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# AQUATIC LIFE AMBIENT WATER QUALITY CRITERIA FOR CARBARYL - 2012

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# AQUATIC LIFE
# AMBIENT WATER QUALITY CRITERIA FOR
# CARBARYL

(CAS Registry Number 63-25-2)

April 2012

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER
OFFICE OF SCIENCE AND TECHNOLOGY
HEALTH AND ECOLOGICAL CRITERIA DIVISION
WASHINGTON, D.C.

# NOTICES

This document has been reviewed by the Health and Ecological Criteria Division, Office of Science and Technology, U.S. Environmental Protection Agency, and is approved for publication.

This document is available to the public through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161.

# FOREWORD

Section 304(a)(l) of the Clean Water Act of 1977 (P.L. 95-217) requires that the Administrator of the Environmental Protection Agency (EPA) publish water quality criteria that accurately reflect the latest scientific knowledge on the kind and extent of all identifiable effects on health and welfare that might be expected from the presence of pollutants in any body of water, including ground water. This document is a final ambient water quality criteria (AWQC) document for the protection of aquatic life based upon consideration of all available information relating to effects of carbaryl on aquatic organisms.

The term "water quality criteria" is used in two sections of the Clean Water Act, section 304(a)(l) and section 303(c)(2). The term has a different program impact in each section. In section 304, the term represents a non-regulatory, scientific assessment of ecological effects. Criteria presented in this document are such scientific assessments. If water quality criteria associated with specific stream uses are adopted by a state or EPA as water quality standards under section 303, they become maximum acceptable pollutant concentrations for permitting and listing in ambient waters within that state. Water quality criteria adopted in state water quality standards could have the same numerical values as criteria developed under section 304. However, in many situations states might want to adjust water quality criteria developed under section 304 to reflect local environmental conditions and human exposure patterns. Alternatively, states may use different data and assumptions than EPA in deriving numeric criteria that are scientifically defensible and protective of designated uses. It is not until their adoption as part of state water quality standards that criteria become regulatory. Guidelines to assist the states and Indian tribes in modifying the criteria presented in this document are contained in the Water Quality Standards Handbook (U.S. EPA 1994). This handbook and additional guidance on the development of water quality standards and other water-related programs of this agency have been developed by the Office of Water.

This final document is guidance only. It does not establish or affect legal rights or obligations. It does not establish a binding norm and cannot be finally determinative of the issues addressed. Agency decisions in any particular situation will be made by applying the Clean Water Act and EPA regulations on the basis of specific facts presented and scientific information then available.

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*This aquatic life criteria document for carbaryl has undergone many revisions and has benefitted from the insights of various reviewers, including members of the Ecological Risk Assessment Branch in the Office of Water, Office of Science and Technology. Additionally, much of the fate and transport information and additional toxicity information have been procured from various ecological risk assessments documents in the Office of Pesticide Programs' Environmental Fate and Effects Division.*

## EXECUTIVE SUMMARY

### Background

Carbaryl (1-naphthyl-N-methylcarbamate; $C_{12}H_{22}NO_2$, CAS #63-25-2) is an insecticide, a molluscide, and is used to thin fruit in orchards, and it belongs to the N-methyl carbamate class of pesticides. Introduced by the Union Carbide Corporation in 1956, carbaryl acts on animals through contact and ingestion. Carbaryl is registered in the United States for use in controlling more than 160 insect pests on over 115 agricultural and non-crop use applications, including home and garden uses (U.S. EPA 2007a; U.S. EPA 2010a). Major uses include insect control on lawns, home gardens, citrus, fruit, forage and field crops, forests, nuts, ornamentals, rangeland, turf, shade trees, poultry and pets (U.S. EPA 2010a). Agricultural crops with the greatest annual use of carbaryl include apples, pecans, grapes, alfalfa, oranges, and corn. Carbaryl was the third most commonly used conventional pesticide used in homes and gardens in 2005 and 2007 with a range of 4 to 6 million pounds of active ingredient used annually (U.S. EPA 2011).

U.S. Geological Survey's National Water Quality Assessment (NAWQA) Program reported carbaryl as the second most frequently found insecticide in water, with detections in approximately 50% of urban streams. Frequencies of detection in surface water associated with urban uses are commonly higher than those associated with agricultural uses. The majority of these detections are below 0.1 µg/L. The NAWQA program analyzed a total of 11,732 water samples from 1999 to 2005 for carbaryl. They reported 29% of all samples with concentrations greater than the minimum detection limit of 0.021 µg/L. The mean concentration reported was 0.058 µg/L and the maximum concentration was 33.5 µg/L, associated with agricultural land. The highest concentration reported in urban areas was 16 µg/L.

### Carbaryl Criteria Derivation

U.S. EPA is developing recommended ambient water quality criteria for carbaryl through its authority under section 304(a) of the Clean Water Act (CWA). These water quality criteria may be used by states and authorized tribes to establish water quality standards for carbaryl. The carbaryl aquatic life criteria are developed using peer reviewed methods and data that are acceptable for the derivation of a freshwater and estuarine/marine criteria. Data evaluated for criteria derivation include data submitted in support of the registration of this pesticide and reviewed by U.S. EPA's Office of Pesticide Programs as well as studies reported in the open literature.

The resulting recommended ambient water quality criteria indicate that freshwater aquatic organisms would have an appropriate level of protection if the one-hour average concentration does not exceed 2.1 µg/L more than once every three years on average and if the four-day average concentration of carbaryl does not exceed 2.1 µg/L more than once every three years on average (except where a locally important species may be more sensitive). Estuarine/marine aquatic organisms would have an appropriate level of protection if the one-hour average concentration does not exceed 1.6 µg/L more than once every three years on average (except where a locally important species may be more sensitive).

This document provides guidance to states and tribes authorized to establish water quality standards under the CWA to protect aquatic life from the acute and chronic effects of carbaryl. Under the CWA, states and authorized tribes may adopt water quality criteria into water quality standards to protect designated uses. While this document constitutes U.S. EPA's scientific recommendations regarding ambient concentrations of carbaryl, this document does not substitute for the CWA or U.S. EPA's regulations; nor is it a regulation itself. Thus, it cannot impose legally binding requirements on U.S. EPA, states, authorized tribes, or the regulated community, and it might not apply to a particular situation based upon the circumstances. State and tribal decision-makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance when appropriate. U.S. EPA may change this guidance in the future.

**Table 1. Summary of Aquatic Life Criteria for Carbaryl**

| | **Acute** | **Chronic** |
|---|---|---|
| **Freshwater** | 2.1 µg/L | 2.1 µg/L |
| **Estuarine/marine** | 1.6 µg/L | N/A |

N/A – not available, unable to calculate estuarine/marine chronic criterion

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## I. INTRODUCTION AND BACKGROUND

U.S. EPA is developing ambient water quality criteria for carbaryl through its authority under section 304(a) of the Clean Water Act (CWA). Although not regulatory in themselves, these water quality criteria may be used by states and authorized tribes to establish water quality standards for carbaryl to protect aquatic life designated uses. The criteria presented herein are the agency's best estimate of maximum concentrations of carbaryl to protect most aquatic organisms from unacceptable short- or long-term effects.

Carbaryl (1-naphthyl-N-methylcarbamate; $C_{12}H_{22}NO_2$, CAS #63-25-2) is an insecticide belonging to the N-methyl carbamate class of pesticides. Carbaryl is registered in the United States for use on over 115 agricultural and non-crop use applications, including home and garden uses (U.S. EPA 2007a; U.S. EPA 2010a). All pesticides distributed or sold in the United States must be registered by U.S. EPA, and the registrations are periodically re-evaluated to determine whether they meet current regulatory standards. The next Registration Review Decision for carbaryl will be made by U.S. EPA Office of Pesticide Programs (OPP) in 2015.

In 2003, OPP completed an ecological risk assessment to support a 2004 Interim Registration Eligibility Decision (IRED) for carbaryl, which identified potential acute risk to fish associated with one use, and acute and chronic risks to aquatic invertebrates associated with most registered uses of carbaryl (U.S. EPA 2004a). The IRED cited a study by the U.S. Geological Survey's National Water Quality Assessment (NAWQA) Program that reported carbaryl as the second most frequently found insecticide in water, with detections in approximately 50% of urban streams (U.S.G.S. 2006). Of the top five most frequently detected insecticides (listed in descending order) – chloropyrifos, carbaryl, carbofuran, diazinon, and malathion (U.S.G.S. 2006), there are existing ambient water quality criteria for chloropyrifos, diazinon and malathion; carbofuran tolerances are now cancelled. In 2007 (U.S. EPA 2007b), OPP updated a summary of U.S. surface water monitoring supporting the final Registration Decision. That assessment concluded that carbaryl had relatively high frequencies of detection, with concentrations as high as 33.5 µg/L in an agricultural area and 16.5 µg/L in urban areas. Detections were more frequent in urban areas than agricultural areas, but concentrations were mostly less than 0.1 µg/L. In more recent assessments by OPP, the Agency has made 'may affect' and 'likely to adversely affect' determinations for the California red-legged frog (*Rana aurora draytonii;* U.S. EPA 2007a) and the California Delta smelt (*Hypomesus transpacificus*; U.S. EPA 2010b) from the use of carbaryl in California. Additionally, the Agency determined that there is the potential for modification of designated critical habitat for both of the Federally-listed species from the use of carbaryl. Based on the conclusions of these assessments, the Agency indicated that formal consultations with the U.S. Fish and Wildlife Service under section 7 of the Endangered Species Act should be initiated for the pesticide registration action.

## II. PROBLEM FORMULATION

Problem formulation provides a strategic framework for water quality criteria development by focusing the effects assessment on the most relevant chemical properties and endpoints. The structure of this effects assessment is consistent with U.S. EPA's *Guidance for Ecological Risk Assessment* (U.S. EPA, 1998) and the approach used by U.S. EPA for pesticide effects assessment (U.S. EPA, 2004a).

This ecological effects assessment develops scientifically defensible water quality criteria values for carbaryl under section 304(a)(1) of the Clean Water Act. The goal of the Clean Water Act is to protect and restore the biological, chemical and physical integrity of waters of the U.S. Section 304(a)(1) of the Clean Water Act requires U.S. EPA to develop criteria for water quality that accurately reflect the latest scientific knowledge. These criteria are based solely on data and best professional scientific judgments on toxicological effects. Criteria are developed following the guidance outlined in the Agency's "*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses"* (Stephan et al. 1985).

Once the section 304(a) water quality criteria are finalized, states and authorized tribes may adopt the criteria into their water quality standards to protect designated uses of water bodies. States and tribes may also modify the criteria to reflect site-specific conditions or use other scientifically defensible methods to develop standards. Water quality standards are subsequently approved by U.S. EPA.

### A. Stressor Characteristics

#### 1. Mode of Action and Toxicity

Carbaryl is an insecticide belonging to the N-methyl carbamate class of pesticides. After contact or ingestion, the toxic mode of action of carbaryl (and other carbamate insecticides) for animals is inhibition of the enzyme acetylcholinesterase (AChE) at synaptic junctions in the nervous system. AChE breaks down the neurotransmitter acetylcholine. Inhibition of AChE results in the accumulation of acetylcholine in the nerve synapses which leads to continual firing of nerve pulses throughout the nervous system. This buildup results in uncontrolled movement, paralysis, convulsions, tetany, and possible death (Gunasekara et al. 2008). Without proper nerve function, the respiratory, circulatory and other vital body systems will fail, ultimately causing death of the organism (Kuhr and Dorough 1976). The acetylcholinesterase inhibition effects of carbaryl are reversible with removal of exposure of the stressor chemical. The primary degradate of carbaryl, 1-naphthol, does not inhibit acetylcholinesterase and its toxic mode of action for animals is thought to be narcosis (Russom et al. 1997). In aquatic organisms, narcosis is a reversible anesthetic effect that is caused by chemicals partitioning into cell membranes and nervous tissue that result in disruption of cell functions including central nervous system function (Barron et al. 2001).

Carbaryl is also used to thin fruit (removing excess fruit so the remaining fruit increase in size and flavor) in orchards; its activity in the abscission (dropping) of flower buds may be related to its structural similarity to plant auxins, such as α-naphthalene acetic acid. The carbaryl degradate 1-naphthol is a known plant auxin (Wood 2010).

Carbaryl is included on the final list of chemicals for initial Tier 1 Screening under U.S. EPA's Endocrine Disruptor Screening Program (EDSP) released on April 2009. This list includes chemicals that the Agency has decided should be tested first, based upon exposure pathway potential to humans; this list should not be construed as a list of known or likely endocrine disruptors. On October 2009, U.S. EPA issued test orders for a data call-in (DCI) from manufacturers/formulators of carbaryl. Test results for carbaryl are due by November 12, 2011.

Water temperature, pH and hardness are factors potentially affecting the toxicity of carbaryl in the aquatic environment. Schoettger and Mauck (1978) found that the toxicity of carbaryl increased with temperature and hardness (that were in the normal range for natural waters) for the brook trout (*Salvelinus fontinalis*). Rainbow trout (*Oncorhyncus mykiss*) and bluegill (*Lepomis macrochirus*) were similarly tested (Sanders et al. 1983). Bluegill showed increased susceptibility to carbaryl with increases in pH, hardness, and temperature, whereas rainbow trout showed no appreciable changes to any of the parameters tested. Midge larva, *Chironomus riparius*, showed no significant changes in toxicity when exposed to carbaryl at pHs of 4, 6 and 8; additional testing at elevated temperatures showed that increased temperature resulted in slight increases in carbaryl toxicity at pHs of 4 and 6, but not at 8 (Fisher and Lohner 1986). Thus, the lack of sufficient data showing consistent trends (with the exception of brook trout) for specific physio-chemical parameters precludes the need to adjust water quality criteria for these parameters.

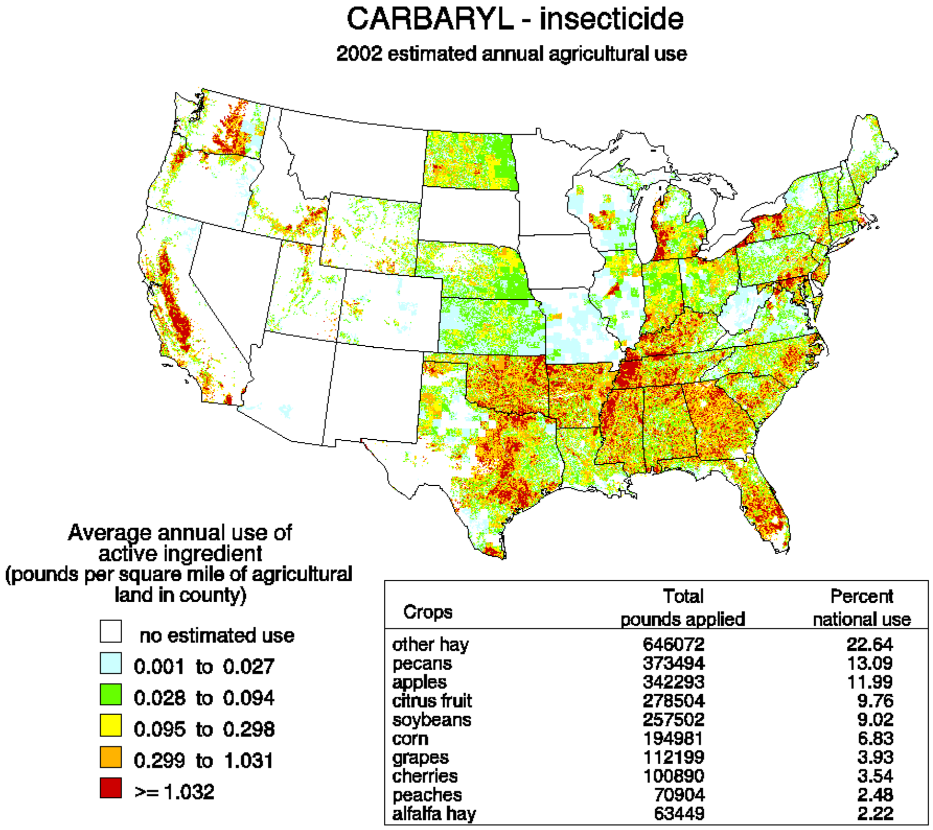
An assessment of the available data regarding the relative toxicity of the degradate 1-naphthol to parent carbaryl compound is inconclusive. Thus, additional acute and chronic aquatic toxicity studies involving fish and invertebrates are needed to complete a more definitive evaluation and to address the uncertainties surrounding the toxicity and effects from 1-naphthol.

## 2. Overview of Pesticide Usage

Carbaryl (main trade names: Sevin, Arilat, Carbatox, Dicarbam) was first registered by the Union Carbide Corporation in 1956. Currently, carbaryl is nationally registered for over 115 uses in agriculture, professional turf management, ornamental production, and residential settings (U.S. EPA 2010a). Carbaryl's main use is an insecticide in the control of mites, fleas, aphids, fire ants, common garden insects, and other insect pests in orchards and agricultural fields. Carbaryl also is registered for use as a mosquito adulticide and as a molluscacide. Agricultural uses include root crops, tree fruit, nuts, fruit and vegetable, and grain crops. Carbaryl is used by homeowners in residential settings for lawn care, gardening (vegetables and ornamentals), and pet care (pet collars, powders, and dips, in kennels, and on pet sleeping quarters). Carbaryl also is used by nursery, landscape, and golf course industries on turf, annuals, perennials, and shrubs. Carbaryl has forestry and rangeland uses and is used for control of grasshoppers and crickets, adult mosquitoes, ticks and fire ants. Additionally, carbaryl is used to thin fruit in orchards to enhance fruit size and enhance repeat bloom. Carbaryl is available for use in various formulations, including baits, dusts, wettable powders, molasses, oil and water suspensions, pellets and granules.

At the time of the carbaryl IRED (U.S. EPA 2004b), approximately 3.9 million pounds of carbaryl active ingredient were sold annually in the U.S.; with about half used in agriculture and half in non-agricultural settings (per 1998 data). The amount of carbaryl usage per year in agriculture has declined somewhat from an average of 1.9 million pounds of active ingredient in

1992 to 1 to 1.5 million pounds of active ingredient in 2001. **Figure 1** depicts the extent of estimated annual carbaryl agricultural use nationally as of 2002. According to U.S. EPA's October 19, 2009 Screening Level Estimates of Agricultural Uses of Carbaryl (U.S. EPA. 2010a), the amount of carbaryl (total formulated product) use has declined to approximately 1.5 million pounds used annually in 2001. The highest annual application is hay (approximately 600,000 lbs), followed by apples (300,000 lbs), pecans (100,000 lbs), and oranges (100,000 lbs) (U.S. EPA 2010a). Usage of carbaryl in the home and garden sector was ranked third most commonly used pesticide active ingredient with a range of 4 to 6 million pounds active ingredient applied in 2005 and 2007. This was a decrease from the 6 to 9 million pounds active ingredient of carbaryl applied in home and gardens during 2003 (U.S. EPA 2011). Usage data in the home and garden sector is not available to allow development of a map for non-agricultural use similar to **Figure 1**.



| Crops | Total pounds applied | Percent national use |
|---|---|---|
| other hay | 646072 | 22.64 |
| pecans | 373494 | 13.09 |
| apples | 342293 | 11.99 |
| citrus fruit | 278504 | 9.76 |
| soybeans | 257502 | 9.02 |
| corn | 194981 | 6.83 |
| grapes | 112199 | 3.93 |
| cherries | 100890 | 3.54 |
| peaches | 70904 | 2.48 |
| alfalfa hay | 63449 | 2.22 |

**Figure 1: Historical Extent (2002) of carbaryl usage in agriculture.**
(Source http://ca.water.usgs.gov/pnsp/pesticide_use_maps/show_map.php?year=02&map=m6006)

## 3. Environmental Fate and Transport

Technical grade carbaryl is an odorless and colorless to tan crystal (depending on purity), and has a molecular weight of 201.22 g/mole. Carbaryl has a density of 1.21 g/mL at 20°C, a vapor pressure of 1.36 x $10^{-7}$ torr at 25°C, and is soluble in water to 32 mg/L at 30°C (U.S. EPA 2010a). It has an n-octanol/water partitioning coefficient ($K_{ow}$) of 229 and an organic-carbon normalized partition coefficient ($K_{oc}$) of 196 $L/kg_{oc}$ (U.S. EPA 2010a). Its Henry's law constant of 1.28 x $10^{-8}$ atm $m^3$ g/mol @ 25°C suggests it will have minimal volatilization from aqueous solutions (U.S. EPA 2010a).

The hydrolysis of carbaryl is pH related, occurring more rapidly in alkaline solutions (U.S. EPA 2010a). There is no evidence of degradation at a pH of 5 and degradation occurs in neutral (pH 7) and alkaline (pH 9) systems with measured half-lives ($t_{½}$) of 12 days and 0.13 days, respectively (U.S. EPA 2010a). Hydrolysis of carbaryl is also evident in saltwater, with reported half-life of one day (pH=7.9) in filtered saltwater (Armbust and Crosby 1991). The major degradate of hydrolysis is 1-naphthol. In aerobic soil and aquatic systems, microbially-mediated degradation (metabolism) of carbaryl occurs fairly rapidly ($t_{½}$ =4.0 and 4.9 days respectively) but more slowly under anaerobic conditions ($t_{½}$ =72 days) (U.S. EPA 2010a). Under both aerobic and anaerobic conditions the major degradate is 1-naphthol.

Aqueous photolysis is another route of degradation for carbaryl, and may occur in the upper water column of an aquatic system, where clearer waters allow light to penetrate. Carbaryl degraded rapidly by aqueous photolysis to 1-naphthol with a half-life of 1.8 days, which in turn degraded very rapidly with a half-life of less than 1 hour.

The primary degradate (*i.e.*, 1-naphthol) in all the degradation studies reviewed, only formed transiently ($t_{½}$~<1 hr) and in most cases completely degraded by the end of each study. Data on the primary degradate, 1-naphthol are limited; however, it appears to be less mobile than the parent (discussed below) and is not likely to persist due to fairly rapid degradation. Since 1-naphthol can occur from a variety of natural and anthropogenic processes, its presence cannot be considered indicative of carbaryl use.

Besides 1-naphthol, the only other major degradate reported was 1, 4-napthoquinone which was found at 17.3% on the third day after study initiation in the aerobic aquatic metabolism study (U.S. EPA 2010a). No additional environmental fate data were available for this degradate.

Carbaryl is considered moderately mobile in soils and sorption of carbaryl is dependent on soil organic matter (U.S. EPA 2010a). Following a high rain event, carbaryl may reach aquatic environments from areas of application in sheet and channel flow runoff. In urban environments, carbaryl present in runoff from yards and gardens could eventually end up in stormwater and wastewater treatment influent. Agricultural applications could have runoff that is subsequently discharged into a surface water body.

Potential transport mechanisms of carbaryl in air include spray drift, and secondary drift of volatilized or soil-bound residues leading to deposition onto nearby or more distant ecosystems. Carbaryl has been shown to be transported and deposited by atmospheric processes (U.S. EPA 2010a); however, given carbaryl's relatively rapid degradation, its potential for long-range atmospheric transport is likely limited.

## 4. Occurrence

In 2003, the OPP Environmental Fate and Effects Division reported that carbaryl was the second most widely detected insecticide in surface water in the U. S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) monitoring program. In the 2003 assessment of NAWQA data, 1,067 (21%) out of 5,198 surface water samples had detections greater than the minimum detectable limit (0.021 µg/L). The maximum reported concentration was 5.5 µg/L across all sites. The mean concentration was 0.11 µg/L, with a standard deviation of 0.43 µg/L. In a summary of pesticide occurrence and concentrations for 40 NAWQA stream sites with primarily agricultural basins, carbaryl was detected in 11% of the samples (N = 1,001) with a maximum concentration of 1.5 µg/L.

In a report released in 2006 summarizing pesticide results from NAWQA from 1992 to 2001 (U.S.G.S. 2006), carbaryl is listed as one of the 14 most frequently detected pesticide compounds in surface water and one of the 3 most frequently detected along with diazinon and chlorpyrifos. Carbaryl was detected in 50% of urban samples over this time period. The majority of carbaryl concentrations reported were low with 35% of the urban samples less than 0.1 µg/L. Detection frequencies in agricultural and mixed land use streams were lower (10% and 17%, respectively), and concentrations associated with those land uses were almost all less than 0.1 µg/L.

In 2007, OPP obtained carbaryl data from the USGS NAWQA data warehouse from 1999 to 2005. A total of 11,732 samples were collected in that timeframe and analyzed for carbaryl with 29% of all samples reporting residues greater than the minimum detection limit. For samples with detections, the mean concentration reported was 0.058 µg/L. The maximum concentration reported was 33.5 µg/L at a location associated with agricultural land (mean in agricultural areas: 0.094 µg/L). The detection frequency associated with agricultural uses was lower (19%) than that associated with urban uses (50%). The highest concentration reported in an urban area was 16 µg/L. The higher detection frequency in urban streams (versus agricultural or mixed land uses) is consistent with data summarized in the USGS reports and earlier EPA 2003 assessment (U.S. EPA 2003). The concentrations detected in urban streams (mostly low concentrations, a few detections in the multiple ppb range), are also consistent with earlier data. The relatively high concentration reported associated with agricultural uses is unusual but not outside of the range predicted by modeling done by EPA for pesticide registration (U.S. EPA 2008). Thus, carbaryl was detected less frequently but at higher concentrations in agricultural areas/uses, while carbaryl was detected more frequently but at lower concentrations in urban areas.

Carbaryl's vapor pressure ($1.36 \times 10^{-6}$ torr) and Henry's law constant ($1.28 \times 10^{-8}$ atm-m$^{-3}$ mol$^{-1}$) are consistent with compounds which are found at least occasionally in the atmosphere. Other than near-field spray drift studies, carbaryl was only measured in a two studies. Carbaryl was detected in 37 percent of rainfall samples collected from Maryland, Indiana, Nebraska and California agricultural watersheds during the 2003 and 2004 growing season, at concentrations ranging from 0.024 to 0.093 µg/L (Vogel et al. 2008). Carbaryl was found in fog in concentrations as high as 0.069 µg/L in six samples collected at three sites along the Pacific Coast in Monterey County, CA (Schomburg et al. 1991). Carbaryl has been also detected in precipitation samples in California (Majewski et al. 2006). Out of 137 rain samples, 93 had detectable carbaryl with a maximum concentration of 0.756 µg/L. Based on these data, it is possible that carbaryl can be deposited on land and aquatic environments in precipitation.

## B. Assessment Endpoints and Measures of Effect

U.S. EPA derives ambient water quality criteria for the protection of aquatic life that are protective of the designated uses established for waters of the United States. U.S. EPA is using the peer-reviewed procedures defined in the Agency's "*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses"* (Stephan et al. 1985) to derive national Water Quality Criteria for carbaryl.

## 1. Stressors of Concern

This criteria document quantitatively considers effects of exposures of carbaryl only. Carbaryl degrades into one major degradate: 1-naphthol; however, 1-naphthol is also formed naturally as a degradation product of naphthalene and other polycyclic aromatic hydrocarbons. Available environmental fate data indicate that 1-naphthol degrades more rapidly and is less mobile than carbaryl. Toxicity data indicate that 1-naphthol is roughly equal to or less toxic than the parent compound depending on the species tested (U.S. EPA 2010b). Additional data are needed to better quantify the relative toxicity of the degradate 1-naphthol to parent carbaryl. Since 1-naphthol is less persistent and less mobile than the parent compound, acts through a different mode of action, and is no more toxic than the parent compound, this criteria document focuses on the parent compound alone.

## 2. Assessment Endpoints

Assessment endpoints are defined as "explicit expressions of the actual environmental value that is to be protected" and are defined by an ecological entity (species, community, or other entity) and its attribute or characteristics (U.S. EPA 1998). Assessment endpoints may be identified at any level of organization (e.g. individual, population, community). In the context of the Clean Water Act, aquatic life criteria rely on the results of growth, reproduction, and survival of the assessed taxa. This information is aggregated into a species sensitivity analyses that evaluates the impact on the aquatic community. Criteria are designed to be protective of the vast majority of aquatic species in an aquatic community (i.e., *5th percentile of tested aquatic animals representing the aquatic community*). As a result, the designated uses (*i.e.*, aquatic life support) and their associated criteria may be considered as assessment endpoints. To develop 304(a) aquatic life criteria under CWA, U.S. EPA typically requires the following:

- Acute toxicity test data for species from a minimum of eight diverse taxonomic groups. The diversity of tested species is intended to ensure protection of various components of an aquatic ecosystem.
    - The acute freshwater requirement is fulfilled with the following 8 minimum data requirements:
        - the family Salmonidae in the class Osteichthyes
        - a second family in the class Osteichthyes, preferably a commercially or recreationally important warmwater species (e.g., bluegill, channel catfish, etc.)
        - a third family in the phylum Chordata (may be in the class Osteichthyes or may be an amphibian, etc.)
        - a planktonic crustacean (e.g., cladoceran, copepod, etc.)
        - a benthic crustacean (e.g., ostracod, isopod, amphipod, crayfish, etc.)
        - an insect (e.g., mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, midge, etc.)
        - a family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca, etc.)
        - a family in any order of insect or any phylum not already represented
    - The acute estuarine/marine requirement is fulfilled with the following 8 minimum data requirements:
        - two families in the phylum Chordata
        - a family in a phylum other than Arthropoda or Chordata
        - either the Mysidae or Penaeidae family
        - three other families not in the phylum Chordata (may include Mysidae or Penaeidae, whichever was not used above)
        - any other family
    - Chronic toxicity test data (longer-term survival, growth, or reproduction) are required for a minimum of three taxa, with at least one chronic test being from an acutely-sensitive species. Acute-chronic ratios can be calculated with data from species of aquatic animals from at least three different families if the following data requirements are met:
        - at least one is a fish
        - at least one is an invertebrate
        - for freshwater chronic criterion: at least one is an acutely sensitive freshwater species (the other two may be estuarine/marine species) or for estuarine/marine chronic criterion: at least one is an acutely sensitive estuarine/marine species (the other two may be freshwater species).

### 3. Measures of Effect

Each assessment endpoint requires one or more "measures of ecological effect" which are defined as changes in the attributes of an assessment endpoint itself or changes in a surrogate entity or attribute in response to chemical exposure. Ecological effect data are used as measures of direct and indirect effects to biological receptors. The measures of effect selected represent the growth, reproduction, and survival of the organisms.

- The acute measures of effect used for organisms in this document are the LC50, EC50, and IC50. LC stands for "Lethal Concentration" and LC50 is the concentration of a chemical that is estimated to kill 50% of the test organisms. EC stands for "Effective Concentration" and the EC50 is the concentration of a chemical that is estimated to produce a specific effect in 50% of the test organisms. IC stands for "Inhibitory Concentration" and the IC50 is the concentration of a chemical that is estimated to inhibit some biological process (i.e. growth, etc.) by 50% compared to a control organism.
- Endpoints for chronic measures of exposure are the NOEC, LOEC, and MATC. The NOEC (i.e., "No-Observed-Effect-Concentration") is the highest test concentration at which none of the observed effects were statistically different from the control. The LOEC (i.e., "Lowest-Observed-Effect-Concentration") is the lowest test concentration at which observed effects were statistically different from the control. The Maximum Acceptable Toxicant Concentration (MATC) is the calculated geometric mean of the NOEC and LOEC.

Data for carbaryl were obtained from studies submitted to EPA's Office of Pesticide Programs by registrants to support registration and from studies published in the open literature and identified in a literature search using the ECOTOXicology database (ECOTOX) as meeting data quality standards. ECOTOX is a source of high quality toxicity data for aquatic life, terrestrial plants, and wildlife. The database was created and is maintained by the U.S. EPA, Office of Research and Development, and the National Health and Environmental Effects Research Laboratory's Mid-Continent Ecology Division. The latest comprehensive literature search for this document was conducted in May 2009.

The amount of toxicity testing data available for any given pollutant varies significantly, depending primarily on whether it has raised any significant environmental issues and, in the case of a pesticide, how long it has been registered. A further evaluation of available data is performed by EPA to determine test acceptability. Appendix A of *Quality Criteria for Water*

*1986* (U.S. EPA 1986) provides an in-depth discussion of the minimum data requirements and data quality requirements for aquatic life criteria development.

The assessment endpoints for aquatic life criteria are based on growth, reproduction, and survival of the assessed taxa. The measures of effect are provided by the acute and chronic toxicity data. These toxicity endpoints [expressed as genus means] are used in the species sensitivity distribution of the aquatic community to derive the aquatic life criteria. Endpoints used in this assessment are listed in **Table 2**.

**Table 2. Summary of Assessment Endpoints and Measures of Effect Used in Criteria Derivation**

| Assessment Endpoints for the Aquatic Community | Measures of Effect |
|---|---|
| Survival, growth, and reproduction of freshwater fish, other freshwater vertebrates, and invertebrates | For acute effects: LC50, EC50<br>For chronic effects: NOEC and LOEC, calculated MATC, or EC20 |
| Survival, growth, and reproduction of estuarine/marine fish and invertebrates | For acute effects: LC50, EC50<br>For chronic effects: NOEC and LOEC, calculated MATC, or EC20 |
| Maintenance and growth of aquatic plants from standing crop or biomass (freshwater and estuarine/marine) | For effects: LOEC, EC20, EC50, IC50, reduced growth rate, cell viability, calculated MATC |

MATC = Maximum acceptable toxicant concentration (geometric mean of NOEC and LOEC)
NOEC = No observed effect concentration
LOEC = Lowest observed effect concentration
LC50 = Lethal concentration to 50% of the test population
EC50/EC20 = Effect concentration to 50%/20% of the test population
IC50 = Concentration of carbaryl at which growth is inhibited 50% compared to control organism growth.

**Table 3** provides a summary of the number of toxicity data available for genera and species that fulfill the minimum dataset requirements for calculation of acute and chronic criteria for both freshwater and estuarine/marine organisms.

## Table 3. Summary Table of Number of Species with Acceptable Toxicity Data Separated into the Minimum Data Requirements in the "Guidelines"

| | Genus Mean Acute Value (GMAV) | Species Mean Acute Value (SMAV) | Genus Mean Chronic Value (GMCV) | Species Mean Chronic Value (SMCV) |
|---|---|---|---|---|
| **Freshwater** | | | | |
| Family Salmonidae in the class Osteichthyes | 3 | 9 | - | - |
| Second family in the class Osteichthyes, preferably a commercially or recreationally important warmwater species | 20 | 23 | 3 | 1 |
| Third family in the phylum Chordata (may be in the class Osteichthyes or may be an amphibian, etc.) | 4[1] | 4[1] | - | - |
| Planktonic Crustacean | 4 | 6 | 2 | 2 |
| Benthic Crustacean | 6 | 8 | - | - |
| Insect | 6 | 6 | - | - |
| Family in a phylum other than Arthropoda or Chordata (*e.g.*, Rotifera, Annelida, or Mollusca) | 3[2] | 3[2] | - | - |
| Family in any order of insect or any phylum not already represented | 1[3] | 1[3] | - | - |
| **Total** | 47 | 60 | 5 | 3 |
| **Estuarine/Marine** | | | | |
| Family in the phylum Chordata: phylum Chordata, family Gasterosteidae | 1 | 1 | - | - |
| Family in the phylum Chordata: phylum Chordata, family Cyprinodontidae | 1 | 1 | - | - |
| Either the Mysidae or Penaeidae family: family Mysidae | 1 | 1 | - | - |
| Family in a phylum other than Arthropoda or Chordata | 1[4] | 1[4] | - | - |
| Family in a phylum other than Chordata | 1[5] | 1[5] | - | - |
| Family in a phylum other than Chordata | 1[6] | 1[6] | - | - |
| Family in a phylum other than Chordata | 1[7] | 2[7] | - | - |
| Any other family | 1[8] | 1[8] | - | - |
| Any other family | 3[9] | 3[9] | - | - |
| **Total** | 11 | 12 | - | - |

[1] Phylum Chordata, Class Amphibia
[2] Phylum Annelida and Phylum Mollusca
[3] Class Insecta, Family Perlidae
[4] Phylum Mollusca, Family Tellinidae
[5] Phylum Mollusca, Family Cardiidae
[6] Phylum Mollusca, Family Veneridae
[7] Phylum Mollusca, Family Ostreidae
[8] Phylum Mollusca, Family Mytilidae
[9] Phylum Arthropoda
Dash indicates not available

The aquatic plant data available for carbaryl indicate that plants are roughly two orders of magnitude less sensitive than the aquatic animals tested (**Appendix E**). Therefore, no further analyses for development of plant criteria were initiated.

## C. Conceptual Model

Conceptual models consist of a written description and diagram (U.S. EPA 1998) that illustrate the relationships between human activities, stressors, and ecological effects on assessment endpoints. The conceptual model links exposure characteristics, with the ecological endpoints important for management goals. Under the Clean Water Act, these management goals are established by states and tribes as designated uses of waters of the United States (for example, aquatic life support). In deriving aquatic life criteria, U.S. EPA is developing acceptable thresholds for pollutants that, if not exceeded, are expected to protect designated uses. A state and/or tribe may implement these criteria by adopting them into their respective water quality standards.

### 1. Conceptual Diagram

Environmental exposure to carbaryl, while ultimately determined by various site specific conditions and processes, is initiated by an application of the pesticide. The environmental fate properties of carbaryl indicate that runoff, ground water recharge, spray drift, and atmospheric deposition represent potential transport mechanisms of carbaryl to surface water which serves as habitat for aquatic organisms. These transport mechanisms are depicted in the conceptual model below (**Figure 2**). The model also depicts exposure pathways for biological receptors of concern (e.g., non-target aquatic animals) and the potential attribute changes (i.e., effects such as reduced survival, growth and reproduction) in the receptors due to carbaryl exposure.

The conceptual model provides a broad overview of how aquatic organisms can potentially be exposed to carbaryl. Transport mechanisms and exposure pathways are not considered in the derivation of aquatic life criteria. Derivation of criteria focuses on effects on survival, growth and reproduction of aquatic organisms. However, the pathways, receptors, and attribute changes depicted in **Figure 2** may be helpful for states and tribes as they adopt criteria into standards and need to evaluate potential exposure pathways affecting designated uses.

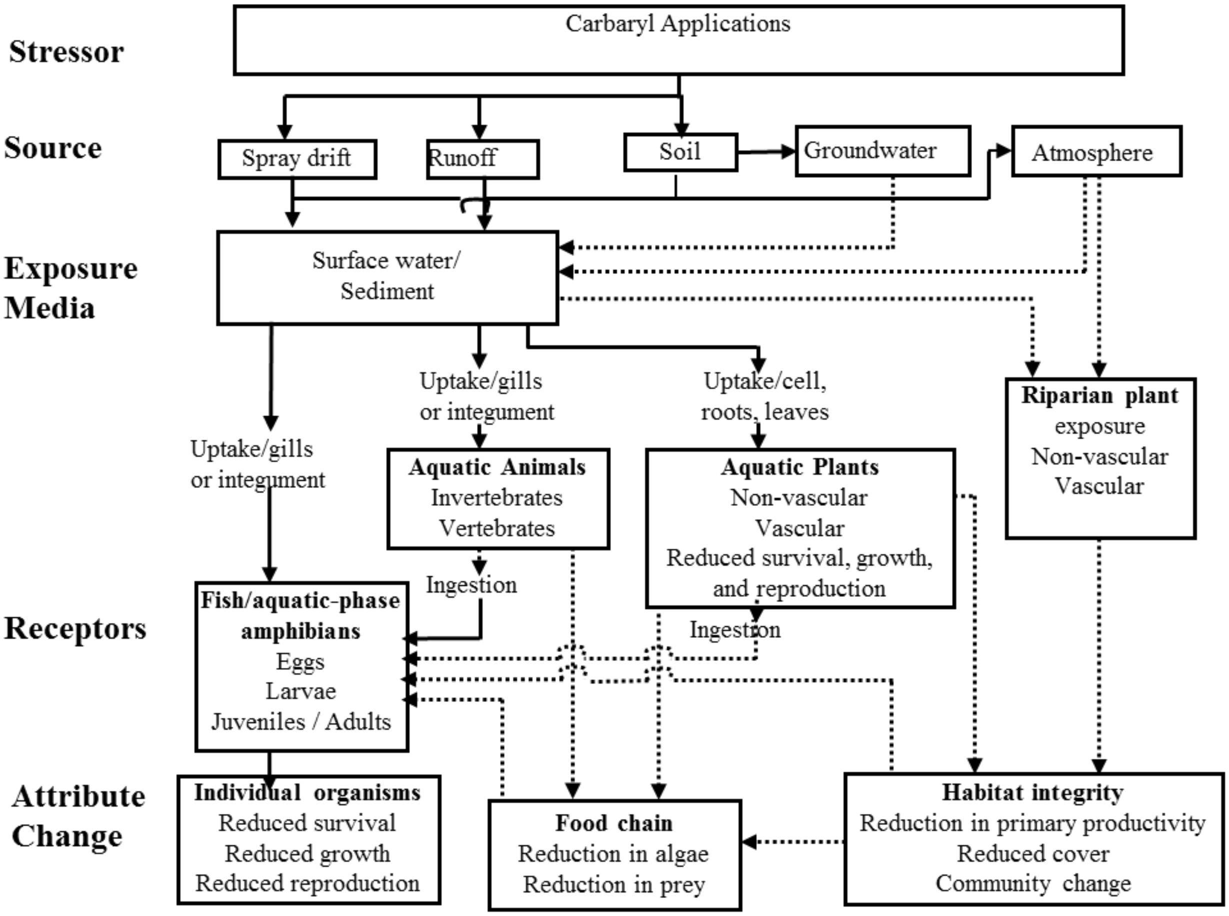


**Figure 2: Conceptual model for carbaryl effects on aquatic organisms.**
(Dotted lines indicate exposure pathways that have a low likelihood of contributing to ecological effects).

