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HAZARD ASSESSMENT OF THE INSECTICIDE CARBOFURAN TO AQUATIC ORGANISMS IN THE SACRAMENTO RIVER SYSTEM

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PREFACE

The California Department of Fish and Game (CDFG) is responsible for fish and wildlife management programs and for the protection of fish and wildlife. The CDFG protects fish and wildlife from damage caused by pesticides through consultation as a member of the mandated California Department of Pesticide Regulation (DPR) Pesticide Registration and Evaluation Committee and Pesticide Advisory Committee. Through consultation with CDFG, 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, DPR contracted with CDFG for the assessment of the effects of pesticides on fish and wildlife and to facilitate the development of water quality criteria which will protect fish and wildlife.

This document is the third in a series of hazard assessments for pesticides used on rice which recommends studies and conditions necessary for the protection of fish and wildlife. Hazard assessments have also been prepared for the herbicides molinate and thiobencarb and the insecticide methyl parathion.

Hazard Assessment of the Insecticide Carbofuran to Aquatic Organisms in the Sacramento River System

by

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SUMMARY

An interim Water Quality Criterion (WQC) for protection of sensitive aquatic organisms from the insecticide carbofuran (Furadan^R) was developed for California's Sacramento River system. The discharge of rice pesticides into the Sacramento-San Joaquin Estuary lasts for 45 to 60 days from May through June. Although focused on effects from rice tailwater in the Sacramento Valley, this assessment may be useful for other crops and environments.

Sixty-one tests on the acute and chronic effects of carbofuran to aquatic plants and animals were evaluated. Insufficient data were available to calculate a Final Acute Value (FAV) for carbofuran according to Environmental Protection Agency (EPA) procedures; data on insects and amphipods were lacking. The most sensitive species tested in acute toxicity tests was the dungeness crab *Cancer magister*, with a 96-h EC_{50} value of 1.5 µg/L. Because of the data deficiency, an interim FAV, equal to the acute toxicity value of carbofuran for the dungeness crab, was proposed.

Similarly, sufficient reliable data were not available to calculate a Final Chronic Value (FCV) from either chronic values or using a Final Acute-to-Chronic Ratio (FACR). A chronic study with the cladoceran *Ceriodaphnia dubia* did not measure exposure levels, and a chronic study with dungeness crab used widely separated (ten-fold) exposure levels. A 28-day chronic test with the nonnative marine mysid *Mysidopsis bahia* did result in a No Observable Effect Concentration (NOEC) of 0.4 µg/L and a Lowest Observable Effect Concentration (LOEC) of 0.98 µg/L; however, there is no LC_{50} value for this species. These conditions produced imprecise ACR values. Because of these concerns, an interim FCV equal to the 70-d NOEC value of 0.5 µg/L carbofuran for the dungeness crab was proposed. Thus, an interim WQC of 0.5 µg/L carbofuran is proposed.

Carbofuran exhibits additive acute toxicity with malathion and methyl parathion, two insecticides used on rice and found concurrently in agricultural drain water. Thus, an acceptable level of carbofuran in the presence of these other two insecticides may be lower than that proposed here. Additional study is needed to further characterize additive toxicity among all pesticides used on rice taking into consideration both lethal

and sublethal effects.

Concentrations of carbofuran were first measured in the agricultural drains in 1987. Maximum concentrations of carbofuran in drains have declined from 13 µg/L in 1987 to 0.6 µg/L in 1991. Concentrations of carbofuran up to 2.1 µg/L have been detected in the Sacramento River near the city of Sacramento. These monitoring data indicate that a hazard to sensitive aquatic invertebrates may have existed in the agricultural drains, especially prior to 1991. Maximum concentrations (in µg/L) of carbofuran in the Colusa Basin Drain exceeded the criterion in 1987 (13), 1988 (4.4), 1989 (1.5), 1990 (1.1) and 1991 (0.6). Similar data for the Sacramento River suggest that a hazard may have existed prior to 1988 but no or little hazard to aquatic invertebrates currently exists; maximum concentrations were 2.1 µg/L carbofuran in 1987 but <1.0 µg/L carbofuran since 1988.

The hazard assessment procedure is a reiterative process by which new data are evaluated to refine water quality criteria. A new criterion will be generated when the necessary data become available. Acceptable acute and chronic tests are needed to better define the WQC and the effects of carbofuran on the environment. Acute toxicity tests with an insect and an amphipod are required to calculate a FAV. It is also required that the chronic test with the cladoceran *Ceriodaphnia dubia* be repeated with measured exposure levels. It is recommended that a chronic test with the estuarine mysid *Neomysis mercedis* be completed because of the their sensitivity to carbofuran and importance in the aquatic environment of the Sacramento-San Joaquin Estuary.

TABLE OF CONTENTS

	Page
PREFACE	i
SUMMARY	ii
TABLE OF CONTENTS	iv
LIST OF TABLES	v
ACKNOWLEDGMENTS	vi
INTRODUCTION	1
ENVIRONMENTAL FATE	4
ACUTE TOXICITY TO AQUATIC ANIMALS	5
CHRONIC TOXICITY TO AQUATIC ANIMALS	9
TOXICITY TO AQUATIC PLANTS	12
HAZARD ASSESSMENT	12
Water Quality Criterion	12
Hazard to Aquatic Animals	13
Data Requirements	14
LITERATURE CITED	17
APPENDIX A. Abstracts of accepted and unaccepted acute toxicity tests reviewed for hazard assessment	27
APPENDIX B. Abstracts of accepted and unaccepted chronic toxicity tests reviewed for hazard assessment	43
APPENDIX C. Abstracts of aquatic plant toxicity tests reviewed for hazard assessment	50
APPENDIX D. Procedures used by the California Department of Fish and Game to assess pesticide hazards to aquatic resources	53

LIST OF TABLES

		Page
1.	Carbofuran use on rice in California, 1979-1990. Data from Department of Pesticide Regulation Pesticide Use Report Database	2
2.	Maximum concentrations (µg/L) of carbofuran detected by CDFG in the Colusa Basin Drain and the Sacramento River at Village Marina, 1987 to 1991. 1991 data from CDFG (unpublished data), 1989 and 1990 data from Harrington and Lew (1992), 1987 and 1988 data from Harrington and Lew (1989)	4
3.	Eight species categories recommended by EPA (1985) for deriving freshwater and saltwater Final Acute Values (FAV)	7
4.	Nine species categories for deriving a Final Acute Value for the Sacramento-San Joaquin Estuary and corresponding animal used for carbofuran.	7
5.	Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on carbofuran	8
6.	Acute-to-Chronic Ratio (ACR) Values for invertebrates and fish exposed to carbofuran	11
7.	Minimum required and suggested data for a complete hazard assessment of carbofuran to aquatic animals	16
A-1.	Values (µg/L) from accepted tests on the acute toxicity of carbofuran to aquatic animals	38
A-2.	Values (µg/L) from unaccepted tests on acute toxicity of carbofuran to aquatic animals	41
B-1.	Values (µg/L) from accepted tests on chronic toxicity of carbofuran to aquatic animals	48
B-2.	Values (µg/L) from unaccepted tests on chronic toxicity of carbofuran to aquatic animals	49
C-1.	Values (µg/L) from tests on toxicity of carbofuran to aquatic plants	52

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INTRODUCTION

Carbofuran (Furadan[R]) is an insecticide registered for use in California on a variety of crops, including rice, sugar beets, alfalfa, and field corn. In a study of carbofuran use in Colusa, Glenn, and Yolo counties conducted by the California Department of Pesticide Regulation (DPR), researchers concluded that the major portion of carbofuran residues found in agricultural drain water of the Sacramento Valley probably originated from rice. This was concluded because carbofuran use on rice was much greater than on any other crop, and the volume of runoff water from rice fields was greater (Nicosia et al. 1990). Use between 1980 and 1990 has varied from approximately 30,000 to 50,000 kilograms (kg) carbofuran (active ingredient [a.i.]) on 40,000 to 80,000 hectares of rice in California (Table 1).

For the past decade there has been concern over the hazards of rice pesticides to aquatic organisms in the Sacramento-San Joaquin Estuary. The discharge of rice pesticides including carbofuran into the Sacramento-San Joaquin Estuary lasts for 45 to 60 days from May through June. Assessments of rice pesticides have identified hazards to aquatic organisms in the agricultural drains and the Sacramento-San Joaquin Estuary (Cornacchia et al. 1984; Finlayson and Faggella 1986; Harrington 1990; State Water Resources Control Board 1990, Menconi and Harrington 1992). The Central Valley Regional Water Quality Control Board (CVRWQCB) found toxicity of Colusa Basin Drain water to aquatic invertebrates in 1988 and 1989 (CVRWQCB 1988, 1989), and the California Department of Fish and Game (CDFG) found toxicity in 1990 (Finlayson et al. 1991). Norberg-King et al. (1991) identified carbofuran and methyl parathion as possible causes of toxicity to cladocerans in Colusa Basin Drain water, and Finlayson et al. (1991) identified methyl parathion toxicity in the Colusa Basin Drain water. The insecticides carbofuran, methyl parathion, and malathion used on rice have also demonstrated additive acute toxicity (Fujimura et al. 1991a).

Table 1. Carbofuran use on rice in California, 1979-1990. Data from Department of Pesticide Regulation Pesticide Use Report Database.

year	kg[a]	ha
1990[b]	28,393	54,002
1989	NA[c]	NA
1988	26,770	53,418
1987	26,126	50,759
1986	25,728	41,039
1985	26,483	39,394
1984	40,167	53,821
1983	33,090	45,681
1982	52,490	80,706
1981	49,208	83,519
1980	37,234	62,458
1979	13,188	23,202

[a] active ingredient (a.i.)
[b] January to June 1990
[c] not available

The CVRWQCB (1990) developed a performance goal of 0.4 µg/L for carbofuran in rice return water. Performance goals are intended to bring surface water pesticide concentrations down to levels that approach water quality objectives. The CVRWQCB reviews new information as it becomes available and may revise performance goals (CVRWQCB 1992).

