1979	1
Rainbow trout *Oncorhynchus mykiss*	fingerling	40%	static	24-h	LC_{50}	11	Coats and O'Donnell-Jeffrey 1979	1, 2

[a] F/T = Flow-through
[b] 1= Testing duration too short.
2 = Formulation not given or percent active ingredient toolow.
3 = Control survival not given or less than 90%.
4 = Mortality range unacceptable or not given.
5 = Value more than 10 times different than others.
[c] N/A = Information not available.

Table B-7. Values (µg/L) from unaccepted test on the acute toxicity of esfenvalerate to aquatic animals.

Species	Life Stage	Formula	Test Method	Test Length	Effect	Values µg/L (95% C.L.)	Reference	Test Deficiencies[a]
Cladoceran *Daphnia magna*	neonates	9.7%	static	48-h	EC_{50}	5.6	Baer 1992b	1

[a] 1 = Formulation not given or percent active ingredient too low.

Table B-8. Values (µg/L) from unaccepted tests on the acute toxicity of permethrin to aquatic animals.

Species	Life Stage	Formula	Test Method[a]	Test Length	Effect	Values µg/L (95% C.L.)	Reference	Test Deficiencies[b]
Atlantic salmon *Salmo salar*	juvenile	N/A	static	96-h	MATC	8.80	Zitko et al. 1979	1, 2, 3, 4
Atlantic salmon *Salmo salar*	juvenile	92.1%	static	96-h	LC_{50}	12	McLeese et al. 1980	4
Bullfrog *Rana catesbeiana*	tadpoles	N/A	static	96-h	LC_{50}	7033 (4129-8735)	Jolly et al. 1978	1, 4, 5
Channel catfish *Ictalurus punctatus*	0.02 g	N/A	static	96-h	LC_{50}	1.1 (0.53-2.43)	Jolly et al. 1978	1, 4, 5
Cladoceran *Daphnia magna*	< 24-h	25%	static	48-h	EC_{50}	0.84 (0.68-1)	Kent et al. 1995a	1
Crayfish *Procambarus clarkii*	0.05 g	N/A	static	96-h	LC_{50}	0.39 (0.25-0.91)	Jolly et al. 1978	1, 4, 5
Crayfish *Procambarus clarkii*	0.50 g	N/A	static	96-h	LC_{50}	0.62 (0.39-0.95)	Jolly et al. 1978	1, 4, 5
Flagfish *Jordanella floridae*	2-d	94.4%	pulse	96-h	LC_{50}	6.12 (3.98-6.12)	Holdway & Dixon 1988	3
Flagfish *Jordanella floridae*	4-d	94.4%	pulse	96-h	LC_{50}	11.16 (4.66-11.16)	Holdway & Dixon 1988	3
Flagfish *Jordanella floridae*	8-d	94.4%	pulse	96-h	LC_{50}	0.68 (0.46-0.68)	Holdway & Dixon 1988	3
Japanese medaka *Oryzias latipes*	30-d	88%	static	48-h	LC_{50}	0.011 (0.01-0.012)	Rice et al. 1997	6
Largemouth bass *Micropterus salmoides*	1.14 g	N/A	static	96-h	LC_{50}	8.50 (8.2-8.8)	Jolly et al. 1978	1, 4, 5
Lobster *Homerus americanus*	adult	N/A	static	96-h	MATC	7.00	Zitko et al. 1979	1, 2, 3
Lobster *Homerus americanus*	N/A	92.1%	static	96-h	LC_{50}	0.73	McLeese et al. 1980	4
Mosquitofish *Gambusia affinis*	0.25 g	N/A	static	96-h	LC_{50}	15 (12.9-17)	Jolly et al. 1978	1, 4, 5
Mosquitofish *Gambusia affinis*	N/A	N/A	static	48-h	LC_{50}	97.0	Mulla et al. 1978	7
Pink shrimp *Penaeus duorarum*	3-5-d	99.99%	static	96-h	LC_{50}	0.17 (0.15-0.19)	Cripe 1994	4
Pupfish *Cyprinodon macularius*	N/A	N/A	static	48-h	LC_{50}	5.0	Mulla et al. 1978	7
Rainbow trout *Oncorhynchus mykiss*	39-55mm	25%	F/T	96-h	LC_{50}	8.5 (6.9-11)	Kent et al. 1995b	1
Rainbow trout *Oncorhynchus mykiss*	N/A	99%	static	24-h	LC_{50}	0.018 (0.015-0.022)	Glickman et al. 1982	4, 7, 8
Rainbow trout *Oncorhynchus mykiss*	N/A	N/A	static	48-h	LC_{50}	6.0	Mulla et al. 1978	7
Rainbow trout *Oncorhynchus mykiss*	fingerling	92-96%	static	24-h	LC_{50}	135	Coats and O'Donnell-Jeffrey 1979	7
Rainbow trout *Oncorhynchus mykiss*	fingerling	25%	static	24-h	LC_{50}	61	Coats and O'Donnell-Jeffrey 1979	1, 7
Shrimp *Crangon septemspinosa*	N/A	92.1%	static	96-h	LC_{50}	0.13	McLeese et al. 1980	4