## D. Analysis Plan

During development of CWA section 304(a) criteria, U.S. EPA assembles available test data and considers all the relevant data that meet acceptable data quality standard together for all genera. In most cases, data on freshwater and estuarine/marine species are grouped separately to develop separate freshwater and estuarine/marine criteria. Thus, where data allow, four criteria are developed (acute freshwater, acute estuarine/marine, chronic freshwater, and chronic estuarine/marine). If plants are more sensitive than vertebrates and invertebrates, plant criteria are developed.

The CWA criteria are based on a species sensitivity distribution (SSD) comprised of genus mean acute values (GMAVs), calculated from species mean acute values (SMAVs) for acceptable available data. SMAVs are calculated using the geometric mean for all acceptable toxicity tests within a given species (e.g. all tests for *Daphnia magna*). If only one test is available, the SMAV is that test value by default. GMAVs are then calculated using the geometric means of all SMAVs within a given genus (e.g. all SMAVs for genus Daphnia - *Daphnia pulex*, *Daphnia magna*). Once again, if only one SMAV is available for a genus, then the GMAV is represented by that value. GMAVs are then rank-ordered by sensitivity from most sensitive to least sensitive. The final acute value (FAV) is determined by regression analysis based on the four most sensitive genera (reflected as GMAVs) in the data set to interpolate or extrapolate (as appropriate) to the 5th percentile of the distribution represented by the tested genera. The acute criterion is the FAV divided by two, which is intended to provide an acute criterion protective of nearly all individuals in such a genus (see “Guidelines”).

Although the aquatic life criteria derivation process relies on selected toxicity endpoints from the sensitive species tested, it does not necessarily mean that the selected toxicity endpoints reflect sensitivity of the most sensitive species existing in a given environment. The intent of the eight minimum data requirements is to serve as a sample representative of the aquatic community. These minimum data requirements represent different ecological, trophic, taxonomic and functional differences observed in the natural aquatic ecosystem. Use of species sensitivity distribution where the criteria values are based on the four most sensitive taxa is reflective of the whole distribution, representing a censored statistical approach that improves estimation of the lower tail when the shape of the whole distribution is uncertain.

The chronic criterion may be determined by one of two methods. If all 8 minimum data requirements are met with acceptable chronic test data, then the chronic criterion is derived using the same method used for the acute criterion. In cases where less chronic data are available (i.e., must have at least three chronic tests from taxa that also have appropriate acute toxicity data) the chronic criterion can be derived by determining an appropriate acute-chronic ratio (ACR). The ACR is a way of relating the acute and chronic toxicities of a material to aquatic organisms. Acute-chronic ratios can be used to derive chronic criteria with data for species of aquatic animals provided that at least three of the minimum data requirements are met and that:

- at least one is a fish
- at least one is an invertebrate
- at least one is an acutely sensitive freshwater species (or estuarine/marine species if estuarine/marine criteria are being derived); the other two species data may be freshwater or estuarine/marine as appropriate to the derivation.

ACRs are calculated by dividing the acute toxicity test values by a “paired” (same lab, same dilution water) chronic test value. Comparisons of ACRs across taxa may elucidate differences and similarities in taxa response. For example, invertebrate ACRs for carbaryl are similar indicating similar taxonomic sensitivity. If variability is greater than ten-fold among calculated ACRs, and no explainable trend exists, then a chronic criterion should not be derived. The Final ACR (FACR) is then derived by calculating the geometric mean of all acceptable ACRs. The Final Chronic Value (FCV) is then estimated by dividing the FAV by the FACR. This serves as the basis for the chronic criterion. Finally, the acute or chronic criterion may be lowered to protect recreationally or commercially important species.

In addition, whenever adequately justified, a state or tribe may replace a national criterion with a site-specific criterion (U.S. EPA 1983a), which may include not only site-specific criterion concentrations, but also site-specific durations of averaging periods and site-specific frequencies of allowed excursions (U.S. EPA 1991). For more information on criteria derivation, see: http://water.epa.gov/scitech/swguidance/waterquality/standards/upload/2009_01_13_criteria_85guidelines.pdf.

The criteria presented herein are the agency’s best estimate of maximum concentrations of carbaryl to protect most aquatic organisms from any unacceptable short- or long-term effects.

Results of such intermediate calculations such as Species Mean Acute Values (**Appendices A** and **B**) and chronic values (**Appendices C** and **D**) are specified to four significant figures to prevent round-off error in subsequent calculations and the number of places beyond the decimal point does not reflect the precision of the value.

## E. Identification of Data Gaps for Aquatic Organisms

Data gaps were identified for carbaryl. No acceptable aquatic vascular plant data are available. However, given the large difference between toxicity to aquatic plants and animals, it is not likely that aquatic vascular plants would be more sensitive to carbaryl that aquatic animals. Also, additional acute and chronic aquatic toxicity studies using the degradate 1-naphthol on fish and invertebrates are recommended to address lack of information for this degradate. This data gap was identified in EPA's problem formulation for the re-evaluation of carbaryl (U.S. EPA 2010a) thus, in the future, additional degradate data may become available. In addition, supplemental estuarine/marine chronic studies would be beneficial since there is only one study available for evaluation.

# III. EFFECTS ANALYSES TO AQUATIC ORGANISMS

## A. Acute Toxicity to Aquatic Animals

All available data relating to the acute effects of carbaryl on aquatic animals were considered in deriving the carbaryl criteria. Data that were suitable (in terms of test acceptability and quality), according to the "Guidelines," for the derivation of a freshwater and estuarine/marine FAV are presented in **Appendices A** and **B, respectively** (most fish and invertebrate data are 96-hr duration, except cladocerans, midges, mysids and certain embryos and larvae of specific estuarine/marine groups are 48-hr duration).

### 1. Freshwater

Sixty freshwater species representing 47 genera were represented in the dataset of acceptable data for acute toxicity to carbaryl. Species Mean Acute Values (SMAV) ranged from 3.175 µg/L for the stonefly (*Isogenus sp.*) to 27,609 µg/L for the catfish (*Clarias batrachus*).

The second, third, fourth and seventh most sensitive tested species SMAVs are also stoneflies (*Skwala sp*., *Pteronarcys californica*, *Claassenia sabulosa* and *Pteronarcella badia*), with SMAVs of 3.6, 4.8, 5.6 and 9.163 µg/L, respectively. Cladocerans are the next most sensitive taxon (SMAVs ranged from 5.958 µg/L for *Ceriodaphnia dubia* to 35 µg/L for *Daphnia carinata*), followed by amphipods (*Gammarus pseudolimnaeus*, *G. lacustris*, *Hyalella azteca* and *Pontoporeia hoyi* with SMAVs of 10.12, 18.76, 15.2 and 250 µg/L, respectively). Thus, the ten freshwater genera most sensitive to carbaryl are in the classes Insecta and Crustacea (**Table 4**), as would be expected for an insecticide.

The most sensitive fish SMAV was for brown trout, *Salmo trutta* (SMAV of 700 µg/L), followed by the rainbow trout (SMAV of 860 µg/L) and lake trout (*Salvelinus namaycush*, SMAV of 988.1 µg/L). Tests relating to effects on several endangered fish species were also available: the shortnosed sturgeon, *Acipenser brevirostrum*, with a SMAV of 1,810 µg/L (Dwyer et al. 2000); the razorback sucker, *Xyrauchen texanus*, with a SMAV of 4,350 µg/L (Dwyer et al. 1995); the Gila topminnow, *Poeciliopsis occidentalis*, with a SMAV of >3,000 µg/L (Dwyer et al. 1999b); the bonytail chub, *Gila elegans*, with a SMAV of 2,655 µg/L (Dwyer et al. 1995; Beyers et al. 1994); the Atlantic salmon, *Salmo salar*, with a SMAV of 1,129 µg/L (Mayer and Ellersieck 1986); and the Colorado pikeminnow (formerly squawfish), *Ptychochelius lucius*, with a SMAV of 2,005 µg/L (Dwyer et al. 1995; Beyers et al. 1994). Tests relating to effects on one threatened fish species was available, i.e., the Apache trout, *Oncorhynchus apache*, with a SMAV of 1,540 µg/L (Dwyer et al. 1995). Tests relating to effects on two threatened/endangered fish species (certain populations threatened, and others endangered) were also available, the Coho salmon, *Oncorhynchus kisutch*, with a SMAV of 1,654 µg/L (Katz 1961; Macek and McAllister 1970; Post and Schroeder 1971; Johnson and Finley 1980; Mayer and Ellersieck 1986) and the Chinook salmon, *Oncorhynchus tshawytscha*, with a SMAV of 2,690 µg/L (Johnson and Finley 1980; Mayer and Ellersieck 1986; Phipps and Holcombe 1985; 1990). Available data indicates endangered fish species tested are not found to be more sensitive than non-endangered fish species.

Aquatic-phase amphibians (*Rana clamitans*, SMAV = 16,296 µg/L; *Bufo boreas*, SMAV = 12,310 µg/L; *Hyla versicolor*, SMAV = 2,470 µg/L and *Xenopus laevis* (frog that is a common test species with fully aquatic life cycle that is non-native to the U.S.), SMAV = 1,730 µg/L), freshwater mussels (*Anodonta imbecillis*, SMAV = 24,632 µg/L) and the aquatic air-breathing snail (*Aplexa hypnorum*, SMAV = >27,000 µg/L) were comparatively insensitive to carbaryl. The least sensitive species tested with carbaryl is *C. batrachus*, with a SMAV of 27,609 µg/L.

GMAVs for 47 freshwater genera are provided in **Table 4**. The four most sensitive genera were within a factor of 1.8 of one another. The freshwater FAV (the 5th percentile of the species sensitivity distribution) for carbaryl is 4.219 µg/L, calculated using the procedures described in the "Guidelines." The Final Acute Value is an estimate of the concentration of the material corresponding to a cumulative probability of 0.05 in the acute toxicity values for the genera with which acceptable acute tests have been conducted on the material. The FAV is slightly higher than the GMAVs for two genera of stoneflies, *Isogenus* (3.175 µg/L) and *Skwala* (3.6 µg/L). The FAV is then divided by two to account for the fact that the toxicity tests were designed to assess LC50 values, and the criterion needed to protect aquatic life at levels below which effects on test organisms are indistinguishable from control (unexposed) organisms. Therefore, the FAV/2, which is the freshwater continuous maximum concentration (CMC), for carbaryl is 2.1 µg/L and should be protective for all freshwater organisms potentially exposed to carbaryl under short-term conditions (**Figure 3**).

## Table 4. Ranked Freshwater Genus Mean Acute Values

| Rank[a] | Genus Mean Acute Value (µg/L) | Species | Species Mean Acute Value[b] (µg/L) |
|---|---|---|---|
| 47 | 27,609 | Walking catfish,<br>*Clarias batrachus* | 27,609 |
| 46 | >27,000 | Snail,<br>*Aplexa hypnorum* | >27,000 |
| 45 | 24,632 | Mussel,<br>*Anodonta imbecillis* | 24,632 |
| 44 | 20,000 | Black bullhead,<br>*Ameiurus melas* | 20,000 |
| 43 | 16,700 | Goldfish,<br>*Carassius auratus* | 16,700 |
| 42 | 16,296 | Green frog,<br>*Rana clamitans* | 16,296 |
| 41 | 12,400 | Channel catfish,<br>*Ictalurus punctatus* | 12,400 |
| 40 | 12,310 | Boreal toad,<br>*Bufo boreas* | 12,310 |
| 39 | 9,039 | Green sunfish,<br>*Lepomis cyanellus* | 9,460 |
|  | - | Redear sunfish<br>*L. microlophus* | 11,200 |
|  | - | Bluegill,<br>*L. macrochirus* | 6,970 |
| 38 | 8,656 | European chub,<br>*Leuciscus cephalus* | 8,656 |
| 37 | 8,200 | Oligochaete worm,<br>*Lumbriculus variegatus* | 8,200 |
| 36 | 8,012 | Fathead minnow,<br>*Pimephales promelas* | 8,012 |
| 35 | 6,400 | Largemouth bass,<br>*Micropterus salmoides* | 6,400 |
| 34 | 4,350 | Razorback sucker,<br>*Xyrauchen texanus* | 4,350 |
| 33 | 4,153 | Common carp,<br>*Cyprinus carpio* | 4,153 |
| 32 | >3,000 | Gila topminnow,<br>*Poeciliopsis occidentalis* | >3,000 |
| 31 | 2,930 | Nile tilapia,<br>*Oreochromis niloticus* | 2,930 |
| 30 | 2,655 | Bonytail chub,<br>*Gila elegans* | 2,655 |
| 29 | 2,600 | Black crappie,<br>*Pomoxis nigromaculatus* | 2,600 |
| 28 | 2,515 | Guppy,<br>*Poecilia reticulate* | 2,515 |

## Table 4. Ranked Freshwater Genus Mean Acute Values

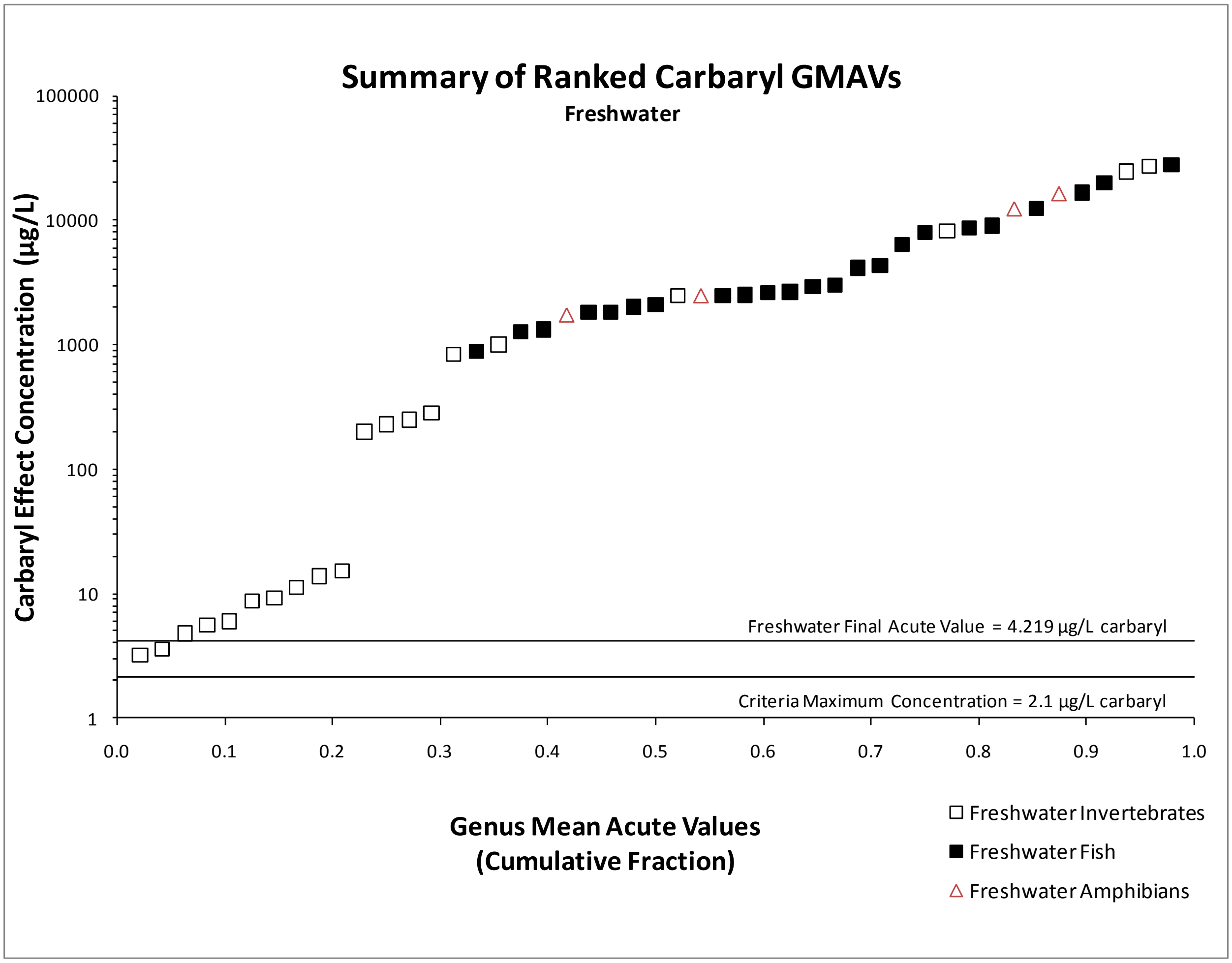
| Rank[a] | Genus Mean Acute Value (µg/L) | Species | Species Mean Acute Value[b] (µg/L) |
|---|---|---|---|
| 27 | 2,480 | Yellow perch,<br>*Perca flavescens* | 2,480 |
| 26 | 2,470 | Gray tree frog,<br>*Hyla versicolor* | 2,470 |
| 25 | 2,462 | Crayfish,<br>*Orconectes immunis* | 2,870 |
|  | - | Crayfish,<br>*O. virilis* | 2,112 |
| 24 | 2,079 | Greenthroat darter,<br>*Etheostoma lepidum* | 2,140 |
|  | - | Fountain darter,<br>*E. fonticola* | 2,020 |
| 23 | 2,005 | Colorado pikeminnow<br>(formerly squawfish),<br>*Ptychochelius lucius* | 2,005 |
| 22 | 1,810 | Apache trout,<br>*Oncorhynchus apache* | 1,540 |
|  | - | Coho salmon,<br>*O. kisutch* | 1,654 |
|  | - | Chinook salmon,<br>*O. tshawytscha* | 2,690 |
|  | - | Cutthroat trout,<br>*O. clarkii* | 3,300 |
|  | - | Rainbow trout,<br>*O. mykiss* | 860 |
| 21 | 1,810 | Shortnosed sturgeon,<br>*Acipenser brevirostrum* | 1,810 |
| 20 | 1,730 | African clawed frog,<br>*Xenopus laevis* | 1,730 |
| 19 | 1,322 | Striped bass,<br>*Morone saxatilis* | 1,322 |
| 18 | 1,269 | Brook trout,<br>*Salvelinus fontinalis* | 1,629 |
|  | - | Lake trout,<br>*S. namaycush* | 988.1 |
| 17 | 1,000 | Crayfish,<br>*Procambarus clarkii* | 1,000 |
| 16 | 889.0 | Atlantic salmon,<br>*Salmo salar* | 1,129 |
|  | - | Brown trout,<br>*S. trutta* | 700 |
| 15 | 839.6 | Crayfish,<br>*Cambarus bartoni* | 839.6 |

**Table 4. Ranked Freshwater Genus Mean Acute Values**

| Rank[a] | Genus Mean Acute Value (µg/L) | Species | Species Mean Acute Value[b] (µg/L) |
|---|---|---|---|
| 14 | 280 | Aquatic sowbug,<br>*Asellus brevicaudus* | 280 |
| 13 | 250 | Amphipod,<br>*Pontoporeia hoyi* | 250 |
| 12 | 230 | Mysid,<br>*Mysis relicta* | 230 |
| 11 | 200 | Backswimmer,<br>*Notonecta undulate* | 200 |
| 10 | 15.2 | Amphipod,<br>*Hyalella azteca* | 15.2 |
| 9 | 13.78 | Amphipod,<br>*Gammarus lacustris* | 18.76 |
|  | - | Amphipod,<br>*G. pseudolimnaeus* | 10.12 |
| 8 | 11.90 | Cladoceran,<br>*Daphnia carinata* | 35 |
|  | - | Cladoceran,<br>*D. magna* | 7.521 |
|  | - | Cladoceran,<br>*D. pulex* | 6.4 |
| 7 | 9.163 | Stonefly,<br>*Pteronarcella badia* | 9.163 |
| 6 | 8.781 | Cladoceran,<br>*Simocephalus serrulatus* | 8.781 |
| 5 | 5.958 | Cladoceran,<br>*Ceriodaphnia dubia* | 5.958 |
| 4 | 5.6 | Stonefly,<br>*Claassenia sabulosa* | 5.6 |
| 3 | 4.8 | Stonefly,<br>*Pteronarcys californica* | 4.8 |
| 2 | 3.6 | Stonefly,<br>*Skwala sp.* | 3.6 |
| 1 | 3.175 | Stonefly,<br>*Isogenus sp.* | 3.175 |

[a] Ranked from the most resistant to the most sensitive based on Genus Mean Acute Value.
[b] From **Appendix A**.

## Figure 3: Ranked Summary of Carbaryl Genus Mean Acute Values (GMAVs) - Freshwater Animals



### 2. Estuarine/Marine

SMAVs (SMAVs and GMAVs are equal with the exception of the genus *Crassostrea*) for 11 genera representing 12 species of estuarine/marine organisms were calculated for carbaryl (**Table 5**). SMAVs and GMAVs are equal when there is only one species present per genus. The most sensitive genus was the mysid (*Americamysis sp.*), with a SMAV of 7.188 µg/L, followed by the Dungeness crab (*Metacarcinus magister*) with a SMAV of 10 µg/L. The two most tolerant genera were the bent-nosed clam (*Macoma nasuta*) and the threespine stickleback (*Gasterosteus aculeatus*), with SMAVs of 17,000 and 3,990 µg/L, respectively (**Figure 4**).

The four most sensitive estuarine/marine genera are *Americamysis*, *Metacarcinus*, *Callianassa* and *Upogebia* with GMAVs that differ by a factor of approximately 8.3. The ghost shrimp (*Callianassa californiensis*) and mud shrimp (*Upogebia pugettensis)* studies were conducted under static conditions with measured concentrations over a 48-hr duration (Stewart et al. 1967). Although the test duration is not the recommended 96-hr duration, these two datapoints were determined to be acceptable and are included in the estuarine/marine acute criteria calculation. Acetylcholinesterase inhibition studies and recovery studies using carbaryl indicate that results for 48-hr acute toxicity tests with invertebrates would be similar to results from 96-hr tests. Scaps et al. (1997) determined the maximum percentage of acetylcholinesterase activity inhibition occurred at 48 hours after exposure and then remained stable for up to seven days for the estuarine/marine polychaete worm, *Nereis diversicolor*. Therefore, the maximum percentage of acetylcholinesterase activity inhibition at 48 hours would lead to the highest level of immobilization or death for the test organisms. Parsons and Surgeoner (1991) found that third-instar mosquito larvae (*Aedes aegypti*) did not recover from immobilization that occurred after a 24-hr exposure to carbaryl. The ability of larvae to recover from immobilization following exposure to carbaryl decreased with increasing exposure time. These results indicate that a 48-hr acute toxicity test EC50 or LC50 would be similar to those for 96-hr tests and provide justification for the use of 48-hr results in the criterion calculation.

Bivalves are moderately insensitive to carbaryl, with GMAVs ranging from 1,650 µg/L for the bay mussel (*Mytilus trossulus*) to 3,850 µg/L for cockle clam (*Clinocardium nuttallii*). The threespine stickleback (*G. aculeatus*) has a similar SMAV of 3,990 µg/L. The most sensitive genus (*Americamysis*, GMAV of 7.188 µg/L) is greater than 2,365 times more sensitive than the most tolerant genus tested, *M. nasuta* (SMAV = 17,000 µg/L).

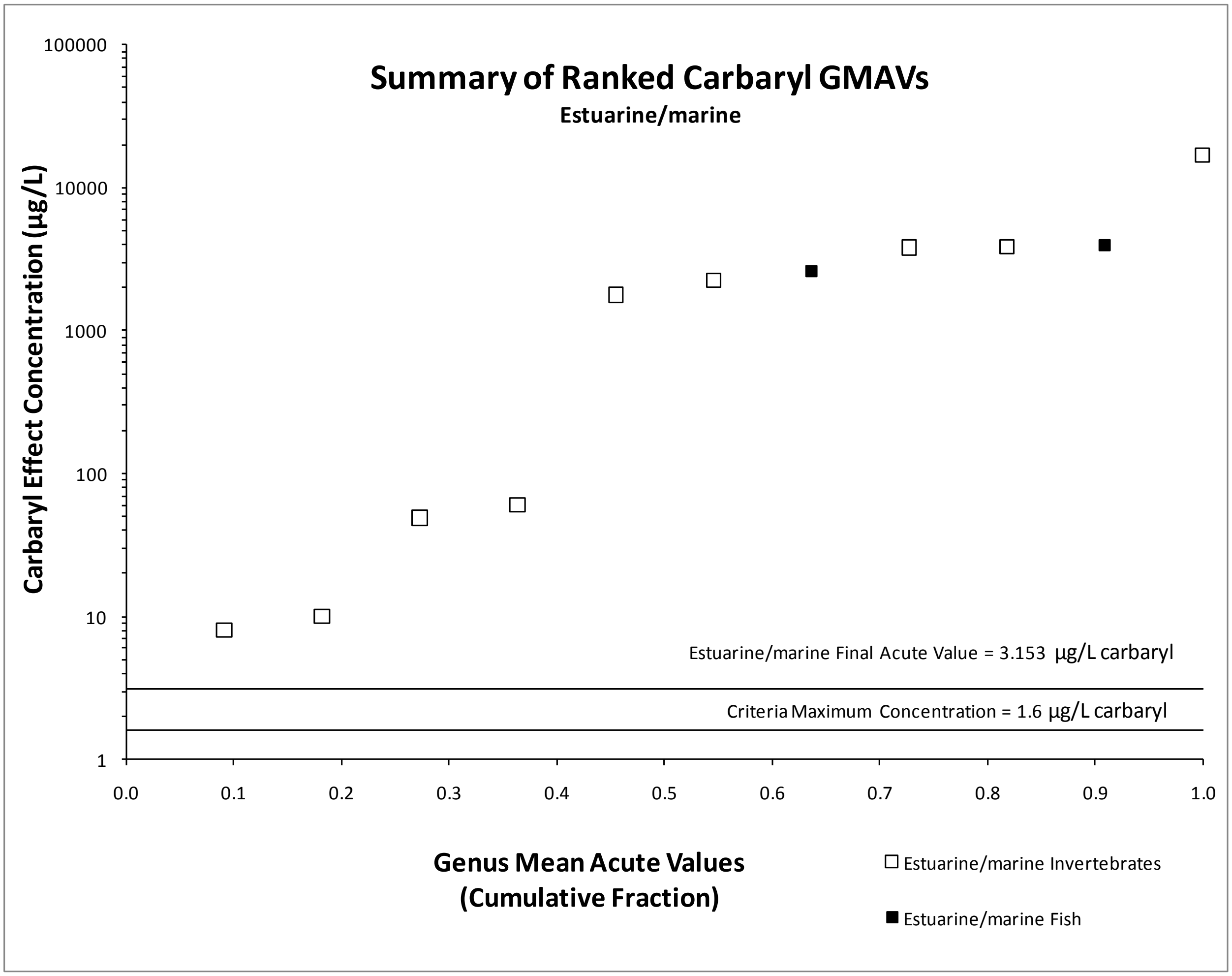
The “Guidelines” indicate that eight minimum data requirements are needed to calculate an estuarine/marine FAV; data are available for 11 genera and meet the family requirement outlined above.  The estuarine/marine FAV is 3.15 µg/L (**Table 5**).  The estuarine/marine CMC (1.58 µg/L) is protective of all estuarine/marine organisms acutely exposed to carbaryl (**Figure 4**).

## Table 5. Ranked Estuarine/Marine Genus Mean Acute Values

| Rank[a] | Genus Mean Acute Value (µg/L) | Species | Species Mean Acute Value[b] (µg/L) |
|---|---|---|---|
| 11 | 17,000 | Bent-nosed clam,<br>*Macoma nasuta* | 17,000 |
| 10 | 3,990 | Threespine stickleback,<br>*Gasterosteus aculeatus* | 3,990 |
| 9 | 3,850 | Cockle clam,<br>*Clinocardium nuttalli* | 3,850 |
| 8 | 3,820 | Hard clam,<br>*Mercenaria mercenaria* | 3,820 |
| 7 | 2,600 | Sheepshead minnow,<br>*Cyprinodon variegatus* | 2,600 |
| 6 | 2,291 | Pacific oyster,<br>*Crassostrea gigas* | 2,200 |
|  | - | Eastern oyster,<br>*C. virginica* | 2,386 |
| 5 | 1,650 | Bay mussel,<br>*Mytilus edulis* | 1,650 |
| 4 | 60.0 | Mud shrimp,<br>*Upogebia pugettensis* | 60.0 |
| 3 | 48.99 | Ghost shrimp,<br>*Callianassa californiensis* | 48.99 |
| 2 | 10 | Dungeness crab,<br>*Metacarcinus magister* formerly *Cancer magister* | 10 |
| 1 | 7.188 | Mysid,<br>*Americamysis bahia* | 7.188 |

[a] Ranked from the most resistant to the most sensitive based on Genus Mean Acute Value.
[b] From **Appendix B**.

## Figure 4: Ranked Summary of Carbaryl Genus Mean Acute Values (GMAVs) - Estuarine/Marine Animals



## B. Chronic Toxicity to Aquatic Animals

### 1. Freshwater

Freshwater chronic toxicity data that meet the test acceptability and quality assurance/control criteria in the "Guidelines" are presented in **Appendix C**. All tests were conducted with measured concentrations of carbaryl. Carbaryl chronic toxicity data are available for five species of freshwater organisms: two invertebrate species (cladocerans) and three fish species.

Carbaryl was evaluated by Oris et al. (1991) using the cladoceran, *Ceriodaphnia dubia*. The pH of the seven-day static-renewal test was 8.18. The mean total young per female was the most sensitive endpoint with a final chronic value (geomean of NOEC and LOEC) of 10.6 µg/L. Replicate seven-day reproduction toxicity tests using hypothesis testing and median inhibition concentration interpolation analysis (median IC50 value approximates chronic values) yielded the same final chronic value. Division of the 48-hr LC50 acute value of 11.6 µg/L from the same study (**Appendix A**) by the chronic value of 10.6 µg/L results in an acute-chronic ratio (ACR) of 1.094 for *C. dubia* (**Table 8**).

Two chronic exposures have been conducted with the cladoceran, *Daphnia magna,* to carbaryl (Brooke 1991 and Surprenant 1985b). *Daphnia magna* was exposed for 21 days to five measured concentrations of carbaryl - 0.29, 0.58, 1.07, 2.16, and 4.04 µg/L at a mean pH of 8.2 (Brooke 1991). Neither survival of the adults nor the number of young produced was significantly different from that of the control organisms at concentrations ≤ 4.04 µg/L. Since there was no significant difference at the highest tested concentration of 4.04 µg/L, the "Guidelines" stipulate that a greater than value (>) be assigned. Therefore, the "no-effect" concentration range for *D. magna* exposed to carbaryl was between 4.04 µg/L and the 48-hr EC50 of 10.1 µg/L. Given the 48-hr EC50 value of 10.1 µg/L from the acute toxicity test (Brooke 1991) this would produce a "theoretical" ACR ranging from 1.0 to < 2.5. This theoretical ACR, while not usable in the direct calculation of the chronic criteria, is consistent with the ACR from freshwater invertebrate taxa that is available, 1.094 for *Daphnia magna*. This indicates that acute and chronic toxicities for the invertebrate taxa are closely related.

Another study with the cladoceran, *D. magna*, was conducted by Surprenant (1985b). The author exposed the cladoceran for 21 days in a flow-through measured exposure. The most sensitive endpoint was an effect of reproduction observed at 3.3 µg/L when compared to the solvent control. The chronic value was calculated to be 2.225 µg/L. An ACR was not derived for this study because there was not an associated acute test.

Two chronic exposures have been conducted with fathead minnows to carbaryl (Carlson 1971 and Norberg-King 1989). Both tests were conducted in the same laboratory by different researchers in different years and with different test durations. Carlson (1971) exposed fathead minnows through a complete life-cycle test beginning with 1- to 5-day old fry at 5 exposure concentrations, i.e., 8, 17, 62, 210, and 680 µg/L. The exposure lasted 9 months resulting in reduced survival at 6 months in the highest exposure concentration of 680 µg/L. After 9 months at the same concentration, fish exhibited reduced egg production and no larvae hatched. No statistically significant effects were noted for survival, growth or reproduction at the 210 µg/L exposure. Thus, the chronic value of 378 µg/L for this study is the geometric mean of the lowest observed effect concentration (LOEC) of 680 µg/L and the no observed effect concentration (NOEC) of 210 µg/L based on reproduction. Division of the 96-hr LC50 of 9,000 µg/L from the same study by the chronic value of 377.9 µg/L results in an ACR of 23.82.

A second chronic test with the fathead minnow was conducted as a 32-day early-life-stage test (Norberg-King 1989). No adverse effects in fish were observed from exposure to carbaryl at concentrations ≤720 µg/L, but adverse effects were measured at 1,600 µg/L. Growth in length, but not weight was reduced at 1,600 µg/L, as was survival. The chronic value for fathead minnows in this test is 1,073 µg/L, which is the geometric mean of the lowest observed effect concentration (LOEC) of 1,600 µg/L and the no observed effect concentration (NOEC) of ≤720 µg/L. Calculation of an ACR from this study is not possible since the authors did not measure the concentration of the exposure in the acute toxicity test. However, two other acute tests for fathead minnows have been conducted at the same laboratory since 1971. Carlson (1971) reported a value of 9,000 µg/L, and Phipps and Holcombe (1985) a value of 5,010 µg/L. The geometric mean of these values is 6,715 µg/L which results in an ACR of 6.258 for the early-life-stage chronic test. The ACR for the complete life cycle test is 23.82, which shows more sensitivity to carbaryl chronic toxicity.

Beyers et al. (1994) conducted individual 32-day early life-stage (ELS) chronic toxicity tests with the endangered Colorado pikeminnow (formerly squawfish), *Ptychochelius lucius*, and the bonytail chub, *Gila elegans*. In both studies, however, considerable ontogenetic development of the test organisms had occurred before test initiation whereby the required embryo and protolarva life stages were not present during the exposure period (mesolarval, metalarval and juvenile life stages were present). Thus, the ELS tests were initiated with 41-day old pikeminnow larvae and 48-day old chub larvae. In both tests, growth was as sensitive as or more sensitive than survival as a measure of chronic toxic effects, and was the only value reported. The NOEC and LOEC for Colorado pikeminnow and bonytail chub were 445 and 866 µg/L, and 650 and 1,240 µg/L, respectively. The final chronic value for *P. lucius* was 620.8 µg/L and 897.8 µg/L for *G. elegans*. ACR values could not be determined for these studies because an accompanying flow-through measured acute toxicity value was not available for each species, nor were there any other available appropriate acute toxicity tests for these species.

**Table 6. Ranked Freshwater Genus Mean Chronic Values**

| Rank[a] | Genus Mean Chronic Value (µg/L) | Species | Species Mean Chronic Value[b] (µg/L) |
|---|---|---|---|
| 5 | 897.8 | Bonytail chub,<br>*Gila elegans* | 897.8 |
| 4 | 636.8 | Fathead minnow,<br>*Pimephales promelas* | 636.8 |
| 3 | 620.8 | Colorado pikeminnow<br>(formerly squawfish),<br>*Ptychochelius Lucius* | 620.8 |
| 2 | 10.6 | Cladoceran,<br>*Ceriodaphnia dubia* | 10.6 |
| 1 | 3.770 | Cladoceran,<br>*Daphnia magna* | 3.770 |

[a] Ranked from the most resistant to the most sensitive based on Genus Mean Chronic Value.
[b] From **Appendix C**.

## 2. Estuarine/Marine

One carbaryl estuarine/marine chronic toxicity test is available for inclusion in the document. A 28-day flow-through test with measured concentrations initiated with 24-hr old neonates was conducted with the mysid, *Americamysis bahia* (Thursby and Champlin 1991b). The NOEC and LOEC based on survival were 7.18 µg/L and 13.7 µg/L, respectively for a final chronic value of 9.918 µg/L carbaryl. The total percent control survival of 63% is below the acceptable total percent control survival of 70% required in ASTM guide E1191-03a (ASTM

2008). The percent control survival for mating pairs is 75% and exceeds the ASTM requirement of 70%. However, the number of young produced by the first-generation females in the controls was less than three which is an ASTM requirement. Two young were produced by the first-generation females in the control and is below the ASTM requirement of three. Therefore, this study is used qualitatively and used in the discussion of acute-chronic ratios. The calculated ACR of 0.8530 is based on the 96-hr LC50 of 8.46 µg/L reported for the same study.

**Table 7. Ranked Estuarine/Marine Genus Mean Chronic Values**

| Rank[a] | Genus Mean Chronic Value (µg/L) | Species | Species Mean Chronic Value[b] (µg/L) |
|---|---|---|---|
| 1 | 9.918 | Mysid,<br>*Americamysis bahia* | 9.918 |

[a] Ranked from the most resistant to the most sensitive based on Genus Mean Chronic Value.
[b] From **Appendix D**.

3. Acute-Chronic Ratio

Four valid ACRs are available for carbaryl using the fifth, eighth and thirty-sixth most sensitive genera of freshwater organisms (**Table 4**). Since the difference between the lowest ACR (1.094 for *Ceriodaphnia dubia*) and the highest ACR (23.82 for *Pimephales promelas*) is a factor of 22, and since the "Guidelines" stipulate that if the species mean ACR seems to increase as the SMAV increases, the FACR (final ACR) should be calculated as the geometric mean of the ACRs for species whose SMAVs are close to the FAV. Using this recommendation, the FACR would be the geometric mean of 1.094 (*C. dubia*) and 1.581 (*D. magna*), or 1.315. However, the "Guidelines", also stipulate that if the most appropriate species mean ACRs are less than 2.0, the FACR should be assumed to be 2.0. Low ACRs may reflect acclimation to the toxicant during the chronic test, or test organisms being fed vs. unfed which may affect bioavailability and susceptibility. Thus, the FACR for carbaryl is assumed to be 2.0 for freshwater organisms.

Dividing the freshwater FAV of 4.219 by the ACR of 2.0 results in a freshwater final chronic value (FCV) of 2.1 µg/L. It is concluded that all freshwater species will be protected

(**Figures 3** and **5**) from adverse effects due to chronic carbaryl exposure with the freshwater FCV of 2.1 µg/L.

## Table 8. Acute-Chronic Ratios

| Species | Acute Value (µg/L) | Chronic Value (µg/L) | Ratio | Reference |
|---|---|---|---|---|
| **Freshwater Species** | | | | |
| Cladoceran,<br>*Ceriodaphnia dubia* | 11.6 | 10.6 | 1.094 | Oris et al. 1991 |
| Cladoceran,<br>*Daphnia magna* | 10.1 | 6.389[a] | 1.581 | Brooke 1991 |
| Fathead minnow,<br>*Pimephales promelas* | 9,000 | 377.9 | 23.82 | Carlson 1971 |
| Fathead minnow,<br>*Pimephales promelas* | 6,715 | 1,073 | 6.258[b] | Norberg-King 1989 |

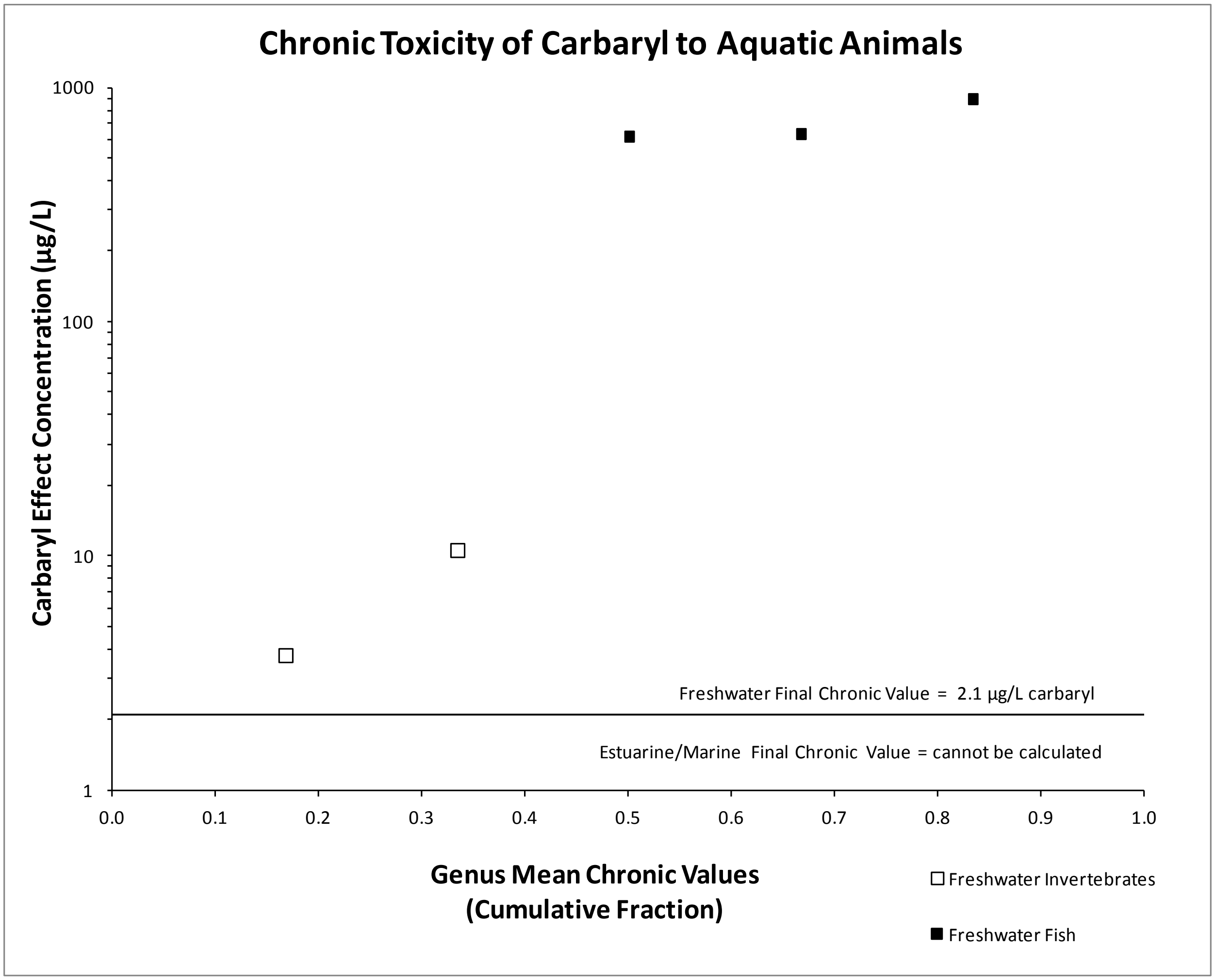
[a] The chronic value of 6.389 µg/L is calculated as the geometric mean of the highest chronic test exposure concentration (4.04 µg/L) which had no adverse impact and the 48-hr EC50 value of 10.1 µg/L from the acute toxicity test.