The CDFG first measured concentrations of carbofuran in the agricultural drains in 1987. From 1987 to 1990, maximum concentrations of carbofuran detected by CDFG in the Colusa Basin Drain have declined from 13 to 0.6 µg/L, and maximum concentrations in the Sacramento River at Village Marina have declined from 2.1 to 0.4 µg/L (Table 2). In 1990 and 1991, carbofuran was present in the Colusa Basin Drain for a period of more than two months, a sufficient length of time to result in chronic exposures for aquatic organisms.

The hazard assessment procedure compares measured environmental concentrations with toxic effects likely to result from those exposures. Environmental fate data including studies on hydrolysis and photodegradation in soil, water, and air; aerobic and anaerobic soil and aquatic metabolism; volatility; leaching; sorption; and uptake by plants and animals were also reviewed. These data were used to determine pesticide degradation rate, environmental transport, and potential to reach nontarget organisms.

Toxic effects of carbofuran to aquatic animals were determined by evaluating tests listed in the published literature and public and corporate laboratory reports. Sources of published literature included CDFG Pesticide Investigations Unit library, the State of California Resource Agency library, and college and university libraries. CDFG also obtained corporate laboratory reports from confidential files which were submitted to DPR in support of pesticide registration.

Available data on carbofuran were evaluated for conformance with specific criteria, outlined by Harrington (1990). Each study was screened for compliance of test methods used with procedures adapted by the EPA (1985) and the American Society of Testing and Materials (ASTM 1980, 1987a, 1987b, 1988a, 1988b, 1989). While tests did not have to comply with all requirements, tests were rejected if they did not observe certain fundamental protocols, such as maintaining proper organism survival in a control treatment, testing only with healthy, unstressed organisms, and using appropriate testing procedures. Test descriptions that did not contain sufficient information for proper evaluation were rejected if attempts to obtain the necessary data from the original researcher failed.

Table 2. Maximum concentrations (µg/L) of carbofuran detected by CDFG in the Colusa Basin Drain and the Sacramento River at Village Marina, 1987 to 1991. 1991 data from DPR (1992), 1989 and 1990 data from Harrington and Lew (1992), 1987 and 1988 data from Harrington and Lew (1989).

Location	Year	Maximum concentration
Colusa Basin Drain		
	1991	0.6
	1990	1.1
	1989	1.5
	1988	4.4
	1987	13.0
Sacramento River		
	1991	<0.4
	1990	0.6
	1989	<1.0
	1988	<1.0
	1987	2.1

ENVIRONMENTAL FATE

Hydrolysis is the primary breakdown mechanism for carbofuran. Carbofuran is stable in water at low and neutral pH but rate of hydrolysis increases rapidly with increasing pH. Carbofuran has a hydrolysis $t_{1/2}$ of 35 days at pH 7.0 and 350 days at pH 6.0. Carbofuran is also degraded through photolysis and is not likely to accumulate in water exposed to sunlight. The $t_{1/2}$ of carbofuran in sediment is between one and two months. Carbofuran does not bioaccumulate (National Research Council of Canada 1979). There have been no detectable residues of carbofuran in catfish collected from the Colusa Basin Drain during several rice growing seasons (Harrington and Lew 1992, 1989).

Based on certain physicochemical properties specified by the California Pesticide Contamination Prevention Act (Stats. 1985, Ch. 1298, Sec. 1), carbofuran is mobile in water and soil. These properties include low soil adsorption coefficient, relatively long hydrolysis and anaerobic soil metabolism half-lives, and high water solubility (DPR 1991). These properties also account for the season-long occurrence of carbofuran in agricultural drain waters containing rice tailwater (Finlayson et al. 1991).

Certain agronomic practices and conditions increase the persistence of carbofuran in soil, including soil incorporation, use of granular formulations, high soil organic matter, low soil pH, and low soil temperature and moisture (DPR 1990). Numerous waterfowl poisonings have shown that carbofuran granules applied during the spring to rice field berms or other areas that remain dry during the rice growing season can cause wildlife mortality the following fall (E.E. Littrell, CDFG, personal communication, 1992).

ACUTE TOXICITY TO AQUATIC ANIMALS

The EPA (1985) guidelines recommend eight categories of freshwater organisms from which data should be available for deriving a freshwater Final Acute Value (FAV), and eight categories of saltwater organisms for deriving a saltwater FAV (Table 3). The EPA (1985) document does not discuss deriving an estuarine FAV. Because the Sacramento River system includes the Sacramento-San Joaquin Estuary, the FAV must protect both fresh and saltwater species. Previous hazard assessments on the pesticides molinate and thiobencarb (Harrington 1990) and methyl parathion (Menconi and Harrington 1992) combined values for freshwater, saltwater, and estuarine organisms. The EPA freshwater and saltwater lists of recommended categories of organisms were combined into a list of nine species categories (Table 4). Although a deviation from EPA (1985) guidelines, the combined list meets EPA taxa requirements, both freshwater and saltwater species are represented, and the combined list represents a broader spectrum of sensitivity to carbofuran.

Fifty tests on the acute toxicity of carbofuran to aquatic animals were evaluated for use in deriving the FAV using CDFG guidelines described by Harrington (1990, 1991). Twenty-eight of these tests were determined to be acceptable for use in deriving the FAV (Appendix A). Values from accepted tests are tabulated in Table A-1; values from unaccepted tests are tabulated in Table A-2. Acute toxicity values ranged from 1.5 µg/L, the 96-h EC_{50} value for dungeness crab *Cancer magister* to >10,000 µg/L, the 48-h EC_{50} value for eastern oyster *Crassostrea virginica*.

Acceptable acute toxicity tests were available for organisms from seven of the nine combined freshwater and saltwater species categories adapted from EPA (1985) recommendations. To fill the two remaining categories, acceptable acute tests are needed for at least one insect and either a second insect or a second species in a phylum other than Arthropoda or Chordata.

Acute toxicity values from accepted tests were ranked (Table 5). The lowest four values are the most significant determinants of the FAV (Appendix D). EPA (1985) procedures specify that the range between the highest and lowest of the four lowest Genus Mean Acute Values (GMAVs) should not be greater than a factor of 10. The GMAV for bluegill (88 µg/L) is greater than the next lowest GMAV (mysid, 3.6 µg/L) by a factor greater than 20. The filling of the existing data gaps will likely result in the range of four lowest values being within a factor of 10. Therefore, the lowest GMAV (1.5 µg/L) will be used as the interim FAV until the two data gaps have been filled.

Table 3. Eight species categories recommended by EPA (1985) for deriving freshwater and saltwater Final Acute Values (FAV).

Freshwater FAV	Saltwater FAV
1. One Salmonid	1, 2. Two families in phylum Chordata
2. Another family in class Osteichthyes	
3. Another family in phylum Chordata	3. One family not in Arthropoda or Chordata
4. One family not in phylum Arthropoda or Chordata	4, 5, 6. Three other families not in Chordata
5. One insect family or any phylum not already represented	
6. One planktonic crustacean	
7. One benthic crustacean	7. Mysidae or penaeidae family
8. One insect	8. One other family not already represented

Table 4. Nine species categories for deriving a Final Acute Value for the Sacramento-San Joaquin Estuary and corresponding animal used for carbofuran.

Category of Species	Animal
1. Family Salmonidae	Rainbow trout
2. Another family in class Osteichthyes	Bluegill

3.	Another family in phylum Chordata	Yellow perch
4.	Family not in phylum Arthropoda or Chordata	Eastern Oyster
5.	Family Mysidae or Penaeidae	Mysid
6.	One planktonic crustacean	Cladoceran
7.	Benthic crustacean	Dungeness crab
8.	An insect	[a]
9.	Another insect, or a phylum not represented	[a]

[a] acceptable test not available for this category

Table 5. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on carbofuran.

Rank	GMAV (µg/L)	Species
1	1.5	Dungeness crab[a,b] *Cancer magister*
2	2.6	Cladoceran[b] *Ceriodaphnia dubia*
3	3.6[c]	Mysid[a,b] *Neomysis mercedis*
4	88	Bluegill[a] *Lepomis macrochirus*
5	164	Lake trout *Salvelinus namaycush*
6	193[c]	Striped bass[a,b] *Morone saxatilis*
7	226[c]	Yellow perch *Perca flavescens*
8	248[c]	Channel catfish[a] *Ictalurus punctatus*
9	386	Sheepshead minnow *Cyprinodon variegatus*
10	396[c]	Brown trout *Salmo trutta*
11	536[d]	Genus: *Oncorhynchus*
		Rainbow trout (477)[a] *Oncorhynchus mykiss*
		Coho salmon (530) *Oncorhynchus kisutch*
		Chinook salmon (610)[a] *Oncorhynchus tshawytscha*
12	1,270	Fathead minnow *Pimephales promelas*
13	>10,000	Eastern oyster *Crassostrea virginica*

[a] species occurs in Sacramento-San Joaquin Estuary.
[b] derived from most sensitive life stage toxicity value(s).
[c] geometric mean of values from several toxicity tests on this species.

[d] geometric mean of values from several toxicity tests on this genus.

CHRONIC TOXICITY TO AQUATIC ANIMALS

Eleven chronic toxicity tests on carbofuran were evaluated for acceptability for use in deriving the Final Chronic Value (FCV). Values from the seven accepted tests and four unaccepted tests are tabulated in Tables B-1 and B-2, respectively.

