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OFFICE OF
PREVENTION, PESTICIDES, AND
TOXIC SUBSTANCES

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MEMORANDUM:

SUBJECT: Revised EFED Risk Assessment of Carbaryl in Support of the Reregistration Eligibility Decision (RED)

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The Environmental Fate and Effects Division has revised the Environmental Fate and Ecological Risk Assessment chapter in support of the reregistration eligibility decision on carbaryl. The chapter has been revised to incorporate recently received fate and effects data and to reflect comments received during the public comment phase of the review process. The revised chapter is attached and contains more detailed information on drinking water monitoring studies and specialized uses of carbaryl, *i.e.*, Section 24c use of carbaryl to control burrowing shrimp and the use of carbaryl for the U. S. Department of Agriculture Animal and Plant Health Inspection Service's grasshopper and Mormon cricket suppression program.

In general, carbaryl is not likely to persist in the environmental; however owing to its mobility and it extensive use, the chemical is frequently detected in surface water and to a much lesser extent in groundwater. Urban use of carbaryl appears to serve as a primary source of carbaryl residues in surface water. Carbaryl's primary degradate, 1-naphthol, is expected to degrade more rapidly and be less mobile than the parent. Since 1-naphthol has many natural and anthropogenic sources other than carbaryl degradation, the presence of this compound cannot be used as a measure of carbaryl use. Furthermore, the Agency does not have soil photolysis (Guideline §161-3) data and recommends the study be submitted.

The registrant voluntarily expended considerable effort to conduct drinking water monitoring studies independent of the Agency; however, EFED's review of the studies indicated that the sampling sites could not be considered representative of highly vulnerable current use sites for carbaryl and the sampling interval (one week) is not likely to adequately capture peak concentrations. While the studies provide useful information on spatial-temporal trends in carbaryl residues in drinking water, the residues cannot be considered high-end values. Therefore, distributions of modeled drinking water concentrations were developed for use in estimating drinking water concentrations for the purposes of human risk assessment.

Although carbaryl is not expected to persist, its mobility coupled with high use is likely to result in residues in both terrestrial and aquatic habitats. Carbaryl is not likely to represent a risk of acute mortality to birds; however, on the majority of uses modeled, the chronic risk level of concern is exceeded. Based on estimated environmental concentrations, over 75% of the registered uses modeled are likely to represent a risk of acute mortality and chronic growth/reproductive effects in mammals. As with most chemicals, smaller-sized animals that consume a larger percentage of their body weight are more vulnerable than larger-sized animals. Carbaryl is also very highly toxic to bees and at current application rates these beneficial insects will likely succumb to acute mortality if they come in direct contact with the chemical in the immediate treatment areas.

No acute risk LOCs are exceeded for estuarine/marine fish and carbaryl use on citrus alone exceeds the acute risk LOC for freshwater fish. The acute endangered species LOC is minimally exceeded for all freshwater fish as the magnitude of the risk quotients is low, *i.e.* < 0.70). Consistent with carbaryl's classification as being very highly toxic to aquatic invertebrates, both acute mortality and chronic reproductive/growth effects are likely for freshwater invertebrates in static bodies of water. In some cases though, like the use of carbaryl to control burrowing shrimp, large influxes of water can significantly reduce chemical residues in nontargeted areas.

While controlled studies of carbaryl's affects on plants do not indicate that the chemical is phytotoxic, field incidents suggest otherwise. It is possible that the carbaryl degradate 1-naphthol, a plant auxin, is impacting the plants rather than the parent compound. Additionally, carbaryl's toxicity to aquatic invertebrates may reduce the potential for zooplankton grazing and result in conditions that may actually favor the growth (survival) of phytoplankton.

Carbaryl is sufficiently volatile to result in aerial transport of the chemical. Consideration should be given to reducing the extent of aerial applications. Given carbaryl's potential to degrade rapidly, mitigation options may include spraydrift and vegetated runoff buffers to slow the chemical's movement and facilitate degradation. Additionally, more protracted reapplication intervals would reduce chemical residues. Where possible, delaying application by several weeks could reduce estimated environmental concentrations by roughly 30 to 40%.

Uncertainties

Although carbaryl is practically nontoxic to birds on an acute oral and subacute dietary exposure basis, there is some uncertainty regarding the sensitivity of smaller-sized passerine species. Open literature and weakly supported field incident data suggest that carbaryl may be more toxic to smaller birds.

Aquatic and terrestrial plant testing with carbaryl was conducted over a limited range of species. Given the field incidents reported where both residential and commercial use of carbaryl has resulted in plant damage, EFED is uncertain regarding the extent to which carbaryl use may impact nontarget plants. EFED recommends that both aquatic (Guideline §122-2) plant growth and terrestrial seedling emergence and vegetative vigor (Tier 2; Guideline §123-1) testing be conducted on the full range of species.

Although EFED does not have data to support concerns that the Section 24c use of carbaryl to control burrowing shrimp in Willapa Bay/Grays Harbor, Washington, represents an unreasonable risk to nontarget areas, it is clear that carbaryl has to potential to drift from its application area due to tidal flow. The extent of this drift has been and continues to be monitored. EFED encourages stakeholders in the area to work together toward limiting potential drift issues by continuing studies to examine alternatives. Additionally, consideration should be given to treating smaller areas of contiguous acres to limit total pesticide loading during any particular treatment cycle.

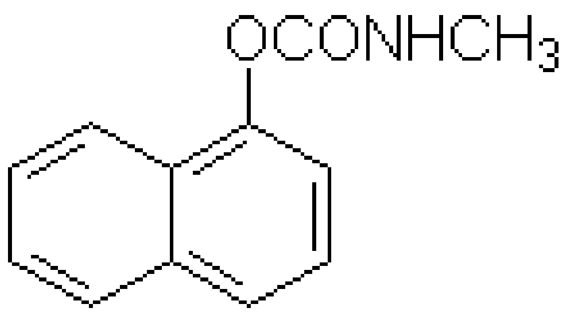
Given carbaryl's rapid degradation potential under most conditions, it is not likely to represent a risk to of chronic exposure in estuarine/marine species. However, there are conditions, i.e., acidic and/or anaerobic environments, where carbaryl can persist. Since no data have been provided on the chronic effects of carbaryl on estuarine/marine fish and invertebrates, EFED recommends that Guideline §74-4 studies on estuarine/marine fish and invertebrates be conducted.

Endangered Species

The U. S. Fish and Wildlife Service rendered a draft biological opinion on the use of carbaryl in 1989. Since that time new uses have been added and additional species have been listed. Consultations with the Fish and Wildlife Service and the National Marine Fisheries Service are either in process or are being planned to afford endangered species protection to the extent possible under the Endangered Species Act.

Office of Prevention, Pesticides, and Toxic Substances

Environmental Fate and Ecological Risk Assessment for the Re-registration of Carbaryl



1-Naphthyl methylcarbamate
1-naphthyl N-methylcarbamine
CAS Registry Number 63-25-2
PC Code 056801

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EXECUTIVE SUMMARY

Carbaryl is a carbamate insecticide registered for control of a wide range of insect and other arthropod pests on over 100 agricultural and noncrop use sites, including home and garden uses. The pesticide is a cholinesterase inhibitor that acts on contact on ingestion. Carbaryl dissipates in the soil environment by abiotic and microbially-mediated degradation. The major degradation product is 1-naphthol, which is further degraded to CO_2. Abiotic routes of degradataion include relatively rapid hydrolysis under alkaline conditions and photolysis in water. Under aerobic conditions, the compound degrades rapidly by microbial metabolism with half-lives of 4 to 5 days in soil and aquatic environments. Carbaryl dissipates rapidly from foliage and is mobile in the environment; however, the compound will increasingly partition to sediment as organic carbon content increases. Both urban and agricultural use have been associated with detections in all environmental compartments. Carbaryl is not expected to bioaccumulate.

Fate data on the primary degradate, is limited; however, 1-naphthol appears to be somewhat mobile but 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.

Carbaryl has been frequently detected in surface water monitoring studies and although infrequent, in ground water monitoring studies as well. Based on these data, residential use of carbaryl is more frequently associated with surface water contamination. A drinking water monitoring study was submitted for review; however, estimates of carbaryl concentrations in surface water-derived drinking water and used in aquatic exposure assessment were based on deterministic models and estimates for groundwater-derived drinking water were based on an empirical model. While the drinking water monitoring study provided information on spatial and temporal trends in carbaryl residues, the study was viewed as not having included what could be considered representative of highly vulnerable sites in current carbaryl use areas. Although carbaryl is frequently detected in surface water monitoring studies, particularly on urban watersheds, and these data suggest that carbaryl is persistent, the frequent detections are more likely an index of the volume of carbaryl being used rather than on the chemical's persistence.

The demonstrated mobility of carbaryl and its likelihood to reach both terrestrial and aquatic habitats has raised concerns regarding its affects on nontarget animals. Carbaryl is practically nontoxic to birds, moderately toxic to mammals and fish, and very highly toxic to bees and aquatic invertebrates on an acute exposure basis. The carbaryl hydrolysis degradate 1-naphthol ranges in toxicity from moderately to highly toxic to aquatic organisms. Since carbaryl is practically nontoxic to birds on both an acute exposure basis, there is a low likelihood that current registered uses of carbaryl will impact birds in terms of acute effects. However, based on a deterministic "risk quotient (RQ)" assessment, i.e., ratio of exposure to toxic effect endpoints, the chronic risk level of concern (LOC) is exceeded (RQ $\geq$ 1) for birds on over 50% of the 70 uses modeled at maximum label rates. At "average" use rates, roughly 49% of the modeled uses exceeded the chronic risk LOC. Although incident data exist for carbaryl, they only weakly support the potential for carbaryl adversely affecting birds.

Acute risk LOCs are exceeded for mammals on over 75% of the uses modeled for small and intermediate-sized animals using both maximum label and "average" application rates. Although large mammals appear to be less vulnerable to carbaryl in terms of exposure, acute risk LOCs are exceeded for 40% of the uses. The chronic risk LOC is exceeded on all uses at maximum label rates and for 89% of the uses at "average" rates. Granular/bait formulations exceeded acute risk LOCs for all 40 registered uses.

Although two incidents involving mammals (one squirrel and one mole) have been reported for carbaryl, neither could be associated with a specific use of the pesticide.

Carbaryl is highly toxic to beneficial insects and bees are likely to be impacted if they are located in the application site. Bee kill incidents have been reported; however, except for a single use of carbaryl on asparagus, a specific use could not be implicated. While concern has been raised regarding the use of carbaryl to thin fruit in orchards, a field study of this use indicated that carbaryl did not impact bee mortality and/or behavior.

Consistent with carbaryl's moderate toxicity to freshwater fish, the acute risk LOC is exceeded for citrus use alone; however, acute endangered species LOC (RQ $\geq$ 0.05) is exceeded for the majority of uses modeled. None of the modeled uses exceeded the chronic LOC. While estuarine/marine fish are equally sensitive to carbaryl, no acute risk LOC was exceeded for this group. No data were available to assess chronic risk to estuarine/marine fish.

Freshwater and estuarine/marine invertebrates are particularly vulnerable to carbaryl and acute risk LOCs are exceeded for all of the uses modeled at maximum label, "average" and maximum reported application rates. No data were available to assess chronic risk to estuarine/marine invertebrates.

Two specific uses of carbaryl were explored in greater detail, these included the Section 24c use of carbaryl to control burrowing shrimp in Willapa Bay and Grays Harbor, Washington, and the use of carbaryl to control grasshoppers and Mormon crickets on rangeland in the Midwest. On the use of carbaryl to control burrowing shrimp, the available data indicate that acute mortality will likely be near 100% for animals trapped on mudflats in the immediate application area and that carbaryl will likely drift off-site with the tide. However, a combination of the rapid degradation of carbaryl due to both biotic and abiotic factors and dilution by a relatively large influx of water together render potential acute and chronic effects remote. While concern has been expressed for birds feeding opportunistically on carbaryl-immobilized prey items, no data have been submitted to substantiate these concerns. Additionally, as stated above, laboratory data indicate that on both an acute oral and subacute dietary exposure basis, carbaryl is practically nontoxic to birds.

With respect to the use of carbaryl to control grasshoppers and Mormon crickets on rangeland, acute and chronic risk LOCs are exceeded for smaller-sized mammals when 0.5 lbs/Acre is applied; however, at 0.25 lbs/A the acute endangered species LOC alone is exceeded for smaller animals. Additionally, assuming 5% spray drift at edge-of-field, acute restricted use and endangered species LOCs are exceeded for freshwater invertebrates. If 95% spraydrift (direct overflight of aquatic habitat) occurrs, then the acute endangered species LOC is exceeded for fish, and acute and chronic risk LOCs are exceeded for aquatic invertebrates.

Based on the potential for both acute and chronic effects to terrestrial (primarily mammals) and aquatic animals (primarily invertebrates), plans are underway to consult with the U.S. Fish and Wildilfe Service and the National Marine Fisheries Service to assure that endangered species are protected to the extent possible. Section 7 consultations on the use of carbaryl on rangelands to control grasshoppers/crickets are ongoing.

Although laboratory studies of aquatic and terrestrial plants suggest that carbaryl exposure is not likely to represent a risk, these data were collected over a limited range of species. However, the largest number of field incidents reported for carbaryl have been associated with phytotoxicity. While the majority of these incidents have involved homeowner use, several were associated with orchards. The discrepancy *between the controlled toxicity testing results and the field incident data represents an uncertainty that should be addressed by additional studies.*

Acknowledgment

This Environmental Fate and Effects Assessment chapter in support of the reregistration eligibility decision (RED) for carbaryl has undergone many revisions and has benefitted from the insights of various reviewers over the years. The most current authors would like to take this opportunity to acknowledge the contributions of the previous lead authors Dr. Angel Chiri and Dr. Laurence Libelo and the former Risk Assessment Process Leader, Mr. Dana Spatz.

TABLE OF CONTENTS

ENVIRONMENTAL FATE ASSESSMENT

Exposure Characterization

Using acceptable and supplemental environmental fate studies submitted by the registrant, along with published scientific literature, a profile of the fate and transport of carbaryl in the environment has been compiled. This information is sufficiently complete to allow the evaluation of the movement and fate of the compound. A study for soil photolysis was submitted by did not provide usable data. However, existing data gaps in and degradate fate and mobility need to be addressed by the registrant.

Carbaryl dissipates in the soil environment by abiotic and microbially mediated degradation. The major degradation products are CO_2 and 1-naphthol, which is further degraded to CO_2 (**Figure 1**). Carbaryl is stable to hydrolysis in acidic conditions, but hydrolyzes rapidly in alkaline environments. Carbaryl is degraded by photolysis in water, with a half-life of 21 days. Under aerobic conditions the compound degrades rapidly by microbial metabolism with half-lives of 4 to 5 days in soil and aquatic environments. In anaerobic environments metabolism is much slower with half-lives on the order of two to three months. Carbaryl is mobile in the environment (K_f=1.7 to 3.5). Sorption onto soils is positively correlated with soil organic content, increasing with higher soil organic content (R^2 = 0.94). **Table 1** summarizes the environmental fate characteristics of carbaryl. Capsule descriptions of the different routes of dissipation are described below.

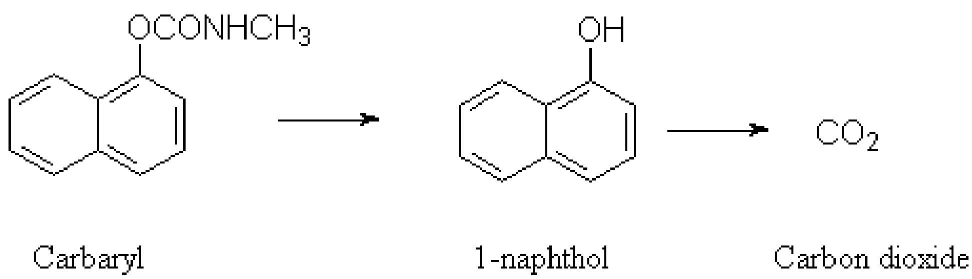

Figure 1. Generalized carbaryl degradation pathway

Hydrolysis

Carbaryl hydrolysis is strongly pH dependent. The compound is stable under acidic conditions and degrades in neutral and alkaline systems with measured half-lives of 12 days (pH 7) and 3.2 hours (pH 9). Only one major degradate was identified, 1-naphthol (MRID 44759301). Chapman and Cole (1982) measured half-lives of 2.0 weeks (pH = 7.0) and 0.07 weeks (pH = 8). Wolfe *et al*. (1978) reported half-life values in natural pond waters at pH 6.7 of 30 days and at pH 7.2 of 12 days. They also estimated minimum hydrolysis half-life in acidic conditions of 1600 days.

Armbrust and Crosby (1991) reported hydrolysis half-lives in filtered seawater of 24 hours at pH 7.9 and 23 hours at pH 8.3. The major degradation product was 1-naphthol which was stable to further hydrolysis. The registrant submitted hydrolysis was used to generate the model input parameters.

Table 1. Summary of Environmental Chemistry and Fate Parameters For Carbaryl (See Text for Analysis)

Parameter		Value	Reference
		Selected Physical/Chemical Parameters	
Molecular Weight		201.22	
Water Solubility		32 mg/L (ppm) at 20° C	Suntio, et al., 1988
Vapor pressure		1.36 10^{-7} mm Hg (25° C)	Ferrira and Seiber, 1981
Henry's Law Constant		1.28 x 10^{-8} atm m^3 mol^{-1}	Suntio, et al., 1988
Octanol/Water Partition		K_{ow} = 229	Windholz et al., 1976
		Persistence	
Hydrolysis $t_{1/2}$	pH 5 pH 7 pH 9	stable 12 days 3.2 hours	MRID 00163847, 44759301
Photolysis $t_{½}$ aqueous		21 days	MRID 41982603
Soil photolysis		assumed stable	No valid data submitted
Soil metabolism T½			
Aerobic		4 days in one sandy loam soil	MRID 42785101
Anaerobic		$t_{1/2}$ = 72 days	Satisfied by 162-3
Aquatic metabolism			
Aerobic		$t_{1/2}$ = 4.9 days	MRID 43143401
Anaerobic		$t_{1/2}$ = 72 days	MRID 42785102

Parameter	Value	Reference

Major Transformation Products Identified in the Fate Studies:

1-naphthol, CO_2

Minor Transformation Products Identified in the Fate Studies:

5-hydroxy-l-naphthyl methylcarbamate (aerobic soil metabolism, anaerobic aquatic)
1-naphthyl(hydroxymethyl)carbamate (aerobic soil metabolism, anaerobic aquatic)
1,4-naphthoquinone (aerobic aquatic metabolism, anaerobic aquatic)
(hydroxy)naphthoquinones (degradates of 1-naphthol)
4-hydroxy-1-naphthyl methylcarbamate (anaerobic aquatic)
1,5-naphthalenediol (anaerobic aquatic)
1,4-naphthalenediol (anaerobic aquatic)

	Mobility/Adsorption-Desorption	
Batch Equilibrium	K_f (K_{oc}) =1.74 (207) - sandy loam 2.04 (249) - clay loam sediment 3.00 (211) - silt loam 3.52 (177) - silty clay loam 1/n values ranged from 0.78-0.84	MRID 43259301
Column Leaching	slightly mobile in columns (30-cm length) of sandy loam, silty clay loam, silt loam, and loamy sand soils	MRID 433207-01
	Field Dissipation	
Terrestrial Dissipation	Submitted study not acceptable	MRID 419826-05
Forestry Dissipation	Foliar *$t_{1/2}$ = 21 days* *Leaf Litter $t_{1/2}$ = 75 days* Soil *$t_{1/2}$ = 65 days*	MRID 43439801
Aquatic	Submitted study not acceptable	MRID 4326001
Foliar Dissipation	30 days	Default value
	Bioaccumulation	
Accumulation in Fish	not expected due to low K_{ow}	

Aqueous photolysis

In an aqueous photolysis study, carbaryl, with an initial concentration of 10.1 mg/L, degraded in a pH 5 solution with a half-life of 21 days after correction for dark controls (MRID 41982603). The only degradate identified was 1-naphthol. Wolfe *et al.* (1978) reported a photolysis half-life in distilled water at pH 5.5 of 45 hours. In filtered seawater carbaryl degraded rapidly to 1-naphthol under artificial sunlight (290-360 nm) with a half-life of 5 hours. The degradation product, 1-naphthol, was degraded very rapidly with half-life of less than 1 hour (Armbrust and Crosby, 1991). The data from the study submitted by the registrant (MRID 41982603) was used to generate the model input parameters.

Microbially-mediated processes

Carbaryl degrades fairly rapidly by microbial processes under aerobic conditions and more slowly under anaerobic conditions. In a guideline study of aerobic soil metabolism carbaryl, with an initial concentration of 11.2 mg/kg, degraded with a half-life of 4.0 days in sandy loam soil incubated in the dark at 25^{B}C (MRID 42785101). The major degradate was 1-naphthol which further degraded rapidly to non-detectable levels within 14 days. In an aerobic aquatic metabolism study carbaryl, with an initial concentration of 9.97 mg/L, degraded with a half-life of 4.9 days in flooded clay loam sediment in the dark at 25° C (MRID 43143401). 1-Naphthol was identified as a major non-volatile degradate. Carbaryl degraded with a half-life of 72.2 days in anaerobic aquatic sediment with an initial carbaryl concentration of about 10 mg/L; 1-naphthol was the major degradate. Minor degradates included 5-hydroxy-1-naphthyl methylcarbamate, 4-hydroxy-1-naphthyl methylcarbamate, 1,5-naphthalenediol, 1,4-naphthalenediol, 1-naphthyl(hydroxymethyl)-carbamate, and 1,4-naphthoquinone.

Liu, *et al.* (1981) studied carbaryl degradation in anaerobic and aerobic fermenters spiked with a mixture of lake sediment, silt loam and domestic activated sludge and buffered to pH 6.8. They reported abiotic degradation half-lives of 8.3 (aerobic) and 15.3 (anaerobic) days. After correcting for abiotic controls, when carbaryl was used as the sole carbon source they found aerobic and anaerobic metabolism half-lives of 54 and 11.6 days, respectively. When glucose and peptone were added co-metabolism aerobic and anaerobic metabolism, half-lives were 7.6 and 6.1 days respectively.

A number of soil microorganisms have been identified which can degrade carbaryl including *Pseudomonas* sp (Chapalmadugu and Chaudhry, 1991; Larken and Day, 1986), *Rhodoccus* sp. (Larkken and Day, 1986), *Bacillus* sp. (Rajagopal. *et al.*,1984), *Arthrobacter* sp. (Hayatsu *et al.*, 1999), and *Achromobacter* sp (Karns *et al.*, 1986). Some bacteria are capable of complete degradation to CO_2 (Chapalamadugu and Chaudhry, 1991) while some stop at 1-naphthol. In soils it appears that consortia of bacteria are able to degrade parent and 1-naphthol completely to $CO_{2.}$ Proposed degradation pathways proceed by using the methylcarbarmate side chain as a carbon source, converting the parent to 1-naphthol. 1-naphthol is then degraded through intermediates salicylaldehyde, salicylic acid, catechol, and gentisate to CO_2 and water (Chapalamadugu and Chaudhry, 1991; Hayatsu *et al.*, 1999). Several studies have shown that bacteria isolated from soil exposed to carbofuran can degrade carbaryl indicating cross adaption by microorganisms allowing degradation of compounds with similar structure (Karns *et al.*, 1986: Chaudhry, *et al.*, 1988). Carbaryl degradation utilizes enzyme systems which may or may not degrade other carbamate compounds (Chapalamadugu and Chaudhry, 1991).

Mobility

Carbaryl is considered to be moderately mobile in soils. Based on batch sorption/ desorption studies, the compound has Freundlich K_f values of ≤ 3.52. Sorption is dependant on the soil organic matter content and increased with increasing K_{oc}.

Batch Adsorption/Desorption

Based on batch equilibrium experiments (*MRID* 43259301) carbaryl was determined to be mobile in soils. In silty clay loam, sandy loam, loamy sand, and silt loam soils and clay loam sediment, mobility decreased with increasing soil organic matter content. K_f values were 1.74 for the sandy loam soil, 2.04 for the clay loam sediment, 3.00 for the silt loam soil, and 3.52 for the silty clay loam soil. An adsorption K_{oc} of 144 was estimated when an regression with a y-intercept was used. When this model is used, there is a residual adsorption of 0.7 L kg^{-1} when there is no organic matter present. This implies carbaryl has some ability to sorb to the clay directly. This model has R^2 of 0.94 and is significant at $p < 0.05$. A model with no-intercept was also fit, and K_{oc} calculated this was is 195, however, the R^2 is only 0.81 and $p = 0.069$. 1/n values ranged from 0.78-0.84. Sorption showed significant hystereses with Freundlich desorption constants ($K_{f(des)}$) values of 6.72 for sandy loam soil, 6.78 for clay loam sediment, 6.89 for silt loam soil, and 7.66 for silty clay loam soil. 1/n values ranged from 0.86-1.02. Literature data confirms that carbaryl is mobile. Nkedi-Kizza and Brown (1998) reported K_f of 4.72 (1/n = 0.80) for soil with an organic content of 590 mg/Kg. They found that sorption was lower on subsoils and attributed this to a lower organic content. The K_{oc} estimated using the no-intercept was used for modeling as this is how K_{oc} is handled internally in both PRZM and EXAMS.

Column Leaching

In column leaching experiments (MRID 43320701), carbaryl residues were determined to be slightly mobile in columns (30-cm length) of sandy loam, silty clay loam, silt loam, and loamy sand soils treated with aged carbaryl residues. This disparity with the batch experiments may possibly be explained by the relatively poor extraction recovery, by slow desorption kinetics and by degradation during the aging period. Unextracted [^{14}C] labeled residues in the soils prior to leaching ranged from 19.0% of the recovered in the loamy sand soil to 39.7% in the silty clay loam soil. The study author believed that 50% of the carbaryl applied to the soil had degraded prior to leaching.

Field Dissipation

Studies of carbaryl dissipation in terrestrial, aquatic and forest environments have been submitted by the registrant. In forest environments carbaryl was found to be moderately persistent in soil (half-live = 65 days) and leaf litter (half-live = 75 days). The submitted field and aquatic dissipation studies were determined to be unacceptable, and did not provide useful information on movement and dissipation of carbaryl or its degradation products.

Field dissipation studies conducted in the 1960s and 1970s in terrestrial (Fiche/Master ID 000108961 and 00159337), aquatic (Fiche/Master ID 001439080, 0124378, 00159337, 00159338, 00159339) and forestry (Fiche/Master ID 00029738, 00159340, 00159341) environments and submitted in the 1980's have been reexamined. When they were initially reviewed they were not considered acceptable for a number of reasons including: sampling frequency was not sufficient to allow calculation of dissipation rates, degradates were not identified or quantified, soil, sediment and water were not sufficiently characterized, problems with analytical method specificity and validity, insufficient sampling frequency and sampling depth, lack of data on irrigation practices measures. These studies do not meet current levels of scientific validity required to be considered acceptable and do not provide useful information on field dissipation of carbaryl and its degradates.

Terrestrial Field Dissipation

Results of two field dissipation studies conducted in California and North Carolina were submitted (MRID 41982605). These studies are considered supplemental and can be upgraded to fully acceptable with submission of additional storage stability data and information on the pH of the irrigation water.

A freezer stability study was reportedly conducted but the results past 90 days were not submitted. There was apparently significant degradation within 90 days. Study samples were analyzed as long as 8 months after collection, making the quality of the data highly questionable. Degradates were not analyzed in either study. In the California study >80% of the applied carbaryl apparently dissipated from the surface 15 cm between the final carbaryl application and the next sampling interval (7 days after the final application). In the NC study > 90 % apparently dissipated from the surface 15 cm between application and the next sampling event (7 days). However, in both studies dissipation after 7 days suggested a half-life on the order of weeks. In both studies rainfall and irrigation were less than evapotranspiration so the data can not be used to assess the potential for carbaryl to leach into the subsurface. In the California study, irrigation with water with a pH of 8.0 was applied 1-3 days after each pesticide application. Because carbaryl hydrolysis is highly pH dependant ($T_{1/2}$ at pH 9 = 3.2 hours) this may have resulted in an increase in the degradation rate, but higher pH irrigation waters are not uncommon in the western United States. Carbaryl was not detected below the 0.90-m soil depth.

California site: Carbaryl dissipated with an observed initial half- life of <4 days from the upper 0.15 m of a plot of Sorrento silt loam soil planted to broccoli in California following five applications at 2.24 kg ai/ha/application (total 11.2 kg ai/ha) of carbaryl; the applications, at 6-10 day intervals, were made in March and April 1990. In the 0- to 0.15-m soil depth, carbaryl was 0.673-1.25 ug/g immediately following the first application, 1.51-2.38 ug/g following the second, 2.03-2.21 ug/g following the third, 1.42-1.73 ug/g following the fourth, and 0.603-1.06 ug/g following the fifth (Tables 2-11 of Appendix 2). Carbaryl was 0.065-0.212 ug/g at 4 and 7 days after the final treatment, 0.068-0.097 ug/g at 15 days, and <0.052 ug/g at 33 and 61 days. In the 0.15- to 0.30-m soil depth, carbaryl was <0.05 ug/g immediately after the second, fourth, and fifth applications and <0.374 ug/g immediately after the third application; carbaryl was <0.015 ug/g at all other sampling intervals. In the 0.30- to 0.45-m soil depth, carbaryl was <0.038 ug/g after each application, and <0.010 ug/g at all other sampling intervals. In the 0.45- to 0.90-m soil depths, carbaryl was sporadically detected at <0.026 ug/g throughout the application period, and was <0.010 ug/g at all other sampling intervals. The formation and decline of carbaryl degradates were not investigated.

North Carolina site: Carbaryl dissipated with an observed initial half-life of <7 days from the upper 0.15 m of a plot of Norfolk sandy loam soil planted to sweet corn in North Carolina, following one application at 7.11 kg ai/ha of carbaryl on May 1, 1990. In the 0- to 0.15-m soil depth, carbaryl was 3.72-7.30 ug/g immediately after treatment, 0.145-0.379 ug/g at 7 days, 0.036-0.105 ug/g at 16 days, 0.017-0.043 ug/g at 30 days, and <0.013 ug/g at 62 days (Tables 13-17 of Appendix 2). Carbaryl was sporadically detected at <0.015 ug/g in the 0.15- to 0.60-m soil depths, except carbaryl was O.D6 ug/g in one of four samples from the 0.30- to 0.45-m depth at 7 days. Carbaryl was not detected in the 0.60- to 0.90-m soil depths at any sampling interval. The formation and decline of carbaryl degradates were not investigated. Rainfall plus irrigation totaled 53.1 mm through 7 days posttreatment (May 1-May 8, 1990), and 174 mm throughout the remainder of the study (May I-July 2). Throughout the study, air temperatures were 8-35 C, and soil temperatures at 0.1 and 0.2 m were 16.7-36.7 and 18.3-30.6 C, respectively. The slope of the test plot was <1% to the south, and the depth to the water table was 3-5 m.

Forestry Field Dissipation

In a supplemental forestry field dissipation study (MRID 43439801) carbaryl was applied on a pine forest site in Oregon. Carbaryl half-lives were found to be 21 days on foliage, 75 days in leaf litter and 65 days in soil. At the time of treatment, the trees of primary interest (pine) were 3-8 feet tall. Carbaryl concentration was a maximum of 264 ppm in the pine foliage at 2 days post-treatment, 28.7 ppm in the leaf litter at 92 days, 0.16 ppm in the upper 15 cm of litter-covered soil at 62 days, and 1.14 ppm in the upper 15 cm of exposed soil at 2 days. Carbaryl was detected in the leaf litter up to 365 days after treatment, and in the litter-covered soil up to 302 days after treatment. Carbaryl was ≤0.003 ppm in water and sediment from a pond and stream located approximately 50 feet from the treated area.

Aquatic Field Dissipation

Results of aquatic field dissipation studies conducted on rice in Texas and Mississippi were submitted (MRID 43263001). The studies were evaluated and found to provide supporting data and could be upgraded to fully acceptable with additional information on storage stability. Frozen storage stability data were provided for only 6 months, although the water samples were stored for up to 14 months and the soil samples were stored for up to 17.5 months prior to analysis. In the six months of storage carbaryl degraded an average of 34 % in Texas water and 39% in from Mississippi. 1-naphthol degraded 50% in water from Texas and 69% from Mississippi. Degradation did not appear linear, and it is not possible to extrapolate out to 14 months.

Carbaryl (1-naphthyl N-methylcarbamate) dissipated with observed half-lives of approximately ≤1.5 days from the floodwater of plots of loam/sandy loam and clay loam/loam soils in Texas and Mississippi which had been planted to rice, flooded, and then treated twice, at 5-day intervals, at 1.65-1.81 kg ai/ha/application with carbaryl (Sevin XLR Plus, 42.38% ai FlC) in June and July 1992. The plots were maintained with a 0.5- to 4.75-inch layer of irrigation water through approximately 1 month after the second application, according to normal cultural practices for rice growing. Carbaryl did not appear to leach below the 7.5-cm soil depth during the study. In the floodwater, the degradate 1-naphthol dissipated to non-detectable concentrations within 7-14 days after the second application; in the soil, 1-naphthol was not detected at any soil depth at any sampling interval.