[b] Only data from Carlson (1971) used to calculate ACR for this species.

Freshwater

Final Acute Value = 4.219 µg/L
Final Acute-Chronic Ratio = 2.0
Final Chronic Value = (4.219 µg/L)/2.0 = **2.1 µg/L**

**Figure 5: Chronic Toxicity of Carbaryl to Aquatic Animals**



## C. Toxicity to Aquatic Plants

No carbaryl toxicity tests with important aquatic plant species in which the concentrations of test material were measured and the endpoint was biologically important are available in the literature. Therefore, a Final Plant Value cannot be determined. Effects on aquatic plants are discussed qualitatively in the Effects Characterization chapter.

## D. Degradate Toxicity

Acute toxicity testing of carbaryl's major degradate 1-naphthol in fish shows that the compound ranged from being moderately to highly toxic (LC50 range 750 to 1,600 µg/L). The toxic mode of action for 1-naphthol is thought to be narcosis (Russom et al. 1997). In aquatic organisms, narcosis is a reversible anesthetic effect that is caused by chemicals partitioning into cell membranes and nervous tissue that result in disruption of central nervous system function (Barron et al. 2001). Chronic exposure of fathead minnows to 1-naphthol reduced larval growth and survival with a NOEC = 100 µg/L (U.S. EPA 2010a). No data are available on the acute or chronic toxicity of 1-naphthol to amphibians. For freshwater invertebrates, 1-naphthol ranged from moderately to highly toxic with an EC50 range: 200 to 3,000 µg/L (U.S. EPA 2010a). Toxicity data are not available for the other major degradate, 1,4-napthoquinone which is a data gap.

## E. Summary of National Criteria

The resulting recommended ambient water quality criteria indicate that freshwater aquatic organisms would have an appropriate level of protection if the one-hour average concentration does not exceed 2.1 µg/L more than once every three years on average and if the four-day average concentration of carbaryl does not exceed 2.1 µg/L more than once every three years on average (except where a locally important species may be more sensitive). Estuarine/marine aquatic organisms would have an appropriate level of protection if the one-hour average concentration does not exceed 1.6 µg/L more than once every three years on average (except where a locally important species may be more sensitive). Note: a Criterion Continuous

Concentration (CCC) could not be calculated for estuarine/marine aquatic organisms due to insufficient data.

**Table 9. Summary Table of Aquatic Life Criteria for Carbaryl**

| | **Acute** | **Chronic** |
|---|---|---|
| **Freshwater** | 2.1 µg/L | 2.1 µg/L |
| **Estuarine/Marine** | 1.6 µg/L | N/A |

N/A – not available, unable to calculate estuarine/marine chronic criterion

## IV. EFFECTS CHARACTERIZATION

Carbaryl is expected to be mobile, but degrades rapidly in neutral to alkaline aquatic systems; however, under acidic conditions, carbaryl is more persistent. Its environmental fate characteristics are consistent with other carbamate insecticides (e.g. carbofuran). Based on environmental fate data, potential exposure would be expected to be greater in aquatic environments with pH less than 7. Fate data on the primary degradate, 1-naphthol, has been identified as a data gap. Although 1-naphthol appears to be somewhat mobile, it is not likely to persist due to fairly rapid degradation.

The primary mode of action for carbaryl is acetylcholinesterase inhibition. This effect is reversible with removal of exposure to carbaryl leading to the possibility of recovery of test organisms at sub-lethal concentrations. The following information addresses studies that are not used in the calculation of criteria but provide supporting evidence for the validity of the criteria.

### A. Effects on Aquatic Animals

#### 1. Freshwater Acute Toxicity

Acceptable acute toxicity data are available for 60 freshwater species representing 47 genera and represents a dataset supporting development of the acute criterion. In general, technical grade carbaryl is classified as highly toxic to fish, aquatic-phase amphibians and is very highly toxic to aquatic invertebrates on an acute exposure basis (U.S. EPA 2010a). Chronic exposure to carbaryl resulted in decreased growth in freshwater fish and decreased reproduction in freshwater invertebrates.

Invertebrate species, particularly arthropods (e.g., daphnids, mysids) are the most sensitive, with the 10 lowest SMAVs (and GMAVs) ranging from 3.175 to 15.2 µg/L, and represented by the classes Insecta and Crustacea (**Table 4**). Cladocerans and amphipods showed high sensitivity to carbaryl in acute toxicity tests. The most sensitive genus tested is the stonefly *Isogenus*, which is more than 8,600 times as sensitive as the most resistant genus tested, i.e., the walking catfish *Clarias* (**Figure 3**).

Several studies were identified as not meeting screening guidelines for inclusion in criterion calculations (**Appendix H**), but showed similar ranges of toxicity and are presented here to provide additional supporting evidence of the potential toxicity of carbaryl to aquatic organisms. *Daphnia magna* LC50 values ranged from 0.66 µg/L (Rawash et al. 1975) to 21 µg/L (Wernersson and Dave 1997) for exposures lasting 24 hours. Mayer and Ellersieck (1986) showed similar sensitivities to the amphipod species *Gammarus pseudolimnaeus*, with 48-hr measured LC50 values of 8 and 13 µg/L carbaryl. Several species of Diptera larvae were also exposed to carbaryl; larvae of midges appear to be more sensitive than larvae of mosquitoes. The LC50 values (24-hr) of various midge species ranged from 1.0 to 110 µg/L. These studies were not used in quantitative criterion calculations because test durations were insufficient.

A study of the persistence of carbaryl toxicity was conducted by Mayer and Ellersieck (1986). Stonefly nymphs (*Isogenus sp*.) were exposed to carbaryl solutions which were fresh (**Appendix A**) and others that had been aged 7, 14 or 21 days (**Appendix H**). Aged solutions were mixed and allowed to sit under normal laboratory conditions. The results showed a trend of decreased toxicity with aging of the solutions. The toxicity of carbaryl solutions aged 21 days decreased the toxicity to about one-third that of fresh solutions. These data support conclusions based on environmental fate properties that the “aging” process decreased exposure concentration, thus decreasing toxicity. Results from the aged solutions were not used in the quantitative criterion calculations because the concentrations of carbaryl were not measured at the initiation or completion of the aged solution toxicity tests.

In general, fish are less sensitive to carbaryl than invertebrates. Of the fish tested, brown trout, *Salmo trutta* (SMAV of 700 µg/L) is the most sensitive tested vertebrate species by a factor of approximately 39 times compared to the least sensitive fish tested, i.e., walking catfish, *Clarias batrachus*, with a SMAV of 27,609 µg/L. Mayer and Ellersieck (1986) exposed cutthroat trout (*Oncorhynchus clarkii*) to carbaryl solutions aged for 0, 7, 14 and 21 days. Again, results from the aged solutions were not used in the quantitative criterion calculations because the concentrations of carbaryl were not measured at the initiation of the aged solution toxicity tests. Cutthroat trout exposed to fresh carbaryl solutions had a 96-hr LC50 of 6,800 µg/L at pH= 7.3 (**Appendix A**), and a LC50 of 2,300 µg/L at pH= 7.2 when exposed to a solution aged 21 days. The results from this study show enhanced sensitivity to aged carbaryl solutions and are not consistent with the similar "aged" solution study with stonefly nymphs (Mayer and Ellersieck 1986). These data may indicate potential taxa differences or differences in responses to degradates.

Similar to the response of fish, amphibians are also less sensitive to carbaryl than invertebrates. Two different FETAX studies showed divergent values for effects on embryos of the African clawed frog, *Xenopus laevis*. A 24-hr static study of carbaryl with unmeasured concentrations had an LC50 of 4,700 µg/L, while an exposure for the same amount of time and experimental conditions caused developmental abnormalities (localized edema and ventral bending) at 110 µg/L (Elliott-Freeley and Armstrong 1982). However, Bacchetta et al. (2008) reported substantially reduced sensitivity for the species with a LC50 of 20,280 µg/L after a 115-hr static exposure (unmeasured concentrations) of larvae. These studies were not used in quantitative criterion calculations because of insufficient duration of the tests. The SMAV calculated using acceptable LC50 values for *X. laevis* in **Appendix A** is 1,730 µg/L carbaryl, which is lower than reported LC50 values in these qualitative studies.

Acetylcholinesterase inhibition in fish is also demonstrated in the results of Zinkl et al. (1987) with rainbow trout (**Appendix H**). The authors observed decreased brain cholinesterase activity within 24 hours at carbaryl concentrations ≥500 µg/L. This study was not included in quantitative criterion calculations because it is an atypical endpoint; while it is reflective of the MOA, it is not directly measuring the typical endpoints of survival, growth, or reproduction.

### 2. Freshwater Chronic Toxicity

Acceptable chronic toxicity data are available for five freshwater species representing five different genera (two crustaceans and three fish; **Appendix C**). No data were available for coldwater fish. Similar to acute toxicity testing results, invertebrates were more sensitive to carbaryl than fish on a chronic toxicity basis as well. Chronic toxicity values for cladocerans ranged from 2.2 to 10.6 µg/L, while fish chronic toxicity values ranged from 620.8 to 897.8 µg/L. However, paired acute and chronic toxicity data were only available for three of the freshwater species (two crustaceans and one fish), and these were the only studies used in derivation of the ACR to calculate the FCV (**Table 8**).

An additional fathead minnow study did not meet screening guidelines for inclusion in criterion calculations because of test duration, but the study showed similar ranges of toxicity and provides additional supporting evidence. Larval fathead minnows (<24-hr old) were exposed for seven days (Norberg-King 1989)(**Appendix H**). Exposure for seven days is too short a duration for this test to be used quantitatively for evaluating chronic toxicity. However, the chronic values estimated for four studies ranged from 576 to 1,088 µg/L, which is consistent with the fathead minnow chronic values of the life-cycle toxicity test (378 µg/L) and the 32-day ELS toxicity test (1,073 µg/L).

The use of NOEC/LOEC/MATC approach in criteria derivation can contribute to uncertainty. Potential sources of uncertainty are the range of test concentrations (dilution series) and the sample size used in the test. Where the design is suboptimal, higher NOEC and LOEC values may be reported due to low statistical power and high error variance. Typically, as the accuracy of the test increases, the NOEC decreases. Additional uncertainty is inherent in the calculation of the MATC which is the geometric mean of the NOEC and LOEC. The calculation compounds the fact that higher NOEC and LOEC values may be reported due to poor design. Thus some effects could occur below the calculated MATC due to the inherent uncertainty in the calculation.

Another source of uncertainty for chronic criterion calculations is the use of ACRs. When chronic data are lacking for a particular species' response to a given chemical, ACRs are determined using a formula that relates acute responses (LC50 values) to chronic concentrations using empirical relationships between acute and chronic values for taxonomically similar species for which both acute and chronic data are available. This approach has been incorporated into the 1985 "Guidelines" for evaluating chronic toxicity thresholds where the species mean chronic value (SMCV) is calculated to be the geometric mean between the NOEC and LOEC. For example, the carbaryl FACR is assumed to be 2.0 for freshwater species. The most appropriate calculated species mean ACRs are less than 2.0, and the "Guidelines" stipulate acclimation has probably occurred during the chronic test and the FACR should be assumed to be 2.0. This assumption is a potential source of uncertainty.

### 3. Freshwater Field Studies

Field studies have been conducted to measure effects of aerial application of carbaryl for forest pest control upon the non-target aquatic stream and pond organisms. In northern Maine, nine streams, with different substrate, velocity and cover conditions, were studied to determine the effect of aerial application of carbaryl formulated endproduct (Sevin$^{®}$-4-oil) on aquatic stream invertebrates applied at a rate of 0.840 kg active ingredient per hectare (0.840 kg a.i./ha). Drift of aquatic invertebrates (defined as the release, dispersal, and downstream displacement of invertebrates normally inhabiting benthic substrates) increased by 170 times two days post-treatment compared to controls, with drift samples commonly containing Plecoptera (stoneflies), Ephemeroptera (Mayflies), and Diptera (flies/mosquitoes) (Courtemanch and Gibbs 1980). In forest ponds, amphipods were severely impacted following aerial spraying of Sevin-4-oil applied at the same rate (Gibbs et al. 1984). The amphipods *Hyalella azteca* and *Crangonyx richmondensis* were completely eliminated and failed to recolonize 30 months after treatment, with maximum residue concentrations of 254 µg/L found in the water and 53,793 µg/kg (dry weight) in the sediment.

In a 77-day mesocosm study, researchers examined the effects of carbaryl on amphibians in terms of body size, length of larval period, and survival to metamorphosis when exposed to carbaryl (21.3% active ingredient) early in the larval period (Boone and Semlitsch 2002). The study units consisted of fifty 1480-L polyethylene ponds (1.85 m in diameter) containing 1,000 L of well water, 1 kg of leaf litter, and plankton from natural ponds. The study manipulated initial larval density, i.e., low (80) and high (240), pond hydroperiod, (constant or drying), and chemical concentration (absent, 3.5 mg/L, 5.0 mg/L, or 7.0 mg carbaryl /L). Frog species included: Southern leopard frog (*Rana sphenocephala*), Plains leopard frog (*R. blairi*), green frog (*R. clamitans*), and the Woodhouse's toad (*Bufo woodhousii*). Toads in the high-density larval ponds showed greater survival than those in low-density larval ponds at the highest carbaryl level. For Southern and Plains leopard frogs, carbaryl treatment did not have a significant effect on either species. For *R. clamitans*, carbaryl exposure had a significant effect

($p<0.05$) on days to metamorphosis with tadpoles in the chemical treatments generally having longer larval periods.

## 4. Estuarine/Marine Acute Toxicity

Acute toxicity data are available for 12 estuarine/marine species representing 11 genera. These data represent a dataset supporting the development of an estuarine/marine acute criterion.

SMAVs for carbaryl range from 7.188 to 17,000 µg/L. The most sensitive genus was the mysid (*Americamysis*), with a GMAV of 7.188 µg/L, followed by the Dungeness crab (*Metacarcinus*) with a GMAV of 10 µg/L. The two most tolerant genera were the bent-nosed clam (*Macoma*) and the threespine stickleback (*Gasterosteus*), with SMAVs of 17,000 and 3,990 µg/L, respectively (**Table 5** and **Figure 4**).

The four most sensitive estuarine/marine genera are *Americamysis*, *Metacarcinus*, *Callianassa* and *Upogebia* with SMAVs of 7.188, 10, 48.99, and 60.0 µg/L, respectively. Additional toxicity data on the effect of carbaryl on estuarine/marine species that were not used quantitatively are very similar to acute and chronic ranges of toxicity and provide additional supporting evidence of potential toxicity of carbaryl. Shrimp were found to be more sensitive than bivalves to carbaryl by different researchers (**Appendix I**). Various 24- to 96-hr LC50 values for different species ranged from 1.5 µg/L (*Penaeus aztecus*) to 76 µg/L (*Palaemonetes pugio*). The LC50 values for other test species include: *Crangon septemspinosa* (20 µg/L), *Americamysis bahia* (21 µg/L), *Penaeus duorarum* (32 µg/L), *Callianassa californiensis* (49 µg/L), and *Upogebia pugettensis* (40 µg/L for 24-hr test and 60 µg/L for a 48-hr test). These studies were excluded from quantitative calculation of a criterion due to test design. Similarly, sensitive organisms include testing with the prezoea Dungeness crab, *Metacarcinus magister*, where a concentration of 6 µg/L for 24 hours prevented half of the test organisms from molting to zoea (Buchannan et al. 1970). The duration of this test was too short for quantitative use in this assessment. Another sensitive species tested was the embryo of the killifish, *Fundulus heteroclitus*, which at a carbaryl concentration of 10 µg/L for 40 days exhibited slowed development and diminished pigmentation in fry (Crawford and Guarino 1985). This study was excluded from use in quantitative criterion calculations because of test design.

Bivalves are moderately insensitive to carbaryl, with SMAVs ranging from 1,650 µg/L for the bay mussel (*Mytilus*) to 3,850 µg/L for cockle clam (*Clinocardium*). Tests with the blue mussel (*Mytilus edulis*) at various lifestages for 1 hour exposure had EC50 values for development (e.g., disjunction of blastomeres, reduced development rate and asynchronus and unaligned cleavages) that ranged from 5,300 to 24,000 µg/L (Armstrong and Milleman 1974c). This study was excluded from quantitative assessment due to less than 3 exposure concentrations and a community field exposure test. However, the test results are consistent with longer term tests (10-40 days) on shell growth that had effect concentrations of >1,300 to >2,900 µg/L (Liu and Lee 1975, **Appendix I**).

The sheepshead minnow (*Cyprinodon variegates)* and the threespine stickleback (*Gasterosteus aculeatus*) have SMAVs of 2,600 and 3,990 µg/L, respectively. Acute toxicity of carbaryl to striped bass, *Morone saxatilis* was reported by (Korn and Earnest 1974). The bioassays were 4-day tests using proportional diluters and carbaryl had a 96-hr LC50 = 1,000 µg/l. Although the LC50 for striped bass is more sensitive than the sheepshead minnow and the threespine stickleback, the study was not included in criterion calculations because control survival was not reported.

There were three studies available for estuarine/marine species that evaluated atypical endpoints and were not included in the quantitative criterion calculations. Sheepshead minnows (*Cyprinodon variegatus*) did not avoid water with 100 µg carbaryl/L after 1.5 hour of exposure (Hansen 1969; 1970). Likewise, grass shrimp (*Palaemonetes pugio*) did not avoid water with 100 µg carbaryl/L after a similar 1.5 hour exposure (Hansen et al. 1973). However, Weis and Weis (1974b) observed schooling behavior disrupted in Atlantic silversides (*Menidia menidia*) after 24 hour exposure at 100 µg carbaryl/L.

### 5. Estuarine/Marine Chronic Toxicity

Only one carbaryl estuarine/marine chronic toxicity test is available for qualitative consideration in this document. Survival was the most sensitive endpoint for the mysid, *A. bahia*, with a chronic value of 9.918 µg/L (Thursby and Champlin 1991b). There is uncertainty associated with this study because reported total control survival was 63% and the number of young produced by the first-generation females in the control was below the accepted ASTM requirement. However, the calculated ACR for this study is similar to the freshwater chronic invertebrate studies and provides an additional line of evidence for the sensitivity of invertebrates to carbaryl.

A ten week flow-through colonization study where exposure concentrations were measured provides qualitative information on the chronic effects of carbaryl on the development of estuarine/marine communities. This study, conducted in laboratory aquaria (Tagatz et al. 1979) showed similar tendencies as the mysid test. The amphipods were exposed to measured carbaryl concentrations of 0, 1.1, 11.1 and 103 µg/L. The number of species collected in the two highest concentrations was approximately half that from the control and lowest concentration, with the Phylum Arthropoda most obviously reduced. The number of amphipods, *Corophium acherusicum*, decreased by about 48 percent relative to the control at 1.1 µg/L, and this amphipod was totally absent at 11.1 and 103 µg/L.

### 6. Bioaccumulation

No acceptable data on the bioaccumulation of carbaryl in freshwater or estuarine/marine waters are available; however, because of its low octanol/water partition coefficient (229), carbaryl is not expected to bioconcentrate to a significant extent (U.S. EPA 2010a). Reported $K_{ow}$ values range from 65 to 229 (Bracha and O'Brian 1966; Mount and Oehme 1981; Windholz et al. 1976).

The U.S. EPA Office of Water’s fish tissue sampling program does not include carbaryl as an analyte, as it is not expected to bioaccumulate or bioconcentrate. No U.S. Food and Drug Administration (FDA) action level or other maximum acceptable concentration in tissue, as defined in the “Guidelines” is available for carbaryl. Therefore, a Final Residue Value cannot be calculated for fish tissue.

## B. Effects on Aquatic Plants

In general, freshwater and estuarine/marine plants appear less sensitive than animals to carbaryl. The most sensitive aquatic plant tests are roughly two orders of magnitude less sensitive to carbaryl than the aquatic animal tests (**Appendix E**). For freshwater plants the effect concentrations ranged from 100 µg/L for the green alga, *Scenedesmus quadricaudata* (Lejczak 1977), to 50,000 µg/L for the blue green alga, *Anabaena torulosa* (Obulakondaiah et al. 1993). A planktonic alga mixture was adversely impacted at a concentration of 10,000 µg/L for two weeks (Butler et al. 1975), and growth of the green alga *Ankistrodesmus braunii* was reduced by a concentration of 25,000 µg/L in a 48-hr test (Kopecek et al. 1975). Other algae were adversely impacted by much lower concentrations. The green alga, *Chlorella pyrenoidosa*, had reduced growth after a four-day exposure to 100 µg/L (Christie 1969), and the blue-green alga, *Microcystis aeruginosa*, began to show adverse effects after eight days of exposure to 1,350 µg/L carbaryl (Bringmann and Kuhn 1978a; 1978b). The only freshwater vascular plant tested is duckweed (*Lemna minor*), which had a 50% inhibition of growth at 23,900 µg/L (Brooke 1993).

Estuarine/marine plant growth effect values varied widely ranging from 100 µg/L for green algae (*Chlorella sp*., *Dunaliella euchora* and *Protococcus sp*.), diatoms (*Phaeodactylum tricornutum*) and golden algae (*Monochrysis lutheri*) to 100,000 µg/L for the same species. The main difference between the values is that cells were viable at the lower concentrations (the effect of carbaryl was algistatic, i.e., the cells recovered after exposure was terminated), but not at the higher values where the effect was algicidal (i.e., the cells were killed as a result of the exposure) (Ukeles 1962).

## V. IMPLEMENTATION

As discussed in the Water Quality Standards Regulation (U.S. EPA 1983a) and the Foreword to this document, a water quality criterion for aquatic life has regulatory impact only when it has been adopted in a state/tribal water quality standard or EPA promulgated standard for a state or tribe. Such a regulatory standard would specify a criterion for a pollutant that would be protective of a particular designated use. With the approval of the U.S. EPA, states/tribes designate one or more uses for waters in their states/tribes and adopt criteria that are protective of those use(s) they have designated (U.S. EPA 1983a;b; 1987; 1994). States/tribes may adopt water quality criteria with the same numerical values as EPA's recommended section 304 criteria. However there are situations where states and authorized tribes might want to adjust water quality criteria developed under section 304 to reflect either statewide or site-specific natural environmental conditions and/or sensitivities of local species. Alternatively, states and tribes may use different data and assumptions than the EPA in deriving numeric criteria when those data have been reviewed and deemed to be scientifically defensible and the resulting criteria value is protective of designated uses. State/tribe water quality standards include both numeric and narrative criteria. A state/tribe may adopt a numeric criterion within its water quality standards and apply it either to all waters for the use the criterion is designed to protect or to a specific site. A state/tribe may use an indicator characteristic or the national criterion supplemented with other relevant information, to interpret its narrative criteria within its water quality standards to develop a numeric value for use in developing National Pollutant Discharge Elimination System (NPDES) effluent limitations under 40 CRF 122.44(d)(1)(vi).2 (http://cfr.vlex.com/vid/122-44-establishing-applicable-npdes-see-123-19811557).

Site-specific criteria may include not only site-specific criterion concentrations (U.S. EPA 1994), but also site-specific, and possibly pollutant-specific, durations of averaging periods and frequencies of allowed excursions (U.S. EPA 1991). The averaging periods of "one hour" and "four days" were selected by the U.S. EPA on the basis of data concerning how rapidly some aquatic species react to increases in the concentrations of some aquatic pollutants, and "three years" return frequency is the Agency's scientific judgment regarding the average amount of time aquatic ecosystems should be provided to recover between excursions (Stephan et al. 1985; U.S. EPA 1991). However, various species and ecosystems react and recover at greatly differing rates. Therefore, if adequate justification is provided, site-specific and/or pollutant-specific concentrations, durations, and frequencies may be higher or lower than those given in national recommended water quality criteria for aquatic life.

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# Appendix A

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| **Freshwater Species** | | | | | | |
| Oligochaete worm,<br>*Lumbriculus variegatus* | S, U | Analytical | 30 | 8,200 | 8,200 | Bailey and Liu 1980 |
| | | | | | | |
| Snail (adult),<br>*Aplexa hypnorum* | F, M | - | 44.4 | >27,000 | >27,000 | Phipps and Holcombe 1985 |
| | | | | | | |
| Mussel<br>(juvenile; 1-2 d),<br>*Anodonta imbecillis* | R, U | 99% | 40-50 | 23,700 | - | Johnson et al. 1993 |
| Mussel<br>(juvenile; 7-10 d),<br>*Anodonta imbecillis* | R, U | 99% | 40-50 | 25,600 | 24,632 | Johnson et al. 1993 |
| | | | | | | |
| Cladoceran (<24 hr),<br>*Ceriodaphnia dubia* | R, M | 98% | 169 | 3.06 | - | Brooke 1990; 1991 |
| Cladoceran (<12 hr),<br>*Ceriodaphnia dubia* | R, M | >99% | 57 | 11.6 | 5.958 | Oris et al. 1991 |
| | | | | | | |
| Cladoceran<br>(adult; 2-2.5 mm),<br>*Daphnia carinata* | S, U | Technical | - | 35 | 35 | Santharam et al. 1976 |
| | | | | | | |
| Cladoceran (5 d),<br>*Daphnia magna* | S, U | 97.6% | - | 7.2[b] | - | Lakota et al. 1981 |
| Cladoceran (<24 hr),<br>*Daphnia magna* | R, M | 99% | 40-50 | 1,900[b]<br>(LC, not EC value) | - | Johnson et al. 1993 |
| Cladoceran (<24 hr),<br>*Daphnia magna* | S, U | 99.5% | 40 | 5.6 | - | Sanders et al. 1983 |
| Cladoceran (<24 hr),<br>*Daphnia magna* | R, M | 98% | 181.8 | 10.1 | 7.521 | Brooke 1991 |
| | | | | | | |
| Cladoceran (<24 hr),<br>*Daphnia pulex* | S, U | - | 40-48 | 6.4 | 6.4 | Sanders and Cope 1966 |
| | | | | | | |
| Cladoceran (<24 hr),<br>*Simocephalus serrulatus* | S, U | 99.5% | 44 | 11<br>(10°C) | - | Mayer and Ellersieck 1986 |
| Cladoceran (<24 hr),<br>*Simocephalus serrulatus* | S, U | - | 44 | 7.6<br>(16°C) | - | Sanders and Cope 1966 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Cladoceran (<24 hr), *Simocephalus serrulatus* | S, U | 99.5% | 44 | 8.1<br>(21ºC) | 8.781 | Mayer and Ellersieck 1986 |
| | | | | | | |
| Mysid, *Mysis relicta* | R, M | 98% | 139.3 | 230 | 230 | Landrum and Dupuis 1990 |
| | | | | | | |
| Aquatic sowbug (mature), *Asellus brevicaudus* | S, U | 99.5% | 44 | 280 | 280 | Johnson and Finley 1980;<br>Mayer and Ellersieck 1986 |
| | | | | | | |
| Amphipod (2 mo), *Gammarus lacustris* | S, U | 100% | 30.5 | 16 | - | Sanders 1969 |
| Amphipod (mature), *Gammarus lacustris* | S, U | 99.5% | 44 | 22 | 18.76 | Johnson and Finley 1980;<br>Mayer and Ellersieck 1986 |
| | | | | | | |
| Amphipod, *Gammarus pseudolimnaeus* | S, U | 99% | 40 | 13<br>(pH=6.5) | - | Woodward and Mauck 1980 |
| Amphipod (mature), *Gammarus pseudolimnaeus* | S, U | 99% | 40 | 7<br>(pH=7.5) | - | Woodward and Mauck 1980 |
| Amphipod (mature), *Gammarus pseudolimnaeus* | S, U | 99% | 40 | 7.2<br>(pH=8.5) | - | Woodward and Mauck 1980 |
| Amphipod (mature), *Gammarus pseudolimnaeus* | S, U | 99.5% | 40 | 16 | 10.12 | Sanders et al. 1983 |
| | | | | | | |
| Amphipod (14 d), *Hyalella azteca* | S, U | Technical | 280 | 15.2 | 15.2 | McNulty et al. 1999 |
| | | | | | | |
| Amphipod, *Pontoporeia hoyi* | R, M | 98% | 139.3 | 250 | 250 | Landrum and Dupuis 1990 |
| | | | | | | |
| Crayfish (3-4 cm), *Cambarus bartoni* | R, U | 99.8% | - | 839.6 | 839.6 | Simon 1982 |
| | | | | | | |
| Crayfish (3.9 g), *Orconectes immunis* | F, M | - | 44.4 | 2,870 | 2,870 | Phipps and Holcombe 1985 |
| | | | | | | |
| Crayfish (5-8 cm; males), *Orconectes virilis* | R, U | 99.8% | - | 2,112 | 2,112 | Simon 1982 |
| | | | | | | |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Crayfish (15-38 g), *Procambarus clarkii* | S, U | - | 250 | 1,000 | 1,000 | Andreu-Moliner et al. 1986 |
| | | | | | | |
| Stonefly (nymph), *Claassenia sabulosa* | S, U | Technical | 44 | 5.6 | 5.6 | Sanders and Cope 1968 |
| | | | | | | |
| Stonefly (1st yr class), *Isogenus sp.* | S, U | 99.5% | 35 | 2.8 | - | Mayer and Ellersieck 1986 |
| Stonefly (1st yr class), *Isogenus sp.* | S, U | 99.5% | 42 | 3.6 | 3.175 | Mayer and Ellersieck 1986 |
| | | | | | | |
| Stonefly (1st yr class; 15-20 mm), *Pteronarcella badia* | S, U | Technical | 44 | 1.7 | - | Sanders and Cope 1968 |
| Stonefly (1st yr class), *Pteronarcella badia* | S, U | 99% | 38 | 11 (pH=6.5) | - | Woodward and Mauck 1980; Mayer and Ellersieck 1986 |
| Stonefly (1st yr class), *Pteronarcella badia* | S, U | 99% | 38 | 13 (pH=7.5) | - | Woodward and Mauck 1980; Mayer and Ellersieck 1986 |
| Stonefly (1st yr class), *Pteronarcella badia* | S, U | 99% | 38 | 29 (pH=8.5) | 9.163 | Woodward and Mauck 1980; Mayer and Ellersieck 1986 |
| | | | | | | |
| Stonefly (1st yr class), *Pteronarcys californica* | S, U | Technical | 44 | 4.8 | 4.8 | Sanders and Cope 1968 |
| | | | | | | |
| Stonefly (naiad), *Skwala sp.* | S, U | 99.5% | - | 3.6 | 3.6 | Johnson and Finley 1980 |
| | | | | | | |
| Backswimmer (adult), *Notonecta undulata* | S, U | 94% | - | 200 | 200 | Federle and Collins 1976 |
| | | | | | | |
| Apache trout (0.38-0.85 g), *Oncorhynchus apache* | S, U | 99.7% | 169 | 1,540 | 1,540 | Dwyer et al. 1995 |
| | | | | | | |
| Coho salmon (2.7-4.1 g), *Oncorhynchus kisutch* | S, U | 95% | - | 997 | - | Katz 1961 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Coho salmon, *Oncorhynchus kisutch* | S, U | 99% | 40-48 | 764 | - | Macek and McAllister 1970 |
| Coho salmon (1.50 g), *Oncorhynchus kisutch* | S, U | 98% | 318-348 | 1,300 | - | Post and Schroeder 1971 |
| Coho salmon (1.0 g), *Oncorhynchus kisutch* | S, U | 99.5% | 44 | 4,340 | - | Johnson and Finley 1980; Mayer and Ellersieck 1986 |
| Coho salmon (4.6 g), *Oncorhynchus kisutch* | S, U | 99.5% | 42 | 2,400 | - | Mayer and Ellersieck 1986 |
| Coho salmon (5.1g), *Oncorhynchus kisutch* | S, U | 99.5% | 42 | 1,750 | - | Mayer and Ellersieck 1986 |
| Coho salmon (10.10 g), *Oncorhynchus kisutch* | S, U | 99.5% | 42 | 2,700 | - | Mayer and Ellersieck 1986 |
| Coho salmon (19.1 g), *Oncorhynchus kisutch* | S, U | 99.5% | 42 | 1,150 | 1,654 | Mayer and Ellersieck 1986 |
| | | | | | | |
| Chinook salmon (fingerling), *Oncorhynchus tshawytscha* | F, U | 99.5% | 314 | 2,400[c] | - | Johnson and Finley 1980; Mayer and Ellersieck 1986 |
| Chinook salmon (3.0 g), *Oncorhynchus tshawytscha* | F, M | - | 44.4 | 2,690 | 2,690 | Phipps and Holcombe 1985; 1990 |
| | | | | | | |
| Cutthroat trout (0.37 g), *Oncorhynchus clarkii* | S, U | 98% | 318-348 | 1,500 | - | Post and Schroeder 1971 |
| Cutthroat trout (1.30 g), *Oncorhynchus clarkii* | S, U | 98% | 318-348 | 2,169 | - | Post and Schroeder 1971 |
| Cutthroat trout (0.5 g), *Oncorhynchus clarkii* | S, U | 99.5% | 40 | 7,100 | - | Johnson and Finley 1980; Mayer and Ellersieck 1986 |
| Cutthroat trout (0.6 g), *Oncorhynchus clarkii* | S, U | 99% | 40 | 6,000 (pH=7.5) (7ºC) | - | Woodward and Mauck 1980; Mayer and Ellersieck 1986 |
| Cutthroat trout (0.7 g), *Oncorhynchus clarkii* | S, U | 99% | 40 | 5,000 (pH=6.5) (12ºC) | - | Woodward and Mauck 1980; Mayer and Ellersieck 1986 |
| Cutthroat trout (0.6 g), *Oncorhynchus clarkii* | S, U | 99% | 40 | 970 (pH=8.5) (12ºC) | - | Woodward and Mauck 1980; Mayer and Ellersieck 1986 |
| Cutthroat trout (0.5 g), *Oncorhynchus clarkii* | S, U | 99% | 320 | 3,950 (pH=7.8) (12ºC) | - | Woodward and Mauck 1980; Mayer and Ellersieck 1986 |
| Cutthroat trout (0.5 g), *Oncorhynchus clarkii* | S, U | 99.5% | 40 | 6,800 (pH=7.3) | - | Mayer and Ellersieck 1986 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Cutthroat trout (0.9 g),<br>*Oncorhynchus clarkii* | S, U | 99.5% | 42 | 6,700<br>(pH=7.5) | - | Mayer and Ellersieck 1986 |
| Cutthroat trout,<br>*Oncorhynchus clarkii* | S, U | 99% | 40 | 3,950<br>(pH=7.5)<br>(12ºC) | - | Woodward and Mauck 1980 |
| Greenback cutthroat trout (0.31 g),<br>*Oncorhynchus clarkii stomias* | S, U | 99.7% | 169 | 1,550 | - | Dwyer et al. 1995 |
| Lahontan cutthroat trout (0.34-0.57 g),<br>*Oncorhynchus clarkii henshawi* | S, U | 99.7% | 169 | 2,250 | 3,300 | Dwyer et al. 1995 |
| | | | | | | |
| Rainbow trout (3.2 g),<br>*Oncorhynchus mykiss* | S, U | 95% | - | 1,350 | - | Katz 1961 |
| Rainbow trout,<br>*Oncorhynchus mykiss* | S, U | 99% | 40-48 | 4,340 | - | Macek and McAllister 1970 |
| Rainbow trout (1.24 g),<br>*Oncorhynchus mykiss* | S, U | 98% | 318-348 | 1,470 | - | Post and Schroeder 1971 |
| Rainbow trout (1.5 g),<br>*Oncorhynchus mykiss* | S, U | 99.5% | 42 | 1,950 | - | Johnson and Finley 1980;<br>Mayer and Ellersieck 1986; |
| Rainbow trout,<br>*Oncorhynchus mykiss* | S, U | 99.5% | 40 | 2,200<br>(12ºC) | - | Sanders et al. 1983 |
| Rainbow trout,<br>*Oncorhynchus mykiss* | S, U | 99.5% | 40 | 2,800<br>(7ºC) | - | Sanders et al. 1983 |
| Rainbow trout,<br>*Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,100<br>(pH=6.5) | - | Sanders et al. 1983 |
| Rainbow trout,<br>*Oncorhynchus mykiss* | S, U | 99.5% | 40 | 800<br>(pH=7.5) | - | Sanders et al. 1983 |
| Rainbow trout,<br>*Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,500<br>(pH=8.5) | - | Sanders et al. 1983 |
| Rainbow trout,<br>*Oncorhynchus mykiss* | S, U | 99.5% | 40 | 900 | - | Sanders et al. 1983 |
| Rainbow trout,<br>*Oncorhynchus mykiss* | S, U | 99.5% | 320 | 800 | - | Sanders et al. 1983 |
| Rainbow trout (1.0 g),<br>*Oncorhynchus mykiss* | S, U | - | - | 935 | - | Marking et al. 1984 |
| Rainbow trout (1.0 g),<br>*Oncorhynchus mykiss* | S, U | - | - | 1,000 | - | Marking et al. 1984 |
| Rainbow trout (1.0 g),<br>*Oncorhynchus mykiss* | S, U | - | - | 1,400 | - | Marking et al. 1984 |
| Rainbow trout (1.0 g),<br>*Oncorhynchus mykiss* | S, U | - | - | 1,000 | - | Marking et al. 1984 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Rainbow trout (1.0 g), *Oncorhynchus mykiss* | S, U | - | - | 1,740 | - | Marking et al. 1984 |
| Rainbow trout (juvenile), *Oncorhynchus mykiss* | R, U | 99% | - | 4,835 | - | Douglas et al. 1986 |
| Rainbow trout (1.5 g), *Oncorhynchus mykiss* | S, U | 99.5% | 272 | 1,200 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (0.8 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,360 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (0.8 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 2,080 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.1 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,900 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.1 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 2,300 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (0.5 g), *Oncorhynchus mykiss* | S, U | 99.5% | 314 | 1,330 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (0.8 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | <750 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.1 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | <320 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.2 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,090 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.1 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,460 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.2 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 3,500 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.2 g), *Oncorhynchus mykiss* | S, U | 99.5% | 320 | 3,000 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.0 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,600 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.0 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,100 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.0 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,200 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.0 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 780 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (1.0 g), *Oncorhynchus mykiss* | S, U | 99.5% | 40 | 1,450 | - | Mayer and Ellersieck 1986 |
| Rainbow trout (0.48-1.25 g), *Oncorhynchus mykiss* | S, U | 99.7% | 169 | 1,880 | - | Dwyer et al. 1995 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Rainbow trout (juvenile; 2.7 g), *Oncorhynchus mykiss* | S, M | 99% | - | 5,400[c] | - | Ferrari et al. 2004 |
| Rainbow trout (19.7 g), *Oncorhynchus mykiss* | F, M | Technical | 44.4 | 860 | 860 | Phipps and Holcombe 1985 |
| | | | | | | |
| Atlantic salmon (0.4 g), *Salmo salar* | S, U | 99.5% | 42 | 4,500 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.8 g), *Salmo salar* | S, U | 99.5% | 42 | 2,070 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.8 g), *Salmo salar* | S, U | 99.5% | 42 | 1,180 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.4 g), *Salmo salar* | S, U | 99.5% | 42 | 905 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.8 g), *Salmo salar* | S, U | 99.5% | 12 | 2,010 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.8 g), *Salmo salar* | S, U | 99.5% | 42 | 1,430 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.2 g), *Salmo salar* | S, U | 99.5% | 42 | 500 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.2 g), *Salmo salar* | S, U | 99.5% | 42 | 1,000 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.2 g), *Salmo salar* | S, U | 99.5% | 42 | 1,150 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.2 g), *Salmo salar* | S, U | 99.5% | 42 | 1,100 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.2 g), *Salmo salar* | S, U | 99.5% | 42 | 1,350 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.2 g), *Salmo salar* | S, U | 99.5% | 42 | 220 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.2 g), *Salmo salar* | S, U | 99.5% | 42 | 900 | - | Mayer and Ellersieck 1986 |
| Atlantic salmon (0.2 g), *Salmo salar* | S, U | 99.5% | 42 | 1,000 | 1,129 | Mayer and Ellersieck 1986 |
| | | | | | | |
| Brown trout, *Salmo trutta* | S, U | 99% | 40-48 | 1,950[b] | - | Macek and McAllister 1970 |
| Brown trout (0.6 g), *Salmo trutta* | S, U | 99.5% | 42 | 6,300[b] | - | Johnson and Finley 1980;<br>Mayer and Ellersieck 1986 |
| Brown trout (fingerling), *Salmo trutta* | F, U | 99.5% | 314 | 2,000[b] | - | Mayer and Ellersieck 1986 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Brown trout (fry),<br>*Salmo trutta* | S, U | 97.6% | - | 700 | 700 | Lakota et al. 1981 |
| | | | | | | |
| Brook trout (1.15 g),<br>*Salvelinus fontinalis* | S, U | 98% | 318-348 | 1,070 | - | Post and Schroeder 1971 |
| Brook trout (2.04 g),<br>*Salvelinus fontinalis* | S, U | 98% | 318-348 | 1,450 | - | Post and Schroeder 1971 |
| Brook trout (1.0 g),<br>*Salvelinus fontinalis* | S, U | 99.5% | 42 | 680 | - | Mayer and Ellersieck 1986 |
| Brook trout (0.7 g),<br>*Salvelinus fontinalis* | S, U | 99.5% | 42 | 4,560 | - | Mayer and Ellersieck 1986 |
| Brook trout (0.7 g),<br>*Salvelinus fontinalis* | S, U | 99.5% | 42 | 2,130 | - | Mayer and Ellersieck 1986 |
| Brook trout (0.7 g),<br>*Salvelinus fontinalis* | S, U | 99.5% | 42 | 1,130 | - | Mayer and Ellersieck 1986 |
| Brook trout (0.8 g),<br>*Salvelinus fontinalis* | S, U | 99.5% | 42 | 1,200 | - | Mayer and Ellersieck 1986 |
| Brook trout (0.8 g),<br>*Salvelinus fontinalis* | S, U | 99.5% | 300 | 1,290 | - | Mayer and Ellersieck 1986 |
| Brook trout (1.3 g),<br>*Salvelinus fontinalis* | S, U | 99.5% | 42 | 4,500 | 1,629 | Mayer and Ellersieck 1986 |
| | | | | | | |
| Lake trout (1.7 g),<br>*Salvelinus namaycush* | S, U | 99.5% | 40 | 690 | - | Johnson and Finley 1980;<br>Mayer and Ellersieck 1986 |
| Lake trout (1.7 g),<br>*Salvelinus namaycush* | S, U | 99.5% | 40 | 740 | - | Mayer and Ellersieck 1986 |
| Lake trout (1.7 g),<br>*Salvelinus namaycush* | S, U | 99.5% | 40 | 920 | - | Mayer and Ellersieck 1986 |
| Lake trout (0.5 g),<br>*Salvelinus namaycush* | S, U | 99.5% | 162 | 872 | - | Mayer and Ellersieck 1986 |
| Lake trout (2.6 g),<br>*Salvelinus namaycush* | F, U | 99.5% | 260 | 2,300 | 988.1 | Mayer and Ellersieck 1986 |
| | | | | | | |
| Goldfish (0.9 g),<br>*Carassius auratus* | S, U | 99% | 40-48 | 13,200[c] | - | Macek and McAllister 1970 |
| Goldfish (0.9 g),<br>*Carassius auratus* | S, U | 99.5% | 272 | 12,800[c] | - | Mayer and Ellersieck 1986 |
| Goldfish<br>(juvenile; 1.3-3.3 g),<br>*Carassius auratus* | S, U | 99.7% | - | 17,500[c] | - | Pfeiffer et al. 1997 |
| Goldfish (14.2 g),<br>*Carassius auratus* | F, M | - | 44.4 | 16,700 | 16,700 | Phipps and Holcombe 1985 |
| | | | | | | |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Common carp (0.6 g), *Cyprinus carpio* | S, U | 99% | 40-48 | 5,280 | - | Macek and McAllister 1970 |
| Common carp (0.38 g), *Cyprinus carpio* | S, U | 94% | 22 | 1,700 | - | Chin and Sudderuddin 1979 |
| Common carp (fry), *Cyprinus carpio* | S, U | 97.6% | - | 4,220 | - | Lakota et al. 1981 |
| Common carp (20-34 mm), *Cyprinus carpio* | S, U | 85% | - | 7,850 | 4,153 | de Mel and Pathiratne 2005 |
| | | | | | | |
| European chub (12.43 cm; 18.14 g) *Leuciscus cephalus* | S,U | 85% | 61-65 | 8,656 | 8,656 | Verep 2006 |
| | | | | | | |
| Fathead minnow (0.5 g), *Pimephales promelas* | S, U | 99.5% | 42 | 14,000[c] | - | Mayer and Ellersieck 1986 |
| Fathead minnow (0.8 g), *Pimephales promelas* | S, U | 99% | 40-48 | 14,600[c] | - | Macek and McAllister 1970; Sanders et al. 1983 |
| Fathead minnow (0.8 g), *Pimephales promelas* | S, U | 99.5% | 272 | 7,700[c] | - | Mayer and Ellersieck 1986 |
| Fathead minnow (larvae), *Pimephales promelas* | R, U | 99% | 44-49 | >1,600[c] | - | Norberg-King 1989 |
| Fathead minnow (0.32-0.56 g), *Pimephales promelas* | S, U | 99.7% | 173 | 5,210[c] | - | Dwyer et al. 1995 |
| Fathead minnow (2 mo), *Pimephales promelas* | F, M | 80% | 41-49 | 9,000 | - | Carlson 1971 |
| Fathead minnow (0.3 g), *Pimephales promelas* | F, M | Technical | 44.4 | 5,010 | - | Phipps and Holcombe 1985 |
| Fathead minnow (31 d), *Pimephales promelas* | F, M | 99% | 43.8 | 9,470 | - | Geiger et al. 1985; 1988 |
| Fathead minnow (28 d), *Pimephales promelas* | F, M | 99% | 45.4 | 8,930 | - | Geiger et al. 1985; 1988 |
| Fathead minnow (28 d), *Pimephales promelas* | F, M | 99% | 44.1 | 10,400 | - | Geiger et al. 1985; 1988 |
| Fathead minnow (29 d), *Pimephales promelas* | F, M | 99% | 45.4 | 6,670 | 8,012 | Geiger et al. 1985; 1988 |
| | | | | | | |
| Bonytail chub (0.29-0.52 g), *Gila elegans* | S, U | 99.7% | 173 | 3,490 | - | Dwyer et al. 1995 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as CaCO$_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Bonytail chub (6 d),<br>*Gila elegans* | R, M | 99% | 212-216 | 2,020 | 2,655 | Beyers et al. 1994 |
| | | | | | | |
| Colorado pikeminnow (formerly squawfish) (0.32-0.34 g),<br>*Ptychochelius lucius* | S, U | 99.7% | 173 | 3,070 | - | Dwyer et al. 1995 |
| Colorado pikeminnow (26 d),<br>*Ptychochelius lucius* | R, M | 99% | 212-216 | 1,310 | 2,005 | Beyers et al. 1994 |
| | | | | | | |
| Razorback sucker (0.31-0.32 g),<br>*Xyrauchen texanus* | S, U | 99.7% | 173 | 4,350 | 4,350 | Dwyer et al. 1995 |
| | | | | | | |
| Black bullhead (1.2 g),<br>*Ameiurus melas* | S, U | 99% | 40-48 | 20,000 | 20,000 | Macek and McAllister 1970 |
| | | | | | | |
| Channel catfish (1.5 g),<br>*Ictalurus punctatus* | S, U | 99% | 40-48 | 15,800[c] | - | Macek and McAllister 1970 |
| Channel catfish (0.3 g),<br>*Ictalurus punctatus* | S, U | 100% | 10 | 1,300[c] | - | Brown et al. 1979 |
| Channel catfish (1.5 g),<br>*Ictalurus punctatus* | S, U | 99.5% | 272 | 7,790[c] | - | Mayer and Ellersieck 1986 |
| Channel catfish (fingerling),<br>*Ictalurus punctatus* | F, U | 99.5% | 314 | 17,300[c] | - | Mayer and Ellersieck 1986 |
| Channel catfish (27.6 g),<br>*Ictalurus punctatus* | F, M | - | 44.4 | 12,400 | 12,400 | Phipps and Holcombe 1985 |
| | | | | | | |
| Walking catfish (17-18 cm; 60-70 g),<br>*Clarias batrachus* | R, U | Technical | - | 46,850 | - | Tripathi and Shukla 1988 |
| Walking catfish (14 cm; 25 g),<br>*Clarias batrachus* | S, U | 99% | - | 16,270 | 27,609 | Lata et al. 2001 |
| | | | | | | |
| Guppy (2.0 cm),<br>*Poecilia reticulata* | R, M | 99% | - | 2,515 | 2,515 | Gallo et al. 1995 |
| | | | | | | |
| Gila topminnow (219 mg),<br>*Poeciliopsis occidentalis* | S, U | 99.7% | 167 | >3,000 | >3,000 | Dwyer et al. 1999b |
| | | | | | | |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Striped bass (56 d),<br>*Morone saxatilis* | S, U | - | 40 | 760 | - | Palawski et al. 1985 |
| Striped bass,<br>*Morone saxatilis* | S, U | - | 45.5 | 2,300 | 1,322 | Palawski et al. 1985 |
| | | | | | | |
| Green sunfish (1.1 g),<br>*Lepomis cyanellus* | S, U | 99.5% | 272 | 9,460 | 9,460 | Mayer and Ellersieck 1986 |
| | | | | | | |
| Redear sunfish (1.1 g),<br>*Lepomis microlophus* | S, U | 99% | 40-48 | 11,200 | 11,200 | Macek and McAllister 1970 |
| | | | | | | |
| Bluegill,<br>*Lepomis macrochirus* | S, U | 99.9% | - | 14,000[c] | - | McCann and Young 1969 |
| Bluegill (1.2 g),<br>*Lepomis macrochirus* | S, U | 99% | 40-48 | 6,760[c] | - | Macek and McAllister 1970 |
| Bluegill,<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 16,000[c]<br>(12ºC) | - | Sanders et al. 1983 |
| Bluegill,<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 8,200[c]<br>(22ºC) | - | Sanders et al. 1983 |
| Bluegill,<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 5,400[c]<br>(pH=6.5) | - | Sanders et al. 1983 |
| Bluegill,<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 5,200[c]<br>(pH=7.5) | - | Sanders et al. 1983 |
| Bluegill,<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 1,800[c]<br>(pH=8.5) | - | Sanders et al. 1983 |
| Bluegill,<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 2,200[c] | - | Sanders et al. 1983 |
| Bluegill,<br>*Lepomis macrochirus* | S, U | 99.5% | 320 | 1,000[c] | - | Sanders et al. 1983 |
| Bluegill (1.2 g),<br>*Lepomis macrochirus* | S, U | 99.5% | 272 | 5,230[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.6 g),<br>*Lepomis macrochirus* | F, U | 99.5% | 314 | 5,047[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.4 g),<br>*Lepomis macrochirus* | S, U | 99.5% | 44 | 7,400[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.4 g),<br>*Lepomis macrochirus* | S, U | 99.5% | 44 | 5,200[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.8 g),<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 16,000[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.8 g),<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 7,000[c] | - | Sanders et al. 1983; Mayer and Ellersieck 1986 |
| Bluegill (0.8 g),<br>*Lepomis macrochirus* | S, U | 99.5% | 40 | 8,200[c] | - | Mayer and Ellersieck 1986 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Bluegill (0.4 g), *Lepomis macrochirus* | S, U | 99.5% | 320 | 6,200[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.7 g), *Lepomis macrochirus* | S, U | 99.5% | 40 | 5,400[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.7 g), *Lepomis macrochirus* | S, U | 99.5% | 40 | 5,200[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.7 g), *Lepomis macrochirus* | S, U | 99.5% | 40 | 1,800[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.7 g), *Lepomis macrochirus* | S, U | 99.5% | 40 | 2,600[c] | - | Mayer and Ellersieck 1986 |
| Bluegill (0.5 g), *Lepomis macrochirus* | F, M | - | 44.4 | 6,970 | 6,970 | Phipps and Holcombe 1985 |
| | | | | | | |
| Largemouth bass (0.9 g), *Micropterus salmoides* | S, U | 99% | 40-48 | 6,400 | 6,400 | Macek and McAllister 1970 |
| | | | | | | |
| Black crappie (1.0 g), *Pomoxis nigromaculatus* | S, U | 99.5% | 40 | 2,600 | 2,600 | Johnson and Finley 1980;<br>Mayer and Ellersieck 1986; |
| | | | | | | |
| Greenthroat darter (133 mg), *Etheostoma lepidum* | S, U | 99.7% | 167 | 2,140 | 2,140 | Dwyer et al. 1999b |
| | | | | | | |
| Fountain darter (62 mg), *Etheostoma fonticola* | S, U | 99.7% | 167 | 2,020 | 2,020 | Dwyer et al. 2005 |
| | | | | | | |
| Yellow perch (1.4 g), *Perca flavescens* | S, U | 99% | 40-48 | 745 | - | Macek and McAllister 1970 |
| Yellow perch (0.6 g), *Perca flavescens* | S, U | 99.5% | 42 | 5,100 | - | Johnson and Finley 1980;<br>Mayer and Ellersieck 1986 |
| Yellow perch (1.0 g), *Perca flavescens* | S, U | 99.5% | 42 | 13,900 | - | Mayer and Ellersieck 1986 |
| Yellow perch (1.0 g), *Perca flavescens* | S, U | 99.5% | 42 | 5,400 | - | Mayer and Ellersieck 1986 |
| Yellow perch (1.0 g), *Perca flavescens* | S, U | 99.5% | 42 | 3,400 | - | Mayer and Ellersieck 1986 |
| Yellow perch (1.0 g), *Perca flavescens* | S, U | 99.5% | 42 | 1,200 | - | Mayer and Ellersieck 1986 |
| Yellow perch (0.9 g), *Perca flavescens* | S, U | 99.5% | 42 | 4,000 | - | Mayer and Ellersieck 1986 |