The No Observable Effects Concentration (NOEC) values from acceptable tests ranged from 0.4 µg/L to 25.0 µg/L for 28-d exposure for *Mysidopsis bahia* and 90-d exposure to dungeness crab *C. magister* adults, respectively. The Lowest Observable Effects Concentration (LOEC) values ranged from 0.98 µg/L to 250 µg/L for *M. bahia* and dungeness crab adults, respectively. Maximum Acceptable Toxicant Concentration (MATC) values $(NOEC \times LOEC)^{1/2}$ ranged from 0.63 to 79 µg/L for *M. bahia* and dungeness crab adults, respectively.

The EPA (1985) specifies two methods for calculating a Final Chronic Value (FCV). If chronic toxicity data are available for all the categories of organisms specified for deriving the FAV, the same method used for calculating the FAV may be used for the FCV. If insufficient data are available, the FCV is obtained by dividing the FAV by a Final Acute-to-Chronic Ratio (FACR). The FACR is usually calculated as the geometric mean of ACR values from a minimum of three species, including a fish, an invertebrate, and an acutely sensitive species. Acceptable chronic toxicity tests were available for the three species categories. However, there are complete (acute and chronic values) data for only one invertebrate species, the dungeness crab. There is no acute value for the mysid *M. bahia*. Invertebrates are the most sensitive to carbofuran. Additionally, the NOEC and the LOEC values for the dungeness crab were separated by an order of magnitude, resulting in imprecise MATC and ACR values. The LOEC is normally only twice the NOEC.

As with other organophosphate and carbamate insecticides, the ACR values appear to increase with increasing acute values (Table 6). This is consistent with other observations on insecticides which show acute and chronic toxicity to invertebrates to be similar (Norberg-King et al. 1991). EPA (1985) procedures specify that if ACR values increase or decrease with acute toxicity values, then the FACR should be calculated as the geometric mean of the ACR values for only those species whose acute toxicity values are close (within a factor of 10) to the FAV. The ACR values from dungeness crab test results were used to estimate a FACR value of 1.5 ($[0.9 \times 2.4]^{1/2}$). However EPA (1985) procedures recommend against using a FACR lower than two, so two was used as the FACR.

The FCV could be derived by dividing the interim FAV by the FACR, resulting in a value of 0.75 µg/L (1.5/2). However, this value is higher than the NOEC values of 0.4 µg/L for the marine mysid *M. bahia* and 0.5 µg/L for the dungeness crab zoeae. We propose to lower the FCV to a level demonstrated to not have an adverse effect on an important indigenous species, the dungeness crab. Therefore, in lieu of additional data, the NOEC for dungeness crab zoeae (0.5 µg/L) was used as the interim FCV.

Table 6. Acute-to-Chronic Ratio (ACR) Values for invertebrates and fish exposed to carbofuran.

Species	LC_{50} (µg/L)	MATC (µg/L)	Reference(s)	ACR
Dungeness crab zoeae *Cancer magister*	1.5	1.6	Caldwell 1977	0.9[a]
Dungeness crab adults *Cancer magister*	190	79	Caldwell 1977	2.4[a]
Sheepshead minnow *Cyprinodon variegatus*	386	33.6	Parrish et al. 1977	11.5
Chinook salmon *Oncorhynchus tshawytscha*	610	12.5	Faggella et al. 1990 Fujimura et al. 1990	48.8

[a] These ACRs were used to derive the calculated ACR

TOXICITY TO AQUATIC PLANTS

Four tests on carbofuran toxicity to aquatic plants were evaluated for acceptability in deriving the Final Plant Value (FPV). The FPV is the lowest toxicity value demonstrated in tests with biologically important endpoints (EPA 1985). None of the tests indicated that carbofuran was more toxic to aquatic plants than to aquatic animals; LOEC values were $\geq$100 µg/L. Thus, levels protective for aquatic animals will also be protective for aquatic plants.

HAZARD ASSESSMENT

Water Quality Criterion

The most sensitive species tested for acute toxicity were the dungeness crab *C. magister* with a GMAV of 1.5 µg/L, the cladoceran *Ceriodaphnia dubia* with a GMAV of 2.6 µg/L, and the mysid *Neomysis mercedis* with a GMAV of 3.6 µg/L. Mysids, cladocerans, and the dungeness crab all occur in the Sacramento-San Joaquin Estuary, and the CDFG WQC guidelines are intended to provide full protection to sensitive resident species (Harrington 1990). The interim FCV of 0.5 µg/L carbofuran would provide protection for these species and is proposed as the interim WQC. The WQC of 0.5 µg/L proposed here approximates the performance goal for carbofuran of 0.4 µg/L established by the CVRWQCB (1990).

The WQC represents maximum rather than average concentrations. Organisms normally respond to average concentrations. Maximum concentrations of rice pesticides including carbofuran have been shown to be approximately twice the average concentration (Finlayson et al. 1991) and therefore, the WQC provides an inherent two-fold safety margin.

The interim WQC is based on the toxicity of carbofuran alone. Because carbofuran exhibits additive toxicity with malathion and methyl parathion (Fujimura et al. 1991a), two other rice insecticides frequently found in Sacramento Valley waterways during the time that carbofuran is present, reevaluation of the WQC may be necessary. An acceptable level of carbofuran in the presence of the other two insecticides would be less than the WQC proposed here because of additive toxicity. Additive toxicity occurs when the observed toxicity for a mixture is equal to the sum of the potential toxicity of the individual components. Acceptable levels (AL) in surface water can be represented by the equation: AL/WQC (carbofuran) + AL/WQC (methyl parathion) + AL/WQC (malathion) = 1. This approach was used by Harrington (1990) in assessing rice herbicide toxicity and by CVRWQCB (1990) in determining deleterious levels of pesticides in surface waters. No information exists on the influence rice herbicides have on the toxicity of rice insecticides and vice versa. Reevaluation of the interim WQC will be necessary when the acute and chronic toxicity data gaps (see below) are filled.

Hazard to Aquatic Animals

The species demonstrating the greatest sensitivity in acute toxicity tests were the saltwater dungeness crab *C. magister* with a 96-h EC_{50} value of 1.5 µg/L and the freshwater cladoceran *C. dubia* with a 48-h EC_{50} value of 2.6 µg/L (Table A-1). *M. bahia* demonstrated the greatest sensitivity in chronic toxicity tests, with a 28-d NOEC value of 0.4 µg/L (Table B-1).

Carbofuran has been used on rice since 1979, with use ranging between 13,188 kg on 23,202 ha in 1979 to 52,490 kg on 83,519 ha in 1982. CDFG first measured concentrations of carbofuran in the agricultural drains in 1987. Concentrations of carbofuran were detected (>0.1 µg/L) in the Colusa Basin Drain in 1990 for a period of more than two months during mid-April through late June (Finlayson et al. 1991). Maximum concentrations of carbofuran in the Colusa Basin Drain have declined from 13.0 µg/L in 1987, to 4.4 µg/L in 1988 (Harrington and Lew 1989), to 1.5 µg/L in 1989, to 1.1 µg/L in 1990 (Harrington and Lew 1992), and to 0.6 µg/L in 1991 (CDFG unpublished data 1991). Maximum concentrations of carbofuran in the Sacramento River have also declined from 2.1 µg/L in 1987 to <1.0 µg/L in 1988 (Harrington and Lew 1989) and 1989, to 0.6 µg/L in 1990 (Harrington and Lew 1992) and to <0.4 in 1991 (DPR 1992).

Although carbofuran levels in the agricultural drains and the Sacramento River have clearly declined since 1987, the data indicate that a hazard to sensitive aquatic invertebrates in the agricultural drains may have existed because environmental levels had exceeded acute toxicity levels for the cladoceran *C. dubia* and the mysid *N. mercedis*, especially in 1987 and 1988. Some of the agricultural drains are contiguous with the Sacramento River and contain water and organisms originating from the Sacramento River. A similar hazard to sensitive aquatic invertebrates in the Sacramento River does not appear to have existed, especially since 1987. Concentrations of carbofuran in the Sacramento River have generally been below detection levels (<0.1 µg/L to <1.0 µg/L) since 1987. Many sensitive aquatic invertebrates inhabit the upper Sacramento River including mysids and several species of cladocerans and copepods (L. Mecum, Bay- Delta Special Projects Division, California Department of Fish and Game, unpublished data, December 7, 1992).

Data Requirements

Data were available for seven of the nine species categories adapted from EPA (1985) recommendations for use in deriving an FAV (Table 3). Acceptable acute toxicity tests are necessary for one insect and a second insect or a species in a phylum other than Arthropoda or Chordata (Table 7). Acute toxicity tests should be performed with the stonefly *Pteronarcys* *californica* and the amphipod *Gammarus* sp., species resident in the Sacramento River drainage and Sacramento-San Joaquin Estuary. A chronic toxicity test with the cladoceran *C. dubia* using measured concentrations of carbofuran is necessary to better define the FACR. An acute toxicity test with the mysid *M. bahia*, or a chronic toxicity test with the mysid *N. mercedis* are recommended to further refine the FACR and WQC.

Table 7. Minimum required and suggested data for a complete hazard assessment of carbofuran to aquatic animals.

Species[a]	Acute Test	Chronic Test
Stonefly *Pteronarcys californica*	required	-----
Scud *Gammarus* sp.	required	-----
Cladoceran *Ceriodaphnia dubia*	-----	required
Mysid[b] *Mysidopsis bahia*	suggested	------
Mysid[b] *Neomysis mercedis*	-----	suggested

[a] These are the most desirable species to test, but other resident species that fulfill EPA data recommendations would also be acceptable.
[b] Either an acute toxicity test with *M. bahia* or a chronic toxicity test with *N. mercedis* is suggested.

