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Thre Resources Agency
DEPARTMENT OF FISH AND GAME

HAZARD ASSESSMENT OF THE INSECTICIDE CARBARYL TO AQUATIC LIFE 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 (DPR) 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, DPR 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 ninth in a series of pesticide hazard assessments. Hazard assessments have also been prepared for the herbicides molinate and thiobencarb, and for the insecticides methyl parathion, carbofuran, chlorpyrifos, diazinon, methidathion, methomyl, and dimethoate.

Hazard Assessment of the Insecticide Carbaryl to Aquatic Organisms in the Sacramento-San Joaquin River System

by

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Summary

Freshwater and saltwater Water Quality Criteria (WQC) for protection of aquatic organisms from the insecticide carbaryl were developed and a hazard assessment was performed for California's Sacramento-San Joaquin River system.

Two hundred and twenty-nine tests on the acute and chronic toxicity of carbaryl to aquatic animals were reviewed and evaluated. The most acutely sensitive freshwater species tested was the stonefly *Pteronarcys califomica* with a Genus Mean Acute Value (GMAV) of 4.8 µg/L. The most acutely sensitive saltwater species tested was the mysid *Mysidopsis bahia* with a GMAV of 5.7 µg/L. The lowest freshwater Maximum Acceptable Toxicant Concentration (MATC) was 4.4 µg/L for the cladoceran *Daphnia magna*. There was little difference between acute and chronic toxicity to the most sensitive organisms; thus, a Final Acute-to-Chronic Ratio of 2 was used to derive the Final Chronic Value (FCV). The freshwater Final Acute Value (FAV) was 5.05 µg/L, the saltwater FAV was 1.62 µg/L. The Criterion Maximum Concentration (CMC) is equal to one half of the FAV; the freshwater and saltwater CMC values are 2.53 µg/L and 0.81 µg/L, respectively. The freshwater Final Chronic Value (FCV) for carbaryl was 2.53 µg/L. The saltwater FCV for carbaryl was 0.81 µg/L. The Criterion Continuous Concentrations (CCC) are equal to the FCVs for freshwater and saltwater.

Carbaryl concentrations in water were monitored in the Sacramento and San Joaquin River systems by three government agencies. During 1991 to 1994, samples were collected from the Sacramento and San Joaquin River systems over a 1.5 and 3 year monitoring period, respectively. Carbaryl was not detected in the Sacramento River system (≤.03 µg/L) during this monitoring period, nor was it detected from December 1996 to March 1997 in the Sacramento River. Carbaryl was detected in the San Joaquin River system at concentrations as high as 8.4 µg/L. Freshwater organisms should not be affected unacceptably if the one-hour average concentration of carbaryl does not exceed the CMC of 2.53 µg/L more than once every three years. This level was exceeded three times in tributaries to the San Joaquin River from March of 1991 to April of 1994. Carbaryl may pose an acute and chronic toxicity hazard in tributaries to the San Joaquin River.

Acute toxicity data were available for seven of the eight freshwater families recommended by the EPA for development of numerical criteria. An acute toxicity test should be conducted on a freshwater mollusk or rotifer to complete the eight families; however, it is unlikely that this value will lower the freshwater WQC. The hazard assessment procedure is an iterative process by which new data are evaluated to refine water quality criteria. A new criterion may be generated if more data become available.

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ACKNOWLEDGMENTS

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INTRODUCTION

Carbaryl is a broad spectrum carbamate insecticide and acetylcholinesterase inhibitor. Carbaryl is used on citrus crops, fruits and vegetables, forage crops, lawns, nuts, ornamentals, range land, turf, and shade trees (Farm Chemicals Handbook 1997). From 1990 to 1995, the amount of carbaryl used in California ranged from 954,280.67 to 1,454,821 pounds per year (Table 1) (Department of Pesticide Regulation (DPR) 1990-95).

The Central Valley Regional Water Quality Control Board (CVRWQCB), DPR, and U.S. Geological Survey (USGS) monitored carbaryl in the San Joaquin River system from January 1991 to April 1994. CVRWQCB analyzed approximately 230 samples for pesticides between March 1991 and June 1992 (CVRWQCB 1995). From March 1991 to February 1993, DPR took samples twice per week during the winter months at one site and performed Langranian sampling when pesticide concentrations began to rise. USGS took samples several times per week at one site from January 1991 to April 1994. Data from the three government agencies were pooled (Table 2). Carbaryl concentrations of up to 8.4 μg/L (detection limit = 0.03 μg/L) were detected.

USGS (1995) monitored carbaryl in the Sacramento River system three times per week from October 1992 to April 1994 but none was detected. No carbaryl was detected in the Sacramento River from December 1996 to March 1997 (DPR 1997).

Hazards from carbaryl to aquatic life in the Sacramento-San Joaquin River system were assessed by comparing expected toxic effects with carbaryl concentrations detected in the Sacramento-San Joaquin River drainage. Acute and chronic toxicity data were obtained from studies published in scientific literature and laboratory reports required by the U.S. Environmental Protection Agency for pesticide registration. Tests were evaluated for compliance with standards for test type, method, design and species, and for water quality standards and toxicant monitoring and maintenance. Although a study need not comply with every standard, tests were rejected if they did not observe certain fundamental procedures or if several important standards were not met. Studies were also rejected if they do not contain sufficient information to be properly evaluated and the necessary information could not be obtained from the researcher (Appendix A).

The U.S. EPA has not established a Water Quality Criterion (WQC) for carbaryl. The California Department of Health Services has set an action level for carbaryl of 60 mg/L in drinking water for the protection of public health (California Department of Health Services 1984).

Table 1. Carbaryl use in California 1990-1995[a]

Year	Number of applications	Pounds used
1990	14,830	954,280.67
1991	12,537	940,981.91
1992	13,632	789,505.95
1993	11,818	786,395.09
1994	12,714	891,745.82
1995	12,934	1,454,820.84

[a]California Department of Pesticide Regulation Pesticide Use Reports 1990-1995

Table 2. Concentrations of carbaryl (µg/L) detected in the San Joaquin River System (SJR), March 1991 through April 1994.[a]

Date	Location	Concentration
3/4/91[b]	Orestimba Creek	1.7
5/15/91[b]	Del Puerto Creek	1.6
4/16/91[c]	Ingram/Hospital Creeks	0.44,0.36[h]
5/15/91[b]	Ingram/Hospital Creeks	8.4
5/4/92[b]	Ingram/Hospital Creeks	2.0
5/11/92[b]	Ingram/Hospital Creeks	2.8
5/18/92[b]	Ingram/Hospital Creeks	0.6
8/16/91[c]	Merced River	0.05
9/10/91[c]	SJR at Laird Park	0.05
1/25/93[e]	SJR at Laird Park	0.05
2/10/93[e]	SJR at Laird Park	0.26
10/26-27/91[d]	SJR at Vernalis	(0.02)[i]
10/30-31/91[d]	SJR at Vernalis	(0.02)
11/1-2/91[d]	SJR at Vernalis	0.05
2/8-9/92[d]	SJR at Vernalis	(0.02)
2/10-11/92[d]	SJR at Vernalis	(0.02)
2/12-13/92[d]	SJR at Vernalis	0.03
3/7-8/92[d]	SJR at Vernalis	0.03
4/22-23/92[d]	SJR at Vernalis	(0.02)
5/2-3/92[d]	SJR at Vernalis	(0.02)
5/4-5/92[d]	SJR at Vernalis	(0.02)
5/14-15/92[d]	SJR at Vernalis	0.04
5/18-19/92[d]	SJR at Vernalis	0.03
12/30-31/92[d]	SJR at Vernalis	0.03
1/1-2/93[d]	SJR at Vernalis	0.051
1/3-4/93[d]	SJR at Vernalis	0.034
1/13/93[d]	SJR at Vernalis	(0.02)
2/8/93[f]	SJR at Vernalis	0.101
2/9/93[f]	SJR at Vernalis	0.11
2/9/93[d]	SJR at Vernalis	0.20
2/10/93[f]	SJR at Vernalis	0.06
2/11/93[f]	SJR at Vernalis	0.04
2/11/93[d]	SJR at Vernalis	0.20
2/12/93[d]	SJR at Vernalis	0.03
2/12/93[f]	SJR at Vernalis	0.014
2/13/93[f]	SJR at Vernalis	0.010
2/15/93[f]	SJR at Vernalis	0.010
3/17/93[d]	SJR at Vernalis	0.03
3/28/93[d]	SJR at Vernalis	(0.02)
3/29/93[d]	SJR at Vernalis	0.03
5/9-10/93[d]	SJR at Vernalis	(0.02)
5/11-12/93[d]	SJR at Vernalis	(0.01)
5/15-16/93[d]	SJR at Vernalis	(0.02)
5/17-18/93[d]	SJR at Vernalis	(0.02)
5/19-20/93[d]	SJR at Vernalis	(0.02)
5/21-22/93[d]	SJR at Vernalis	(0.02)
5/25-26/93[d]	SJR at Vernalis	(0.02)
5/29-30/93[d]	SJR at Vernalis	(0.02)
6/2-3/93[d]	SJR at Vernalis	(0.02)
6/4-5/93[d]	SJR at Vernalis	(0.01)
6/12-13/93[d]	SJR at Vernalis	(0.02)
6/16-17/93[d]	SJR at Vernalis	(0.01)
6/18-19/93[d]	SJR at Vernalis	(0.02)
6/22-23/93[d]	SJR at Vernalis	0.03
7/4-5/93[d]	SJR at Vernalis	0.03

Table 2. (continued) Concentrations of carbaryl (µg/L) detected in the San Joaquin River System (SJR), March 1991 through April 1994.[a]

Date	Location	Concentration
8/3-4/93[d]	SJR at Vernalis	0.06
8/7-8/93[d]	SJR at Vernalis	(0.01)
8/9-10/93[d]	SJR at Vernalis	(0.01)
1/5-1/6/93[d]	SJR at Vernalis	(0.02)
8/17-18/93[d]	SJR at Vernalis	0.04
8/19/93[d]	SJR at Vernalis	(0.02)
8/20-21/93[d]	SJR at Vernalis	0.10
1/25/94[d]	SJR at Vernalis	0.05
2/9/94[d]	SJR at Vernalis	(0.02)
3/3-4/94[d]	SJR at Vernalis	(0.02)
3/5-6/94[d]	SJR at Vernalis	(0.02)
4/9-10/94[d]	SJR at Vernalis	0.10
4/11-12/94[d]	SJR at Vernalis	(0.02)
4/13-14/94[d]	SJR at Vernalis	0.04
4/15-16/94[d]	SJR at Vernalis	0.05
4/17-18/94[d]	SJR at Vernalis	0.03
4/19-20/94[d]	SJR at Vernalis	0.06
4/21-22/94[d]	SJR at Vernalis	0.07
4/23-24/94[d]	SJR at Vernalis	0.18
1/29/92[e]	TID[g] #5 at Carpenter Road	1.0
2/18/92[e]	TID #5 at Carpenter Road	0.11
8/26/92[c]	TID #5 at Carpenter Road	0.20
2/9/93[e]	TID #5 at Carpenter Road	0.83
2/17/92[e]	SJR at Newman Wasteway	0.06
1/15/93[e]	SJR at Newman Wasteway	0.06
2/8/93[e]	SJR at Highline Spillway	0.07
2/9/93[e]	Merced River at Hatfield Rec. Area	3.95, 3.44
2/9/93[e]	SJR at Hills Ferry Road	0.80
2/10/93[e]	SJR at West Main Street	0.14
2/10/93[e]	SJR at Maze Blvd.	0.10
2/10/93[e]	SJR at Airport Road	0.09

[a] These and other locations were sampled in 1991-1994. Only the dates on which carbaryl were detected are listed
[b] Central Valley Regional Water Quality Control Board (1995)
[c] Unpublished Department of Pesticide Regulation (DPR) data
[d] USGS (1995)
[e] DPR (1996)
[f] Kuivila and Foe (1995)
[g] Turlock Irrigation District
[h] Split sample analyzed
[i] ( ) Indicate that the concentration was below detection limit of 0.03 µg/L, and are estimates (USGS 1995)

ENVIRONMENTAL FATE

Carbaryl is a broad spectrum carbamate insecticide and acetylcholinesterase inhibitor. Hydrolysis $t_{1/2}$ is 5.2 days (Johnson 1991). The water solubility of carbaryl is 110 mg/L at a temperature of 25°C (Johnson 1991). Carbaryl soil adsorption is relatively low, with an average soil adsorption coefficient (K_{oc}) of 360 cm^3/g (Johnson 1991). The aerobic metabolism $t_{1/2}$ of carbaryl is eight days and the anaerobic metabolism $t_{1/2}$ is 76 days (Johnson 1991).