## Appendix A. Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as CaCO$_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| Yellow perch (0.9 g), *Perca flavescens* | S, U | 99.5% | 42 | 4,200 | - | Mayer and Ellersieck 1986 |
| Yellow perch (0.9 g), *Perca flavescens* | S, U | 99.5% | 42 | 480 | - | Mayer and Ellersieck 1986 |
| Yellow perch (0.9 g), *Perca flavescens* | S, U | 99.5% | 42 | 350 | - | Mayer and Ellersieck 1986 |
| Yellow perch (1.0 g), *Perca flavescens* | S, U | 99.5% | 42 | 3,800 | - | Mayer and Ellersieck 1986 |
| Yellow perch (1.0 g), *Perca flavescens* | S, U | 99.5% | 170 | 5,000 | - | Mayer and Ellersieck 1986 |
| Yellow perch (1.0 g), *Perca flavescens* | S, U | 99.5% | 300 | 3,750 | - | Mayer and Ellersieck 1986 |
| Yellow perch (fingerling), *Perca flavescens* | F, U | 99.5% | 314 | 1,420 | 2,480 | Mayer and Ellersieck 1986 |
| | | | | | | |
| Shortnosed sturgeon, *Acipenser brevirostrum* | S, U | 99.7% | 170 | 1,810 | 1,810 | Dwyer et al. 2000 |
| | | | | | | |
| Nile tilapia (45-55 mm; 3.17 g), *Oreochromis niloticus* | S, U | 85% | - | 2,930 | 2,930 | dela Cruz and Cagauan 1981 |
| | | | | | | |
| Green frog (Gosner stage 25 tadpole), *Rana clamitans* | S, U | 99.7% | 286 | 22,020 (17°C) | - | Boone and Bridges 1999 |
| Green frog (Gosner stage 25 tadpole), *Rana clamitans* | S, U | 99.7% | 286 | 17,360 (22°C) | - | Boone and Bridges 1999 |
| Green frog (Gosner stage 25 tadpole), *Rana clamitans* | S, U | 99.7% | 286 | 11,320 (27°C) | 16,296 | Boone and Bridges 1999 |
| | | | | | | |
| Boreal toad (200 mg), *Bufo boreas* | S, U | 99.7% | 286 | 12,310 | 12,310 | Dwyer et al. 1999b |
| | | | | | | |
| Gray tree frog (tadpole), *Hyla versicolor* | S, U | 99.7% | - | 2,470 | 2,470 | Zaga et al. 1998 |
| | | | | | | |
| African clawed frog (embryo), *Xenopus laevis* | S, U | 99.7% | - | 15,250[b] | - | Zaga et al. 1998 |

## Appendix A.  Acceptable Acute Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Method[a] | Chemical | Hardness (mg/L as $CaCO_3$) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | Reference |
|---|---|---|---|---|---|---|
| African clawed frog (tadpole),<br>*Xenopus laevis* | S, U | 99.7% | - | 1,730 | 1,730 | Zaga et al. 1998 |

[a] S = static; R = renewal; F = flow-through; M = measured; U = unmeasured.

[b] Data not used to calculate SMAV because a more sensitive life stage or endpoint, or definitive value available for the species.

[c] Data not used to calculate SMAV because a more sensitive test exposure available for the species.

Dash indicates not available

# Appendix B

## Appendix B. Acceptable Acute Toxicity Data of Carbaryl to Estuarine/Marine Aquatic Animals

| Species | Method[a] | Chemical | Salinity (g/kg) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | References |
|---|---|---|---|---|---|---|
| **Estuarine/marine Species** | | | | | | |
| Bay mussel (adult), *Mytilus edulis* | S, M | 99.7% | 25 | 22,700[b] | - | Liu and Lee 1975 |
| Bay mussel (embryo/larva), *Mytilus edulis* | S, M | 99.7% | 25.9 | 1,480 (22°C) | - | Liu and Lee 1975 |
| Bay mussel (embryo/larva), *Mytilus edulis* | S, M | 99.7% | 25.9 | 1,800 (22°C) | - | Liu and Lee 1975 |
| Bay mussel (embryo/larva), *Mytilus edulis* | S, M | 99.7% | 25.9 | 1,210 (22°C) | - | Liu and Lee 1975 |
| Bay mussel (larva), *Mytilus edulis* | S, U | 80% | 25 | 2,300 | 1,650 | Stewart et al. 1967 |
| | | | | | | |
| Pacific oyster (larva), *Crassostrea gigas* | S, U | 80% | 25 | 2,200 | 2,200 | Stewart et al. 1967 |
| | | | | | | |
| Eastern oyster (embryo/larva), *Crassostrea virginica* | S, U | - | - | 3,000 (24°C) | - | Davis and Hidu 1969 |
| Eastern oyster (juvenile), *Crassostrea virginica* | F, U | 99.7% | 27 | >2,000 (29°C) | - | Hansen 1980; Mayer 1987 |
| Eastern oyster (juvenile), *Crassostrea virginica* | F, U | 99.7% | 17 | >2,000 (20°C) | | Hansen 1980 |
| Eastern oyster (embryo), *Crassostrea virginica* | S, M | 99% | - | 2,700 | 2,386 | Surprenant et al. 1985 |
| | | | | | | |
| Cockle clam (2-5 mm), *Clinocardium nuttalli* | R, U | 80% | 25 | 3,850 | 3,850 | Butler et al. 1968 |
| | | | | | | |
| Bent-nosed clam (2.5 g), *Macoma nasuta* | R, U | 80% | 25 | 17,000 | 17,000 | Armstrong and Millemann 1974b |
| | | | | | | |
| Hard clam (embryo/larva), *Mercenaria mercenaria* | S, U | - | - | 3,820 (24°C) | 3,820 | Davis and Hidu 1969 |
| | | | | | | |
| Mysid (24 hr) *Americamysis bahia* | R, U | 99% | 30 | 19[c] | - | Thursby and Champlin 1991a |
| Mysid (juvenile), *Americamysis bahia* | F, M | - | - | >7.7 | - | Nimmo et al. 1981 |

## Appendix B. Acceptable Acute Toxicity Data of Carbaryl to Estuarine/Marine Aquatic Animals

| Species | Method[a] | Chemical | Salinity (g/kg) | LC50 or EC50 (µg/L) | Species Mean Acute Value (µg/L) | References |
|---|---|---|---|---|---|---|
| Mysid (24 hr)<br>*Americamysis bahia* | F, M | 99% | 31 | 8.46<br>(pH=7.85) | - | Thursby and Champlin 1991b |
| Mysid (<24 hr)<br>*Americamysis bahia* | F, M | 99.7% | 20 | 5.7 | 7.188 | Lintott 1992a |
| | | | | | | |
| Mud shrimp (larva; 3 mm), *Upogebia pugettensis* | S, U | 80% | 25 | 90<br>(16ºC) | - | Stewart et al. 1967 |
| Mud shrimp (larva; 3 mm), *Upogebia pugettensis* | S, U | 80% | 25 | 40<br>(20ºC) | 60.0 | Stewart et al. 1967 |
| | | | | | | |
| Ghost shrimp (larva; 3 mm), *Callianassa californiensis* | S, U | 80% | 25 | 80<br>(17ºC) | - | Stewart et al. 1967 |
| Ghost shrimp (larva; 3 mm), *Callianassa californiensis* | S, U | 80% | 25 | 30<br>(20ºC) | 48.99 | Stewart et al. 1967 |
| | | | | | | |
| Dungeness crab (9th stage), *Metacarcinus magister* (formerly *Cancer magister*) | R, U | 80% | 25 | 300[b]<br>(10ºC) | - | Buchanan et al. 1970 |
| Dungeness crab (9th stage), *Metacarcinus magister* (formerly *Cancer magister*) | R, U | 80% | 25 | 280[b]<br>(10ºC) | - | Buchanan et al. 1970 |
| Dungeness crab (adult), *Metacarcinus magister* (formerly *Cancer magister*) | R, U | 80% | 25 | 180[b]<br>(18ºC) | - | Buchanan et al. 1970 |
| Dungeness crab (adult), *Metacarcinus magister* (formerly *Cancer magister*) | R, U | 80% | 25 | 260[b]<br>(11ºC) | - | Buchanan et al. 1970 |
| Dungeness crab (zoea), *Metacarcinus magister* (formerly *Cancer magister*) | S, U | 80% | 25 | 10<br>(10ºC) | 10 | Buchanan et al. 1970 |
| | | | | | | |
| Sheepshead minnow (10.27 g; 24 mm), *Cyprinodon variegatus* | S, U | 99% | 32 | 2,200[c] | - | Surprenant 1985a |

## Appendix B. Acceptable Acute Toxicity Data of Carbaryl to Estuarine/Marine Aquatic Animals

| **Species** | **Method[a]** | **Chemical** | **Salinity (g/kg)** | **LC50 or EC50 (µg/L)** | **Species Mean Acute Value (µg/L)** | **References** |
|---|---|---|---|---|---|---|
| Sheepshead minnow (juvenile; 0.9 g; 29 mm), *Cyprinodon variegatus* | F, M | 99.7% | 20 | 2,600 | 2,600 | Lintott 1992b |
| | | | | | | |
| Threespine stickleback (0.38-0.77 g; adult), *Gasterosteus aculeatus* | S, U | 95% | 5 | 3,990 | - | Katz 1961 |
| Threespine stickleback (0.38-0.77 g; adult), *Gasterosteus aculeatus* | S, U | 95% | 25 | 3,990 | 3,990 | Katz 1961 |

[a] S = static; R = renewal; F = flow-through; M = measured; U = unmeasured.

[b] Data not used to calculate SMAV because a more sensitive life stage or endpoint, or definite value available for the species.

[c] Data not used to calculate SMAV because a more sensitive test exposure available for the species.

Dash indicates not available

# Appendix C

## Appendix C. Acceptable Chronic Toxicity Data of Carbaryl to Freshwater Aquatic Animals

| Species | Test[a] | Chemical | Hardness (mg/L as $CaCO_3$) | Chronic Limits[b] (µg/L) | Chronic Value[c] (µg/L) | Species Mean Chronic Value (µg/L) | Reference |
|---|---|---|---|---|---|---|---|
| **Freshwater Species** | | | | | | | |
| Cladoceran (<12 hr),<br>*Ceriodaphnia dubia* | LC | >99% | 57 | - | 10.6 | 10.6 | Oris et al. 1991 |
| | | | | | | | |
| Cladoceran (≤24 hr),<br>*Daphnia magna* | LC | 99% | 140-170 | 1.5-3.3 | 2.225 | - | Surprenant 1985b |
| Cladoceran,<br>*Daphnia magna* | LC | 98% | 201.5 | 4.04-10.1[d] | 6.389 | 3.770 | Brooke 1991 |
| | | | | | | | |
| Fathead minnow,<br>*Pimephales promelas* | LC | 80% | 41-49 | 210-680 | 377.9 | - | Carlson 1971 |
| Fathead minnow,<br>*Pimephales promelas* | ELS | 99% | 44-49 | 720-1,600 | 1,073 | 636.8 | Norberg-King 1989 |
| | | | | | | | |
| Bonytail chub (48 d),<br>*Gila elegans* | ELS | 99% | 344-378 | 650-1,240 | 897.8 | 897.8 | Beyers et al. 1994 |
| | | | | | | | |
| Colorado pikeminnow (formerly squawfish) (41 d),<br>*Ptychochelius lucius* | ELS | 99% | 344-378 | 445-866 | 620.8 | 620.8 | Beyers et al. 1994 |

[a] LC = life-cycle or partial life-cycle; ELS = early life-stage.
[b] NOEC is listed first, then the LOEC.
[c] Chronic value = calculated geometric mean of NOEC and LOEC
[d] LOEC is based on the EC50 value obtained in a parallel acute test conducted in the same study (Brooke 1991). Chronic value should be considered an upper bound value for the species from this study.
Dash indicates not available

# Appendix D

## Appendix D. Chronic Toxicity Data of Carbaryl to Estuarine/Marine Aquatic Animals used Qualitatively in the Assessment

| Species | Test[a] | Chemical | Salinity (g/kg) | Chronic Limits[b] (µg/L) | Chronic Value[c] (µg/L) | Species Mean Chronic Value (µg/L) | Reference |
|---|---|---|---|---|---|---|---|
| **Estuarine/marine Species** | | | | | | | |
| Mysid (24 hr),<br>*Americamysis bahia* | LC | 99% | 31.5 | 7.18-13.7 | 9.918 | 9.918 | Thursby and Champlin 1991b |

[a] LC = life-cycle or partial life-cycle; ELS = early life-stage.
[b] NOEC is listed first, then the LOEC.
[c] Chronic value = calculated geometric mean of NOEC and LOEC

# Appendix E

## Appendix E. Acceptable Toxicity Data of Carbaryl to Freshwater Aquatic Plants

| Species | Chemical | Method[a] | Hardness (mg/L as $CaCO_3$) | Duration (days) | Effect | Concentration (µg/L) | Reference |
|---|---|---|---|---|---|---|---|
| **Freshwater Species** | | | | | | | |
| Blue green alga, *Nostoc muscorum* | 99.9% | S,U | - | 4 | Chronic Value (growth) | 7,071 | Bhunia et al. 1994 |
| Blue green alga, *Anabaena torulosa* | 99.9% | S,U | - | 21 | LOEC (growth) | 50,000 | Obulakondaiah et al. 1993 |
| Green alga, *Pseudokirchneriella subcapitata* | Analytical | S,U | - | 4 | EC20 (growth, cell #) | 1,040 | Versteeg 1990 |
| Green alga, *Pseudokirchneriella subcapitata* | 99.7% | S, M | - | 5 | Chronic Value (cell number) | 537.2 | Lintott 1992c |
| Green alga, *Pseudokirchneriella subcapitata* | 98% | - | 81.9 | 4 | IC50[b] | 490 | Brooke 1993 |
| Green alga, *Scenedesmus quadricauda* | 97% | S,U | - | 10 | LOEC (chlorophyll content) | 100 | Lejczak 1977 |
| Green alga, *Scenedesmus quadricauda* | 97% | - | - | 10 | Reduced chlorophyll content | 100 | Lejczak 1977 |
| Diatom, *Navicula pelliculosa* | 99.7% | S, M | - | 5 | LOEC (cell number) | 400 | Lintott 1992d |
| Duckweed, *Lemna minor* | 98% | - | 171 | 4 | IC50[b] | 23,900 | Brooke 1993 |

[a] S = static; R = renewal; F = flow-through; M = measured; U = unmeasured.
[b] IC50 = concentration of carbaryl at which growth is inhibited 50% compared to control organism growth.
Dash indicates not available

# Appendix F

## Appendix F. Acceptable Toxicity Data of Carbaryl to Estuarine/Marine Aquatic Plants

| Species | Chemical | Method[a] | Salinity (g/kg) | Duration (days) | Effect | Concentration (µg/L) | Reference |
|---|---|---|---|---|---|---|---|
| **Estuarine/marine Species** | | | | | | | |
| Green alga, *Chlorococcum sp.* | - | S, U | - | 4 | EC50 (growth) | 2,100 | Walsh and Alexander 1980 |
| Green alga, *Chlorococcum sp.* | - | S, U | - | 4 | EC50 (growth) | 1,800 | Walsh and Alexander 1980 |
| Green alga, *Chlorococcum sp.* | - | S, U | - | 12 | EC50 (growth) | 2,700 | Walsh and Alexander 1980 |
| Green alga, *Chlorococcum sp.* | - | S, U | - | 12 | EC50 (growth) | 2,900 | Walsh and Alexander 1980 |
| Green alga, *Chlorella sp.* | - | S, U | - | 4 | EC50 (growth) | 1,000 | Walsh and Alexander 1980 |
| Green alga, *Chlorella sp.* | - | S, U | - | 4 | EC50 (growth) | 600 | Walsh and Alexander 1980 |
| Green alga, *Chlorella sp.* | - | S, U | - | 12 | EC50 (growth) | 1,200 | Walsh and Alexander 1980 |
| Green alga, *Chlorella sp.* | - | S, U | - | 12 | EC50 (growth) | 1,400 | Walsh and Alexander 1980 |
| Green alga, *Chlorella sp.* | 95% | S, U | - | 10 | 10% reduced growth rate | 100 | Ukeles 1962 |
| Green alga, *Chlorella sp.* | 95% | S, U | - | 10 | 20% reduced growth rate | 1,000 | Ukeles 1962 |
| Green alga, *Chlorella sp.* | 95% | S, U | - | 10 | 100% reduced growth rate, cells not viable | 10,000 | Ukeles 1962 |
| Green alga, *Chlorella sp.* | 95% | S, U | - | 10 | 100% reduced growth rate, cells not viable | 100,000 | Ukeles 1962 |
| Green alga, *Dunaliella euchora* | 95% | S, U | - | 10 | 10% reduced growth rate | 100 | Ukeles 1962 |
| Green alga, *Dunaliella euchora* | 95% | S, U | - | 10 | 35% reduced growth rate | 1,000 | Ukeles 1962 |
| Green alga, *Dunaliella euchora* | 95% | S, U | - | 10 | 100% reduced growth rate, cell viable | 10,000 | Ukeles 1962 |
| Green alga, *Dunaliella euchora* | 95% | S, U | - | 10 | 100% reduced growth rate, cells not viable | 100,000 | Ukeles 1962 |
| Green alga, *Protococcus sp.* | 95% | S, U | - | 10 | 20% reduced growth rate | 100 | Ukeles 1962 |
| Green alga, *Protococcus sp.* | 95% | S, U | - | 10 | 26% reduced growth rate | 1,000 | Ukeles 1962 |
| Green alga, *Protococcus sp.* | 95% | S, U | - | 10 | 100% reduced growth rate, cell viable | 10,000 | Ukeles 1962 |
| Green alga, *Protococcus sp.* | 95% | S, U | - | 10 | 100% reduced growth rate, cells not viable | 100,000 | Ukeles 1962 |

## Appendix F. Acceptable Toxicity Data of Carbaryl to Estuarine/Marine Aquatic Plants

| Species | Chemical | Method[a] | Salinity (g/kg) | Duration (days) | Effect | Concentration (µg/L) | Reference |
|---|---|---|---|---|---|---|---|
| Diatom, *Skeletonema costatum* | - | S, U | - | 4 | EC50 (growth) | 1,700 | Walsh and Alexander 1980 |
| Diatom, *Skeletonema costatum* | - | S, U | - | 4 | EC50 (growth) | 900 | Walsh and Alexander 1980 |
| Diatom, *Skeletonema costatum* | - | S, U | - | 12 | EC50 (growth) | 1,800 | Walsh and Alexander 1980 |
| Diatom, *Skeletonema costatum* | - | S, U | - | 12 | EC50 (growth) | 1,600 | Walsh and Alexander 1980 |
| Diatom, *Nitzschia angularum* | - | S, U | - | 4 | EC50 (growth) | 1,500 | Walsh and Alexander 1980 |
| Diatom, *Nitzschia angularum* | - | S, U | - | 4 | EC50 (growth) | 1,000 | Walsh and Alexander 1980 |
| Diatom, *Nitzschia angularum* | - | S, U | - | 12 | EC50 (growth) | 1,600 | Walsh and Alexander 1980 |
| Diatom, *Nitzschia angularum* | - | S, U | - | 12 | EC50 (growth) | 1,500 | Walsh and Alexander 1980 |
| Diatom, *Phaeodactylum tricornutum* | 95% | S, U | - | 10 | 100% reduced growth rate, cells viable | 100 | Ukeles 1962 |
| Diatom, *Phaeodactylum tricornutum* | 95% | S, U | - | 10 | 100% reduced growth rate, cells viable | 1,000 | Ukeles 1962 |
| Diatom, *Phaeodactylum tricornutum* | 95% | S, U | - | 10 | 100% reduced growth rate, cells viable | 10,000 | Ukeles 1962 |
| Diatom, *Phaeodactylum tricornutum* | 95% | S, U | - | 10 | 100% reduced growth rate, cells viable | 100,000 | Ukeles 1962 |
| Chrysophyte, *Monochrysis lutheri* | 95% | S, U | - | 10 | 13% reduced growth rate | 100 | Ukeles 1962 |
| Chrysophyte, *Monochrysis lutheri* | 95% | S, U | - | 10 | 100% reduced growth rate, cells viable | 1,000 | Ukeles 1962 |
| Chrysophyte, *Monochrysis lutheri* | 95% | S, U | - | 10 | 100% reduced growth rate, cells not viable | 10,000 | Ukeles 1962 |
| Chrysophyte, *Monochrysis lutheri* | 95% | S, U | - | 10 | 100% reduced growth rate, cells not viable | 100,000 | Ukeles 1962 |

[a] S = static; R = renewal; F = flow-through; M = measured; U = unmeasured.
Dash indicates not available

# Appendix G

## Appendix G. Acceptable Bioaccumulation Data of Carbaryl by Aquatic Organisms

There are no acceptable bioaccumulation data for carbaryl.