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APPENDIX A. Abstracts of accepted and unaccepted acute toxicity tests reviewed for hazard assessment.

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

Brandt et al. (1992) - In 1988 and 1990, 96-h flow-through acute toxicity tests were conducted by the California Department of Fish and Game (CDFG) on carbofuran technical (98.1% active ingredient) on juvenile and neonate mysid *Neomysis mercedis* (two tests for each life stage). Testing standards from ASTM (1988b) were generally used. Five concentrations of carbofuran were tested in replicate and solvent controls were used. Water quality parameters during the tests were: temperature of 17 $\pm$ 0.5^{o}C, dissolved oxygen of 90-100% of saturation, pH of 8.2, and hardness of 250-400 mg/L as $CaCO_3$. Carbofuran exposure levels were measured twice with an average measured concentration of 92% of nominal. Control survival was greater than 90% in all cases. The 96-h LC_{50} values for juveniles were 21 and 27 µg/L. The 96-h LC_{50} values for neonates were 4.7 and 2.7 µg/L.

Caldwell (1977), Caldwell (pers. comm.) - In 1973 and 1974, 96-h static toxicity tests were conducted by U.S. Environmental Protection Agency (EPA) on carbofuran technical (% active ingredient not given) with first instar zoeae and adult dungeness crabs *Cancer magister*. Six concentrations of carbofuran were tested and there were acetone and water controls. Water quality parameters during the tests were: temperature of 13 ^{o}C, pH of 7.8 (zoeae) and 7.5 (adult), dissolved oxygen of >7.0 mg/L (zoeae) and 6.0 mg/L (adult), and salinity of 25 $^{o}/_{oo}$. Control survival and the measurement of carbofuran exposure levels were not mentioned. The 96-h LC_{50} values were 2.5 µg/L for zoeae and 190 µg/L for adults and the 96-h EC_{50} value based on inhibition of swimming as effect criterion was 1.5 µg/L for zoeae.

Faggella et al. (1990) - In 1988, a 96-h flow-through toxicity test was conducted by CDFG on carbofuran technical (98.1% active ingredient) with chinook salmon *Oncorhynchus tshawytscha*. ASTM (1988b) test methods were used. Five concentrations of carbofuran were tested in duplicate and a solvent control was included. Water quality parameters during the test were: temperature of 10.3 ^{o}C, Ph of 8.05, dissolved oxygen of 10.1 mg/L, hardness of 130 mg/L, and alkalinity of 111 mg/L. Control survival was >90%. Carbofuran exposure levels were measured at 24 and 72 hours. The 96-h LC_{50} value was 610 µg/L for carbofuran.

FMC (1985c) - In 1985, a 48-h static toxicity test was conducted by Environmental Science and Engineering, Inc. on carbofuran technical (96.1%) with Eastern oyster *Crassostrea virginica* larvae. Internal lab testing procedures were used. A geometric series of six concentrations of carbofuran (dilution factor of 0.6) were tested in replicate and solvent and seawater controls were used. Water quality parameters during the tests were: temperature of 22 $\pm 1^{o}C$, pH of 8.0-8.1, dissolved oxygen of 5.3-6.6 mg/L, and salinity of 21 $^{o}/_{oo}$. Control survival was 100% in both controls. The measurement of carbofuran exposure levels was not mentioned. The 48-h EC_{50} values based on a reduction in the number of normal larvae as effect criterion was >5.0 mg/L, the highest concentration tested.

Fujimura et al. (1991b) - In 1988 and 1989, four 96-h acute toxicity tests were conducted by CDFG on carbofuran technical (98.1% active ingredient) with larval and juvenile striped bass *Morone saxatilis*. Test methods recommended by ASTM (1988b) were generally followed. Five concentrations of carbofuran were tested in replicate and solvent controls were used. Water quality parameters during the tests were: temperature of 17-19^{o}C, Ph of 7.8-8.2, and hardness of 367-470 mg/L as $CaCO_3$. Carbofuran exposure levels were measured at 24 and 72 hour intervals during the 96-h tests. Control survival varied from 90 to 100%. The 96-h LC_{50} values varied between 130 to 180 µg/L for juveniles and 370 µg/L for larvae.

Mayer and Ellersieck (1986), Dwyer and Sappington (pers. comm.) - From 1965 to 1985, 96-h static and flow-through toxicity tests were conducted by the Columbia National Fisheries Laboratories of the U.S. Fish and Wildlife Service on carbofuran technical (99-100%) with coho salmon *Oncorhynchus kisutch*, steelhead (or rainbow) trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, fathead minnow *Pimephales promelas*, bluegill *Lepomis macrochirus*, lake trout *Salvelinus namaycush*, and yellow perch *Perca flavescens*. ASTM and EPA testing procedures were generally followed. Four or more concentrations of carbofuran were tested in replicate and a solvent (acetone) control was used. Water quality parameters during the tests averaged: pH of 7.1-9.5 and hardness of 40-314 mg/L $CaCO_3$. Carbofuran exposure concentrations were measured at 24-h intervals. The 96-h LC_{50} values (in µg/L) were: coho salmon 530 (static), rainbow trout 380 and 600 (both static), brown trout 560 (static) and 280 (flow-through), lake trout 164 (flow-through), fathead minnow 1,990 and 872 (both static) and 1,180 (flow-through), channel catfish 248 (static), bluegill 88 (static), and yellow perch 240, 120 and 400 (all static). Although dissolved oxygen levels were not given, these tests were accepted because ASTM and EPA procedures were used and because of the reputation of the laboratories.

Norberg-King et al. (1991), Norberg-King (pers. comm.) - In 1990, a renewal acute toxicity test was performed on technical carbofuran (98.1% active ingredient) with cladoceran *Ceriodaphnia dubia*. EPA (1989) test methods were used. Five concentrations of carbofuran were tested (dilution factor 0.5) and a water control was included. Water quality parameters were: temperature of 25$\pm$ 1°C, dissolved oxygen levels "adequate", pH of

7.9 and hardness of 45-50 mg/L as $CaCO_3$. Carbofuran exposure levels were not measured. Control survival was 100%. The 48-h LC_{50} value was 2.6 µg/L. None of the test concentrations induced partial mortality, and therefore confidence limits were not calculated.

Parrish (1977) - In 1974 and 1975, a 96-h intermittent flow toxicity test was conducted by Bionomics, Inc. (under contract to EPA) on carbofuran technical (99%) with sheepshead minnow *Cyprinodon variegatas*. The bioassay methodology of APHA (1976) and EPA (1975) were used. Five concentrations of carbofuran were tested in replicate and a solvent control was used. Water temperature was 30 $\pm 1^{o}$ C. Carbofuran exposure levels ranged from 18-24% of nominal. Control survival was 100%. The 96-h LC_{50} value was 386 µg/L .

Unaccepted acute toxicity tests - The following tests did not use accepted test methods and/or produce accepted results.

Brown et al. (1979) - In 1978, 96-h static and intermittent flow toxicity tests were conducted at Texas A & M University on carbofuran technical (99%) with 6-week old catfish *Ictalurus punctatus*. APHA (1971) testing procedures were followed. Tap and rice paddy water were used for dilution water (two paddy water tests for static conditions). Number of carbofuran concentrations, measuring carbofuran concentrations, and control survival were not mentioned. Concentrations of carbofuran were tested in replicate. Water quality parameters during the tests were: temperature of 23 ^{o}C, salinity of 0.5 $^{o}/_{oo}$ and pH of 8.5 (tap water) and 6.4 (paddy water), and "adequate" dissolved oxygen levels. The 96-h LC_{50} values under static conditions were: 1,420 µg/L (tap water), 130 µg/L (paddy water) and 370 µg/L (paddy water). The 96-h LC_{50} values under flow-through conditions were: 510 µg/L (tap water) and 480 µg/L (paddy water). These tests were not used due to lack of information on test procedures and results, including control survival, number and range of toxicants tested, and dissolved oxygen levels. Only the test results from tap water are listed in Table A-2.

Carter and Graves (1973) - In 1973, 96-h and 24-h static tests were conducted on carbofuran (formulation not given) with White River crawfish *Procambarus acutus*, bluegill *Lepomis macrochirus*, mosquitofish *Gambusia affinis*, channel catfish *Ictalurus punctatus*, and bullfrog *Rana catesbeiana* tadpoles. APHA testing procedures were used. Tests were performed on 5 replicate concentrations of carbofuran for crawfish and 2 replicate concentrations for the other species. Water quality parameters during the test were: temperature of 23-26 ^{o}C, and dissolved oxygen of 7-10 mg/L. Controls, control survival, exposure regime, and carbofuran exposure measurements were not mentioned. The 96-h LC_{50} values ranged from 80 µg/L for bluegill to 2,700 μg/L for bullfrog tadpoles. These tests was not used because information on control survival and the number and range of toxicant levels tested was not given.

Cheah et al (1980), Graves (pers. comm.) - In 1980, 96-h static tests were performed at Louisiana State University on carbofuran technical with juvenile red swamp crawfish *Procambarus clarkii*. EPA testing procedures were used. Four to seven concentrations of carbofuran were tested in replicate three times. Three solution controls were used. Water quality parameters were: temperature of $30 \pm 3^{o}C$, dissolved oxygen maintained by aeration, pH of 8.4, and hardness of 100 mg/L as $CaCO_3$. Carbofuran exposure levels were apparently not measured. Control survival averaged 95% (lowest was 86.7%). The 96-h LC_{50} value for the crawfish was 500 μg/L. This data was not used because temperature variation was too great.