The high water solubility and low K_{oc} values indicate that carbaryl has the potential to be carried in field runoff to surface water or to leach into groundwater.

TOXICITY TO AQUATIC ORGANISMS

Acute Toxicity To Aquatic Animals

A total of 227 tests on the acute toxicity of carbaryl to aquatic animals were evaluated (Appendix B). Of these 227 tests, 159 tests were accepted (Table B-1) and 68 tests were not accepted (Table B-2).

EPA (1985) guidelines recommend eight families of freshwater organisms for which acceptable data should be available for deriving a freshwater Final Acute Value (FAV) (Table 3). Acceptable data were available for seven of the recommended eight freshwater families. Of the eight recommended families for calculation of a saltwater FAV, toxicity data were available for eight families (Table 4). Genus Mean Acute Values (GMAVs) were calculated using data from accepted acute toxicity tests for freshwater and saltwater organisms and were ranked in ascending order (Table 5 and Table 6, respectively). The freshwater GMAVs ranged from 4.8 µg/L for the stonefly *Pteronarcys californica* to 20,000 µg/L for the bullhead *Ameiurus melas*. The saltwater GMAVs ranged from 6.18 µg/L for the mysid *Mysidopsis bahia* to 22,700 µg/L for the bay mussel *Mytilus edulis*.

Usually, the four lowest GMAVs are the most significant determinants of the FAV. For carbaryl, the lowest four GMAVs for freshwater organisms were for the stonefly *Pteronarcys californica*, the stonefly *Isogenus sp.*, the prawn *Palaemonetes kadiakensis*, and the stonefly *Claassenia sabulosa*. Although only seven of the eight families are represented, additional data in the remaining category would likely be for a mollusk. As indicated by the LC_{50} value for the saltwater bay mussel (22,700 µg/L), mollusks are not very sensitive to carbaryl and therefore the remaining category would not likely lower the FAV. The freshwater FAV was 5.05 µg/L. The four lowest GMAVs for saltwater organisms were for the mysid *Mysidopsis bahia*, the shrimp *Penaeus aztecus* and *P. duorarum*, the prawns *Palaemonetes kadiakensis* and *P. pugio*, and the urchin *Psuedochinus promelas*. The saltwater FAV was 1.62 µg/L.

Table 3. Eight families of freshwater aquatic animals recommended by EPA (1985) for use in deriving the freshwater Final Acute Value (FAV) and representative species for which carbaryl acute toxicity data were available.

Family	Available species
1. One Salmonid	Rainbow trout
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]
5. One insect family or any phylum not already represented	Midge
6. One planktonic crustacean	Cladoceran
7. One benthic crustacean	Amphipod
8. One insect	Stonefly

[a]Not applicable- Data unavailable for category.

Table 4. Eight families of saltwater aquatic animals recommended by EPA (1985) for use in deriving the saltwater Final Acute Value (FAV) and representative species for which carbaryl acute toxicity data were available.

Family	Available species
1, 2. Two families in phylum Chordata	Sheepshead minnow Longnose killifish
3. One family not in phylum Arthropoda or Chordata	Eastern oyster
4, 5, 6. Three other families Not in phylum Chordata	Bay mussel Blue crab Grass shrimp
7. A mysid or penaeid	Brown shrimp
8. One other family not already represented	Sea urchin

Table 5. Ranked Genus Mean Acute Values (GMAV) and Species Mean Acute Values (SMAV) from accepted acute toxicity tests on freshwater species used to calculate the freshwater Final Acute Value (FAV).

Rank	GMAV (µg/L)	Organism	Species
1	4.8	Stonefly	*Pteronarcys californica*
2	5.55[a]	Stonefly	*Isogenus sp.*
3	5.6	Prawn	*Palaemonetes kadiakensis*
4	5.6	Stonefly	*Claassenia sabulosa*
5	5.9[a]	Cladoceran	*Daphnia magna* (SMAV = 5.6) *Daphnia pulex* (SMAV = 6.4)
6	8.8[a]	Cladoceran	*Simocephalus serrulatus*
7	9.16[a]	Stonefly	*Pteronarcella sp.*
8	10	Midge	*Chironomus plumosus*
9	18[a]	Amphipod	*Gammarus fasciatus* (SMAV = 26 µg/L) *Gammarus lacustris* (SMAV = 22 µg/L) *Gammarus psuedolimnaeus* (SMAV = 9.65 µg/L)
10	115	Ostracod	*Cypridopsis vidua*
11	280	Isopod	*Asellus brevicaudus*
12	1,310	Colorado squawfish	*Ptychocheilus lucius*
13	1,259.1[a]	Char	*Salvelinus fontinalis* (1,604.27 µg/L) *Salvelinus namaycush* (SMAV = 988.15 µg/L)
14	1,900	Crayfish	*Procambarus sp.*
15	2,010.08[a]	Salmon (Old World)	*Salmo salar* (SMAV = 1,138.26 µg/L) *Salmo trutta* (SMAV = 3,549.65 µg/L)
16	2,020	Bonytail	*Gila elegans*
17	2,230[a]	Salmon (New World)	*Oncorhynchus clarki* (SMAV = 3,531.42 µg/L) *Oncorhynchus kisutch* (SMAV = 2,047.03 µg/L) *Oncorhynchus mykiss* (SMAV = 1,424.99 µg/L) *Oncorhynchus tshawytscha* (SMAV = 2,400 µg/L)
18	2,479.66[a]	Perch	*Perca flavescens*
19	2,600	Crappie	*Pomoxis nigromaculatus*
20	5,280	Carp	*Cyprinus carpio*
21	6,400	Largemouth bass	*Micropterus salmoides*
22	7,643.17[a]	Sunfish	*Lepomis cyanellas* (SMAV = 10,293.30) *Lepomis macrochirus* (SMAV = 5,675.34)
23	9,886.61[a]	Fathead minnow	*Pimephales promelas*
24	12,865[a]	Catfish	*Ictalurus punctatus*
25	12,998.46[a]	Goldfish	*Carassius auratus*
26	20,000	Bullhead	*Ameiurus melas*

[a]GMAV based on a geometric mean of more than one LC_{50} / EC_{50} for this genus.

Table 6. Ranked Genus Mean Acute Values (GMAV) and Species Mean Acute Values (SMAV) from accepted acute toxicity tests on saltwater species used to calculate the saltwater Final Acute Value (FAV).

Rank	GMAV (µg/L)	Organism	Species
1	6.18[a]	Mysid	*Mysidopsis bahia*
2	6.93[a]	Shrimp	*Penaeus aztecus* (SMAV = 1.5 µg/L) *Penaeus duorarum* (SMAV = 32 µg/L)
3	28	Prawn	*Palaemonetes pugio*
4	92.5	Urchin	*Pseudechinus magellanicus*
5	320	Blue crab	*Callinectes sapidus*
6	1,600	Killifish	*Fundulus similis*
7	2,400	Striped mullet	*Mugil cephalus*
8	2,600	Sheepshead minnow	*Cyprinodon variegatus*
9	13,942.74[a]	Oyster	*Crassostrea virginica*
10	22,700[a]	Bay mussel	*Mytilus edulis*

[a] GMAV based on a geometric mean of more than one LC_{50} / EC_{50} for this genus.

Chronic Toxicity to Aquatic Animals

Two tests on the chronic toxicity of carbaryl were evaluated (Appendix C), and accepted (Table C-1). The Maximum Acceptable Toxicant Concentration value (MATC) was 4.4 µg/L for the cladoceran *Daphnia magna* and 380 µg/L for the fathead minnow *Pimephales promelas* (Table C-1).

The EPA (1985) guidelines specify calculating the Acute-to-Chronic Ratio (ACR) for a species using for the numerator the geometric mean of LC_{50} values and for the denominator the geometric mean of MATC values. Freshwater or saltwater Final ACR values are derived using ACR values of both freshwater and saltwater species, including at least a fish, an invertebrate, and an acutely sensitive species. The FACR value used to derive a freshwater Final Chronic Value (FCV) should include an acutely sensitive freshwater species. The other species used may be either freshwater or saltwater. For carbaryl, chronic values were available for a freshwater invertebrate, the cladoceran *Daphnia magna* and a freshwater fish, fathead minnow *Pimephales promelas*. *D. magna* is considered to be an acutely sensitive species. However, the ACR values for carbaryl appear to increase with increasing acute values (Table 7). 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 the species where acute toxicity values are close (within a factor of 10) to the FAV. Therefore, the ACR value for *D. magna* was used to estimate a FACR value of 1.3. However, EPA (1985) procedures further specify that if the most appropriate ACR values are less than two, it should be assumed that acclimation occurred in the chronic tests and the FACR should be set at two. The freshwater FCV was derived by dividing the freshwater FAV by the FACR

(2), resulting in a value of 2.53 µg/L. The saltwater FCV was derived by dividing the saltwater FAV by the FACR (2), resulting in a value of 0.81 µg/L.

Table 7. Acute to Chronic Ratios (ACR) of Accepted Tests

Organism	Species	ACR
Cladoceran	*Daphnia magna*	5.6 / 4.4 = 1.27
Fathead minnow	*Pimephales promelas*	8,868.97 / 380 = 23.34

Toxicity to Aquatic Plants

Four tests on the toxicity of carbaryl to aquatic plants were evaluated (Appendix D) to derive a Final Plant Value (FPV). The FPV is the lowest concentration of a pesticide that demonstrates a biologically important toxic endpoint (EPA 1985). In tests for which specific values were reported, the lowest biologically toxic endpoint was an EC_{50} value of 350 µg/L for the saltwater diatom *Skeletonema costatum.* The FPV for carbaryl is 350 µg/L. None of the tests indicated that carbaryl was more toxic to aquatic plants than to the more sensitive aquatic animals, therefore criteria that protect aquatic animals will also protect aquatic plants.

HAZARD ASSESSMENT

Water Quality Criteria

The EPA (1985) guidelines specify that a WQC consists of two concentrations, the Criterion Maximum Concentration (CMC) to protect against acute toxicity and the Criterion Continuous Concentration (CCC) to protect against chronic toxicity. According to the guidelines, aquatic organisms should not be affected unacceptably if the four-day average concentration of carbaryl does not exceed the CCC value and if the one-hour average concentration does not exceed the CMC value more than once every three years on the average. 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) (Appendix A). The FRV is intended to prevent pesticide concentrations in commercially or recreationally important species from affecting marketability because of excedence of applicable action levels and to protect wildlife that consume aquatic organisms (EPA 1985).

Carbaryl does not appear to bioconcentrate to a significant degree (Chib 1986, Korn 1973). Korn (1973) also suggests that carbaryl appears to be metabolized and excreted quickly. Therefore, no FRV was calculated.

Both the freshwater CMC and CCC for carbaryl are 2.53 µg/L. Both the saltwater CMC and CCC for carbaryl are 0.81 µg/L. The WQC may be refined as more chronic data becomes available.

Hazard to Aquatic Animals

Carbaryl has been detected in the San Joaquin River system at concentrations as high as 8.4 µg/L (DPR 1996). The concentration of carbaryl in the San Joaquin River system exceeded the CMC and CCC value three times during three years of monitoring (Table 2). However, these detections were in tributaries containing agricultural runoff water. Carbaryl may pose an acute and chronic hazard in tributaries containing agricultural runoff water in the San Joaquin River system. While monitoring data included in this report are from grab samples, CMC values are based on one-hour averages and CCC values are based on four-day averages. No carbaryl was detected in water from the Sacramento River system from October 1992 to April of 1994 (USGS 1995).

It appears that the toxicities of some insecticides commonly found together in the Sacramento-San Joaquin drainage are additive (CDFG 1992). Calculation of WQC may need to take into account additive effects of pesticides likely to be present concurrently in the Sacramento-San Joaquin drainage. Monitoring data for saltwater are not available, but as a result of dilution and transport time, carbaryl concentrations in saltwater are likely to be lower than in freshwater.

Data Requirements

Acceptable acute data were available for seven of the eight freshwater families recommended by the EPA. Additional data in the remaining category would most likely be for a mollusk or rotifer. As neither of these organisms is likely to be sensitive to carbaryl, it is unlikely that the data from the missing category would lower the FAV. Acceptable chronic toxicity data were available for one invertebrate and one fish. Paired acute and chronic toxicity tests should be conducted on other invertebrates and fish to provide acute-to-chronic ratios (ACR). Once additional studies become available, the CDFG may reassess the hazards posed by carbaryl to aquatic species.