Table B-8. Cont.

Species	Life Stage	Formula	Test Method [a]	Test Length	Effect	Values µg/L (95% C.L.)	Reference	Test Deficiencies [b]
Tilapia Tilapia mossambica	N/A		static	48-h	LC_{50}	50.0	Mulla et al. 1978	7
White sucker *Catostomus commersoni*	13-d	94.4%	pulse	96-h	LC_{50}	0.184 (0.037-0.331)	Holdway & Dixon 1988	3
White sucker *Catostomus commersoni*	20-d	94.4%	pulse	96-h	LC_{50}	0.010 (0.006-0.014)	Holdway & Dixon 1988	3
White sucker *Catostomus commersoni*	26-d	94.4%	pulse	96-h	LC_{50}	3.668 (1.075-6.261)	Holdway & Dixon 1988	3

[a] F/T = Flow-through

[b] 1 = Formulation not given or percent active ingredient too low.
2 = LC_{50} values not determined.
2 = Control survival not given or less than 90%.
3 = Too few concentrations tested, must be five or greater.
4 = Test design unacceptable.
5 = Species not resident to North America.
6 = Mortality range unacceptable or not given.
7 = Test duration too short.

[c] N/A = Information not available.

APPENDIX C. Abstracts of Accepted and Unaccepted Chronic Toxicity Tests Reviewed for Hazard Assessment.

Accepted chronic toxicity tests- The following tests used accepted test methods.

EG&G Bionomics (1977b)- In 1977, a 246-d life-cycle flow-through chronic toxicity test was performed by the Aquatic Toxicology Laboratory in Wareham, Massachusetts on technical grade bifenthrin (95.7%) with fathead minnow fry *Pimephales promelas.* Five concentrations and water controls were tested in duplicate. Water quality parameters during the test were: temperature of 24 to 26°C; pH of 6.7 to 7.4; dissolved oxygen of 6.3 to 9.7 mg/L; and hardness of 26.2 to 41.8 mg/L as $CaCO_3$. The full life cycle LOEC was 0.41 µg/L and the NOEC was 0.30 µg/L.

Hansen et al. (1983) – In 1983, 28-d early life stage flow-through toxicity test was performed by the USEPA Gulf Breeze Environmental Research Laboratory in Gulf Breeze, Florida on permethrin (93%) with sheepshead minnows *Cyprinodon variegatus*. Six concentrations and solvent controls were tested in replicate. Water quality parameters during the test were: temperature of 30°C and salinity of 22-32 ‰. The LOEC and NOEC values for *C. variegatus* were 22 µg/L and 10 µg/L, respectively.

Little et al. (1993) – In 1991, a 90-d chronic flow-through toxicity test was performed by the U.S. Fish and Wildlife Service Laboratory in Columbia, Missouri on esfenvalerate (84%) with juvenile bluegill *Lepomis macrochirus*. Five concentrations and solvent controls were tested in duplicate. Water quality parameters during the test were measured weekly and found to be acceptable. The LOEC and NOEC values, based on survival, were 0.025 and 0.01 µg/L, respectively.