Foliar Dissipation/Foliar Washoff

In the preliminary assessment of carbaryl, a half-life of 35 days was used as a default value to represent the degradation of carbaryl on leaf surfaces. In submitted comments on that draft, the registrant submitted a review of data that was relevant to the degradation of carbaryl and leaf surfaces. That document (Holmsen , 2003) and the supporting studies and data have been reviewed (See Appendix C) and the foliar degradation half-life has been revised accordingly. Based on thirty acceptable studies, the mean foliar half-life of carbaryl was determined to be 3.2 d. These studies were predominantly magnitude of residue studies used to support the setting of tolerances for food as well as some other data from the open literature. A set of criterion (described in detail in Appendix C) for data quality and study appropriateness were established to select those studies which were appropriate for making the estimate. A value of 3.7 d was used for foliar degradation in estimating for both terrestrial, aquatic and drinking water exposure estimates. This value is the upper 90% confidence bound on the mean value. Upper confidence bounds values are used as input parameters for other input parameters which are based on metabolic degradation processes.

While not specifically addressed in the comments from the registrant, two studies (Willis *et al,* 1988, Willis *et al,* 1996) were submitted by the registrant which could be used to estimate the foliar washoff rate which is a input parameter for PRZM. In the absence of data, this parameter is usually set to 0.5. Washoff coefficients estimated from these two studies were 0.83 and 0.98 respectively with a mean of 0.91. In both these cases, the washoff coefficient was estimated from only two points, so no error could be estimated. The mean of 0.91 was used in the modeling.

Bioaccumulation in Fish

Because of the low octanol/water partition coefficient carbaryl is not expected to significantly bioaccumulate. Reported K_{ow} values range from 65 to 229 (Bracha, and O'Brian, 1966; Mount and Oehme, 1981; Windholz *et al.*, 1976). A fish bioaccumulation study reviewed in 1988 (Chib, 1986, Fiche/Master ID 00159342) suggested that bioaccumulation factors were 14x in edible tissue, 75x in visceral tissue and 45x in whole fish. Though the study does not meet current acceptable standards it does support the conclusion that significant bioaccumulation is not expected. No additional data on bioaccumulation is required at this time.

Aerial Transport

Carbaryl has been shown to be transported and deposited aerially (Waite, *et al.*, 1995; Foreman, *et al.*, 2000; Sanusi *et al.*, 2000). As with all chemicals applied by aerial or ground spray, spray drift can cause exposure to non-target organisms downwind. Beyer *et al.*, (1995) studied spray drift from aerial application to rangeland near the Little Missouri River in North Dakota. In 1991 carbaryl was applied to 35,130 ha at 560 g/ha (0.62 lb) A.I. A 152-m no-spray buffer zone was maintained. River water samples collected 1 hour after completion of spraying had a mean concentration of 85.1 : g/l. Concentration decreased over time, and 96 hours after application the mean was 0.1 : g/l. In 1993 a similar application resulted in a maximum concentration 1 hour after spraying of 12.6 : g/l decreasing to 5.14 : g/L after 96 hours. The researchers found that invertebrates in the river were minimally effected while fish brain acetylcholinesterase activity was not effected.

Vapor phase transport and particulate transport may carry the compound far from the area of application. In the atmosphere, partitioning between particulate and gas phase is a function of temperature and changes from about 30% vapor phase to about 90% when temperature increases from 283 to 303°K (10 - 30°C) (Sanusi *et al.*, 1999). This suggests that aerial transport distance and deposition are a function of temperature.

Carbaryl has been detected in air in urban and suburban areas with limited influence from agricultural spraying. It is detected more frequently and generally at higher concentrations at sampling locations in urban areas than in agricultural areas (Foreman *et al.*, 2000). Pesticide concentrations in fog formed in the vicinity of applications often are higher than those observed in rain water or surface water and may represent a significant, though generally overlooked, route of exposure. Schomburg *et al.* (1991) reported carbaryl concentrations in fog ranging from 0.069 to 4.0 : g/L. In general though, given carbaryl's relatively rapid degradation, its potential for long-range atmospheric transport is very limited.

1-naphthol Fate and Transport

Limited information is available for the environmental fate and transport of the major carbaryl degradate 1-naphthol. 1-naphthol was formed in laboratory degradation studies and represented a major portion of the applied mass (maximum of 22 % in aerobic aquatic metabolism, 58% in aerobic soil metabolism and 67% in photolysis). 1-naphthol was not persistent in the studies and appears to have degraded more rapidly then the parent.

1-Naphthol a natural product and is also formed as a degradation product of naphthalene and other polycyclic aromatic hydrocarbons. It appears to degraded more rapidly then the parent in the submitted studies but there is not sufficient information the develop a detailed fate profile. While guideline studies were not submitted specifically for the degradate, literature information suggests that it is less persistent and less mobile than parent carbaryl. Armbrust and Crosby (1991) reported that 1-Naphthol was stable to hydrolysis in filtered seawater at pH 7.9 and 8.3. Hydrolytic degradation of 1-naphthol is reported to be due to reaction with dissolved O_2 and is highly pH dependant (Karthikeyan and Chorover, 2000). Oxidation increases with pH and ionic strength. Below pH 7 oxidation is minimal and reaches a maximum at about pH 9. Oxidation of 1-naphthol reportedly results in production of (hydroxy)naphthoquinones and dimer coupled reaction products, though the reaction rates for 1-naphthol degradation is not well known (Karthikeya and Chorover, 2000). In filtered seawater carbaryl degraded rapidly to 1-naphthol under artificial sunlight (290-360 nm), with half-life of 5 hours. The degradation product, 1-naphthol, was degraded very rapidly with half-life of less than 1 hour (Armbrust and Crosby, 1991).

1-naphthol is degraded rapidly by microbial processes in aerobic systems. In an aerobic soil metabolism study (MRID 42785101) 1-naphthol degraded rapidly to non-detectable levels within 14 days. Armbrust and Crosby (1991) reported that 1-naphthol degraded in unfiltered seawater to below detectable level within 94 hours. Burgos *et al.* (1999) found that greater than 90% of aqueous 1-naphthol was degraded to CO_2 within 10 days. However, they found that sorption to soil greatly reduced the degradation rate; when sorbed degradation was greatly slowed to 25-40% degradation in 90 days.

No guideline information was submitted on 1-naphthol sorption. Literature information suggests that it is not strongly sorbed. Sorption to poorly crystalline aluminum hydroxide was pH dependant and appeared to occur only after oxidation (Karthikeyan *et al.*, 1999). Hassett *et al.* (1981) reported an average 1-naphthol K_{oc} of 431 (± 40) for 10 of the 16 soils tested. They also found that in other soils with very low organic carbon to clay ratios clay surfaces controlled sorption. Additional data on 1-naphthol sorption is required to fully characterize mobility.

WATER RESOURCES

Due to its mobility, carbaryl is expected to reach surface water resources by spray drift and runoff and it has a limited ability to reach ground water through leaching. Carbaryl is not persistent in most cases and would not be expected to be found frequently in neutral and alkaline conditions; however, under acid conditions with low biological activity, the pesticide is likely to persist. Carbaryl was found in about 1.5% of wells in the NAWQA program. In groundwater carbaryl is detected less often and at lower levels (generally less than 0.01 :/L). Carbaryl is the second most commonly found insecticide (after diazinon) in surface water with 21% of samples having detectable, but usually sub-: g L^{-1} level concentrations and the maximum reported value is less than 10 : g/L. Detections are more frequent in urban than agricultural watersheds.

Both modeling and monitoring data were used to assess the concentrations of carbaryl in water resources. Monitoring data from the United States Geological Survey, EPA's STORET database and Pesticides in Ground Water Database, and a registrant study are described below. Modeling of ground water was performed with SCIGROW. A drinking water exposure assessment was carried out with the Pesticide Root Zone Model coupled with the Exposure Assessment Model System (PRZM/EXAMS) using the Index Reservoir scenario. Aquatic EEC's were estimated with PRZM/EXAMS and the standard pond. The monitoring studies are summarized first, followed by the modeling.

Monitoring: Ground Water

Available evidence from valid scientific studies show that carbaryl has a limited potential to leach to ground water.

Pesticides in Ground Water Database

As a result of normal agricultural use, detections of carbaryl residues have been reported in groundwater from several states. As reported in the U.S. EPA. Pesticides in Groundwater Database (Jacoby *et al.*, 1992), carbaryl was detected in 0.4% of wells sampled. Carbaryl was detected in California (2 out of 1433 wells), Missouri (11 out of 325 wells), New York (69 out of 21027 wells) Rhode Island (13 out of 830 wells) and Virginia (11 out of 138 wells). The maximum concentration detected was 610 : g L^{-1} in NY, though typically the measured concentrations were orders of magnitude lower.

STORET

The EPA Storage and Retrieval (STORET) water quality database was queried on May 12, 1999 for reports of measurements of carbaryl in groundwater. The database contained 9,389 records indicating that analysis was done for carbaryl. Out of these, only 4 reported concentrations above the detection limits. These analyses were all from one well in Cleveland, OK in 1988. The 4 reported concentrations were between 0.8 and 1 ppb.

NAWQA

Carbaryl was detected at greater than the detection limit (0.003 µg/L) in 1.1 % of groundwater samples from 1,034 sites across the country by U. S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. The maximum observed concentration was 0.021 µg/L. Detections were mainly from three use sites: wheat (5.8 % of well samples from wheat land use), orchards and vineyards (1.7 % of well samples from orchard and vineyard land use), and urban (1.8% of urban groundwater samples). Data on pesticides in groundwater were reviewed by Kolpin *et al.* (1998) and updated information is available at: http://water.wr.usgs.gov/pnsp/pestgw/.

Monitoring: Surface Water

Carbaryl is widely detected in non-targeted and targeted monitoring studies. Observed concentrations are generally low with fifty percent of the samples below minimum detection limits and ninety five percent of the samples less than 0.065 :g/L. Carbaryl is not very persistent in most surface water conditions suggesting that the wide spread occurrence is a result of its extensive use in a variety of applications. Because of limitation in the analytical methods used there is some uncertainty in the quantitative accuracy of carbaryl analysis. Additionally, non-targeted monitoring may not coincide with vulnerable application areas and times and typically not include low-order streams or lentic (*e.g.* ponds and wetlands) environments. Specific data sets are discussed below:

NAWQA

Carbaryl is the second most widely detected insecticide in surface water after diazinon in the NAWQA program (http://water.usgs.gov/nawqa/nawqa_home.html). Carbaryl was detected in 46% of 36 NAWQA study units between 1991 and 1998. The reported concentrations are believed to be reliable detections but have greater than average uncertainty in quantification. The data in the NAWQA database are amended with an "E" qualifier to indicate the variability found in the analysis. This suggests that the reported values may not represent the maximum concentrations that exist.

Out of 5,198 surface water samples analyzed 1,067 (21%) were reported as having detections greater than the minimum detectable limit. The maximum reported concentration was 5.5 µg/L across all sites.. For samples with positive detections the mean concentration was 0.11 :g/L, with a standard deviation of 0.43 :g/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. A significant portion of the total carbaryl applied was transported to streams. In areas with high agricultural use the load measured in surface waters was relatively consistent across the country at about 0.1 percent of the amount used in the basins (Larson *et al.*, 1999) http://water.wr.usgs.gov/pnsp/rep/wrir984222/load.html. The estimated carbaryl use in agricultural applications is about 2.5 million pounds suggesting that 2,500 pounds are delivered to the nations streams draining agricultural areas.

Streams draining urban areas showed more frequent detections and higher concentrations than streams draining agricultural or mixed land use areas. For example, in a study of 11 stream sites (N = 327) with primarily urban basins, carbaryl was detected in 45% of the samples with a maximum concentration of 3.2 µg/L (http://water.wr.usgs.gov/pnsp/rep/wrir984222/load.html). Additionally, Kimbrough and Litke (1996) reported that, in the South Platte River Basin Study Unit, between April and December of 1993, carbaryl was detected in 14 urban drainage samples and 6 agricultural drainage samples. Carbaryl had the highest concentration of the four insecticides analyzed with a maximum concentration of 2.5 :g/L in the urban basin and 1.5 :g/L in the agricultural basin (http://webserver.cr.usgs.gov/nawqa/splt/meetings/KIMB1.html). In the South-Central Texas Study Unit carbaryl was detected in 12% of streams draining agricultural areas and 52 % draining urban areas (Bush *et al.*, 2000) http://water.usgs.gov/pubs/circ/circ1212/.

STORET

The EPA STORET database (was queried on May 12, 1999 for reports of measurements of carbaryl in surface water. The database contained 8048 records indicating that analysis was done for carbaryl. Out of these 432 reported concentrations above the detection limits. The maximum value reported was 5.5 µg/L. Of the reported detections 18 were above 1 ppb. The data is the STORET database is used to give a general indication of the occurrence pattern only. Lack of QA/QC and analytical methodology limitations limit the usefulness of the STORET data. However, reported detections of carbaryl suggest that the compound is infrequently detected in surface water and at low levels.

Pilot Reservoir Monitoring Study

This study was conducted by the USGS and EPA to gain better understanding of pesticide behavior in reservoirs. Twelve reservoirs were sampled across the country with an emphasis on watersheds that were expected to be vulnerable to pesticide contamination, but with no particular emphasis on any particular pesticide. Samples were collected at the drinking water intake (312 total samples), the reservoir outflow (73 samples) and finished water from the water supply (225 samples). Not all sites had samples collected at the reservoir outflow. Carbaryl was detected at 5 sites (**Table 2**), 4 at the intake, 2 at the outflow, and two in finished. In addition, 3 samples, all from intakes, contained 1-naphthol. The highest carbaryl concentration detected was 0.043 :g L^{-1} at Blue Marsh Reservoir in Pennsylvania while the carbaryl degradate, 1-naphthol, was found at 0.228 :g L^{-1} at Higginsville, Missouri. It is worth noting that 1-naphthol has other sources in the environment, including some which are natural. It is also worth noting that, as with the NAWQA data which uses similar analytical protocols, all detections of carbaryl were qualified due to high background variability of the measurements. These data are consistent withe other data which show widespread low-level contamination of carbaryl in surface water.

Table 2. Summary of carbaryl detections in the Pilot Reservoir Monitoring Study. (Blomquist *et al. 2001)*

Location	Number of Samples	Number of Detections	Maximum Concentration (: g L^{-1})
	Drinking water Intakes		
Higginsville Lake, Higginsville, MO	40	1	0.008
Tar River Reservoir, Rocky Mount, NC	10	1	0.004
East Fork Lake, Batavia, OH	21	1	0.012
Blue Marsh Reservoir, Reading, PA	23	4	0.047
	Reservoir Outflow		
Blue Marsh Reservoir, Reading, PA	24	1	0.005
Lake Mitchell, Mitchell, SD	9	1	0.001
	Finished Water		
Higginsville Lake, Higginsville, MO	25	1	0.004
Blue Marsh Reservoir, Reading, PA	23	1	0.003
	1-Naphthol		
Higginsville Lake, Higginsville, MO	38	1	0.228
Blue Marsh Reservoir, Reading, PA	24	1	0.006
South Pacolet Reservoir, Spartanburg, SC	44	1	0.008

Registrant Drinking Water Monitoring Study

EFED reviewed in detail the final report from a study voluntarily conducted by Aventis for carbaryl. The study was designed and implemented voluntarily by Rhone-Poulenc Agricultural Company (RPAC), with the purpose of providing the Agency data useful in refining the drinking water exposure estimates for carbaryl. The main study goal is in line with data needed by the Agency to refine the drinking water risk. However, the implementation of the study (especially site selection) was not consistent with the study goal. Despite these drawbacks, the study design was one of the better surface-water monitoring studies submitted to the Agency over the past several years. The analytical methodology and method sensitivity, quality assurance procedures, study duration, and aspects of their approach to site selection were sound. This study provides useful information on measured concentrations of carbaryl in selected surface waters of the United States. These data will be used in conjunction with other monitoring data, to characterize surface water modeling estimates of carbaryl exposure from surface-water source drinking water.

A detailed critique of the monitoring data identified several major drawbacks to the quantitative use of these data to represent drinking water exposure:

- With only 16 sites to represent vulnerable surface water bodies for selected agricultural uses (really 15, as the LA site was selected to represent population exposure not because source waters were vulnerable) and four suburban sites, this study is not likely to provide comprehensive coverage of all carbaryl usage sites, given the great geographic diversity of carbaryl use areas and carbaryl uses. Because little supporting data were provided on non-agricultural sales and national-scale non-agricultural carbaryl usage, the relative vulnerability of the systems selected to represent "home and garden" usage effects could not be determined

- We do not concur that sites sampled represent the “the highest probable risk of human exposure to carbaryl in surface water in each state”, based on our analysis of carbaryl usage and vulnerability characteristics of CWS watersheds selected.

- The monitoring interval (one week to two weeks) is unlikely to capture peak concentrations necessary for estimating acute dietary risk, given the variable nature of the exposure.

Results of this study indicate that carbaryl was found in source drinking water (raw water) at low concentrations in the majority of sites (13 of 16 sites) selected to represent impacts from agricultural uses, despite the relative lack of vulnerability of these sites. Concentrations measured at these sites were low (roughly 2 to 31 ppt) in raw water and generally lower in treated drinking water; however, the highest concentrations were found in finished, not raw, drinking water (181 ppt). Where residues were detected, frequency of detection in raw water samples ranged from a few percent of total samples (1-6 %) at 9 of the 13 sites to about 20% of total samples (14 - 21%) at 4 sites. At several agricultural sites, low-level concentrations were measured over 3-4 week periods in weekly samples. Given the environmental fate characteristics of this compound, this is most likely the result of the volume of usage rather than the persistence of the compound.

Carbaryl was reported in raw water of all four CWS selected to represent impacts from home and garden uses. Concentrations measured in raw water at these sites were low (roughly 2 to 44 ppt) and detection frequencies ranged from approximately 1 to 20 %. How representative these systems are of the home and garden use of carbaryl cannot be determined from the data provided. However, the lowest detection frequency occurred at the CWS with the largest watershed size (exceeding the 70th percentile nationally). At one site, concentrations were reported in sequential weekly samples for a period of several months, likely due to the volume of usage.

Because raw and finished samples were not temporally paired, we cannot make quantitative statements about the impact of treatment processes in removing carbaryl from source water. In fact, in several instances the treated water concentrations were higher than the raw water concentration in the "pair", including the highest reported concentrations

Modeling.

Because of the relatively limited persistence of the compound in the environment it is unlikely that non-targeted monitoring studies will detect the maximum concentrations that occur. Because of the limited amount of data available and because of potential problems with extant data, monitoring data are of limited utility in developing estimated environmental concentrations (EEC's) for ecological and human health risk assessment. Therefore, EFED used computer modeling to estimate surface water and groundwater concentrations that could be expected from normal agricultural use. For developing surface water EEC's EFED used EPA PRZM 3.12 and EXAMS 2.98 programs to estimate the concentration of carbaryl in surface water. For ecological risk assessment the standard pond scenario was used. For human health risk assessment index reservoir scenario was used. For ground water, the Screening Concentrations in Ground Water (SCI-GROW) model was used.

Ground water modeling

The concentration of carbaryl that might be found in vulnerable ground water used as drinking water was derived using SCI-GROW (EFED, 2002). SCI-GROW is a regression model which relates simple environmental fate parameters with concentrations which have been seen in prospective ground water studies (PGW). These studies are generally done on sites prone to leaching with shallow ground water and are thus highly vulnerable. Estimated groundwater concentrations derived using SCI-GROW are for both acute and chronic human health assessment. The SCI-GROW EEC for carbaryl is 0.08 μg/L. It must be noted that carbaryl has an aerobic metabolism half-life (4 days) which is outside the range of values for which SCI-GROW was developed (17-1000 days). The OPP currently does not have more advanced groundwater models and targeted studies specifically designed to evaluate the potential for carbaryl to move to groundwater are not available.

Surface water modeling

Tier 2 modeling was used to calculate EEC's for both aquatic and drinking water. The calculation of drinking water EEC's are described in detail in **APPENDIX A** and the aquatic EEC's in **APPENDIX B**. For both sets of EEC's, five crops were modeled: citrus in Florida, sweet corn and field corn in Ohio, apples in Pennsylvania and sugar beets in Minnesota. Application rates and intervals for the selected uses are presented in **Table 3**.

Table 3. Maximum use patterns for carbaryl application on selected crops based on the EPA label

Crop	Single app. Rate (lb $acre^{-1}$)	Number of Applications	Application Interval	Application Method	Date of First Application
Apples	2	5	3 days	aerial	June 1
Citrus	5	4	14 days	aerial	April 1
Field Corn	2	4	14 days	aerial	June 1
Sweet Corn	2	8	14 days	aerial	May 1
Sugar Beets	1.5	2	14 days	aerial	June 1

Several application rates were used in modeling: the maximum allowed for the specific crop, an "average" rate[1], and the maximum rate reported to actually be used[2]. The maximum rate was taken from the carbaryl labels (**Table 3**). "Average" and maximum reported rates (**Table 4** and **5**) were determined by EPA's Biological and Economic Assessment Division (BEAD) based on data collected by Doane's surveys and registrant market analysis. EEC's varied greatly depending on the geographic location, crop, and application rate. Modeling "average" and maximum reported use rates yielded EEC values generally 40-60% lower than maximum. EFED normally uses the maximum allowed application rates in modeling. In this assessment other, "less than maximum", rates were modeled in order to evaluate how conservative maximum label rate modeling estimates are. The average and maximum rates may or may not be representative of actual use rates and are of limited certainty due to the quality and extent of the data available to calculate them. As described in the BEAD chapter, the average application rates were derived by dividing total pounds used by the overall use area. The resulting average does not represent the actual average applied to any specific area. The maximum reported rate was determined from Doane's survey results. These data, while the best available, are very limited. The number of farmers surveyed is small, often only one or two per state, and the statistical validity of the results are not known but it is highly unlikely that the survey identified the actual maximum value. There are some notable unexplained discrepancies in the data. In particular, the average and maximum reported use rates of carbaryl on sweet corn are higher than the maximum label rate. The reason for the discrepancy could has not been determined.

Table 4. Maximum reported use patterns for carbaryl application on selected crops

Crop	Single app. Rate (lb acre^{-1})	Number of Applications	Application Interval	Application Method	Date of First Application
Apples	1.6	2	14 days	aerial	June 1
Citrus	4.26	3	14 days	aerial	April 30
Field Corn	1.5	2	14 days	aerial	June 1
Sweet Corn	3*	1	---	aerial	June 1
Sugar Beets	1.2	1	---	aerial	June 1

* The maximum reported rate is greater than the maximum label rate. The seasonal maximum rate is not exceeded, however.

1 **"Average"** is the average rate as determined by OPP/BEAD and reported in the a memo titled Quantitative Usage Analysis for Carbaryl, prepared July 21, 1998 by Frank Hernandez, OPP/BEAD.

2 **Maximum used** is the highest rate of application that is actually reported to be used based on OPP/BEAD analysis of DoaneS survey data by Donald Atwood, Personal communication, January 31, 2001.

Table 5. 'Average' use patterns for carbaryl application on selected crops

Crop	Single app. Rate (lb $acre^{-1}$)	Number of Applications	Application Interval	Application Method	Date of First Application
Apples	1.2	2	14 days	air blast	June 1
Citrus	3.4	2	14 days	aerial	April 30
Field Corn	1	2	14 days	aerial	June 1
Sweet Corn	3.4	2	14 days	aerial	June 1
Sugar Beets	1.5	1	---	aerial	June 1

* The maximum reported rate is greater than the maximum label rate. The seasonal maximum rate is not exceeded, however.
** The 'average' rate is greater than maximum reported rate. The reason for this discrepancy is not known.

The chemical parameters used in the simulations are in **Table 6.** Detailed descriptions of the development of these parameters and the data quality characterizations are in **APPENDIX A**. Generally parameters estimates from multiple reproducible studies are characterized as very good, parameters from limited numbers of studies are good with less reproducibility are good or fair, and parameters estimated from surrogate data are poor.

Table 6. Chemical input parameters for carbaryl

Parameter	Value	Quality
Molecular weight	201.22 g mol^{-1}	excellent
Solubility	32 mg L^{-1}	good
Henry's Law Constant	1.28×10^{-8} atm-m^{-3} mol^{-1}	fair
K_{oc}	196 L kg^{-1}	good
Aerobic soil metabolism half-life	12 d	fair
Aerobic aquatic metabolism half-life	29.6 d	fair
Anaerobic aquatic metabolism half-life	216.6 d	fair
Hydrolysis half-life	pH 5 - assumed stable pH 7 - 12 d pH 9 - 0.133 d	very good
Aqueous photolysis	21 d	very good
Foliar Degradation Rate	3.71 d	excellent
Foliar Washoff Coefficient	0.91	fair

Drinking water EEC's for these crops and use patterns are in **Table 7**. The EEC's for citrus were recommended for single point estimation of drinking water exposure. EEC's for citrus, apples, and sugar beets were calculated with the percent crop area (PCA) of 0.87 which represents the largest amount of agricultural land in any basin in the United States represented with an 8-digit hydrologic unit code (Seaber *et al.,* 1987), or HUC. Sweet corn and field corn used a PCA value of 0.46 which is the largest proportion of corn in any 8-digit HUC.

Table 7. Drinking Water EEC's for carbaryl based maximum, ''average'' and maximum reported use patterns.

Crop	Usage Rate	Number of Applications per Year	Pounds A.I. per application	Surface Water Acute (ppb) (1 in 10 year peak single day concentration)	Surface Water Chronic (ppb) (1 in 10 year annual average concentration)
Sweet Corn (OH) (PCA = 0.46)	Maximum[1]	8	2	57.3	5.53
	Average[2]	2	3.4	49.8	2.31
	Maximum[3] Reported	3	1	25.6	1.26
Field Corn (OH) (PCA = 0.46)	Maximum[1]	4	2	51.3	2.72
	Average[2]	2	1	14.6	0.68
	Maximum[3] Reported	2	1.5	21.9	1.02
Apples (PA) (PCA = 0.87)	Maximum[1]	5	2	62.9	2.20
	Average[2]	2	1.2	23.4	0.63
	Maximum[3] Reported	2	1.6	34.4	1.04
Sugar Beats (MN) (PCA = 0.87)	Maximum[1]	2	1.5	48.2	2.16
	Average[2]	1	1.5	13.6	0.73
	Maximum[3] Reported	1	1.2	10.8	0.58
Citrus (FL) (PCA = 0.87)	Maximum[1]	4	5	316	14.2
	Average[2]	2	3.4	203	7.33
	Maximum[3] Reported	3	4.26	272	10.0

[1] Maximum application rate on label
[2] Average application rate from Quantitative Usage Analysis for Carbaryl, prepared July 21, 1998 by Frank Hernandez, OPP/BEAD
[3] Maximum rate of application reported in Doanes survey data

Aquatic EEC's for the maximum label use rate are in **Table 8**. The EEC's for 'average use rates are in **Table 9**, and the those for maximum reported use patterns are in **Table 10.**

Table 8. Aquatic EEC's for the 'maximum' use patterns for carbaryl on selected agricultural crops.

Crop	Peak	4 Day Mean	21 Day Mean	60 Day Mean
		------------------------------ : g L^{-1} carbaryl ----------------------------		
Apples (PA)	30.6	25.6	14.8	6.55
Citrus (FL)	152.6	135.7	82.0	41.0
Sweet Corn	52.7	48.8	30.2	19.2
Field Corn	46.9	41.9	24.9	14.4
Sugar beets	23.3	20.6	12.8	6.2

Table 9. Aquatic EEC's for the 'average' use patterns for carbaryl on selected agricultural crops.

Crop	Peak	4 Day Mean	21 Day Mean	60 Day Mean
		------------------------------ ∶ g L^{-1} carbaryl ----------------------------		
Apples (PA)	11.8	9.911.3	4.6	2.0
Citrus (FL)	99.9	89.3	51.3	22.7
Sweet Corn	45.84	40.6	24.9	12.7
Field Corn	13.4	11.9	7.3	3.7
Sugar beets	6.5	5.8	3.4	2.1

Table 10. Aquatic EEC's for the 'maximum reported' use patterns for carbaryl on selected agricultural crops.

Crop	Peak	4 Day Mean	21 Day Mean	60 Day Mean
		------------------------------ ∶ g L^{-1} carbaryl ----------------------------		
Apples (PA)	15.8	13.2	6.2	1.7
Citrus (FL)	130.6	115.7	68.5	30.7
Sweet Corn	23.5	20.9	11.6	6.8
Field Corn	20.8	17.9	11.0	6.6
Sugar beets	5.2	4.6	2.7	1.7

AQUATIC EXPOSURE ASSESSMENT

For aquatic exposure, the scenario uses a 10-ha water shed feeding into a 1-ha standard pond, 2-meters deep with no outlet. The standard pond serves not only to protect ponds and small lakes but also is intended as a surrogate for a variety of small water bodies at the top of watersheds. These include prairie potholes, vernal pools, playa lakes, bogs, swamps, and other wetlands, and first-order streams. Shallower static water bodies will tend to have higher concentrations as will first-order streams, although peak concentrations in streams tends to be of much shorter duration. Because these water bodies are at the top of the watershed, the assumption of 100% cropping for the watershed, essentially one farm field, is reasonable. Water bodies further downstream will have lower concentrations due to dilution with waters coming rom land which was not treated. Some watersheds may have greater treated surface-area-to-pond volume ratios which will increase the loading of pesticide to the pond; however, this effect is limited because larger watersheds are less likely to be cropped to a single crop all treated with a single pesticide, and the associated increase in the volume of runoff water makes it more likely that there will be pesticide transported out of the pond when the pond overflows. (Pond overflow is currently not simulated in these assessments.)

Drinking Water

For drinking water exposure, the standard scenario uses the index reservoir. The index reservoir geometry is based on a small reservoir in Illinois. The watershed is 172.8 ha and feeds a 2.74-m deep reservoir that is 640-m long by 82-m wide with an area of 5.2 ha. As opposed to the standard static pond, water flows through reservoir and the rate is set for each location depending upon the total amount of runoff entering the reservoir. As with the standard pond, the index reservoir watershed geometry is combined with local weather and soils to create scenarios for a specific crop in a specific location (**APPENDICES A1** and **A2**).

While the aquatic EEC's are a good estimate of what is expected to be in waters in certain waterbodies which are vulnerable to pesticide contamination, EEC's for drinking water tend to exceed those seen at drinking water facilities. These values are greater than those that would be expected to be found in the environment primarily for three reasons. First, we have used the default PCA of 0.87, as the PCA for citrus in Florida. The default PCA is the maximum proportion of agricultural land found in any basin in the country, In fact, the actual PCA in Florida is probably closer to one-third this value, although a precise estimate is not available at this time. Secondly, the percent crop treated has been assumed to be 100%. In fact, according to BEAD (Hernandez, 2002), the percent crop treated for different citrus crops ranges for 1.5 to 6%, depending on the crop. Thirdly, since the labels have not specified maximum number of applications, the maximum practice modeled is substantially greater than that which is usually used in practice. In particular, the rate per acre, and the number of treatments per season is often less than that allowed on the label. In addition, the interval between applications, when there is more than one is usually longer than has been simulated for the maximum use pattern. This third factor has been addressed in this assessment, and is reflected in the EEC's from the 'average' and maximum reported use patterns from **Table 9** and **10.**

Three additional simulations were done for citrus in order to better characterize the exposure in this scenario. In the first simulation, the application date for the first application was changed from April 30 to August 31, otherwise using the maximum application practice. The second simulation also changed the first application date but with ‘average’ application practice. While there are pests which could be of concern on citrus as early as April, monitoring data from the area indicates that most of the usage actually occurs in the late summer. The 1-in-10 year peak EEC for the April application and maximum label practice is 316 µg L^{-1} while for September the value is 220 µg L^{-1}. For ‘average’ application practice, the respective EEC’s are 203 and 125 µg L^{-1}. Another run was done where best estimates for all the metabolism values were used as inputs (4 day half-life for aerobic soil metabolism, a 9.6 day half-life for aerobic aquatic metabolism, 72.2 days for anaerobic aquatic metabolism, and 3.2 days for foliar degradation) combined with ‘’average’’ application practice in September to give a ‘best’ estimate of the EEC for this site. The 1-in-10 year peak in this case was 78.9 µg L^{-1}.