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APPENDIX A. *Procedures used by the California Department of Fish and* Game to prepare hazard assessments.

The California Department of Fish and Game (CDFG) Pesticide 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 for test type, method, design and 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 EPA (1985) guidelines recommend eight categories of saltwater organisms for deriving a saltwater FAV.

The FAV is calculated as follows:

1. The Species Mean Acute Value (SMAV) is the geometric mean of EC_{50} values from all accepted toxicity tests performed on that species.

2. The Genus Mean Acute Value (GMAV) is 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 Ps, as follows:

$$S^2 = \frac{\sum((\ln \text{GMAV})^2) - ((\sum(\ln \text{GMAV}))^2/4)}{\sum(P) - ((\sum(\sqrt{P}))^2/4)}$$

$$L = (\sum(\ln \text{GMAV}) - S(\sum(\sqrt{P})))/4$$

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

$$\text{FAV} = e^A$$

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 families, 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 form 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 the species 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 EPA 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 (EPA 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.

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:

Beyers et al. (1994) - In 1989 and 1990, 96-h static acute and 32-day flow-through toxicity tests were performed at Colorado State University, Colorado on technical carbaryl (99%) with larval stages of Colorado squawfish *Ptychocheilus lucius* and bonytail *Gila elegans*. Five concentrations and a solvent and water control were tested. There were 2 replicates per treatment with 10 organisms per replicate. Water quality parameters during the test were: temperature of 22° C; pH of 7.9-8.6; D.O. of 6.1-7.2 mg/L; and a hardness of 344-378 mg/L as $CaCO_3$. Control survival was statistically checked with a T-test $\alpha = 0.05$. The 96-h LC_{50} values were: *P. lucius* 1,310 µg/L, and *G. elegans* 2,020 µg/L. The NOEC values were 445 µg/L for *P. lucius*, and 650 µg/L for *G. elegans.*

Dione et al. (1985a) - In 1985, a 48-h static acute toxicity test was performed by Springborn Bionomics, Inc. Aquatic Toxicology Laboratory in Wareham, Massachusetts on carbaryl (99%) with the embryo and larvae of the eastern oyster *Crassostrea virginica.* ASTM and EPA (1985) test standards were used. Seven concentrations and solvent and water controls were tested. Three replicates per concentration with approximately 28,000 organisms per replicate were used. Water quality parameters during the test were: temperature of 20° C; pH of 7.8; dissolved oxygen level of 71% saturation; and a salinity of 30%. The percentage of oyster larvae that developed normal shells was ~73% in the water control and ~74% in the solvent control. The 96-h EC_{50} for *C. virginica* was 2,700 µg/L.

Dione et. al. (1985b) - In 1985, a 96-h static acute toxicity test was performed by Springborn Bionomics, Inc. Aquatic Toxicology Laboratory in Wareham, Massachusetts on technical grade carbaryl (99%) with 1-5 day old mysids *Mysidopsis bahia*. Six concentrations of carbaryl and solvent and water controls were tested. Two replicates per treatment with five organisms per replicate were used. Water quality parameters during the test were: temperature of 21-23° C; pH of 7.9; and a salinity of 20 ‰. Control survival was 90% in the solvent control and 100% in the water control. The LC_{50} for *M. bahia* was 6.7 μg/L.

Geiger et. al. (1988) - In 1988, four 96-h flow-through acute toxicity tests were performed by Lake Superior Center for Environmental Studies, University of Wisconsin, Superior on carbaryl (99%) with the fathead minnow *Pimephales promelas*. Five concentrations and a control were tested. Twenty organisms per concentration were used. Water quality parameters during the test were: temperature of 25.8° C, pH of 7.7, dissolved oxygen level of 6.7 mg/L, and a hardness of 45.4 mg/L as $CaCO_3$ (test 1); temperature of 24.5° C, pH of 7.7, dissolved oxygen level of 7.0 mg/L, and a hardness of 44.1 mg/L as $CaCO_3$ (test 2); temperature of 24.2° C, pH of 7.7, dissolved oxygen level of 7.0 mg/L, and a hardness of 43.8 mg/L as $CaCO_3$ (test 3); temperature of 26.0° C, pH of 7.7, dissolved oxygen level of 6.7 mg/L, and a hardness of 45.4 mg/L as $CaCO_3$ (test 4);. Control survival was 100%. The 96-h LC_{50} for *P. promelas* was 6,670 μg/L and the 96-h EC_{50} was 5,290 μg/L (test 1); 10,400 μg/L 6,400 μg/L (test 2); 9,470 μg/L and 6,420 μg/L (test 3); and 8,930 μg/L and 7,470 μg/L (test 4).

Hernandez et al. (1990) - In 1989, a 96-h static acute toxicity test was performed by the Laboratory of Ecotoxicology, Lujan, Argentina on carbaryl (99%) with various life stages of the sea urchin *Pseudechinus magellanicus*. Five concentrations of carbaryl and water and solvent controls were tested. Two replicates per treatment with approximately 12,500 organisms per replicate were used. Water quality parameters during the test were: temperature of 13 ± 1°C; pH of 7.4; dissolved oxygen level of 7.8 mg/L; and a salinity of 33%. Survival in all controls were above 90%. The 96-h EC_{50} for *P. magellanicus* was 92.5 µg/L.

Lintott (1992a) - In 1992, a 96-h flow-through acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, Connecticut on technical grade carbaryl (99.7%) with the mysid *Mysidopsis bahia*. Five concentrations and solvent and water controls were tested. One replicate per test with twenty organisms per replicate were used. Water quality parameters during the test were: temperature of 21.5-23.1°C; pH of 8.2-8.5; and a salinity of 20 ± 1°/₀₀. Control survival was 100% in both controls. The LC_{50} for *M. bahia* was 5.7 µg/L and the NOEC was 3.2 µg/L.

Lintott (1992b) - In 1992, a 96-h flow-through acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, Connecticut on carbaryl technical (99.7%) with juvenile sheepshead minnow *Cyprinodon variegatus*. Five concentrations and solvent and water controls were used. One replicate per concentration with twenty organisms per test were used. Water quality parameters during the test were: temperature of 24.1-25.6°C; dissolved oxygen level of 76% saturation; and a salinity of 20°/₀₀. Control survival was 100% in both controls. The LC_{50} for *C. variegatus* was 2,600 µg/L and the NOEC was 1,100 µg/L.

Liu and Lee (1975) - In 1975, a 96-h acute toxicity test was performed by the National Environmental Research Center, Corvallis, Oregon on carbaryl (99.7%) with the adult bay mussel *Mytilus edulis*. Four concentrations and a water control were tested with ten organisms each. Water quality parameters during the tests were: temperature of 20 ± 2° C; pH of 8 ± 0.2; dissolved oxygen of 7.2 mg/L; and salinity of 25°/₀₀. Control survival was 100%. The 96-h LC_{50} for *M. edulis* was 22,700 µg/L.

Mayer (1987) - From 1961 to 1986, 48-h and 96-h flow-through and static toxicity tests were performed by the Environmental Research Laboratory, Gulf Breeze, Florida on technical grade carbaryl (99.7%) with brown shrimp *Penaeus aztecus* at a temperature of 30° C and salinity of 28°/$_{00}$; pink shrimp *Penaeus duorarum* at a temperature of 23° C and salinity of 29°/$_{00}$; grass shrimp *Palaemonetes pugio* at a temperature of 23° C and salinity of 29°/$_{00}$; blue crab *Callinectes sapidus* at a temperature of 30° C and salinity of 28°/$_{00}$; eastern oyster *Crassostrea virginica* at a temperature of 29° C and salinity of 27°/$_{00}$; longnose killifish *Fundulus similis* at a temperature of 28° C and salinity of 19°/$_{00}$; and striped mullet *Mugil cephalus* at a temperature of 24° C and salinity of 17°/$_{00}$. The values obtained were: brown shrimp 48-h flow-through EC_{50} of 1.5 µg/L; pink shrimp 48-h flow-through EC_{50} of 32 µg/L; grass shrimp 48-h flow-through EC_{50} of 28 µg/L; blue crab 48-h flow-through EC_{50} of 320 µg/L; eastern oyster 96-h flow-through EC_{50} of 72,000 µg/L; longnose killifish 48-h static LC_{50} of 1,600; and striped mullet 48-h static LC_{50} of 2,400 µg/L. Although control survival, dissolved oxygen level levels, and pH were not given, the tests were accepted as they were deemed acceptable by the EPA.

Mayer and Ellersieck (1986); Dwyer and Sappington (pers. comm). - From 1965 to 1985, 24-h, 48-h, and 96-h static toxicity tests were performed by the Columbia National Fisheries Research Laboratory of the U.S. Fish and Wildlife Service, Columbia, Missouri on technical grade carbaryl (99.5%). The species tested were: cladocerans *Daphnia magna, Daphnia pulex,* and *Simocephalus serrulatus* (three tests); ostracod *Cypridopsis vidua;* isopod *Asellus brevicaudus;*

amphipods *Gammarus fasciatus*, *G. lacustris*, and *G. pseudolimnaeus* (four tests); stoneflies *Claassenia sabulosa*, *Isogenus sp.* (five tests); *Pteronarcella badia* (four tests); and *Pteronarcys californica;* crayfish *Procambarus sp.;* prawn *Palaemonetes kadiakensis;* bluegill *Lepomis macrochirus* (thirteen tests); cutthroat trout *Oncorhynchus clarki* (ten tests); lake trout *Salvelinus namaycush* (five tests); brook trout *Salvelinus fontinalis* (nine tests); brown trout *Salmo trutta* (two tests); rainbow trout *Oncorhynchus mykiss* (twenty tests); coho salmon *Oncorhynchus kisutch* (five tests); Atlantic salmon *Salmo salar* (fifteen tests); chinook salmon *Onchorhynchus tshawytscha*, carp *Cyprinus carpio*; fathead minnow *Pimephales promelas* (three tests); black bullhead *Ameiurus melas;* channel catfish *Ictalurus punctatus* (three tests); green sunfish *Lepomis cyanellus* (two tests); largemouth bass *Micropterus salmoides*; black crappie *Pomixis nigromaculatus* ; yellow perch *Perca flavescens* (fourteen tests); and goldfish *Carassius auratus* (two tests). Four or more concentrations were tested in replicate and solvent (acetone) controls were tested. Carbaryl concentrations were not measured during the tests. Water quality parameters during the tests were: pH of 6.5-9.5 and a hardness of 12-330 mg/L as $CaCO_3$. Control survival was acceptable in all tests. Although dissolved oxygen levels were not given, these tests were accepted because control survival was acceptable and ASTM standards were followed.

Post and Schroeder (1971) - In 1971, 96-h static acute toxicity tests were performed by Colorado State University, Fort Collins, Colorado on carbaryl (98%) with brook trout *Salvelinus fontinalis*, rainbow trout *Oncorhynchus mykiss*, cutthroat trout *O. clarki*, and coho salmon *O. kisutch*. Five or six concentrations and a solvent control were tested. There were two replicates per concentration with three to five organisms per replicate. Water quality parameters during the tests were: temperature of 13.6-14.6°C; pH of 7.2-7.6; dissolved oxygen level of

5.9-6.0; and hardness of 318-348 ppm. The LC_{50} values were: *S. fontinalis* 1,070-1,450 µg/L; *O. mykiss* 1,470 µg/L; *O. clarki* 1,500-2,169 µg/L; and *O. kisutch* 1,300 µg/L.

Sanders et al. (1983) - In 1983, 48-h and 96-h static acute toxicity tests were performed on carbaryl (99.5%) by the U.S. Fish and Wildlife Service, Columbia, Missouri on the cladoceran *Daphnia magna*, amphipod *Gammarus pseudolimnaeus*, midge larvae *Chironomus plumosus*, bluegill *Lepomis macrochirus*, rainbow trout *Oncorhynchus mykiss*, fathead minnow *Pimephales promelas*, and channel catfish *Ictalurus punctatus*. Water quality parameters during the test were: temperatures of 7, 12, or 22°C with fish and 17°C with invertebrates; pH of 7.4; and hardness of 40 mg/L. Control survival, number of carbaryl concentrations, and dissolved oxygen level were not given. The EC_{50} values for *D. magna, G. pseudolimnaeus,* and *C. plumosus* were 5.6, 16, and 10 µg/L respectively. The LC_{50} values for *L. macrochirus, O. mykiss, P. promelas,* and *I. punctatus* were 7,000, 2,200, 14,600, and 15,800 µg/L respectively.