McAllister (1988) – In 1988, a 368-d lifecycle flow-through chronic toxicity test was performed by Analytical Biochemistry Laboratories in Columbia, Missouri on technical grade bifenthrin (96.2%) with fathead minnow *Pimephales promelas*. Five concentrations and solvent and water controls were tested in replicate. Water quality parameters during the test were: temperature of 23 to 25°C; pH of 7.8 to 8.2; dissolved oxygen of 3.9 to 8.7 mg/L; and hardness of 246 to 346 mg/L as $CaCO_3$. The full lifecycle NOEC, LOEC, and MATC for *P. promelas* were 0.040, 0.090, and 0.067 µg/L, respectively.

USEPA (1999c)- Between 1974 and 1994, several flow-through and static chronic toxicity tests were performed on technical grade cypermethrin, esfenvalerate, and permethrin, with a variety of aquatic organisms. These tests were reviewed and determined to have followed acceptable testing procedures. Water quality parameters were not listed in the database but are considered acceptable under USEPA guidelines. LOEC and NOEC values for tests with cypermethrin are found in Table C-2.

Unaccepted chronic toxicity tests-The following were unaccepted because they used unapproved testing methods and/or produced unaccepted results.

ABC (1980b)- In 1980, a 21-d chronic toxicity test was performed by Analytical Bio Chemistry Laboratories, Inc., Columbia, Missouri on ^{14}C-permethrin with *Daphnia magna*. Five concentrations and appropriate controls were tested. Water quality parameters, control survival and mortality range were not available but are considered acceptable. Total mortality occurred at the highest concentration (608 μg/L), and offspring production was reduced at 271 μg/L on day 14 and 21, and on day 21 at the concentration of 118 μg/L. The 21-d MATC for *D. magna* is estimated to be between 60 and 118 μg/L. This test was not accepted because the percent active ingredient was not given.

Table C-1. Values (μg/L) from accepted tests on the chronic toxicity of bifenthrin to aquatic animals.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness[b]	Effect	Values μg/L	Reference
Fathead minnow *Pimephales promelas*	life-cycle	95.7%	F/T	246-d	25-47	LOEC NOEC MATC	0.41 0.30 0.351	EG&G Bionomics 1977b
Fathead minnow *Pimephales promelas*	life-cycle	96.2%	F/T	368-d	246-346	LOEC NOEC MATC	0.090 0.050 0.067	McAllister 1988

[a] F/T = Flow-through
[b] Hardness expressed as mg/L $CaCO_3$

Table C-2. Values (μg/L) from accepted tests on the chronic toxicity of cypermethrin to aquatic animals.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness[b]	Effect	Values μg/L	Reference
Fathead minnow *Pimephales promelas*	early life	91.5%	F/T	30-d	N/A	LOEC NOEC MATC	0.33 0.14 0.24	USEPA 1999c

Table C-3. Values (μg/L) from accepted tests on the chronic toxicity of esfenvalerate to aquatic animals.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness[b]	Effect	Values μg/L	Reference
Bluegill *Lepomis macrochirus*	juvenile	84%	F/T	90-d	N/A[c]	LOEC NOEC MATC	0.025 0.01 0.02	Little et al. 1993

[a] F/T = Flow-through
[b] Hardness expressed as mg/L $CaCO_3$

Table C-4. Values (μg/L) from accepted tests on the chronic toxicity of permethrin to aquatic animals.

Species	Life Stage	Formula	Test Method [a]	Test Length	Salinity/ Hardness[b]	Effect	Values μg/L	Reference
Sheepshead minnow *Cyprinodon variegatus*	N/A	93%	F/T	28-d	22-32	LOEC NOEC	22 10	Hansen et al. 1983

[a] F/T = Flow-through
[b] Salinity expressed in ‰

Table C-5. Values (μg/L) from unaccepted tests on the chronic toxicity of permethrin to aquatic animals.

Species	Life Stage	Formula	Test Method	Test Length	Effect	Values μg/L	Test Reference	Deficiencies [b]
Cladoceran *Daphnia magna*	life cycle	N/A[a]	F/T	21-d	MATC	60-118	ABC 1980b	1, 2

[a] N/A = Information not available.
[b] 1 = Formulation not given or percent active ingredient too low.
2 = Control survival below 90%.