# Appendix H

# Appendix H. Other Data on Effects of Carbaryl to Freshwater Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| **Freshwater Species** | | | | | | |
| Bacterium, *Vibrio fischeri* | Analytical | 30 min | EC50 (luminescence) | 2,440 | Hernando et al. 2007 | Single-cell organism |
| Bacteria, *Pseudomonas putida* | - | - | LOEC (reduced cell growth) | >5,000 | Bringmann and Kuhn 1977 | Single-cell organism |
| Planktonic algae mixture | 99.7% | 14 day | LOEC (growth inhibition) | 10,000 | Butler et al. 1975 | Community exposure |
| Blue-green algae mixture | - | 24 hr | Reduced carbon uptake | 500 | Vickers and Boyd 1971 | Community exposure |
| Blue-green algae, *Microcystis aeruginosa* | - | 8 day | LOEC (reduced cell growth) | 1,350 | Bringmann and Kuhn 1978a; b | Lack of exposure details |
| Green alga, *Ankistrodesmus braunii* | - | 48 hr | Reduced growth | 25,000 | Kopecek et al. 1975 | Duration |
| Green algae, *Chlorella pyrenoidosa* | - | 96 hr | LOEC (growth) | 100 | Christie 1969 | Lack of exposure details |
| Green alga, *Raphidocelis subcapitata* | Analytical | 6 day | LOEC (growth) | 5,030 | Bierkens et al. 1998 | Lack of exposure details |
| Green alga, *Raphidocelis subcapitata* | Analytical | 6 day | LOEC (heat shock protein 70) | 2,072 | Bierkens et al. 1998 | Atypical endpoint |
| Green algae, *Scenedesmus quadricaudata* | - | 6 day | Increased cell biomass | 100 | Stadnyk et al. 1971 | Lack of exposure details |
| Green algae, *Scenedesmus quadricaudata* | - | 8 day | Reduced cell growth | 1,400 | Bringmann and Kuhn 1977; 1978a; b | Lack of exposure details |
| Ciliate protozoa, *Colpidium campylum* | - | 43 hr | LOEC (growth inhibition) | <10,000 | Dive et al. 1980 | Duration |
| Protozoa (7 day), *Paramecium aurelia* | 97.5% | 24 hr | LC50 | 46,000 | Edmiston et al. 1984 | Single-cell organism |
| Protozoa (7 day), *Paramecium bursaria* | 97.5% | 24 hr | LC50 | 31,000 | Edmiston et al. 1984 | Single-cell organism |
| Protozoa (7 day), *Paramecium caudatum* | 97.5% | 24 hr | LC50 | 10,000 | Edmiston et al. 1984 | Single-cell organism |
| Protozoa (7 day), *Paramecium multimicronucleatum* | 97.5% | 24 hr | LC50 | 24,000 | Edmiston et al. 1984 | Single-cell organism |
| Protozoa (12 day), *Paramecium multimicronucleatum* | 97.5% | 24 hr | LC50 | 28,000 | Edmiston et al. 1985 | Single-cell organism |
| Tubificid worm, *Branchiura sowerbyi* | - | 72 hr | LOEC (mortality) | 4,000 | Naqvi 1973 | Duration |

## Appendix H. Other Data on Effects of Carbaryl to Freshwater Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Snail (< 24 hr), *Lymnea stagnalis* | 97-99% | 1 mo | 82.5% mortality | 2,000 | Seuge and Bluzat 1983 | Unmeasured exposure |
| Snail, *Physa acuta* | Technical | 48 hr | LC50 | 27,000 | Hashimoto and Nishiuchi 1981 | Duration |
| Cladoceran (<24 hr), *Ceriodaphnia dubia* | 99.7% | 7 day | IC25 | <330 | Dwyer et al. 1999a | Static, unmeasured exposure |
| Cladoceran (2nd instar), *Daphnia galeata mendotae* | >99% | 8-14 hr | LOEC (enlarged helmet) | 5 | Hanazato and Dodson 1993 | Duration |
| Cladoceran (1st and 2nd instar), *Daphnia lumholtzi* | >99% | 8-14 hr | LOEC (enlarged helmet) | 10 | Hanazato and Dodson 1993 | Duration |
| Cladoceran (<26 hr), *Daphnia magna* | - | 24 hr | LC50 | 1.1 | Gaaboub et al. 1975 | Duration |
| Cladoceran (<24 hr), *Daphnia magna* | Technical grade | 0.5 hr | EC50 (erratic swimming) | 12 | Parker et al. 1970 | Duration |
| Cladoceran (0-24 hr), *Daphnia magna* | - | 24 hr | LC50 | 0.66 | Rawash et al. 1975 | Duration |
| Cladoceran (4 day), *Daphnia magna* | - | 24 hr | LC50 | 21 | Wernersson and Dave 1997 | Duration |
| Cladoceran (2nd instar), *Daphnia pulex* | >99% | 8-14 hr | LOEC (enlarged helmet) | 15 | Hanazato and Dodson 1993 | Duration |
| Cladoceran, *Dapnia pulex* | - | 3 hr | LC50 | 0.85 | Nishiuchi and Hashimoto 1967 | Duration |
| Cladoceran, *Daphnia pulex* | Technical | 3 hr | LC50 | 50 | Hashimoto and Nishiuchi 1981 | Duration |
| Cladoceran (1st and 2nd instar), *Daphnia retrocurva* | >99% | 8-14 hr | LOEC (enlarged helmet) | 20 | Hanazato and Dodson 1993 | Duration |
| Cladoceran, *Moina macrocopa* | - | 3 hr | LC50 | 1.0 | Nishiuchi and Hashimoto 1967 | Duration |
| Cladoceran, *Moina macrocopa* | Technical | 3 hr | LC50 | 50 | Hashimoto and Nischiuchi 1981 | Duration |
| Cladoceran (adult female), *Bosmina longirostris* | >99% | 24 hr | LC50 | 8.597 | Sakamoto et al. 2005 | Duration |
| Cladoceran (juvenile/adult), *Leptodora kindtii* | >99% | 24 hr | LC50 | 3.477 | Sakamoto et al. 2005 | Duration |
| Ostracod, *Cypretta kawatai* | 99.9% | 72 hr | LC50 | 1,800 | Hansen and Kawatski 1976 | Duration |
| Opossum shrimp (adult), *Mysis relicta* | 98% | 6 hr | Avg. BCF = 149 | 7.24 and 15.95 | Landrum and Dupuis 1990 | Duration |
| Seed shrimp (mature), *Cypridopsis vidua* | 99.5% | 48 hr | EC50 | 115 | Johnson and Finley 1980 | Duration |

## Appendix H. Other Data on Effects of Carbaryl to Freshwater Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Amphipod (mature), *Pontoporeia hoyi* | 98% | 6 hr | Avg. BCF = 18,700 | 1.44-3.81 | Landrum and Dupuis 1990 | Duration |
| Amphipod, *Gammarus pseudolimnaeus* | 99.5% | 96 hr | LC50 | 16 | Schoettger and Mauck 1978 | Control survival not reported |
| Amphipod (mature), *Gammarus pseudolimnaeous* | 99.5% | 48 hr | LC50 | 13 | Mayer and Ellersieck 1986 | Duration |
| Amphipod (mature), *Gammarus pseudolimnaeous* | 99.5% | 48 hr | LC50 | 8 | Mayer and Ellersieck 1986 | Duration |
| Grass shrimp, *Palaemonetes kadiakensis* | - | 24 hr | LC50 | 42.5 | Naqvi and Ferguson 1970 | Duration |
| Red Crayfish, *Procambarus clarkii* | Technical | 72 hr | LC50 | 2,000 | Muncy and Oliver 1963 | Duration |
| Mayfly (nymph), *Cloeon dipterum* | Technical | 48 hr | LC50 | 370 | Hashimoto and Nishiuchi 1981 | Duration |
| Stonefly (1st year class), *Isogenus sp.* | 99.5% | 96 hr | LC50 (solution aged 7 days) | 6.6 | Mayer and Ellersieck 1986 | Aged solution |
| Stonefly (1st year class), *Isogenus sp.* | 99.5% | 96 hr | LC50 (solution aged 14 days) | 6.6 | Mayer and Ellersieck 1986 | Aged solution |
| Stonefly (1st year class), *Isogenus sp.* | 99.5% | 96 hr | LC50 (solution aged 21 days) | 12 | Mayer and Ellersieck 1986 | Aged solution |
| Stonefly (nymph), *Pteronarcys californica* | 99.5% | 96 hr | LC50 | 2 | Schoettger and Mauck 1978 | Control survival not reported |
| Crawling water beetle (5 mg), *Peltodytes sp.* | ≥94% | 96 hr | LC50 | 3,300 | Federle and Collins 1976 | Three species exposed simultaneously |
| Blackfly (larva), *Simulium vittatum* | ≥98% | 48 hr | LC50 | 23.72 | Overmyer et al. 2003 | Duration |
| Midge (4th instar), *Chironomus plumosus* | 99.5% | 48 hr | EC50 | 10 | Sanders et al. 1983 | Duration |
| Midge (4th instar), *Chironomus riparius* | Analytical | 24 hr | EC50 (reduced lactate) | 1.0 | Forcella et al. 2007 | Duration |
| Midge (4th instar), *Chironomus riparius* | >98% | 24 hr | LC50 | 110 | Lydy et al. 1990 | Duration |
| Midge (4th instar), *Chironomus tentans* | 99.9% | 72 hr | LC50 | 5,900 | Hansen and Kawatski 1976 | Duration |
| Mosquito (2nd stage), *Aedes aegypti* | 97.6% | 36 hr | LC50 | 336 | Lakota et al. 1981 | Duration |
| Mosquito (4th instar larvae), *Culex pipiens* | - | 24 hr | LC50 | 75 | Rawash et al. 1975 | Duration |

## Appendix H. Other Data on Effects of Carbaryl to Freshwater Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Mosquito (4th instar larvae), *Culex pipiens* | - | 24 hr | LC50 | 170 | Gaaboub et al. 1975 | Duration |
| Apache trout, *Oncorhynchus apache* | - | 96 hr | NOEC (muscarinic cholinergic receptors) | 1,300 | Jones et al. 1998 | Atypical endpoint |
| Coho salmon (6-18 mo), *Oncorhynchus kisutch* | - | ≤ 30 day | BCF = 3.58 (substantial mortality at 30 days) | 2,600 | Walsh and Ribelin 1973 | Control issues |
| Coho salmon (4.9 cm; 1.3 g; 4-7 mo), *Oncorhynchus kisutch* | 99% | 96 hr | LC50 | >150 | Laetz et al. 2009 | Control survival not reported |
| Rainbow trout, *Oncorhynchus mykiss* | 99% | 96 hr | EC50 (muscular cholinesterase) | 270 | Ferrari et al. 2007a | Atypical endpoint |
| Rainbow trout, *Oncorhynchus mykiss* | 99% | 96 hr | EC50 (brain cholinesterase) | 19.24 | Ferrari et al. 2007a | Atypical endpoint |
| Rainbow trout (2 yr), *Oncorhynchus mykiss* | - | 48 hr | LC0 | 30,000 | Lysak and Marcinek 1972 | Duration |
| Rainbow trout (2 yr), *Oncorhynchus mykiss* | - | 24 hr | LC100 | 100,000 | Lysak and Marcinek 1972 | Duration |
| Rainbow trout (1-1.5 yr), *Oncorhynchus mykiss* | - | 4.5 hr | LOEC (respiration rate) | 2,000 | Lunn et al. 1976 | Duration |
| Rainbow trout (1-1.5 yr), *Oncorhynchus mykiss* | - | 4.5 hr | NOEC (respiration rate) | 1,000 | Lunn et al. 1976 | Duration |
| Rainbow trout (1.8 g), *Oncorhynchus mykiss* | 99.5% | 24 hr | LC50 | 4,620 | Mayer and Ellersieck 1986 | Duration |
| Rainbow trout (2.2 g), *Oncorhynchus mykiss* | 99.5% | 24 hr | LC50 | 6,090 | Mayer and Ellersieck 1986 | Duration |
| Rainbow trout (30-80 g), *Oncorhynchus mykiss* | Technical | 24 hr | LC50 | 1,410 | Zinkl et al. 1987 | Duration |
| Rainbow trout (30-80 g), *Oncorhynchus mykiss* | Technical | 24 hr | LOEC (depression of brain cholinesterase activity) | 500 | Zinkl et al. 1987 | Atypical endpoint |
| Rainbow trout (0.5-1.0 g), *Oncorhynchus mykiss* | 99.9% | 96 hr | LOEC (survival from predation) | 10 | Little et al. 1990 | Atypical endpoint |
| Rainbow trout, *Oncorhynchus mykiss* | - | 96 hr | NOEC (muscarinic cholinergic receptors) | 3,600 | Jones et al. 1998 | Atypical endpoint |

## Appendix H.  Other Data on Effects of Carbaryl to Freshwater Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Lahontan cutthroat trout, *Oncorhynchus clarkii henshawi* | - | 96 hr | NOEC (muscarinic cholinergic receptors) | 2,200 | Jones et al. 1998 | Atypical endpoint |
| Cutthroat trout (0.5 g), *Oncorhynchus clarkii* | 99.5% | 96 hr | LC50 (solution aged 7 days) | 4,000 (pH=7.3) | Mayer and Ellersieck 1986 | Aged solution |
| Cutthroat trout (0.5 g), *Oncorhynchus clarkii* | 99.5% | 96 hr | LC50 (solution aged 14 days) | 3,380 (pH=7.2) | Mayer and Ellersieck 1986 | Aged solution |
| Cutthroat trout (0.5 g), *Oncorhynchus clarkii* | 99.5% | 96 hr | LC50 (solution aged 21 days) | 2,300 (pH=7.2) | Mayer and Ellersieck 1986 | Aged solution |
| Atlantic salmon (3-4 cm), *Salmo salar* | - | 24 hr | NOEC (temperature preference) | 1,000 | Peterson 1976 | Atypical endpoint |
| Atlantic salmon (0.4 g), *Salmo salar* | 99.5% | 24 hr | LC50 (pH=6.5) | 1,400 | Mayer and Ellersieck 1986 | Duration |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=7.5) (7°C) | 3,000 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=7.5) (12°C) | 2,100 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=7.5) (17°C) | 900 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=8) (12°C) | 5,400 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=8) (12°C) | 2,500 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=6.5) (12°C) | 4,600 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=7.5) (12°C) | 3,700 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=8.5) (12°C) | 2,100 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout, *Salvelinus fontinalis* | 99.5% | 96 hr | LC50 (pH=9.0) (12°C) | 1,100 | Schoettger and Mauck 1978 | Control survival not reported |
| Brook trout (0.8 g), *Salvelinus fontinalis* | 99.5% | 24 hr | LC50 | 10,000 | Mayer and Ellerseick 1986 | Duration |

## Appendix H. Other Data on Effects of Carbaryl to Freshwater Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Lake trout (6-18 month old), *Salvelinus namaycush* | - | ≤ 30 day | BCF = 4.00 (substantial mortality at 30 days) | 2,600 | Walsh and Ribelin 1973 | Control issues |
| Goldfish, *Carassius auratus* | - | 48 hr | LC50 | >10,000 | Nishiuchi and Hashimoto 1967 | Duration |
| Goldfish, *Carassius auratus* | 99% | 10 day | LC50 | >10,000 | Shea and Berry 1983 | Duration |
| Goldfish, *Carassius auratus* | - | 7 day | 40% with vertebral deformation | 5,000 | Imada 1976 | Duration |
| Carp, *Cyprinus carpio* | Technical | 48 hr | LC50 | 13,000 | Hashimoto and Nishiuchi 1981 | Duration |
| Common carp (larva; 8 mm; 3 day), *Cyprinus carpio* | Commercial | 96 hr | LC50 | 2,000 | Verma et al. 1981a | Formulation |
| Common carp (larva; 8 mm; 3 day), *Cyprinus carpio* | Commercial | 60 day | NOEC (growth) | 50 | Verma et al. 1981a | Formulation |
| Common carp (larva; 8 mm; 3 day), *Cyprinus carpio* | Commercial | 60 day | LOEC (growth) | 80 | Verma et al. 1981a | Formulation |
| Common carp, *Cyprinus carpio* | - | 48 hr | LC50 | >10,000 | Nishiuchi and Hashimoto 1967 | Duration |
| Common carp (20-34 mm), *Cyprinus carpio* | 85% | 7 & 14 day | LOEC (reduced AChE activity in brain) | 39 | de Mel and Pathiratne 2005 | Atypical endpoint |
| Common carp (egg), *Cyprinus carpio* | - | 55-74 hr | LC50 | 1,400 | Kaur and Toor 1977 | Duration |
| Common carp (egg), *Cyprinus carpio* | - | 55-74 hr | 100% mortality | 2,500 | Kaur and Toor 1977 | Duration |
| Carp (1.2 g), *Cyrpinus carpio* | Technical | 72 hr | LC50 | 13,000 | Nishiuchi and Asano 1981 | Duration |
| Carp (3.0 g), *Cyrpinus carpio* | Technical | 48 hr | LC50 | 13,000 | Nishiuchi and Asano 1981 | Duration |
| Zebrafish (embryo), *Danio rerio* | 99.9% | 24 hr | LC50 | 44,660 | Lin et al. 2007 | Duration |
| Zebrafish (embryo), *Danio rerio* | 99.9% | 24 hr | EC50 (pericardial edema, tail malformations) | 7,520 | Lin et al. 2007 | Duration |
| Fathead minnow (1-2 g), *Pimephales promelas* | 95% | 96 hr | LC50 | 13,000 | Henderson et al. 1960 | Control survival not reported |
| Fathead minnow (1-2 g), *Pimephales promelas* | 95% | 96 hr | LC50 | 7,000 | Henderson et al. 1960 | Control survival not reported |
| Fathead minnow (larva), *Pimephales promelas* | 99.9% | 7 day | Chronic Value (growth) | 576 | Norberg-King 1989 | Duration |

## Appendix H. Other Data on Effects of Carbaryl to Freshwater Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Fathead minnow (larva), *Pimephales promelas* | 99.9% | 12 day | Chronic Value (growth) | 1,275 | Norberg-King 1989 | Duration |
| Fathead minnow (larva), *Pimephales promelas* | 99.9% | 7 day | Chronic Value (survival and growth) | 1,088 | Norberg-King 1989 | Duration |
| Fathead minnow (larva), *Pimephales promelas* | 99.9% | 7 day | Chronic Value (survival) | 1,018 | Norberg-King 1989 | Duration |
| Fathead minnow (larva), *Pimephales promelas* | 99.9% | 7 day | Chronic Value (growth) | 569 | Norberg-King 1989 | Duration |
| Fathead minnow (larva), *Pimephales promelas* | 99.9% | 7 day | Chronic Value (survival and growth) | 976 | Norberg-King 1989 | Duration |
| Fathead minnow (1 day), *Pimephales promelas* | 99.8% | 7 day | Chronic Value (growth) | 707 | Pickering et al. 1996 | Duration |
| Fathead minnow (4 day), *Pimephales promelas* | 99.8% | 7 day | Chronic Value (growth) | <250 | Pickering et al. 1996 | Duration |
| Fathead minnow (7 day), *Pimephales promelas* | 99.8% | 7 day | Chronic Value (growth) | 707 | Pickering et al. 1996 | Duration |
| Fathead minnow (<24 hr), *Pimephales promelas* | 99.7% | 7 day | IC25 | 420 | Dwyer et al. 1999a | Duration |
| Colorado pikeminnow (formerly squawfish), *Ptychocheilus lucius* | 99% | 24 hr | NOEC (AChE inhibition) | 29.3 | Beyers and Sikoski 1994 | Duration |
| Colorado pikeminnow, *Ptychocheilus lucius* | 99% | 24 hr | LOEC (AChE inhibition) | 49.1 | Beyers and Sikoski 1994 | Duration |
| Colorado pikeminnow (5-6 day), *Ptychocheilus lucius* | 99.7% | 7 day | IC25 | 1,330 | Dwyer et al. 1999a | Duration |
| Bonytail chub (2-7 day), *Gila elegans* | 99.7% | 7 day | IC25 | 250 | Dwyer et al. 1999a | Duration |
| Razorback sucker (6-7 day), *Xyrauchen texanus* | 99.7% | 7 day | IC25 | 2,060 | Dwyer et al. 1999a | Duration |
| Yellow bullhead (adult), *Ictalurus natalis* | 80% | 48 hr | LOEC (behavior) | 1,000 | Morison 1984 | Duration |
| Walking catfish (15-20 cm; 20-30 g), *Clarias batrachus* | 99% | 15 day | Decreased glucose and protein | 4,000 | Sharma 1999 | Atypical endpoint |

## Appendix H. Other Data on Effects of Carbaryl to Freshwater Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Walking catfish (15-20 cm; 70-90 g), *Clarias batrachus* | 99% | 96 hr | Increased lactic acid in liver and muscle | 1,000 | Sharma and Gopal 1995 | Atypical endpoint |
| Walking catfish (15-20 cm; 70-90 g), *Clarias batrachus* | 99% | 96 hr | Increased lactic acid in heart, gills, kidney and spleen | 2,000 | Sharma and Gopal 1995 | Atypical endpoint |
| Walking catfish (15-20 cm; 70-90 g), *Clarias batrachus* | 99% | 96 hr | Reduced AChE levels in various tissues | 1,000 | Sharma et al. 1993 | Atypical endpoint |
| Killifish, *Fundulus heteroclitus* | 99% | 10 day | 40% Mortality | 10,000 | Shea and Berry 1983 | Duration |
| Mosquitofish (20-45 mm), *Gambusia affinis* | 98% | 24 hr | Irritated | 10,000 | Hansen et al. 1972 | Duration |
| Mosquitofish, *Gambusia affinis* | Analytical | 24 hr | Avoidance | 13,000 | Krieger and Lee 1973 | Duration |
| Mosquitofish, *Gambusia affinis* | Analytical | 24 hr | LC50 | 13,000 | Krieger and Lee 1973 | Duration |
| Guppy (juvenile), *Poecilia reticulata* | 97.6% | 36 hr | LC50 | 3,840 | Lakota et al. 1981 | Duration |
| Bluegill (adult), *Lepomis macrochirus* | - | 96 hr | Increased ventilator response | 2,400 | Carlson 1990 | Atypical endpoint |
| Bluegill (1-2 g), *Lepomis macrochirus* | 95% | 96 hr | LC50 | 5,600 | Henderson et al. 1960 | Control survival not reported |
| Bluegill (0.87 g), *Lepomis macrochirus* | Technical | 96 hr | LC50 | 2,000 | Cope 1965 | Control survival not reported |
| Mozambique tilapia, *Tilapia mossambica* | Commercial | 48 hr | LC50 | 5,495 | Basha et al. 1983 | Duration |
| Plains Leopard frog, *Rana blairi* | 99.7% | 24 hr | LOEC (reduced activity) | 3,500 | Bridges 1997 | Duration |
| Gray tree frog (Gosner stage 25), *Hyla versicolor* | 99.7% | 48 hr | LC50 | >2,510 | Little et al. 2000 | Duration |
| African clawed frog (embryo), *Xenopus laevis* | - | 24 hr | LC50 | 4,700 | Elliott-Freeley and Armstrong 1982 | Duration |
| African clawed frog (tadpole), *Xenopus laevis* | - | 24 hr | Abnormal development | 110 | Elliott-Freeley and Armstrong 1982 | Duration |
| African clawed frog (embryo), *Xenopus laevis* | 99.8% | 115 hr | LC50 | 20,280 | Bacchetta et al. 2008 | Duration |

Dash indicates not available

# Appendix I

## Appendix I. Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| **Estuarine/marine Species** | | | | | | |
| Bacteria | 99% | 34 day | Reduction in diversity | 100,000 | Weber and Rosenberg 1984 | Single-cell organism |
| Bacteria | 99% | 42 day (field) | No effect on numbers, diversity or filter paper composition | 1,000 | Weber and Rosenberg 1984 | Single-cell organism |
| Bacteria | 99% | 42 day (field) | No effect on numbers, diversity or filter paper composition | 10,000 | Weber and Rosenberg 1984 | Single-cell organism |
| Bacteria | 99% | 42 day (field) | No effect on numbers, diversity or filter paper composition | 100,000 | Weber and Rosenberg 1984 | Single-cell organism |
| Bacteria | 99% | 70 day (lab) | No effect on filter paper decomposition | 1,000 | Weber and Rosenberg 1984 | Single-cell organism |
| Bacteria | 99% | 70 day (lab) | No effect on filter paper decomposition | 10,000 | Weber and Rosenberg 1984 | Single-cell organism |
| Bacteria | 99% | 70 day (lab) | Complete inhibition of filter paper decomposition | 100,000 | Weber and Rosenberg 1984 | Single-cell organism |
| Bacterium, *Vibrio fischeri* | Analytical | 30 min | EC50 (luminescence) | 1,651 | Hernando et al. 2007 | Single-cell organism |
| Green alga, *Chlorococcum sp.* | - | 48 hr | 75% reduced growth rate | 10,000 | Maly and Ruber 1983 | Duration |
| Green alga, *Chlorococcum sp.* | - | 48 hr | 40% reduced growth rate | 2,000 | Maly and Ruber 1983 | Duration |
| Green alga, *Chlorococcum sp.* | - | 48 hr | 48% reduced growth rate | 1,000 | Maly and Ruber 1983 | Duration |
| Green alga, *Chlorococcum sp.* | - | 48 hr | No significant reduction in growth rate | 500 | Maly and Ruber 1983 | Duration |
| Green alga, *Chlorococcum sp.* | - | 96 hr | >100% reduced growth rate | 10,000 | Maly and Ruber 1983 | Lack of exposure details |
| Green alga, *Chlorococcum sp.* | - | 96 hr | 92% reduction in growth rate between 48 & 96 hr | 2,000 | Maly and Ruber 1983 | Lack of exposure details |
| Green alga, *Chlorococcum sp.* | - | 96 hr | 54% reduction in growth rate between 48 & 96 hr | 1,000 | Maly and Ruber 1983 | Lack of exposure details |
| Green alga, *Chlorococcum sp.* | - | 96 hr | No sign. reduction in growth rate between 48 and 96 hr | 500 | Maly and Ruber 1983 | Lack of exposure details |
| Diatom, *Nitzschia closterium* | - | 48 hr | >100% reduced growth rate | 10,000 | Maly and Ruber 1983 | Duration |
| Diatom, *Nitzschia closterium* | - | 48 hr | 69% reduced growth rate | 2,000 | Maly and Ruber 1983 | Duration |
| Diatom, *Nitzschia closterium* | - | 48 hr | No significant reduction in growth rate | 1,000 | Maly and Ruber 1983 | Duration |

## Appendix I. Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Diatom, *Nitzschia closterium* | - | 96 hr | No significant reduction in growth rate between 48 and 96 hr | 10,000 | Maly and Ruber 1983 | Lack of exposure details |
| Diatom, *Amphora coffeaformis v. borealis* | - | 48 hr | >100% reduced growth rate | 10,000 | Maly and Ruber 1983 | Duration |
| Diatom, *Amphora coffeaformis v. borealis* | - | 48 hr | >100% reduced growth rate | 2,000 | Maly and Ruber 1983 | Duration |
| Diatom, *Amphora coffeaformis v. borealis* | - | 48 hr | 99% reduced growth rate | 1,000 | Maly and Ruber 1983 | Duration |
| Diatom, *Amphora coffeaformis v. borealis* | - | 48 hr | No significant reduction in growth rate | 500 | Maly and Ruber 1983 | Duration |
| Diatom, *Amphora coffeaformis v. borealis* | - | 96 hr | 69% reduction in growth rate between 48 & 96 hr | 10,000 | Maly and Ruber 1983 | Lack of exposure details |
| Diatom, *Amphora coffeaformis v. borealis* | - | 96 hr | No significant reduction in growth rate between 48 & 96 hr | 2,000 | Maly and Ruber 1983 | Lack of exposure details |
| Diatom, *Amphiprora sp.* | - | 48 hr | >100% reduced growth rate | 10,000 | Maly and Ruber 1983 | Duration |
| Diatom, *Amphiprora sp.* | - | 48 hr | 75% reduced growth rate | 2,000 | Maly and Ruber 1983 | Duration |
| Diatom, *Amphiprora sp.* | - | 48 hr | 63% reduced growth rate | 1,000 | Maly and Ruber 1983 | Duration |
| Diatom, *Amphiprora sp.* | - | 48 hr | No significant reduction in growth rate | 500 | Maly and Ruber 1983 | Duration |
| Diatom, *Amphiprora sp.* | - | 96 hr | No significant reduction in growth rate between 48 & 96 hr | 10,000 | Maly and Ruber 1983 | Lack of exposure details |
| Dinoflagellate, *Gonyaulax sp.* | - | 48 hr | No significant reduction in growth rate | 10,000 | Maly and Ruber 1983 | Duration |
| Dinoflagellate, *Gonyaulax sp* | - | 96 hr | No significant reduction in growth rate between 48 & 96 hr | 10,000 | Maly and Ruber 1983 | Lack of exposure details |
| Hermatypic coral, *Pocillopora damicornis* | Analytical | 96 hr | NOEC (survival) | 10,000 | Acevedo 1991 | Duration |

## Appendix I. Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Polychaete worm, *Nereis diversicolor* | - | 2-8 day | Reduced AChE activity | 201.2 | Scaps et al. 1997 | Atypical endpoint |
| Lugworm, *Arenicola marina* | 99% | 48 hr | LC50 | 7,200 | Conti 1987 | Duration |
| Bay mussel (30-40 mm), *Mytilus edulis* | 98% | 72 hr | EC50 (feeding rate) | 8,370 | Donkin et al. 1997 | Atypical endpoint |
| Bay mussel (embryo), *Mytilus edulis* | 80% | 48 hr | EC50 (development) | 2,400 | Dimick and Breese 1965 | Control survival not reported |
| Blue mussel (unfertilized egg), *Mytilus edulis* | 80% | 1 hr | EC50 (development) | 20,070 | Armstrong and Milleman 1974c | Duration |
| Blue mussel (1st polar body), *Mytilus edulis* | 80% | 1 hr | EC50 (development) | 5,300 | Armstrong and Milleman 1974c | Duration |
| Blue mussel (2 cell), *Mytilus edulis* | 80% | 1 hr | EC50 (development) | 7,000 | Armstrong and Milleman 1974c | Duration |
| Blue mussel (≥64 cell), *Mytilus edulis* | 80% | 1 hr | EC50 (development) | 8,300 | Armstrong and Milleman 1974c | Duration |
| Blue mussel (ciliated blastula), *Mytilus edulis* | 80% | 1 hr | EC50 (development) | 16,000 | Armstrong and Milleman 1974c | Duration |
| Blue mussel (trochophore), *Mytilus edulis* | 80% | 1 hr | EC50 (development) | 19,000 | Armstrong and Milleman 1974c | Duration |
| Blue mussel (early veliger), *Mytilus edulis* | 80% | 1 hr | EC50 (development) | 24,000 | Armstrong and Milleman 1974c | Duration |
| Blue mussel, *Mytilus edulis* | 99.7% | 10 day | EC50 (shell growth) | >2,610 | Liu and Lee 1975 | Control issues |
| Blue mussel, *Mytilus edulis* | 99.7% | 20 day | EC50 (shell growth) | >1,300 | Liu and Lee 1975 | Control issues |
| Blue mussel, *Mytilus edulis* | 99.7% | 20 day | EC50 (metamorphosis with dissoconch shell) | >2,900 | Liu and Lee 1975 | Control issues |
| Blue mussel, *Mytilus edulis* | 99.7% | 40 day | LC50 | >2,900 | Liu and Lee 1975 | Control issues |
| Blue mussel, *Mytilus edulis* | 99.7% | 40 day | EC50 (shell growth) | >2,900 | Liu and Lee 1975 | Control issues |
| Blue mussel, *Mytilus edulis* | 99.7% | 20 day | Chronic Value (growth) | 463.1 | Liu and Lee 1975 | Control issues |
| Blue mussel, *Mytilus edulis* | - | 24 hr | EC50 (# of byssal threads) | >30,000 | Roberts 1975 | Atypical endpoint |
| Blue mussel, *Mytilus edulis* | - | 48 hr | EC50 ( # of byssal threads) | >30,000 | Roberts 1975 | Atypical endpoint |
| Eastern oyster, *Crassostrea virginica* | >95% | 24 hr | LOEC (growth) | 1,000 | Butler et al. 1960 | Duration |

## Appendix I. Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Eastern oyster (fertilized egg), *Crassotrea virginica* | - | 48 hr | LOEC (development) | 1,000 | Davis 1961 | Lack of exposure details |
| Eastern oyster, *Crassostrea virginica* | - | 12 day | LC50 (larvae) | 3,000 | Davis and Hidu 1969 | Duration |
| Eastern oyster, *Crassostrea virginica* | - | 96 hr | 19% decrease in shell growth | 2,000 | Butler 1963 | Lack of exposure details |
| Eastern oyster, *Crassostrea virginica* | - | 96 hr | 14% decrease in shell growth | 2,000 | Butler 1963 | Lack of exposure details |
| Cockle clam (adult), *Clinocardium nuttallii* | 80% | 24 hr | EC50 | 7,300 | Stewart et al. 1967 | Duration |
| Hard clam, *Mercenaria mercenaria* | - | 14 day | LC50 (larvae) | >2,500 | Davis and Hidu 1969 | Lack of exposure details |
| Quahog clam (fertilized egg), *Mercenaria mercenaria* | - | 48 hr | LOEC (development) | 2,500 | Davis 1961 | Lack of exposure details |
| Amphipod, *Corophium acherusicum* | 99.5% | 10 wk | 48% reduction in # of individuals | 1.1 | Tagatz et al. 1979 | Community exposure |
| Amphipod, *Corophium acherusicum* | 99.5% | 10 wk | 100% reduction in # of individuals | 11.1 | Tagatz et al. 1979 | Community exposure |
| Amphipod, *Corophium acherusicum* | 99.5% | 10 wk | 100% reduction in # of individuals | 103 | Tagatz et al. 1979 | Community exposure |
| Mysid shrimp (juvenile), *Americamysis bahia* | 99% | 72 hr | LC50 | 8.45 | Thursby and Champlin 1991b | 96 hr value used |
| Mysid shrimp (juvenile), *Americamysis bahia* | 99% | 24 hr | LC50 | 21 | Thursby and Champlin 1991a | 96 hr value used |
| Mysid shrimp (juvenile), *Americamysis bahia* | 99% | 48 hr | LC50 | 19 | Thursby and Champlin 1991a | 96 hr value used |
| Mysid shrimp (juvenile), *Americamysis bahia* | 99% | 72 hr | LC50 | 19 | Thursby and Champlin 1991a | 96 hr value used |
| Grass shrimp, *Palaemonetes pugio* | 99% | 24 hr | LC50 | 76 | Thursby and Champlin 1991a | Duration |
| Grass shrimp, *Palaemonetes pugio* | 99% | 72 hr | LC50 (fed) | 22 | Thursby and Champlin 1991a | Test species fed |
| Grass shrimp, *Palaemonetes pugio* | 99% | 96 hr | LC50 (fed) | 22 | Thursby and Champlin 1991a | Test species fed |
| Grass shrimp, *Palaemonetes pugio* | 98% | 1.5 hr | NOEC (contaminant avoidance) | 100 | Hansen et al. 1973 | Atypical endpoint |

## Appendix I. Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Grass shrimp, *Palaemonetes pugio* | 98% | 1.5 hr | LC50 | 38 | Hansen et al. 1973 | Atypical endpoint |
| Grass shrimp (juvenile), *Palaemonetes pugio* | 99.7% | 48 hr | LC50 | 28 | Hansen 1980; Mayer 1987 | Duration |
| Brown shrimp (juvenile), *Penaeus aztecus* | 99.7% | 48 hr | LC50 | 1.5 | Hansen 1980; Mayer 1987 | Duration |
| Brown shrimp (adult), *Penaeus aztecus* | - | 48 hr | LC50 | 2.5 | Butler 1963 | Duration |
| Brown shrimp, *Penaeus aztecus* | - | 24 hr | EC50 | 5.5 | Butler 1963 | Duration |
| Pink shrimp (juvenile), *Penaeus duorarum* | 99.7% | 48 hr | LC50 | 32 | Hansen 1980; Mayer 1987 | Duration |
| Mud shrimp (larva), *Upogebia pugettensis* | 80% | 24 hr | LC50 | 130 | Stewart et al. 1967 | Duration |
| Mud shrimp (larva), *Upogebia pugettensis* | 80% | 24 hr | LC50 | 40 | Stewart et al. 1967 | Duration |
| Ghost shrimp (larva), *Callianassa californiensis* | 80% | 24 hr | EC50 | 470 | Stewart et al. 1967 | Duration |
| Ghost shrimp (larva), *Callianassa californiensis* | 80% | 24 hr | EC50 | 170 | Stewart et al. 1967 | Duration |
| Ghost shrimp (larva), *Callianassa californiensis* | 80% | 24 hr | EC50 | 5,600 | Stewart et al. 1967 | Duration |
| Ghost shrimp (adult), *Callianassa californiensis* | 80% | 24 hr | EC50 | 130 | Stewart et al. 1967 | Duration |
| Sand shrimp (2.4-4.5 g), *Crangon septemspinosa* | - | 96 hr | Lethal threshold | 20 | McLeese et al. 1979 | Atypical endpoint |
| American lobster (1st stage), *Homarus americanus* | 99% | 24 hr | LC50 | 38.73 | Champlin and Poucher 1992 | Duration |
| American lobster (1st stage), *Homarus americanus* | 99% | 48 hr | LC50 | 23.13 | Champlin and Poucher 1992 | Test species fed |
| American lobster (1st stage), *Homarus americanus* | 99% | 72 hr | LC50 | 20.89 | Champlin and Poucher 1992 | Test species fed |
| American lobster (1st stage), *Homarus americanus* | 99% | 96 hr | LC50 | 20.89 | Champlin and Poucher 1992 | Test species fed |
| Blue crab (juvenile), *Callinectes sapidus* | 99.7% | 48 hr | LC50 | 320 | Hansen 1980; Mayer 1987 | Duration |

## Appendix I.  Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Blue crab (juvenile), *Callinectes sapidus* | - | 48 hr | LC50 | 550 | Butler 1963 | Duration |
| Dungeness crab (prezoea), *Metacarcinus magister (formerly Cancer magister)* | 80% | 24 hr | NOEC (hatching) | 1,000 | Buchanan et al. 1970 | Duration |
| Dungeness crab (juvenile male), *Metacarcinus magister* | 80% | 24 hr | EC50 | 600 | Stewart et al. 1967 | Duration |
| Dungeness crab (juvenile female), *Metacarcinus magister* | 80% | 24 hr | EC50 | 630 | Stewart et al. 1967 | Duration |
| Dungeness crab (egg), *Metacarcinus magister* | 80% | 24 hr | NOEC (hatching @ 10ºC) | 1,000 | Buchannan et al. 1970 | Duration |
| Dungeness crab (prezoea), *Metacarcinus magister* | 80% | 24 hr | EC50 (molting to zoea @ 10ºC) | 6 | Buchannan et al. 1970 | Duration |
| Dungeness crab (prezoea), *Metacarcinus magister* | 80% | 24 hr | EC50 (molting to zoea @ 10ºC) | 20 | Buchannan et al. 1970 | Duration |
| Dungeness crab (prezoea), *Metacarcinus magister* | 80% | 24 hr | EC50 (molting to zoea @ 10ºC) | 30 | Buchannan et al. 1970 | Duration |
| Dungeness crab (zoea; 1-2 day), *Metacarcinus magister* | 80% | 24 hr | LC50 (17ºC) | 80 | Buchannan et al. 1970 | Duration |
| Dungeness crab (zoeae; 1-2 day), *Metacarcinus magister* | 80% | 24 hr | LC50 (17ºC) | 5 | Buchannan et al. 1970 | Duration |
| Dungeness crab (zoeae), *Metacarcinus magister* | 80% | 24 hr | EC50 (cessation of swimming) (10ºC) | 6.5 | Buchanan et al. 1970 | Duration |
| Dungeness crab (zoea; 1 day), *Metacarcinus magister* | 80% | 24 hr | EC50 (10ºC) | >1,000 | Buchannan et al. 1970 | Duration |
| Dungeness crab (juvenile), *Metacarcinus magister* | 80% | 48 hr | EC50 (14ºC) | 76 | Buchannan et al. 1970 | Duration |

## Appendix I. Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Dungeness crab (juvenile), *Metacarcinus magister* | 80% | 48 hr | EC50 (12ºC) | 57 | Buchannan et al. 1970 | Duration |
| Dungeness crab (9th stage; juvenile), *Metacarcinus magister* | 80% | 24 hr | EC50 (18ºC) | 350 | Buchannan et al. 1970 | Duration |
| Dungeness crab (9th stage; juvenile), *Metacarcinus magister* | 80% | 24 hr | EC50 (18ºC) | 320 | Buchannan et al. 1970 | Duration |
| Dungeness crab (9th stage; juvenile), *Metacarcinus magister* | 80% | 48 hr | EC50 (18ºC) | 620 | Buchannan et al. 1970 | Duration |
| Dungeness crab (9th stage; juvenile), *Metacarcinus magister* | 80% | 48 hr | EC50 (18ºC) | 220 | Buchannan et al. 1970 | Duration |
| Dungeness crab (adult), *Metacarcinus magister* | 80% | 24 hr | EC50 (11ºC) | 320 | Buchannan et al. 1970 | Duration |
| Dungeness crab (adult), *Metacarcinus magister* | 80% | 24 hr | EC50 (18ºC) | 490 | Buchannan et al. 1970 | Duration |
| Shore crab (adult male), *Hemigrapsus oregonensis* | 80% | 24 hr | EC50 | 710 | Stewart et al. 1967 | Duration |
| Shore crab (adult female), *Hemigrapsus oregonensis* | 80% | 24 hr | EC50 | 270 | Stewart et al. 1967 | Duration |
| Sand dollar, *Echinarachnius parma* | - | 72 hr | NOEC (development) | 10,000 | Crawford and Guarino 1976 | Duration |
| Sea urchin (embryo/larva), *Arbacia punctulata* | 99% | 48 hr | LC50 | 4,700 | Thursby and Champlin 1991a | Duration |
| Sheepshead minnow, *Cyprinodon variegatus* | 99% | 24 hr | LC50 | 6,300 | Thursby and Champlin 1991a | Duration |
| Sheepshead minnow, *Cyprinodon variegatus* | 99% | 48 hr | LC50 | 6,300 | Thursby and Champlin 1991a | Duration |
| Sheepshead minnow, *Cyprinodon variegatus* | 99% | 72 hr | LC50 | 6,000 | Thursby and Champlin 1991a | Duration |

## Appendix I. Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Sheepshead minnow, *Cyprinodon variegatus* | 99% | 96 hr | LC50 (fed) | 5,800 | Thursby and Champlin 1991a | Test species fed |
| Sheepshead minnow, *Cyprinodon variegatus* | 98% | 24 hr | LC50 | 2,800 | Hansen 1969; 1970 | Duration |
| Sheepshead minnow, *Cyprinodon variegatus* | 98% | 1.5 hr | No avoidance | 100 | Hansen 1969; 1970 | Duration |
| Longnose killifish (juvenile), *Fundulus similis* | 99.7% | 48 hr | EC50 (mortality) | 1,600 | Hansen 1980; Mayer 1987 | Duration |
| Longnose killifish, *Fundulus similis* | - | 24 hr | LC50 | 1,750 | Butler 1963 | Duration |
| Longnose killifish, *Fundulus similis* | - | 48 hr | LC50 | 1,750 | Butler 1963 | Duration |
| Killifish (embryo), *Fundulus heteroclitus* | - | 40 day | LOEC (fry development) | 10 | Crawford and Guarino 1985 | Duration |
| Killifish, *Fundulus heteroclitus* | 99% | 10 day | LC50 | >10,000 | Shea and Berry 1983 | Duration |
| Mummichog, *Fundulus heteroclitus* | 99.1% | 10 day | LC40 | 10,000 | Shea and Berry 1983 | Duration |
| Killifish, (8-16 cell stage), *Fundulus heteroclitus* | 99.2% | 72 hr | NOEC (development arrest) | 100 | Weis and Weis 1974a | Duration |
| Atlantic silverside (2-3 wk), *Menidia beryllina* | 99% | 24 hr | LC50 | 1,800 | Thursby and Champlin 1991a | Duration |
| Atlantic silverside (2-3 wk), *Menidia beryllina* | 99% | 48 hr | LC50 | 1,700 | Thursby and Champlin 1991a | Duration |
| Atlantic silverside (2-3 wk), *Menidia beryllina* | 99% | 72 hr | LC50 | 1,600 | Thursby and Champlin 1991a | Duration |
| Atlantic silverside (2-3 wk), *Menidia beryllina* | 99% | 96 hr | LC50 (fed) | 1,600 | Thursby and Champlin 1991a | Test species fed |
| Atlantic silverside (juvenile), *Menidia beryllina* | 99.2% | 24 hr | Disruption in schooling behavior | 100 | Weis and Weis 1974b | Duration |
| Threespine stickleback (juvenile), *Gasterosteus aculeatus* | 80% | 24 hr | EC50 | 6,700 | Stewart et al. 1967 | Duration |
| Threespine stickleback, *Gasterosteus aculeatus* | 95% | 48 hr | LC50 | 10,450 | Katz 1961 | Duration |

## Appendix I. Other Data on Effects of Carbaryl to Estuarine/Marine Aquatic Organisms

| Species | Chemical | Duration | Effect | Concentration (µg/L) | Reference | Reason Other Data |
|---|---|---|---|---|---|---|
| Threespine stickleback, *Gasterosteus aculeatus* | 95% | 72 hr | LC50 | 4,940 | Katz 1961 | Duration |
| Threespine stickleback, *Gasterosteus aculeatus* | 95% | 48 hr | LC50 | 16,625 | Katz 1961 | Duration |
| Threespine stickleback, *Gasterosteus aculeatus* | 95% | 72 hr | LC50 | 6,175 | Katz 1961 | Duration |
| Striped bass (31 mm; 0.42 g), *Morone saxatilis* | 98% | 96 hr | LC50 | 1,000 | Korn and Earnest 1974 | Control survival not reported |
| Shiner perch (juvenile), *Cymatogaster aggregate* | 80% | 24 hr | EC50 | 3,900 | Stewart et al. 1967 | Duration |
| Mullet (juvenile), *Mugil cephalus* | 99.7% | 48 hr | EC50 (mortality) | 2,400 | Hansen 1980;<br>Mayer 1987 | Duration |
| White mullet (juvenile), *Mugil curema* | - | 48 hr | LC50 | 2,500 | Butler 1963 | Duration |
| English sole (juvenile), *Parophrys vetulus* | 80% | 24 hr | EC50 | 4,100 | Stewart et al. 1967 | Duration |