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

Basha et al. (1983) - In 1983, a static acute toxicity test was performed by S.V. University, Kavali, India on carbaryl (commercial grade) with the freshwater fish *Tilapia mossambica*. Water quality parameters during the test were: temperature of 26-28° C; pH of 7.0 ± 0.2; and a hardness of 140± 20 mg/L. The LC_{50} for *Tilapia mossambica* was 5,495 µg/L. This value was not used because percent active ingredient tested, dissolved oxygen levels, control survival, and test design were not given. Attempts at correspondence with the author were unsuccessful.

Bhatia (1971) - A 96-h static acute toxicity test was performed by the Fisheries Research Laboratory, Bhopal on carbaryl (99%) with the freshwater fish *Punctius ticto*. Ten concentrations were tested with ten organisms per concentration. Water quality parameters during the test were: temperature of 10.5-29°C; pH of 7.6-8.3; D.O. of 7.2-9.2 mg/L; and a hardness of 68-88 mg/L. The 96-h LC_{50} value for *Punctis ticto* was 3,700 µg/L. This value was not used because control survival was not reported and the temperature range was in excess of guidelines.

Bills and Marking (1988) - In 1984, a 96-h static toxicity test was performed by the U.S. Fish and Wildlife Service in LaCrosse, Wisconsin on carbaryl (percent active ingredient not given) with adult crayfish *Orconectes rusticus*. The number of concentrations and controls used were not given. Concentrations were not measured. Water quality parameters during the test were: temperature of 12° C; pH of 7.98; and hardness of 256 mg/L as $CaCO_3$. The LC_{100} value for crayfish was 20,000 µg/L. This value was not used because essential information, such as control survival and percent active ingredient, were not given and no LC_{50} was determined.

Chaiyarch et al. (1975) - In 1975, an acute toxicity test was performed by Lamar University, Beaumont, Texas on carbaryl (80% active ingredient) with mosquito fish *Gambusia affinis*, grass shrimp *Palaemonetes kadiakensis*, crayfish *Procambarus simulans*, and the mactrid clam *Rangia cuneata*. The number of replicates, number of organisms per replicate, and control mortality were not given. Water quality parameters were also not given. The 96-h LC_{50} values for *G. affinis, P. kadiakensis, P. simulans, and R. cuneata* were: 31,800, 120, 2,430, and 125,000 μg/L respectively. These values were not accepted because the percent active ingredient was too low and many important parameters, such as control survival, were not measured or reported.

Cheah et al. (1980) - In 1979, a 96-h static acute toxicity test was performed by Louisiana State University, Baton Rouge, Louisiana on carbaryl (percent active ingredient not given) with the crayfish *Procambarus clarkii*. EPA (1975) test standards were used. Four to seven concentrations and a control were used. There were three replicates per concentration with 10 organisms per replicate. Water quality parameters during the test were: temperature of 20 ± 3°C; pH of 8.4; and hardness of 100 mg/L. dissolved oxygen level levels were not measured during the test. Control survival was 95%. The 96-h LC_{50} for *P. clarkii* was 500 μg/L. This value could not be used because the percent active ingredient was not given.

Chitra and Pillai (1984) - In 1984, 24-h static acute toxicity tests and generation of resistance tests were performed by the University of Delhi, India on carbaryl (95-98%) with the fourth instar larvae of the mosquito *Anopheles stephensi*

(Delhi and Haryana stains). Exposure was for 240 minutes; toxicity was measured at 24 hours. Water quality parameters during the test were not reported with the exception of temperature which was 28 ± 2° C. Each concentration (number of concentrations not given) was tested with four replicates, each replicate contained 20 organisms. The 24-h LC_{50} values for *Anopheles stephensi* were 212 µg/L (Delhi) and 256 µg/L (Haryana). These values were not used because the number of concentrations tested and control survival were not reported. The generation of resistance tests were inappropriate for hazard assessment review.

Conti (1987) - In 1986, a 48-h static acute toxicity test was performed by the Station Biologique, Roscoff, France on carbaryl (99%) with the lugworm *Arenicola marina*. No recognized test standards were used during the test. Five concentrations and a solvent control were used and there were 10 organisms per replicate. Water quality parameters during the test were: temperature of 15°C; dissolved oxygen level of 150 torr; pH of 8.05. Water hardness was not given. Control survival was not given. The LC_{50} for *A. marina* was 7,200 µg/L. This value could not be used because control survival was not given. Attempts at correspondence with the author were unsuccessful.

Fisher et al. (1993) - In 1991, a 24-h static acute toxicity test was performed on carbaryl (99%) with the midge *Chironomus riparius*. Twenty organisms were used per replicate with three replicates per treatment. Water quality parameters during the test were not given. Control survival was not given. The EC_{50} value for *C. riparius* was 110 µg/L. This value could not be used because the test length was not sufficient and essential information, such as control survival, was lacking.

Hanazato (1991) - In 1990, a 10-h static acute toxicity tests were performed on carbaryl (99%) with the cladoceran *Daphnia ambigua*. No recognized test standards were followed. Five concentrations and a solvent control were used. The temperature was 23 ± 0.5°C; pH, dissolved oxygen level , and hardness were not given. Control survival was 100%. No toxicity values were given and therefore this test could not be used.

Jacob et al. (1982) - 24-h and 48-h static acute toxicity tests were performed by the University of Kerala, Trivandrum, India on carbaryl (50%) with the larvivorous fishes *Aplocheilus lineatus* and *Macropodus cupanus*. Five concentrations were tested. Water quality parameters during the tests were: temperature of 28 ± 2°C; and a pH of 7.1. Dissolved oxygen and hardness were not given. The 48-h LC_{50} values for *A. lineatus* and *M. cupanus* were 3,747 µg/L and 13,910 µg/L. These values were not used because the percent active ingredient was too low.

Katz (1961) - In 1959-1960, 96-h static acute toxicity tests were performed on carbaryl (95%) with coho salmon *Oncorhynchus kisutch*, rainbow trout *O. mykiss*, and the threespine stickleback *Gasterosteus aculeatus*. Five concentrations of carbaryl and water and solvent controls were tested. Tests were run in duplicate with 3-5 salmonids, and 11-20 sticklebacks per replicate. The number of fish per concentration was reduced to five in some concentrations after 48-h. Water quality parameters during the test were: temperature of 20 ± 5°C; pH of 6.8-7.4; dissolved oxygen level of 7.8 mg/L; and an alkalinity of 45-57 ppm. The LC_{50} values were *O. kisutch* 997 µg/L, *O. mykiss* 1,350 µg/L, and *G. aculeatus* 3,990 µg/L. These values were not used because there were too few fish in some concentrations.

Kaur and Dhawan (1993) - In 1991, static acute toxicity tests were performed on carbaryl (50%) with the eggs, larvae, and fry of the carp *Cyprinus carpio*. Eight concentrations with three replicates per concentration (including control) were performed with 50 organisms per replicate. Water quality parameters during the test were: temperature of 24 ± 1°C; pH of 7.5 ± 0.2; dissolved oxygen level of 5.5 ± 0.5 mg/L; and a hardness of 272 ± 2 mg/L. The LC_{50} for *C. carpio* was 1,190 µg/L. This value was not used because the percent active ingredient was too low.

Kimura and Keegan (1966) - In 1963 and 1964, 48-h static acute toxicity tests were performed by the Department of Entomology, U.S. Army Medical Command of Japan on technical grade carbaryl (percent active ingredient unknown) with the leech *Hirudo nipponia* (Japanese and Korean strains). An unknown number of concentrations were tested with five organisms each. No water quality parameters were given. The 48-h LC_{50} values for *H. nipponia* were 5,500 and 17,000 µg/L (Japanese and Korean strains, respectively). These values were not used because control survival, number of concentrations, and water quality parameters were not given.

Korn and Earnest (1974) - A 96-h static acute toxicity test was performed by the National Marine Fisheries Service in Tiburon, California on carbaryl (95%) with the striped bass *Morone saxatilis*. Water quality parameters during the test were: temperature of 17 ± 0.5°C, and a salinity of 30 ± 1°/$_{oo}$. Dissolved oxygen was not measured and pH and water hardness were not given. The 96-h LC_{50} value for *M. saxatilis* was 1,000 µg/L. This value was not used because dissolved oxygen was not measured, and control survival and the number of concentrations tested were not given.

Lintott (1992c) - In 1992, 96-h a static acute toxicity tests was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (43.3%) with the eastern oyster *Crassostrea virginica*. Five concentrations and water and solvent controls were tested. There were 20 organisms per concentration. Water quality parameters during the test were: temperature of 24.7-25.5°C; pH of 6.7-8.1; dissolved oxygen level of 97-107% saturation; and a salinity of 20‰. Control survival was 100%. The EC_{50} and NOEC for *C. virginica* were 10,200 µg/L, and 3,770 µg/L. These values could not be used because the percent active ingredient was too low.

Lintott (1992d) - In 1992, a 96-h static acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (81.5%) with the mysid *Mysidopsis bahia*. Five nominal concentrations and water and solvent controls were tested. There were 20 organisms per concentration. Water quality parameters during the test were: temperature of 19.9-23.9°C; pH of 7.8-8.4; dissolved oxygen level of 84% saturation; and a salinity of 20‰. Control survival was 100% in the solvent control and 95% in the water control. The LC_{50} and NOEC for *M. bahia* were 7,580 µg/L, and 6,050 µg/L. These values could not be used because the percent active ingredient was too low.

Lintott (1992e) - In 1992, a 96-h static acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (43.7%) with the mysid *Mysidopsis bahia*. Five nominal concentrations and water and solvent controls were tested. There were two replicates per treatment with 10 organisms per replicate. Water quality parameters during the test were: temperature of 20.5-22.4°C; pH of 8.3-8.4; dissolved oxygen level of 96-112% saturation; and a salinity of 20 ± 1‰. Control survival was 100% in the solvent control and 90% in the water control. The LC_{50} and NOEC for *M. bahia* were 8,810 µg/L, and 4,830 µg/L. These values could not be used because the percent active ingredient was too low.

Lintott (1992f) - In 1992, a 96-h static acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (43.7%) with the sheepshead minnow *Cyprinodon variegatus*. Five nominal concentrations and water and solvent controls were tested. There were twenty organisms per concentration. Water quality parameters during the test were: temperature of 22.1 ±1.6°C; dissolved oxygen level of 62-97% saturation; and a salinity of 20 ±3°/₀₀. Control survival was 100%. The LC_{50} and NOEC for *C. variegatus* were 5,400 µg/L, and 3,200 µg/L. These values could not be used because the percent active ingredient was too low.

Lintott (1992g) - In 1992, a 96-h static acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (47.3%) with the cladoceran *Daphnia magna*. Six nominal concentrations and water and solvent controls were tested. There were two replicates per treatment with 10 organisms per replicate. Water quality parameters during the test were: temperature of 19.8-24.8°C; pH of 6.4-7.8; dissolved oxygen level of 63-84% saturation; and a hardness of 68-76 mg/L. Control survival was 100%. The LC_{50} and NOEC for *D. magna* was 2,770 µg/L, and 1,570 µg/L. These values could not be used because the percent active ingredient was too low.

Lintott (1992h) - In 1992, a 96-h static acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (43.7%) with the cladoceran *Daphnia magna*. Six nominal concentrations and water and solvent controls were tested. There were two replicates per treatment with 10 organisms per replicate. Water quality parameters during the test were: temperature of 17.9-21.3°C; pH of 7.0-7.4; dissolved oxygen level of 84-124% saturation; and a salinity of 20 ±1‰. Control survival was 100% in the solvent control and 90% in the water control. The EC_{50} and NOEC for *D. magna* was 5,020 µg/L, and 2,270 µg/L. These values could not be used because the percent active ingredient was too low.

Lintott (1992i) - In 1992, a 96-h static acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (81.5%) with the rainbow trout *Oncorhynchus mykiss*. EPA (date unknown) test standards were followed during the test. Five nominal concentrations, with corresponding measured values, and water and solvent controls were tested. There were twenty organisms per replicate. Water quality parameters during the test were: temperature of 10.7-10.9°C; pH of 7.5-8.9; dissolved oxygen level of 90-110% saturation; and a hardness of 72mg/L. Control survival was 100% in the solvent control and the water control. The LC_{50} and NOEC for *O. mykiss* was 3,330 µg/L, and 730 µg/L. These values could not be used because the percent active ingredient was too low.