In addition to the point estimate EEC’s for drinking water exposure described above. We have provided the time series of concentrations for the entire duration of the simulation for the different citrus scenarios. These series of estimates are intended for use in a more full of the whole range dietary exposure for carbaryl and are being combined with pesticide residues in food using the Dietary Exposure Estimation Model (DEEM). Making wider use of the whole time series for drinking water exposure is expected to improve the description of the dietary risk. However, using the time series for water in combination with the distribution of food residues and consumption patterns normally used in DEEM substantially alters the interpretation of the risk represented by the output of the model. This is because the drinking water component introduces a time component which is not present in the food and consumption data and any time component in the data is ignored by DEEM. Technically, the food and consumption distributions are assumed to be ‘stationary’ with respect to time and location, *i.e.*, the distributions are always the same at any point in time and any location in the United States. This is a reasonable assumption for food residues and consumption, but not a reasonable one for pesticide residues in drinking water which are expected to vary by orders of magnitude with both time and location. The difference in interpretation can be best illustrated by describing how the interpretation differs when the different exposure components dominate the exposure profile. When food (other than water dominates the exposure and the drinking water contribution is negligible, an exceedance of the 99.9% threshold implies that one person in 1000 across the whole U. S. population is above the threshold each day. If drinking water dominates and food contributions are negligible, an exceedance of the 99.9% means that the entire population provided drinking water from a facility represented by scenario, are expected to exceed the risk once every 1000 days, a little less that once every three years. When both water and food sources make significant contributions to exposure, a more detailed analysis of the structure of the data is necessary to determine the nature of the risk. Depending on the structure of the risk, regulating on the 99.9 percentile in a manner similar to that used previously may not provide a intended level of safety similar to that which is provided by using DEEM with food only and the drinking water level of concern (DWLOC) approach with water.

Effects of Drinking Water Treatment

There is some evidence that conventional drinking water treatment, that is coagulation, flocculation and settling, is expected to reduce carbaryl concentration by 43% of the concentration prior to treatment (US EPA, 1989). This is based on a study of wastewater containing carbaryl treated with alum at 100 mg L^{-1} and 1 mg L^{-1} of anionic polymer (Whittaker *et al.* 1982). In addition, ozone has been shown to be 99% effective at removing carbaryl from water (Shevchenko *et al.,*1982) and removes it from water at a rate too fast to measure (Mason *et al.* 1990). Evidence suggests that chlorine and hypochlorite may be ineffective at degrading carbaryl (*ibid.*). At this point in time, ozonation is only infrequently used for disinfection of public drinking water in the United States. Based on the hydrolysis data, softening would be expected to substantially reduce carbaryl concentrations (via alkaline hydrolysis) as softening raises the pH of the water as high as 11. Softening is used on 'hard' water that is high in calcium and magnesium and decreases the concentrations of these cations. The Office of Pesticide Programs currently does not have sufficient information to account for locations where water softening processes are utilized at public drinking water treatment facilities, and thus cannot systematically use this information in estimating EEC's.

Drinking Water Monitoring Study

Aventis voluntarily conducted a study entitled *"Surface Water Monitoring for Residue of Carbaryl in High Use Areas in the United States: Final Report*". The study provided useful information on measured concentrations of carbaryl in selected surface waters of the United States. Based on an analysis of sites selected, it was determined that the results of the study could not be used directly in the dietary risk assessment to represent exposure to carbaryl in surface water source drinking water (**APPENDICES B1** and **B2**). The information from this study provided some good quality data that could be used in association with other monitoring data sets in conjunction with surface water modeling to characterize carbaryl exposure from surface-water source drinking water

TERRESTRIAL EXPOSURE ASSESSMENT

Terrestrial exposure was evaluated using estimated environmental concentrations generated from a spreadsheet-based model (EL-FATE) that calculates the decay of a chemical applied to foliar surfaces for single or multiple applications (**APPENDIX C**). The model uses the same principle as the batch code models FATE and TERREEC for calculation of terrestrial estimated exposure concentrations (TEEC) on plant surfaces following application. Further explanation of the model is presented in Appendix D.

The terrestrial exposure assessment is based on the methods of Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994). Terrestrial estimated environmental concentrations (EECs) for nongranular and granular formulations (**Table 11**) were derived for major crops using current application rates and intervals between applications. Uncertainties in the terrestrial EECs are primarily associated with a lack of data on interception and subsequent dissipation from foliar surfaces. However, the registrant submitted foliar dissipation studies from which a 90^{th} percent confidence interval value for the mean (8.07 days) was used as a foliar dissipation rate for modeling purposes.

For pesticides applied as a nongranular product (*e.g.*, liquid, dust), the estimated environmental concentrations (EECs) on food items following product application are compared to LC_{50} values to assess risk. The predicted 0-day maximum and 56-day mean residues of a pesticide that may be expected to occur on selected avian or mammalian food items immediately following a direct single application at 1 lb ai/A and 3 lbs ai/A are presented in Table 8.

Table 11. Estimated environmental concentrations on avian and mammalian food items (ppm) following single applications at 1 lb ai/A.

Application Rate	Food Items	EEC (ppm) Predicted Maximum Residue[1]	EEC (ppm) 56 Day Mean[1]
1 lb a.i./A	Short grass	240	27
	Tall grass	110	10
	Broadleaf/forage plants and small insects	135	11
	Fruits, pods, seeds, and large insects	15	1

[1] Predicted maximum and mean residues are for a 1 lb ai/a application rate and are based on Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994).

ECOLOGICAL EFFECTS ASSESSMENT

APPENDIX D1 summarizes the 105-plus ecological toxicity studies considered in this evaluation. Information on acute and chronic effects is drawn from both guideline and nonguideline studies. Toxicity testing reported in this section does not represent all species of bird, mammal, or aquatic organism. Only a few surrogate species for both freshwater fish and birds are used to represent all freshwater fish (2000+) and bird (680+) species in the United States. For mammals, acute studies are usually limited to Norway rat or the house mouse. Estuarine/marine testing is usually limited to a crustacean, a mollusk, and a fish. Also, neither reptiles nor amphibians are tested. The assessment of risk or hazard makes the assumption that avian and reptilian toxicities are similar. The same assumption is used for fish and amphibians.

Carbaryl is practically nontoxic to birds, moderately toxic to mammals and fish, and very highly toxic to bees and aquatic invertebrates on an acute exposure basis. **Table 12** provides a summary of the most sensitive ecological toxicity endpoints used in the hazard assessment of terrestrial animals and **Table 13** summarizes the most sensitive endpoints used in the hazard assessment of aquatic animals. A more detailed discussion of the ecological toxicity studies that went into this assessment can be found in **APPENDIX D1.** Additionally, data indicate that the carbaryl hydrolysis degradate 1-naphthol ranges in toxicity from moderately to highly toxic to aquatic organisms.

Table 12. Summary of acute and chronic toxicity data for terrestrial organisms exposed to carbaryl.

Species	Acute Toxicity				Chronic Toxicity	
	LD_{50} (ppm)	Acute Oral Toxicity (MRID)	5-day LC_{50} (ppm)	Subacute Dietary Toxicity (MRID)	NOEC/LOEC (ppm) (MRID)	Affected Endpoints
Mallard duck *Anas platyrhynchos*	>2000	practically nontoxic (458206-01)	>5000	practically nontoxic (00022923)	300 / 600 (ACC263701)	decreased number of eggs; eggs cracked
Honey bee *Apis meliferus*	0.0011	very highly toxic (05004151)	--	--	--	--
Laboratory rat *Rattus norvegicus*	301	moderately toxic (00148500)	--	--	75 / 300 (447329-01)	decreased pup survival

Table 13. Summary of acute and chronic aquatic toxicity estimates using technical grade carbaryl.

Species	Acute Toxicity			Chronic Toxicity	
	96-hr LC_{50} (mg/L)	48-hr EC_{50} (mg/L)	Acute Toxicity (MRID)	NOEC / LOEC (mg/L)	Affected Endpoints (MRID)
Atlantic Salmon *Salmo salar*	0.250	--	very highly toxic (40098001)	--	--
Fathead Minnow *Pimephales promelas*		--	--	0.21 / 0.68	reduced growth (TOUCAR05)
Stonefly *Chloroperla grammatica*	0.0051		very highly toxic (458206-02)		
Water flea *Daphnia magna*	--	--	--	0.0015 / 0.0033	reproduction (00150901)
Sheepshead minnow *Cyprinodon variegatus*	2.6	--	moderately toxic (423728-01)	--	--
Mysid shrimp *Mysidopsis bahia*	0.45	0.0057	very highly toxic (423434-01)	--	--

Effects Assessment for Terrestrial Organisms

Birds

Carbaryl is practically nontoxic to birds on both an acute exposure (LD_{50} > 2,000 mg/Kg) and subacute dietary exposure basis (LC_{50} > 5,000 mg/Kg of diet). Acute toxicity estimates as low as 16 mg/Kg and 56 mg/Kg have been reported for starlings (*Sturnus vulgaris*) and red-winged black birds (*Agelaius phoeniceus*), respectively (Schafer *et al.* 1983) and it is uncertain whether smaller passerine species may be more sensitive to the effects of carbaryl. EFED recommends that acute toxicity testing be conducted with passerine species to address this uncertainty.

Exposure to carbaryl on a chronic exposure basis resulted in adverse reproductive effects including decreased number of eggs produced, increased number of eggs cracked and decreased fertility (NOEC = 300 mg/Kg of diet).

A total of five incidents (**APPENDIX D1**) involving birds have been reported under 6(a)2 in the Ecological Incident Information System (EIIS) database. However, only two of the five appear to clearly attributed to carbaryl and only one of those two could be linked to a specific registered use. The remaining incidents appear to have been associated with either intentional poisoning or the co-occurrence of much more toxic pesticides. In one incident (I012817-001) a single morning dove (*Zenaida macroura*) was discovered dead; the animal exhibited reduced acetylcholinesterase activity and had 2.4 mg/Kg of carbaryl in its stomach contents. The report suggests that birdseed around a feeder had become contaminated after carbaryl was applied to the property owner's lawn. In a second incident (I000802-001), five blackbirds were discovered dead. No residue analysis was conducted on the birds but carbaryl residues were detected in dead squirrel found in the vicinity; acetylcholinesterase activity was not reduced in the squirrel. While these incidents do not provide substantial evidence that carbaryl is impacting birds in the wild, they do emphasize the need to address the uncertainty regarding the sensitivity of passerine species to carbaryl.

Mammals

Carbaryl is moderately toxic (LD_{50} = 301 mg/Kg) to mammals on an acute exposure basis. Chronic exposure to carbaryl resulted in decreased second-generation pup survival (NOEC = 75 mg/kg of diet).

A total of two incidents were reported, one (I000802-001) involving a gray squirrel (*Sciurus carolinensin*) and a second involving a hairytail mole (*Parascalops breweri*). In neither case was information provided on the use of carbaryl that may have resulted in the deaths of these animals.

Insects

Carbaryl is highly toxic to honey bees (*Apis mellifera*) on an acute contact basis (LD_{50} = 0.0011 mg/bee); however, acute contact toxicity testing of Carbaryl SC indicates bees are less sensitive to the formulated product (LD_{50} = 0.0040 mg/bee). Acute oral toxicity studies with carbaryl reveal that technical grade carbaryl (LC_{50} = 0.0001 mg/bee) is roughly ten times more toxic than the formulated soluble concentrate (Carbaryl SC LC_{50} = 0.0016 mg/bee). Carbaryl ranged from being moderately to highly toxic to predacious insects, mites and spiders.

In a field study to examine the effects of carbaryl on bees when the chemical is used to thin fruit, Carbaryl SC applications to apple orchards at a rate of 0.8 lbs a.i./Acre did not have a significant ($P > 0.05$) affect on bee mortality and/or behavior.

A total of 5 incidents related to carbaryl are reported in the EIIS database. Two of the reports (I005855-001 and B0000-300-03) do not contain any data but rather reflect general concerns expressed by the American Beekeeper Federation and the Honey Industry Council on the role pesticides in bee kills. The Honey Industry Council sited the specific use of carbaryl on alfalfa during the day. In North Carolina (incident #I003826-021), a bee mortality was associated with 0.8 ppm carbaryl residues; however, in a second incident (#I003826-0090 in North Carolina, bee mortality was more likely attributed to methyl parathion than carbaryl. Only in one incident (I001611-002) though, was the use of carbaryl on a specific crop, *i.e.*, asparagus in Washington, clearly associated with carbaryl residues in dead bees.

Hazard Assessment for Aquatic Organisms

Freshwater Fish

On an acute exposure basis, technical grade (purity > 90%) carbaryl ranged in toxicity from highly to slightly toxic (LC_{50} = 0.25 - 20 mg/L) to freshwater fish and to fish that spend a portion of their life cycle in fresh water, such as the Atlantic salmon (*Salmo salar*). **Figure 2** shows a cumulative percent frequency distribution of 96-hour LC_{50} values for freshwater fish and

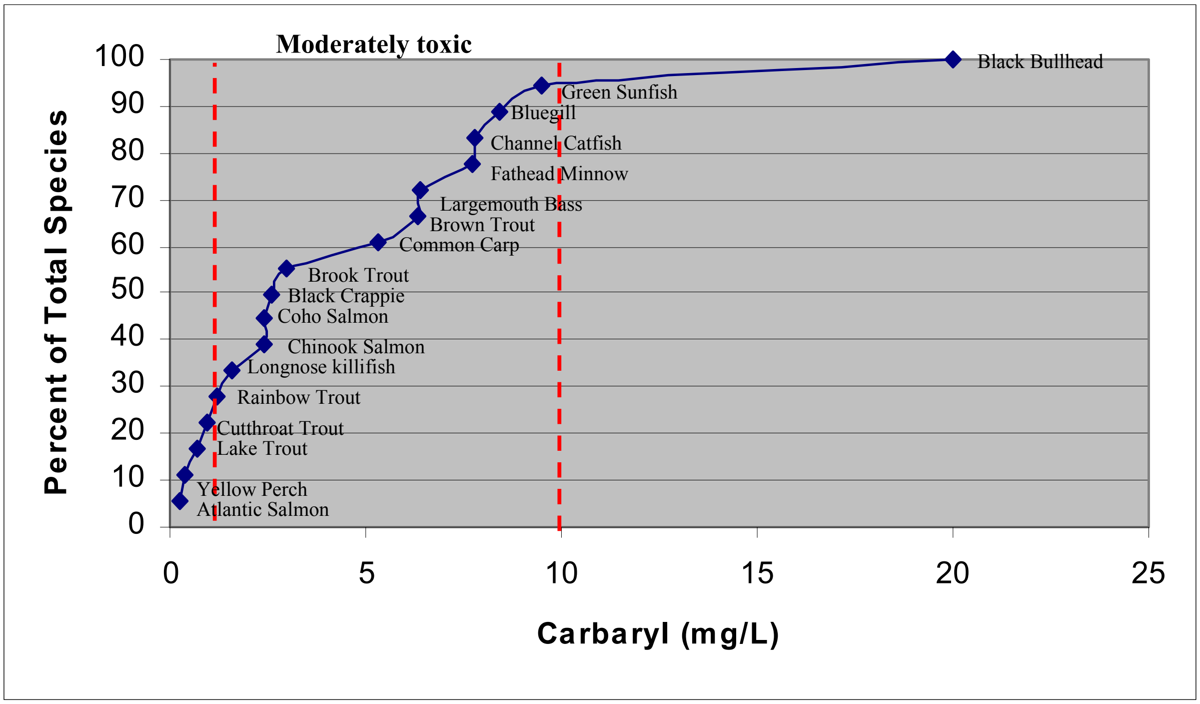

Figure 2.. Cumulative percent distribution of 96-hour acute LC_{50} values in mg/L (ppm) for freshwater fish exposed to technical grade carbaryl. Vertical dashed lines indicate range of LC_{50} values classified as moderately toxic. LC_{50} values 10 - 100 mg/L are considered slightly toxic.

demonstrates that for the majority (78%) of fish tested, carbaryl was moderately toxic (LC_{50} range: 1 - 10 mg/L). In general, coldwater species, *e.g.* salmonids, appear to be more sensitive to carbaryl than warm water species (*e.g.*, centrarchid sunfish and bass). Although Atlantic salmon (*Salmo salar*) are used as the most sensitive species (96-hr LC_{50} = 0.250 mg/L), they represent an extreme in the range of sensitivities among freshwater fish; assuming a log-normal distribution for the LC_{50} values, the mean is 1.28 mg/L and the lower 5% confidence interval is 1.23 mg/L. LC_{50} values for the typical end use products (purity range: 5 to 82%) from 1.4 to 290 mg/L, falling in the moderately to practically nontoxic categories. Acute toxicity testing of carbaryl's hydrolysis degradate 1-naphthol in fish shows that the compound ranged from being moderately to highly toxic (LC_{50} range 0.75 - 1.6 mg/L).

Chronic exposure of fathead minnows (*Pimephales promelas*) to carbaryl resulted in reduced survival and reproductive effects (NOEC = 0.210 mg/L) including reduced number of eggs per female and reduced number of eggs spawned. Chronic exposure of fathead minnows to 1-naphthol reduced larval growth and survival (NOEC = 0.1 mg/L); at the.

Although a total of three fish-kill incidents were reported for carbaryl (**APPENDIX D1**), only one report (#B0000-501-92) could be credibly associated with a specific carbaryl use, *i.e*., to control gypsy moth in New Jersey.

Amphibians

The majority of data available on amphibians focused on the juvenile tadpole stage of frogs. Carbaryl ranged from moderately toxic (96-hr LC_{50} = 8.4 mg/L) to Southern leopard frogs (*Rana sphenocephalia*) to slightly toxic (96-hr LC_{50} = 12.2 mg/L) to boreal toads (*Bufo boreas*) on an acute exposure basis (**APPENDICES D2** and D23). In toxicity testing with formulated product (purity = 50% carbaryl was practically nontoxic to bullfrogs (*Rana catesbeiana*) with an LD_{50} greater than 4,000 mg/kg (MRID 00160000). The sensitivity of tadpoles to carbaryl exhibited considerable intra- and interspecies variability. Depending on the stage of development, the conditions of exposure, and which frog populations were sampled, frog susceptibility to carbaryl varied. For example, the 96-hr LC_{50} for green frogs (*Rana clamitans*) roughly doubled when temperature dropped from 27^{o}C (LC_{50} = 11.3 mg/L) to 17^{o}C (LC_{50} = 22 mg/L).

Information on the sublethal effects of carbaryl on amphibians indicated that a single acute exposure of plains leopard frog tadpoles (*Rana blairi*) to carbaryl concentrations ranging from 3.5 - 7.2 mg/L resulted in a 90% reduction in swimming activity (including sprint speed and sprint distance) with activity completely ceasing at 7.2 mg/L (Bridges 1997). Slower swimming speeds, altered activity patterns and prolonged juvenile stages have been suggested as increasing the vulnerability of frogs to predation (Bridges 1997; Bridges 1999; Relyea and Mills 2001) and/or that the threat of predation renders the animals more susceptible to the direct toxicity of carbaryl (Relyea and Mills 2001). While the Relyea and Mills paper indicates that carbaryl was 2 to 4 times more lethal to gray treefrogs (*Hyla versicolor*) in the presence of a predator, the study is confounded by the potential effects of water quality on mortality (**APPENDIX D3**).

On a chronic exposure basis, carbaryl has been shown to have the potential to adversely affect amphibians. Southern leopard frog tadpoles exposed to carbaryl during development exhibited some type of developmental deformity, including both visceral and limb malformations, compared to less than 1% in control tadpoles (Bridges, 2000). Although the length of the larval period was the same for all experimental groups, tadpoles exposed throughout the egg stage were smaller than their corresponding controls. However, in some cases, it is unclear whether the effects of carbaryl on amphibians has been entirely adverse. For example, Southern leopard frogs exposed to carbaryl at 5 mg/L exhibited a 20% increase in weight at metamorphosis(Bridges and Boone 2003) and that at concentrations as high as 7 mg/L, Woodhouse's toad (*Bufo woodhousii*) survival was roughly 30% higher than controls (Boone and Semlitsch 2002).

Freshwater Invertebrates

Technical grade carbaryl is very highly toxic to aquatic invertebrates with EC_{50} values ranging from 0.0017 - 0.026 mg/L on an acute exposure basis. **Figure 3** shows a cumulative percent distribution of 96-hr EC_{50} values for freshwater invertebrates; roughly 80% of the species tested had EC_{50} values between 0.002 and 0.006 mg/L. In general, freshwater invertebrates exhibited the same sensitivity (EC_{50} range:0.007 - 0.013 mg/L) to formulated end products (purity range: 44 - 81%). In studies examining the toxicity of carbaryl to aquatic invertebrates in the presence of sediment, toxicity values were more widely distributed (EC_{50} range 0.005 to > 2.5 mg/L) suggesting that tendency of carbaryl and its hydrolysis degradate 1-naphthol to partition to sediment may limit their bioavailability and hence lower toxicity under more natural exposure conditions. Additionally, in an acute 1-hr "pulse" exposure, 50% of the stonefly larvae (*Chloroperla grammatica*) were immobilized by 0.028 mg/L; however, the affected animals recovered completely after removal to freshwater. The ability of invertebrates to fully recover is uncertain though as one study (Mora *et al.* 2000) showed that following a 72 -hr exposure to carbaryl at 0.0032 mg/L snail, acetylcholine esterase activity did not return to pre-exposure levels. Studies have indicated that acute exposure to carbaryl impacts predator avoidance mechanisms in invertebrates (Hanazato 1995), reduces overall zooplankton abundance (Havens 1995; Hanazato 1989), and may actually promote phytoplankton growth through reduced predation by zooplankton (Bridges and Boone 2003).

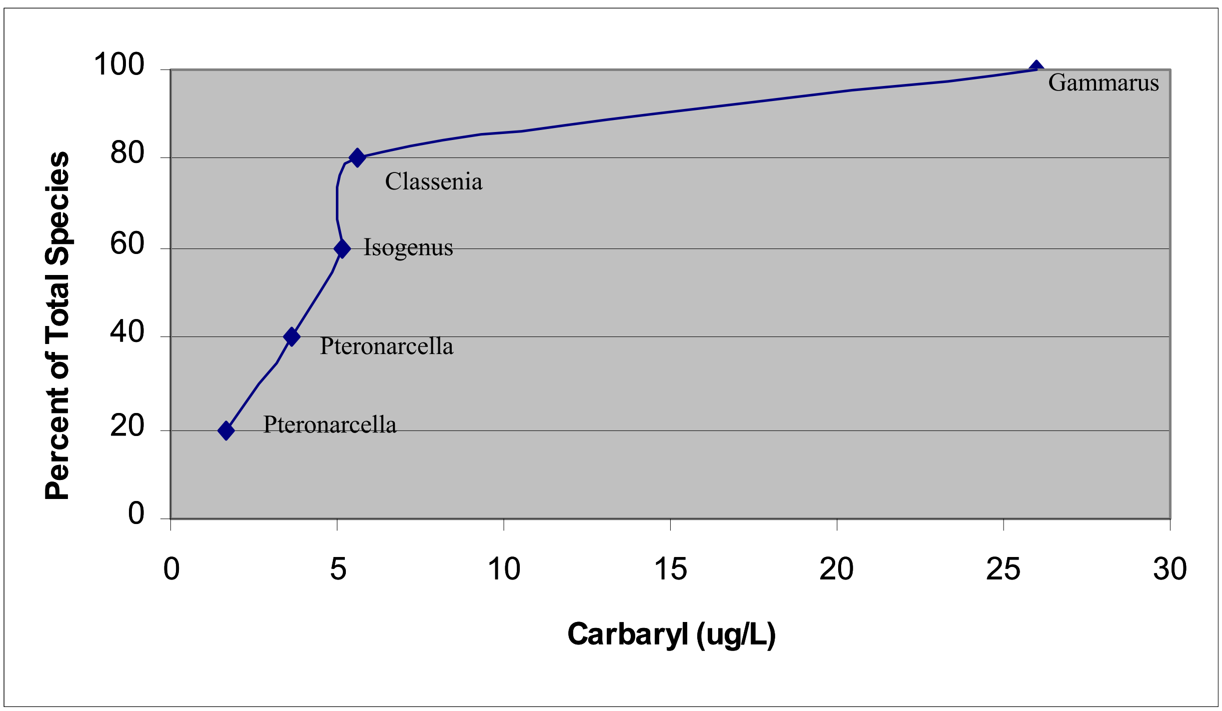

Figure 3. Cumulative percent distribution of acute 96-hr EC_{50} values in µg/L (ppb) for freshwater invertebrates exposed to carbaryl.

Exposure of freshwater invertebrates to 1-naphthol indicated the degradate ranged from being moderately to highly toxic (EC_{50} range: 0.2 - 3.3 mg/L).

On a chronic exposure basis, carbaryl affected reproduction (NOEC = 0.0015 mg/L) in water fleas (*Daphnia magna*). Following a 28-day static exposure study of midge larvae *(Chironomous riparius*) with sediment, reduced emergence and developmental rates were the most sensitive endpoints; however, the midge was considerably less sensitive (NOEC = 0.5 mg/L). It is unclear from the results of this study what the actual exposure conditions were however; midge larvae are benthic macroinvertebrates and exposure may have been better characterized had it been based on sediment pore water concentrations as opposed to carbaryl concentrations in overlying water. This study did indicate though that both carbaryl and its 1-naphthol degradate were below detection limits by Day 7 of exposure.

Estuarine/Marine Fish

Considerably less data were available on carbaryl's affect on estuarine/marine fish; on average though, carbaryl is moderately toxic (LC_{50} = 2.2 mg/L) to Sheepshead minnow (*Cyprinodon variegatus*) on an acute exposure basis.. In sublethal effect tests, exposure to a single dose of carbaryl at 0.10mg/L adversely affected schooling behavior in the silverside (Weis and Weis, 1974). Additionally, exposure to carbaryl at 0.01 mg/L caused retardation of fin regeneration during the first week of the study in the killifish (*Fundulus heteroclitus*) (Weis and Weis 1975). Field exposure to a maximum carbaryl water concentration of 1.2 mg/L affected burying behavior in caged English sole young (Pozorycki, 1999).

At present there are no data with which to evaluate the chronic toxicity of carbaryl for marine/estuarine; therefore, EFED is recommending that chronic toxicity testing be conducted using estuarine/marine fish. Guideline testing requirement 72-4(a) is not fulfilled.

Estuarine/Marine Invertebrates

Technical grade carbaryl ranged from being moderately to very highly toxic estuarine/marine invertebrates on an acute basis (48-hr EC_{50} range 0.0015 to 2.7 mg/L). A cumulative percent distribution of 48-hr EC_{50} values (**Figure 4**) shows that for 75% of shrimp species tested, carbaryl is very highly toxic, *i.e.*, EC_{50} < 0.1 mg/L while oysters were relatively insensitive to the effects of carbaryl (EC_{50} = 2.7 mg/L). Similarly, formulated end products (purity range: 43 - 82%) were very highly toxic to mysid shrimp (*Mysidopsis bahia*) while slightly toxic to Eastern oysters (*Crassostrea virginica*) with EC_{50} values of 0.009 mg/L and 23.6 mg/L, respectively.

No data were available to assess the chronic risk of carbaryl to estuarine/marine invertebrates and EFED recommends that such studies be undertaken.

Aquatic Plants

Only two studies of the filamentous green algae *Pseudokirchneriella subcaptitata* were available to assess the toxicity of carbaryl to aquatic plants. With technical grade carbaryl the concentration inhibiting plant growth (in terms of number of algal cells) by 50% (IC_{50} = 1.27 mg/L) was roughly similar to the endpoint for formulated end product (IC_{50} = 3.2 mg/L). In neither study were abnormalities in cell morphology or signs of phytotoxic effects observed. As reported earlier, carbaryl use has been associated with increases in phytoplankton numbers. Whether this is due to reduced predation by zooplankton as a result of their greater susceptibility to carbaryl and/or a response to 1-naphthol being a plant auxin is unclear. EFED recommends that additional aquatic plant studies be undertaken with the following species: duckweed (*Lemna gibba*), freshwater blue-green algae (*Anabaena flos-aquae*), the freshwater diatom (*Navicula pelliculosa*) and the marine diatom (*Skeletonema costatum*).

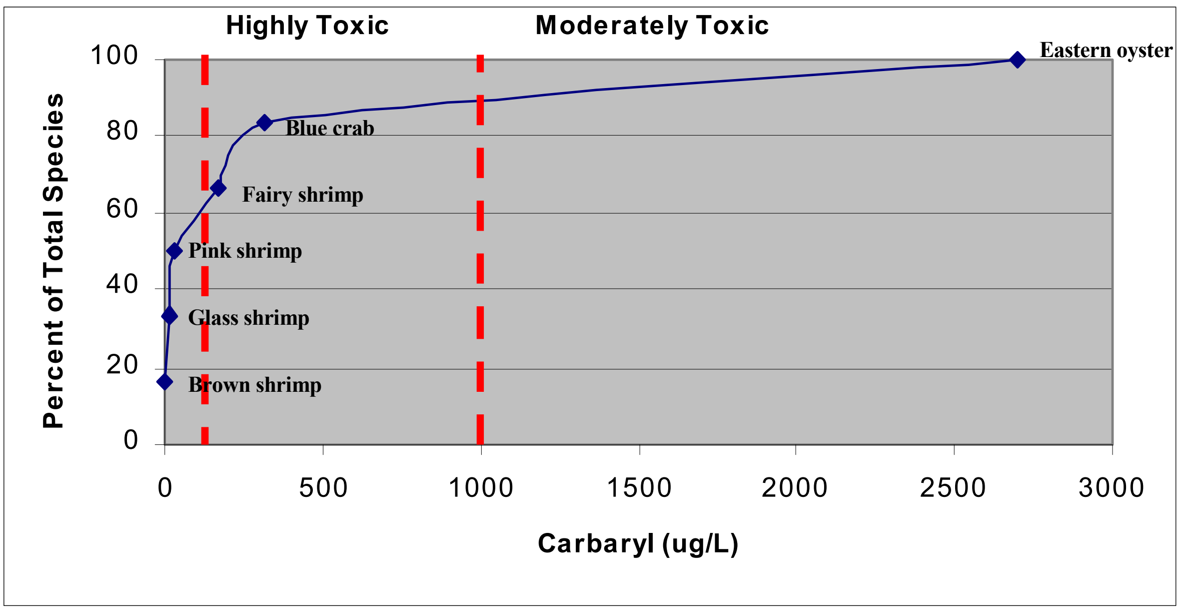

Figure 4. Cumulative percent distribution of acute 48-hr EC_{50} values in µg/L (ppb) for estuarine/marine invertebrates exposed to carbaryl. The area between the vertical dashed lines represent EC_{50} values classified as highly toxic; to the right of the dashed vertical line where EC_{50} values lie between 1000 and 10,000 :g/L is classified as moderately toxic.

ECOLOGICAL HAZARD ASSESSMENT

To evaluate the potential risk to nontarget organisms from the use of carbaryl products, risk quotients (RQs) are calculated from the ratio of estimated environmental concentrations (EECs) to ecotoxicity values. RQs are then compared to levels of concern (LOCs) used by OPP to indicate potential risk to nontarget organisms and the need to consider regulatory action (see **APPENDIX F** for more discussion).

Nontarget Terrestrial Animals

The estimated environmental concentration (EEC) values used for terrestrial exposure are derived from the Kenaga nomograph, as modified by Fletcher *et al.* (1994), based on a large set of actual field residue data. The upper limit values from the nomograph represent the 95th percentile of residue values from actual field measurements (Hoerger and Kenega, 1972). The Fletcher *et al.* (1994) modifications to the Kenaga nomograph are based on measured field residues from 249 published research papers, including information on 118 species of plants, 121 pesticides, and 17 chemical classes. These modifications represent the 95th percentile of the expanded data set. Risk quotients are based on the most sensitive LC_{50} and NOAEC for birds (in this instance, mallard ducks) and LD_{50} for mammals (based on lab rat studies).

Birds

Since carbaryl is practically nontoxic to birds on both an acute and subacute dietary exposure basis, no acute RQ values have been calculated and acute risk to birds is assumed to lie below the established level of concern, *i.e.*, RQ < 0.1. Chronic risk quotients (**APPENDIX F**) based on an mallard duck NOEC of 300 mg/Kg of diet (ppm) for birds feeding on four categories of food, *i.e.*, short grasses, tall grasses, broadleaf plants/small insects, and fruit/seeds/large insects, are depicted in **Figure 5**. For birds feeding on short grasses, the chronic risk LOC (RQ = 1) is exceeded for all nongranular uses. For birds feeding on tall grasses and broadleaf plants/small insects, 55% and 60% of the modeled use categories exceed the chronic LOC, respectively. None of the modeled uses exceeded the chronic LOC for birds feeding on fruit/seeds/large insects. Generally, crops groupings receiving multiple applications of greater than 3 lbs/Acre per application (citrus, olives, pome fruits, stone fruits, tree nuts and turf) or crop groupings receiving four or more applications of 2 lbs/acre with short (# 7days) reapplication intervals (sweet corn, asparagus, solanaceous crops, small fruits and berries) are likely to result in risk of chronic reproductive effects in birds feeding on three out of the four food categories (short grasses, tall grasses and broadleaf plants/small insects).