Dash indicates not available

# Appendix J

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| | | | | | | |
| Abbasi and Soni | Studies on the environmental impact of three common pesticides with respect to toxicity towards a larvivore (channelfish *N. denricus*). | 1991 | Channelfish, *Nuria denricus* | 96 hr LC50=34,670 | Not North American species | |
| Adhikary | Effect of pesticides on the growth, photosynthetic oxygen evolution and nitrogen fixation of *Westiellopsis prolific*. | 1989 | Cyanobacteria, *Westiellopsis prolifica* | - | Formulation | Sevin (50% carbaryl) |
| Adhikary et al. | Effect of the carbamate insecticide sevin® on *Anabaena sp*. and *Westiellopsis prolifica.* | 1984 | Cyanobacteria, *Anabaena sp. Westiellopsis prolifica* | - | Formulation | Sevin (50% carbaryl) |
| Aggarwal et al. | Effect of some carbamate pesticides on nodulation, plant yield and nitrogen fixation by *Pisum sativum* and *Vigna sinensis* in the presence of their rhizobia. | 1986 | Garden pea, *Pisum sativum*<br>Cow pea, *Vigna sinensis* | - | Sediment exposure | |
| Agrawal | The accumulation of biocide residues in a few tissues of *Lamellidens marginalis*. | 1986 | Bivalve, *Lamellidens marginalis* | - | Bioaccumulation: steady state not reached | Static, unmeasured study |
| Almar et al. | Influence of temperature on several pesticides toxicity to *Melanopsis dufouri* under laboratory conditions. | 1988 | Snail, *Melanopsis dufouri* | 96 hr LC50=10,100 | Not North American species | |
| Anbu and Ramaswamy. | Adaptive changes in respiratory movements of an air-breathing fish, *Channa striatus* (Bleeker) exposed to carbamate pesticide, sevin. | 1991 | Snakehead catfish, *Channa striatus* | - | Formulation | Sevin (10% dust) |
| Ansara-Ross et al. | Probabilistic risk assessment of the environmental impacts of pesticides in the Crocodile (west) Marico catchment, North-West Province. | 2008 | - | - | Data modeling | |
| Areekul | Toxicity to fishes of insecticides used in paddy fields and water resources. I. Laboratory experiment. | 1986 | - | - | Lack of exposure details | Text in foreign language |
| Ariaratnam and Georghiou | Carbamate resistance in *Anopheles albimanus*. | 1975 | Mosquito, *Anopheles albimanus* | - | Not North American species | Metabolism study |
| Armstrong and Millemann | Effects of the insecticide carbaryl on clams and some other intertidal mud flat animals. | 1974a | - | - | Too few exposure concentrations (<3) | Community field exposure |
| Arora and Kulshrestha | Comparison of the toxic effects of two pesticides on the testes of a fresh water teleost *Channa striatus* Bloch. | 1984 | Snakehead catfish, *Channa striatus* | - | Not North American species; Formulation | Sevin (50 WP) |
| Arora and Kulshrestha | Effects of chronic exposure to sublethal doses of two pesticides on alkaline and acid phosphatase activities in the intestine of a fresh water Teleost, *Channa striatus* Bloch. (Channidae). | 1985 | Snakehead catfish, *Channa striatus* | - | Not North American species; Formulation | Sevin (50 WP) |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Arunachalam and Palanichamy | Sublethal effects of carbaryl on surfacing behaviour and food utilization in the air-breathing fish, *Macropodus cupanus*. | 1982 | Paradise fish, *Macropodus cupanus* | - | Not North American species; Formulation | Carbaryl (50 WP) |
| Arunachalam et al. | Toxic and sublethal effects of carbaryl on a freshwater catfish, *Mystus vittatus* (Bloch). | 1980 | Catfish, *Mystus vittatus* | - | Not North American species; Formulation | Carbaryl (50 WP) |
| Arunachalam et al. | Effect of carbaryl on esterases in the air-breathing fish *Channa punctatus* (Bloch). | 1985a | Snakehead catfish, *Channa punctatus* | - | Not North American species; Only one exposure concentration | |
| Arunachalam et al. | Sublethal effects of carbaryl on food utilization and oxygen consumption in the air-breathing fish, *Channa punctatus* (Bloch). | 1985b | Snakehead catfish, *Channa punctatus* | 96 hr LC50=6,000 | Not North American species | |
| Arunachalam et al. | The impact of pesticides on the feeding energetics and body composition in the freshwater catfish, *Mystus vittatus*. | 1990 | Catfish, *Mystus vittatus* | - | Not North American species; Formulation | Carbaryl (50 EC) |
| Ashauer et al. | Simulating toxicity of carbaryl to *Gammarus pulex* after sequential pulsed exposure. | 2007a | Amphipod, *Gammarus pulex* | - | Not North American species | Pulsed exposure |
| Ashauer et al. | Modeling combined effects of pulsed exposure to carbaryl and chlorpyrifos on *Gammarus pulex*. | 2007b | Amphipod, *Gammarus pulex* | - | Not North American species; Mixture; Pulsed exposure | Carbaryl and chlorpyrifos |
| Atallah and Ishak | Toxicity of some commonly used insecticides to the snail *Biomphalaria alexandria*, intermediate host of *Schistosoma mansoni* in Egypt. | 1971 | Snail, *Biomphalaria alexandria* | 24 hr LC50=47,000 | Not North American species | |
| Bajpai and Perti | Resistance to malathion. | 1969 | Mosquito, *Culex fatigans* | - | Prior exposure | Malathion resistant strain |
| Bakr et al. | Insect growth regulators: I. Biological activity of some IGR's against the susceptible and resistant strains of *Culex pipiens* larvae: II. Pattern of cross resistance to IGR's in carbaryl-resistant strain. | 1989 | Mosquito, *Culex pipiens* | - | Prior exposure | Carbaryl-resistant strain |
| Balasubramanian and Ramaswami | Effect of pesticide sevin on acetylcholinesterase (AchE) activity in different tissues of *Oreochromis mossambicus* (Peters). | 1991 | Mozambique tilapia, *Oreochromis mossambicus* | 24 hr decrease AChE activity in brain and heart at 3,000 | Only two exposure concentrations | |
| Bansal et al. | Pesticide-induced alterations in the oxygen uptake rate of a freshwater major carp *Labeo rohita*. | 1979 | Carp, *Labeo rohita* | - | Not North American species; Formulation | Sevin (50% WP) |
| Bansal et al. | Predicting long-term toxicity by subacute screening of pesticides with larvae and early juveniles of four species of freshwater major carp. | 1980 | Carp,<br>*Labeo rohita*,<br>*Cirrhina mrigala*,<br>*Catla catla*,<br>*Cyprinus carpio* | - | Formulation | Sevin (50% WP) |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Barahona and Sanchez-Fortun. | Toxicity of carbamates to the brine shrimp *Artemia salina* and the effect of atropine, BW284c51, iso-OMPA and 2-PAM on carbaryl toxicity. | 1999 | Brine shrimp, *Artemia salina* | | Brine shrimp | |
| Barker et al. | Relationship between *Legionella pneumophila* and *Acanthamoeba polyphaga*: physiological status and susceptibility to chemical inactivation. | 1992 | - | - | Not applicable | No carbaryl toxicity information |
| Barry | The effects of a pesticide on inducible phenotypic plasticity in *Daphnia*. | 1999 | Cladoceran, *Daphnia longicephala* | - | Formulation | Yates Carbaryl® |
| Basak and Konar | Effects of an organophosphorus insecticide, dimethoate, on the survival, behavior, growth and reproduction of fish. | 1975 | - | - | Not applicable | No carbaryl toxicity information |
| Basak and Konar | Toxicity of six insecticides to fish. | 1976a | Carp, *Cyprinus carpio*<br>Mozambique tilapia, *Oreochromis mossambicus*<br>Catfish, *Heteropneustes fossilis* | - | Formulation | Sevin (50% WP) |
| Basak and Konar | Pollution of water by pesticides and protection of fishes: parathion. | 1976b | Carp, *Cyprinus carpio*<br>Mozambique tilapia, *Oreochromis mossambicus*<br>Catfish, *Heteropneustes fossilis* | - | Formulation | Sevin (50% WP) |
| Basha et al. | Respiratory potentials of the fish (*Tilapia mossambica*) under malathion, carbaryl and lindane intoxication. | 1984 | Mozambique tilapia, *Oreochromis mossambicus* | 48 hr decreased oxygen consumption at 1,832 | Only one exposure concentration | |
| Basol et al. | Comparative toxicity of some pesticides on human health and some aquatic species. | 1980 | Electric eel | - | Altered test species; No scientific name given | |
| Basso et al. | Alterations of *Aplysia* feeding behavior following acute carbamate intoxication. | 1986 | Marine snails, *Aplysia depilans*, *Aplysia punctata*, *Aplysia fasciata* | - | Formulation | AS 50, Sipcam (47.5% carbaryl) |
| Beauvais et al. | Cholinergic and behavioral neurotoxicty of carbaryl and cadmium to larval rainbow trout (*Oncorhynchus mykiss*). | 2001 | Rainbow trout, *Oncorhynchus mykiss* | - | Excessive solvent | 0.75 mL/L acetone |
| Beyers et al. | Effects of rangeland aerial application of sevin-4-oil® on fish and aquatic invertebrate drift in Little Missouri River, North Dakota. | 1995 | - | - | Formulation | Sevin-4-oil® |
| Bhatia | Toxicity of some pesticides to *Puntius ticto* (Hamilton). | 1971a | Ticto barb, *Puntius ticto* | 96 hr TLm=70,000 | Not North American species | |

## Appendix J.  List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Bhatia | Toxicity of some insecticides to *Cirrhinus mrigala* (Hamilton) and *Colisa fasciata* (Bloch & Schneider). | 1971b | Mrigal,<br>*Cirrhinus mrigala*<br>Kholisa,<br>*Colisa fasciata* | 96 hr<br>LC50=3,168<br>LC50=1,237 | Not North American species | |
| Bhattacharya | Target and non-target effects of anticholinesterase pesticides in fish. | 1993 | Snakehead catfish,<br>*Channa punctatus* | - | Formulation | 50% carbaryl |
| Bhattacharya | Stress response to pesticides and heavy metals in fish and other vertebrates. | 2001 | - | - | Review of previous studies | |
| Bhavan and Geraldine | Carbaryl-induced alterations in biochemical metabolism of the prawn, *Macrobrachium malcolmsonii*. | 2002 | Prawn,<br>*Macrobrachium malcolmsonii* | - | Not North American species;<br>Formulation | Sevin<br>(50% carbaryl) |
| Bhunia et al. | Carbaryl-induced effects of glutathione content, glutathione reductase and superoxide dismutase activity of the cyanobacterium *Nostoc muscorum*. | 1993 | Cyanobacterium,<br>*Nostoc muscorum* | - | Altered test species | Excised tissue |
| Bhunya and Sahoo | Genotoxic potential of carbaryl in the peripheral blood erythrocytes of *Anabas testudineus*. | 2004 | Climbing perch,<br>*Anabas testudineus* | - | Injected toxicant;<br>Formulation | Sevin<br>(50% carbaryl) |
| Bielecki | The effect of phoschlorine, carbatox and copper sulphate on the development of eggs and hatching of miracidia in *Fasciola hepatica* L. | 1987 | Liver fluke,<br>*Fasciola hepatica* | 3 hr<br>inhibit egg development at 3,000,000 | Only one exposure concentration | |
| Binelli et al. | New evidence for old biomarkers: effects of several xenobiotics on EROD and AChE activities in zebra mussel (*Dreissena polymorpha*). | 2006 | Zebra mussel,<br>*Dreissena polymorpha* | 96 hr<br>Decrease AChE activity at 100,000 | Only one exposure concentration | |
| Bluzat and Seuge | Effects of three insecticides (lindane, fenthion, and carbaryl) on the acute toxicity to four aquatic invertebrate species and the chronic toxicity. | 1979 | Amphipod,<br>*Gammarus pulex*<br>Mayfly,<br>*Cleon sp.*<br>Midge,<br>*Chaoborus sp.*<br>Snail,<br>*Lymnaea stagnalis* | 48 hr<br>LC50=29<br>LC50=480<br>LC50=296<br>LC50=21,000 | Excessive solvent used; Text in foreign language | 1% solvent |
| Bogacka and Groba | Toxicity and biodegradation of chlorfenvinphos, carbaryl and propoxur in water environment. | 1980 | Cladoceran,<br>*Daphnia magna* | 48 hr<br>LC50=1 | Lack of detail; text in foreign language | |
| Bogaerts et al. | Use of ciliated protozoan *Tetrahymena pyriformis* for the assessment of toxicity and quantitative structure-activity relationships of xenobiotics: comparison with the microtox test. | 2001 | Protozoan,<br>*Tetrahymena pyriformis* | - | Excessive solvent used | DMSO (0.12%) |
| Bonning and Hemingway | The efficacy of acetylcholinesterase in organophosphorus and carbamate resistance in *Culex pipiens* L. from Italy. | 1991 | Mosquito,<br>*Culex pipiens* | - | Prior exposure | Carbaryl resistant strain |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Boone | Examining the single and interactive effects of three insecticides on amphibian metamorphosis. | 2008 | American toad, *Bufo americanus*<br>Green frog, *Rana clamitans* | - | Formulation; Only two exposure concentrations | Sevin (22.5% carbaryl) |
| Boone and Bridges | Effects of carbaryl on green frog (*Rana clamitans*) tadpoles: timing of exposure versus multiple exposures. | 2003 | Green frog, *Rana clamitans* | - | Pulsed exposure | |
| Boone and James | Interactions of an insecticide, herbicide, and natural stressors in amphibian community mesocosms. | 2003 | American toad, *Bufo americanus*<br>Southern leopard frog, *Rana sphenocephala*<br>Spotted salamander, *Ambystoma maculatum*<br>Small-mouth salamander, *A. texanum* | - | Only two exposure concentrations; Formulation | Sevin (21.3% carbaryl) |
| Boone and Semlitsch | Interactions of an insecticide with larval density and predation in experimental amphibian communities. | 2001 | Woodhouse toad, *Bufo woodhouse*<br>Gray treefrog, *Hyla versicolor*<br>Green frog, *Rana clamitans* | - | Formulation | Sevin (21.3% carbaryl) |
| Boone and Semlitsch | Interactions of bullfrog tadpole predators and an insecticide: predation release and facilitation. | 2003 | Bullfrog, *Rana catesbeiana*<br>Red-spotted newt, *Notophthalmus viridescens*<br>Bluegill, *Lepomis macrochirus*<br>Crayfish, *Orconectes sp.* | - | Only two exposure concentrations; Formulation | Sevin (21.3% carbaryl) |
| Boone et al. | Growth and development of larval green frogs (*Rana clamitans*) exposed to multiple doses of an insecticide. | 2001 | Green frog, *Rana clamitans* | - | Formulation | Sevin (21.3% carbaryl) |
| Boone et al. | Effects of an insecticide on amphibians in large-scale experimental ponds. | 2004 | Woodhouse toad, *Bufo woodhouse*<br>Southern leopard frog, *Rana sphenocephala* | - | Formulation | Sevin (21.3% carbaryl) |
| Boone et al. | Multiple sublethal chemicals negatively affect tadpoles of the green frog, *Rana clamitans*. | 2005 | Green frog, *Rana clamitans* | - | Only one exposure concentration; Formulation | Sevin (22.5% carbaryl) |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Boone et al. | Multiple stressors in amphibian communities: Effects of chemical contamination, bullfrogs, and fish. | 2007 | American toad, *Bufo americanus*<br>Southern leopard frog, *Rana sphenocephala*<br>Bullfrog, *Rana catesbeiana*<br>Spotted salamander, *Ambystoma maculatum*<br>Bluegill, *Lepomis macrochirus* | - | Formulation | Sevin (22.5% carbaryl) |
| Boran et al. | Acute toxicity of carbaryl, methiocarb and carbosulfan to the rainbow trout (*Oncorhynchus mykiss*) and guppy (*Poecilia reticulata*). | 2007 | Rainbow trout, *Oncorhynchus mykiss*<br>Guppy, *Poecilia reticulata* | 96 hr<br>LC50=522<br>LC50=1,383 | Excessive solvent used | 0.2% |
| Bradbury et al. | Use of respiratory-cardiovascular responses of rainbow trout (*Oncorhynchus mykiss*) in identifying acute toxicity syndromes in fish: part 4. Central nervous system seizure agents. | 1991 | Rainbow trout, *Oncorhynchus mykiss* | - | Too few test organisms; Surgically altered test species | Spinally transected trout |
| Bridges | Effects of a pesticide on tadpole activity and predatory avoidance behavior. | 1999a | Gray treefrog, *Hyla versicolor* | 24 hr decrease tadpole activity at 2,500 | Only two exposure concentrations | |
| Bridges | Predator-prey interactions between two amphibian species: effects of insecticide exposure. | 1999b | Southern leopard frog, *Rana sphenocephala*<br>Red-spotted newt, *Notophthalmus viridescens* | 1 hr decrease newt consumption of tadpoles at 2,500 | Only one exposure concentration | |
| Bridges | Long-term effects of pesticide exposure at various life stages of the southern leopard frog (*Rana sphenocephala*). | 2000 | Southern leopard frog, *Rana sphenocephala* | - | Unmeasured chronic exposure | |
| Bridges and Boone | The interactive effects of UV-B and insecticide exposure on tadpole survival, growth and development. | 2003 | Southern leopard frog, *Rana sphenocephala* | - | Formulation | Sevin ® (22.5% carbaryl) |
| Bridges and Semlitsch | Variation in pesticide tolerance of tadpoles among and within species of ranidae and patterns of amphibian decline. | 2000 | - | - | Only one exposure concentration | |
| Bridges and Semlitsch | Genetic variation in insecticide tolerance in a population of southern leopard frogs (*Rana sphenocephala*): implications for amphibian conservation | 2001 | Southern leopard frog, *Rana sphenocephala* | - | Only one exposure concentration | |
| Bridges et al. | Comparative contaminant toxicity: are amphibian larvae more sensitive than fish? | 2002 | - | - | Review of previous studies | |

# Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Brown | Effects of split applications of sevin-4-oil® on aquatic invertebrate drift. | 1980 | - | - | Formulation | Sevin-4-oil® |
| Bruner and Fisher | The effects of temperature, pH, and sediment on the fate and toxicity of 1-naphthol to the midge larvae *Chironomus riparius*. | 1993 | Midge, *Chironomus riparius* | - | Not applicable | No carbaryl toxicity information |
| Burdick et al. | Effect of sevin upon the aquatic environment. | 1960 | - | - | Formulation | Sevin |
| Burdick et al. | Toxicity of sevin (carbaryl) to fingerling brown trout. | 1965 | Brown trout | - | Lack of detail; Formulation | Sevin; Species name not given |
| Butler | Pesticide-wildlife studies, 1964. A review of Fish and Wildlife Service investigations during the calendar year. | 1964 | Marine shrimp and drills | - | Formulation | Sevin<br>(10%, 3% and 2%) |
| Cajaraville et al. | Acute toxicity of two hydroxylated hydrocarbons to the prosobranch gastropod *Littorina littorea*. | 1989a | Snail, *Littorina littorea* | - | Not applicable | No carbaryl toxicity information |
| Cajaraville et al. | A stereological survey of lysosomal structure alterations in *Littorina littorea* exposed to 1-naphthol. | 1989b | Snail, *Littorina littorea* | - | Not applicable | No carbaryl toxicity information |
| Cajaraville et al. | Short-term toxic effects of 1-naphthol on the digestive gland-gonad complex of the marine prosobranch *Littorina littorea* (L): a light microscopic study. | 1990 | Snail, *Littorina littorea* | - | Not applicable | No carbaryl toxicity information |
| Calapaj | Chemical pollution of Mytilus. I. Radiostrontium, radiocesium, inorganic mercury, hexavalent chromium. | 1973 | - | - | Lack of detail | Text in foreign language |
| Campero et al. | Ecological relevance and sensitivity depending on the exposure time for two biomarkers. | 2007a | Damselfly, *Coenagrion puella* | 7d Growth<br>NOEC=5<br>LOEC=40 | Not North American species | |
| Campero et al. | Sublethal pesticide concentrations and predation jointly shape life history: Behavioral and physiological mechanisms. | 2007b | Damselfly, *Coenagrion puella* | - | Not North American species | Predator present in exposure medium |
| Capaldo | Effects of carbaryl (SEVIN) on the stage I zoeae of the red-jointed fiddler crab, *Uca minax* (LeConte). | 1987 | Red-jointed fiddler crab, *Uca minax* | - | Formulation | Sevin<br>(27% carbaryl) |
| Carlson et al. | Neurological effects on startle response and escape from predation by medaka exposed to organic chemicals. | 1998 | Medaka, *Oryzias latipes* | 48 hr<br>LC50=9,400 | Not North American species | |
| Carter | 'In vivo' studies of brain acetylcholinesterase inhibition by organophosphate and carbamate insecticides in fish. | 1971 | - | - | Excessive solvent | |
| Carter and Graves | Measuring effects of insecticides on aquatic animals. | 1972 | - | - | Lack of exposure details | No scientific names given |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Chaiyarach et al. | Acute toxicity of the insecticides toxaphene and carbaryl and the herbicides propanil and molinate to four species of aquatic organisms. | 1975 | Mosquitofish, *Gambusia affinis*<br>Grass shrimp, *Palaemonetes kadiakensis*<br>Crayfish, *Procambarus simulans*<br>Clam, *Rangia cuneata* | 96 hr<br>LC50=31,800<br>LC50=120<br>LC50=2,430<br>LC50=125,000 | Prior exposure | |
| Chakrawarti and Chaurasia | Toxicity of some organophosphate, chlorinated and carbamate pesticides to some fresh water fishes. | 1981 | Walking catfish, *Clarias batrachus*<br>Catfish, *Heteropneustes fossilis* | 96 hr LC50= >1,200,000 for both species | Lack of exposure details | Dilution water not characterized |
| Chambers | Investigation of chemical control of ghost shrimp on oyster grounds 1960-1963. | 1969 | Ghost shrimp, *Callianassa californiensis* | - | Formulation | Sevin |
| Chandran et al. | Method for the estimation of safe experimental concentration for intermediate toxicity test. | 1991 | Catfish, *Mystus tengara*<br>Catfish, *Heteropneustes fossilis*<br>Catfish, *Anabas testudineus* | 96 hr<br>LC50=18,000<br>LC50=58,000<br>LC50=20,500 | Not North American species | |
| Chang et al. | Impact of pesticide application on zooplankton communities with different densities of invertebrate predators: an experimental analysis using small-scale mesocosms. | 2005 | - | - | Only one exposure concentration | |
| Chari | A rapid bioassay procedure to determine the toxicity of pesticides to *Channa punctatus* Bloch. | 1992 | Snakehead catfish, *Channa punctatus* | - | Formulation | Sevin |
| Cheah et al. | Some effects of rice pesticides on crawfish. | 1980a | Crayfish, *Procambarus clarkii* | 96 hr<br>LC50=500 | Lack of exposure details | |
| Cheah et al. | Acute toxicity of selected rice pesticides to crayfish, *Procambarus clarkii*. | 1980b | Crayfish, *Procambarus clarkii* | - | Formulation | Sevin |
| Chen et al. | Laboratory studies on the susceptibility of mosquito-eating fish, *Lebistes reticulatus* and the larvae of *Culex pipiens fatigans* to insecticides. | 1971 | Guppy, *Lebistes reticulatus*<br>Mosquito, *Culex pipiens fatigans* | 24 hr<br>LC50=2,600<br>LC50=400 | Excessive solvent used; Lack of exposure details | 0.4%; Dilution water not characterized |
| Chen and Sudderuddin | Toxicological studies of insecticides on *Culex quinquefasciatus* Say and *Aedes aegypti* (L.). | 1978 | Mosquito, *Culex quinquefasciatus*<br>Mosquito, *Aedes aegypti* | 24 hr<br>LC50=680<br>LC50=690 | Lack of exposure details | Dilution water not characterized |
| Chitra and Pillai | Development of organophosphorus and carbamate-resistance in Indian strains of *Anopheles stephensi* Liston. | 1984 | Mosquito, *Anopheles stephensi* | - | Excessive solvent | 4 mL/L ethanol |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Choudhury et al. | Non lethal concentrations of pesticide impair ovarian function in the freshwater perch, *Anabas testudineus*. | 1993 | Perch,<br>*Anabas testudineus* | - | Not North American species; Only one exposure concentration | |
| Christensen and Tucker | Effects of selected water toxicants on the in vitro activity of fish carbonic anhydrase. | 1976 | Channel catfish,<br>*Ictalurus punctatus* | - | Surgically altered test species | Red blood cells |
| Christoffers and Ernst | The in-vivo fluorescence of *Chlorella fusca* as a biological test for the inhibition of photosynthesis. | 1983 | Green alga,<br>*Chlorella fusca* | - | Only one exposure concentration; Excessive solvent | 1% acetone |
| Chung et al. | Toxicity of carbaryl, diquat dibromide, and fluoranthene, individually and in mixture, to larval grass shrimp, *Palaemonetes pugio*. | 2008 | Grass shrimp,<br>*Palaemonetes pugio* | 96 hr<br>LC50=43.02 | Excessive solvent used | 0.1% |
| Cocks | The effect of aldrin on water balance in the freshwater pulmonate gastropod (*Biomphalaria glabrata*). | 1973 | Snail,<br>*Biomphalaria glabrata* | 24 hr<br>heart beat 31% of control at 64,390 | Not North American species | |
| Conners and Black | Evaluation of lethality and genotoxicity in the freshwater mussel *Utterbackia imbecillis* (Bivalvia: Unionidae) exposed singly and in combination to chemicals used in lawn care. | 2004 | Mussel,<br>*Utterbackia imbecillis* | - | Formulation | Sevin<br>(22.5% carbaryl) |
| Cook et al. | Succession of microfungi in estuarine microcosms perturbed by carbaryl, methyl parathion and pentachlorophenol. | 1980 | - | - | Only one exposure concentration | |
| Coors and De Meester | Synergistic, antagonistic and additive effects of multiple stressors: Predation threat, parasitism and pesticide exposure in *Daphnia magna*. | 2008 | Cladoceran,<br>*Daphnia magna* | 21 d reduced reproduction at 5.6 | Only one exposure concentration; Lack of exposure details | Dilution water not characterized |
| Coppage | Anticholinesterase action of pesticidal carbamates in the central nervous system of poisoned fishes. | 1977 | Sailfin molly,<br>*Poecilia latipinna* | 15 hr reduced survival at 1,333 | Only one exposure concentration; Lack of exposure details | Dilution water not characterized |
| Courtemanch and Gibbs | The effects of sevin-4-oil® on lentic communities. | 1978 | - | - | Formulation | Sevin-4-oil® |
| Cutkomp et al. | ATPase activity in fish tissue homogenates and inhibitory effects of DDT and related compounds. | 1971 | Bluegill,<br>*Lepomis macrochirus* | - | Surgically altered test species | Homogenized tissue |
| Dahlberg | Toxicity to acrolein to barnacles (*Balanus eburneus*). | 1971 | Barnacle,<br>*Balanus eburneus* | - | Not applicable | No carbaryl toxicity information |
| Damalas et al. | Bispyribac-sodium efficacy on early watergrass (*Echinochloa oryzoides*) and late watergrass (*Echinochloa phyllopogon*) as affected by coapplication of selected rice herbicides and insecticides. | 2008 | Early Watergrass,<br>*Echinochloa oryzoides*<br>Late Watergrass,<br>*Echinochloa phyllopogon* | - | Mixture | Bispyribac-sodium and carbaryl |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Das and Adhikary | Toxicity of three pesticides to several rice-field cyanobacteria. | 1996 | Cyanobacteria | - | Formulation | Sevin (50% WP) |
| Das and Kumar | Toxicity of carbaryl on α-amylase of the fish *Colisa fasciatus*. | 1993 | Giant gourami, *Colisa fasciatus* | 48 hr LC50=112 | Not North American species; Lack of detail | No procedure information provided |
| Das and Rajagopalan | Susceptibility of larvae of *Culex fatigans* (Wiedmann), *Anopheles stephensi* (Liston) and *Aedes aegypti* (Linn.) to insecticides in Pondicherry. | 1979 | Mosquito, *Culex fatigans*<br>Mosquito, *Anopheles stephensi*<br>Mosquito, *Aedes aegypti* | - | Formulation | Sevimol (40% carbaryl) |
| Davey et al. | Toxicity of five ricefield pesticides to the mosquitofish, *Gambusia affinis*, and green sunfish, *Lepomis cyanellus*, under laboratory and field conditions in Arkansas. | 1976 | Mosquitofish, *Gambusia affinis*<br>Green sunfish, *Lepomis cyanellus* | - | Formulation | |
| Davidson et al. | Effects of chytrid and carbaryl exposure on survival, growth and skin peptide defenses in foothill yellow-legged frogs. | 2007 | Foothill yellow-legged frog, *Rana boylii* | - | Formulation; Only one exposure concentration | |
| Deshmukh and Keshavan | Acute toxicity of DDT and sevin to the bullfrog, *Rana tigrina*. | 1984 | Bullfrog, *Rana tigrina* | 96 hr LC50=70,000 | Not North American species | |
| Dhanapakiam and Premlatha | Histopathological changes in the kidney of *Cyprinus carpio* exposed to malathion and sevin. | 1994 | Carp, *Cyprinus carpio* | - | Formulation | Sevin (commercial grade) |
| Dimayuga et al. | Insecticide-induced accumulation of melanomacrophage centers (MMCs) in Nile tilapia (*Oreochromis niloticus* Linn.). | 2008 | Nile tilapia, *Oreochromis niloticus* | - | Formulation | Sevin |
| Dodson et al. | Behavioral responses of *Daphnia pulex* exposed to carbaryl and *Chaoborus* kairomone | 1995 | Cladoceran, *Daphnia pulex* | - | Only two exposure concentrations | |
| Downing et al. | Community and ecosystem responses to a pulsed pesticide disturbance in freshwater ecosystems. | 2008 | Aquatic mesocosm | - | Formulation | Sevin (5% carbaryl) |
| Dumbauld et al. | Efficacy of the pesticide carbaryl for thalassinid shrimp control in Washington State oyster (*Crassostrea gigas*, Thunberg, 1793) aquaculture. | 1997 | - | - | Mixture, Field exposure; Formulation | |
| Dumbauld et al. | Response of an estuarine benthic community to application of the pesticide carbaryl and cultivation of Pacific oysters (*Crassostrea gigas*) in Willapa Bay, Washington. | 2001 | Estuarine benthic community | - | Formulation; Mixture | Field exposure |
| Dumbauld et al. | An integrated pest management program for burrowing shrimp control in oyster aquaculture. | 2006 | - | - | Mixture | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Durfey and Simpson | Control of two burrowing shrimp species, ghost shrimp, *Callianassa californiensis* and mud shrimp, *Upogebia pugettensis*, using subsurface injection of carbaryl ("sevin") as an alternative to aerial application in preparation of oyster beds for seeding. | 1995 | Ghost shrimp, *Callianassa californiensis*<br>Mud shrimp, *Upogebia pugettensis* | - | Sediment exposure | |
| El-Magid | Effects of some pesticides on the growth of blue-green alga *Spirulina platensis*. | 1986 | Blue-green alga, *Spirulina platensis* | 5 d Growth NOEC=1,000 LOEC=5,000 | Not North American species | |
| Epstein and Legator | The mutagenicity of pesticides concepts and evaluation. | 1971 | - | - | Review of previous studies | |
| Estenik and Collins | In vivo and in vitro studies of mixed-function oxidase in an aquatic insect, *Chironomus riparius*. In: Pesticide and xenobiotic metabolism in aquatic organisms. | 1979 | Midge, *Chironomus riparius* | 24 hr LC50=104.5 | Excessive solvent used | 0.1% |
| European Commission DG Environment | Endocrine disrupters: Study on gathering information on 435 substances with insufficient data. | 2002 | - | - | Review of previous studies | |
| Feldhaus et al. | Interactive effects of pesticide mixtures on the neurobehavioral responses and AChE levels of the planaria. | 1998 | Brown planaria, *Dugesia tigrina* | - | Dilution water is deionized water without the proper salts added | |
| Fernandez et al. | Amphibian micronucleus test(s): A simple and reliable method for evaluating in vivo genotoxic effects of freshwater pollutants and radiations: Initial assessment. | 1993 | Newt, *Pleurodeles waltl* | 8 d increased micronucleus frequency at 2,500 | Only one exposure concentration | |
| Fernandez-Alba et al. | Toxicity of pesticides in wastewater: a comparative assessment of rapid bioassays. | 2001 | Bacterium, *Vibrio fischeri*<br>Cladoceran, *Daphnia magna* | - | Not applicable | No carbaryl toxicity information |
| Ferrari et al. | Effects of carbaryl and azinphos methyl on juvenile rainbow trout (*Oncorhynchus mykiss*) detoxifying enzymes. | 2007b | Rainbow trout, *Oncorhynchus mykiss* | 96 hr decreased liver CbE at 1,000 | Only two exposure concentrations | |
| Ferrari et al. | Antioxidant responses to azinphos methyl and carbaryl during the embryonic development of the toad *Rhinella* (*Bufo*) *arenarum* Hensel. | 2009 | Toad, *Rhinella (Bufo) arenarum* | Increased embryonic development malformations at 20,000 | Not North American species; Only one exposure concentration | |
| Fischer et al. | The effect of benzimidazole, carbamate and organophosphorous pesticides on the oxygen-dependent nuclear volume alterations in the chloragocytes of *Tubifex tubifex* Mull. | 1982 | Tubificid worm, *Tubifex tubifex* | 5 d did not induce nuclear swelling within the physiological range at 1,000 | Only one exposure concentration | |
| Fisher and Lohner | Studies on the environmental fate of carbaryl as a function of pH. | 1986 | Midge, *Chironomus riparius* | 24 hr LC50=103 | Excessive solvent used | 1 mL/L |

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| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Fisher et al. | Quantitative structure-activity relationships for predicting the toxicity of pesticides in aquatic systems with sediment. | 1993 | Midge, *Chironomus riparius* | - | Excessive solvent used; Sediment in exposure media | 1 mL/500 mL acetone |
| Fitzgerald et al. | Studies on chemicals with selective toxicity to blue-green algae. | 1952 | - | - | Not applicable | No carbaryl toxicity information |
| Fleeger et al. | Indirect effects of contaminants in aquatic ecosystems. | 2003 | - | - | Review of previous studies | |
| Foster and Tullis | A quantitative structure-activity relationship between partition coefficients and the acute toxicity of naphthalene derivatives in *Artemia salina* nauplii. | 1984 | Brine shrimp, *Artemia salina* | - | Brine shrimp | |
| Freitag et al. | Ecotoxicological profile analysis. VII. Screening chemicals for their environment behavior by comparative evaluation | 1982 | Green alga, *Chlorella fusca var. vacuolated* | - | Bioaccumulation study: steady state not reached, static exposure | |
| Frempong-Boadu | A laboratory study of the effectiveness of methoxychlor, fenthion and carbaryl against blackfly larvae (Diptera: Simuliidae). | 1966 | Blackflies, *Prosimulium mixtum*, *P. magnum*, *Simulium venustum*, *S. tuberosum* | - | Formulation | 1% carbaryl |
| Galindo Reyes et al. | Effects of pesticides on DNA and protein of shrimp larvae *Litopenaeus stylirostris* of the California Gulf. | 2002 | Shrimp larvae, *Litopenaeus stylirostris* | - | Formulation | Sevin |
| Garcia-Ripoll et al. | Confirming *Pseudomonas putida* as a reliable bioassay for demonstrating biocompatibility enhancement by solar photo-oxidative process of a biorecalcitrant effluent. | 2009 | Bacteria, *Pseudomonas putida* | - | Sediment exposure | |
| Ghosh | Interrelationship of acetylcholinesterase-acetylcholine, triiodothyronine-thyroxine and gonadotropin-gonadotropin releasing hormone in pesticide treated murrel, *Channa punctatus* (Bloch). | 1990 | Snakehead catfish, *Channa punctatus* | - | Lack of detail (procedures); Not North American species; Only one exposure concentration | |
| Ghosh and Bhattacharya | Elevation of c-reactive protein in serum of *Channa punctatus* as an indicator of water pollution. | 1992 | Snakehead catfish, *Channa punctatus* | - | Not North American species; Only one exposure concentration | |
| Ghosh et al. | Impact of nonlethal levels of metacid-50 and carbaryl on thyroid function and cholinergic system of *Channa punctatus*. | 1989 | Snakehead catfish, *Channa punctatus* | - | Not North American species; Only one exposure concentration | |
| Ghosh et al. | Impairment of the regulation of gonadal function in *Channa punctatus* by the metacid-50 and carbaryl under laboratory and field conditions. | 1990 | Snakehead catfish, *Channa punctatus* | - | Not North American species; Only one exposure concentration | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Ghosh et al. | Glutathione depletion in the liver and kidney of *Channa punctatus* exposed to carbaryl and metacid-50. | 1993 | Snakehead catfish,<br>*Channa punctatus* | - | Not North American species;<br>Only one exposure concentration | |
| Gibbs | Effects of a split application of sevin-4-oil on aquatic organisms. | 1979 | - | - | Formulation | Sevin-4-oil |
| Gibbs et al. | The effects on pond macroinvertebrates from forest spraying of carbaryl (sevin-4-oil) and its persistence in water and sediment. | 1981 | - | - | Formulation | Sevin-4-oil |
| Gibbs et al. | The effects in 1982 on pond macroinvertebrates from forest spraying of carbaryl, sevin-4-oil, in 1980. | 1982 | - | - | Formulation | Sevin-4-oil |
| Gibbs et al. | Persistence of carbaryl (sevin-4-oil) in woodland ponds and its effects on pond macroinvertebrates following forest spraying. | 1984 | Spruce budworm,<br>*Choristoneura fumiferana* | - | Formulation | Sevin-4-oil<br>(49% carbaryl) |
| Gilbert et al. | Rapid assessment of metabolic activity in marine microalgae: application in ecotoxicological test and evaluation of water quality. | 1992 | Green alga,<br>*Tetraselmis suecica*<br>*Skeletonema costatum*<br>*Prorocentrum lima* | - | Lack of details (procedure, purity, exposure media) | |
| Gill et al. | Gill, liver, and kidney lesions associated with experimental exposures to carbaryl and dimethoate in the fish (*Puntius conchonius* Ham.). | 1988 | Barb,<br>*Puntius conchonius* | - | Not North American species;<br>Formulation | Sevin (50% WP) |
| Gillott et al. | The role of sediment as a modifying factor in pesticide-algae interactions. | 1975 | Alga,<br>*Euglena gracilis* | 24 hr<br>C-14 incorporation<br>NOEC=5<br>LOEC=10 | Excessive solvent used | 1 mL/L |
| Goel and Srivastava | Laboratory evaluation of some molluscicides against fresh water snails, *Indoplanorbis* and *Lymnaea* species. | 1981 | Snail,<br>*Indoplanorbis exustus*<br>Snail,<br>*Lymnaea acuminata* | 24 hr<br>LC50=30,000<br>LC50=15,980 | Not North American species;<br>Lack of exposure details | Dilution water not characterized |
| Gouda et al. | Toxicity of dimecron, sevin and lindex to *Anabas scandens* and *Heteropneustes fossilis*. | 1981 | Climbing perch,<br>*Anabas scandens*<br>Catfish,<br>*Heteropneustes fossilis* | - | Not North American species;<br>Formulation | Sevin<br>(50% carbaryl) |
| Gray et al. | Emerging issues: The effects of endocrine disrupters on reproductive development. | 1996 | - | - | Not applicable | No carbaryl toxicity information |
| Groba and Trzcinska | Effect of selected organophosphorous and carbamate insecticides on rainbow trout (*Salmo gairdneri* R.). | 1979 | Rainbow trout,<br>*Oncorhynchus mykiss* | - | Only two exposure concentrations;<br>Lack of exposure details | Text in foreign language |
| Grosch | Reproduction tests: the toxicity for *Artemia* of derivatives from non-persistent pesticides. | 1973 | Brine shrimp,<br>*Artemia salina* | - | Brine shrimp | |