Lintott (1992j) - In 1992, a 96-h static acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (81.5%) with the cladoceran *Daphnia magna*. Six nominal concentrations and water and solvent controls were tested. There were two replicates per treatment with 10 organisms per replicate. Water quality parameters during the test were: temperature of 18.6-20.7°C; pH of 7.5-7.8; dissolved oxygen level of 93-102% saturation; and a hardness of 56-72 mg/L. Control survival was 100% in the solvent control and the water control. The EC_{50}

and NOEC for *D. magna* was 6,180 µg/L, and 1,390 µg/L. These values could not be used because the percent active ingredient was too low.

Lintott (1992k) - In 1992, a 96-h static acute toxicity test was performed by Toxicon Environmental Sciences, Research Triangle Park, North Connecticut on carbaryl (81.5%) with the mysid *Mysidopsis bahia*. Five nominal concentrations, with corresponding measured values, and water and solvent controls were tested. There were two replicates per treatment with 10 organisms per replicate. Water quality parameters during the test were: temperature of 19.7-25.8°C; pH of 8.4; dissolved oxygen level of 86-105% saturation; and a salinity of 21 ± 1°/$_{oo}$. Control survival was 90% in the solvent control and 100% in the water control. The LC50 and NOEC for *M. bahia* were 9,600 µg/L, and 3,150 µg/L. These values could not be used because the percent active ingredient was too low.

Lohner and Fisher (1990) - In 1989, 24-h static acute toxicity tests were performed by Ohio State University, Columbus, Ohio on carbaryl (99%) with the midge *Chironomus riparius*. EPA (1975) test standards were followed for water quality parameters. Five concentrations and a solvent control were tested. Two to three replicates were run per treatment. Water quality parameters during the test were: temperature of 10, 20, and 30°C; and a pH of 4, 6, and 8. Control survival was greater than 90% in the solvent controls. The EC_{50} values for *C. riparius* were from 61-133 µg/L. These values could not be used because the length of the test period was not sufficient.

Mayer (1970) - 96-h static acute toxicity tests were performed on carbaryl (99-100%) on Korean shrimp *Palaemon macrodactylus* and striped bass *Morone saxatilis*. Water quality parameters were: temperature of 17.8°C, and a salinity of 30°/$_{oo}$. Dissolved oxygen levels, pH, and water hardness were not reported. The

96-h LC_{50} values were: *P. macrodactylus* 12.0 and 7.0 µg/L (two tests), *M. saxatilis* >1000 µg/L. These values were not used because control survival, dissolved oxygen levels, and the number of concentrations tested were not reported. Attempts made to contact the author were unsuccessful.

Mayer and Ellersieck (1986); Dwyer and Sappington (pers. comm). - From 1965 to 1985, 96-h static acute toxicity tests were performed by the Columbia National Fisheries Research Laboratory of the U.S. Fish and Wildlife Service, Columbia, Missouri on carbaryl (49%) with the following species: at 7-12° C the 1st year class stoneflies *Isogenus sp.;* at 17° C the bluegill *Lepomis macrochirus;* and at 12° C the brook trout *Salvelinus fontinalis.* Four or more concentrations were tested in replicate and solvent (acetone) controls were tested. Carbaryl concentrations were not measured during the tests. Water quality parameters during the tests were: pH of 6.5-9.5 and a hardness of 12-42 mg/L as $CaCO_3$. Control survival was acceptable in all tests. Dissolved oxygen levels were not given. The LC_{50} values were: *I. sp.* 9.2 µg/L, *L. macrochirus* 39,000 µg/L, and *S. fontinalis* 4,500 µg/L. These values were not used because the percent active ingredient was too low.

Muncy (1963) - In 1963, a 72-h static acute toxicity test was performed by Louisiana State University, Baton Rouge, Louisiana on carbaryl (technical) with the red crayfish *Procambarus clarkii.* The number of concentrations tested, the number of replicates, and the number of organisms per replicate were not given. Water quality parameters during the test were: temperature of 16-32°C; and a pH of 7.6. dissolved oxygen level and hardness were not given. Control survival was not given. The LC_{50} for *P. clarki* was 200 µg/L. This value was not used because essential information, such as control survival and number of concentrations tested, were not given.

Naqvi and Hawkins (1988) - In 1987, a 96-h static acute toxicity test was performed by on carbaryl (5%) with the mosquito fish *Gambusia affinis*. Five concentrations with six replicates per concentration (including control) were tested with ten organisms per replicate. Water quality parameters during the test were: temperature of 20 ± 3° C; pH of 7.8; dissolved oxygen level of 6.5-7.0 mg/L; and a hardness of 12 mg/L. The LC_{50} for *G. affinis* was 204,000 µg/L. This value was not used because the percent active ingredient was too low.

Nicholson et al. (1985) - In 1985, 48-h static acute toxicity tests were performed by Bionomics Inc., Wareham, Massachusetts on carbaryl (44-49%) with the cladoceran *Daphnia magna*. Six concentrations (nominal) and solvent and water controls were tested with 15 organisms per concentration. Water quality parameters during the tests were: temperature of 19 and 20°C; pH of 8.0; dissolved oxygen level of 91-100% saturation; and a hardness of 160 mg/L. Control survival was 100% in both solvent and water controls. The LC_{50} for *D. magna* was 7.1 and 13 µg/L. These values could not be used because the percent active ingredient was too low.

Parsons and Surgeoner (1991) - In 1990, 24-h static acute toxicity tests were performed by the University of Guelph, Ontario, Canada on carbaryl (99.5%) with third instar mosquito larvae *Aedes aegypti*. Six concentrations of carbaryl were tested with water and solvent controls. Three to five replicates were run with 20 organisms per replicate. Water quality parameters during the test were: temperature of 25 ± 1°C; and a pH of 7.8-8.0. Water hardness and dissolved oxygen level levels were not given. Control survival was not given. The EC_{50} for *A. aegypti* was 510 µg/L. This value could not be used because the test length was not sufficient.

Poole and Willis (1970) - In 1956-57 and 1963-64, static acute toxicity tests were performed by the Marine Resources Laboratory, Menlo Park, California on carbaryl (technical) with the dungeness crab *Cancer magister* and the red crab *C. productus*. Three concentrations were tested and a solvent control, and there were 10 organisms per concentration. Water quality parameters during the test were: temperature of 8-12°C; salinity of 26-28°/$_{00}$; pH and dissolved oxygen level were not given. Control survival was not given. These tests could not be used because no LC_{50} or EC_{50} values were calculated.

Rawash et al. (1975) - In 1974, static acute toxicity tests were performed by the University of Alexandria, Egypt on carbaryl (% active ingredient unknown) with fourth instar mosquito *Culex pipiens* and adult cladoceran *Daphnia magna*. Six concentrations were tested. Water quality parameters during the tests were not given. The LC_{50} values were: *Culex pipiens* 75 µg/L, and *Daphnia magna* 0.26 µg/L. These values were not used because the percent active ingredient, control survival, and water quality parameters were not given. Attempts made to contact the author were unsuccessful.

Rettich (1977) - In 1974, 24-h static acute toxicity tests were performed by the Institute of Hygiene and Epidemiology, Prague, Czechoslovakia on carbaryl (% active ingredient unknown) with eight species of mosquito (fourth instar larvae) *Aedes cantans, A. vexans, A. excrucians, A. communis, A. strictius, A. punctor, Culex pipiens pipiens, C. pipiens molestus, and Culiseta annulata.* Five to six concentrations were tested in triplicate with 25 organisms each. Water quality parameters during the tests were not given with the exception of temperature which was 20-23° C. The LC_{50} values were: 376.6 µg/L for *A. cantans,* 322.6 µg/L for *A. vexans,* 145.5 µg/L for *A. excrucians, A. communis* for 167.9 µg/L, 298.3 µg/L for *A. punctor,* 333.9 µg/L for *C. pipiens pipiens,* 418.8 µg/L for *C. pipiens molestus*, and 179.5 µg/L for *Culiseta annulata.* These values were not used because percent active ingredient and control survival were not given. Attempts to contact the author were unsuccessful.

Shea and Berry (1983) - In 1983, 10-d static acute toxicity tests were performed by Northeastern University, Boston, Massachusetts on carbaryl (99.07%) with goldfish *Carassius auratus* and killfish *Fundulus heteroclitus.* Three concentrations and a control were tested. Ten organisms of each species were used per concentration. Water quality parameters during the tests were not given. Control survival was 100%. Because LC_{50} values were not given, the tests could not used.

Singh et al. (1984) - In 1983. 96-h static acute toxicity tests were performed by the Punjab Agricultural University, Ludhiana, India on carbaryl (50%) with the teleosts *Channa punctatus* and *Heteropneustes fossilis.* Water quality parameters during the tests were not given. An unknown number of concentrations were tested with ten organisms each. The 96-h LC_{50} values for *C. punctatus* and *H. fossilis* were 19,500 µg/L and 20,100 µg/L. These values were not used because the percent active ingredient was too low, control survival was not given, and water quality parameters were not listed.

Sousa et al. (1985a) - In 1985, two 96-h static acute toxicity tests were performed by Bionomics Inc., Wareham, Massachusetts on carbaryl (43.92% in #1 and 49% in #2) with the rainbow trout *Onchorhynchus mykiss.* Multiple concentrations (6 in #1 and 5 in #2) and a water control (test #2 included a solvent control) were tested with 10 organisms per concentration. Water quality parameters during the test were: temperature of 12-13°C; pH of 7.6; dissolved oxygen level of 37-94% saturation; and a hardness of 40 and 45 mg/L respectively. Control survival was 100% in both tests. The LC_{50} values for *O. mykiss* were 1,400 and 1,300 µg/L respectively. These values were not used because the percent active ingredients were too low.

Sousa et al. (1985b) - In 1985, two 96-h static acute toxicity tests were performed by Bionomics Inc., Wareham, Massachusetts on carbaryl (43.92% in #1 and 49% in #2) with the bluegill *Lepomis macrochirus*. Multiple concentrations (Five in #1 and seven in #2) and a water control (test #2 included a solvent control) were tested with 10 organisms per concentration. Water quality parameters during the test were: temperature of 22°C; pH of 7.6; and a hardness of 40 and 45mg/L respectively. Control survival was 100% in both tests. The LC_{50} values for *L. macrochirus* were 9,800 and 10,000 µg/L respectively. These values were not used because the percent active ingredients were too low, and dissolved oxygen level levels were not given.

Sousa et al. (1985c) - In 1985, 96h static acute toxicity tests were performed by Bionomics Inc., Wareham, Massachusetts on carbaryl (99%) with the sheepshead minnow *Cyprinodon variegatus*. Five concentrations and water and solvent controls were tested with 10 organisms per concentration. Only nominal concentrations were given. Water quality parameters during the test were: temperature of 22°C; pH of 7.8; dissolved oxygen level of 12-103% saturation; and a hardness of 45 mg/L as $CaCO_3$. Control survival was 100%. The LC_{50} for *C. variegatus* was 2,200 µg/L. This value was not used because the dissolved oxygen level levels dropped below accepted values.

Strickman (1985) - In 1985, 7-d static acute toxicity tests were performed by USAF Occupational and Environmental Health Laboratory, Brooks AFB, Texas on carbaryl (93-100%) with the larval stage of the pitcher plant mosquito *Wyeomyia smithii.* Three concentrations were tested with ten organisms per concentration. The only water quality parameters during the tests was a temperature of 27°C. Control survival was 100%. Because LC_{50} values were not given, the test could not be used.

Tripathi and Shukla (1988) - In 1987, 96-h static acute toxicity tests were performed by Banaras Hindu University, Varanasi, India on technical grade carbaryl (% not listed) on the freshwater catfish *Clarias batrachus.* No recognized test standards were mentioned. There were 20 organisms per treatment, but the number of concentrations and the number of replicates were not given. No water quality parameters were given. Control survival was 100% in a solvent control. The LC_{50} for *C. batrachus* was 46,850 µg/L. This value could not be used because water quality parameters, number of concentrations tested, or mortality range were not given. Attempts at correspondence with the author was unsuccessful.

Whitten and Goodnight (1966) - A 96-h static acute toxicity test was performed on technical grade carbaryl (percent active ingredient unknown) with the aquatic worms *Tubifex sp.* and *Limnodrilus sp.* Five concentrations and a solvent control were tested in duplicate with 50 organisms per replicate. Water quality parameters during the test were: temperature of 20° C; pH of 7.5; and a D.O. of 4 mg/L. The 96-h LC_{50} for *Tubifex sp.* and *Limnodrilus sp.* (combined) was >50,000 µg/L. This value was not used because control survival was not reported and two genera were tested simultaneously.