Dad et al. (1982) - In 1982, 96-h static tests were conducted on Furadan[R] (3% carbofuran formulation) with tubificid worms *Tubifex tubifex* and *Limnodrilus hoffmeisteri*. APHA (1971) testing procedures were used. Ten concentrations of carbofuran were tested in replicate. A control was also tested (addition of solvent in control was not mentioned). Water quality parameters during the test were: temperature of $18 \pm 0.3^{o}C$, dissolved oxygen of 8.5 ± 0.3 mg/L, pH of 8.15 ± 0.3, and hardness of 165 ± 5 mg/L as $CaCO_3$. Carbofuran exposure levels were apparently not measured and control survivals were not mentioned. The 96-h EC_{50} values for *T. tubifex* and *L. hoffmeisteri* were: 14,000 μg/L and 11,000 μg/L, respectively. These data were not used because of no control survival data and a formulation with a low percentage of carbofuran was used.

Davey et al. (1976) - From 1973 to 1975, 72-h static toxicity tests were conducted at the University of Arkansas on carbofuran (3%) with adult mosquitofish *Gambusia affinis* and juvenile green sunfish *Lepomis cyanellus*. Concentrations of carbofuran were tested in replicate three times, and solvent controls were included. Water quality parameters, number of treatments, carbofuran exposure level measurements, and control survival were not mentioned. The 72-h LC_{50} value was 0.52 mg/L for mosquitofish and 0.16 mg/L for green sunfish. These data were not used because the exposures weren't 96 hours and essential information on control survival, water quality parameters, and exposure levels was not given.

FMC (1985a) - In 1985, a 96-h flow-through toxicity test was conducted by Environmental Science and Engineering, Inc. on carbofuran technical (96.1%) with Atlantic silverside *Menidia menidia*. ASTM (1980) testing procedures were used. A geometric series of six concentrations of carbofuran (dilution factor of 0.5) were tested in replicate. Natural seawater and acetone controls were included. Water quality parameters during the test were: temperature of 22-24 ^{o}C, pH of 7.5-8.3, dissolved oxygen of $ 52% saturation, and salinity of 20 $^{o}/_{oo}$. Control survival was 100% in both the solvent control and seawater control. Carbofuran exposure levels were measured on day 0 and day 4 and averaged 72% of nominal concentrations. The 96-h LC_{50} value was 49 µg/L. This test was not accepted because dissolved oxygen levels were too low.

FMC (1985b) - In 1985, a 96-h flow-through toxicity test was conducted by Environmental Science and Engineering, Inc. on technical carbofuran (96.1%) with pink shrimp *Penaenus duorarum*. Internal lab testing procedures were used. Five concentrations of carbofuran (dilution factor of 0.5) were tested in replicate. Acetone and seawater controls were included. Water quality parameters during the tests were: temperature of 24 ^{o}C, pH of

7.7-8.0, dissolved oxygen of $ 65% saturation, and salinity of 22 $^{o}/_{oo}$. Carbofuran exposure levels were measured at 0 and 96 hours during the test and averaged 85% of nominal (range:80-90%). Survival was 100% for both controls. The 96-h LC_{50} value was 12 µg/L. This value was not used because the temperature dropped to 15 ^{o}C during the first 24 hours of the test, thus possibly putting stress on the test organism.

Hartman and Martin (1985) - In 1984, 48-h static toxicity tests were conducted by the U.S. Fish and Wildlife Service on Furadan 4 (40.6% carbofuran) with adult cladoceran *Daphnia pulex*. EPA (1975) testing procedures were followed. Three concentrations of carbofuran (dilution factor 0.1) were tested in replicate and one water control was used. Water quality parameters during the test were: temperature of 15 ^{o}C, pH of 7.6, and hardness of 282 mg/L $CaCO_3$. The measurement of carbofuran exposure level and control survival were not mentioned. The 48-h EC_{50} values based on mortality were 35 µg/L without suspended sediment and 45 µg/L with suspended sediment. These values were not used because the test description failed to report control survival and dissolved oxygen levels, only three concentrations of carbofuran were tested, and a formulation with a low percentage of carbofuran was used.

Johnson (1986), Johnson (pers. comm.) - In 1986, 48-h static toxicity tests were conducted by the U.S. Fish and Wildlife Service on technical carbofuran (99% active ingredient) with first instar cladoceran *Daphnia magna* and fourth instar midge *Chironomus riparius*. EPA (1975) testing procedures were used for testing. Three concentrations of carbofuran were tested with four replicates and a control was used. Water quality parameters for both tests were: temperature of 20 ± 1^{o}C, pH of 7.2, hardness of approximately 30 mg/L as $CaCO_3$ and alkalinity of 35 mg/L as $CaCO_3$. Survival of cladoceran controls was 100%. Survival of midge controls was not mentioned. Measurement of carbofuran exposure levels were not mentioned. The 48-h EC_{50} values for cladoceran and midge were 48 and 56 µg/L, respectively. These tests were not used because only three concentrations of carbofuran were tested.

Kornak and Collins (1974) - In 1974, a 24-h static toxicity test was performed on technical carbofuran (>90% active ingredient) with larvae midge *Chironomus tentans*. No recognized testing procedures (i.e., ASTM, EPA, APHA) were used. Concentrations of carbofuran were tested in triplicate and a control was included. Water temperature was maintained at 22°C. Dissolved oxygen was maintained by "gentle aeration". Measurement of carbofuran exposure levels and survival of controls were not mentioned. The 24-h LC_{50} value was 1.6 µg/L (based on no response to prodding) and 0.7 µg/L (based on non-responsive and moribund individual counts). These values were not used because the number of concentrations, dilution factor, and control survival were not mentioned and the test was only 24 hours in duration.

Mayer and Ellersieck (1986), Dwyer and Sappington (pers. comm.) - Between 1965 and 1985, a 96-h static toxicity test was conducted by the Columbia National Fisheries Laboratories of the U.S. Fish and Wildlife Service on carbofuran formulation (50% active ingredient) with the bluegill *Lepomis macrochirus*. ASTM and EPA testing procedures were generally followed. Concentrations of carbofuran were tested in replicate and there was a solvent (acetone) control. Water quality parameters during the test were pH 7.1-9.5, and hardness 40-44 mg/L $CaCO_3$. Toxicant concentrations were measured at 24-h intervals. The 96-h LC_{50} value was 240 µg/L. This test was not accepted because a formulation with a low percentage of carbofuran was used.

Pawar and Katdare (1984) - In 1983, 96-h static toxicity tests were conducted at University of Poona, India, on carbofuran technical (75% active ingredient) with frog *Microhyla ornata* embryos and tadpoles. No recognized testing procedures (i.e., ASTM, APHA, EPA) were used. Six concentrations of carbofuran were tested in replicate four times and a solvent control was used. Measurements of water quality parameters and carbofuran exposure levels were not mentioned. Control survival was 97.5%. The 96-h LC_{50} values for embryos and tadpoles were 44,230 and 13,470 μg/L, respectively. These values were not used because dissolved oxygen and temperature levels were not reported, and a formulation with a low percentage of carbofuran was used.

Verma et al. (1980) - In 1979, 96-h toxicity tests were performed at the Pollution Relevant Research Laboratory of D.A.V. College in India on Furadan[R] (75% active ingredient) with catfish *Mystus vittatus*. A previous test done by the same researcher was used as a method guide. The number and levels of carbofuran concentrations tested, water quality parameters, control survival, and carbofuran exposure level measurements were not mentioned. The 96-h LC_{50} value was 310 μg/L. This value was not used because a formulation with a low percentage of carbofuran was used, most of the test parameters were not reported, and this species is not found in the United States.

Verma et al. (1982) - In 1982, 96-h static toxicity tests were performed at the D.A.V. college in India on Furadan[R] (75% active ingredient) with the freshwater fish *Saccobranchus fossilis*. APHA (1971) testing methods were used. A logarithmic series of carbofuran concentrations were tested in replicate, and a solvent control was used. Water quality parameters during the test were: temperature of $18.2 \pm 2^{o}C$, pH of 7.2 ± 0.2, dissolved oxygen of 4.84 mg/L (approximately 50% saturation), hardness of approximately 50 mg/L as $CaCO_3$, and of alkalinity 59 mg/L as $CaCO_3$. Measurements of carbofuran exposure levels were not mentioned. Control survival was 100%. The 96-h LC_{50} value was 547 μg/L. This value was not used because a formulation with a low percentage of carbofuran was used, and dissolved oxygen levels were below 60%.