In addition to maximum label use rates, avian RQs were also calculated for nongranular carbaryl based on quantitative use assessment (QUA) rates for 70 crops. Furthermore, chronic RQ values were calculated based on maximum reported use rates derived from Doane Report data on 42 crops. For both use rates, risk quotients were only calculated for birds feeding on short grasses since this food sources represents the highest exposure potential. When RQ values are based on QUA average use rates, the chronic LOC is exceeded for 49% of the uses (**APPENDIX F Table 5b**). When RQ values are based on maximum reported use rates, the chronic LOC is met

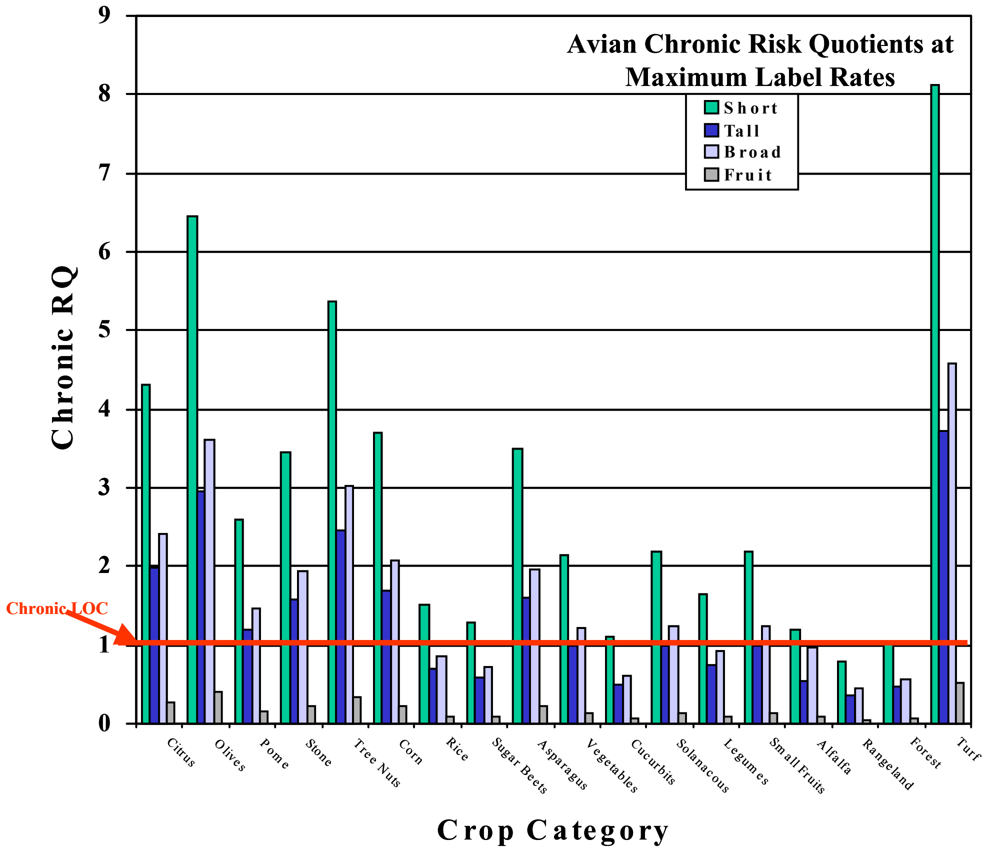

Figure 5. Chronic risk quotients (RQ) in selected crop categories for birds feeding on short grasses, tall grasses, broadleaf plants/small insects and fruits/seeds/large insects at maximum label application rates. The chronic level of concern (LOC) is exceeded at RQ $ 1.

or exceeded for 81% of the uses (**APPENDIX F Table 5c**). Typically, single average application rates of more than 1.3 lbs/Acre or multiple rates of greater than 1 lbs/Acre are likely to exceed the chronic risk LOC. At maximum reported application rates, the only crops where the chronic risk LOC was not exceeded (canola, carrots, cauliflower, cucumbers, lettuce, sorghum, sunflower and wheat) all had single application rates of less than 1 lb/Acre.

As noted earlier, although carbaryl is characterized as being practically nontoxic to birds, there is uncertainty whether small birds may be more sensitive. Open literature suggests that carbaryl may be moderately toxic to small birds. Additionally, the only two field incidents that could be associated with carbaryl use affected smaller-sized birds. Further study should be directed toward addressing this uncertainty.

Mammals

Similar to exposure estimates for birds, residues on mammalian food items are determined using Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994). A description of the method used in deriving mammalian RQs can be found in **APPENDIX F**.

<u>**Acute Risk**</u>

Figures 6, **7** and **8** depict acute risk quotients for small, intermediate and large-sized mammals, respectively, feeding on short grasses, broadleaf/forage plants/small insects, fruit/pods/seeds and large insects and seeds on nongranular carbaryl uses at maximum label rates. The acute risk LOC (RQ $ 0.5) is exceeded for all small (**Figure 6**; RQ range 0.76 to 12) and intermediate-sized (**Figure 7**; RQ range: 0.53 - 8.4) mammals feeding on short grasses. For large-sized mammals, the acute risk LOC is exceeded for 40% of the use categories (**Figure 8**). The acute endangered species LOC (RQ $ 0.1) is exceeded for all-sized mammals feeding on short grasses.

For mammals feeding on broadleaf/forage plants and small insects, the acute risk LOC is exceeded on all uses except rangeland for small-sized mammals (**Figure 6**). For intermediate-sized animals (**Figure 7**), 75% of the use categories exceed the acute high risk LOC (RQ range: 0.56 - 4.74). For large-sized animals (**Figure 8**), the acute risk LOC is reached or exceeded for olives (RQ = 0.54) and turfgrass (RQ = 0.68). RQ values equal or exceed the acute restricted use or the endangered species LOCs for most uses except cucurbits, trees, ornamentals, rangeland and forested areas.

For mammals feeding on fruits, pods, seeds and large insects, the acute risk LOC is only exceeded on citrus for small-sized mammals (**Figure 6**; RQ = 0.76). For large-sized mammals (**Figure 8**), the acute risk LOC is not exceeded on any use. The acute endangered species LOC is exceeded in citrus (RQ = 0.12).

Although neither acute risk nor acute restricted use LOC is exceeded for granivores for any of the nongranular uses, the acute endangered species LOC is reached or exceeded for citrus (RQ = 0.17) and turfgrass (RQ = 0.11) and for citrus alone (RQ = 0.12) for small (**Figure 6**) and intermediate-sized (**Figure 7**) granivores, respectively. No acute LOC is exceeded for large-sized granivores (**Figure 8**).

When RQ values are based on QUA average use rates, the acute risk LOC is exceeded (RQ range: 0.53 - 4.0) on 89% of the uses (**APPENDIX F Table 9a**) and the acute restricted use LOC is exceeded for 99% (all but Chinese cabbage) of the uses. The acute endangered species LOC however, is exceed on all uses (RQ range: 0.15 - 4.0). When RQ values are based on maximum reported (Doane) use rates (**APPENDIX F Table 9b**), the acute risk LOC is exceeded on 95% of the uses (RQ range: 0.60 - 11). The acute restricted use and endangered species LOCs are exceeded on all of the uses (RQ range: 0.38 - 11).

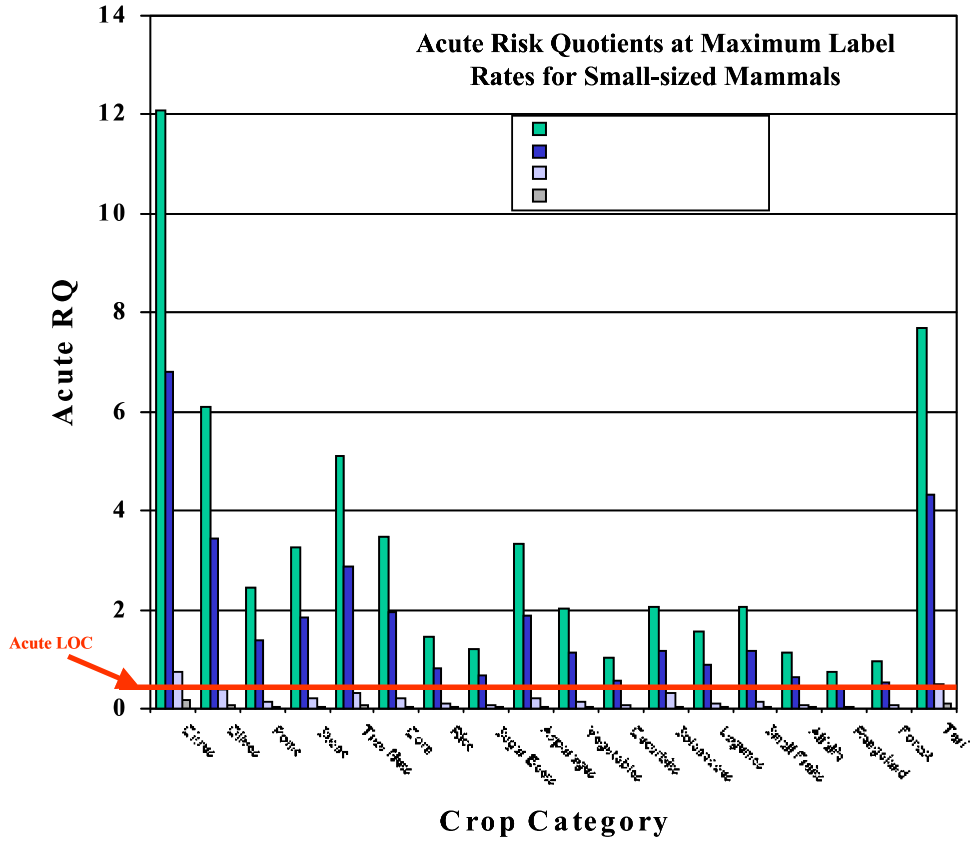

Figure 6. Acute risk quotients (RQ) in selected crop categories for small-sized mammals feeding on short grasses, forage/small insects, large insects and seeds at maximum label application rates. The acute risk level of concern (LOC) is exceeded at RQ $ 0.5 .

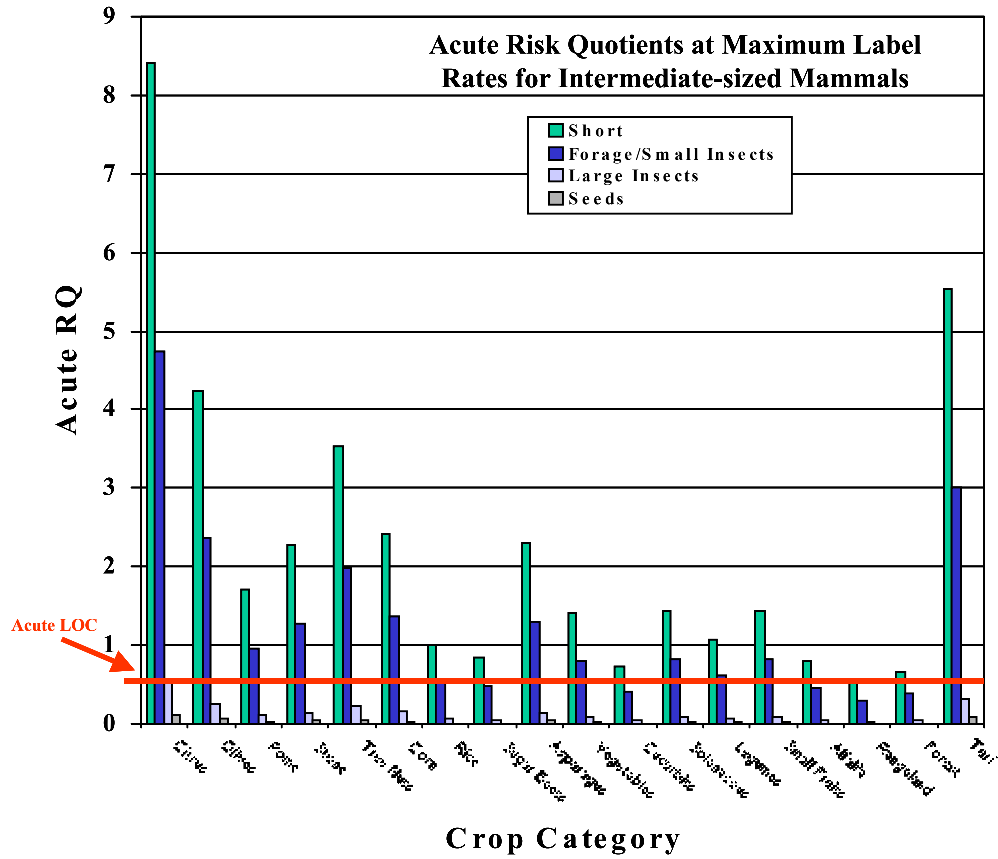

Figure 7. Acute risk quotients (RQ) in selected crop categories for intermediate-sized mammals feeding on short grasses, forage/small insects, large insects and seeds at maximum label application rates. The acute risk level of concern (LOC) is exceeded at RQ $ 0.5 .

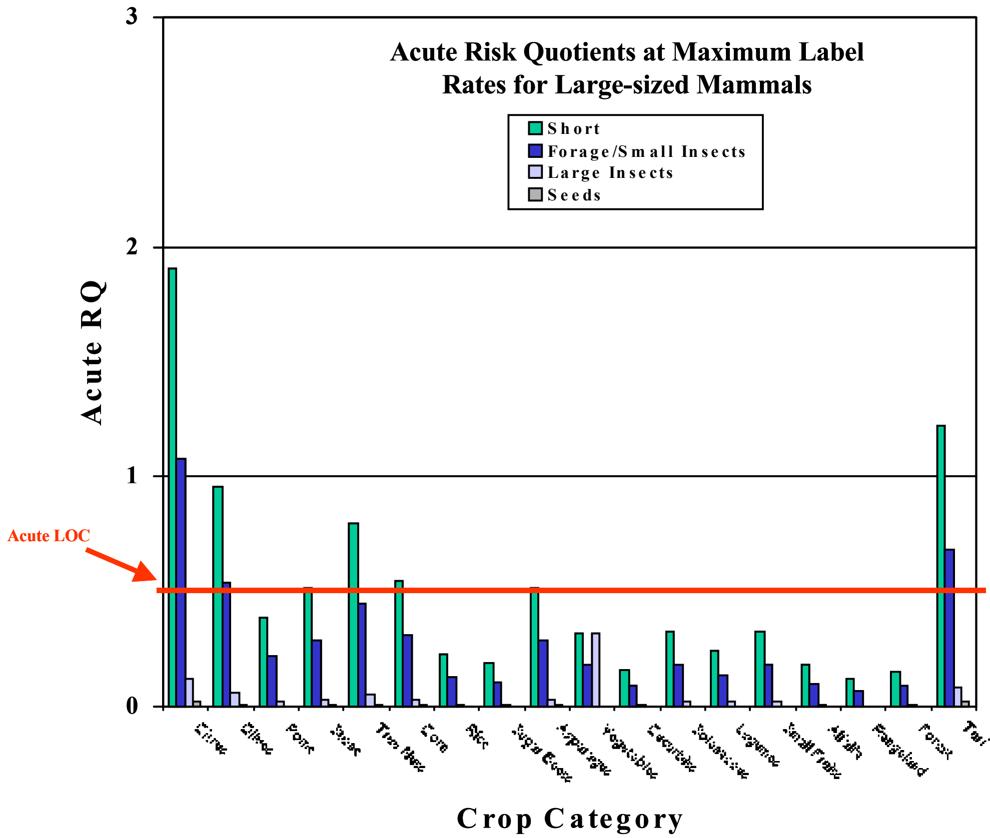

Figure 8. Acute risk quotients (RQ) in selected crop categories for large-sized mammals feeding on short grasses, forage/small insects, large insects and seeds at maximum label application rates. The acute risk level of concern (LOC) is exceeded at RQ $ 0.5 .

Chronic Risk

As reported in **APPENDIX F Table 8** and depicted in **Figure 9**, the mammalian chronic risk LOC (RQ $ 1) is exceeded on all registered uses for mammals feeding on short grasses (RQ range: 3 - 51), forage/small insects (RQ range: 1.4 - 24) and fruit/seeds/large insects (RQ range: 1.7 - 29). For granivores, the chronic risk LOC is exceeded on five uses: citrus, olives, stone fruit, tree nuts and turf grass (RQ range: 1.1 - 3.2).

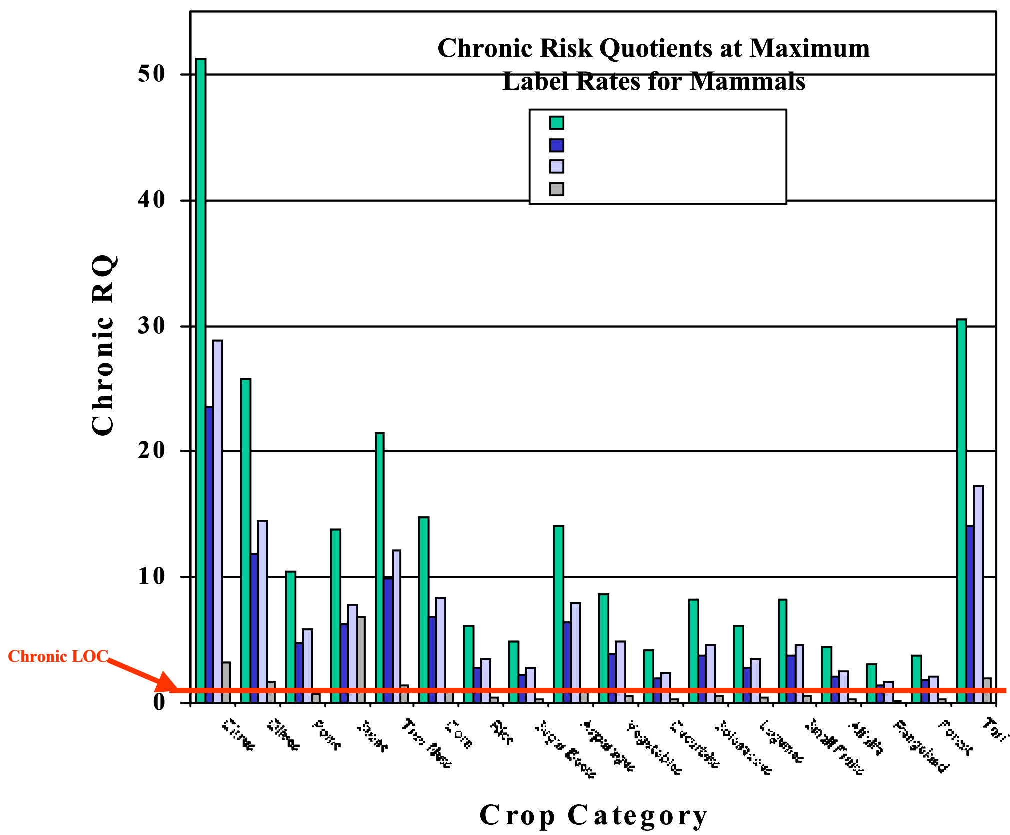

Figure 9. Chronic risk quotients (RQ) in selected crop categories for mammals feeding on short grasses, forage/small insects, large insects and seeds at maximum label application rates. The chronic risk level of concern (LOC) is exceeded at RQ $ 1.0 .

Risks from Granular Products

Mammals may also be exposed to granular/bait pesticides through ingestion or by walking on exposed granules. **APPENDIX F** provides a description of how risk quotients are derived for this exposure. Based on this analysis, acute LOCs are exceeded for all 40 registered granular uses (**APPENDIX F Table 10**) for small- and intermediate-sized mammals (RQ range 0.99 - 21). For large mammals, acute restricted use and endangered species LOCs are exceeded on applications to trees/ ornamentals, turfgrass, and for tick control (RQ = 0.32).

Hazard to Terrestrial Plants

Terrestrial and semi-aquatic plants may be exposed to pesticides from runoff, spray drift or volatilization. Semi-aquatic plants are those that inhabit low-laying wet areas that may be dry at certain times of the year. Ecological effects testing on a range of terrestrial and semi-aquatic plants revealed that the detrimental effects for all the test endpoints were less than 25% when compared with the controls (**APPENDIX D1**). As a result, the EC_{25} was greater than 0.083 lb a.i./Acre. Therefore, RQ values have not been calculated for terrestrial and semi-aquatic plants and it is assumed that at application rates less than or equal to 0.083 lbs/Acre, carbaryl use does not represent a risk to plants. As noted earlier though, terrestrial plant testing was limited in the scope of plants tested and EFED recommends that a more comprehensive Tier I and, if necessary, Tier II Seed Germination and Seedling Emergence and Vegetative Vigor studies. Additionally, since 1-naphthol is a plant auxin, the effects of this carbaryl degradate should also be evaluated.

Hazard to Nontarget Aquatic Animals

Estimated environmental concentrations for determining risk to aquatic organisms are derived using the Pesticide Root Zone Model coupled with the Exposure Analysis Model System (PRZM/EXAMS). A more detailed description of how aquatic RQ values are determined can be found in **APPENDIX F**.

Freshwater Fish

Figure 10 shows acute risk quotients for freshwater fish based on maximum label rates; the acute risk LOC (RQ ≥0.5) is exceeded on citrus alone. Endangered species LOC is met or exceeded on all of the crops modeled. RQ's based on QUA average and reported average rates (**APPENDIX F Table 12**) exceeded the acute risk LOC for citrus while the endangered species was exceeded on all crops for both use rates except on sugar beets; at average and maximum reported rates, sugar beets did not exceed any acute LOC.

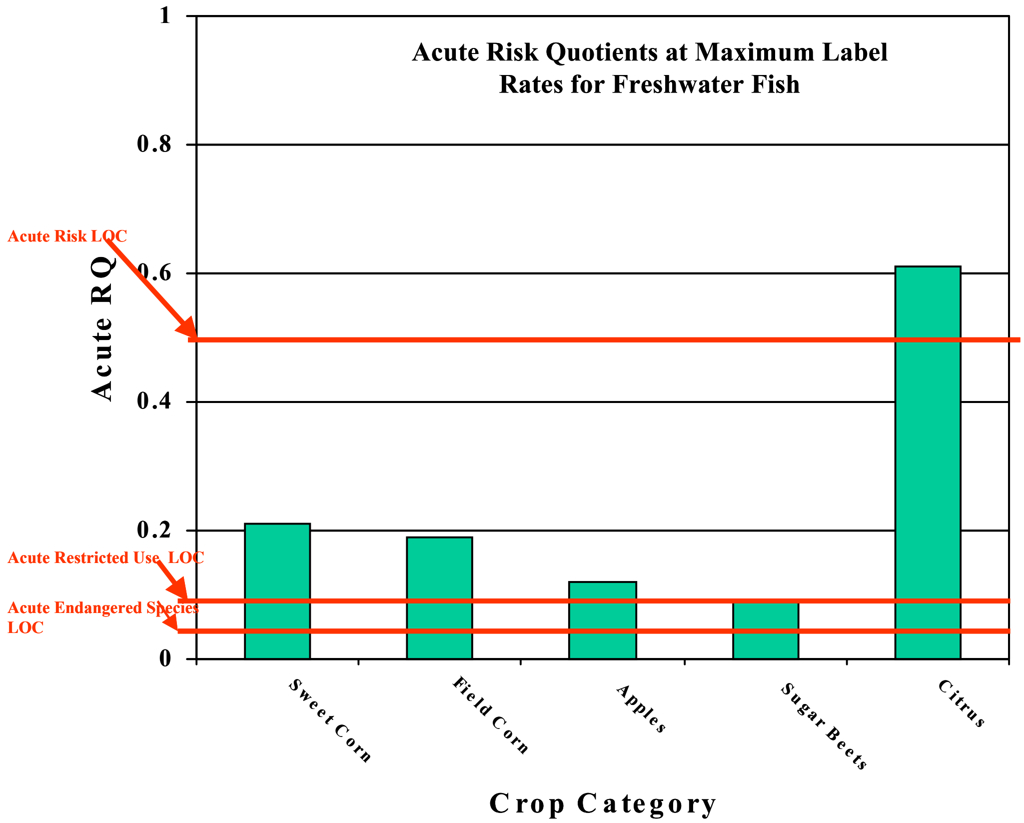

Figure 10. Acute risk quotients (RQ) in selected crop categories for freshwater fish at maximum label application rates. Acute risk level of concern (LOC) is exceeded at RQ $ 0.5; acute restricted use LOC is exceeded at RQ $ 0.1 and acute endangered species LOC is exceeded at RQ $0.05 .

Freshwater Invertebrates

Acute risk quotients (RQ range: 4.5 - 30) for freshwater invertebrates at maximum label rates **(Figure 11)**, QUA average rates (RQ range: 1.4 - 20) and Doane maximum reported rates (RQ range: 1.0 - 26) all exceed acute risk levels of concern (**APPENDIX F Table 13**).

Chronic risk quotients for freshwater invertebrates exceed the chronic LOC for maximum label rates (RQ range: 8.7 - 55), QUA average rates (RQ range: 2 - 34) and Doane maximum reported rates (RQ range: 2 - 45) (**APPENDIX F Table 13**).

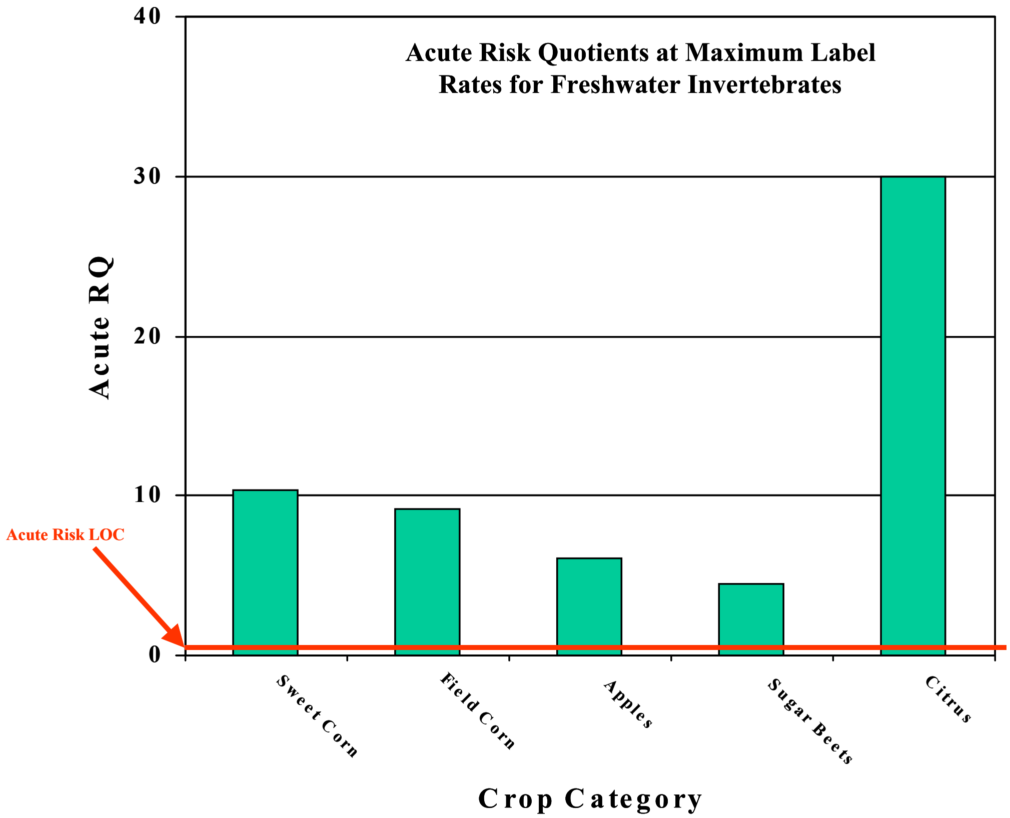

Figure 11. Acute risk quotients (RQ) in selected crop categories for freshwater invertebrates at maximum label application rates. Acute risk level of concern (LOC) is exceeded at RQ $ 0.5; acute restricted use LOC is exceeded at RQ $ 0.1 and acute endangered species LOC is exceeded at RQ $0.05 .

Estuarine/Maine Fish

None of the uses modeled exceeded acute risk or restricted use LOCs at maximum label rates, QUA average rates or maximum (Doane) reported rates (**APPENDIX F Table 14**). The endangered species LOC was minimally exceeded for maximum label and maximum reported rate rates on citrus (RQ = 0.06).

Estuarine/Marine Invertebrates

The acute risk LOC for estuarine/marine invertebrates is exceeded for all five carbaryl uses modeled at maximum label rates (**Figure 12**) (RQ range: 4 - 27), QUA average rates (RQ range: 1.2 - 18) and Doane maximum reported rates (RQ range: 0.9 - 23) (**APPENDIX F Table 15**).

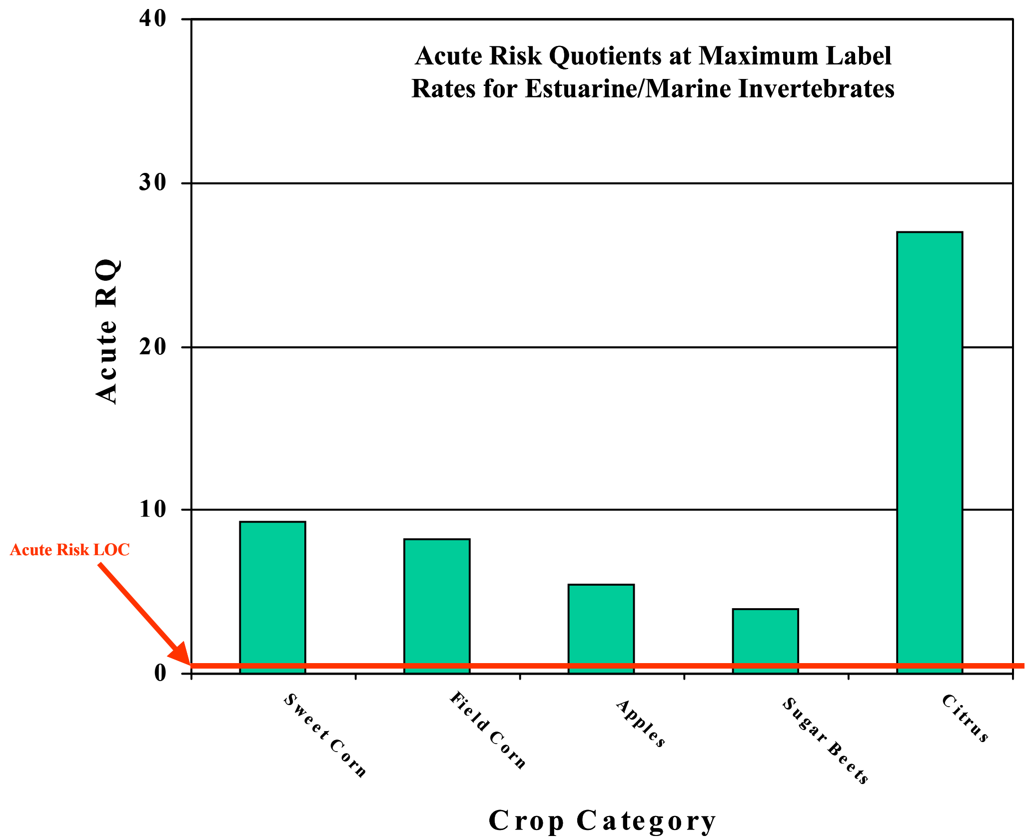

Figure 12. Acute risk quotients (RQ) in selected crop categories for estuarine/marine invertebrates at maximum label application rates. Acute risk level of concern (LOC) is exceeded at RQ $ 0.5; acute restricted use LOC is exceeded at RQ $ 0.1 and acute endangered species LOC is exceeded at RQ $0.05 .

Aquatic Plants

Based on a single core aquatic plant toxicity study available, neither the acute risk nor the endangered species LOC (RQ $\geq$ 1) is exceeded for any of the five use scenarios modeled, at maximum label (RQ range: 0.11 - 0.66), QUA average (RQ range: 0.05 - 0.43), and maximum reported use rates (RQ range: 0.01 - 0.56) (**APPENDIX F Table 16**). However, to fully assess carbaryl risk to aquatic plants, it is recommended that toxicity studies with *Lemna gibba, Anabaena flos-aquae, Skeletonema costatum,* and a freshwater diatom be submitted.

ECOLOGICAL RISK CHARACTERIZATION

Carbaryl is a carbamate insecticide registered for control of a wide range of insect and other arthropod pests on over 100 crop and noncrop use sites, including home and garden uses. The pesticide is a cholinesterase inhibitor that acts on contact or ingestion by competing for binding sites on the enzyme acetyl cholinesterase, thus preventing the breakdown of acetyl choline.