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

Species	Life Stage/ Size	Method[a]	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Amphipod *Gammarus fasciatus*	Mature	S/U	44 mg/L	96-h	LC_{50}	26(16, 39)	Mayer and Ellersieck 1986
Amphipod *Gammarus lacustrus*	Mature	S/U	44 mg/L	96-h	LC_{50}	22 (16, 30)	Mayer and Ellersieck 1986
Amphipod *Gammarus pseudolimnaeus*	Mature	S/U	40 mg/L	48-h	LC_{50}	13.0 (8.89, 19.010)	Mayer and Elle
	Mature	S/U	40 mg/L	48-h	LC_{50}	8.0 (4.930,13.000)	
	Mature	S/U	40 mg/L	96-h	LC_{50}	7.0 (4.120,11.900)	
	Mature	S/U	40 mg/L	96-h	LC_{50}	7.2 (5.600, 9.260)	
	N/A[c]	S/U	40 mg/L	96-h	LC_{50}	16 (12, 19)	Sanders et al. 1983
Atlantic salmon *Salmo salar*	0.40 g	S/U	42 mg/L	96-h	LC_{50}	4,500 (3820, 5310)	Mayer and Ellersieck 1986
	0.80 g	S/U	42 mg/L	96-h	LC_{50}	2,070 (1850, 2310)	
	0.80 g	S/U	42 mg/L	96-h	LC_{50}	1,180 (988, 1410)	
	0.40 g	S/U	42 mg/L	96-h	LC_{50}	1,270 (902, 1790)	
	0.40 g	S/U	42 mg/L	96-h	LC_{50}	905 (569, 1440)	
	0.80 g	S/U	12 mg/L	96-h	LC_{50}	2,010 (1540, 2630)	
	0.80 g	S/U	42 mg/L	96-h	LC_{50}	1,430 (1060, 1930)	
	0.20 g	S/U	42 mg/L	96-h	LC_{50}	500 (352, 710)	
	0.20 g	S/U	42 mg/L	96-h	LC_{50}	1,000 (704, 1420)	
	0.20 g	S/U	42 mg/L	96-h	LC_{50}	1,150 (910, 1450)	
	0.20 g	S/U	12 mg/L	96-h	LC_{50}	1,100 (884, 1370)	
	0.20 g	S/U	42 mg/L	96-h	LC_{50}	1,350 (996, 1830)	
	0.20 g	S/U	42 mg/L	96-h	LC_{50}	250 (118, 787)	
	0.20 g	S/U	42 mg/L	96-h	LC_{50}	900 (721, 1120)	
	0.20 g	S/U	42 mg/L	96-h	LC_{50}	1,000 (822, 1220)	
Bay mussel *Mytilus edulis*	Larval	S/M	N/A	96-h	LC_{50}	22,700 (15,500, 33,400)	Liu and Lee 1975
Black bullhead *Ameiurus melas*	1.2 g	S/U	40 mg/L	96-h	LC_{50}	20,000 (18,000, 24,000)	Mayer and Ellersieck 1986
Black crappie *Pomoxis nigromaculatus*	1.0 g	S/U	40 mg/L	96-h	LC_{50}	2,600 (1,180, 9,200)	Mayer and Ellersieck 1986
Blue crab *Callinectes sapidus*	N/A	F/U	28‰	48-h	EC_{50}	320 (N/A)	Mayer 1987
Bluegill *Lepomis macrochirus*	1.2 g	S/U	40 mg/L	96-h	LC_{50}	6,760 (5220,8760)	Mayer and Ellersieck 1986
	1.2 g	F/U	272 mg/L	96-h	LC_{50}	5,230 (4010,6820)	
	0.60 g	S/U	314 mg/L	96-h	LC_{50}	5,047 (4357,5847)	
	0.40 g	S/U	44 mg/L	96-h	LC_{50}	7,400 (5420, 10100)	
	0.40 g	S/U	44 mg/L	96-h	LC_{50}	5,200 (3660, 7390)	
	0.80 g	S/U	40 mg/L	96-h	LC_{50}	16,000 (11410, 22430)	
	0.80 g	S/U	40 mg/L	96-h	LC_{50}	7,000 (5020, 9760)	
	0.80 g	S/U	40 mg/L	96-h	LC_{50}	8,200 (6170, 10890)	
	0.40 g	S/U	320 mg/L	96-h	LC_{50}	6,200 (4310, 8920)	
	0.70 g	S/U	40 mg/L	96-h	LC_{50}	5,400 (4260, 6830)	
	0.70 g	S/U	40 mg/L	96-h	LC_{50}	5,200 (4060, 6640)	
	0.70 g	S/U	40 mg/L	96-h	LC_{50}	1,800 (1390, 2320)	
	0.70 g	S/U	40 mg/L	96-h	LC_{50}	2,600 (2070, 3250)	
	N/A	S/U	40 mg/L	96-h	LC_{50}	7,000 (5,100, 9,800)	Sanders et al. 1983

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

Species	Life Stage/ Size	Method[a]	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Bonytail *Gila elegans*	Larval	S/U	344-378 mg/L	96-h 32-day	LC_{50} NOEC	2,020 (1,780, 2,250) 650	Beyers et al. 1994
Brook trout *Salvelinus fontinalis*	0.80 g	S/U	42 mg/L	96-h	LC_{50}	2,100 (1684, 2618)	Mayer and Ellersieck 1986
	0.80 g	S/U	42 mg/L	96-h	LC_{50}	3,000 (2009, 4480)	
	1.00 g	S/U	42 mg/L	96-h	LC_{50}	680 (585, 790)	
	0.70 g	S/U	42 mg/L	96-h	LC_{50}	4,560 (3497, 5947)	
	0.70 g	S/U	42 mg/L	96-h	LC_{50}	2,130 (1719, 2640)	
	0.70 g	S/U	42 mg/L	96-h	LC_{50}	1,130 (792, 1612)	
	0.80 g	S/U	42 mg/L	96-h	LC_{50}	1,200 (868, 1658)	
	0.80 g	S/U	300 mg/L	96-h	LC_{50}	1,290 (887, 1878)	
	1.15g	S/U	318-348 mg/L	96-h	LC_{50}	1,070 (905-1,263)	Post and Schroeder 1971
	2.04g	S/U		96-h	LC_{50}	1,450 (1,047-2,008)	
Brown shrimp *Penaeus aztecus*	N/A	F/U	28‰	48-h	EC_{50}	1.5 (N/A)	Mayer 1987
Brown trout *Salmo trutta*	0.60 g	S/U	42 mg/L	96-h	LC_{50}	6,300 (5520, 7190)	Mayer and Ellersieck 1986
	Finger-ling	F/U	314 mg/L	96-h	LC_{50}	2,000 (1656, 2414)	
Carp *Cyprinus carpio*	0.60 g	S/U	40 mg/L	96-h	LC_{50}	5,280 (4620, 6050)	Mayer and Ellersieck 1986
Channel catfish *Ictalurus punctatus*	1.5 g	S/U	40 mg/L	96-h	LC_{50}	15,800 (13,900, 18,000)	Mayer and Ellersieck 1986
	1.5 g	S/U	272 mg/L	96-h	LC_{50}	7,790 (4,750, 12,800)	
	Finger-ling	F/U	314 mg/L	96-h	LC_{50}	17,300 (16,360, 18,290)	
Chinook salmon *Onchorhynchus tshawytscha*	Finger-ling	F/U	314 mg/L	96-h	LC_{50}	2,400 (1623, 3549)	Mayer and Ellersieck 1986
Coho salmon *Onchorhynchus kisutch*	1.00 g	S/U	44 mg/L	96-h	LC_{50}	4,340 (3310, 5690)	Mayer and Ellersieck 1986
	4.60 g	S/U	42 mg/L	96-h	LC_{50}	2,400 (1865, 3088)	
	5.10 g	S/U	42 mg/L	96-h	LC_{50}	1,750 (1258, 2434)	
	10.10 g	S/U	42 mg/L	96-h	LC_{50}	2,700 (1570, 4643)	
	19.10 g	S/U	42 mg/L	96-h	LC_{50}	1,150 (845, 1564)	
	1.50g	S/U	318-348 mg/L	96-h	LC_{50}	1,300 (1,074-1,573)	Post and Schroeder 1971
Colorado squawfish *Ptychocheilus lucius*	Larval	S/U	212-216 mg/L	96-h 32-day	LC_{50} NOEC	1,310 (1,230, 1,400) 445	Beyers et al. 1994
Cladoceran *Daphnia magna*	1st Instar	S/U	42 mg/L	48-h	EC_{50}	5.6 (2.7 , 12)	Mayer and Ellersieck 1986
Cladoceran *Daphnia pulex*	1st Instar	S/U	44 mg/L	48-h	LC_{50}	6.4 (4.5 , 8.9)	Mayer and Ellersieck 1986
Cladoceran *Simocephalus serrulatus*	1st Instar	S/U	44 mg/L	48-h	EC_{50}	11 (7.8, 16)	Mayer and Ellersieck 1986
		S/U	44 mg/L	48-h	EC_{50}	7.6 (6.2, 9.3)	
		S/U	44 mg/L	48-h	EC_{50}	8.1 (6.7, 9.8)	
Crayfish *Procambarus sp.*	Imma-ture	S/U	42 mg/L	96-h	LC_{50}	1,900 (1,161, 3,108)	Mayer and Ellersieck 1986

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

Species	Life Stage/ Size	Method[a]	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Cutthroat trout *Oncorhynchus clarki*	0.50 g	S/U	40 mg/L	96-h	LC_{50}	7,100 (5240, 9620)	Mayer and Ellersieck 1986
	0.60 g	S/U	42 mg/L	96-h	LC_{50}	6,000 (4630, 7770)	
	0.70 g	S/U	40 mg/L	96-h	LC_{50}	5,000 (4100, 6100)	
	0.60 g	S/U	40 mg/L	96-h	LC_{50}	970 (770, 1220)	
	0.50 g	S/U	330 mg/L	96-h	LC_{50}	3,950 (3370, 4630)	
	0.50 g	S/U	40 mg/L	96-h	LC_{50}	6,800 (5230, 8840)	
	0.50 g	S/U	40 mg/L	96-h	LC_{50}	4,000 (3130, 5110)	
	0.50 g	S/U	40 mg/L	96-h	LC_{50}	3,380 (2300, 4960)	
	0.50 g	S/U	40 mg/L	96-h	LC_{50}	2,300 (1830, 2890)	
	0.90 g	S/U	40 mgL	96-h	LC_{50}	6,700 (5230, 8580)	
	0.37g	S/U	318-348	96-h	LC_{50}	1,500 (1,176-1.913)	Post and Schoeder 1971
	1.30g	S/U	mg/L	96-h	LC_{50}	2,169 (2,067-2,276)	
Eastern oyster *Crassostrea virginica*	Larvae	S/M	30‰	48-h	EC_{50}	2,700 (2,400, 3,900)	Dionne et al. 1985a
	N/A	F/U	27‰	96-h	EC_{50}	72,000 (N/A)	Mayer 1987
Fathead minnnow *Pimephales promelas*	31-day	S/M	43.8 mg/L	96-h	LC_{50}	9,470 (8,600-10,400)	Geiger et al. 1988
					EC_{50}	6,420 (5,570-7,400)	
	28-day	S/M	44.1 mg/L	96-h	LC_{50}	10,400 (9,550-11,300)	
					EC_{50}	6,400 (5,200-7,870)	
	29-day	S/M	45.4 mg/L	96-h	LC_{50}	6,670 (6,050-7,340)	
					EC_{50}	5,290 (4,800-5,820)	
	28-day	S/M	45.4 mg/L	96-h	LC_{50}	8,930 (8,430-9,460)	
					EC_{50}	7,470 (6,000-9,300)	
	0.50 g	S/U	42 mg/L	96-h	LC_{50}	14,000 (11,400, 17,200)	Mayer and Ellersieck 1986
	0.80 g	S/U	40 mg/L	96-h	LC_{50}	14,600 (11,700, 19,800)	
	0.80 g	S/U	272 mg/L	96-h	LC_{50}	7,700 (4,800, 12,200)	
Goldfish *Carassius auratus*	0.90 g	S/U	40 mg/L	96-h	LC_{50}	13,200 (8,310, 20,800)	Mayer and Ellersieck 1986
	0.90 g	S/U	272 mg/L	96-h	LC_{50}	12,800 (8,100, 20,300)	
Grass shrimp *Palaemonetes pugio*	N/A	F/U	29‰	48-h	EC_{50}	28 (N/A)	Mayer 1987
Green sunfish *Lepomis cyanellas*	1.10 g	S/U	40 mg/L	96-h	LC_{50}	11,200 (8,140, 15,500)	Mayer and Ellersieck 1986
	1.10 g	S/U	272 mg/L	96-h	LC_{50}	9,460 (7,000, 12,800)	
Isopod *Asellus brevicaudus*	Mature	S/U	44 mg/L	96-h	LC_{50}	280 (214, 367)	Mayer and Ellersieck 1986
Lake trout *Salvelinus namaycush*	1.70 g	S/U	40 mg/L	96-h	LC_{50}	690 (520, 910)	Mayer and Ellersieck 1986
	1.70 g	S/U	40 mg/L	96-h	LC_{50}	740 (600, 910)	
	1.70 g	S/U	40 mg/L	96-h	LC_{50}	920 (700, 1200)	
	0.50 g	S/U	162 mg/L	96-h	LC_{50}	872 (466, 1630)	
	2.60 g	F/U	162 mg/L	96-h	LC_{50}	2,300 (1950, 2710)	
Largemouth bass *Micropterus salmoides*	0.90 g	S/U	40 mg/L	96-h	LC_{50}	6,400 (4,400, 9,200)	Mayer and Ellersieck 1986
Longnose killifish *Fundulus similis*	N/A	S/U	19‰	48-h	LC_{50}	1,600 (N/A)	Mayer 1987