## Appendix J.  List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Gruber and Munn | Organophosphate and carbamate insecticides in agricultural waters and cholinesterase (ChE) inhibition in common carp (*Cyprinus carpio*). | 1998 | Common carp, *Cyprinus carpio* | - | Mixture | |
| Gupta and Sahai | Qualitative detection of organochlorine and carbamate residues in the brain of catfish, *Heteropenustes fossilis* (Bloch) by thin layer chromatography | 1989 | Catfish, *Heteropenustes fossilis* | - | Lack of detail (procedure) | |
| Gupta and Sundararaman | Correlation between burrowing capability and AChE activity in the earthworm, *Pheretima posthuma*, on exposure to carbaryl. | 1991 | Earthworm, *Pheretima posthuma* | - | Dilution water is distilled water without proper salts added | |
| Haines | Effect of an aerial application of carbaryl on brook trout (*Salvelinus fontinalis*) | 1981 | Brook trout, *Salvelinus fontinalis* | - | Lack of details (procedure) | |
| Han Il et al. | Studies on control effects of pesticide applications against the vector mosquito larvae in rice fields in Korea. | 1981 | Mosquito, *Culex tritaeniorhynchus*<br>*Anopheles sinensis* | - | Formulation | Sevin<br>(50% carbaryl) |
| Hanazato | Effects of long- and short-term exposure to carbaryl on survival, growth and reproduction of *Daphnia ambigua*. | 1991a | Cladoceran, *Daphnia ambigua* | - | Lack of details (procedure, duration) | |
| Hanazato | Effects of repeated application of carbaryl on zooplankton communities in experimental ponds with or without the predator *Chaoborus*. | 1991b | Zooplankton community | - | Only two exposure concentrations | |
| Hanazato | Pesticides as chemical agents inducing helmet formation on *Daphnia ambigua*. | 1991c | Cladoceran, *Daphnia ambigua* | - | Excessive solvent used | 3.5 mL/L ethanol |
| Hanazato | Insecticide inducing helmet development in *Daphnia ambigua*. | 1992 | Cladoceran, *Daphnia ambigua* | - | Only two exposure concentrations | |
| Hanazato | Combined effect of the insecticide carbaryl and the *Chaoborus* kairomone on helmet development in *Daphnia ambigua*. | 1995 | Cladoceran, *Daphnia ambigua* | - | Lack of details (procedure, duration) | |
| Hanazato and Dodson | Complex effects of a kairomone of *Chaoborus* and an insecticide on *Daphnia pulex*. | 1992 | Cladoceran, *Daphnia pulex* | - | Lack of details (procedure, duration) | |
| Hanazato and Hirokawa | Changes in vulnerability of *Daphnia* to an insecticide application depending on the population phase. | 2004 | Cladoceran, *Daphnia pulex* | - | Only one exposure concentration | |
| Hanazato and Yasuno | Effects of a carbamate insecticide, carbaryl, on the summer phyto- and zooplankton communities in ponds. | 1987 | Zooplankton community | - | Only one exposure concentration | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Hanazato and Yasuno | Influence of overwintering *Daphnia* on spring zooplankton communities: an experimental study. | 1989a | Zooplankton community | - | Only one exposure concentration; Possible mixture used | |
| Hanazato and Yasuno | Effects of carbaryl on the spring zooplankton communities in ponds. | 1989b | Zooplankton community | - | Only one exposure concentration | |
| Hanazato and Yasuno | Influence of persistence period of an insecticide on recovery patterns of a zooplankton community in experimental ponds. | 1990a | Zooplankton community | - | Formulation | 50% carbaryl |
| Hanazato and Yasuno | Influence of time of application of an insecticide on recovery patterns of a zooplankton community in experimental ponds. | 1990b | Zooplankton community | - | Formulation | 50% carbaryl |
| Hanazato and Yasuno | Influence of *Chaoborus* density on the effects of an insecticide on zooplankton communities in ponds. | 1990c | Zooplankton community | - | Formulation | 50% carbaryl |
| Hardersen and Wratten | The sensitivity of the nymphs of two New Zealand damselfly species (Odonata: Zygoptera) to azinphos-methyl and carbaryl. | 1996 | Damselfly,<br>*Xanthocnemis zealandia*<br>*Austrolestes colensonis* | 48 hr<br>LC50=600<br>LC50=3,130 | Not North American species | |
| Hardersen and Wratten | The effects of carbaryl exposure on the penultimate larval instars of *Xathocnemis zealandica* on emergence and fluctuating asymmetry. | 1998 | Damselfly, *Xanthocnemis zealandia* | - | Not North American species; Exposure concentrations fluctuated widely | |
| Harilal and Sahai | Qualitative identification of metabolites of carbaryl in the gonads of catfish *Heteropneustes fossilis* (Bloch). | 1990 | Catfish, *Heteropneustes fossilis* | - | Bioaccumulation study: steady state not reached; Mot North American species | |
| Havens | An experimental comparison of the effects of two chemical stressors on a freshwater zooplankton assemblage. | 1994 | Zooplankton community | - | Dilution water not characterized; Formulation | Commercial grade |
| Havens | Insecticide (carbaryl, 1-napthyl-n-methylcarbamate) effects on a freshwater plankton community: zooplankton size, biomass, and algal abundance. | 1995 | Plankton community | - | Formulation | Commercial grade |
| Haynes et al. | The toxicity of sevin to goldfish. | 1958 | Goldfish, *Carassius auratus* | - | Formulation | Sevin<br>(50% carbaryl) |
| Heldal et al. | Toxic responses of the green alga *Dunaliella bioculata* (Chlorophycea, Volvocales) to selected oxidized hydrocarbons. | 1984 | Green alga, *Dunaliella bioculata* | - | Not applicable | No carbaryl toxicity information |
| Hemingway and Georghiou | Studies on the acetylcholinesterase of *Anopheles albimanus* resistant and susceptible to organophosphate and carbamate insecticides. | 1983 | Mosquito, *Anopheles albimanus* | 24 hr<br>LC50=890 | Excessive solvent used; Waxed cups used | 1 mL/100 mL |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Hendrick et al. | Effects of some insecticides on the survival, reproduction, and growth of the Louisiana red crawfish. | 1966 | Crawfish, *Procambarus clarkia* | - | Formulation; Field application | |
| Hermann | Routine testing of new Bayer pesticides for fish toxicity, as part of the product development programme. | 1975 | - | - | Review of previous studies | |
| Hernandez et al. | Toxicity of ethil-parathion and carbaryl on early stages of the development of sea urchin. | 1986 | Sea urchin, *Pseudechinus magellanicus* | - | Text in foreign language; Not North American species | |
| Hernandez et al. | Toxicity of ethyl-parathion and carbaryl on early development of sea urchin. | 1990 | Sea urchin, *Pseudechinus magellanicus* | 96 hr EC50=92.5 | Not North American species | |
| Hidaka et al. | Avoidance of pesticides with medakas (*Oryzias latipes*). | 1984 | Medaka, *Oryzias latipes* | - | Not North American species; Lack of exposure details | Text in foreign language |
| Hiltibran | Oxygen and phosphate metabolism of bluegill liver mitochondria in the presence of some insecticides. | 1974 | Bluegill, *Lepomis macrochirus* | - | Surgically altered test species | Liver mitochondria |
| Hirose and Kitsukawa | Acute toxicity of agricultural chemical to seawater teleosts, with special respect to TLm and the vertebral abnormality. | 1976 | Medaka, *Oryzias latipes* | - | Text in foreign language | |
| Holcombe et al. | The acute toxicity of selected substituted phenols, benzenes and benzoic acid esters to fathead minnows *Pimephales promelas*. | 1984 | Fathead minnows, *Pimephales promelas* | - | Not applicable | No carbaryl toxicity information |
| Hopf and Muller | Laboratory breeding and testing of *Australorbis glabratus* for molluscicidal screening. | 1962 | Snail, *Australorbis glabratus* | - | Lack of details (procedure) | |
| Hopkins and Winne | Influence of body size on swimming performance of four species of neonatal natricine snakes acutely exposed to a cholinesterase-inhibiting pesticide. | 2006 | Semi-aquatic snakes, *Nerodia taxispilota*, *N. rhombifer*, *N. fasciata*, *Seminatrix pygaea* | - | Formulation | Sevin (commercial grade) |
| Hopkins et al. | Differential swimming performance of two natricine snakes exposed to a cholinesterase-inhibiting pesticide. | 2005 | Black swamp snake, *Seminatrix pygaea*<br>Diamondback water snake, *Nerodia rhombifer* | - | Only two exposure concentrations; Formulation | Sevin® |
| Hota et al. | Metabolic effects of kilex carbaryl on a fresh water teleost, *Channa punctatus* (Bloch). | 1993 | Snakehead catfish, *Channa punctatus* | 24 hr decline in protein concentration in liver at 2,000 | Only one exposure concentration; Not North American species | |
| Hulbert | Effects of sevin, a spruce budworm insecticide on fish and invertebrates in the Mattawamkeag River in 1976. | 1978 | - | - | Formulation | Sevin-4-oil |

## Appendix J.  List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Huque | Preliminary report on the residues of carbaryl granules in rice plants. | 1972 | - | - | Formulation; Bioaccumulation study: steady state not reached | Carbaryl 10% granules |
| Hydorn et al. | Effect of forest spraying with acephate insecticide on consumption of spiders by brook trout (*Salvelinus fontinalis*). | 1979 | - | - | Not applicable | No carbaryl toxicity information |
| Ishii and Hashimoto | Metabolic fate of carbaryl (1-naphthyl N-methyl carbamate) orally administered to carp, *Cyprinus carpio*. | 1970 | Carp,<br>*Cyprinus carpio* | - | Dietary exposure; Lack of exposure details | Text in foreign language |
| Jacob et al. | Toxicity of certain pesticides found in the habitat to the larvivorous fishes *Aplocheilus lineatus* (Cuv. & Val.) and *Macropodus cupanus* (Cuv. & Val.). | 1982 | Panchax,<br>*Aplocheilus lineatus*<br>Paradise fish,<br>*Macropodus cupanus* | - | Not North American species; Formulation | Sevin (50% WP) |
| Jadhv et al. | Effect of pesticides on amylase activity in digestive gland of fresh water bivalve *Corbicula striatella*. | 1995 | Bivalve,<br>*Corbicula striatella* | 96 hr<br>decrease amylase activity at 2,500 | Not North American species; Only one exposure concentration | |
| Jadhv et al. | Carbaryl toxicity to freshwater bivalve *Corbicula striatella*. | 1996 | Bivalve,<br>*Corbicula striatella* | 96 hr<br>LC50=5,100 | Not North American species | |
| James and Sampath | Combined toxic effects of carbaryl and methyl parathion on survival, growth, and respiratory metabolism in *Heteropneustes fossilis* (Bloch). | 1994 | Catfish,<br>*Heteropneustes fossilis* | - | Not North American species; Formulation | Carbaryl (50% WDP) |
| Jamnback and Frempong-Boadu | Testing blackfly larvicides in the laboratory and in streams. | 1966 | Blackfly,<br>*Simulium sp.* | 5 min.<br>47% detachment at 400 | Only two exposure concentrations; Lack of exposure details | Dilution water not characterized |
| Jauhar and Kulshrestha | Histopathological changes induced by the sublethal doses of endosulfan and carbaryl in the intestine of *Channa striatus* Bloch. | 1983 | Snakehead catfish,<br>*Channa striatus* | - | Not North American species; Formulation | Sevin (50 WP) |
| Jauhar and Kulshrestha | Histopathological effects induced by sublethal doses of sevin and thiodan on the gills of *Channa striatus* Bloch. (Pisces, Channidae). | 1985 | Snakehead catfish,<br>*Channa striatus* | - | Not North American species; Formulation | Sevin (50 WP) |
| Jayaprada and Ramana Rao | Carbaryl toxicity on tissue acetylcholinesterase in the penaeid prawn, *Metapenaeus monceros* (Fabricius) a monitoring study. | 1991 | Prawn,<br>*Metapenaeus monceros* | 96 hr<br>LC50=24.87 | Not North American species | |
| Jeyasingam et al. | The relative toxicities of insecticides on aquatic insect *Eretes sticticus* (Linn.) (Coleoptera: Dytiscidae). | 1978 | Diving beetle,<br>*Eretes sticticus* | 48 hr<br>TLm=890 | Not North American species | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| John | Alteration of certain blood parameters of freshwater teleost *Mystus vittatus* after chronic exposure to metasystox and sevin. | 2007 | Catfish, *Mystus vittatus* | 30 d decreased blood ESR and Hb% at 7,000 | Not North American species; Only one exposure concentration; Lack of exposure details | Dilution water not characterized |
| John and Prakash | Acute toxicity of metasystox and sevin to *Mystus vittatus*. | 1998 | Catfish, *Mystus vittatus* | - | Not North American species; Formulation | Sevin®<br>(505 carbaryl) |
| Joshi and Kumar | Acid and alkaline phosphates activity in different tissues of fresh water crab, *Paratelphusa masoniana* (Henderson) to pesticide exposure. | 2001 | Crab, *Paratelphusa masoniana* | - | Lack of details (procedure) | |
| Juchelka and Snell | Rapid toxicity assessment using ingestion rate of cladocerans and ciliates. | 1995 | - | - | Not applicable | No carbaryl toxicity information |
| Juhnke and Luedemann | Results of the investigation of 200 chemical compounds for acute fish toxicity with the golden orfe test. | 1978 | Golden orfe, *Leuciscus idus melanotus* | 48 hr LC50=20,000 | Lack of exposure details | Dilution water not characterized |
| Jyothi and Narayan | Toxic effects of carbaryl on gonads of freshwater fish, *Clarias batrachus* (Linnaeus). | 1999a | Walking catfish, *Clarias batrachus* | - | Only one exposure concentration; Formulation | Commercial grade |
| Jyothi and Narayan | Certain pesticide-induced carbohydrate metabolic disorders in the serum of freshwater fish *Clarias batrachus* (Linn.). | 1999b | Walking catfish, *Clarias batrachus* | - | Only one exposure concentration; Formulation | Sevin<br>(50% WDP powder) |
| Jyothi and Narayan | Pesticide induced alterations of non-protein nitrogenous constituents in the serum of a fresh water cat fish, *Clarias batrachus* (Linn.). | 2000 | Walking catfish, *Clarias batrachus* | - | Formulation | Sevin<br>(50% WDP powder) |
| Jyothi and Narayan | Effect of pesticides carbaryl and phorate on serum cholesterol level in fish, *Clarias batrachus* (Linn). | 2001 | Walking catfish, *Clarias batrachus* | - | Only one exposure concentration; Formulation | Commercial grade |
| Kader et al. | The relative toxicities of ten biocides on *Spicodiaptomus chelospinus* Rajendran (1973) [Copepoda: Calanoida]. | 1976 | Copepod, *Spicodiaptomus chelospinus* | 48 hr TLm=130 | Not North American species; Lack of exposure details | Dilution water not characterized |
| Kallander et al. | Recovery following pulsed exposure to organophosphorus and carbamamte insecticides in the midge, *Chironomus riparius*. | 1997 | Midge, *Chironomus riparius* | - | Excessive solvent used | 1.0 mL/L acetone |
| Kanazawa | Uptake and excretion of organophosphorus and carbamate insecticides by fresh water fish, motsugo, *Pseudorasbora parva*. | 1975 | Motsugo, *Pseudorasbora parva* | - | Not North American species; Bioaccumulation study: steady state not reached | |
| Kanazawa | Prediction of biological concentration potential of pesticides in aquatic organisms. | 1980 | Topmouth gudgeon, *Pseudorasbora parva* | 14 d BCF=9 (whole body) | Not North American species | |
| Kanazawa | Bioconcentration potential of pesticides by aquatic organisms. | 1981 | - | - | Review of previous studies | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Kanazawa | In vitro and in vivo effects of organophosphorus and carbamate insecticides on brain acetylcholinesterase activity of fresh-water fish, topmouth gudgeon. | 1983a | Topmouth gudgeon, *Pseudorasbora parva* | 24 hr reduced brain AChE by 72-78% at 4,000 | Not North American species | |
| Kanazawa | A method of predicting the bioconcentration potential of pesticides by using fish. | 1983b | Topmouth gudgeon, Pseudorasbora parva | - | Not North American species; Bioaccumulation: steady state not reached | |
| Kanazawa et al. | Distribution of carbaryl and 3,5-xylyl methylcarbamate in an aquatic model ecosystem. | 1975 | Community model ecosystem | - | Sediment present in test media | |
| Karnak and Collins | The susceptibility to selected insecticides and acetylcholinesterase activity in a laboratory colony of midge larvae, *Chironomus tentans* (Diptera: Chironomidae). | 1974 | Midge, *Chironomus tentans* | 24 hr LC50=2.5 | Excessive solvent used; Test species fed | |
| Kasai et al. | P450 monooxygenases are an important mechanism of permethrin resistance in *Culex quinquefasciatus* Say larvae. | 1998 | Mosquito, *Culex quinquefasciatus* | - | Dilution water is distilled water without proper salts added | |
| Kashiwada et al. | Stage-dependent differences in effects of carbaryl on population growth rate in Japanese medaka (*Oryzias latipes*). | 2008 | Medaka, *Oryzias latipes* | 14 d decreased embryo growth at 5,000 | Not North American species; Only two exposure concentrations; Excessive solvent | 0.1% |
| Kaur and Dhawan | Variable sensitivity of *Cyprinus carpio* eggs, larvae, and fry to pesticides. | 1993 | Common carp, *Cyprinus carpio* | - | Formulation | Sevin (50 WP) |
| Kaur and Dhawan | Effect of carbaryl on tissue composition, maturation, and breeding potential of *Cirrhina mrigala* (Ham.). | 1996 | Carp, *Cirrhina mrigala* | - | Formulation | 50% WP |
| Kaur and Toor | Role of abiotic factors in the embryonic development of scale carp. | 1980 | Common carp, *Cyprinus carpio* | - | Lack of details (procedure) | |
| Kaur and Toor | Toxicity of some insecticides to the fingerlings of Indian major carp, *Cirrhina mrigala* (Hamilton). | 1995 | Carp, *Cirrhina mrigala* | - | Formulation | Carbaryl 50 WP |
| Kaur and Toor | Histopathological changes in the liver of fingerlings of Indian major carp, *Cirrhina mrigala* (Hamilton) exposed to some biocides. | 1997 | Carp, *Cirrhina mrigala* | - | Only one exposure concentration | |
| Kaushik and Kumar | Susceptibility of the freshwater crab *Paratelphusa masoniana* (Henserson) to three pesticides, singly and in combination. | 1993 | Crab, *Paratelphusa masoniana* | - | Not North American species; Formulation | Carbaryl 50% WP |
| Kaushik and Kumar | Midgut pathology of aldrin, monocrotophos, and carbaryl in the freshwater crab, *Paratelphusa masoniana* (Henderson). | 1998 | Crab, *Paratelphusa masoniana* | - | Not North American species; only one exposure concentration | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Kay | Toxicology of pesticides: Recent advances. | 1973 | - | - | Review of previous studies | |
| Kem et al. | Inhibition of barnacle larval settlement and crustacean toxicity of some hoplonemertine pyridyl alkaloids. | 2003 | Barnacle, *Balanus amphitrite* | - | Not applicable | No carbaryl toxicity information |
| Khalil et al. | Filarial infectivity rate of *Culex pipiens molestus* subjected to sublethal concentrations of insecticides abate and sevin and distribution of infective filaria larvae in mosquito body regions. | 1974 | - | - | Lack of exposure details; Mixture | Dilution water not characterized |
| Khan and Nelson | Adverse effects of some selected agrochemicals and pharmaceuticals in aquatic environment with reference to amphibians and fish. | 2005 | - | - | Review of previous studies | |
| Khangarot et al. | Man and biosphere - studies on the Sikkim Himalayas. Part 6: Toxicity of selected pesticides to frog tadpole *Rana hexadactyla* (Lesson). | 1985 | Frog, *Rana hexadactyla* | - | Not North American species; Formulation | Kelex (50% carbaryl) |
| Khillare and Wagh | Chronic effects of endosulfan, malathion and sevin in the fresh water fish, *Barbus stigma* testis histopathology. | 1987a | Barb, *Barbus stigma* | - | Not North American species; Only one exposure concentration | |
| Khillare and Wagh | Developmental abnormalities induced by the pesticides in the fish, *Barbus stigma* (Ham.). | 1987b | Barb, *Barbus stigma* | - | Not North American species; Only one exposure concentration | |
| Khillare and Wagh | Long-term effects of pesticides endosulfan, malathion and sevin on the fish, *Puntius stigma*. | 1988a | Fish, *Puntius stigma* | - | Not North American species; Lack of details (procedure) | |
| Khillare and Wagh | Acute toxicity of pesticides in the freshwater fish *Barbus stigma*: histopathology of the stomach. | 1988b | Barb, *Barbus stigma* | - | Not North American species; Lack of details (procedure) | |
| Khillare and Wagh | Effect of certain pesticides on spermatogenesis in fish *Barbus stigma* (Ham.). | 1989 | Barb, *Barbus stigma* | - | Not North American species; Only one exposure concentration | |
| Kikuchi et al. | Screening of organophosphate insecticide pollution in water by using *Daphnia magna*. | 2000 | - | - | Not applicable | No carbaryl toxicity information |
| Kimura and Keegan | Toxicity of some insecticides and molluscicides for the Asian blood sucking leech, *Hirudo nipponia* Whitman. | 1966 | Leech, *Hirudo nipponia* | 48 hr LC50=5,500 | Not North American species | |
| Klassen et al. | Toxicities of certain larvicides to resistant and susceptible *Aedes aegypti* (L.) | 1965 | Mosquito, *Aedes aegypti* | LC50=4,400 | Prior exposure; Lack of exposure details | Dilution water not characterized; Duration not given |
| Kolankaya | Organochlorine pesticide residues and their toxic effects on the environment and organisms in Turkey. | 2006 | - | - | Not applicable | No carbaryl toxicity information |

# Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Korn | The uptake and persistence of carbaryl in channel catfish. | 1973 | Channel catfish, *Ictalurus punctatus* | - | Bioaccumulation: steady state not reached | |
| Koundinya and Murthi | Haematological studies in *Sarotherodon* (*Tilapia*) *mossambica* (Peters) exposed to lethal (LC50/48 hrs) concentration of sumithion and sevin. | 1979 | Mozambique tilapia, *Oreochromis mossambica* | - | Formulation | Sevin (commercial grade) |
| Koundinya and Ramamurthi | Comparative study of inhibition of acetylcholinesterase activity in the freshwater teleost *Sarotherodon* (*Tilapia*) *mossambica* (Peters) by sevin (carbamate) and sumithion (organophosphate). | 1979 | Mozambique tilapia, *Oreochromis mossambica* | - | Formulation | Sevin (commercial grade) |
| Koundinya and Ramamurthi | Effect of sub-lethal concentration of sumithion and sevin on certain hematological values of *Sarotherodon mossambicus* (Peters). | 1980a | Mozambique tilapia, *Oreochromis mossambica* | - | Formulation | Carbaryl (50% WP) |
| Koundinya and Ramamurthi | Toxicity of sumithion and sevin to the freshwater fish, *Sarotherodon mossambicus* (Peters). | 1980b | Mozambique tilapia, *Oreochromis mossambica* | - | Formulation | Sevin (50% WP) |
| Koundinya and Ramamurthi | Tissue respiration in *Sarotherodon mossambicu*s (Peters) exposed to sub-lethal concentration of sumithion and sevin. | 1981 | Mozambique tilapia, *Oreochromis mossambica* | - | Formulation | Sevin |
| Koval'Chuk et al. | Acute toxicity of yalan, eptam and sevin for *Daphnia magna*. | 1971 | Cladoceran, *Daphnia magna* | - | Lack of exposure details | Text in foreign language |
| Krishnan and Chockalingam | Toxic and sublethal effects of endosulfan and carbaryl on growth and egg production of *Moina micrura* Kurz (Cladocera: Moinidae). | 1989 | Cladoceran, *Moina micrura* | 24 hr LC50=119.6 | Not North American species | |
| Kulshrestha and Arora | Effect of sublethal doses of carbaryl and endosulfan on the skin of *Channa striatus* Bloch. | 1984a | Snakehead catfish, *Channa striatus* | - | Not North American species; Formulation | Sevin (50% WP) |
| Kulshrestha and Arora | Impairments induced by sublethal doses of two pesticides in the ovaries of a freshwater teleost *Channa striatus* Bloch. | 1984b | Snakehead catfish, *Channa striatus* | - | Not North American species; Formulation | Sevin (50 WP) |
| Kulshrestha and Jauhar | Impairments induced by sublethal doses of sevin and thiodan on the brain of a freshwater teleost *Channa striatus* Bloch. (Channidae). | 1986 | Snakehead catfish, *Channa striatus* | - | Not North American species; Formulation | Sevin |
| Kumar and Banerjee | Effects of lethal toxicity of sevin (carbaryl) on the blood parameters in *Clarias batrachus* (L). | 1991 | Walking catfish, *Clarias batrachus* | - | Only one exposure concentration | |

## Appendix J.  List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Kurtak et al. | Management of insecticide resistance in control of the *Simulium damnosum* complex by the onchocerciasis control programme, West Africa: Potential use of negative correlation between organophosphate resistance and pyrethroid susceptibility. | 1987 | Blackfly, *Simulium damnosum* | - | Not North American species; Lack of exposure details | Dilution water not characterized; Duration not given |
| Labenia et al. | Behavioral impairment and increased predation mortality in cutthroat trout exposed to carbaryl. | 2007 | Cutthroat trout, *Oncorhynchus clarkii clarkii* | 6 hr decreased swimming performance at 750 | Lack of exposure details | Dilution water not characterized |
| Lakshmi et al. | Toxicity of endosulfan and carbaryl to a brackish water oligochaete *Pontodrilus bermudensis*. | 2002 | Oligochaete, *Pontodrilus bermudensis* | - | Not North American species; Lack of details (procedure) | |
| Lange et al. | Comparison of testing acute toxicity on embryo of zebrafish, *Brachydanio rerio* and RTG-2 cytotoxicity as possible alternatives to the acute fish test. | 1995 | Zebrafish, *Danio rerio* | - | In vitro study | |
| Li and Chen | Study on the acute toxicities of commonly used pesticides to two kinds of fish. | 1981 | Mosquitofish, *Gumbusia patruelis*<br>Tilapia, *Tilapia sp.*<br>Carp, *Cyprinus carpio* | 48 hr<br>TLm=955<br>TLm=1,958<br>TLm=10,000 | Text in foreign language | |
| Lichtenstein et al. | Toxicity and fate of insecticide residues in water. | 1966 | Mosquito, *Aedes aegypti* | 24 hr 70% mortality at 1,000 | Only one exposure concentration; Lack of exposure details | Distilled water without proper salts added |
| Lingaraja and Venugopalan | Pesticide induced physiological and behavioural changes in an estuarine teleost *Therapon jarbua* (Forsk). | 1978 | Fish, *Therapon jarbua* | - | Not North American species; Lack of details (procedure) | |
| Lloyd | The toxicity of ammonia to rainbow trout (*Salmo gairdnerii* Richardson). | 1961 | Rainbow trout, *Oncorhynchus mykiss* | - | Not applicable | No carbaryl toxicity information |
| Lohner and Fisher | Effects of pH and temperature on the acute toxicity and uptake of carbaryl in the midge, *Chironomus riparius*. | 1990 | Midge, *Chironomus riparius* | 24 hr EC50=96 | Excessive solvent used | 2 mL/L |
| Lowe | Effects of prolonged exposure to sevin on an estuarine fish, *Leiostomus xanthurus* Lacepede. | 1967 | Spot, *Leiostomus xanthurus* | - | High control mortality; Only one exposure concentration | 65% |
| Lubick | Order matters in pesticide exposures. | 2007 | Amphipod, *Gammarus pulex* | - | Mixture | Carbaryl and chlorpyrifos |
| Ma et al. | Differential responses of eight cyanobacterial and green algal species, to carbamate insecticides. | 2006 | Cyanobacteria and green alga | - | Lack of detail | LC50 values are not identified to the species |
| Macek | Acute toxicity of pesticide mixtures to bluegills. | 1975 | Bluegill, *Lepomis macrochirus* | - | Mixture | Sevin and malathion |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| MacKenzie and Shearer | Chemical control of *Polydora websteri* and other annelids inhabiting oyster shells. | 1959 | Worm,<br>*Polydora websteri* | - | Only one exposure concentration | |
| Maly | A study of the effects of pesticide on single and mixed species cultures of algae. | 1980 | - | - | Only one exposure concentration; No control information | |
| Manna and Ghosh | Anaerobic toxicity of sublethal concentration of carbaryl pesticide sevin to guppy *Lebistes reticulatus*. | 1987 | Guppy,<br>*Lebistes reticulatus* | - | Lack of details (procedure, purity not given) | |
| Manonmani et al. | Establishment of a standard test method for determining susceptibility of mesocyclops to different insecticides. | 1989 | Copepod,<br>*Mesocyclops sp.* | - | Not North American species; Formulation | Carbaryl (50% WP) |
| Mansour and Hassan | Pesticides and Daphnia. 3. An analytical bioassay method, using *Ceriodaphnia quadrangula*, for measuring extremely low concentrations of insecticides in waters. | 1993 | Cladoceran,<br>*Ceriodaphnia quadrangula* | - | Mixture | |
| Marian et al. | Acute and chronic effects of carbaryl on survival, growth, and metamorphosis in the bullfrog (*Rana tigrina*). | 1983 | Bullfrog,<br>*Rana tigrina* | - | Not North American species; Formulation | 50% WP |
| Markey et al. | Insecticides and a fungicide affect multiple coral life stages. | 2007 | Coral,<br>*Acropora millepora* | 18 hr EC50=1 | Not North American species | |
| Marking and Bills | Effects of contaminants on toxicity of the lampricides TFM and Bayer 73 to three species of fish. | 1985 | Rainbow trout,<br>*Oncorhynchus mykiss*<br>White sucker,<br>*Catostomus commersoni*<br>Fathead minnow,<br>*Pimephales promelas* | - | Mixture | Carbaryl and TFM or Bayer 73 |
| Marutani and Edirveerasingam | Influence of irrigation methods and an adjuvant on the persistence of carbaryl on pakchoi. | 2006 | Pakchoi,<br>*Brassica rapa* L. subsp. *chinensis* | - | Only one exposure concentration; Filed exposure; Sediment present | |
| Massachusetts Pesticide Board | Report of the surveillance program conducted in connection with an application of carbaryl (sevin) for the control of gypsy moth on Cape Cod, Massachusetts. | 1966 | - | - | Formulation; Only one exposure concentration; Aerial application | |
| Mathur | Toxicity of sevin to certain fishes. | 1974 | Barb,<br>*Esomus danrica*<br>Catfish,<br>*Heteropneustes fossilis*<br>Catfish,<br>*Channa punctatus*<br>Rasbora,<br>*Rasbora daniconius* | - | Not North American species; Formulation | Sevin |

## Appendix J.  List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Matos et al. | Biochemical and histological hepatic changes of Nile tilapia *Oreochromis niloticus* exposed to carbaryl. | 2007 | Nile tilapia, *Oreochromis niloticus* | 14 d decreased hepatic activity at 250 | Only two exposure concentrations | |
| Matsumura | Toxicology of insecticides. | 1975 | - | - | Review of previous studies | |
| Mazzeo et al. | Interclonal variation in response to simazine stress in *Lemna gibba* (Lemnaceae). | 1998 | Duckweed, *Lemna gibba* | - | Not applicable | No carbaryl toxicity information |
| McKim et al. | Use of respiratory-cardiovascular responses of rainbow trout (*Salmo gairdneri*) in identifying acute toxicity syndromes in fish: Part 2. Malathion, carbaryl, acrolein and benzaldehyde. | 1987 | Rainbow trout, *Oncorhynchus mykiss* | - | Surgically altered test species | Spinally transected |
| Megharaj et al. | The use of unicellular soil green algae for insecticide bioassay. | 1989 | Green alga,<br>*Chlorella vulgaris*<br>*Scenedesmus bijugatus* | - | Agar exposure media | |
| Metcalf and Sanborn | Pesticides and environmental quality in Illinois. | 1975 | - | - | Review of previous studies | |
| Metts et al. | Interaction of an insecticide with larval density in pond-breeding salamanders (*Ambystoma*). | 2005 | Salamander,<br>*Ambystoma maculatum*<br>*A. opacum* | - | Only two exposure concentrations; Formulation | Sevin (22.5% carbaryl) |
| Meyer | Quarterly report of progress, April-June, 1981. | 1981 | Rainbow trout | - | Lack of exposure details | Dilution water not characterized; No scientific name given |
| Mills and Semlitsch | Competition and predation mediate the indirect effects of an insecticide on southern leopard frogs. | 2004 | Southern leopard frog, *Rana sphenocephala* | - | Formulation | Sevin (21.35 carbaryl) |
| Mishra et al. | Toxicity of kilex carbaryl to a fresh water teleost *Channa punctatus* (Bloch). | 1991 | Snakehead catfish, *Channa punctatus* | 96 hr TLm=14,000 | Not North American species | |
| Mishra et al. | Responses of interregnal cells of freshwater teleost, *Channa punctatus* (Bloch), exposed to sublethal concentrations of carbaryl and cartap. | 2006 | Snakehead catfish, *Channa punctatus* | 96 hr caused kidney hyperplasia at 5,200 | Not North American species; Only one exposure concentration | |
| Mitsuhashi et al. | Effects of insecticides on cultures of insect cells. | 1970 | Mosquito, *Aedes aegypti* | - | Surgically altered test species | Cell culture |
| Mora et al. | Cholinesterase activity as potential biomarker in two bivalves. | 1999 | Mussel,<br>*Mytilus galloprovincialis*<br>Asiatic clam,<br>*Corbicula fluminea* | - | Lack of exposure details | Dilution water not characterized |
| Mora et al. | Relationship between toxicokinetics of carbaryl and effect on acetylcholinesterase activity in *Pomacea patula* snail. | 2000 | Snail, *Pomacea patula* | - | Excessive solvent used | 4 mL/L ethanol |
| Morgan | Monitoring pesticides by means of changes in electric potential caused by fish opercular rhythms. | 1975 | Largemouth bass | - | Formulation; No scientific name given | Karbaspray (50% carbaryl) |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Muirhead-Thomson | Laboratory evaluation of pesticide impact on stream invertebrates. | 1973 | Dragonfly naiads | - | Formulation | Sevin |
| Mulla et al. | Control of chironomid midges in recreational lakes. | 1971 | Midges | - | Formulation | 20% carbaryl |
| Mulla et al. | Aquatic midge larvicides, their efficacy and residues in water, soil, and fish in a warm-water lake. | 1973 | Midges | - | Formulation | Carbaryl<br>(20% granules) |
| Murray and Guthrie | Effects of carbaryl, diazinon and malathion on native aquatic populations of microorganisms. | 1980 | - | - | Only one exposure concentration;<br>Lack of exposure details | Dilution water not characterized |
| Nalecz-Jawecki and Sawicki | Spirotox - a new tool for testing the toxicity of volatile compounds. | 1999 | - | - | Not applicable | No carbaryl toxicity information |
| Nalecz-Jawecki et al. | The sensitivity of protozoan *Spirostomum ambiguum* to selected pesticides. | 2002 | Protozoan, *Spirostomum ambiguum* | - | Excessive solvent used | 1% acetone |
| Naqvi and Ferguson | Pesticide tolerances of selected freshwater invertebrates. | 1968 | Cyclopoid copepods | - | Prior exposure pesticides | |
| Naqvi and Hawkins | Toxicity of selected insecticides (thiodan, security, spartan, and sevin) to mosquitofish, *Gambusia affinis*. | 1988 | Mosquitofish, *Gambusia affinis* | - | Formulation | Sevin<br>(5% carbaryl) |
| Nishiuchi | Toxicity of formulated pesticides to some fresh water organisms. | 1976 | Japanese toad, *Bufo bufo japonicas* | - | Not North American species;<br>Lack of exposure details | Text in foreign language |
| Nishiuchi | Toxicity of formulated pesticides to some freshwater organisms. | 1977 | - | - | Not North American species;<br>Lack of exposure details | Text in foreign language |
| Nishiuchi and Asano | Toxicity of formulated agrochemicals to fresh water organisms. | 1978 | Dragonfly, *Orthetrum albistylum speciosum* | - | Not North American species;<br>Lack of exposure details | Text in foreign language |
| Nishiuchi and Yoshida | Toxicities of pesticides to some fresh water snails. | 1972 | Red snail, *Indoplanorbis exustus*<br>Marsh snail, *Semisulcospira libertina*<br>Round snail, *Cipangopaludina malleata*<br>Saka snail, *Physa acuta* | 48 hr<br>TLm=28,000<br>TLm=25,000<br>TLm=30,000<br>TLm=27,000 | Not North American species | |
| Nogrady and Keshmirian | Rotifer neuropharmacology - I. Cholinergic drug effects on oviposition of *Philodina acuticornis* (Rotifera, Aschelminthes). | 1986 | Rotifer, *Philodina acuticornis* | - | Formulation | Sevin |

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| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Nollenberger | Toxicant-induced changes in brain, gill, liver, and kidney of brook trout exposed to carbaryl, atrazine, 2,4-dichlorophenoxyacetic acid, and parathion: a cytochemical study. | 1981 | Brook trout, *Salvelinus fontinalis* | - | Only one exposure concentration | |
| Omkar and Murti | Toxicity of some pesticides to the freshwater prawn *Macrobrachium dayanum* (Henderson) (Decapoda, Caridea). | 1985 | Prawn, *Macrobrachium dayanum* | - | Formulation | Sevin (50 WP) |
| Omkar and Shukla | Toxicity of insecticides to *Macrobrachium lamarrei* (H. Milne Edwards) (Decapoda: Palaemonidae). | 1985 | Prawn, *Macrobrachium lamarrei* | 96 hr LC50=19 | Not North American species | |
| Owen | Aquatic insect populations reduced by aerial spraying of insecticide sevin. | 1967 | - | - | Formulation | Sevin |
| Padhy and Mohapatra | Toxicity of two carbamate insecticides to the cyanobacterium *Anabaena* PCC 7120 and the computations of partial lethal concentrations by the probit method. | 2001 | Cyanobacteria, *Anabaena* | - | Formulation | Sevin (50W) |
| Palanichamy et al. | Effect of pesticides on protein metabolism in the freshwater catfish *Mystus vittatus*. | 1989 | Catfish, *Mystus vittatus* | - | Not North American species; Only one exposure concentration | |
| Panigrahy and Padhy | Toxicity of carbamate pesticides to cells, heterocysts and akinetes of the cyanobacterium *Cylindrospermum sp*. | 2000 | Cyanobacterium, *Cylindrospermum sp.* | - | Formulation | Sevin (50W) |
| Pant and Singh | Inducement of metabolic dysfunction by carbamate and organophosphorus compounds in a fish, *Puntius conchonius*. | 1983 | Barb, *Puntius conchonius* | - | Not North American species; Formulation | Sevin (50% WP) |
| Patil et al. | Toxicity of carbamate insecticides to freshwater crab *Paratelphusa jacquemontii* (Rathbun). | 1992 | Crab, *Paratelphusa jacquemontii* | - | Not North American species; Formulation | Sevimol |
| Patnaik and Patra | Haemoatopoietic alterations induced by carbaryl in *Clarias batrachus* (Linn.). | 2006 | Walking catfish, *Clarias batrachus* | 96 hr LC50=15,300 | Lack of exposure details | Dilution water not characterized |
| Pauli et al. | RATL: A database of reptile and amphibian toxicology literature. | 2000 | - | - | Review of previous studies | |
| Pelletier et al. | Symposium-in-print: UV effects on aquatic and coastal ecosystems. Ecotoxicological effects of combined UVB and organic contaminants in coastal waters: A review. | 2006 | - | - | Mixture | Carbaryl, atrazine, and acifluorfen |
| Perry | Pesticide and PCB residues in the Upper Snake River ecosystem, southeastern Idaho, following the collapse of the Teton Dam 1976. | 1979 | - | - | Mixture | |

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| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Pesando et al. | Biological targets of neurotoxic pesticides analyzed by alteration of developmental events in the Mediterranean sea urchin, *Paracentrotus lividus*. | 2003 | Mediterranean sea urchin, *Paracentrotus lividus* | - | Not North American species; Lack of details (procedure) | |
| Pesch and Hoffman | Adaption of the polychaete *Neanthes arenaceodentata* to copper. | 1982 | Polychaete, *Neanthes arenaceodentata* | - | Not applicable | No carbaryl toxicity information |
| Peterson et al. | Effect of varying pesticide exposure duration and concentration on the toxicity of carbaryl to two field-collected stream invertebrates, *Calineuria californica* (Plecoptera: Perlidae) and *Cinygma sp*. (Ephemeroptera: Heptageniidae). | 2001a | Stonefly, *Calineuria californica*<br>Mayfly, *Cinygma sp*. | - | Formulation | Clean Crop ® (43% carbaryl) |
| Peterson et al. | A test system to evaluate the susceptibility of Oregon, USA, native stream invertebrates to triclopyr and carbaryl. | 2001b | Stonefly, *Calineuria californica*<br>Mayfly, *Cinygma sp.*<br>Caddisfly, *Brachycentrus americanus*<br>Caddisfly, *Lepidostoma unicolor*<br>Caddisfly, *Psychoglypha sp*.<br>Mayfly, *Ameletus sp*. | - | Formulation | Clean Crop ® (43% carbaryl) |
| Pozarycki | Sublethal effects of estuarine carbaryl applications on juvenile English sole (*Pleuronectes vetulus*). | 1999 | English sole, *Pleuronectes vetulus* | - | Mixture | |
| Prescott et al. | The effects of pesticides, polychlorinated biphenyls and metals on the growth and reproduction of *Acanthamoeba castellanii*. | 1977 | Amoeba, *Acanthamoeba castellanii* | 6 d decreased growth at 10,000 | Only one exposure concentration | |
| Pridgeon et al. | Susceptibility of *Aedes aegypti*, *Culex quinquefasciatus* Say and *Anopheles quadrimaculatus* Say to 19 pesticides with different modes of action. | 2008 | Mosquito, *Aedes aegypti*<br>Mosquito, *Culex quinquefasciatus*<br>Mosquito, *Anopheles quadrimaculatus* | - | Topically applied contaminant | |
| Puglis and Boone | Effects of fertilizer, an insecticide, and a pathogenic fungus on hatching and survival of bullfrog (*Rana catesbeiana*) tadpoles. | 2007 | Bullfrog, *Rana catesbeiana* | - | Formulation | Sevin (22.5% carbaryl) |
| Rajendran and Venugopalan | Effect of pesticides on phytoplankton production. | 1983 | - | - | Mixture | |