Carbaryl is not very persistent and dissipates in the soil environment by abiotic and microbially- mediated degradation and is not likely to persist. The major degradation products are CO_2 and 1-naphthol, which is further degraded to CO_2. Carbaryl is stable to hydrolysis in acidic conditions, but hydrolyzes rapidly in alkaline environments. The compound is degraded by photolysis in water, with a half-life of 21 days. Under aerobic conditions the compound degrades rapidly by microbial metabolism with half-lives of 4 to 5 days in soil and aquatic environments. In anaerobic environments metabolism is much slower with half-lives on the order of two to three months. Carbaryl is mobile in the environment (K_f =1.7 to 3.5) and has been detected in all environmental compartments; it dissipates rapidly from foliage with a mean half-life of 3.2 d, but is easily washed off leaf surfaces, with 91% removal with 1 cm of rain. Sorption onto soils is positively correlated with soil organic content, increasing with higher soil organic content (R^2 = 0.94.) Carbaryl is not expected to bioaccumulate (BCF = 45X).

In field studies, carbaryl dissipated from terrestrial field dissipation studies with DT_{50} of 4 (California) and 7 (North Carolina) days. No leaching was observed in either study. but recharge may not have been sufficient to cause downward movement. In a forestry dissipation study, time to fifty percent removal was 21 days on foliage, 75 days on leaf litter, and 65 days on soil. In two aquatic (rice paddy) dissipation studies in Texas and Mississippi, DT_{50}'s at both sites were less than two days.

Fate data on the primary degradate, is limited; however, 1-naphthol appears to be somewhat mobile but 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.

Carbaryl is widely detected in non-targeted and targeted monitoring studies. Observed concentrations are generally low with fifty percent of the samples below minimum detection limits and ninety five percent of the samples less than 0.065 : g/L. Carbaryl is not very persistent in most surface water conditions suggesting that the wide spread occurrence is a result of its extensive use in a variety of applications.

As noted above, carbaryl is expected to be mobile, but degrade rapidly in the environment in most cases. However, there are circumstances, *i.e.*, under acidic conditions with low biological activity and/or in reducing (anaerobic) conditions, where carbaryl is likely to persist. Available field data are in general agreement with the laboratory data, with the forestry dissipation study indicates somewhat longer persistence than the other studies, but not so far as to be an outlier. The fate and transport data has a relatively complete coverage of the expected routes of fate and transport, but is limited in the amount of data for any particular study. In particular, there is only one available guideline metabolism study for each route of metabolism. Given the high variability typically associated with these studies, there is some uncertainty in these rates. Since this uncertainty is factored into the aquatic and drinking water exposure estimates, an increase in the number of metabolism studies could potentially decrease current exposure estimates.

Additionally, there are a number of factors inherent in the modeling that can affect the accuracy and precision of this analysis including the selection of the high exposure scenarios, the quality of the input data, the ability of the models to represent the real world, and the number of years that were modeled. The EEC's in this analysis are accurate only to the extent that the site represents this hypothetical high exposure site.

Although carbaryl is not expected to be persistent, on low organic carbon content soils and following high rain events the pesticide is likely to be mobile. Laboratory studies of terrestrial and aquatic animals indicates that carbaryl is practically nontoxic to birds, moderately toxic to mammals and fish, and very highly toxic to bees and aquatic invertebrates on an acute exposure basis. Additionally, data indicate that the carbaryl hydrolysis degradate 1-naphthol ranges in toxicity from moderately to highly toxic to aquatic organisms.

Risk to Terrestrial Animals

Given that carbaryl is practically nontoxic to birds on both an acute oral exposure and a subacute dietary exposure basis, the threat of adverse effects to birds resulting from acute exposure to carbaryl is considered low. On an chronic exposure basis however, the chronic risk level of concern (RQ = 1) is exceeded on over 50% of the crops modeled for birds feeding on short grasses (100%), tall grasses (55%) and broadleaf plants/small insects (66%) for nongranular product at maximum label rates. In general, crops receiving multiple applications of nongranular products greater than 3 lbs a.i./acre with short (# 7 day) reapplication intervals were likely to represent a risk of chronic effects in birds. At "average" application rates modeled for short grasses the number of exceedances was reduced from 100% to 49% of the crops.

Although bird incidents (5) have been reported for carbaryl, only two could be clearly attributed to the chemical and only one could be linked to a specific registered use. The one incident reported a single morning dove (*Zenaida macroura*) dying following application to a homeowner's lawn in the vicinity of a bird feeder.

Even though carbaryl has been classified as practically nontoxic to birds on an acute exposure basis, there is uncertainty regarding the sensitivity of smaller, passerine birds. Open literature on smaller birds and incidents involving blackbirds and starlings suggest that perching birds may be more sensitive.

Consistent with carbaryl's moderate acute toxicity to mammals, the acute risk level of concern (RQ $ 0.5), acute restricted use (RQ $ 0.2) and acute endangered species (RQ $ 0.1) are exceeded for majority (> 75%) of the uses modeled for small (15 g) and intermediate-sized (35 g) animals feeding on short grasses and broadleaf/forage plants. For large-sized mammals (1000 g), acute risk LOCs are exceeded on 40% of the uses modeled for animals feeding on short grasses and for over 50% of the uses modeled for large animals feeding on broadleaf/forage plants. For mammals feeding on fruits/pods/seeds/large insects, the acute risk LOC is exceeded for small-sized animals and the acute endangered species LOC is exceeded for large-sized mammals following application to citrus. For granivores, acute endangered species LOCs are minimally exceeded for small (RQ = 0.17) and intermediate-sized mammals (RQ = 0.12) following application to citrus and for small-sized mammals alone (RQ = 0.11) following application to turfgrass. The mammalian chronic risk LOC is exceeded for all registered uses for animals feeding on short grasses, forage/small insects, and fruits/large insects (RQ range: 1.1 - 31). For mammals feeding on seed fruit, the chronic LOC is exceeded on citrus, olives, stone fruit, tree nuts and turf (RQ range: 1.1 - 3.2). Even when looking at average application rates, acute risk LOCs are exceeded on 89% of the uses while the chronic risk LOC is exceeded on all uses except Chinese cabbage.

Mammals may also be exposed to granular/bait formulations of carbaryl through ingestion and/or walking on exposed granules. The acute risk LOC for small and intermediate-sized mammals is exceeded (RQ range: 0.99 - 21) for all 40 registered granular uses. For large-sized mammals, acute restricted use and endangered species LOCs are exceeded following application for trees and ornamentals, turfgrass, and tick control.

Although 2 incidents have attributed to carbaryl, one involving a gray squirrel (*Sciurus carolinensin*) and the second involving a hairytail mole (*Parascalops breweri*), neither could be associated with a specific use of carbaryl. However, based on the risk quotients for small and intermediate sized animals, estimated acute environmental concentrations are sufficiently high to result in mortality.

Carbaryl is highly toxic to beneficial insects on an acute exposure basis. Bee-kill incidents have been reported; however, all but one involving the use of carbaryl on asparagus in Washington, contained sufficient information to implicate a specific use of carbaryl. Although the bee industry has expressed its concerns regarding the toxicity of carbaryl to bees, it has not provided sufficient data to support its concerns.

The risk to bees from the use of carbaryl to thin orchard fruit has recently been evaluated. Under the conditions tested in the German apple orchards, carbaryl SC applications to thin fruit did not have a significant ($P > 0.05$) effect on bee mortality and/or behavior.

Risks to Aquatic Animals

In general, carbaryl is moderately toxic to freshwater fish and the acute risk LOC is exceeded for citrus alone (RQ = 0.61); acute endangered species LOCs are exceeded (RQ range: 0.06 - 0.61) on all crops modeled except sugar beets. None of the uses modeled exceeded the chronic risk LOC. Although three fish kill incidents hare been reported for carbaryl, there appears to be only one credible report where carbaryl used to control gypsy moth (*Lymantria dispar*) could be directly associated with a fish kill.

Carbaryl ranged from being slightly to moderately toxic to amphibians on an acute exposure basis. Intra and inter-species variability contributed to the range of responses to carbaryl. While much of the current research focuses on direct acute effects of carbaryl on tadpoles/frogs, the indirect effects of carbaryl on impairing predator avoidance is frequently raised as a concern. Additionally, carbaryl exposure has been associated with skeletal deformities in frogs.

Consistent with carbaryl's classification as being very highly toxic to freshwater invertebrates, acute risk LOCs are exceeded (RQ range 1 - 30) for all uses modeled at maximum label rates, average rates and maximum reported rates. Similarly, the chronic risk LOC is exceeded (RQ range: 2 - 55) for all uses at all rates. Interestingly, carbaryl's toxicity to aquatic macroinvertebrates has been associated with phytoplankton blooms where it is hypothesized that selective mortality on zooplankton reduced grazing on phytoplankton to a sufficient extent to favor/promote phytoplankton abundance. Increased growth rates in tadpoles exposed to carbaryl has been theorized as a response of the amphibians to increased phytoplankton food supplies.

Similar to freshwater fish, carbaryl is moderately toxic to estuarine/marine fish; however, none of the estimated environmental concentrations exceeded acute risk LOCs. The acute endangered species LOC was minimally exceeded (RQ = 0.06) for citrus.

Carbaryl is very highly toxic to estuarine/marine invertebrates and the acute risk LOC is exceeded on all uses modeled at maximum label, average and maximum reported application rates (RQ range: 0.9 - 27).

Risks to Plants

For both aquatic and terrestrial plants, the likelihood of adverse effects from maximum label use rates appears to be low; however, there were limited data on which to evaluate the effects of carbaryl on a range of plants. Studies over a broader range of terrestrial and aquatic plants should be submitted to address this uncertainty. Although, toxicity data suggest that carbaryl is relatively innocuous to plants, the greatest number of incidents (11) for carbaryl have involved terrestrial plants (**APPENDIX D1**). While the majority of these reports have been associated with homeowner use of the product, some agricultural crops, *e.g.*,quince and olive, have reported losses resulting from spotting, low fruit set and malformations in fruit shape. Reconciling the phytotoxicity reported in field incidents with the laboratory data represents an uncertainty.

Additional Concerns

Grasshopper and Mormon Cricket Control on Rangeland

With respect to U. S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS) Grasshopper and Mormon Cricket Suppression Program use of carbaryl to control grasshoppers and Mormon crickets, acute and chronic risk LOCs are exceeded for smaller-sized mammals when 0.5 lbs/Acre is applied; however, at 0.25 lbs/A the acute endangered species LOC alone is exceeded for smaller animals (**APPENDIX G**). Additionally, assuming 5% spray drift, acute restricted use and endangered species LOCs are exceeded for freshwater invertebrates. If 95% spraydrift (direct overflight of aquatic habitat), then acute endangered species LOC is exceeded for fish and acute and chronic risk LOCs are exceeded for aquatic invertebrates.

Based on the potential for both acute and chronic effects to terrestrial (primarily mammals) and aquatic animals (primarily invertebrates), plans are underway for USDA APHIS to consult with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to assure that endangered species are protected to the extent possible. Section 7 consultations on the use of carbaryl on rangelands to control grasshoppers/crickets are ongoing.

Section 24c Use of Carbaryl to Control Burrowing Shrimp

For several decades, carbaryl has been used to control burrowing shrimp on tidal mudflats in Willapa Bay and Grays Harbor, Washington (**APPENDICES E1 to E3**) . Although concern has been raised regarding this use and its potential impact to nontarget animals outside of treated areas, very little data have been provided to substantiate these concerns. The available data indicate that acute mortality will likely be near 100% for animals trapped on mudflats in the immediate application area and that carbaryl will likely drift off-site with the tide. However, a combination of the rapid degradation of carbaryl due to both biotic and abiotic factors and dilution by a relatively large influx of water together render potential acute and chronic effects remote. Additionally, as part of a memorandum of agreement between the Washington Stage government representatives and various stakeholders, the oystergrowers have agreed to developed an integrated pest management program to look at alternatives to carbaryl and to conduct studies to determine the extent to which carbaryl impacts areas adjacent to treated sites. Through this cooperative approach it may be possible to better document by monitoring of surface waters and sediments the extent to which carbaryl drifts. Studies are also planned to determine to what extent salmonids may be impacted. However, at this time, given the limited number of acres treated and the combination of chemical degradation and potential dilution by successive tides, there is insufficient data to warrant concern that nontarget animals are at risk throughout the Willapa Bay/Grays Harbor area.

Endocrine Disruption Concerns

There are data indicating that carbaryl exposure may impact endocrine-mediated processes in both aquatic and terrestrial animals. Serum and pituitary levels of gonadotropic hormone and gonadotropin-releasing hormone (GnRH) in the freshwater snakehead fish (*Channa punctatus*) are reduced by exposure to 1.66 - 3.73 ppm of carbaryl in laboratory and paddy field tests (Ghosh *et al.*, 1990). The decrease in GnRH levels could be explained by exposure to high estrogen levels, acting through a negative feedback pathway to inhibit GnRH release, and thus the release of gonadotropins (Klotz *et al.*, 1997). Plasma and ovarian estrogen levels in freshwater perch (*Anabas testudineus*) exposed to 1.66 ppm of carbaryl for 90 days increase until day 15 and then decline, relative to control fish, indicating that long-term exposure to this chemical may cause an inhibitory effect on fish reproduction (Choudhury *et al.,* 1993).

In addition, chronic exposure of fathead minnows (*Pimephales promelas*) to carbaryl resulted in reduced survival and reproductive effects (LOEC = 0.680 ppm) including reduced number of eggs per female and reduced number of eggs spawned. Chronic studies with aquatic macroinvertebrates resulted in reduced emergence and developmental rates in midges, *Chironomous riparius*, and reproductive effects in *Daphnia magna*. In avian reproduction studies of the mallard duck (*Anas* *platyrhynchos*) carbaryl exposure resulted in reduced number of eggs produced and increased number of eggs cracked.

These chronic toxicity measurement endpoints are considered consistent with a chemical that acts on endocrine-medicated pathways. When considered in concert with open literature, there is uncertainty regarding the endocrine disrupting potential of carbaryl and its 1-naphthol degradate.

EPA is required under the Federal Food, Drugs, and Cosmetics Act (FFDCA), as amended by Food Quality Protection Act (FQPA), to develop a screening program to determine whether certain substances (including all pesticide active and other ingredients) "may have an effect in humans that is similar to an effect produced by a naturally-occurring estrogen, or other such endocrine effects as the Administrator may designate." Following the recommendations of its Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC), EPA determined that there was scientific basis for including, as part of the program, the androgen- and thyroid hormone systems, in addition to the estrogen hormone system. EPA also adopted EDSTAC's recommendation that the Program include evaluations of potential effects in wildlife. For pesticide chemicals, EPA will use FIFRA and, to the extent that effects in wildlife may help determine whether a substance may have an effect in humans, FFDCA authority to require the wildlife evaluations. As the science develops and resources allow, screening of additional hormone systems may be added to the Endocrine Disruptor Screening Program (EDSP).

When the appropriate screening and or testing protocols being considered under the Agency's Endocrine Disruptor Screening Program have been developed, it is recommended that carbaryl be subjected to additional screening and or testing to better characterize effects related to endocrine disruption.

Endangered Species

Avian

Chronic LOCs are exceeded for birds feeding on short grasses for all uses modeled except rangeland. For birds feeding on tall grasses, the avian chronic LOC is exceeded for 55% of the modeled uses and for birds feeding on broadleaf/forage plants and small insects, the chronic LOC is exceeded for 60% of the uses modeled. When RQs were based on average use rates, 49% of the uses exceeded chronic LOCs. When RQs were based on maximum reported use rates, 81% of the uses exceeded the chronic LOC.

Mammals

For mammals, all uses modeled exceeded the acute endangered species LOC for herbivores. For mammals foraging on broadleaf plants and small insects, the endangered species LOC is exceeded for all uses except cucurbits, trees, ornamentals, rangeland and forested areas. For mammals feeding on large insects, roughly 70% and 45% of the use categories modeled exceeded the acute endangered species LOC small (15 g) and intermediate-sized (35 g) mammals, respectively. Only one use, i.e., citrus, exceeded the LOC for large-sized animals (1,000 g). For granivores, the acute endangered species LOC is exceeded for small-sized animals feeding in citrus and turfgrass areas and for intermediate-sized mammals feeding in citrus areas. Chronic LOCs are exceeded for all modeled uses for mammals feeding on all food items except seeds/fruits and large insects. For granivores, the chronic LOC is exceeded for citrus, olives, stone fruits, tree nuts and turf grass. When RQ were based on average rates or maximum reported rates, acute and chronic endangered species LOCs are exceeded for all of the modeled uses. Additionally, granular products represented an acute risk to both small and intermediate-sized mammals all on of the uses modeled. Granules were only a risk to large-sized mammals for trees, ornamental, turfgrass and tick control uses.

Aquatic Animals

For freshwater fish the endangered species LOC is exceeded for all of the crops modeled for all three use rates except for sugar beets. The LOC for endangered species was not exceeded on for sugar beets at the maximum reported use rate. For freshwater invertebrates, the both acute and chronic endangered species LOCs are exceeded for all of the uses modeled. For estuarine/marine fish, only use on citrus exceeded the acute LOC for all three use rates. For estuarine/marine invertebrates, the acute endangered species LOC is exceeded for all of the use and rates modeled; however, there currently are no federally listed estuarine invertebrates. At the current application rates, carbaryl use is likely to result in both acute and chronic risks to endangered/threatened species of animals.

In 1989 the U.S. Fish and Wildlife Service (USFWS) issued a biological opinion (USFWS 1989) on carbaryl in response to the U. S. Environmental Protection Agency's request for consultation. In issuing its opinion the USFWS considered the following factors: (1) potential for exposure of the listed species to the pesticide; (2) information on the chemical toxicity relative to estimated environmental concentrations; (3) potential for secondary impacts; and (4) special concerns not specifically addressed in the preceding factors or unique to the situation being evaluated. Given the evaluation criteria, a total 127 species (6 amphibians, 77 fish, 32 mussels, 9 crustaceans, 1 insect, and 2 bird species) were considered potentially affected by the use of carbaryl. Of those organisms potentially affected, the USFWS listed 85 aquatic species as jeopardized, of which the majority (51%) were endangered/threatened species of freshwater fish. One terrestrial (avian) species was also classified as being in jeopardy. The remaining potentially affected organisms were listed either as having no potential for exposure or as not being in jeopardy. For all of the species listed as jeopardized the USFWS lists reasonable and prudent alternatives (RPA) to mitigate the effects of carbaryl use. For some of the species listed as not jeopardized, the USFWS lists reasonable and prudent measures (RPM) and incidental take (IT) to mitigate effects. For details on the RPA and RPM recommendations, the reader is referred to USFWS 1989 publication. Many additional species, especially aquatic species, have been federally listed as endangered/threatened since the biological opinion of 1989 was written, and determination of jeopardy to these species has not been assessed for carbaryl.

EPA's current assessment of ecological risks uses both more refined methods to define ecological risks of pesticides and new data, such as that for spray drift. Therefore, the Reasonable and Prudent Alternatives and Reasonable and Prudent Measures in the Biological Opinion may need to be reassessed and modified based on these new approaches.

The Agency is currently engaged in developing a consultation package for transmittal to National Marine Fisheries Service (NMFS) on April 1, 2003, to address listed Pacific salmon and steelhead. EPA is committed to look at other species beyond those discussed in this consultation package; additional consultations with both USFWS and NMFS are expected to cover other terrestrial and aquatic species.

The Agency is also engaged in a Proactive Conservation Review with USFWS and the National Marine Fisheries Service under section 7(a)(1) of the Endangered Species Act. The objective of this review is to clarify and develop consistent processes for endangered species risk assessments and consultations. Subsequent to the completion of this process, the Agency will reassess the potential effects of carbaryl use to federally listed threatened and endangered species. At that time the Agency will also consider any regulatory changes recommended in the IRED that are being implemented. Until such time as this analysis is completed, the overall environmental effects mitigation strategy articulated in this document and any County Specific Pamphlets described in Section IV which address carbaryl, will serve as interim protection measures to reduce the likelihood that endangered and threatened species may be exposed to carbaryl at levels of concern.

The Agency has developed the Endangered Species Protection Program to identify pesticides whose use may cause adverse impacts on endangered and threatened species, and to implement mitigation measures that address these impacts. The Endangered Species Act requires federal agencies to ensure that their actions are not likely to jeopardize listed species or adversely modify designated critical habitat. To analyze the potential of registered pesticide uses to affect any particular species, EPA puts basic toxicity and exposure data developed for REDs into context for individual listed species and their locations by evaluating important ecological parameters, pesticide use information, the geographic relationship between specific pesticide uses and species locations, and biological requirements and behavioral aspects of the particular species. This analysis will take into consideration any regulatory changes recommended in this RED that are being implemented at this time. A determination that there is a likelihood of potential impact to a listed species may result in limitations on use of the pesticide, other measures to mitigate any potential impact, or consultations with the Fish and Wildlife Service and/or the National Marine Fisheries Service as necessary.

The Endangered Species Protection Program as described in a Federal Register notice (54 FR 27984-28008, July 3, 1989) is currently being implemented on an interim basis. As part of the interim program, the Agency has developed County Specific Pamphlets that articulate many of the specific measures outlined in the Biological Opinions issued to date. The Pamphlets are available for voluntary use by pesticide applicators on EPA's website at www.epa.gov/espp. A final Endangered Species Protection Program, which may be altered from the interim program, was proposed for public comment in the Federal Register ~~in~~ December 2, 2002.

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APPENDIX A1. DRINKING WATER MEMO

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
PREVENTION, PESTICIDES
AND TOXIC SUBSTANCES

MEMORANDUM March 12, 2003

SUBJECT: Final Report of Carbaryl EEC's for Drinking Water
DB Barcode: D288455
PC Code: 056801

TO: Anthony Britten,
Chemical Review Manager,
Reregistration Branch 3
Special Review and Reregistration Division

FROM: R. David Jones, Ph.D., Senior Agronomist
Environmental Risk Branch 4

THROUGH: Elizabeth Behl, Chief
Environmental Risk Branch 4
Environmental Fate and Effects Division

This is the final report for revised estimated environmental concentrations (EEC's) in surface water for the use of carbaryl on selected crops. These EEC's are intended to replace those in the *Environmental Fate and Ecological Risk Assessment for the Reregistration of Carbaryl* (Libelo *et al.*, 2002). Since the issuance of that document, new information has been received by the Agency in response to a request for public comments on the draft assessment (particularly on foliar degradation rates) that warranted a re-evaluation of the aquatic exposure. We have also taken the opportunity to make some other changes that improve the general quality and reliability of the estimates.

The EEC's in Table 1 represent the 90 percentile exposure value for carbaryl use on representative crops. These EEC's are based on the maximum use patterns allowed on each label as described below. Because we estimate that the highest carbaryl concentrations will result from the use of carbaryl on citrus, those values are used as a screen in estimating potential drinking water exposure nationally. It should be noted that concentrations estimated to result from carbaryl use on other crops are substantially lower than for the citrus use(see table 1). In addition to the point estimates, we have also provided the time series of carbaryl concentrations for the entire duration of the simulation for the different citrus scenarios. These estimates are intended for use in a more refined estimate of dietary exposure for carbaryl and are being combined with carbaryl residues in food using the DEEM model.

The following changes were made in the selection of input parameters used in this assessment relative to those used in the original set of estimates:

C The foliar half-life was changed from 35 to 3.71 days, to reflect relevant data submitted by the registrant.

C The foliar washoff coefficient was also changed from a default value of 0.5 to 0.91 based on estimates made from two literature studies submitted by the registrant.

C The site for used to represent a vulnerable site for apples was changed from Oregon to Pennsylvania, which better reflects a vulnerable use site for apples across the whole country and is more consistent with EFED's policy on Tier 2 site selection.

C In the original assessment, measured soil-water partition coefficient's (K_d's) were used based on the texture of a measured soil. This was changed to using a single K_{oc} of 196 L kg^{-1} based on the texture in the soil represented in the model scenario, which better reflects current policy.

C The value used to represent microbial degradation in the pond sediment was changed from 72.2 to 216 days in keeping with current policy of parameter selection which indicates single metabolism values should be multiplied by three.

Table 1. EEC's for the 'maximum' use patterns for carbaryl on selected agricultural crops

Crop	Acute EEC	Chronic EEC
	-------------------- :g L^{-1} carbaryl equivalents --------------------	
Apples	62.9	2.20
Citrus	316	14.2
Field Corn	51.3	2.72
Sweet Corn	57.3	5.53
Sugar Beets	48.2	2.16

C The value originally used for aerobic aquatic metabolism, 12 days, unintentionally resulted in double counting of hydrolysis. A revised value of 29.6 days avoids doubling the hydrolysis rate.

C The application date on some sites was changed to better reflect the actual use practice.

A more complete description of rationale and effects of these changes is provided below. The revised EEC's for the maximum use pattern are in Table 1. A complete list of EEC's for all use patterns is in Table 6.

Models

These estimates were calculated using PRZM version 3.12 dated May 24, 2001 and EXAMS version 2.98.04 dated July 18, 2002. These models were run in the EFED PRZM EXAMS shell, PE3 version 1.2, dated October 15, 2002. The shell also processed the output from EXAMS to estimate the 1 in 10 year return values reported here. In addition, time series of daily values for thirty years were output and have been provided for use in more refined dietary exposure assessment. A list of the input files used to generate these EEC's is in the APPENDIX A2.

It is worth noting that the Office of Pesticide Programs is aware of an error in the current modeling system that results in the "peak" EEC's reported actually representing not instantaneous peak concentrations, but 24-hour mean concentrations on the day the peak occurs. The OPP is currently taking corrective action, but revisions had not completed QA review prior to initiation of this analysis. For the case of carbaryl, this likely results in an approximately five percent underestimation of the peak. However, this error is certainly covered by other substantial conservatisms which are inherent in these estimates.

Scenarios

EEC's were calculated for 5 crops which include those which are the major use sites for carbaryl. These sites are: apples, citrus, field corn, sweet corn, and sugar beets. The scenario for apples is in Lancaster County, Pennsylvania and represents a Elioak silt loam soil, Hydrologic Group C soil. The scenario for citrus is in Collier and Hendry Counties Florida and represents a Wabasso sand soil. The scenario for field corn and sweet corn is in Darke and Rickaway Counties, Ohio and represents a Cardington silt loam soil which is Hydrologic Group C. The scenario for sugar beets is in Polk County, Minnesota. The soil there is an Adair clay loam in Hydrologic Group C.

The apple scenario used in previous modeling was set in Oregon rather than Pennsylvania. The site was switched to Pennsylvania as this site is thought to better represent a vulnerable site among all apple orchards across the United States. The Oregon site may not be protective of drinking water facilities downstream from apple orchards in the eastern United States as that geographic region receives lower rainfall and runoff during the growing season than the site in the East.

Use Patterns

The use patterns for each crop were adapted from the carbaryl labels to represent the maximum use patterns. The input parameters used to represent these use patterns are in Table 2. These values are essentially the same as in for the previous set of EEC's except that the date of first application was changed for some crops to better represent the use pattern. For citrus, simulations for two different initial application dates were done, April 1 and August 31. The April 1 date appears to be plausible for Florida given the pests carbaryl is intended to control, but monitoring data in Florida citrus watersheds indicate that there is use during August and September (D285826). The results for the citrus scenario are discussed in the characterization section below. In cases where a minimum re-application interval was specified on the label this value was used in the maximum application pattern. In cases when no minimum interval is specified, a interval of 3 days was used. The OPP current has no written guidance for this subject. However, three days is a reasonable minimum retreatment interval, given that scouting and evaluation of efficacy would have to occur before another treatment is undertaken. This minimum value has been used by OPP for Tier 2 modeling in the absence of guidance for 10 years. Metadata for each scenario is described in EFED, 2002b.

Table 2. Maximum use patterns for carbaryl application on selected crops based on the EPA label.

Crop	Single app. Rate (lb $acre^{-1}$)	Number of Applications	Application Interval	Application Method	Date of First Application
Apples	**2**	**5**	**3 days**	**aerial**	**June 1**
Citrus	**5**	**4**	**14 days**	**aerial**	**April 1**
Field Corn	**2**	**4**	**14 days**	**aerial**	**June 1**
Sweet Corn	**2**	**8**	**14 days**	**aerial**	**May 1**
Sugar Beets	**1.5**	**2**	**14 days**	**aerial**	**June 1**

Table 3. Maximum reported use patterns for carbaryl application on selected crops					
Crop	**Single app. Rate (lb $acre^{-1}$)**	**Number of Applications**	**Application Interval**	**Application Method**	**Date of First Application**
Apples	**1.6**	**2**	**14 days**	**aerial**	**June 1**
Citrus	**4.26**	**3**	**14 days**	**aerial**	**April 30**
Field Corn	**1.5**	**2**	**14 days**	**aerial**	**June 1**
Sweet Corn	**3***	**1**	**---**	**aerial**	**June 1**
Sugar Beets	**1.2**	**1**	**---**	**aerial**	**June 1**
*** The maximum reported rate is greater than the maximum label rate. The seasonal maximum rate is not exceeded, however.**					

Table 3 contains maximum reported use patterns (application rate and number of applications), and represents the high end of actual carbaryl use patterns for these crops as determined from survey usage data available from the Doane's Agricultural Services. Table 4 contains "average" use patterns, developed from estimates of the mean (50 percentile??) number of applications application rate, the total number of acres receiving an application and total applied to each acre for each crop. (Hernandez, 2002). For the "average" use pattern, the number of applications more closely reflects those that are reported by BEAD in the QUA (Hernandez, 2002).

Table 3. 'Average' use patterns for carbaryl application on selected crops					
Crop	**Single app. Rate (lb $acre^{-1}$)**	**Number of Applications**	**Application Interval**	**Application Method**	**Date of First Application**
Apples	**1.2**	**2**	**14 days**	**air blast**	**June 1**
Citrus	**3.4**	**2**	**14 days**	**aerial**	**April 30**
Field Corn	**1**	**2**	**14 days**	**aerial**	**June 1**
Sweet Corn	**3.4**	**2**	**14 days**	**aerial**	**June 1**
Sugar Beets	**1.5**	**1**	**---**	**aerial**	**June 1**
*** The maximum reported rate is greater than the maximum label rate. The seasonal maximum rate is not exceeded, however. ** The 'average' rate is greater than maximum reported rate. The reason for this discrepancy is not known.**					

In all cases, an aerial application was used for the maximum use pattern and the maximum reported use pattern as this is the application practice on the label which results in the most drift. In practice, the orchard crops would most often receive an application by air blast equipment, therefore air blast was simulated for average uses. Aerial application is represented by using a spray drift efficiency of 0.16 and an application efficiency of 0.95 while air blast is represented by values of 0.064 and 0.99 for these parameters respectively.

Chemical Parameters

The input parameters used to describe the chemical properties of carbaryl are in Table 5. In most cases these parameters were selected in accordance with guidance (Environmental Fate and Effects Division, 2002). Data quality descriptions for each parameter were derived as follows. 'Excellent' was used to describe parameters which very well know and had little or no error associated with them (*e.g.* molecular weight) or when there is an abundance of high quality data available. 'Very good' is used to describe parameters from high quality studies and the study is generally reproducible (*e.g.* hydrolysis) , or when there is substantial background variability (*e.g.* aerobic soil metabolism) there are multiple high quality studies used to develop the input parameter. Good is used to describe abiotic process data where there the data is expected to be reproducible, but is more uncertain than normal, or metabolism parameters base on two high quality, or multiple studies which are usable but not high quality. Fair is used to describe metabolism parameters based on a single study, or significantly flawed by usable data for describing abiotic processes. Poor is used describe input parameters based on surrogate data .

In the previous drinking water modeling, soil water partitioning was represented by Kd values which were keyed to the soil texture in studies where K_d's were measured. Since texture is usually only a factor of secondary importance, this does not always result in great accuracy. In this assessment, a K_{oc} was estimated by regressing the K_d's values against the organic carbon content. The K_{oc} value estimated using a regression model with both a slope and an intercept is significant at $p = 0.05$. However, the K_{oc} model used in both PRZM and EXAMS assumes that the binding at zero organic carbon content is zero (no y-intercept). The regression to this model is significant at $p = 0.1$ but not 0.05 and results in a K_{oc} estimate of 196 kg L^{-1}. This will result in some underestimation of the binding (and overestimation of carbaryl mobility) in soils with low organic carbon content, but greater accuracy over all scenarios.

Metabolism half-lives were estimated from single studies available for each of the following three studies: aerobic soil metabolism, aerobic aquatic metabolism, and anaerobic aquatic metabolism. The aerobic soil and anaerobic aquatic metabolism half-lives were consequently multiplied by three in keeping with current policy to account for the uncertainty caused by the high background variability in these parameters. The anaerobic aquatic metabolism values in the previous modeling assessment was not adjusted by three. In the previous assessment, the aerobic aquatic metabolism half life input parameter was 14.7 days, or three times the single estimate. However, this value was not adjusted to account for hydrolysis, resulting in the effect of hydrolysis being double counted in the previous assessment. This assessment corrected that error; the expected hydrolysis rate (9.3 days) at the study pH (7.1) was subtracted from the rate constant for the measurement from the aerobic aquatic metabolism study. The resulting value, 9.87 days, which is the half-life in the aerobic aquatic metabolism study due to metabolism alone, was multiplied by three for an input parameter of 29.6 days.