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

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Bluegill *Lepomis macrochirus*	Juv	S,M	Technical (99%)	40 mg/L as $CaCO_3$	96-h	LC_{50}	88 (75-104)	Mayer and Ellersieck 1986
Brown trout *Salmo trutta*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	560 (475-660)	Mayer and Ellersieck 1986
Brown trout *Salmo trutta*	Juv	F,M	Technical (99%)	314 mg/L as $CaCO_3$	96-h	LC_{50}	280 (204-382)	Mayer and Ellersieck 1986
Channel catfish *Ictalurus punctatus*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	248 (94-649)	Mayer and Ellersieck 1986
Chinook salmon *Oncorhynchus tshawytscha*	Juv	F,M	Technical (98.1%)	130 mg/L as $CaCO_3$	96-h	LC_{50}	610 (490-800)	Faggella et al. 1990
Cladoceran *Ceriodaphnia dubia*	Neonate	S,U	Technical (98.1%)	45-50 mg/L as $CaCO_3$	48-h	LC_{50}	2.6 (---)[c]	Norberg-King et al. 1991
Coho salmon *Oncorhynchus kisutch*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	530 (432-650)	Mayer and Ellersieck 1986
Dungeness crab *Cancer magister*	Zoeae	S,U	Technical (96.1%)	25 $^o/_{oo}$	96-h	LC_{50} EC_{50}	2.5 (---)[b] 1.5 (---)	Caldwell 1977
Dungeness crab *Cancer magister*	Adult	S,U	Technical (96.1%)	25 $^o/_{oo}$	96-h	LC_{50}	190 (---)[b]	Caldwell 1977
Eastern oyster *Crassostrea virginica*	Embryo, Larvae	S,U	Technical (96.1%)	21 $^o/_{oo}$	48-h	EC_{50}	>5,000 (--)	FMC 1985c
Fathead minnow *Pimephales promelas*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	1,990 (1385-2859)	Mayer and Ellersieck 1986
Fathead minnow *Pimephales promelas*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	872 (479-1590)	Mayer and Ellersieck 1986

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (µg/L) (95% C.L.[b])	Reference
Fathead minnow *Pimephales promelas*	Juv	F,M	Technical (99%)	314 mg/L as $CaCO_3$	96-h	LC_{50}	1,180 (813-1711)	Mayer and Ellersieck 1986
Lake trout *Salvelinus namaycush*	Juv	F,M	Technical (99%)	314 mg/L as $CaCO_3$	96-h	LC_{50}	164 (119-226)	Mayer and Ellersieck 1986
Mysid *Neomysis mercedis*	Juv	F,M	Technical (98.1%)	250-400 mg/L as $CaCO_3$	96-h	LC_{50}	21 (17-25)	Brandt et al. 1992
Mysid *Neomysis mercedis*	Juv	F,M	Technical (98.1%)	250-400 mg/L as $CaCO_3$	96-h	LC_{50}	27 (22-33)	Brandt et al. 1992
Mysid *Neomysis mercedis*	Neo-nate	F,M	Technical (98.1%)	250-400 mg/L as $CaCO_3$	96-h	LC_{50}	4.7 (4.2-5.1)	Brandt et al. 1992
Mysid *Neomysis mercedis*	Neo-nate	F,M	Technical (98.1%)	250-400 mg/L as $CaCO_3$	96-h	LC_{50}	2.7 (2.5-5.2)	Brandt et al. 1992
Rainbow trout *Oncorhynchus mykiss*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	380 (272-531)	Mayer and Ellersieck 1986
Sheepshead minnow *Cyprinodon variegatus*	---	F,M	Technical (99%)	21 $^{o}/_{oo}$	96-h	LC_{50}	386 (311-480)	Parrish 1977
Steelhead *Oncorhynchus mykiss*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	600 (436-826)	Mayer and Ellersieck 1986
Striped bass *Morone saxatilis*	Juv	F,M	Technical (98.1%)	381 mg/L as $CaCO_3$	96-h	LC_{50}	130 (110-150)	Fujimura et al. 1991b
Striped bass *Morone saxatilis*	Juv	F,M	Technical (98.1%)	367 mg/L as $CaCO_3$	96-h	LC_{50}	160 (130-200)	Fujimura et al. 1991b
Striped bass *Morone saxatilis*	Larvae	F,M	Technical (98.1%)	470 mg/L as $CaCO_3$	96-h	LC_{50}	370 (320-440)	Fujimura et al. 1991b
Striped bass *Morone saxatilis*	Juv	F,M	Technical (98.1%)	390 mg/L as $CaCO_3$	96-h	LC_{50}	180 (160-200)	Fujimura et al. 1991b

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (µg/L) (95% C.L.[b])	Reference
Yellow perch *Perca flavescens*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	240 (208-277)	Mayer and Ellersieck 1986
Yellow perch *Perca flavescens*	Juv	S,M	Technical (99%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	120 (82-176)	Mayer and Ellersieck 1986
Yellow perch *Perca flavescens*	Juv	S,M	Technical (99%)	42 mg/L as $CaCO_3$	96-h	LC_{50}	400 (289-553)	Mayer and Ellersieck 1986

[a]
S = Static
F = Flow-through
M = Measured concentrations
U = Unmeasured concentrations

[b] Confidence limits in parenthesis

[c] Not generated (see abstracts in Appendix A)

Table A-2. Values (μg/L) from unaccepted tests on acute toxicity of carbofuran to aquatic animals.

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (μg/L) (95% C.L.[b])	Reference	Test Deficiencies[c]
Atlantic silverside *Menidia menidia*	Juv	F,M	Technical (96.1%)	18-19‰	96-h	LC_{50}	49 (38-72)	FMC 1985a	1
Bluegill *Lepomis macrochirus*	Juv	S,U	Furadan[R] (99%)	2-5 mg/L as $CaCO_3$	96-h	LC_{50}	80 (--)	Carter and Graves 1973	2
Bluegill *Lepomis macrochirus*	Juv	S,M	Technical (50%)	44 mg/L as $CaCO_3$	96-h	LC_{50}	240 (186-310)	Mayer and Ellersieck 1986	3
Bullfrog *Rana catesbeiana*	Tadpole	S,U	Furadan[R] (--)	2-5 mg/L as $CaCO_3$	96-h	LC_{50}	2,700 (--)	Carter and Graves 1973	2
Catfish *Mystus vittatus*	---	F,U	Furadan[R] (75%)	---	96-h	LC_{50}	310 (--)	Verma et al. 1980	2,3
Channel catfish *Ictalurus punctatus*	Juv	S,U	Furadan[R] (--)	2-5 mg/L as $CaCO_3$	24-h	LC_{50}	2,030 (--)	Carter and Graves 1973	2
Channel catfish *Ictalurus punctatus*	Juv	F,U	Technical (99%)	---	96-h	LC_{50}	510 (460-560)	Brown et al. 1979	2
Channel catfish *Ictalurus punctatus*	Juv	S,U	Technical (99%)	---	96-h	LC_{50}	1420 (1,290-1,700)	Brown et al. 1979	2
Cladoceran *Daphnia pulex*	Adult	S,U	Furadan[R] (40.6%)	282 mg/L as $CaCO_3$	48-h	EC_{50}	35(26.8-45.8)[d] 45(33.1-61.1)[e]	Hartman and Martin 1985	2,3,4
Cladoceran *Daphnia magna*	1st instar	S,U	Technical (99%)	30 mg/L as $CaCO_3$	48-h	EC_{50}	48(35-64)	Johnson 1986	4
Frog *Microhyla ornata*	---	S,U	Technical (--)	---	96-h	LC_{50}	embryo 44,230 tadpole 13,470	Pawar and Katdare 1984	1,5
Green sunfish *Lepomis cyanellus*	Juv	S,U	Carbofuran (3%)	----	72-h	LC_{50}	160 (100-210)	Davey et al. 1976	3,6
Midge *Chironomus riparius*	4th instar	S,U	Technical (99%)	30 mg/L as $CaCO_3$	48-h	EC_{50}	56 (31-99)	Johnson 1986	4

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (µg/L) (95% C.L.[b])	Reference	Test Deficiencies[c]
Midge *Chironomus tentans*	Larvae	S,U	Technical (>90%)	---	24-h	LC_{50}	1.6 (--0 0.7[f] (--)	Kornak and Collins 1974	2,6
Mosquitofish *Gambusia affinis*	Juv	S,U	Furadan[R] (--)	2-5 mg/L as $CaCO_3$	96-h	LC_{50}	300 (--)	Carter and Graves 1973	2
Mosquitofish *Gambusia affinis*	Adult	S,U	Carbofuran (3%)	----	72-h	LC_{50}	520 (450-570)	Davey et al. 1976	2,6
Pink shrimp *Penaenus duorarum*	Adult	F,M	Technical (96.1%)	22 $^{o}/_{oo}$	96-h	LC_{50}	12 (9.4-14.0)	FMC 1985b	5
Red swamp crawfish *Procambarus clarkii*	Juv	S,U	Technical (--)	100 mg/L as $CaCO_3$	96-h	LC_{50}	500 (--)	Cheah et al. 1980	5
Saccobranchus fossilis	---	S,U	Furadan[R] (75%)	50 mg/L as $CaCO_3$	96-h	LC_{50}	547 (470-637)	Verma et al. 1982	3,1
Tubificid worm *Tubifex tubifex*	---	S,U	Furadan[R] (3%)	165 mg/L as $CaCO_3$	96-h	EC_{50}	14,000 (--)	Dad et al. 1982	2,3
Tubificid worm *Limnodrilus hoffmeisteri*	---	S,U	Furadan[R] (3%)	165 mg/L as $CaCO_3$	96-h	EC_{50}	11,000 (--)	Dad et al. 1982	2,3
White River crawfish *Procambarus actutus*	Juv	S,U	Furadan[R] (--)	2-5 mg/L as $CaCO_3$	96-h	EC_{50}	500 (--)	Carter and Graves 1973	2

[a] S = Static
F = Flow-through
M = Measured concentrations
U = Unmeasured concentrations

[b] Confidence limits in parenthesis

[c] 1 = Dissolved oxygen level too low
2 = Essential test information not given
3 = Formulation tested <80% a.i.
4 = Insufficient number of concentrations tested
5 = Temperature variation too wide
6 = Test duration <96-h

[d] Without sediment

[e] With sediment

[f] Based on combined moribund and death counts

APPENDIX B. Abstracts of accepted and unaccepted chronic toxicity tests reviewed for hazard assessment.