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| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Ramachandran et al. | Effect of pesticides on photosynthesis and respiration of marine macrophytes. | 1984 | Macrophytes | - | Only one exposure concentration | |
| Ramakrishnan et al. | Sublethal effects of pesticides on feeding energetics in the air breathing fish *Channa striatus*. | 1997a | Snakehead catfish, *Channa striatus* | - | Not North American species; Formulation | Hexavin |
| Ramakrishnan et al. | Sublethal effects of pesticides on physiological energetics of freshwater fish, *Oreochromis mossambicus*. | 1997b | Mozambique tilapia, *Oreochromis mossambicus* | - | Not North American species; Formulation | Hexavin |
| Ramaswami | Adaptive trends in lipid levels of liver and muscle of *Sarotherodon mossambicus* (Peters) exposed to sevin. | 1990 | Mozambique tilapia, *Oreochromis mossambicus* | | Not North American species; Formulation | Sevin (10% dust) |
| Ramaswamy | Effects of sevin on blood free amino acid levels of the fish *Sarotherodon mossambicus*. | 1987 | Mozambique tilapia, *Oreochromis mossambicus* | - | Not North American species; Formulation | Sevin |
| Ramaswamy and Maheswari | Comparative lactic acidosis in fishes following pesticide stress. | 1993 | Mozambique tilapia, *Oreochromis mossambicus* | - | Not North American species; Formulation | Sevin (10% dust) |
| Ramaswamy et al. | Glutamic oxaloacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT) enzyme activities in different tissues of *Sarotherodon mossambicus* (Peters) exposed to a carbamamte pesticide, carbaryl. | 1999 | Mozambique tilapia, *Oreochromis mossambicus* | | Not North American species; Formulation | Commercial grade (100g/kg dust) |
| Rao | Effect of γ-hexachloran and sevin on the survival of the Black Sea mussel, *Mytilus galloprovincialis* Lam. | 1981 | Mussel, *Mytilus galloprovincialis* | 96 hr LC50=>10,000 | Not North American species | |
| Rao | Variations in the nitrogen products of *Channa punctatus* augmented by interaction of carbaryl and phenthoate in the media. | 1987 | Snakehead catfish, *Channa punctatus* | 48 hr decreased level of ammonia and urea at 3,000 | Not North American species; Only one exposure concentration; Lack of exposure details | Dilution water not characterized |
| Rao and Kannupandi | Acute toxicity of three pesticides and their effect on the behavior of the edible crab *Scylla serrata* (Forskal). | 1990 | Crab, *Scylla serrata* | 96 hr LC50=466 | Not North American species | |
| Rao and Rao | Independent and combined action of carbaryl and phethoate on snake head, *Channa punctatus* (Bloch). | 1987 | Snakehead catfish, *Channa punctatus* | - | Not North American species; Lack of exposure details | |
| Rao et al. | Relative toxicity of technical grade and formulated carbaryl and 1-naphthol to, and carbaryl-induced biochemical changes in the fish *Cirrhinus mrigala*. | 1984a | Carp, *Cirrhinus mrigala* | 96 hr LC50=2,500 | Not North American species | |
| Rao et al. | Differential action of malathion, carbaryl and BHC on acetyl-cholinesterase activity of a teleost, *Tilapia mossambica* (Peters). | 1984b | Mozambique tilapia, *Oreochromis mossambicus* | - | Formulation | Carbaryl (50% EC) |

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| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Rao et al. | Combined action of carbaryl and phenthoate on a freshwater fish (*Channa punctatus* Bloch). | 1985a | Snakehead catfish, *Channa punctatus* | 48 hr LC50=8,710 | Not North American species; Lack of exposure details | Dilution water not characterized |
| Rao et al. | Combined action of carbaryl and phenthoate on tissue lipid derivatives of murrel, *Channa punctatus* (Bloch). | 1985b | Snakehead catfish, *Channa punctatus* | 48 hr lethal concentration at 8,710 | Not North American species; Lack of exposure details | Dilution water not characterized |
| Rao et al. | Inhibition and recovery of selected target enzyme activities in tissues of penaeid prawn, *Metapenaeus monoceros* (Fabricus), exposed to different insecticides. | 1991 | Prawn, *Metapenaeus monoceros* | 48 hr LC50=137 | Not North American species | |
| Ray and Poddar | Carbaryl induced elevation of corticosterone level and cholinergic mechanism. | 1983 | - | - | Not applicable | No carbaryl toxicity information |
| Razmi et al. | Persistence of toxicity of some insecticides against the neonate larvae of *Leucinodes orbonalis* Guen. | 1991 | Shoot borer, *Leucinodes orbonalis* | - | Not North American species; Aerial application | |
| Reddy and Rao | Tissue glycolytic potentials of penaeid prawn, *Metapenaeus monoceros* during methylparathion, carbaryl and aldrin exposure. | 1991a | Prawn, *Metapenaeus monoceros* | 96 hr LC50=120 | Not North American species; Lack of exposure details | |
| Reddy and Rao | Methylparathion, carbaryl and aldrin impact on nitrogen metabolism of prawn, *Penaeus indicus*. | 1991b | Prawn, *Penaeus indicus* | 96 hr LC50=21 | Not North American species | |
| Reddy and Rao | Toxicity of selected insecticides to the penaeid prawn, *Metapenaeus monoceros* (Fabricius). | 1992 | Prawn, *Metapenaeus monoceros* | 96 hr LC50=24.3 | Not North American species | |
| Reddy et al. | Recovery of carbaryl inhibited AChE in penaeid prawn, *Metapenaeus monoceros*. | 1990 | Prawn, *Metapenaeus monoceros* | 96 hr LC50=24.87 | Not North American species; Lack of exposure details | |
| Regoli et al. | Effects of copper and cadmium on the presence of renal concretions in the bivalve *Donacilla cornea*. | 1992 | Bivalve, *Donacilla cornea*. | - | Not applicable | No carbaryl toxicity information |
| Relyea | Growth and survival of five amphibian species exposed to combinations of pesticides | 2004 | Gray tree frog, *Hyla versicolor*<br>Leopard frog, *Rana pipiens*<br>Bullfrog, *R. catesbeiana*<br>Green frog, *R. clamitans*<br>Bullfrog, *Bufo americanus* | - | Formulation; Only two exposure concentrations | Commercial grade |
| Relyea | The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities. | 2005 | Various species | - | Formulation | Carbaryl (22.3%) |

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| Author | Title | Date | Organism(s) | Concentration (μg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Relyea | The effects of pesticides, pH, and predatory stress on amphibians under mesocosm conditions. | 2006 | Bullfrog,<br>*Rana catesbeiana*<br>Green frog,<br>*R. clamitans* | - | Lack of exposure details;<br>Formulation | Dilution water not characterized;<br>Sevin<br>(22% carbaryl) |
| Relyea | A cocktail of contaminants: How mixtures of pesticides at low concentrations affect aquatic communities. | 2009 | Gray tree frog,<br>*Hyla versicolor*<br>Leopard frog,<br>*Rana pipiens* | ~57 d<br>no effect on metamorphosis, growth, and survival at 6.9 (both species) | Only one exposure concentration;<br>High TOC | |
| Relyea and Mills | Predator-induced stress makes the pesticide carbaryl more deadly to gray treefrog tadpoles (*Hyla versicolor*). | 2001 | Gray tree frog,<br>*Hyla versicolor* | 10-16 d<br>3-4% of LC50 killed 10-60% of frog | Unmeasured chronic exposure | |
| Rettich | The susceptibility of mosquito larvae to eighteen insecticides in Czechoslovakia. | 1977 | Mosquitoes,<br>*Aedes cantans*,<br>*A. vexans*,<br>*A. excrucians*,<br>*Culex pipiens*,<br>*A. punctor* | 24 hr<br>LC50=376.6<br>LC50=322.6<br>LC50=145.5<br>LC50=333<br>LC50=298.3 | Lack of exposure details | Distilled water without proper salts added |
| Riad et al. | Aromatic sulphides, sulphoxides, and sulphones as larvicides for *Culex pipiens* molestus and *Aedes caspius* (Diptera: Culicidae). | 1992 | Mosquito,<br>*Culex pipiens*<br>*Aedes caspius* | - | Lack of exposure details; Excessive solvent used | 4 mL/L acetone |
| Rifaat et al. | Effect of sublethal concentrations of the insecticides DDT, abate and sevin applied to 3rd stage larvae of *Anopheles pharoensis* on malaria cycle in the adult mosquito. | 1974 | Mosquito,<br>*Anopheles pharoensis* | 24 hr<br>LC50=600 | Lack of exposure details | Dilution water not characterized, purity not given |
| Rohr et al. | Lethal and sublethal effects of atrazine, carbaryl, endosulfan, and octylphenol on the streamside salamander (*Ambystoma barbouri*). | 2003 | Streamside salamander,<br>*Ambystoma barbouri* | - | Prior exposure | Organisms collected in an agricultural area |
| Rohr et al. | Understanding the net effects of pesticides on amphibian trematode infections. | 2008 | Trematode,<br>*Echinostoma trivolvis*<br>Snail,<br>*Planorebella trivolvis*<br>Green frog,<br>*Rana clamitans* | Survival<br>24 hr NOEC<br>14 d NOEC<br>14 d NOEC<br>at 33.5 | Only one exposure concentration | |
| Rossini and Ronco | Acute toxicity bioassay using *Daphnia obtusa* as a test organism. | 1996 | Cladoceran,<br>*Daphnia obtusa* | 48 hr<br>EC50=11.5 | Not North American species | |
| Ruber and Baskar | Sensitivities of selected microcrustacea to eight mosquito toxicants. | 1968 | Mosquitoes | - | Lack of exposure details | Dilution water not characterized |
| Rybakova | On the toxic effect of sevin on animals. | 1966 | - | - | Not applicable | No carbaryl toxicity information |
| Rzehak et al. | The effect of karbatox 75, a carbaryl insecticide, upon the development of tadpoles of *Rana temporaria* and *Xenopus laevis*. | 1977 | Common frog,<br>*Rana temporaria*<br>African clawed frog,<br>*Xenopus laevis* | - | Formulation | Karbatox 75 |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Sadek et al. | Effect of sublethal concentrations of the insecticides DDT, abate and sevin, applied to 3rd stage larvae of *Culex pipiens molestus* on certain biological aspects of the mosquito. | 1974 | Mosquito, *Culex pipiens molestus* | - | Lack of exposure details;<br>Formulation | Dilution water not characterized |
| Sahai and Gupta | Residue analysis of some pesticides in the brain of a teleost fish *Heteropneustes fossilis* (Bloch). | 1992 | Catfish, *Heteropneustes fossilis* | - | Not North American species;<br>Only one exposure concentration | |
| Sahu et al. | Reaction of blue-green algae of rice-field soils to pesticide application. | 1992 | Blue-green alga | - | Formulation | Carbaryl (50%) |
| Sakamoto et al. | Inhibition of development of anti-predator morphology in the small cladoceran *Bosmina* by an insecticide: Impact of an anthropogenic chemical on prey-predator interactions. | 2006 | Cladoceran, *Bosmina fatalis* | 6d<br>reduced reproduction at 2 | Not North American species;<br>Only one exposure concentration | |
| Sampath and Elango | Lipid metabolism in common frog (*Rana tigrina*) exposed to carbaryl. | 1997 | Common frog, *Rana tigrina* | - | Not North American species;<br>Formulation | Sevin<br>(50% WP) |
| Sampath et al. | Effect of carbaryl (sevin) on the carbohydrate metabolism of the common frog *Rana tigrina*. | 1992 | Common frog, *Rana tigrina* | - | Not North American species;<br>Formulation | Sevin<br>(50% WDP) |
| Sampath et al. | Effect of carbaryl on the levels of protein and amnioacids of common frog *Rana tigrina*. | 1995 | Common frog, *Rana tigrina* | - | Not North American species;<br>Formulation;<br>Injected toxicant | Sevin<br>(50% WDP) |
| Sampath et al. | Pesticide impact on excretory physiology of the common frog, *Rana tigrina*. | 2002 | Common frog, *Rana tigrina* | - | Not North American species;<br>Lack of exposure details | Dilution water not characterized, purity unknown |
| Sanders | Toxicity of some insecticides to four species of malacostracan crustaceans. | 1972 | Amphipod, *Gammarus fasciatus*<br>Sowbug, *Asellus brevicaudus*<br>Shrimp, *Palaemonetes kadinkensis*<br>Crayfish, *Orconectes nais* | 96 hr<br>LC50=26<br>LC50=240<br>LC50=5.6<br>LC50=8.6 | Excessive solvent used | 1 mL/L |
| Sastry and Siddiqui | Chronic toxic effects of the carbamate pesticide sevin on carbohydrate metabolism in a freshwater snakehead fish, *Channa punctatus*. | 1982 | Snakehead, *Channa punctatus* | 60 d<br>caused blood alterations at 1,050 | Not North American species;<br>Only one exposure concentration | |
| Sastry and Siddiqui | Effect of the carbamate pesticide sevin on the intestinal absorption of some nutrients in the teleost fish, *Channa punctatus*. | 1985 | Snakehead, *Channa punctatus* | 1 hr<br>decreased rate of absorption of glucose at 10,000 | Not North American species | |
| Sastry et al. | Acute and chronic toxic effects of the carbamate pesticide sevin on some haematological, biochemical and enzymatic parameters in the fresh water teleost fish *Channa punctatus*. | 1988 | Snakehead, *Channa punctatus* | - | Not North American species;<br>Only one exposure concentration | |

## Appendix J.  List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Saxena and Aggarwal | Toxicity of some insecticides to the Indian catfish, *Heteropneustes fossilis* (Bloch). | 1970 | Catfish, *Heteropneustes fossilis* | - | Not North American species; Formulation | 50% WP |
| Saxena and Garg | Effect of insecticidal pollution on ovarian recrudescence in the fresh water teleost *Channa punctatus* (Bloch). | 1978 | Snakehead catfish, *Channa punctatus* | - | Not North American species; Formulation | Carbaryl (50% WP) |
| Saxena et al. | Effects of some pesticides on in-vitro lipid and protein synthesis by the liver of the freshwater teleost, *Channa punctatus* (Bl.). | 1989 | Snakehead catfish, *Channa punctatus* | - | Not North American species; Formulation | Carbaryl (50% WP) |
| Sayce and Chambers | Observations on potential uptake of sevin by Pacific oysters. | 1969 | - | - | Lack of details | Dilution water not characterized |
| Scaps et al. | Biochemical and physiological responses induced by toxics in annelida: utilization as biomarkers. | 2002 | Polychaete, *Nereis diversicolor* | - | Only one exposure concentration | |
| Schacht et al. | Bioassays for risk assessment of coal conversion products. | 1999 | - | - | Not applicable | No carbaryl toxicity information |
| Scholz et al. | Dose-additive inhibition of Chinook salmon acetylcholinesterase activity by mixtures of organophosphate and carbamate insecticides. | 2006 | Chinook salmon, *Oncorhynchus tshawytscha* | - | Surgically altered test species | Olfactory rosettes removed |
| Schulz | Field studies on exposure, effects, and risk mitigation of aquatic nonpoint-source insecticide pollution: A review. | 2004 | - | - | Review of previous studies | |
| Scott and Georghiou | Malathion-specific resistance in *Anopheles stephensi* from Pakistan. | 1986 | Mosquito, *Anopheles stephensi* | 24 hr LC50=720 | Not North American species | |
| Scott and Sloman | The effects of environmental pollutants on complex fish behavior: integrating behavioural and physiological indicators of toxicity. | 2004 | - | - | Review of previous studies | |
| Seiffer and Schoof | Tests of 15 experimental molluscicides against *Australorbis glabratus*. | 1967 | Snail, *Australorbis glabratus* | 6 hr 100% death at 10,000 | Not North American species; Only one exposure concentration | |
| Selvakumar et al. | Stressor-specific induction of heat shock protein 70 in the freshwater prawn *Macrobrachium malcolmsonii* (H. Milne Edwards) exposed to the pesticides endosulfan and carbaryl. | 2005 | Prawn, *Macrobrachium malcolmsonii* | - | Not North American species; Only two exposure concentrations | |
| Semlitsch et al. | Genetic variation and a fitness tradeoff in the tolerance of gray treefrog (*Hyla versicolor*) tadpoles to the insecticide carbaryl. | 2000 | Green treefrog, *Hyla versicolor* | - | Only one exposure concentration | |
| Seuge and Bluzat | Chronic toxicity of carbaryl and lindane to the freshwater mollusc *Lymnaea stagnalis* L. | 1979a | Snail, *Lymnaea stagnalis* | - | Only two exposure concentrations; Text in foreign language | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Seuge and Bluzat | Study of the chronic toxicity of two insecticides (carbaryl and lindane) toward the F-sub-1 generation of *Lymnaea stagnalis* L. (Mollusca, Gasteropoda, Pulmonata). 2. Consequences on the reproductive potential. | 1979b | Snail, *Lymnaea stagnalis* | - | Only two exposure concentrations; Text in foreign language | |
| Shacklock and Croft | Effect of grazers on *Chondrus crispus* in culture. | 1981 | Irish moss, *Chondrus crispus* | - | Formulation | Sevin (50% carbaryl) |
| Shaikila et al. | Adaptive trends in tissue acid and alkaline phosphatases of *Sarotherodon mossambicus* (Peters) under sevin toxicity. | 1993 | Mozambique tilapia, *Oreochromis mossambicus* | 96 hr increased alkaline phosphatase enzyme activities of liver and muscle at 3,000 | Only one exposure concentration | |
| Shamaan et al. | Insecticide toxicity, glutathione transferases and carboxylesterase activities in the larva of the *Aedes* mosquito. | 1993 | Mosquito, *Aedes aegypti* | - | Dilution water is distilled water without the proper salts added | |
| Shanmugam et al. | Effect of pesticides on the freshwater crab *Barytelphusa cunicularis* (West Wood). | 2000 | Crab, *Barytelphusa cunicularis* | - | Not North American species; Formulation | 50% carbaryl |
| Shea | Testing of chemical and microbial insecticides for safety...some techniques. | 1977 | - | - | Formulation | Sevin-4-oil |
| Sherstneva, | Effect of some pesticides on the fresh water crustaceans. | 1978 | - | - | Lack of details | Text in foreign language |
| Shrivastava and Singh | Toxic effect of carbaryl on glucose level in the muscles of *Heteropneustes fossilis*. | 2003 | Catfish, *Heteropneustes fossilis* | 30 d decrease in glucose content of muscles at 40 | Not North American species; Only one exposure concentration | |
| Shrivastava and Singh | Changes in protein content in the muscle of *Heteropneustes fossilis* exposed to carbaryl. | 2004 | Catfish, *Heteropneustes fossilis* | 30 d decrease in protein of muscles at 40 | Not North American species; Only one exposure concentration | |
| Shrivastava et al. | Study of cholesterol content in muscle of carbaryl exposed *Heteropneustes fossilis* (Bloch.). | 2005 | Catfish, *Heteropneustes fossilis* | 30 d decrease in cholesterol content of muscles at 40 | Not North American species; Only one exposure concentration | |
| Shukla and Mishra | Bioassay studies on effects of carbamate insecticides on dragonfly nymphs. | 1980 | Dragonfly, *Brachythermis contaminate* | - | Not North American species; Formulation | Carbaryl (WDP 10%) |
| Shukla and Omkar | Insecticide toxicity to *Macrobrachium lamarrei* (H. Milne Edwards) (Decapoda, Palaemonidae). | 1984 | Prawn, *Macrobrachium lamarrei* | - | Not North American species; Formulation | Sevin (50 WP) |
| Shukla et al. | Acute toxicity of few pesticides to an aquatic insect, *Ranatra elongata* (Fabr.). | 1982 | Water scorpion, *Ranatra elongata* | - | Not North American species; Formulation | 50% WP |
| Sikka and Rice | Interaction of selected pesticides with marine microorganisms. | 1974 | - | - | Lack of exposure details | |
| Sikka et al. | Metabolism of selected pesticides by marine microorganisms. | 1973 | - | - | Excessive carrier solvent | 1% ethanol |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Singh and Agarwal | Toxicity of certain pesticides to two economic species of snails in northern India. | 1981 | Snail,<br>*Lymnaea acuminata*<br>*Pila globosa* | 96 hr<br>LC50=4,500<br>LC50=36,500 | Not North American species | |
| Singh and Agarwal | In vivo and in vitro studies on synergism with anticholinesterase pesticides in the snail *Lymnaea acuminata*. | 1983a | Snail,<br>*Lymnaea acuminata* | 96 hr<br>LC50=4,400 | Not North American species | |
| Singh and Agarwal | Inhibition kinetics of certain organophosphorus and carbamate pesticides on acetylcholinesterase from the snail *Lymnaea acuminata*. | 1983b | Snail,<br>*Lymnaea acuminata* | - | Not North American species; Surgically altered test species | Nervous tissue around the buccal mass |
| Singh and Agarwal | Carbamate and organophosphorus pesticides against snails. | 1984 | Snail,<br>*Lymnaea acuminata*<br>*Pila globosa* | 96 hr<br>LC50=4,150<br>LC50=35,500 | Not North American species | |
| Singh and Agarwal | Synergistic effect of sulfoxide with carbaryl on the in vivo acetylcholinesterase activity and carbohydrate metabolism of the snail *Lymnaea acuminata*. | 1986a | Snail,<br>*Lymnaea acuminata* | - | Not North American species; Mixture | |
| Singh and Agarwal | Toxicity of pesticides to fecundity, hatchability and survival of young snails of *Lymnaea acuminata*. | 1986b | Snail,<br>*Lymnaea acuminata* | 48 hr<br>LOEC(fecundity) =11,000<br>LOEC (hatchability) =1,000 | Not North American species | |
| Singh and Agarwal | Toxicity of piperonyl butoxide - carbaryl synergism on the snail *Lymnaea acuminata*. | 1989 | Snail,<br>*Lymnaea acuminata* | - | Not North American species; Only two exposure concentrations | |
| Singh and Shrivastava | Histopathological changes in the liver of the fish *Nandus nandus* exposed to endosulfan and carbaryl. | 1998 | Fish,<br>*Nandus nandus* | - | Not North American species; Only one exposure concentration | |
| Singh et al. | Evaluation of acute toxicity of carbaryl and malathion to freshwater teleosts, *Channa punctatus* (Bloch) and *Heteropneustes fossilis* (Bloch). | 1984 | Snakehead catfish,<br>*Channa punctatus*<br>Catfish,<br>*Heteropneustes fossilis* | - | Not North American species; Formulation | 50% WP |
| Singh et al. | Toxicity of malathion and carbaryl pesticides: effects on some biochemical profiles of the freshwater fish *Colisa fasciatus*. | 2004 | Gourami,<br>*Colisa fasciatus* | 96 hr<br>LC50=8,000 | Not North American species | |
| Sinha et al. | Thiodicarb, an effective molluscicide for grazer snails of blue green algae. | 1986a | Snails | - | Formulation | Carbaryl 50 WP |
| Sinha et al. | An effective molluscide for grazer snails of blue green algae. | 1986b | Snails | - | Formulation | Carbaryl 50 WP |
| Sinha et al. | Carbaryl-induced thyroid dysfunction in the freshwater catfish *Clarias batrachus*. | 1991a | Walking catfish,<br>*Clarias batrachus* | 96 hr<br>decreased thyroxin levels at 12,000 | Only two exposure concentrations | |
| Sinha et al. | Pesticides induced changes in circulating thyroid hormones in the freshwater catfish *Clarias batrachus*. | 1991b | Walking catfish,<br>*Clarias batrachus* | - | Formulation | 50% carbaryl |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (μg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Sinha et al. | Effect of pesticides on extrathyroidal conversion of $T_4$ to $T_3$ in the freshwater catfish *Clarias batrachus*. | 1993 | Walking catfish, *Clarias batrachus* | - | Only one exposure concentration | |
| Smith and Grigoropoulos | Toxic effects of odorous trace organics. | 1968 | Trout<br>Red shiner | - | Formulation; No scientific names given | Sevin<br>(50% carbaryl) |
| Smulders et al. | A noncompetitive, sequential mechanism for inhibition of rat α4β2 neuronal nicotinic acetylcholine receptors by carbamate pesticides. | 2004 | - | - | In vitro test | |
| Solomon | The teratogenic effects of the insecticides DDT, carbaryl, malathion and parathion on developing medaka eggs (*Oryzias latipes*). | 1978 | Medaka, *Oryzias latipes* | 96 hr<br>10,000 negatively affected embryonic development | Not North American species | |
| Solomon and Weis | Abnormal circulatory development in medaka caused by the insecticides carbaryl, malathion and parathion. | 1979 | Medaka, *Oryzias latipes* | ED50=2,500 (circulatory anomalies) | Not North American species | |
| Somnuek et al. | Gene expression of acetylcholinesterase in hybrid catfish (*Clarias gariepinus* x *Clarias macroephalus*) exposed to chlorpyrifos and carbaryl. | 2009 | Hybrid catfish, *Clarias gariepinus* x *C. macrocephalus* | 24 hr<br>gene expression NOEC=8,652 | Not North American species | |
| Srivastava and Pandey | Effect of carbaryl on *Chironomus* larvae (Chironomidae). | 2007 | Midge, *Chironomus sp.* | - | Lack of exposure details;<br>Formulation | |
| Statham and Lech | Potentiation of the acute toxicity of several pesticides and herbicides in trout by carbaryl. | 1975a | Rainbow trout, *Oncorhynchus mykiss* | - | Mixture | |
| Statham and Lech | Synergism of the acute toxic effects of 3,4-D butyl ester, dieldrin, rotenone, and pentachlorophenol in rainbow trout by carbaryl. | 1975b | Rainbow trout, *Oncorhynchus mykiss* | - | Mixture | |
| Statham and Lech | Studies on the mechanism of potentiation of the acute toxicity of 2,4-D n-butyl ester and 2',5-dichloro-4'-nitrosalicylanilide in rainbow trout by carbaryl. | 1976 | Rainbow trout, *Oncorhynchus mykiss* | - | Mixture | |
| Strickman | Aquatic bioassay of 11 pesticides using larvae of the mosquito, *Wyeomyia smithii* (Diptera: Culicidae). | 1985 | Mosquito, *Wyeomyia smithii* | 7d survival LOEC=1,000 | Excessive solvent used | 3.3 mL/L |
| Sukumar and Rao | Toxicity of *y*-HCH, methyl parathion and carbaryl to two varieties of a tropical freshwater gastropod, *Bellamya bengalensis* (Lamarck) (Gastropoda: Viviparidae). | 1985 | Gastropod, *Bellamya bengalensis* | - | Not North American species;<br>Formulation | Sevin |
| Sundaram and Szeto | Distribution and persistence of carbaryl in some terrestrial and aquatic components of a forest environment. | 1987 | Brook trout, *Salvelinus fontinalis*<br>Slimy sculpin, *Cottus cognatus* | - | Formulation | Sevin-2-oil |

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| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Suseela et al. | Toxic effects of pesticides on survival and proximate composition of *Tubifex tubifex*. | 1994 | Tubificid worm, *Tubifex tubifex* | - | Formulation | Sevin |
| Suwanchaichinda and Brattsten | Effects of exposure to pesticides on carbaryl toxicity and cytochrome P450 activities in *Aedes albopictus* larvae (Diptera: Culicidae). | 2001 | Mosquito, *Aedes albopictus* | 24 hr<br>LC50=830 | Inappropriate dilution water | Distilled water without proper salts added |
| Suwanchaichinda and Brattsten | Induction of microsomal cytochrome P450s by tire-leachate compounds, habitat components of *Aedes albopictus* mosquito larvae. | 2002 | Mosquito, *Aedes albopictus* | - | Mixture;<br>Inappropriate dilution water | Pure water without proper salts added |
| Swanson et al. | Testing for pesticide toxicity to aquatic plants: Recommendations for test species. | 1991 | - | - | Review of previous studies | |
| Takahashi and Yasutomi | Insecticidal resistance of *Culex tritaeniorhynchus* (Diptera: Culicidae) in Japan: Genetics and mechanisms of resistance to organophosphorus insecticides. | 1987 | Mosquito, *Culex tritaeniorhynchus* | 24 hr<br>LC50=268 | Not North American species;<br>Lack of exposure details | Dilution water not characterized |
| Tegelberg and Magoon | Sevin treatment of a subtidal oyster bed in Grays Harbor. | 1969 | - | - | Lack of exposure details;<br>Formulation | Dilution water not characterized |
| Tejada et al. | Toxicity of pesticides to target and non-target fauna of the lowland rice ecosystem. | 1994 | Various species | - | Formulation | Sevin |
| Thakur and Sahai | Toxicity assessment of some commonly used pesticides to three species of fishes. | 1994 | Snakehead catfish,<br>*Channa punctatus*<br>*C. striatus*<br>*Garra gotyla gotyla* | 96 hr<br>LC50=15,000<br>LC50=17,500<br>LC50=7,500 | Not North American species | |
| Thakur et al. | Effect of pesticides on N-use efficiency and growth dynamic in rice. | 1988 | Rice | - | Formulation;<br>Only one exposure concentration | Carbaryl 4G |
| Tham et al. | Assessment of *Clarias batrachus* as a source of acetylcholinesterase (AChE) for the detection of insecticides. | 2009 | Walking catfish, *Clarias batrachus* | - | Surgically altered test species | Brain extract |
| Thomas and Murthy | Acid phosphatase activity in a fresh-water air breathing fish *Heteropneustes fossilis* and the effect of certain organic pesticides on it. | 1976 | Catfish, *Heteropneustes fossilis* | - | Not North American species;<br>Injected toxicant | |
| Tierney et al. | Linuron and carbaryl differentially impair baseline amino acid and bile salt olfactory responses in three salmonids. | 2007 | Coho salmon, *Oncorhynchus kisutch*<br>Sockeye salmon, *O. nerka*<br>Rainbow trout, *O. mykiss* | - | Surgically altered test species | Olfactory rosette removed |
| Tilak | Relative toxicity of carbaryl, 1-naphthol, and three formulations of carbaryl to *Channa punctata* (Bloch). | 1982 | Snakehead catfish, *Channa punctatus* | 96 hr<br>LC50=5,000 | Not North American species | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Tilak et al. | Toxicity of carbaryl and 1-naphthol to the freshwater fish *Labeo rohita*. | 1980 | Rohu,<br>*Labeo rohita* | 96 hr<br>LC50=4,600 | Not North American species | |
| Tilak et al. | Toxicity of carbaryl and 1-naphthol to four species of freshwater fish. | 1981 | Catfish,<br>*Catla catla*<br>*Anabas testudineus*<br>*Mystus cavasius*<br>*Mystus vittatus* | 96 hr<br>LC50=6,400<br>LC50=5,500<br>LC50=4,600<br>LC50=2,400 | Not North American species | |
| Todd and Leeuwen | Effects of sevin (carbaryl insecticide) on early life stages of zebrafish (*Danio rerio*). | 2002 | Zebrafish,<br>*Danio rerio* | - | Not North American species; Formulation | 21.3% carbaryl |
| Tompkins | Report of the surveillance program conducted in connection with an application of carbaryl (sevin) for the control of gypsy moth on Cape Cod, Massachusetts. | 1966 | - | - | Field survey; Mixture | |
| Toor and Kaur | Toxicity of pesticides to the fish, *Cyprinus carpio communis* Linn. | 1974 | Carp,<br>*Cyprinus carpio* | - | Formulation | Carbaryl (50% WP) |
| Trial | The effects of sevin-4-oil on aquatic insect communities of streams: a continuation of 1976 studies. | 1978 | - | - | Formulation | Sevin-4-oil |
| Trial | The effects of sevin-4-oil on aquatic insect communities of streams (1976-1978). | 1979 | - | - | Formulation | Sevin-4-oil |
| Trial | The effects of sevin-4-oil on aquatic insect communities of streams (1976-1979). | 1980a | - | - | Formulation | Sevin-4-oil |
| Trial | The effectiveness of unsprayed buffers in lessening the impact of aerial applications of carbaryl on aquatic insects. | 1980b | - | - | Formulation | Sevin-4-oil |
| Trial | The effect of carbaryl on leaf litter processing in Maine streams. | 1981 | - | - | Formulation; Lack of exposure details (procedure) | |
| Trial | The effectiveness of upstream refugia for promoting recolonization of plecoptera killed by exposure to carbaryl. | 1982 | - | - | Formulation | Sevin-4-oil |
| Trial and Gibbs | Effects of orthene®, sevin 4 oil® and dylox® on aquatic insects incidental to attempts to control spruce budworm in Maine, 1976. | 1978 | - | - | Formulation | Sevin-4-oil |
| Tripathi and Agarwal | Synergism in tertiary mixtures of pesticides. | 1997 | Snail,<br>*Lymnaea acuminata* | - | Not North American species; Mixture | Sevin and Decis |
| Tripathi and Singh | Toxic effects of dimethoate and carbaryl pesticides on carbohydrate metabolism of freshwater snail *Lymnaea acuminata*. | 2002 | Snail,<br>*Lymnaea acuminata* | 96 hr decrease hepatopancreas glycogen at 3,000 | Not North American species | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Tripathi and Singh | Toxic effects of dimethoate and carbaryl pesticides on protein metabolism of freshwater snail *Lymnaea acuminata*. | 2003a | Snail,<br>*Lymnaea acuminata* | 96 hr decrease hepatopancreas total protein at 3,000 | Not North American species | |
| Tripathi and Singh | Toxic effects of dimethoate and carbaryl pesticides on reproduction and related enzymes of freshwater snail *Lymnaea acuminata*. | 2003b | Snail,<br>*Lymnaea acuminata* | - | Not North American species | |
| Tripathi and Singh | Carbaryl induced alterations in the reproduction and metabolism of freshwater snail *Lymnaea acuminata*. | 2004 | Snail,<br>*Lymnaea acuminata* | 96 hr decrease number of eggs at 2,000 | Not North American species | |
| Tsuge et al. | Uptake of pesticides from aquarium tank water by aquatic organisms. | 1980 | Guppy,<br>*Lebistes reticulatus*<br>Red snail,<br>*Indoplanorbis exustus*<br>Mosquito,<br>*Culex pipiens*<br>Cladoceran,<br>*Daphnia pulex* | - | Lack of exposure details | Text in foreign language |
| Upadhyay and Upadhyay | Development of marked basophilia in the liver of *Heteropneustes fossilis* by some selected chemicals. | 1993 | Catfish,<br>*Heteropneustes fossilis* | - | Not North American species; Only one exposure concentration | |
| Vaishampayan | Mutagenic activity of alachlor, butachlor and carbaryl to a N2-fixing cyanobacterium *Nostoc muscorum*. | 1985 | Cyanobacterium,<br>*Nostoc muscorum* | - | Sediment present | |
| Van Hoof | Evaluation of an automatic system for detection of toxic substances in surface water using trout. | 1980 | Rainbow trout,<br>*Oncorhynchus mykiss* | - | Only one exposure concentration | |
| Van Hoof et al. | The evaluation of bacterial biosensors for screening of water pollutants. | 1992 | - | - | Lack of exposure details; Only two exposure concentrations | |
| Vasseur et al. | Interactions between copper and some carbamates used in phytosanitary treatments. | 1988 | Bacteria,<br>*Photobacterium phosphoreum*<br>Protozoa,<br>*Colpidium campylum* | - | Mixture | Carbaryl and copper |
| Vasumathi et al. | Acute toxicity of endosulfan, methyl parathion and carbaryl on *Macropodus cupanus*. | 2001 | Paradisefish,<br>*Macropodus cupanus* | 96 hr LC50=14,540 | Not North American species | |
| Venkateswaran and Ramaswamy | Lactic acidosis in different of *Sarotherdon mossambicus* (Peters) exposed to sevin. | 1987 | Mozambique tilapia,<br>*Oreochromis mossambicus* | - | Formulation | Sevin<br>(10% dust) |
| Verma and Gupta | Pesticide in relation to water pollution (accumulation of aldrin and ethyl parathion in the few tissues of *Colisa fasciatus* and *Notopterus notopterus*). | 1976 | Fish,<br>*Colisa fasciatus*<br>*Notopterus notopterus* | - | Not applicable | No carbaryl toxicity information |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Verma and Tonk | Biomonitoring of the contamination of water by a sublethal concentration of pesticides - a system analysis approach. | 1984 | Catfish, *Heteropneustes fossilis* | - | Not North American species; Formulation | Sevin (50% WP) |
| Verma et al. | Quantitative estimation of biocide residues in a few tissues of *Labeo rohita* and *Saccobranchus fossilis*. | 1977 | Rohu, *Labeo rohita*<br>Catfish, *Saccobranchus fossilis* | - | Not North American species; Lack of exposure details | Dilution water not characterized |
| Verma et al. | Acute toxicity of twenty three pesticides to a fresh water teleost, *Saccobranchus fossilis*. | 1979 | Catfish, *Saccobranchus fossilis* | - | Not North American species; Lack of exposure details (procedure) | |
| Verma et al. | Studies on the accumulation and elimination of three pesticides in the gonads of *Notopterus notopterus* and *Colisa fasciatus*. | 1981b | Fish, *Colisa fasciatus*<br>*Notopterus notopterus* | - | Not North American species; Formulation | Sevin (50% WP) |
| Verma et al. | Bioassay trials with twenty three pesticides to a fresh water teleost, *Saccobranchus fossilis*. | 1982 | Catfish, *Saccobranchus fossilis* | - | Not North American species; Formulation | Sevin (50% WP) |
| Verma et al. | Evaluation of an application factor for determining the safe concentration of agricultural and industrial chemicals. | 1984 | Carp, *Cirrhina mrigala* | - | Not North American species; Formulation | Sevin (50% WP) |
| Virk et al. | Histopathological and biochemical changes induced by endrin and carbaryl in the stomach, intestine and liver of *Mystus tengara*. | 1987 | Catfish, *Mystus tengara* | - | Not North American species; Formulation | Carbaryl (50% WP) |
| von Windeguth et al. | The efficacy of carbaryl, propoxur, abate and methoxychlor as larvicides against field infestations of *Aedes aegypti*. | 1971 | Mosquito, *Aedes aegypti* | - | Formulation | 0.5, 1.25 and 2.5% carbaryl |
| Vonesh and Buck | Pesticide alters oviposition site selection in gray tree frogs. | 2007 | Gray treefrog, *Hyla chrysoscelis* | - | Only one exposure concentration; Formulation | Sevin (commercial grade) |
| Vryzas et al. | Spatial and temporal distribution of pesticide residues in surface waters in northeastern Greece. | 2009 | - | - | Not applicable | No carbaryl toxicity information |
| Walsh | The pathology of pesticide poisoning in fish. | 1974 | Coho salmon, *Oncorhynchus kisutch*<br>Lake trout, *Salvelinus namaycush* | 30 d decreased relative spleen weight at 1,000 | Only one exposure concentration | |
| Weber et al. | Toxicity of certain insecticides to protozoa. | 1982 | Protozoa | - | Lack of exposure details (procedure) | |
| Weis and Mantel | DDT as an accelerator of limb regeneration and molting in fiddler crabs. | 1976 | Fiddler crab, *Uca pugilator*<br>*U. pugnax* | - | Not applicable | No carbaryl toxicity information |
| Weis and Weis | Retardation of fin regeneration in *Fundulus* by several insecticides. | 1975 | Killifish, *Fundulus sp.* | - | Surgically altered test species | |

## Appendix J. List of Carbaryl Studies Not Used in Document Along with Reasons

| Author | Title | Date | Organism(s) | Concentration (µg/L) | Reason Unused | Expanded Reason |
|---|---|---|---|---|---|---|
| Weis and Weis | Optical malformations induced by insecticides in embryos of the Atlantic silverside, *Menidia menidia*. | 1976 | Atlantic silverside, *Menidia menidia* | - | Lack of exposure details (procedure) | |
| Whitmore and Hodges | In vitro pesticide inhibition of muscle esterases of the mosquitofish, *Gambusia affinis*. | 1978 | Mosquito, *Gambusia affinis* | - | Surgically altered test species | Homogenized muscle tissue |
| Whitten and Goodnight | Toxicity of some common insecticides to tubificids. | 1966 | Tubificid worms, *Tubifex sp.* *Limnodrilus sp.* | - | Formulation | Sevin (20% EC) |
| Whyard et al. | Isolation of an esterase conferring insecticide resistance in the mosquito *Culex tarsalis*. | 1994 | Mosquito, *Culex tarsalis* | - | Prior exposure | |
| Wilder and Stanley | RNA-DNA ratio as an index to growth in salmonid fishes in the laboratory and in streams contaminated by carbaryl. | 1983 | - | - | Only one exposure concentration; Formulation | Sevin-4-oil |
| Wood et al. | Carbamate and organophosphate resistance in *Culex pipiens* L. (Diptera: Culicidae) in southern France and the significance of EST-3A. | 1984 | Mosquito, *Culex pipiens* | 24 hr LC50=500 | Inappropriate dilution water | Deionized water without proper salts added |
| Worthley and Schott | The comparative effects of Cs and various pollutants on fresh water phytoplankton colonies of *Wolffia papulifera* Thompson. | 1972 | Duckweed, *Wolffia papulifera* | - | Formulation | 21.5% carbaryl |
| Yasutomi et al. | Insecticide-resistance of *Anopheles sinensis* and *Culex tritaeniorhynchus* in Saitama Prefecture, Japan. | 1986 | Mosquito, *Anopheles sinensis*<br>Mosquito, *Culex tritaeniorhynchus* | - | Lack of exposure details | Text in foreign language |
| Yokoyama et al. | Sensitivity of Japanese eel, *Anguilla japonica*, to 68 kinds of agricultural chemicals. | 1988 | Japanese eel, *Anguilla japonica* | - | Lack of exposure details | Text in foreign language |
| Yoshida and Nishiuchi | Toxicity of pesticides to some water organisms. | 1972 | - | - | Lack of exposure details | Text in foreign language |
| Yoshioka et al. | The estimation for toxicity of chemicals on fish by physico-chemical properties. | 1986 | - | - | Review of previous studies | |

Dash indicates not available