In the original assessment, the foliar degradation rate was set to 35 days, the default value based on current OPP policy for terrestrial exposure assessments which is not the same as the current guidance for aquatic modeling. Current guidance for setting the foliar degradation rate for PRZM (the PLDKRT parameter) recommends, in the absence of data to set the parameter to zero (no degradation) or no degradation is this correct. The primary registrant, Bayer CropScience, provided data (MRID 45860501) in their comments on the draft Carbaryl EFED chapter (Libelo *et al*, 2002) demonstrating that carbaryl degrades on foliage at a substantially faster rate than 35 days. The data submitted with the report was reviewed and analyzed (D288376). Based on this assessment, a new value of 3.71 days was used as the foliar degradation half-life. This represents an upper 90% confidence bound on the mean from 30 studies from which foliar dissipation of carbaryl could be estimated.

Table 5. Chemical input parameters for carbaryl.

Parameter	Value	Quality
Molecular weight	201.22 g mol^{-1}	excellent
Solubility	32 mg L^{-1}	good
Henry's Law Constant	1.28×10^{-8} atm-m^{-3} mol^{-1}	fair
K_{oc}	196 L kg^{-1}	good
Aerobic soil metabolism half-life	12 d	fair
Aerobic aquatic metabolism half-life	29.6 d	fair
Anaerobic aquatic metabolism half-life	216.6 d	fair
Hydrolysis half-life	pH 5 - assumed stable pH 7 - 12 d pH 9 - 0.133 d	very good
Aqueous photolysis	21 d	very good
Foliar Degradation Rate	3.71 d	excellent
Foliar Washoff Coefficient	0.91	fair

As part of the data submitted for consideration in estimating the foliar degradation rate, the registrant also submitted data which supported a revised estimate of the foliar washoff coefficient. In the absence of data, current EFED policy recommends value of 0.5 which represents the fraction of chemical that washes off with each 1 cm of rainfall. An analysis of two relevant studies indicates that carbaryl washoff is greater; a washoff coefficient of 0.91 is more appropriate based on the data reviewed. However, the estimates for both studies were based on two data point, so no error term or determination of variability in the data could be made. A more complete description of how the studies were assessed is in OPP review D288376.

Effects of Drinking Water Treatment

There is some evidence that conventional drinking water treatment, that is coagulation, flocculation and settling, is expected to reduce carbaryl concentration by 43% of the concentration prior to treatment (US EPA, 1989). This is based on a study of wastewater containing carbaryl treated with alum at 100 mg L^{-1} and 1 mg L^{-1} of anionic polymer (Whittaker *et al.* 1982). In addition, ozone has been shown to be 99% effective at removing carbaryl from water (Shevchenko *et al.,*1982) and removes it from water at a rate too fast to measure (Mason *et al.* 1990). Evidence suggests that chlorine and hypochlorite may be ineffective at degrading carbaryl (*ibid.*). At this point in time, ozonation is only infrequently used for disinfection of public drinking water in the United States. Based on the hydrolysis data, softening would be expected to substantially reduce carbaryl concentrations (via alkaline hydrolysis) as softening raises the pH of the water as high as 11. Softening is used on 'hard' water that is high in calcium and magnesium and decreases the concentrations of these cations. The Office of Pesticide Programs currently does not have sufficient information to account for locations where water softening processes are utilized at public drinking water treatment facilities, and thus cannot systematically use this information in estimating EEC's.

Results and Characterization

EEC's were calculated as described above and then adjusted for percent cropped area (PCA), based on OPP guidance (OPP, 2000). For apples, citrus, and sugar beets, the default PCA for all agricultural land of 0.87 was used. The individual PCA for corn of 0.46 was used for field corn and sweet corn. These adjusted EEC's were reported in Table 1 at the front of the document, and the full distribution of EEC's were made available for use in dietary exposure estimation. The citrus scenario is recommended in estimating EEC's for Tier II drinking water assessment. A Tier II EEC uses a single site which represents a high exposure scenario for the use of the pesticide on a particular crop or non-crop use site. The weather and agricultural practice are simulated at the site over multiple (in this case, 30) years so that the probability of an EEC occurring at that site can be estimated. Sites are selected to represent a site which is more vulnerable than 90% of the sites which are used for growing the crop on a nationwide basis. Sites are currently selected to meet this standard by best professional judgement. For each simulation, the exposure of interest, either the annual peak or mean, is identified for each year. These 30 values are sorted and the single point estimate is selected by identifying the value that would be expected to recur once every 10 years. For these simulations, this specific value is linearly interpolated from between the third and fourth highest annual values.

These values are greater than those that would be expected to be found in the environment primarily for three reasons. First, we have used the default PCA of 0.87, as the PCA for citrus in Florida. The default PCA is the maximum proportion of agricultural land found in any basin in the country, In fact, the actual PCA in Florida is probably closer to one-third this value, although a precise estimate is not available at this time. Secondly, the percent crop treated has been assumed to be 100%. In fact, according to BEAD (Hernandez, 2002), the percent crop treated for different citrus crops ranges for 1.5 to 6%, depending on the crop. Thirdly, since the labels have not specified maximum number of applications, the maximum practice modeled is substantially greater than that which is usually used in practice.

Table 6. Drinking Water EEC's for carbaryl based maximum, ''average'' and maximum reported use patterns.

Crop		Number of Applications per Year	Pounds A.I. per application	Surface Water Acute (ppb) (1 in 10 year peak single day concentration)	Surface Water Chronic (ppb) (1 in 10 year annual average concentration)
Sweet Corn (OH) (PCA = 0.46)	Maximum[1]	8	2	57.3	5.53
	Average[2]	2	3.4	49.8	2.31
	Maximum[3] Reported	3	1	25.6	1.26
Field Corn (OH) (PCA = 0.46)	Maximum[1]	4	2	51.3	2.72
	Average[2]	2	1	14.6	0.68
	Maximum[3] Reported	2	1.5	21.9	1.02
Apples (PA) (PCA = 0.87)	Maximum[1]	5	2	62.9	2.20
	Average[2]	2	1.2	23.4	0.63
	Maximum[3] Reported	2	1.6	34.4	1.04
Sugar Beats (MN) (PCA = 0.87)	Maximum[1]	2	1.5	48.2	2.16
	Average[2]	1	1.5	13.6	0.73
	Maximum[3] Reported	1	1.2	10.8	0.58
Citrus (FL) (PCA = 0.87)	Maximum[1]	4	5	316	14.2
	Average[2]	2	3.4	203	7.33
	Maximum[3] Reported	3	4.26	272	10.0

[1] Maximum application rate on label
[2] Average application rate from Quantitative Usage Analysis for Carbaryl, prepared July 21, 1998 by Frank Hernandez, OPP/BEAD
[3] Maximum rate of application reported in Doanes survey data

In particular, the rate per acre, and the number of treatments per season is often less than that allowed on the label. In addition, the interval between applications, when there is more than one is usually longer than has been simulated for the maximum use pattern. This third factor has been addressed in this assessment, and is reflected in the EEC's from the 'average' and maximum reported use patterns from Table 3 and 4.

Three additional simulations were done for citrus in order to better characterize the exposure in this scenario. In the first simulation, the application date for the first application was changed from April 30 to August 31, otherwise using the maximum application practice. The second simulation also changed the first application date but with 'average' application practice. While there are pests which could be of concern on citrus as early as April, monitoring data from the area indicates that most of the usage actually occurs in the late summer. The 1-in-10 year peak EEC for the April application and maximum label practice is 316 while for September the value is 220 :g L^{-1}. For ‘average’ application practice, the respective EEC’s are 203 and 125 :g L^{-1}. Another run was done where best estimates for all the metabolism values were used as inputs (4 day half-life for aerobic soil metabolism, a 9.6 day half-life for aerobic aquatic metabolism, 72.2 days for anaerobic aquatic metabolism, and 3.2 days for foliar degradation) combined with ‘’average’’ application practice in September to give a ‘best’ estimate of the EEC for this site. The 1-in-10 year peak in this case was 78.9 :g L^{-1}.

In addition to the point estimate EEC’s for drinking water exposure described above. We have provided the time series of concentrations for the entire duration of the simulation for the different citrus scenarios. These series of estimates are intended for use in a more full of the whole range dietary exposure for carbaryl and are being combined with pesticide residues in food using the DEEM model. While making fuller use of the whole time series for drinking water exposure is expected to improve the description of the dietary risk, using the time series for water in combination with the distribution of food residues and consumption patterns normally used in DEEM substantially alters the interpretation of the risk represented by the output of the model because the drinking water component introduces a time component which is not present in the food and consumption data - any time component in the data is ignored by DEEM. Technically, the food and consumption distributions are assumed to be ‘stationary’ with respect to time and location, that is the distributions are always the same at any point in time and any location in the United States. This is a reasonable assumption for food residues and consumption, but not a reasonable one for pesticide residues in drinking water which are expected to vary by orders of magnitude with both time and location. The difference in interpretation can be best illustrated by describing how the interpretation differs when the different exposure components dominate the exposure profile. When food (other than water dominates the exposure and the drinking water contribution is negligible, an exceedance of the 99.9% threshold implies that one person in 1000 across the whole U. S. population is above the threshold each day. If drinking water dominates and food contributions are negligible, an exceedance of the 99.9% means that the entire population provided drinking water from a facility represented by scenario, are expected to exceed the risk once every 1000 days, a little less that once every three years. When both water and food sources make significant contributions to exposure, a more detailed analysis of the structure of the data is necessary to determine the nature of the risk. Depending on the structure of the risk, regulating on the 99.9 percentile in a manner similar to that used previously may not provide a intended level of safety similar to that which is provided by using DEEM with food only and the DWLOC approach with water.

Beyond the three major factors which are described above, there are a number of other factors inherent in the modeling can affect the accuracy and precision of this analysis including the selection of the high exposure scenarios, the quality of the input data, the ability of the models to represent the real world, and the number of years that were modeled.

Scenarios that are selected for use in Tier 2 EEC calculations are ones that are likely to produce large concentrations in the aquatic environment. It should represent a site that really exists and would be likely to have the pesticide in question applied to it. It should be extreme enough to provide conservative estimates of the EEC, but not so extreme that the model cannot properly simulate the fate and transport processes at the site. Currently, sites are chosen by best professional judgement to represent sites which generally produce EEC's larger than 90% of all sites use for that crop. The EEC's in this analysis are accurate only to the extent that the site represents this hypothetical high exposure site.

The quality of the analysis is directly related to the quality of the input parameters. In general, the fate data for carbaryl are good. The paucity of soil and aquatic metabolism data is the main limitation of the data set. Because metabolism values are set to the upper 90% confidence limit of the mean, the EEC's will be conservative to the extent we are uncertain of the true central tendency of the metabolism data. Additional metabolism data would greatly increase our confidence, and likely reduce our EEC estimates. As noted above, using best estimates for "average" application practice rather than the standard upper bound estimates reduced the EEC from 125 $\mu g\ L^{-1}$ to 78.9 $\mu g\ L^{-1}$. This indicates that the quantity and quality of the metabolism data can substantially effect the estimates.

The models themselves represent a limitation on the analysis quality. While the models are some of the best environmental fate estimation tools available, they have significant limitations in their ability to represent some processes. Spray drift is estimated as a straight 16% of the application rate reaching the reservoir for each application. In actuality, this value should vary with each application from zero when the wind blows away from the reservoir to perhaps as high as 20%. A second major limitation of the models is the lack of validation at the field level for pesticide runoff. While several of the algorithms (volume of runoff water, eroded sediment mass) are well validated and well understood, there is less confidence that PRZM 3.12 well represents the amount of pesticide transported in runoff events. Some validation efforts undertaken by the pesticide industry and under review by the Agency indicate that PRZM gives reasonable estimates of pesticide extraction into runoff, but validation of the runoff portion of PRZM is not extensive. Another limitation of the models used is their inability to handle within-site variation (spatial variability), lack of crop growth algorithms, and an overly simple soil water transport algorithm (the "tipping bucket" method). A final limitation is that only thirty years of weather data were available for modeling at each site. Consequently there is approximately a 1-in-20 chance that the true 10% exceedance EEC's are larger than the maximum EEC in the calculated in the analysis. If the number of years of weather data could be increased it would increase the confidence that the estimated value for the 1-in-10 year exceedance EEC was close to the true value.

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APPENDIX A2. INPUT FILES FOR ESTIMATING DRINKING WATER EXPOSURE FOR TOTAL CARBARYL RESIDUES.

Table C-1. Input files archived for azinphos methyl applied to pome fruits.

File Name	Date	Description
W12842.dvf	July 3, 2002	weather data for Florida citrus scenario
W14637.dvf	July 3, 2002	weather data for Pennsylvania apple scenario
W14914.dvf	November 20, 2002	weather data for Minnesota sugar beet scenario.
W93815.dvf	July 3, 2002	weather data for Ohio corn scenario
Flcitrus.txt	October 12, 2002	Florida citrus scenario parameters for PRZM & EXAMS
MNsugarbeet.txt	October 12, 2002	Minnesota scenario parameters for PRZM & EXAMS
OHcorn.txt	October 12, 2002	Ohio corn scenario parameters for PRZM & EXAMS
PAapple.txt	October 12, 2002	Pennsylvania apple scenario parameters for PRZM & EXAMS
Input Data Files for specific simulations (.PZR extension)		
FLCits00	February 13, 2003	citrus, maximum use pattern, index reservoir
FLCits01	February 13, 2003	citrus, maximum use pattern, Sept application, index reservoir
FLCits02	February 13, 2003	citrus, 'average' use pattern, index reservoir
FLCits03	February 13, 2003	citrus, maximum reported use pattern, index reservoir
FLCits04	February 13, 2003	citrus, 'average' use pattern, air blast, September application, best estimate metabolism parameters.
FLCits10	March 7, 2003	citrus, 'average' use pattern, air blast, September application
OHCorn00	February 13, 2003	field corn, maximum use pattern, index reservoir
OHCorn01	February 13, 2003	field corn, 'average' use pattern, index reservoir
OHCorn02	February 13, 2003	field corn, maximum reported use pattern, index reservoir
OHCorn03	February 13, 2003	sweet corn, maximum use pattern, index reservoir
OHCorn04	February 13, 2003	sweet corn, 'average' use pattern, index reservoir
OHCorn05	February 13, 2003	sweet corn, maximum reported use pattern, index reservoir
PAAppl00	February 13, 2003	apples, maximum use , index reservoir
PAAppl01	February 13, 2003	apples, 'average' use, index reservoir
PAAppl02	February 13, 2003	apples, maximum reported use, index reservoir
MNSbet00	February 13, 2003	sugar beets, maximum use pattern, index reservoir
MNSbet01	February 13, 2003	sugar beets, 'average' use pattern, index reservoir
MNSbet02	February 13, 2003	sugar beets, maximum reported use pattern, index reservoir

cc: Jeff Dawson
Felicia Fort
chemical
actions

APPENDIX B1. REVIEW OF DRINKING WATER MONITORING STUDY.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

PC Code:056801
DP Bar Code D285826
DATE: March 13, 2003

MEMORANDUM

SUBJECT: Review of "*Surface Water Monitoring for Residue of Carbaryl in High Use Areas in the United States: Final Report*"

FROM: Elizabeth Behl, Chief
Environmental Risk Branch IV
Environmental Fate and Effects Division (7507C)

THROUGH: R.David Jones, Sr. Agronomist, ERB4
Environmental Fate and Effects Division (7507C)

TO: Anthony Britten, PM Team Reviewer Branch X
Michael Goodis, Acting Chief
Special Review and Reregistration Division (7508C)

This memo presents EFED's review of the final report from a study voluntarily conducted by Aventis for carbaryl. Interim results from this study were reviewed previously by the Agency (DP Bar Code D274824; 8/7/2001), and a preliminary review of the study and data from the interim report were included in the EFED Risk Assessment of Carbaryl (USEPA, 2002). Aventis provided feedback to the Agency on our review of that study, which the Agency responded to (USEPA 2002a). Aventis provided further comment (largely a repetition of their original comments) on the Agency's review of this monitoring study in public comments submitted to the electronic docket in October 2002.

Conclusions

This study provides useful information on measured concentrations of carbaryl in selected surface waters of the United States. Based on our analysis of sites selected, we do not concur that these results can be used directly in the dietary risk assessment to represent exposure to carbaryl in surface water source drinking water. The information from this study does provide some good quality data that can be used in association with other monitoring data sets to characterize carbaryl exposure.

These data will be used in conjunction with other monitoring data, to characterize surface water modeling estimates of carbaryl exposure from surface-water source drinking water.

Involving EFED/OPP in the scoping and planning of this study, developing the protocol design, and during site selection is necessary to ensure that the data collection effort is focused on adequately addressing the specific risk assessment questions. The main study goal is in line with data needed by the Agency to refine the drinking water risk. However, the implementation of the study (especially site selection) was not consistent with the study goal and the data can be used only qualitatively.

A detailed critique of the monitoring data are presented in the body of this review. Several major drawbacks to the quantitative use of these data to represent drinking water exposure are:

- With only 16 sites to represent vulnerable surface water bodies for selected agricultural uses (really 15, as the LA site was selected to represent population exposure not because source waters were vulnerable) and four suburban sites, this study is not likely to provide comprehensive coverage of all carbaryl usage sites, given the great geographic diversity of carbaryl use areas and carbaryl uses.

- We do not concur that sites sampled represent the “the highest probable risk of human exposure to carbaryl in surface water in each state”. A majority of the agricultural sites monitored do not have "high" carbaryl usage in the county, based on registrant criteria. The size of watersheds (another measure of site vulnerability) exceeded the 70th percentile nationally (about 1000 aquare kilometers) for all but five agricultural CWSs. Overall, the majority of monitoring sites are located in areas where carbaryl usage is not the highest nationally, on water bodies draining large watersheds, or on systems which derive their water from large lakes or rivers. Although there is some carbaryl usage in the watersheds of these CWS, a minority of monitoring locations appear to represent CWS which are most vulnerability to contamination.

- Because little supporting data were provided on non-agricultural sales and national-scale non-agricultural carbaryl usage, the relative vulnerability of the systems selected to represent "home and garden" useage effects could not be determined. The majority of those systems were located on smaller sized waterbodies, and from that perspective are vulnerable to contamination. Only one system had watershed which exceeded the 70th percentile CWS watershed size nationally (Blomquist, 2003).

- The monitoring interval (one week to two weeks) is unlikely to capture peak concentrations necessary for estimating acute dietary risk, given the variable nature of the exposure.

- The finished water data are difficult to interpret. According to the study design finished water samples were collected before raw samples, complicating the temporal pairing of samples. Also, to collect temporally paired raw and finished samples (and to interpret the resulting data) there must be data on temporally relevent treatment processes in place at each sampling point during the sampling period. These data were not provided or discussed.

Despite these drawbacks, the study design was one of the better surface-water monitoring studies submitted to the Agency over the past several years. The analytical methodology and method sensitivity, quality assurance procedures, study duration, and aspects of their approach to site selection were sound.

Results of this study indicate that carbaryl was found in source drinking water (raw water) at low concentrations in the majority of sites (13 of 16 sites) selected to represent impacts from agricultural uses, despite the relative lack of vulnerability of these sites. Concentrations measured at these sites were low (roughly 2 to 31 ppt) in raw water and generally lower in treated drinking water; however, the highest concentrations were found in finished, not raw, drinking water (181 ppt). Where residues were detected, frequency of detection in raw water samples ranged from a few percent of total samples (1-6 %) at 9 of the 13 sites to about 20% of total samples (14 - 21%) at 4 sites. Two of these higher detection frequency sites are on the Sacramento River, one site in Florida, and one site in Massachusetts representing impacts from use on cranberries. There is some correspondence annually with the timing of detections at each site, but it is not uniformly strong. At several sites, low-level concentrations were measured over 3-4 week periods in weekly samples. Given the environmental fate characteristics of this compound, this is most likely the result of the volume of usage rather than the persistence of the compound.

Carbaryl was reported in raw water of all four CWS selected to represent impacts from home and garden uses. Concentrations measured in raw water at these sites were low (roughly 2 to 44 ppt) and detection frequencies ranged from approximately 1 to 20 %. How representative these systems are of the home and garden use of carbaryl cannot be determined from the data provided. However, the lowest detection frequency occurred at the CWS with the largest watershed size (exceeding the 70th percentile nationally). At one site, concentrations were reported in sequential weekly samples for a period of several months, likely due to the volume of usage.

Because raw and finished samples were not temporally paired, we cannot make quantitative statements about the impact of treatment processes in removing carbaryl from source water. In fact, in several instances the treated water concentrations were higher than the raw water concentration in the "pair", including the highest reported concentrations

Background:

This study was voluntarily conducted by the registrant of carbaryl, and no protocol was submitted for review by the Agency prior to it's initiation. Interim results from this study, containing data covering the period February 19, 1999 through December 31, 2000, were reviewed previously by the Agency (USEPA, 2001). At the time the Agency concluded that:

> *"The results of this study may provide useful, though limited, information on the level of carbaryl contamination in raw surface water used for drinking water. It may also provides limited information on concentrations present in finished water. It is hoped that the results of this study, in combination with data from other sources, will increase our understanding of exposure to carbaryl in drinking water. Information*

> *on site selection, source water, carbaryl use and how the sampled water supplies relate to population distribution are required to fully evaluate the data collected in this study.*

The site selection was subsequently submitted to the Agency (10/1/2002) as an appendix to the final report.

OPP uses the models PRZM and EXAMS to estimate concentrations of pesticides that can occur in surface water, and evaluates available monitoring data in developing pesticide exposure assessments. For chemicals with relatively short half-lives and when acute exposure is of key concern, model estimates provide a more realistic estimate of upper-end exposure than most monitoring data, largely due to the prohibitive costs associated with very frequent sample collection and analysis of large numbers of samples.

Monitoring data do provide a valuable check on model values, which are intended to represent the upper end of potential exposure. Comparison of model and monitoring results are most relevant when monitoring sites are selected to be similarly representative of the upper end of potential exposure. In general, review of a monitoring study will focus first on the overall design of the monitoring study to determine if the study design is consistent with the study purpose. Second, the review should determine if the implementation of the study is consistent with the study design (and the study purpose). Finally, the results of the study are evaluated in terms of data quality and in the context of the study design.

Problem Formulation

Problem formulation should occur prior to initiation of a monitoring program and should involve interaction between risk assessors, risk managers and other interested parties. The interactive nature of this activity is critical to ensure that the data will address regulatory questions. Problem formulation prior to initiation of this study appears to have been done primarily by Rhone-Poulenc.

Study Purpose

In their final report, Aventis states the purpose of the study as follows:

> *"This study was conducted to determine the potential for carbaryl residues to reach public water supplies resulting from the use of SEVIN brand insecticides..... This study was conducted to provide an assessment of the potential of carbaryl residues in surface water to contribute to dietary exposure due to consumption of drinking water."*

Assessment Endpoints

Bayer does not explicitly identify assessment endpoints for carbaryl. Carbaryl risk from drinking water sources will be determined by the Agency in association with other dietary components, including assessment of both acute and chronic endpoints. Acute endpoints are of particular interest in assessing carbaryl risk, and require an estimate of peak carbaryl concentrations in drinking water. Consideration of this endpoint is not evident in the study design.

Conceptual Model

There is no description of the overall system and conceptual model for this monitoring study; however, one can be interpreted from the study design that resulted.

- Monitoring points selected were at community water supply facilities, so drinking water exposure was targeted. All community water supply facilities monitored derived their water from surface water sources and treat the water prior to distribution. This represents the majority of surface-water source drinking water consumed by the US population (there are some surface-water source drinking waters that are not treated prior to consumption, but very few). Ground water sources are not included in the study design.

- Sites were selected to represent locations that are "vulnerable" to carbaryl exposure largely on the basis of pesticide sales.

- A secondary study goal is to represent impacts from specific uses in selecting some of the agricultural monitoring sites.

- A third study goal is to incorporate a measure of potential exposure to large human populations (rather than rather than system vulnerability to contamination)

- Aventis collected both raw and finished drinking water samples, representing the finished drinking water samples collected in this study as more relevant to human exposure than raw water samples.

Study Design (Analysis Plan)

The following sections describe study design components, study implementation, and results.

Number of sites to monitor. RPAC determined that 16 sites would be monitored in “areas of high agricultural carbaryl use”; and four in “large suburban areas of highest regional carbaryl sales for non-crop use”. The rationale for the overall number of monitoring sites (20 sites) is not provided but was a constraint in the study design, most likely due to cost considerations. Because carbaryl is widely used for both agricultural and home and garden uses, the monitoring sites were apportioned to represent these two major usage categories.

No summary information is provided describing the universe of carbaryl use nationally ("agricultural" and "home and garden") for reference in determining the number of sites which would be adequate to monitor to meet the study goals. Carbaryl is used on a variety of crops in almost every State in the U.S. (based on Doane usage maps) and is a major insecticide for home and garden use in the U.S. Given the diversity of uses and the hydrologic diversity of the use areas it is difficult to adequately represent overall carbaryl impacts on surface water quality with this small number of monitoring sites.

RPAC also indicated that they tried to meet a secondary study goal, to represent impacts from specific uses (for example, from cranberries), in selection of some of the 16 agricultural sites. This second goal further complicates the study design adding an additional level of complexity. For example, to represent a range of potential impacts on surface water quality from cranberry uses would require monitoring at several sites where cranberries agriculture dominates water quality impacts or alternatively a description of why only that one site was selected to represent all potential cranberry sites. How crop type would play into site selection decisions is not clear.

Bayer's third study goal, of trying to include sampling of sites which result in high exposure, would result in a very different set of site selection criteria. These criteria are not presented, not is there a description for why the one site selected was chosen over other potential sites.

Site Selection. Aventis characterizes the sites selected for monitoring as:

> "*The source water for all selected water treatment facilities was surface waters originating in watershed areas with a high carbaryl use on agricultural crops or which drain suburban areas with high sales of carbaryl for home and garden use.*"

Monitoring sites were all existing Community Water Supply facilities (CWS), which supply drinking water to the local population. All CWS had to have surface water as their primary exclusive source (not ground water, not a blend of ground and surface water, not fa surface water source used as a backup to the primary supply).

With the exception of one system, RPAC characterized all CWS as potentially vulnerable to carbaryl contamination, primarily on the basis of "high" carbaryl sales (or high usage in California) in the counties where the watershed of the CWS is located. The exception was a CWS located in Riverside Co., CA which supplies a very large population (Los Angeles, CA) and was selected on the basis of potential population exposure rather than vulnerability to contamination. County-level sales was stated to be the prime criterion for selection of the other 15 agricultural sites, and high sales in the "sales region" was the prime criterion for selection of the four urban sites. Sales regions typically cover many states; the top distribution city in the sales region was assumed to have the highest sales (and resulting usage).

Differences between usage and sales are recognized, and "refinements" are described to better represent actual carbaryl usage in a watershed. Use of GIS tools is described for refining the site selection, identifying watersheds boundaries and overlaying sales data. Refinement of crop location was also to be done by consultation with local experts (RPAC sales personnel and CWS personnel) familiar with the specific sales area. How this will be documented is not clear. Land use data was also to be used in home and garden site selection to screen out agricultural use and identify large suburban areas with CWS using small rivers draining only urban areas. Suburban land use was identified in NLCD data coverages and"low intensity residential". Specific criteria to be used (what defines a small river; what density of housing defines suburban land; what percentage of the watershed in suburban land use made it qualify) are not provided.

Study design criteria state that:

> "*CWS using small and medium sized watersheds will be selected, although large watersheds may be selected if the primary carbaryl application area is located near the intake location. This is done to maximize the likelihood of detecting carbaryl residues"*

No definitions are provided for the terms "small", "medium", and "large" watersheds and criteria describing the size of the water body being sampled are also not quantified. In identifying vulnerable monitoring sites for the USGS-EPA Pilot Reservoir (Blomquist et al, 2001) monitoring study EPA focused on identifying reservoirs with high potential pesticide use, high intensity agriculture in a watershed, relatively small volume reservoirs (120 – 92,600 acre feet) and relatively small watershed size (3.3 – 784 square miles). These parameters are important in identifying and appropriately characterizing watersheds as vulnerable for site selection.

Several of the rejection criteria identified in the study design are reasonable to use to select CWS as assessment points consistent with the study design goals. In general, for example, the CWS selected must be in a watershed that has significant carbaryl use, derives their water from surface water sources, and represents source waters that are most likely to be contaminated. Consistent with these design goals, CWS were rejected if:

- The CWS watershed was in a non-agricultural area of a high carbaryl sales county
- Source waters were either: ground water, mixed surface and ground water, or surface water was only the secondary source.
- Source was a Great Lake (based on concerns about the size of the watershed and storage)
- Personnel were unwilling to participate
- Source water is pumped from high elevation reservoirs which are outside agricultural areas (specifically in CA)
- the ratio of county-level sales area to non-sales area in watershed was "low" (low is not defined)

Several other criteria are not consistent with the study goal of identifying vulnerable sites for sampling, for example:

- Retaining CWS for county with a low county-level sales area to non-sales area in watershed when the high sales county was in "proximity" to the CWS intake. The relative influence of the carbaryl use area in comparison to the impact of the rest of the watershed may or may not be significant, and must be documented. If potential carbaryl impacts at the CWS are not likely to occur, these systems should be rejected as measurement locations which are not be consistent with study design goals.

- Retaining CWS for systems with large watersheds or rivers if the "high" sales county was in “proximity” to the CWS intake. Again, the relative influence of the carbaryl use area in comparison to the impact of the rest of the watershed may or may not be significant, and must be documented with all termed defined. If potential carbaryl impacts at the CWS are not likely to occur, these systems should be rejected, as they would not be consistent with study design goals.

- Rejecting CWS in California which draw water from canals or aqueducts (because of difficulties in accounting for input from flood-irrigated fields and "ground water sources"). The rationale for this rejection criterion is unclear, as irrigated fields which may drain into canals (or for that matter rivers) exist and affect surface water quality in California. Rejection CWS which could have water quality affected by irrigation return flow preferentially removes some of the most potentially vulnerable CWS from consideration. This is not consistent with the study design goal.

Sampling frequency, interval, and study duration. According to the study design, sampling at the agricultural sites begins two weeks prior to the typical carbaryl application period with samples collected weekly during the application period and at least one month afterward. . The timing is based on local expert advice, but how this was determined was not described. Samples are to be collected monthly for the remainder of the year. The exception to this is at the Florida site, as a result of the broad use season, where sampling continued on a weekly basis throughout the year. For the "home and garden" sites, sample is scheduled to begin in March or April, and continued weekly throughout the study. The study protocol was amended to provide a total of three years of sampling, consistent with EFED recommendations.

Targeting sampling frequency to the application period is a reasonable approach. The duration of the study is consistent with EFED study design recommendations, and should be adequate to meet study design goals. Weekly sampling is not likely to provide an adequate estimate of peak concentrations for use in acute exposure assessment, a key design goal.

Sample matrix. Samples are to be collected from raw drinking water at the intake and finished water after passing through the treatment plant. Duplicates of both raw and finished are to be collected, with the duplicate available for analysis as needed. All raw water samples are being analyzed. Finished water samples are being analyzed when the paired raw water sample has detectable concentrations of carbaryl. This procedure is consistent with EFED guidance for reactive sampling design, with the stipulation that the drinking water treatment train is well know at each sampling interval so that samples can be considered to be paired. The protocol stipulated that finished samples be collected prior to raw samples, so raw and finished sample "pairs" will not be collected in a time frame relative to the treatment train.

Current OPP guidance (OPP, 2000) for monitoring surface-water source drinking water indicates that to represent drinking water exposure, raw water samples should be sampled because of added complexities and uncertainties introduced into estimates. These recommendations were made for two reasons. First, to minimize spatial and temporal variability introduced during treatment. Second, to enable necessary mitigation to be targeted to sources waters of concern. The purpose of collecting temporally paired raw and finished drinking water should be to determine the effect of treatment on exposure. Mixing the raw and finished water results combines two separate sample populations and makes interpretation difficult.

Ancillary data collection. A substantial amount of information is provided for each treatment facility and watershed area including watershed delineation and GIS characterization. Although the information is better than what is presented in the vast majority of monitoring studies, it is difficult to determine a number of important factors about the facilities which control their vulnerability. For example, it is difficult to determine the location of treated areas within the watershed or the location of crops treated, from the information provided. Relatively little information is submitted on the source water (volume of reservoir or lake, or average monthly flowrate). Information on treatment processes used at each facility is provided, but not in a way that can be used quantitatively to estimate removal or to evaluate the timing required to adequately pair raw and treated samples. The nearest NOAA station is identified as a source of precipitation data. Soils information is also provided for the watershed.

Sample collection and handling: For the most part sample collection and handling procedures as described in the protocol will meet the study design guidelines. Sample collection, handling and shipment procedures according to Stone Environmental SOP's. Samples will be shipped on the day of collection with ice packs (described in SOP's) and samples frozen upon receipt at the lab until analysis. Samples will be stored for a maximum of 99 days (from receipt to analysis) Handling procedures will depend on the pH of the water. Since carbaryl is unstable in alkaline water at room temperature, 0.5 ml of formic acid is added to stabilize potential carbaryl residues.