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

Caldwell (1977) - In 1974, 70-d and 90-d flow-through toxicity tests were conducted by EPA on carbofuran technical (% not given) with zoeae (70-d) and adult (90-d) dungeness crabs *Cancer magister*. Four replicates of three concentrations were tested with zoeae. Two replicates of four concentrations were tested with adults. The dilution factor of carbofuran in both tests was 0.1. Solvent and dilution water controls were included. Water quality parameters during the tests were: temperature 12.3 ^{o}C (zoeae) and 10.0 ^{o}C (adult), pH 8.1 (zoeae) and 7.9 (adult), dissolved oxygen 8.7 mg/L (zoeae) and 8.2 mg/L (adult), and salinity 28.8 $^{o}/_{oo}$ (zoeae) and 25.4 $^{o}/_{oo}$ (adult). Control survival with and without solvent was >80% for adults and <60% for zoeae. Measured carbofuran concentrations averaged 81.3% of nominal concentrations for tests with adults (range: 68-94%) and 136% of nominal concentrations for tests with zoeae (range: 126-146%). Although survival of zoeae controls declined dramatically after 50 days of testing, the dose response relationship was very clear. Complete (100%) mortality occurred at the LOEC exposure level (5 µg/L) and test species survival at the NOEC exposure level (0.5 µg/L) approximated that of control survival. The NOEC and LOEC values, based on survival, were 0.5 and 5 µg/L for zoeae and 25 and 250 µg/L for adults.

FMC (1981b) - In 1981, a 101-d flow-through embryos-to-fry toxicity test was conducted by Analytical Biochemistry Laboratories, Inc. on carbofuran technical (96.1%) with rainbow trout *Oncorhynchus mykiss*. ASTM (1979) and EPA (1972) testing procedures were followed. Five concentrations of carbofuran (dilution factor of 0.5) were tested with four replicates.

Acetone and water controls were included. Water quality parameters during the test were: temperature of 10 °C (eggs) and 12 °C (fry), pH of 8.1, dissolved oxygen of 7.8 mg/L, and ammonia of 0.53 mg/L. Control survival was 100% for both controls. Concentrations of carbofuran were measured on days 0, 1, 5, 10, and every 10 days after and averaged 136% of nominal concentrations (range: 114-144%). The NOEC and LOEC values, based on percentage of eggs hatched was 24.8 and 56.7 µg/L.

<u>FMC (1982)</u> - In 1982, a 21-d flow-through life-cycle toxicity test was conducted by Analytical Biochemistry Laboratories, Inc. on carbofuran technical (95.6%) with first instar of the cladoceran *Daphnia magna*. ASTM (1979, 1987), EPA (1975), and U.S. Federal Register (1978) testing procedures were followed. Five concentrations of carbofuran (dilution factor 0.5) were tested with four replicates. A solvent control was also included. Water quality parameters during the test were: temperature of 20 °C, pH of 8.1-8.7, and dissolved oxygen of 6.5-7.9 mg/L. Control survival averaged 93%. Toxicant concentrations were measured on days 0, 4, 7, 14, and 21 but were not compared with nominal concentrations. The NOEC and LOEC values based on survival were 9.8 and 27 µg/L, respectively.

<u>FMC (1987)</u> - In 1987, a 28-d flow-through life-cycle toxicity test was conducted by Enseco, Inc. on carbofuran technical (98.6%) with $\leq$24-hr old *Mysidopsis bahia*. ASTM (1987) testing procedures were followed. Five concentrations of carbofuran were tested with two replicates. A water control was also included. Water quality parameters during the test were: temperature of 27 $\pm$1° C (on days 14 and 15 temperature was ranged from 25 to 27.6°C), pH of 8.0, and average dissolved oxygen of 4.9 mg/L. The average dissolved oxygen was above 60% of saturation 94% of the time. Dissolved oxygen concentration was at least 56% the other 6% of the time. Control survival averaged 77.5%. Toxicant concentrations were measured on days 4, 7, 10, 14, 17, 21, and

28. The NOEC and LOEC values based on survival were 0.4 and 0.98 µg/L, respectively. Although temperature varied more than 2^{o} C and dissolved oxygen concentrations dropped below 60% this test was accepted because the temperature and dissolved oxygen deviations were slight and of short duration.

Fujimura et al. (1990) - In 1989, a 75-d flow-through embryos-to-fry toxicity test was performed by CDFG on carbofuran technical (98.1%) with chinook salmon *Oncorhynchus tshawtscha*. ASTM (1988a) bioassay standards were generally followed. Five concentrations of carbofuran were tested in replicate. Water and solvent controls were used. Water quality parameters during the test were: temperature of 10.2 ^{o}C, pH of 8.3, dissolved oxygen of 9.75 mg/L, and hardness of 83 mg/L as $CaCO_3$. Carbofuran concentrations were measured twice weekly during the test and averaged 97% of nominal (range: 92-104%). Control survival was 99%. The 75-d NOEC and LOEC values based on growth were 9.2 and 17 µg/L, respectively.

Parrish et al. (1977) - In 1974 and 1975, a 131-d flow-through embryos-to-fry toxicity test was conducted by Bionomics, Inc. (under contract to EPA) on carbofuran technical (99%) with sheepshead minnows *Cyprinodon variegatus*. APHA (1976) and EPA (1975) testing procedures were followed. Five concentrations of carbofuran (dilution factor of 0.5) were tested in replicate. Acetone and water controls were used. Water temperature was 30 ^{o}C. Control survival was 93% for both controls. Carbofuran exposure levels were measured and ranged from 18 to 24% of nominal concentrations. The NOEC and LOEC values, based on survival and hatching success were 23 and 49 µg/L, respectively.

Unaccepted chronic toxicity tests - The following tests used unaccepted test methods and/or produced unaccepted results.

FMC (1981a) - In 1981, a 14-d flow-through toxicity test was conducted by Analytical Biochemistry Laboratories, Inc. on carbofuran technical (96.1%) with juvenile rainbow trout *Oncorhynchus mykiss*. APHA (1976) and EPA (1975) testing procedures were used. Five concentrations of carbofuran (dilution factor 0.5) were tested. A dilution water control was included. The number of replicates tested for each concentration was not mentioned. Water quality parameters during the test were: temperature of 12 ^{o}C, pH of 7.8, dissolved oxygen of 9.2 mg/L, and ammonia of < 0.6 mg/L. Control survival was 100%. Toxicant concentrations averaged 87% of nominal concentrations (range: 78-110%). The NOEC and LOEC values based on the loss of equilibrium, were 56 and 98 µg/L, respectively. This test was not used because the test duration was not a significant portion of the rainbow trout life-cycle.

Isensee and Tayaputch (1986) - In 1985, a 60-d chronic microecosystem toxicity test was conducted on carbofuran technical (97%) which included mosquito fish *Gambusia affinis*. Two concentrations of carbofuran were tested in replicate three times. Two controls were included. Water quality parameters were not mentioned. Carbofuran exposure levels were measured on 5 occasions resulting in values which were 39 to 98% of nominal. No NOEC or LOEC values were given and unexplained mass mortality occurred in the control and treatment groups during the test.

Johnson 1986 - In 1986, a 30-d microcosm test was conducted by the U.S. Fish and Wildlife Service with technical carbofuran (99% active ingredient) which included first star instar *Daphnia magna.* EPA (1975) testing procedures were used. Four replicates of three concentrations of carbofuran were tested with a control. Water quality parameters were: temperature 20$\pm$ 1^{o}C, pH 7.2, and alkalinity 35 mg/L as $CaCO_3$. The researcher (contacted by phone) was unable to obtain information on control survival and NOEC and LOEC values.

Norberg-King et al. (1991), Norberg-King (pers. comm.) - In 1990, 7-d static chronic tests were performed on technical carbofuran (98.1% active ingredient) with cladoceran *Ceriodaphnia dubia*. Five concentrations of carbofuran were tested (dilution factor 0.5) and a water control was included. Water quality parameters were: temperature of $25 \pm 1^{\circ}C$, dissolved oxygen levels "adequate", pH of 7.9 and hardness of 45-50 mg/L as $CaCO_3$. Carbofuran exposure levels were not measured. Control survival was 100%. The 7-d NOEC and LOEC values based on survival were 2.6 and 1.3 µg/L, respectively. This test was not accepted because carbofuran exposure levels were not measured.

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

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Cladoceran *Daphnia magna*	1st instar	F,M	Technical (95.6%)	255 mg/L as $CaCO^3$	21-d	NOEC LOEC	9.8 27	FMC 1982
Chinook salmon *Onchorhynchus tshawytscha*	Embryos-Fry	F,M	Technical (98.1%)	83 mg/L as $CaCO_3$	75-d	NOEC LOEC	9.2 17	Fujimura et al. 1990
Dungeness crab *Cancer magister*	Adult	F,M	Technical (96.1%)	25.4 $^o/_{oo}$	90-d	NOEC LOEC	25 250	Caldwell 1977
Dungeness crab *Cancer magister*	Zoeae	F,M	Technical (96.1%)	28.8$\pm$1.4 $^o/_{oo}$	70-d	NOEC LOEC	0.5 5.0	Caldwell 1977
Mysid *Mysidopsis bahia*	24-h	F,M	Technical (98.6%)	28-30 $^{o/oo}$	28-d	NOEC LOEC	0.4 0.98	FMC 1987
Rainbow trout *Oncorhychus mykiss*	Embryos-Fry	F,M	Technical (96.1%)	255 mg/L as $CaCO_3$	101-d	NOEC LOEC	24.8 56.7	FMC 1981b
Sheepshead minnow *Cyprinodon variegatus*	Embryos-Fry	F,M	Technical (99%)	(--)	131-d	NOEC LOEC	23.0 49.0	Parrish et al. 1977

[a]
S = Static
F = Flow-through
M = Measured concentration
U = Unmeasured concentration

[b] Confidence limits in parenthesis

Table B-2. Values (μg/L) from unaccepted tests on chronic toxicity of carbofuran to aquatic animals.