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

Species	Life Stage/ Size	Method[a]	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Midge *Chironomus plumosus*	Larvae	S/U	40 mg/L	96-h	LC_{50}	10 (7, 16)	Sanders et al. 1983
Mysid *Mysidopsis bahia*	1-5 d	S/U	20 °/₀₀	96-h	LC_{50}	6.7 (5.1, 8.7)	Dionne et al. 1985b
	Post larval	S/M	20 " 1°/₀₀	96-h	LC_{50} NOEC	5.7 (4.9, 6.6) 3.2	Lintott 1992a
Ostracod *Cypridopsis vidua*	Mature	S/U	272 mg/L	48-h	EC_{50}	115 (74, 179)	Mayer and Ellersieck 1986
Pink shrimp *Penaeus duorarum*	N/A	F/U	29°/₀₀	48-h	EC_{50}	32 (N/A)	Mayer 1987
Prawn *Palaemonetes kadiakensis*	Mature	S/U	44 mg/L	96-h	LC_{50}	5.6 (3.6,8.3)	Mayer and Ellersieck 1986
Rainbow trout *Oncorhynchus mykiss*	1.10 g	S/U	42 mg/L	96-h	LC_{50}	1,950 (1450, 2630)	Mayer and Ellersieck 1986
	0.50 g	S/U	272 mg/L	96-h	LC_{50}	1,200 (800, 1800)	
	0.80 g	S/U	40 mg/L	96-h	LC_{50}	1,360 (992, 1860)	
	1.10 g	S/U	40 mg/L	96-h	LC_{50}	2,080 (1580, 2730)	
	1.20 g	S/U	40 mg/L	96-h	LC_{50}	1,900 (1590, 2263)	
	1.80 g	S/U	40 mg/L	96-h	LC_{50}	2,300 (1500, 3500)	
	1.10 g	S/U	314 mg/L	96-h	LC_{50}	1,330 (1030, 1716)	
	2.20 g	S/U	40 mg/L	96-h	LC_{50}	1,460 (1010, 2110)	
	1.20 g	S/U	40 mg/L	96-h	LC_{50}	3,500 (2450, 4990)	
	1.20 g	S/U	320 mg/L	96-h	LC_{50}	3,000 (2080, 4320)	
	1.00 g	S/U	40 mg/L	96-h	LC_{50}	1,600 (1070, 2370)	
	1.00 g	S/U	40 mg/L	96-h	LC_{50}	1,100 (760, 1500)	
	1.00 g	S/U	40 mg/L	96-h	LC_{50}	1,200 (806, 1790)	
	1.00 g	S/U	40 mg/L	96-h	LC_{50}	780 (649, 937)	
	1.00 g	S/U	40 mg/L	96-h	LC_{50}	1,450 (1169, 1797)	
	0.80 g	S/U	40 mg/L	96-h	LC_{50}	< 750 (N/A)	
	1.10 g	S/U	40 mg/L	96-h	LC_{50}	< 320 (N/A)	
	1.20 g	S/U	40 mg/L	96-h	LC_{50}	1090 (N/A)	
	1.24g	S/U	318-348 mg/L	96-h	LC_{50}	1,470 (980-2,205)	Post and Schroeder 1971
	N/A	S/U	40 mg/L	96-h	LC_{50}	2,200 (1,700, 2,800)	Sanders et al. 1983
Sea urchin *Pseudechinus magellanicus*	Pluteus	S/U	33°/₀₀	96-h	EC_{50}	92.5 (50.6, 106.4)	Hernandez et al. 1990
Sheepshead minnow *Cyprinodon variegatus*	25-35 mm	S/M	20 °/₀₀	96-h	LC_{50} NOEC	2,600 (2,300, 2,800) 1,100	Lintott 1992b
Stonefly *Claassenia sabulosa*	2nd year class	S/U	44 mg/L	96-h	LC_{50}	5.6 (3.9, 8.1)	Mayer and Ellersieck 1986

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

Species	Life Stage/ Size	Method[a]	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Stonefly *Isogenus sp.*	1st YC	S/U	35 mg/L	96-h	LC_{50}	2.8 (2, 4)	Mayer and Ellersieck 1986
	1st YC	S/U	42 mg/L	96-h	LC_{50}	3.6 (2.4, 5.5)	
	1st YC	S/U	42 mg/L	96-h	LC_{50}	6.6 (5, 8.9)	
	1st YC	S/U	42 mg/L	96-h	LC_{50}	6.6 (5.3, 8.3)	
	1st YC	S/U	42 mg/L	96-h	LC_{50}	12 (9.7, 15)	
Stonefly *Pteronarcella badia*	1st YC	S/U	44 mg/L	96-h	LC_{50}	1.7 (1.4, 2.4)	Mayer and Ellersieck 1986
	1st YC	S/U	38 mg/L	96-h	LC_{50}	11 (9.7, 13)	
	1st YC	S/U	38mg/L	96-h	LC_{50}	13 (12, 16)	
	1st YC	S/U	38 mg/L	96-h	LC_{50}	29 (21, 41)	
Stonefly *Pteronarcys californica*	1stYC	S/U	38 mg/L	96-h	LC_{50}	4.8 (3, 7.7)	Mayer and Ellersieck 1986
Striped mullet *Mugil cephalus*	N/A	S/U	17‰	48-h	LC_{50}	2,400 (N/A)	Mayer 1987
Yellow perch *Perca flavescens*	1.40 g	S/U	40 mg/L	96-h	LC_{50}	745 (611, 904)	Mayer and Ellersieck 1986
	0.60 g	S/U	42 mg/L	96-h	LC_{50}	5,100 (4,520, 5,760)	
	1.00 g	S/U	42 mg/L	96-h	LC_{50}	13,900 (11,700, 16,510)	
	1.00 g	S/U	42 mg/L	96-h	LC_{50}	5,400 (4,140, 7,050)	
	1.00 g	S/U	42 mg/L	96-h	LC_{50}	3,400 (2,690, 4,290)	
	1.00 g	S/U	42 mg/L	96-h	LC_{50}	1,200 (1,000, 1,440)	
	0.90 g	S/U	42 mg/L	96-h	LC_{50}	4,000 (3,030, 5,290)	
	0.90 g	S/U	42 mg/L	96-h	LC_{50}	4,200 (3,100, 5,690)	
	0.90 g	S/U	42 mg/L	96-h	LC_{50}	480 (304, 757)	
	0.90 g	S/U	42 mg/L	96-h	LC_{50}	350 (280, 430)	
	1.00 g	S/U	42 mg/L	96-h	LC_{50}	3,800 (2,730, 5,500)	
	1.00 g	S/U	170 mg/L	96-h	LC_{50}	5,000 (4,030, 6,200)	
	1.00 g	S/U	300 mg/L	96-h	LC_{50}	3,750 (2,850, 4,930)	
	Finger-ling	F/U	42 mg/L	96-h	LC_{50}	1,420 (1,040, 1,938)	

[a]Method S=Static, F=Flowthrough, M=Measured, U=Unmeasured
[b]C.L. Confidence limits
[c]N/A Information not available

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

Species	Life Stage	Salinity/ Hardness	Test Length	Formulation (% carbaryl)	Effect	Values (95% C.L.)[a]	Reference	Test Deficiencies[b]
Bluegill *Lepomis macrochirus*	0.70 g	40 mg/L	96-h	Oil dispersion (49%)	LC_{50}	39,000 (29,732, 51,157)	Mayer and Ellersieck 1986	2
	N/A	40 mg/L	96-h	Sevin XLR (43.92%)	LC_{50}	9,800 (7,800, 13,000)	Sousa et al. 1985b	2
	32-44 mm	45 mg/L	96-h	Sevin-4-oil (49%)	LC_{50}	10,000 (7,200, 13,000)	Sousa et al. 1985b	2
Brook trout *Salvelinus fontinalis*	1.30 g	42 mg/L	96-h	Oil dispersion (49%)	LC_{50}	4,500 (3,948, 5,066)	Mayer and Ellersieck 1986	2
Carp *Cyprinus carpio*	Eggs	272 "2 mg/L	96-h	Sevin 50 WP	LC_{50}	1,190 (1,030, 1,380)	Kaur and Dhawan 1993	2
Catfish *Clarias batrachus*	65-70 g	N/A	96-h	Technical (N/A)	LC_{50}	46,850 (40,960, 52,770)	Tripathi and Shukla 1988	1
Cladoceran *Daphnia ambigua*	larvae	N/A	10-h	Technical (99%)	N/A	N/A	Hanazato 1991	3
Cladoceran *Daphnia magna*	N/A mg/L	56-72	96-h	Sevin 80s (81.5%)	EC_{50} NOEC	6,180 (3,100, 9,220) 1,390	Lintott 1992j	2
	N/A	76 mg/L	96-h	Sevin XLR plus (43.7%)	EC_{50} NOEC	5,020 (N/A) 2,270	Lintott 1992h	2
	N/A	68-76 mg/L	96-h	Sevin-4-oil ULV (47.3%)	EC_{50} NOEC	2,770 (N/A) 1,570	Lintott 1992g	2
	#24-h	160 mg/L	48-h	Sevin 4-oil (49%)	LC_{50}	7.1 (6.0, 8.4)	Nicholson et al. 1985	2
	#24-h	160 mg/L	48-h	Sevin XLR (43.92%)	LC_{50}	13 (10, 20)	Nicholson et al. 1985	2
	Adult	N/A	N/A	N/A	LC_{50}	0.26 (N/A)	Rawash et al. 1975	1
Coho salmon *Onchorhynchus kisutch*	N/A	N/A	96-h	Sevin (95%)	LC_{50}	997 (N/A)	Katz 1961	7
Crayfish *Orconectes rusticus*	N/A	256 mg/L	96-h	Carbaryl (% unknown)	LC_{100}	20,000	Bills and Marking 1988	1,7
Crayfish *Procambarus simulans*	25-31 mm	N/A	96-h	Sevin WP (80%)	LC_{50}	2,430 (N/A)	Chaiyarch et al. 1975	1, 2
Crayfish *Procambarus clarkii*	Imma-ture	100 mg/L	96-h	Field formulation	LC_{50}	500 (400, 600)	Cheah et al. 1980	2
	4-10 g	N/A	72-h	Technical (N/A)	LC_{50}	200	Muncy 1963	4
Dungeness crab *Cancer magister*	1st and 2nd stage Zoea	26-28 ‰	48-h	Sevin N/A	LC_{100}	N/A	Poole and Willis 1970	1, 2, 3,7
Eastern Oyster *Crassostrea virginica*	Juvenile	30‰	96-h	Carbaryl (43.3%)	LC_{50} NOEC	10,200 (9,240, 11,000) 3,770	Lintott 1992c	2