Analytical Method The analytical method described in the protocol, including the method detection limit, are adequate to meet the study goal. LOD is 2 ppt; LOQ is 30 ppt. An independent laboratory validation (ILV) was submitted for the method. Residues detected between LOD and LOQ were estimated. No degradates of carbaryl will be analyzed. An ILV of the method was completed prior to initiation of the study. Samples are extracted prior to analysis (SPE using C18 SPE cartridges). Analysis is by reverse phase HPLC, quantified by MS/MS. The protocol indicates that the control test matrix in quality control samples (i.e. matrix spikes) uses "Type I" water The source of this water is not clear, and should be described in detail. The effect of this cannot be determined from the data provided.

QA/QC. Storage stability studies were conducted for field and lab samples. A method blank and a field spike appear to be included with each sample set analysis, but the description is confusing and the overall number is not clear. A sample set appears to consist of: one field spike at 30 ppt, one at 300 ppt in HPLC grade water, one control blank, and some number of field samples. . Clarification is needed to confirm that this is the case. It appears that each sample set included 8 field samples, however this also needs confirmation. Clarification is also needed regarding the use of field blanks.

Storage stability was tested in field recovery studies at 5 locations using field spikes: duplicate samples of raw and finished water (200 ml) were spiked at 300 ppt and 30 ppt of carbaryl.
Storage stability studies indicated that frozen samples were stable when stored for total of 4 months.

Summary Aspects of the study design are consistent with Agency guidance and the primary study design goals. Useful ancillary data is collected for this study which aids in analysis of the study design and implementation, particularly related to sample QA, analytical results, and collection and handling procedures. Important parameters describing CWS vulnerability (reservoir volume or stream flowrate) are not taken into consideration in site selection, a significant flaw in the study design. Sampling frequency is not likely to be adequate to meet the primary study design goal. Some important parameters lack adequate definition. Without better more quantitative definition or clear decision criteria important aspects of site selection are subject to interpretation. Adequate information is not provided to determine if the number of sites selected to monitor such a complex and varied use area is adequate. Not enough information is provided to determine if the secondary goal of representing impacts from specific crops could be met by this design. OPP guidance on the use of finished drinking water rather than raw water samples to estimate pesticide exposure is well documented (OPP, 2000). Because of the protocol for collection of raw and finished samples it will be difficult to draw quantitative conclusions regarding the effect of treatment on carbaryl residues.

Study Implementation

Number of sites to monitor
It appears that RPAC identified 20 counties in certain states which met their criteria and provided this information to a contractor to finish selection of individual CWS and to implement the study.

According to their contractor:

> "*The goal for each state* [identified by RPAC] *was to establish a monitoring program using the CWSs that represented the highest probable risk of human exposure to carbaryl through surface drinking water. Highest probable risk is assumed to be associated with those watersheds draining the highest sales counties in each state.*"

RPAC identified 20 municipal water treatment facilities which derive their water from surface water sources. RPAC identified sixteen agricultural sites in: California (5 sites); Florida (1 site), Michigan (2 sites), New York (2 sites), Oregon (2 sites), Texas (2 sites), and Washington (2 sites). Sites selected for potential inclusion as "large suburban areas of highest regional carbaryl sales for non-crop use" were: Dallas, TX; Atlanta, GA; Little Rock, AK, and Greensboro, NC

Trying to meet a secondary study goal, to represent impacts from specific uses (for example, from cranberries) played a role in selection of some of the 16 agricultural sites. This second goal complicates the study purpose adding an additional level of complexity to the conceptual model. However, it does not appear that additional monitoring sites were selected to meet these additional criteria. For example, to represent a range of potential impacts on surface water quality from cranberry uses would likely require monitoring at more than one site where cranberry agriculture dominates water quality impacts. At the very least a description of why this one site was selected to represent all potential cranberry sites where carbaryl is used should have been provided.

Bayer's third study goal, of trying to include sampling of sites which result in high exposure, would result in a very different set of site selection criteria. These criteria are not presented, not is there a description for why the one site selected was chosen over other potential sites.

Site Selection

The initial scope of the study ("20 CWS that have potential risk of exposure to carbaryl") was determined by Rhone-Poulenc Agricultural Company (RPAC) based on sales information, location of CWS, and somehow distributed to "encompass different types of agricultural use". Sales data were used as a surrogate for determining actual agricultural usage, except in California where county-level use data was available. To estimate home and garden use, Aventis relied on regional sales information from "stores such as Walmart, Home Depot, and Sam's Club". Although the site selection report contains a table (see Table 1 below) of major carbaryl use crops, how this information was used to systematically select sites is not clear.

Table 1 Crop Usage (as presented in study design) and monitoring locations selected

Crop	Usage	Agricultural Monitoring Site
Citrus	17%	Riverside, CA, Manatee Co.
Vegetables	14%	Manatee Co., Lenawee Co., Marion Co.
Tree nuts	12%	W. Sacramento, Lodi, CA Wagoner Co. Calhoun Co Jefferson Co.
Pastures	9%	Wagoner Co. Calhoun Co , Jefferson Co.
Stone fruit	8%	W. Sacramento, Lodi,CA
Pome fruits	7%	Lenawee Co. Yates, Co. Chelan Co., Franklin, Co
Grains	6%	
Grapes	5%	Chatauqua Co., Yates, Co.
Roots/tubers	5%	Lenawee Co., Franklin, Co
Soybeans	4%	

Other	**7%**	**cranberry -Plymouth, MA** **rice- Calhoun, TX**

Table 1 represents major use crops and related monitoring sites, according to Aventis. From this table it appears that the effort to distribute sites to represent the variety of carbaryl uses played a relatively major role in site selection efforts. Sites do represent multiple uses; however there is an embedded decision to select sites representing some relatively minor uses rather than to select multiple sites representing major uses. Also, while the stated use may occur in the county, it is not clear how dominant these uses (or home and garden uses) are in the watersheds.

<u>Agricultural site selection</u>

This section describes major factors considered in site selection, and some drawbacks and inconsistencies in applying these factors which resulted in selecting a number of sites for monitoring which were not particularly vulnerable. Information is presented on the agricultural sites selected in Table 2.

Sales. High county-level sales, the primary criterion for selection of the agricultural sites, was defined by RPAC as sales greater than 15,000 lb a.i. The intervals used to map county-level sales (in lb. a. i.) were: 0-1,999; "low" 2,000-4,999; "medium" 5,000-14,999; and "high" 15,000- 265,000. Using such a large interval to represent the "high sales" of carbaryl masked several of the higher carbaryl sales counties with CWS which should have been considered in site selection. According to the site selection report only 13 candidate systems were found in the high sales category counties, and thus additional systems were selected from "the high end of the medium sales category" (not defined). Using Doane data (1999-2--1) we identified 20 counties nationally with surface water source CWS and carbaryl sales over 15,000 pounds. Five of these counties were represented in the final set of monitoring sites. Several of the CWS selected for monitoring in this study were in counties which would be characterized by RPAC's scale as "low" usage (less than 5000 pounds), for example: Calhoun Co., 900 pounds; Lenawee Co., 1,500 pounds; Wagoner Co., 1850 pounds; Manatee Co., 3200 pounds; Jefferson Co., 4,300 pounds. Thus, five of the 16 agricultural sites selected did not meet this vulnerability criterion.

Watershed Size and Source Volume.

In selecting sites for the carbaryl monitoring program, information was not gathered on the volume of the reservoir or the flow rate of rivers, and these parameters were not considered in determining the vulnerability of sites. The importance of these factors (and a third factor, watershed size, which was collected as ancillary data but not used as a vulnerability criterion), on site vulnerability was recognized in study design rejection criterion. CWS which relied on the Great Lakes as their water source were rejected due to the large size of their watersheds and storage of the lakes. Information was not provided to make site selection determinations based on the size or volume of reservoirs and flowrate of rivers.

The USGS-EPA Pilot reservoir monitoring study targeted reservoirs believed to be vulnerable to pesticide contamination (but not necessarily the most vulnerable in any given region). Reservoirs selected had a storage capacity of between 120 and 92,600 acre-feet and watershed sizes ranging from 3.3 to 784 square miles (8.6 - 2030 square kilometers). Reservoirs vulnerable to pesticide contamination were characterized overall as small reservoirs in high pesticide-use areas having high runoff potential.

In an ongoing project, the USGS and EPA have determined the size of watersheds for approximately 7,000 US surface-water source CWS (Blomquist, 2003). The 75 percentile watershed size is approximately 1,000 square kilometers; the 95th percentile value is approximately 40,000 square kilometers. In Table 2 are estimates of watershed size, as described in the final report from this monitoring study, and as determined by the USGS/EPA effort. Only five of the CWS monitored in this study had watersheds smaller than 1,000 square kilometers. Two of these five watersheds fell into the "low" carbaryl sales category, based on Doane usage estimates. Of the remaining three CWS, one is located on a Keuka Lake, a lake with a large storage capacity. Another, the Minton Reservoir, has the second smallest drinking water watershed in the United States. And the third, Silver Lake, represents a relatively minor use of carbaryl (cranberries).

In general, CWS with large watersheds are located on very large bodies of water, and are not typically considered as vulnerable. The watersheds of CWS located on the Columbia River, Washington; the Sacramento River, CA, and the California aqueduct intake, which were selected for monitoring are larger than the 95th percentile nationally (40,000 square kilometers).The CWS on in Pasco, WA is downstream of the confluence of the Columbia River with the Snake River, where two of the West's largest rivers merge. The CWS site on the Neches River (Beaumont TX)is also larger than the 90th percentile CWS watershed size nationally.

The practice of inter-basin water transfer makes site selection difficult in the West. The Henry J Mills water treatment plant in Riverside, CA is one of five facilities supplying water to the Los Angeles metropolitan area and treats water from multiple sources. The water is derived from a system of rivers and reservoirs located in the high Sierras, flowing through the Feather River, and the Sacramento where it is withdrawn at the Harvey Banks Filtration Plant to the South of San Francisco and transported hundreds of miles to the south to Los Angeles. Riverside County, listed as the intake location, is actually the location of the treatment facility and quality is unaffected by usage there. Lake Mathews, the water source for the City of Corona, is the Western terminus of the Colorado River Aqueduct, whose intake is on the Colorado River at Lake Havasu, Arizona. Therefore, the water in Lake Mathews would not be expected to be affected by carbaryl use in the watershed immediately surrounding the lake.

CWS selected for this study were located on several large lakes, for example Lake Chelan is 55 miles long and is the third deepest lake in the US. A small portion of the watershed of this lake is used in agriculture, however, the majority of the watershed drains pristine forest land. The overall impact of this agriculture on the quality of the drinking water, given it's large storage capacity is difficult to determine, and maybe locally important to determine. However, there are reasonable questions about it's overall vulnerability and selection as one of 16 locations nationally in this monitoring study. Similarly, Keuka Lake is a mid-sized Finger Lake in upstate New York. Formed during the last glaciation, the lake has a relatively large storage capacity and an estimated residence time for pollutants of 6-8 years. It is not as vulnerable as smaller-sized systems which more rapidly respond to environmental effects. The CWS located on Canyon Lake did not function as a treatment system for the majority of the study due to low reservoir levels calling into question the degree to which runoff and carbaryl usage affected water quality at that location.

It is clear that in most cases there was some degree of carbaryl usage in the watershed and the results of the monitoring are useful; however, the majority of sites selected in implementation of this study are not consistent with the study design purpose as stated.

Watershed sales and usage and crop type. Crop data (from the 1992 Census of Agriculture and a cranberry bog database) was used by RPAC in 4 states (New York, Michigan, Washington, and Massachusetts) as a surrogate for carbaryl use to refine watersheds of interest. In other states refinements were made on the basis of discussions with RPAC field personnel or CWS personnel which were largely undocumented. Also, information provided to make determinations about the ratio or cropped versus non-cropped area in a watershed is anecdotal at best, derived from observation of CWS and RPAC sales personnel implementation. For example, the CWS on the Neches River in Beaumont Texas is characterized as a high sales site, based on RPAC sales data, but this could not be confirmed using Doane usage data, which indicates usage in Jefferson County is low (4300 pounds).

Representing a variety of crops was a secondary criterion in site selection; however, the basis for the carbaryl use within the watershed and the spatial extent of this use within the watershed is not entirely clear. As another example, crops in the watershed of Canyon Lake, the water source for the Elsinore Valley MWD, are identified as citrus, vegetables, and olives. Land Cover information does not include these crops, but does indicate that “orchard/vineyard/other” constitute 0.04% of the watershed; “row crops” 14.2%, “residential and commercial” 7.2 %, and “small grains 2.4%. The USGS-EPA pilot reservoir monitoring program characterized dominate pesticide usage in this same watershed as urban, with row crops dominated by alfalfa and wheat. Actual crops to which carbaryl is applied and their dominance on water quality in this watershed is unclear.

The rationale for selection of sites representing what appear to be a relatively minor percentage of the overall carbaryl usage (cranberries) is not clear. The decision to select a monitoring site to characterize exposure from this use appears to be driven more by the desire to represent a broad array of carbaryl uses than the high carbaryl sales county selection criteria. The way in which the study design is implemented calls into question the ability f the results to adequately address the conceptual model. The pasture and pecan use in Wagoner County, OK also appears to have played a dominant role in selecting that site despite the very low sales in that county. The site selection report indicates that a site was sought in Oklahoma after a second site could not be identified in Oregon; however the rationale for focusing on a site in Oklahoma is not provided. There are other geographic locations in the carbaryl use area with higher sales where no monitoring site was selected

“Home and Garden” Sites:

No analysis has been done of the relative vulnerability of drinking water systems resulting from the home and garden use of carbaryl, because sales or usage data for these sites is not presented to enable the relative vulnerability of these sites to be determined. Sites were selected in different locations form those originally identified. Characteristics are presented in Table 3. In terms of watershed size, these are roughly the 70th percentile or slightly higher, according to the USGS data (Blomquist, 2003)

Sampling frequency, interval, and study duration.

Some sampling periods were missed, overall the implementation of this design feature was reasonable. However, the adequacy of weekly sampling in collecting quality data to represent peak exposure values is unlikely and data produced have high uncertainty in representing values useful for acute exposure assessment. The study duration was three years, as indicated in the study design.

Sample matrix

Samples are being collected from raw drinking water at the intake and finished water after passing through the treatment plant. All raw water samples are being analyzed. Finished water samples are analyzed when raw water collected at the same time show detectable concentrations of carbaryl. This design component was implemented in reverse. Raw water should have been sampled first and after some time lag linked to the treatment train at each CWS, the finished water sampled. Samples cannot be considered temporally paired and cannot be use quantitatively to assess removal efficiency.

Ancillary data collection

Ancillary data was collected as described in the study design. The design provides for the collection of a substantial amount of ancillary data. However, data are not collected on an number of important factors controlling site variability. The treatment train is not described in enough detail to allow quantitative determinations regarding effects on exposure to be made.

Sample Collection Procedure and Handling

Procedures are adequate for the most part, with protocol deviations identified. Studies done on unfortified samples from Lake Manattee indicate carbaryl is stable in non-acidified water (pH 6 or higher) under standard sample handling and storage conditions (freezing conditions).

Fished water collected prior to treated water sample (backwards). There is no description of the timing of the treatment train. It may still be possible to look in general at the overall data and make observations about trends in levels of carbaryl in finished versus raw water based on these data.

Chemical Analysis

Samples were analyzed before the maximum allowed time of 99 days with the exception of two samples. Deviations from the protocol were identified; none significantly affected analytical results. When a sample and it's duplicate were analyzed, average values were reported. In some tables, results for finished water samples were substituted for raw samples. Careful interpretation of the results from these two separate water sample populations (finished and raw) is necessary.

Quality Assurance and Quality Control

The laboratory QA samples appear to be adequate for the purposes of the study. Clarification is needed on the size and make up of the sample set.

- method performance indicated recoveries of spiked samples 101+/- 12 %.
- All but one control were negative.
- Field recovery: 72-145 % when analyzed within 6 days of fortification (field spikes)
- storage stability: non-acidified and acidified samples showed no decline in frozen raw or finished water up to 14 weeks (98 days).

Summary: Implementation of the study design compromised the study goal. The majority of the agricultural sites monitored do not appear to be vulnerable to carbaryl impacts, based on the sales and watershed characteristics evaluated. Carbaryl usage is likely to occur in the watersheds of most of these systems and results can be evaluated in that context; however, the overall vulnerability of these systems is not as stated in the conceptual model of this study.

Results

Monitoring results presented in Table 4 indicate that carbaryl was found in source drinking water (raw water) at low concentrations in the majority of sites (13 of 16 sites) selected to represent impacts from agricultural uses, despite the relative lack of vulnerability of these sites. Concentrations measured at these sites were low (roughly 2 to 31 ppt) in raw water and generally lower in treated drinking water. However, the highest concentrations were found in finished, not raw, drinking water (181 ppt). Only three agricultural sites had quantified detections (at levels greater than the LOQ): Lodi, CA (31 ppt, raw); Brockton, MA (31 ppt, raw), and Deerfield, MI (160 ppt, finished). These levels were observed in a single sampling interval (weekly sampling), and concentrations were lower in preceding and succeeding samples collected at those sites.

Where residues were detected, frequency of detection in raw water samples ranged from a few percent of total samples (1-6 %) at 9 of the 13 sites to about 20% of total samples (14 - 21%) at 4 sites. Two of these sites are on the Sacramento River, one site in Florida, and one site in Massachusetts representing impacts from use on cranberries. There is some correspondence annually with the timing of detections at each site (that is they appear to occur in the same season), but it is not strong. At several sites, low-level concentrations were measured in weekly samples collected over 3-4 week periods. Measured levels are variable due in part to the nature of the fate and transport of carbaryl and in part to the noise in analytical measurements at these low concentrations. Because treated water sampling was reactive, frequencies of detection were not determined.

No carbaryl residues were detected in raw water at three locations: Corona CA, (Lake Mathews); Beaumont TX (Neches River); Manson, WA (Lake Chelan). Lake Mathews actually derives it's water from inter-basin transfer, serving as the western terminus of the Colorado River Aqueduct. Carbaryl usage in the Colorado River watershed and Lake Havasu, AZ area (the aqueduct withdrawal point) are not described, but expected vulnerability is low. Although carbaryl usage occurs in the other two systems, there are questions about the characterization of the vulnerability of the systems due to watershed size and storage.

Carbaryl was reported in raw water of all four CWS selected to represent impacts from Home and Garden uses. Concentrations measured in raw water at these sites were low (roughly 2 to 44 ppt) and detection frequencies ranged from 1 - about 20 %. In the Birmngham, AL CWS, concentrations were measured at levels greater than the LOQ at four times (with a raw and finished "pair" both exceeding the LOQ): (35 ppt, raw; 38 ppt, raw; 32 ppt, finished; 40 ppt, raw; 40 ppt raw). At this site, concentrations of carbaryl were detected in sequential weekly samples for several months in one year (out of three years) of monitoring. The pattern of detections was not as strong in other years. How representative these systems are of the home and garden use of carbaryl cannot be determined from the data provided. The lowest detection frequency occurred at the CWS with the largest watershed size (exceeding the 70th percentile nationally).

The data do not give any indication of the effectiveness of treatment in removing carbaryl. Because the samples were collected at the same time the water exiting the treatment plant was temporally different than the water sampled at the intake. In several cases finished water had higher concentrations then raw water, and finished water had detectable carbaryl when the raw water did not. The highest concentration measured was in finished water (0.18 ppb). Raw water sampled at the same time had much lower concentration (0.011). This illustrates that carbaryl contamination is transient, and that it is unlikely that weekly or monthly sampling are adequate to capture actual peak concentrations

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APPENDIX B2. SUPPLEMENTAL TABLES IN SUPPORT OF DRINKING WATER MONITORING STUDY ANALYSES.

Table 2: Characteristics of Agricultural Monitoring Sites selected for Carbaryl Monitoring Study.

intake location (city and state)	system name	watershed location (SEI #)	carbaryl use crop	carbaryl sales (RPAC)	carbaryl use (lbs per county), based on Doane	source water	volume of waterbody	watershed size	
								Aventis (acres)	EFED (square km)
Lake Elsinore, CA	Elsinore Valley MWD	Riverside Co (CA-12-LE-CB) San Jacinto river?	citrus vegetables olives (urban; alfalfa)	high	47833	Railroad Canyon Reservoir (Canyon Lake)	11,867 acre-ft	Small 445,551	1720 (Oak Ridge)
Corona, CA	City of Corona	Riverside Co (CA-16-CO-CB) (actually, Colorado River)	citrus vegetables olives	high	47833	Lake Mathews (Colorado River aquaduct)	182,000 acre ft	Small 16,350s watershed is Colorado River upstream from Lake Havasu	inter-basin transfer
Lodi, CA	Little Potato Slough Mutual	San Joachin, Co (CA-25-ST-CB)	tree nuts, stone fruit	high	23896	Little Potato Slough	---	Medium 1,319,214	5341 (Aventis)
West Sacramento, CA	City of West Sacramento	Yolo, Co (CA-37-WS-CB)	tree nuts, stone fruit (orchard: 2.7% watershed)	high	13065	Sacramento River	---	Medium 14,301,323	57,895 (Aventis)
Sacramento, CA (aka Riverside, CA	CA aquaduct Harvy O Banks Filtration Plant (State Water Project)	multiple counties from Lake Shasta to Sacramento Delta	tree nuts, stone fruit	high	cannot be estimated	Origin in high Sierras, Feather River, Sacramento River and Delta.	2,700,000 acre-ft storage in Oroville dam. California aquaduct capacity: 2 billion gallons per day	Very large 27,826,575	112,651 (Aventis)
Bradenton, FL	Manatee Co. Water Treatment Plant	Manatee Co. (FL-2-BR-CB)	citrus, vegetables	medium	3200	Lake Manatee (impoundment of Little Manattee R)	32,500 acre-ft (est)	Small 90,609	300 (Oak Ridge)
Brockton, MA	Brockton Water Treatment Plant	Plymouth, MA (MA-7-BR-CB)	cranberries	medium	8318	Silver Lake	1100 acre ft (est.)	Small 2,620	10.6 (Aventis)

intake location (city and state)	system name	watershed location (SEI #)	carbaryl use crop	carbaryl sales (RPAC)	carbaryl use (lbs per county), based on Doane	source water	volume of waterbody	watershed size	
								Aventis **(acres)**	EFED (square km)
Deerfield, MI	Village of Deerfield	Lenawee Co. (MI-4-DE-CB)	potatoes, apples, vegetables, corn	medium	1500	River Raisin	---	Medium 453,648	1,575 (Oak Ridge)
Westfield, NY	Village of Westfield	Chatauqua Co. (NY-13-WE-CB)	grapes	high	29,901	Minton Reservoir (90%)	10.7 acre-ft	Small 502	0.005 (Oak Ridge)
								Aventis 400 times Oak Ridge	
Penn Yan, NY	Penn Yan Village	Yates, Co. (NY-3-PY-CB)	grapes, apples	medium	9553	Keuka Lake	1,162,157 acre-ft (1)	Medium: 123,536	438 (Oak Ridge)
Coweta, OK	Wagoner Rural Water District #5	Wagoner Co. (OK-11-WR-CB)	Pecans, pasture	high	1850	Verdigris River oxbow of Verdegris R	large (tributary to Arkansas river)	small 31800 medium 5,162,475	129 20,900 (Aventis)
Jefferson, OR	City of Jefferson	Marion Co. (OR-3-JE-CB)	vegetables	high	16718	Santiam River (Willamette Valley)		Medium: 1,140,819	4,620 (Oak Ridge)
Point Comfort, TX	City of Point Comfort	Calhoun Co. (TX-2-PC-CB)	rice, pasture, tree nuts	high	900	Lake Texana (Navidad River impoundment)	165,900 acre-ft	Medium: 886,462	3,345 (Oak Ridge)
Beaumont, TX	City of Beaumont Water Utility Department	Jefferson Co. (TX-3-BE-CB)	rice, pasture, tree nuts (largely undeveloped)	high	4300	Neches River	---	Medium: 5,819,700	25,178 (Oak Ridge)
Manson, WA	Lake Chelan reclaimation District	Chelan Co. (WA-13-LC-CB)	apples	high	16898	Lake Chelan	15,800,000 acre-ft	Medium: 558,885	2,384 (Aventis)

intake location (city and state)	system name	watershed location (SEI #)	carbaryl use crop	carbaryl sales (RPAC)	carbaryl use (lbs per county), based on Doane	source water	volume of waterbody	watershed size	
								Aventis **(acres)**	EFED (square km)
Pasco, WA	City of Pasco	Franklin, Co (WA-7-PA-CB)	apples, potatoes	high	13122	Columbia River (downstream of confluence w/Snake R)		large 65,994,684	267,168 (Aventis)

(1) from NY state Depart of Environmental Conservation, 2001, Finger Lakes Synoptic Water Quality Study, http://www.dec.state.ny.us/website/dow/fingerlakes/chapter2.pdf, accessed 3/13/03.

Table 3: Characteristics of Home and Garden Monitoring Sites selected for Carbaryl Monitoring Study.

intake location (city and state)	system name	watershed location (SEI #)	source	watershed size		home and garden sales (RPAC)	county ag sales in pounds (Doane)
				Aventis (Acres)	**EFED (square km)**		
Birmingham, AL	Shades Mt. Filter Plant	Jefferson Co. (AL-1-B1-CB)	Cahaba River/ Lake Purdy	Small 125,703	509 (Aventis)	N/A	45
East Point, GA	East Point Water Treatment Plant	Fulton Co. (GA-1-EP-CB)	Sweetwater Creek	Small 170,007	682 (Oak Ridge)	N/A	20
Cary, NC	Town of Cary Water Treatment Plant	Wake Co. (NC-3--CA-CB)	Jordan Lake Reservoir	Medium: 188,618	3455 (Oak Ridge)	N/A	2100
				Oak ridge 4 times Aventis			
Midlothian, TX	City of Midlothian,	Ellis Co. (TX-30-MI-CB)	Joe Pool Lake	Small 147,667	313 (Oak Ridge)	N/A	4600
				Aventis 2 times Oak Ridge			

Table 4. Results of Sampling at all Community Water Supply System Locations (Agricultural and Home and Garden)

Site type	**intake location (city and state)**	**source**	**detection frequesny (raw only)**	year	months with detections (1 = January)	Raw Water Results		Finished Water Results	
						# detects raw	Conc. (ppt)	# detects finished	Conc. (ppt)
A	Lake Elsinore, CA	Railroad Canyon Reservoir (aka Canyon Lake)	3%	1 2 3	2 – 3 - 6	2 0 1	2 – 3 (?) - 6 (?)	NA - ND	
A	Corona, CA	Lake Mathews (Colorado River)	not detected	1 2 3	- - -		ND		
A	Lodi, CA	Little Potato Slough	21%	1 2 3	5 – 12 2 – 9 4 - 12	6 12 4	2.38 – 12.48 2.18 – 30.55 2.3 – 4.1	2 4 0	2.09 -3.44 3.63 – 6.66 -
A	West Sacramento, CA (Yolo)	Sacramento River	14%	1 2 3	6 - 8 4 - 12 3 - 8	2 8 4	2.33 – 3.22 2.54 – 24.44 2.09 – 14.4	1 3 2	2.86 8.34 – 9.91 2.19 – 9.32
A	Henry O Banks Filtration Plant, Sacramento, CA (aka Riverside CA)	State Water Project CA Aquaduct Feather and Sacramento Rivers	1%	1 2 3	- 2 -	- 1 -	- 8 -		Not detected
A	Bradenton, FL	Lake Manatee	14%	1 2 3	7-10 8-9 7-10	7 2 13	2.48 - 8.95 2.15 – 2.73 2.04 – 24.58	2 0 9	6.12 – 10.54 -- 2.72 – 19.04
A	Brockton, MA	Silver Lake	17%	1 2 3	6, 7 8-10 3, 4	5 7 2	2.12 – 31.4 2.2 – 26.6 2.67 – 4.64	0 1 0	- 3.37 -
A	Deerfield, MI	River Raisin	4%	1 2 3	6 9 7	1 1 1	8.01 – 12.26 3.7 21.94	2 0 1	4.31 – 180.7 - 4.43
A	Westfield, NY	Minton Reservoir	6%	1 2 3	6, 8 7 -	3 2 -	2.4 – 20.58 3.94 – 5.24 -	- 1 -	- 8.64 -
A	Penn Yan, NY	Keuka Lake	1%	1 2 3	- 1 -	- 8 -	- 22.82 -		Not detected
A	Coweta, OK	Verdigris River	4%	1 2 3	9 – 12 2 -	3 1 0	2.09 – 3.6 2.94 -		Not detected
A	Jefferson, OR	Santiam River		1 2	- 8	- 1	- 9.99		Not detected

			2%	3	9	1	3.58		
A	Point Comfort, TX	Lake Texana	3%	1 2 3	- 1,12 1	- 2 1	- 4.54 – 17.51 3.05	- - -	Not detected
A	Beaumont, TX	Neches River	Not detected	1 2 3	- - -		Not detected		
A	Manson, WA	Lake Chelan	Not detected	1 2 3			Not detected		
A	Pasco, WA	Columbia (downstream of confluence of Snake River)	3%	1 2 3	5,10 6 -	2 1 -	2.19 – 2.76 2.71 -		Not detected
H&G	Birmingham, AL	Cahaba River/Lake Purdy	19%	1 2 3 4	5-12 1-11 4-11 4	10 8 12 1	2.41-23.25 3.01 - 35.48 2.85 - 44.41 3.03	0 0 8 0	- - 2.85 - 31.99 -
H&G	East Point, GA	Sweetwater Creek	19%	1 2 3	5-12 1-12 1-10	10 12 8	2.01 - 17.56 2.15 - 17.64 2.96 - 12.52	1 1 0	2.90 7.61 -
H&G	Cary, NC	Jordan Lake Reservoir	1%	1 2 3	10 - -	2 - -	3.21 - 3.89 - -		Not detected
H&G	Midlothian, TX	Joe Pool Lake	6%	1 2 3	4 - 6-8	1 - 9	13.2 - 14.9 - 2.94 - 13.69		Not detected

APPENDIX C. SPREADSHEET-BASED TERRESTRIAL EXPOSURE VALUES

A first-order decay assumption is used to determine the concentration at each day after initial application based on the concentration resulting from the initial and additional applications. The decay is calculated from the first order rate equation:

$$\mathbf{C_T = C_i e^{-kT}}$$

or in log-transformed form:

$$\ln (C_T/C_i) = -kT$$

Where:

C_T = concentration at time T

C_i = concentration in parts per million (ppm) present initially (on day zero) on the surfaces.
C_i is calculated based on Kenaga and Fletcher by multiplying the application rate, in pounds active ingredient per acre, by 240 for short grass, 110 for tall grass, and 135 for broad-leaf plants/insects and 15 for seeds. Additional applications are converted from pounds active ingredient per acre to parts per million (PPM) on the plant surface and the additional mass added to the mass of the chemical still present on the surfaces on the day of application.

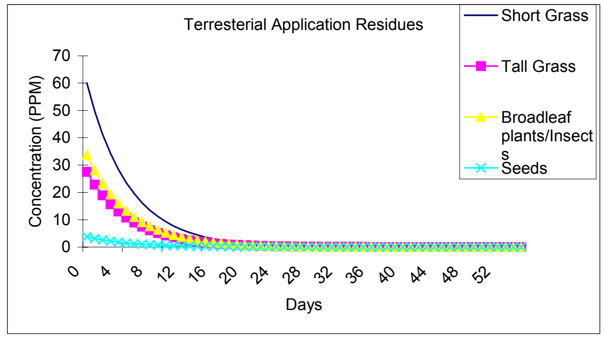
k= degradation rate constant determined from studies of hydrolysis, photolysis, microbial degradation, etc. Since degradation rate is generally reported in terms of half-life, the rate constant is calculated from the input half-life ($k = \ln 2/t_{½}$) instead of being input directly. Choosing which process controls the degradation rate and which half-life to use in terrestrial exposure calculations is open for debate and should be done by a qualified scientist.

T= time, in days, since the start of the simulation. The initial application is on day 0. The simulation is set to run for 365 days.

The program calculates concentration on each type of surface on a daily interval for one year. The maximum concentration during the year and the average concentration during the first 56 days are calculated.