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference	Test Deficiencies[c]
Cladoceran *Daphnia magna*	1st instar	C, U	Technical (99% a.i.)	---	30-d	NOEC/LOEC	none given	Johnson 1986	1
Mosquito fish *Gambusia affinis*	---	C, U	Technical (97% a.i.)	---	60-d	NOEC/LOEC	none given	Isensee and Tayaputch 1986	1,2
Rainbow trout *Oncorhynchus mykiss*	Juv	F, M	Technical (96.1%)	255 mg/L as $CaCO_3$	14-d	NOEC LOEC	56.0 98.0	FMC 1981a	3
Cladoceran *Ceriodaphnia dubia*	Neonate	S,U	Technical (98.1%)	45-50 mg/L as $CaCO_3$	7-d	NOEC LOEC	1.3 2.6	Norberg-King et al. 1991	1

[a] C = Microcosm
S = Static
F = Flow through
M = Measured concentrations
U = Unmeasured concentrations

[b] Confidence limits in parenthesis

[c]
1 = Essential information not given
2 = Unexplainable mass mortality in control
3 = Test length unacceptable

APPENDIX C. Abstracts of aquatic plant toxicity tests reviewed for hazard assessment.

Hartman and Martin (1985) - In 1984, 14-d and 48-h static tests were conducted by the U.S. Fish and Wildlife Service on Furadan[R] (40.6% active ingredient) with sago pondweed *Potamogeton pectinatus* and little duckweed *Lemna minor*, respectively. Little duck weed was tested with and without sediment. No major recognized testing standards were used. Three carbofuran concentrations were tested in replicate and a control was used with pondweed tests. Six concentrations of carbofuran and a control were tested with and without sediment with duckweed tests. Water temperature was maintained at 22°C. Measurement of carbofuran exposure levels was not mentioned. Neither the 14-d nor the 48-h tests showed significant growth inhibition at any of the carbofuran levels ($\leq$ 10 mg/L) tested. Thus, the effect values for both plants were $\geq$ 10 mg/L carbofuran.

Johnson (1986) - In 1986, a 30-d microcosm test was conducted by the U.S. Fish and Wildlife Service with technical carbofuran (99% active ingredient) which included green alga *Selenastrium capricornutum*. EPA (1975) testing procedures were used. Four replicates of three concentrations of carbofuran were tested with a control. Water quality parameters were: temperature of 20$\pm$ 1°C, pH of 7.2, and alkalinity of 35 mg/L as $CaCO_3$. Treatments with higher concentrations of carbofuran exhibited higher growth rates.

Kar and Singh (1978) - In 1978, a 10-d static toxicity test was conducted by the Central Rice Research Institute, India on Furadan[R] (3% active ingredient) with blue-green alga *Nostoc muscorum*. No recognized testing procedures were used. Nine concentrations of carbofuran were tested. Water temperature was 24$\pm$2°C. Measurement of carbofuran exposure levels was not mentioned. The 10-d NOEC and LOEC values were approximated as 50 and 100 mg/L, respectively. A formulation with a low percentage of carbofuran was used.

Megharaj et al. (1989) - In 1989, 32-d toxicity tests were conducted on technical carbofuran (75% active ingredient) with green alga *Scenedesmus mijugatus*. Bioassay procedures of Goulding and Ellis (1981) were used. Seven concentrations of carbofuran (1, 2, 5, 10, 20, 50 and 100 mg/L) were tested in triplicate. A water control was included. Water temperature was 28 $\pm$ 4°C and dissolved oxygen levels were maintained by shaking the test containers four times a day. Measurement of carbofuran exposure levels was not mentioned. The 6-d NOEC and LOEC values based on growth, were 5 and 10 mg/L, respectively. The 32-d NOEC and LOEC values were 10 and 20 mg/L, respectively.

Table C-1. Values (µg/L) from tests on toxicity of carbofuran to aquatic plants.

Species	Life Stage	Method[a]	Formulation	Salinity/ Hardness	Test Length	Effect	Values (µg/L) (95% C.L.[b])	Reference	Test Deficiencies[c]
Blue-green alga *Nostoc muscorum*	---	S, U	Furadan[R] (3% a.i.)	---	10-d	NOEC LOEC	50 100	Kar and Singh 1978	1
Green alga *Scenedesmus bijugatus*	---	S, U	Technical (75% a.i.)	---	6-d	NOEC LOEC	5,000 10,000	Megharaj et al 1989	2
					32-d	NOEC LOEC	10,000 50,000		
Green alga *Selenastrium capricornutum*	---	S, U	Technical (99% a.i.)	---	30-d			Johnson 1986	3
Little duckweed *Lemna minor*	---	S, U	Furadan[R] (40.6% a.i.)	282 mg/L as $CaCO_3$	48-h	EC_{50}	>10,000	Hartman and Martin 1985	1,3
Sago pondweed *Potamogeton pecinatus*	---	S, U	Furadan[R] (40.6% a.i.)	282 mg/L as $CaCO_3$	14-d	LOEC	>10,000	Hartman and Martin 1985	1,3

[a] S = Static
F = Flow through
M = Measured concentrations
U = Unmeasured concentrations

[b] Confidence limits in parenthesis

[c] 1 = Formulation with a low percentage of carbofuran was used in testing
2 = Test duration unacceptable
3 = No detrimental effect observed.

APPENDIX D. Procedures used by the California Department of Fish and Game to assess pesticide hazards to aquatic resources.

The California Department of Fish and Game's (CDFG) Pesticide Investigations Unit (PIU) assesses the hazards of pesticides to California's aquatic resources. An important element of CDFG's hazard assessment procedure is establishing water quality criteria (WQC) for specific waters of the state using a method modified from guidelines developed by the U.S. Environmental Protection Agency (EPA 1985). The hazard assessment procedure also evaluates toxicity studies and includes only toxicity data generated in tests using accepted procedures to generate the WQC. Finally, hazard assessments evaluate the effectiveness of the WQC in protecting sensitive aquatic organisms.

Toxicity test data are obtained from the scientific literature, and from confidential laboratory reports submitted to the EPA and the California Department of Pesticide Regulation (DPR). CDFG evaluates the acceptability of the test methods used in these toxicity tests by examining the following aspects of both acute and chronic tests: 1) test method, 2) test type, 3) test species, 4) water quality maintenance and monitoring, 5) toxicant maintenance, and 6) test design. Within each of these categories as many as nine elements are used to evaluate test procedures. Studies are not required to comply with every element, but tests are rejected if they do not observe certain fundamental procedures such as maintaining proper survival of organisms in a control treatment or testing only with healthy, unstressed organisms. Studies are also rejected if they contain insufficient information to properly evaluate the tests or if the study did not follow standard testing procedures (ASTM 1980, 1987a, 1987b, 1988a, 1988b, 1989).

Data from acceptable acute and chronic toxicity studies on freshwater and saltwater organisms are used in determining a

Final Acute Value (FAV), Final Chronic Value (FCV) and Final Plant Value (FPV). The FAV is derived using the following procedure:

1. The Species Mean Acute Value (SMAV) is calculated for each species for which at least one acute value is available. The SMAV is the geometric mean of the results of all acceptable toxicity tests. When one or more life stages are available for the same species, the data for the more sensitive life stages are used to calculate the SMAV. Acute values that appeared to be questionable (i.e., that differ by more than a factor of 10 in comparison with other acute data for the same species and for other species in the same genus) are not used in calculating the SMAV.

2. The Genus Mean Acute Value (GMAV) is calculated for each genus for which one or more SMAVs are available. The GMAV is the geometric mean of the SMAVs available for the genus.

3. The GMAVs are ranked (R) from "1" for the lowest to "N" for the highest. GMAVs are arbitrarily assigned successive ranks when two or more are identical.

4. The cumulative probability (P) is calculated for each GMAV as R/(N+1).

5. The four GMAVs having cumulative probabilities closest to 0.05 are selected. If fewer than 59 GMAVs are available, these four will always be the four lowest GMAVs.

6. The FAV is calculated using the selected GMAVs and Ps, as:

$$S^2 = \frac{3((\ln GMAV)^2)-((3(\ln GMAV))^2/4)}{3(P) - ((3(\%P))^2/4)}$$

$$L = (3(\ln GMAV) - S(3\%P)))/4$$

$$A = S(\%0.05) + L$$

$$FAV = e^{A}$$

If sufficient data are available, 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 from an acceptable chronic toxicity test.

2. Acute-Chronic Ratios (ACR) are calculated for each chronic value for which at least one corresponding appropriate acute value is available using for the numerator the geometric mean of the results of all acceptable acute tests. Whenever possible, the acute test(s) should be part of the same study as the chronic test.

3. The species mean ACR is calculated for each species as the geometric mean of all ACRs available for that species.

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

5. The FCV is then calculated by dividing the FAV by the Final ACR.

If no chronic toxicity data are available, the FCV can be estimated by applying a conversion factor of 0.1 to the lowest acute value.

The FPV is derived using the following procedure:

1. A plant value is the result of a 96-hour test conducted with an algae or a chronic test conducted with an aquatic vascular plant. Because standardized testing procedure have not been established for algae or aquatic vascular plants, all test durations are considered.

2. The FPV is obtained by selecting the lowest result from a test with an aquatic plant species in which the endpoint was biologically important.

The lowest of these three values is used as the WQC. Separate WQCs can be generated for freshwater and saltwater species if toxicity differences are noted or if the specific water system is strictly saltwater or freshwater, i.e. if the water system does not include an estuary. The WQC can be lowered further to protect important sensitive species.

Hazard assessments compare the WQC generated for specific waters with environmental concentrations determined through monitoring programs. If environmental concentrations are greater than the WQC, CDFG determines that aquatic resources are threatened and proposes hazard mitigation.

The hazard assessment procedure is a reiterative process by which new data are evaluated to refine the WQC. Hazard assessments usually recommend additional toxicity tests with commonly used testing organisms and potentially sensitive native species.