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

Species	Life Stage	Salinity/ Hardness	Test Length	Formulation (% carbaryl)	Effect	Values (95% C.L.)[a]	Reference	Test Deficiencies[b]
Freshwater fish *Punctius ticto*	50-68 mm	68-88 mg/L	96-h	Technical (99%)	LC_{50}	3,700 (N/A)	Bhatia 1971	1
Freshwater fish *Aplocheilus lineatus*	25-40 mm	N/A	48-h	Sevin 50 EC (50%)	LC_{50}	3,747 (N/A)	Jacob et al. 1951	2
Freshwater fish *Macropodus cupanus*	20-28 mm	N/A	48-h	Sevin 50 EC (50%)	LC_{50}	13,910 (N/A)	Jacob et al. 1951	2
Freshwater fish *Channa punctatus*	N/A	N/A	96-h	Sevin 50 EC	LC_{50}	19,500 (19,320, 19,740)	Singh et al. 1984	1, 2
Freshwater fish *Heteropneustes fossilis*	N/A	96-h		Sevin 50 EC	LC_{50}	20,100 (19,995, 20,250)	Singh et al. 1984	1, 2
Goldfish *Carassius auratus*	N/A	N/A	10-day	Technical (99.07%)	N/A	N/A	Shea and Berry 1983	1, 3
Grass shrimp *Palaemonetes kadiakensis*	60-70 mm	N/A	96-h	Sevin WP (80%)	LC_{50}	120 (N/A)	Chaiyarch et al. 1975	1, 2
Killifish *Fundulus heteroclitus*	N/A	N/A	10-day	Technical (99.07%)	N/A	N/A	Shea and Berry 1983	1, 3
Korean shrimp *Palaemon macrodactylus*	N/A	30‰	96-h	Technical (99-100%)	LC_{50} LC_{50}	12.0 (N/A) 7.0 (N/A)	Mayer 1970	1 1
Leech *Hirundo nipponia*	4-5 cm	N/A	48-h	Technical (% unknown)			Kimura and Keegan 1966	
Japanese strain					LC_{50}	5,500 (N/A)		1
Korean strain					LC_{50}	17,000 (N/A)		1
Lugworm *Arenicola marina*	N/A	N/A	48-h	Technical (99%)	LC_{50}	7,200 (5,700, 9,000)	Conti 1987	1
Mactrid clam *Rangia cuneata*	35-50 mm	5‰	96-h	Sevin WP (80%)	LC_{50}	125,000 (N/A)	Chaiyarch et al. 1975	2
Midge *Chironomus riparius*	4th instar larvae	N/A	24-h	Technical (99%)	EC_{50}	110 (N/A)	Fisher et al. 1993	4, 5
	4th instar larvae	N/A	24-h	Technical (99%)	EC_{50}	96 (89, 102)	Lohner and Fisher 1990	1
Mosquito *Anopheles stephansi*	4th	N/A	240 minute	Technical (95%)			Chitra and Pillai 1984	
Delhi strain					LC_{50}	212 (175, 255)		1, 7
Haryana					LC_{50}	256 (200, 329)		1, 7
Mosquito *Aedes aegypti*	3rd instar larvae	N/A	24-h	Technical (99%)	LC_{50}	510 (N/A)	Parsons and Surgeoner 1991	1
Mosquito *Culex pipiens*	4th instar larvae	N/A	N/A	N/A	LC_{50}	75 (59, 95)	Rawash et al. 1975	1

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

Species	Life Stage	Salinity/ Hardness	Test Length	Formulation (% carbaryl)	Effect	Values (95% C.L.)[a]	Reference	Test Deficiencies[b]
Mosquito	4th	N/A	24-h	Carbaryl			Rettich 1977	1, 2
Aedes cantans	instar			(% unknown)	LC_{50}	376.6 (209.9, 682.6)		
A. vexans	larvae				LC_{50}	322.6 (73.9, 633.1)		
A. excrucians					LC_{50}	145.5 (N/A)		
A. communis					LC_{50}	167.9 (N/A)		
A. strictius					LC_{50}	(N/A)		
A. punctor					LC_{50}	298.3 (N/A)		
Culux pipiens pipiens					LC_{50}	333.9 (67.7, 889.8)		
C. pipiens molestus					LC_{50}	418.8 (N/A)		
Culiseta annulata					LC_{50}	179.5 (N/A)		
Mosquito *Wyeomyia smithii*	Larval	N/A	7-day	Carbaryl (93-100%)	N/A	N/A	Strickman 1985	1, 3,6
Mosquito fish *Gambusia affinis*	30-40 mm	N/A	96-h	Sevin WP (80%)	LC_{50}	31,800 (N/A)	Chaiyarch et al. 1975	1, 2
	0.289 " 0.031 g	12 mg/L	96-h	Sevin (5%)	LC_{50}	204,000 (190,000, 223,000)	Naqvi and Hawkins 1988	2
Mysid *Mysidopsis bahia*	Post larval	21‰	96-h	Sevin 80s (81.5%)	LC_{50}	9,600 (8,300, 11,00)	Lintott 1992k	2
	Post larval	20‰	96-h	Sevin 80s (81.5%)	LC_{50} NOEC	7,580 (6,050, 8,390) 6,050	Lintott 1992d	2
	Post larval	20 " 1‰	96-h	Sevin XLR Plus (43.7%)	LC_{50} NOEC	8,810 (7,480, 10,400) 4830	Lintott 1992e	2
Rainbow trout	N/A	N/A	96-h	Sevin (95%)	LC_{50}	1,350 (N/A)	Katz 1961	7
Oncorhynchus mykiss	42-51 mm	45 mg/L	96-h	Sevin XLR (43.92%)	LC_{50}	1,400 (1,100, 1,700)	Sousa et al. 1985a	2
	42-51 mm	40 mg/L	96-h (49%)	Seven 4-oil	LC_{50} (1,100, 1,600)	1,300	Sousa et al. 1985a	1, 2
	N/A	72 mg/L	96-h	Sevin 80s (81.5%)	EC_{50} NOEC	3,300 (2,700, 4,000) 730	Lintott 1992i	2
Red crab *Cancer productus*	1st and 2nd stage	26-28 ‰	48-h	Sevin (N/A)	Total Mortality	N/A	Poole and Willis 1970	1, 2, 3,7
Sheepshead minnow *Cyprinodon variegatus*	N/A	20 " 3‰	96-h	Sevin XLR Plus (43.7%)	LC_{50} NOEC	5,400 (N/A) 3200	Lintott 1992f	2
	18-29 mm	32 ‰	96-h	Technical (99%)	LC_{50}	2,200 (1,300, 3,600)	Sousa et al. 1985c	5
Stickleback *Gasterosteus aculeatus*	adult	N/A	96-h	Sevin (95%)	LC_{50}	3,990 (N/A)	Katz 1961	7
Stonefly *Isogenus sp.*	1st Year class	42 mg/L	96-h	Oil dispersion (49%)	LC_{50}	9.2 (7.4, 12.0)	Mayer and Ellersieck 1986	2
Striped bass *Morone saxatilis*	N/A	30 " 1‰	96-h	Technical (98%)	LC_{50}	1,000 (N/A)	Korn and Earnest 1974	1
	N/A	30‰	96-h	Technical (99-100%)	LC_{50}	> 1,000 (N/A)	Mayer 1970	1
Tilapia *Tilapia mossambica*	N/A	140 " 20 mg/L	48-h	Commercial grade (N/A)	LC_{50}	5,495 (4,400-6,590)	Basha et al. 1983	1, 2

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

Species	Life Stage	Salinity/ Hardness	Test Length	Formulation (% carbaryl)	Effect	Values (95% C.L.)[a]	Reference	Test Deficiencies[b]
Tubificid *Tubifex sp.* *Limnodrilus sp.*	N/A	N/A	96-h	Technical (99.6%)	LC_{50} (combined)	> 50,000 (N/A)	Whitten and Goodnight 1966	1

[a]C.L. Confidence limits

[b]Test deficiencies:

1 Essential information lacking, such as control survival
2 Formulation too low in percent active ingredient
3 No effect criteria given, such as LC_{50} or EC_{50}
4 Unacceptable mortality range, must be ≤ 30 % mortality to ≥ 60 % mortality
5 Dissolved oxygen levels fell below acceptable levels (60%) during test
6 Inadequate number of concentrations tested, must be four or greater
7 Innapropriate test design (duration or effect criteria)

[c]N/A Information not available

APPENDIX C. Abstracts of accepted chronic toxicity tests reviewed for hazard assessment.

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

Hoberg et. al. (1985) - In 1985, 21-d chronic toxicity tests were performed on carbaryl (99%) with the cladoceran *Daphnia magna*. Five concentrations and water and solvent controls were tested. Four replicates per treatment with 80 organisms per replicate were used. Water quality parameters during the test were: temperature of 20±1°C; pH of 7.9-8.3; dissolved oxygen level of >60% saturation; and a hardness of 160-180 mg/L. Control survival was 92% in the water control and 95% in the solvent control. The MATC for *D. magna* was 4.4 µg/L.

Carlson (1971) - In 1971, 9 month chronic toxicity tests were performed on carbaryl (80%) with the fathead minnow *Pimephales promelas*. Five concentrations and a control were tested. Water quality parameters during the test were: temperature of 25 ± 2°C; pH of 7.1-7.6; dissolved oxygen level of 7.1-8.0 mg/L; and a hardness of ~45 mg/L. The MATC for *P. promelas* was 380 µg/L.

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

Species	Life Stage	Method[a]	Salinity/ Hardness	Test Length	Effect	Values (95% C.L.[b])	Reference
Cladoceran *Daphnia magna*	N/A[c]	F/M	160-180 mg/L	21-d	MATC	4.4 (N/A)	Hoberg et al. 1985
Fathead minnow *Pimephales promelas*	1-5 day	F/M	45 mg/L	9 months	MATC	380 (210 -680)	Carlson 1971

[a]Method F=flow through, M=measured concentrations
[b]C.L. Confidence limits
[c]N/A Information not available

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

Lintott (1992l) - In 1992, 14-d static acute toxicity tests (5-d exposure and 9-d recovery) were performed by Toxicon Environmental Sciences on carbaryl (99.7%) with freshwater green alga *Selenastrum capricornutum.* Six concentrations and solvent and water controls were used. There were 3,000 organisms/ mL per concentration, including controls. Water quality parameters during the test were: temperature of 22.4-23.9° C, and a pH of 7.4-10.3. There was no apparent inhibition or stimulation in the control. The EC_{50} and NOEC for *S. capricornutum* were 2,400 µg/L and 370 µg/L respectively.

Lintott (1992m) - In 1992, 14d static acute toxicity tests (5d exposure and 9d recovery) were performed by Toxicon Environmental Sciences on carbaryl (99.7%) with blue green alga *Anabaena flos-aquae.* Six concentrations and solvent and water controls were used. There were 3,000 organisms/ mL per concentration, including controls. Water quality parameters during the test were: temperature of 24 ± 2° C, and a pH of 7.5. There was no apparent inhibition or stimulation in the control. The EC_{50} and NOEC for *A. flos-aquae* were 3,800 µg/L and 430 µg/L respectively.

Lintott (1992n) - In 1992, 14d static acute toxicity tests (5d exposure and 9d recovery) were performed by Toxicon Environmental Sciences on carbaryl (99.7%) with saltwater diatom *Skeletonema costatum.* Six concentrations and solvent and water controls were used. There were 10,000 organisms/ mL per concentration, including controls. Water quality parameters during the test were: temperature of 20 ± 2° C, and a pH of 8.0. Control survival was 100%. The EC_{50} for *S. costatum* was 3,500 µg/L.

Lintott (1992o) - In 1992, 14d static acute toxicity tests (5d exposure and 9d recovery) were performed by Toxicon Environmental Sciences on carbaryl (99.7%) with freshwater diatom *Navicula pilliculosa*. Six concentrations and solvent and water controls were used. There were 3,000 organisms/ mL per concentration, including controls. Water quality parameters during the test were: temperature of 24 ± 2° C, and a pH of 6.1-8.4. Control survival was 83% in the solvent control and 100% in the water control. The EC_{50} and NOEC for *N. pilliculosa* were 6,100 µg/L and 400 µg/L respectively.

Table D-1. Values (µg/L) from tests on the toxicity of carbaryl to aquatic plants.

Species	Formulation (% A.I.[a])	Test Length	Endpoint/ Effect	Concentration (µg/L)	Reference
Blue-Green Alga	Technical (99.7%)	14-d	NOEC	430	Lintott 1992m
Abaena flos-aquae			EC_{50}	380	
Green Alga *Selenastrum*	Technical (99.7%)	14-d	NOEC	370	Lintott 1992l
capricornutum			EC_{50}	1,200	
Freshwater Diatom	Technical (99.7%)	14-d	NOEC	400	Lintott 1992o
Navicula pelliculosa			EC_{50}	610	
Saltwater Diatom	Technical (99.7%)	14-d	NOEC	N/A[b]	Lintott 1992n
Skeletonema costatum			EC_{50}	350	

[a]A.I. Active ingredient
[b]N/A Information not available