Terrestrial Exposure Model Output

Chemical Name:	Carbaryl		
Use	Grasshoppers		
Formulation			



Inputs

Application Rate	0.25	lbs a.i./acre
Half-life	3.708	days
Frequency of Application		days
Maximum # Apps./Year	1	

Outputs

	Maximum Concentration (PPM)	56 day Average Concentration (PPM)	
Short Grass	**60.00**	**6.28**	
Tall Grass	**27.50**	**2.88**	# days
Broadleaf plants/Insects	**33.75**	**3.53**	Exceeded
Seeds	**3.75**	**0.39**	on short grass
			(in first 56)

Avian

Acute LC50 (ppm)	5000	0
Chronic NOAEC (ppm)	300	0

Max Single Application which does NOT exceed

Avian Acute	20.833	
Avian Chronic	1.250	(lb a.i.)
Mammalian Acute	8.36	
Mammalian Chronic	0.31	

	Acute RQ	Chronic RQ (Max. res. mult. apps.)	
Short Grass	**0.01**	**0.20**	
Tall Grass	**0.01**	**0.09**	# days
Broadleaf plants/Insects	**0.01**	**0.11**	Exceeded
Seeds	**0.00**	**0.01**	on short grass
			(in first 56)

Mammalian

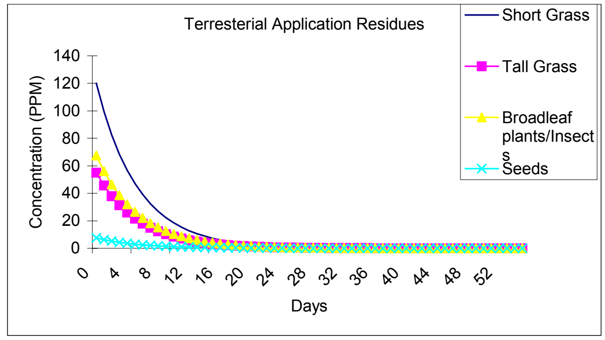
Acute LD50 (mg/kg)	301	0
Chronic NOAEL (mg/kg)	75	0

Rat Calculated LC50 (ppm): 6020

	15 g mammal Acute RQ (mult. apps)	35 g mammal Acute RQ (mult. apps)	1000 g mammal Acute RQ (mult. apps)	Rat Acute Dietary RQ	Rat Chronic Dietary RQ
Short Grass	**0.19**	**0.13**	**0.03**	**0.01**	**0.80**
Broadleaf plants/ insects	**0.09**	**0.06**	**0.01**	**0.00**	**0.37**
Large Insects	**0.11**	**0.07**	**0.02**	**0.01**	**0.45**
Seeds (granivore)	**0.00**	**0.00**	**0.00**	**0.00**	**0.05**

Length of Simulation	1 year	
Level of Concern		(ppm)

Chemical Name: Carbaryl
Use: Grasshoppers
Formulation



Inputs

Application Rate	0.5	lbs a.i./acre
Half-life	3.708	days
Frequency of Application		days
Maximum # Apps./Year	1	

Outputs

	Maximum Concentration (PPM)	56 day Average Concentration (PPM)
Short Grass	**120.00**	**12.57**
Tall Grass	**55.00**	**5.76**
Broadleaf plants/Insects	**67.50**	**7.07**
Seeds	**7.50**	**0.79**

<u>Avian</u>

		# days Exceeded on short grass (in first 56)
Acute LC50 (ppm)	5000	0
Chronic NOAEC (ppm)	300	0

	Acute RQ	Chronic RQ (Max. res. mult. apps.)
Short Grass	**0.02**	**0.40**
Tall Grass	**0.01**	**0.18**
Broadleaf plants/Insects	**0.01**	**0.23**
Seeds	**0.00**	**0.03**

Max Single Application which does NOT exceed

Avian Acute	20.833	
Avian Chronic	1.250	(lb a.i.)
Mammalian Acute	8.36	
Mammalian Chronic	0.31	

<u>Mammalian</u>

		# days Exceeded on short grass (in first 56)
Acute LD50 (mg/kg)	301	0
Chronic NOAEL (mg/kg)	75	3

Rat Calculated LC50 (ppm): 6020

	15 g mammal Acute RQ (mult. apps)	35 g mammal Acute RQ (mult. apps)	1000 g mammal Acute RQ (mult. apps)	Rat Acute Dietary RQ	Rat Chronic Dietary RQ
Short Grass	**0.38**	**0.26**	**0.06**	**0.02**	**1.60**
Broadleaf plants/ insects	**0.17**	**0.12**	**0.03**	**0.01**	**0.73**
Large Insects	**0.21**	**0.15**	**0.03**	**0.01**	**0.90**
Seeds (granivore)	**0.01**	**0.00**	**0.00**	**0.00**	**0.10**

Length of Simulation 1 year

APPENDIX D1: ECOLOGICAL EFFECTS ASSESSMENT

Toxicity testing reported in this section is not representative of the wide diversity of terrestrial and aquatic organisms in the United States. Two surrogate bird species, the bobwhite quail and the mallard duck, are used to represent the 680+ species of birds found in this country. For mammals, acute studies are usually limited to the Norway rat or the house mouse. Reptiles are not tested, as these are assumed to be subject to similar toxicological effects as birds. Of approximately 100,000 species of insects, spiders, and other terrestrial arthropods, toxicity tests are usually required only for the honey bee. Only two surrogate fish species (rainbow trout and bluegill sunfish) are used to represent the over 2,000 species of freshwater fish found in this country. Amphibians are not tested, as these are assumed to be subject to similar toxicological effects as fish. One crustacean, the water flea, is used to represent all freshwater invertebrates. Estuarine/marine animal acute toxicity testing is usually limited to a crustacean, a mollusk, and a fish.

Toxicity to Terrestrial Animals

Birds, Acute and Subacute Toxicity

Based on two core studies of Mallard ducks (*Anas platyrhynchos*), carbaryl is practically nontoxic (LD_{50} > 2000 mg/Kg) to birds on an acute exposure basis (**Table 1**). While less reliable data suggested that carbaryl may be moderately toxic to ring-necked pheasants (LD_{50} = 707 mg/Kg) and red-winged blackbirds (LD_{50} = 56.2 mg/Kg; Schafer *et al.*, 1983) and highly toxic (LD_{50} =16.2 mg/Kg) to starlings (Schafer *et al.*, 1983), these data are based on simple screening tests, and are therefore not reliable for risk assessment purposes. However, these data do suggest that passerine birds may be significantly more sensitive to carbaryl exposure than non-passerine birds. The registrant is strongly encouraged to submit acute oral toxicity tests with passerine avian species. The guideline 71-1 is fulfilled (MRID 00160000; 458206-01).

Table 1. Summary of avian acute oral toxicity in mg/kg (ppm) of technical grade carbaryl

Species	% ai	LD50 (mg/kg)	Toxicity Category	MRID No. Author/Year	Study Classification[1]
Mallard Duck (*Anas platyrhynchos*)	85	> 2,564	Practically non-toxic	00160000 Hudson *et al.* (1984)	Core
Mallard Duck	99.1%	>2,000	Practically non-toxic	458206-01 Ensenbach	Core
Canada Goose *Branta canadensis*	50	1,790	Slightly toxic	00160000 Hudson *et al.* (1984)	Supplemental
Ring-necked Pheasant male *(Phasianus colchicus)*	95	> 2,000	Practically non-toxic	00160000 Hudson *et al.* (1984)	Supplemental
Ring-necked Pheasant female *(Phasianus colchicus)*	480g/L	707	Moderately toxic	00160000 Hudson *et al.* (1984)	Supplemental
Sharp-tailed grouse *Tympanuchus phasianellus*	85	< 1000	Slightly toxic	00160000 Hudson *et al.* (1984)	Supplemental
California quail *Lophortyx californicus*	480 g/L	> 2000	Practically non-toxic	00160000 Hudson *et al.* (1984)	Supplemental
Rock Dove (*Columba livia)*	85	1,000 - 3000[2]	Slightly toxic to Practically non-toxic	00160000 Hudson *et al.* (1984)	Supplemental

[1] Core study satisfies guideline requirements. Supplemental study is scientifically sound, but does not satisfy guidelines.

[2] 95% confidence interval

Two subacute dietary studies using the TGAI are required to establish the toxicity of carbaryl to birds. The preferred test species are mallard duck and bobwhite quail. Results of these tests are summarized in **Table 2**. The LC_{50} is higher than 5000 mg/kg (ppm) of diet for both species. Therefore, carbaryl is categorized as practically nontoxic to avian species on a subacute dietary exposure basis. An LC_{50} greater than 10,000 ppm has been reported by Hill and Camardese (1986), confirming that carbaryl's low toxicity to birds on a subacute, dietary basis. The guideline 71-2 is fulfilled (MRID 00028757, 00022923).

Table 2 : Summary of avian subacute dietary toxicity in mg/Kg of diet (ppm) for technical grade carbaryl

Species	% ai	5-Day LC50 (ppm)	Toxicity Category	MRID No. Author/Year	Study Classification
Ring-necked Pheasant (*Phasianus calchicus*)	99.8	> 5,000	practically non-toxic	00028757 Hill *et al.* (1975)	Core
Northern bobwhite Quail *(Colinus virginianus)*	99.8	> 5,000	Practically non-toxic	00028757 Hill *et al.* (1975)	Core
Japanese Quail *(Coturnix japonica)*	99.8.	> 5,000	Practically non-toxic	00022923 Hill *et al.* (1975)	Supplemental
Mallard Duck *(Anas platyrhynchos)*	99.8	> 5000	Practically non-toxic	00022923 Hill *et al.* (1975)	Core

Incidents Involving Birds

According to the Ecological Incident Information System (EIIS) database summarizing 6(a)2 incident reports, bird kills have been attributed to carbaryl and have involved "blackbirds", starlings, grackles, Mallard ducks, Canadian geese and a morning dove in New York, South Carolina, Virginia, Michigan and New Jersey (#I002048-001, #I000802-001, #I007720-020, #I004375-004). However, two of the incidents appear to be attributed to the registered use of carbaryl. In incident #I007720-020 involving 10 Mallard ducks both carbaryl and bendiocarb were detected in bird stomach contents; bendiocarb is very highly toxic (LD_{50} = 3.1 mg/Kg) to birds an is more likely the cause of this incident.

In incident #I004375-004, 18 Canadian Geese (*Branta canadensis*) were reported killed; necropsy of 4 birds indicated that diazinon was present in the highest concentration in each of the birds with minor amounts of lindane and carbaryl. Diazinon is very highly toxic (LD_{50} = 6.16 mg/kg) to Canadian geese and is therefore the most likely cause of this incident.

In incident I002048-001, one common grackle and five European starlings (*Sturnus vulgaris*) were found dead. Pooled stomach contents showed carbaryl at 17 ppm; however, brain cholinesterase levels were normal. In what appears to be a follow-up report (I004169-094), corn kernels were strewn around the base of the incident site suggesting that there was an intentional poisoning of the birds.

Incident I012817-001 involved a single morning dove (*Zenaida macroura*) with 2.4 ppm carbaryl in its stomach contents and acetylcholinesterase activity was reduced. The report suggests that the birdseed from a feeder may have been contaminated when carbaryl was applied to the property owner's lawn.

In incident I000802-001, five blackbirds were discovered dead; stomach contents from a single squirrel also found dead on the farm property showed carbaryl residues; however, acetylcholine esterase activity was not reduced.

Based on these incident reports, only two appear to be clearly attributed to carbaryl and not due to misuse or the presence of some other chemical. However, only one incident involving the morning dove is attributed to a particular registered use or carbaryl. Additionally, based on the reported carbaryl residues, it is unclear how the chemical could have inflicted mortality given that carbaryl is practically nontoxic to birds on both an acute and subacute exposure basis. These incidents however underscore the uncertainty whether passerine birds are more sensitive to the effects of carbaryl than current surrogate test species results indicate.

Birds, Chronic Toxicity

Exposure to carbaryl at levels equal to or greater than 300 mg/kg of diet (ppm) in the mallard duck results in adverse reproductive effects, such as decreased number of eggs produced, increased number of cracked eggs, and decreased fertility (**Table 3**). Guideline 71-4 is fulfilled (ACC263701; MRID 00160044).

Table 3. Summary of avian reproduction toxicity in mg/Kg of diet (ppm) for technical grade carbaryl

Species	% ai	NOAEC (ppm)	LOAC Endpoints	MRID. No. Author/Year	Study Classification
Northern bobwhite Quail *(Colinus virginianus)*	99.9	> 3,000	N/A	00160044 Fletcher (1986)	Core
Mallard Duck *(Anas platyrhynchos)*	99.9	300	Number of eggs produced	ACC263701 Fletcher (1986)	Core

Mammals, Acute and Chronic

As shown in **Table 4**, carbaryl is categorized as moderately toxic to small mammals on an acute oral basis (LD_{50} = 301 mg/kg). In a two-generation rat reproduction study (MRID 454481-01) the LOAEL for reproductive toxicity could not be established because no effects were observed at any does level; therefore the NOAEL is 1500 ppm; however, the LOAEL for offspring toxicity was 300 ppm based on increased number of second generation offspring with no milk in the stomach and decreased pup survival. The NOAEL is 75 ppm.

Table 4. Summary of mammalian toxicity for technical grade carbaryl

Species	% ai	Test Type	Toxicity Value	Affected Endpoints	MRID No.
Laboratory Rat *(Rattus norvegicus)*	99.0%	Acute oral	LD_{50} = 301.0 mg/kg	Morbidity	00148500
Laboratory Rat *(Rattus norvegicus)*	99.1%	2-generation Rate Reproduction	NOAEC/LOAEC 75 / 300 ppm	Decreased pup survival	44732901

Incidents Involving Mammals

Incidents involving small mammal kills have been recorded in South Carolina and Virginia. In incident I000802-001, stomach contents from a gray squirrel (*Sciurus carolinensin*) were found to have “significant” amount of carbaryl; however, brain acetylcholine activity was not “significantly depressed.”.

In the second incident involving carbaryl, a hairytail mole (*Parascalops breweri*) was found to have 6 ppm carbaryl in its viscera. No information was provided on how the animal may have come in contact with the pesticide.

Based on these incident reports, it is not possible to determine what use of carbaryl was associated with these deaths. However, carbaryl is moderately toxic to mammals (LD_{50} = 301 mg/Kg) to rodents on an acute exposure basis.

Insect Toxicity

Technical carbaryl is categorized as highly toxic to bees on an acute contact basis (**Table 5**). Guideline 141-1 is fulfilled (MRID 00036935, 05001991, 05004151). More recent studies with technical grade carbaryl (purity 99.1%) indicate roughly similar acute oral toxicity (LC_{50} = 0.23 :g/bee). Although a more recent contact toxicity study of technical grade carbaryl was undertaken (MRID 457854-04), the study was classified as invalid since it relied on dimethylsulfoxide (DMSO) as a co-solvent; EPA recommends against the used of DMSO as a solvent due to the extent to which this solvent can impact cell membranes and hence the uptake and distribution of chemicals. Acute oral toxicity testing with the soluble concentrate (Carbaryl SC) indicates that the formulated product is roughly an order of magnitude less toxic (LC_{50} = 1.57 :g/bee) than the technical grade. Acute contact toxicity with the soluble concentrate also showed reduced toxicity (LD_{50} = 4.02 :g/bee) compared to the technical grade.

Table 5. Summary of honey bee acute contact (LD_{50} in :g/bee) and acute oral (LC_{50} in :g/bee) toxicity for technical grade carbaryl

Species	% ai	Contact LD_{50} (µg/bee)	Oral LC_{50} (µg/bee)	Toxicity Category	MRID No. Author/Year	Study Classification
Honey Bee (*Apis mellifera*)	tech.	1.3	0.14	Highly toxic	05001991 Stevenson (1978)	Core
Honey Bee (*Apis mellifera)*	tech	2.0	---	Highly toxic	00036935 Atkins *et al*. (1975)	Core
Honey Bee (*Apis mellifera*)	tech	1.1	0.11	Highly toxic	05004151 Stevenson (1968)	Core
Honey Bee (*Apis mellifera*)	99.1	--	0.231	--	457854-03 Waltersdorfer (2002)	Supplemental
Honey Bee (*Apis mellifera*)	479 g/L	--	1.57	--	457854-06 Waltersdorfer (2002)	Supplemental
Honey Bee (*Apis mellifera*)	479 g/L	4.02	--	moderately toxic	457854-07 Waltersdorfer (2002)	Supplemental

The topical LD_{50} for alfalfa leaf-cutter bee (*Megachile pacifica = M. rotundata*) = 262.4 µg/g (05015678) (Lee & Brindley 1974). However, exposing leaf-cutter bees (Megachilidae), alkali bees (Halictidae), and honey bees (Apidae) to 24-hr residues from 80% WP carbaryl applied at the rate of 1 lb/acre resulted, respectively, in a 85%, 78%, and 69% mortality rate (Johansen 1972) (ID #05000837). Some carbaryl formulations can be highly toxic to bees exposed to direct application, *i.e.*, when bees are actively visiting blooming crops or weeds. Residual toxicity varies with the crops and weather conditions.

Carbaryl can also range from moderately to highly toxic to predaceous arthropods. These include lace bugs (Nabidae) (MRID #05010807), big eyed bugs (Geocoridae: *Geocoris*) (MRID #05010807, lady beetles (Coccinellidae: *Coccinella*, *Cryptolaemus, Hippodamia, Lindorus, Rhodolia, Stethorus*) (MRID #05013372, 05003978, 05005640), ground beetles (Carabidae: *Scarites, Pterostichus, Bembidion, Harpalus*) (MRID #05008149), hymenopterous parasitoids (*Aphytis, Metaphycus,* *Spalangia, Leptomastix*) (MRID #05003978, 05005640), predaceous mites (*Amblyseius, Typhlodromus*) (MRID #05004148, 05013359, 05009346), and spiders (MRID #05010807).

In a 7-day field study (MRID 457854-07) designed to examine the effects of carbaryl on bees when the chemical is used to thin fruit, carbaryl SC (water miscible concentrate) was applied by mist blower at a rate of 0.80 lbs a.i./Acre to apple orchards in Germany. Bee mortality and behavior was monitored for two days leading up to application and for 7 days following application. Under the conditions tested in Germany, carbaryl SC applications to apple orchards did not have a significant ($P > 0.05$) effect on bee mortality and/or behavior. This nonguideline study is classified as supplemental.

Incidents Involving Bees

Bee kill incidents have been reported for carbaryl. In incident I001611-002 Sevin XLR was applied to 200 acres of asparagus in Washington and carbaryl residues were detected in the bees.

In incident I003826-009, a bee keeper in North Carolina reported a bee kill. A variety of pesticides had been used in the vicinity and residues of methyl parathion (3.1 ppm), chlorpyrifos (0.1 ppm), dimethoate (1.7 ppm) and endosulfan (0.2 ppm) were detected. Although carbaryl had been used in the vicinity, no residues were detected in the bees. Given that bees are roughly an order of magnitude more sensitive to methyl parathion (LD_{50} = 0.11 :g/bee) and that residues of methyl parathion were detected, the organophosphate is a more likely culprit in this bee incident.

In incident I003826-021, a bee hive owner in North Carolina reported bee mortality. Although a number of pesticides were being used in the vicinity of the apiary, only carbaryl residues (0.08 ppm) were detected in the bees. The bee hive owner did not know what served as a source of the carbaryl.

In incident I005855-001, the American Beekeeper Federation, Inc. submitted a report dated August 26, 1997, about the ongoing problem of bees being killed by pesticides in the United States. The report lists several pesticides (carbofuran, methyl parathion, parathion, carbaryl, naled) associated with bee kills during the period of January 1 through June 16, 1997. No data were provided on chemical residues or on the pesticide uses associated with the kills.

In a related report (B0000-300-03), the Honey Industry Council of America reported that farmers spraying alfalfa crops with toxaphene, parathion, and Sevin in the middle of the day was resulting in bee kills due to drift. No data were provided to support these concerns though.

Other than the use of carbaryl on asparagus in Washington, none of the other reports on bee kills contain sufficient information to implicate a specific use of carbaryl. Although the bee industry has expressed its concerns regarding the toxicity of carbaryl to bees, it has not provided sufficient data to support its concerns.

Earthworms

An acute toxicity study of the carbaryl degradate 1-naphthol was conducted using earthworms and is reported in greater detail in the 1-naphthol toxicity section to follow.

Toxicity to Freshwater Aquatic Animals

Freshwater Fish, Acute

Results of toxicity tests with freshwater fish are tabulated in **Table 6**. Since the LC_{50} values for the species tested are in the 0.25 - 20.0 mg/L (ppm) range, carbaryl can therefore range from highly to slightly toxic to freshwater fish on an acute exposure basis. Guidelines 72-1(a) and 72-1(c) are fulfilled (MRID 40098001, 00043115).

Table 6. Summary of freshwater fish acute toxicity in mg/L (ppm) for technical grade carbaryl

Species	% ai	96-hour LC_{50} (mg/L) (nominal)	Toxicity Category	MRID No. Author/Year	Study Classification
Rainbow Trout *(Onchorynchus mykiss)*	99.5	1.2	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core
Chinook Salmon *(Onchorynchus tshawytacha)*	99.5	2.4	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Supplemental
Bluegill Sunfish *(Lepomis macrochirus)*	99.9	14.0	Slightly Toxic	00043115 McCann *et al* (1969)	Core
Bluegill Sunfish *(Lepomis macrochirus)*	99.9	5.04	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core
Bluegill Sunfish *(Lepomis macrochirus)*	99.1	> 7.3*	Moderately Toxic	457854-01 Sowig & Gosch (2002)	Supplemental
Channel Catfish (*Ictalurus punctatus*)	99.9	7.79	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core
Fathead Minnow (*Pimephales promelas*)	99.5	7.7	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core
Black Crappie (*Pomoxis nigromaculatus*)	99.5	2.6	Moderately Toxic	40094602 Johnson & Finley (1986)	Core
Atlantic Salmon (*Salmo salar*)	99.5	0.25	Highly Toxic	40098001 Mayer & Ellersieck (1986)	Core
Brown Trout *(Salmo trutta)*	99.5	6.3	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core
Brook Trout (*Salvelinus fontinalis*)	99.5	3.0	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core
Lake Trout (*Salvelinus namaycush)*	99.5	0.69	Highly Toxic	40098001 Mayer & Ellersieck (1986)	Core
Coho Salmon (*Onchorynchus kisutch*)	99.5	2.4	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core

Species	% ai	96-hour LC_{50} (mg/L) (nominal)	Toxicity Category	MRID No. Author/Year	Study Classification
Yellow Perch (*Perca flavescens)*	99.5	0.35	Highly Toxic	40098001 Mayer & Ellersieck (1986)	Core
Cutthroat Trout *(Onchorynchus clarkii)*	99.5	0.97	Highly Toxic	40098001 Mayer & Ellersieck (1986)	Core
Largemouth Bass *(Micropterus salmoides)*	99.5	6.4	Moderately Toxic	40094602 Johnson & Finley (1980)	Core
Green Sunfish (*Lepomis cyanellus*)	99.5	9.5	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core
Black Bullhead *(Ictalurus melas)*	99.5	20.0	Slightly Toxic	40098001 Mayer & Ellersieck (1986)	Core
Longnose Killifish (*Fundulus similis*)	99.7	1.6	Moderately Toxic	40228401 Mayer (1986)	Supplemental
Carp (*Cyprinus carpio*)	99.5	5.3	Moderately Toxic	40098001 Mayer & Ellersieck (1986)	Core

* mean-measured concentration over 0 - 96 hours.

Toxicity was determined for the typical end-use product as well, with all LC_{50} values, except one, ranging from 1.4 to 49 mg/L (ppm), which indicates that carbaryl can be classified as slightly to moderately toxic to freshwater fish (**Table 7**). Guidelines (b) and 72-1(d) are fulfilled (MRID #s 00059202, 00042381, 00151519, 00151417, 42397901, 00124383, 00124391).

Incidents Involving Freshwater Fish

A total of three fish kill incidents are recorded in the EIIS database. In incident B0000-501-92 carbaryl was associated with a fish kill in New Jersey (1980) following the application of carbaryl to control gypsy moth. No data on residues were provided.

In a second incident (I000910-001) in Louisiana, a fish kill was reported to have occurred during in early June 1992. A number of pesticides (carbaryl, MSMA, atrazine, iprodione, dimethylamine, dicamba with 2,4-D, and chlorpyrifos) had been applied to area lawns and golf courses prior to the incident which followed a high rain event. No chemical residues were reported; however, carbaryl had not been applied in the area since late April while chlorpyrifos (bluegill LC_{50} = 3 :g/L) and iprodione (LC_{50} = 3.1 mg/L) had been applied less than a week before the incident. It is unlikely that carbaryl residues would have been sufficiently high to result in a fish kill if the chemical had been applied two months prior. Both chlorpyrifos and iprodione are more likely candidates for being responsible for this fish kill.

In a third incident report (B0000-246-01) a number of pesticides (toxaphene, carbaryl, endrin, methyl parathion and DDT) were associated with a fish kill in Oklahoma where approximately 22,000 catfish died. No residue data were provided; however, given that toxaphene and endrin are both classified as very highly toxic to catfish with LC_{50} values of 2.7 :g/L and 0.32 :g/L, respectively, it is likely that they are more credible candidates for having caused the fish kill than carbaryl.

Therefore, based on the incident reports, there appears to be only one credible report where carbaryl use could be directly associated with a fish kill.

Table 7. Summary of freshwater fish acute toxicity in mg/L (ppm) for carbaryl (typical end-use product)

Species	% ai	96-hr LC_{50} (mg/L)	Toxicity Category	MRID No. Author/Year	Study Classification
Rainbow Trout (*Onchorynchus mykiss*)	44	1.4	Moderately Toxic	00151417 Sousa (1985)	Core
Rainbow Trout (*Onchorynchus mykiss*)	81.5	3.3	Moderately Toxic	42397901 Lintott (1992)	Core
Rainbow Trout (*Onchorynchus mykiss*)	50	3.45	Moderately Toxic	00124383 McCann (1971)	Core
Rainbow Trout (*Onchorynchus mykiss)*	50	4.5	Moderately Toxic	00124383 McCann (1971)	Core
Bluegill Sunfish (*Lepomis macrochirus*)	30	49.0	Slightly Toxic	00059202 Mc Caan (1970)	Core
Bluegill Sunfish *(Lepomis macrochirus*)	5	290.0	Practically Non-toxic	00042381 McCann (1968)	Core
Bluegill Sunfish *(Lepomis macrochirus*)	44	9.8	Moderately Toxic	00151519 Sousa (1985)	Core
Bluegill Sunfish *(Lepomis macrochirus*)	50	22.0	Slightly Toxic	00124391 McCann (1971)	Core

Freshwater Fish, Chronic

Results of the required early life-stage with fish are summarized in **Table 8**. Exposure to 680 : g/L (ppb) reduced survival of larvae, reduced number of eggs per female and reduced number of eggs spawned (TOUCARO5); of the eggs spawned at 680 µg/L, none hatched.

Table 8. Summary of freshwater fish life-cycle toxicity in mg/L (ppm) under flow-through conditions for technical grade carbaryl

Species	% ai	NOAEC/LOAC (mg/L)	Endpoints Affected	MRID No. Author/Year	Study Classification
Fathead Minnow (*Pimephales promelas*)	99	0.21/ 0.68	Survival and Reproduction	TOUCARO5 Carlson (1972)	Core

Amphibians

According to a supplemental study with an end-use product containing 50% carbaryl (MRID 00160000), the LD_{50} for, the bullfrog (*Rana catesbeiana*) is greater than 4,000 mg/kg, or practically nontoxic.

The U. S. Geological Survey Biological Resource Division's Columbia Environmental Research Center has examined the effects of carbaryl on amphibians (**APPENDIX D2**). These studies have shown that frogs can exhibit considerable intraspecies (Boone and Bridges 1998) and interspecies (Boone and Semlitsch 2002) variability in their response to carbaryl exposure. Genetic factors and stage of development during which exposure took place can impact the vulnerability of frogs. For example, frogs exposed during egg stage had lower weights than corresponding control animals and nearly 18% of leopard frogs exposed to carbaryl during development exhibited some type of developmental deformity (including visceral and limb malformations). Additionally, environmental conditions such as temperature appear to impact the sensitivity of frogs to carbaryl. In a 96-hr acute toxicity study, green frogs (*Rana climitans*) had an LC_{50} of 22.0 mg/L at 17ºC but at 27 ºC the LC_{50} was roughly half (96-hr LC_{50} = 11.32 mg/L) (Boone and Bridges 1998).

Furthermore, in studies comparing the direct toxicity of carbaryl to Southern leopard frogs (*Rana sphenocephala*) and fish, tadpoles were relatively tolerant (96-hr LC_{50} = 8.4) to carbaryl compared to bluegill sunfish (96-hr LC_{50} = 6.2 mg/L, fathead minnow (96-hr LC_{50} = 5.21 mg/L) and rainbow trout (LC_{50} = 1.88 mg/L). The study also reports the 96-hr LC_{50} (12.31 mg/L) for the boreal toad (*Bufo boreas*); these data suggest that the surrogate fish species used to evaluate the toxicity to carbaryl are protective for amphibians (Bridges *et al.* 2002).

Of additional concern is the potential for secondary effects. Several studies have suggested that carbaryl exposure impairs predator avoidance behavior in frogs (Bridges 1997; Bridges 1999), affects the length of time required for tadpoles to complete metamorphosis into adults (Boone and Semlitsch 2002), and affected the weight of animals undergoing metamorphosis. Carbaryl concentrations greater than 3.5 mg/L significantly affected the time tadpoles spent being active where control animals exhibited greater sprint speeds and were able to swim greater distances (Bridges 1997). Slower swimming speeds, altered activity patterns and prolonged juvenile stages have been suggested as increasing the vulnerability of frogs to predation (Bridges 1997; Bridges 1999; Relyea and Mills 2001) and/or that the threat of predation renders the animals more susceptible to the direct toxicity of carbaryl (Relyea and Mills 2001). While the Relyea and Mills paper indicates that carbaryl was 2 to 4 times more lethal to gray treefrogs (*Hyla versicolor*) in the presence of a predator, the study is confounded by the potential effects of water quality on mortality (**APPENDIX D3**). Additionally, increased vulnerability to predation assumes that only the prey are incapacitated by carbaryl. The Bridges (1999) study indicates however, the predators may also be impacted and that gray treefrogs actually spent less time being active, but that the active times were primarily spent foraging. However, in some cases, it is unclear whether the effects of carbaryl on amphibians has been entirely adverse. For example, Southern leopard frogs exposed to carbaryl at 5 mg/L exhibited a 20% increase in weight at metamorphosis(Bridges and Boone 2003) and that at concentrations as high as

7 mg/L, Woodhouse's toad (*Bufo woodhousii*) survival was roughly 30% higher than controls (Boone and Semlitsch 2002).

Freshwater Invertebrates, Acute

Since the EC_{50} falls in the range of 1.7 - 26 :g/L (ppb), carbaryl is categorized as very highly toxic to aquatic invertebrates on an acute exposure basis (**Table 9**). Toxicity studies with the typical end-use product show that carbaryl is very highly toxic to daphnids, with an EC_{50} in the 4.29 - 13.0 :g/L range (Table 10). Guideline 72-2 is fulfilled (MRID #s 400980-01, 423979-02, 423979-03).

Acute toxicity studies of the stonefly larvae *Chloroperla grammatica* with technical grade carbaryl using a 96-hr exposure period (MRID 458206-02) and a 1-hour (pulse) exposure period (MRID 458206-03) resulted in LC_{50} values of 5.14 :g/L and 28.1 :g/L (ppb), respectively. Following the 1-hour "pulse" exposure, treated Mayflies were transferred to untreated water and monitored for 95 hours. Although 50% of the stonefly larvae were immobilized at 28 :g/L after a 1-hour exposure period, all of the exposed animals appeared to be completely recovered during the 95 hour post-exposure period in untreated waters.

Table 9. Summary of freshwater invertebrate acute toxicity in :g/L (ppb) for technical grade carbaryl

Species/Static or Flow-through	% ai	48-hour EC_{50} (:g/L) (nominal)	Toxicity Category	MRID No. Author/Year	Study Classification
Water flea (*Daphnia magna*)	99.5	5.6	Very Highly Toxic	400980-01 Mayer & Ellersieck (1986)	Core
Stonefly (*Classenia sabulosa)*	99.5	96hr LC_{50}=5.6	Very Highly Toxic	400980-01 Mayer & Ellersieck (1986)	Supplemental
Stonefly (*Isogenus sp.)*	99.5	96hr LC_{50}=3.6	Very Highly Toxic	400980-01 Mayer & Ellersieck (1986)	Supplemental
Stonefly *(Pteronarcella badia)*	99.5	96hr LC_{50}=1.7	Very Highly Toxic	400980-01 Mayer & Ellersieck (1986)	Supplemental
Stonefly (*Chloroperla grammatica*)	99.1	96-hr LC_{50} = 5.14*	Very Highly Toxic	458206-02 Schäfers (2002)	Supplemental
Stonefly (*Chloroperla grammatica*)	99.1	1-hr LC_{50} = 28.1* :g/L	Very Highly Toxic	458206-03 Schäfers (2002)	Supplemental
Scud (*Gammarus fasciatus)*	99.5	96hr EC_{50}=26	Very Highly Toxic	400980-01 Mayer & Ellersieck (1986)	Core

* Mean-measured concentrations over study period.

Table 10. Acute carbaryl toxicity in :g/L (ppb) to freshwater invertebrates using technical end-product (TEP).

Species	% ai	48-hour EC_{50} (:g/L)	Toxicity category	MRID No. Author/Year	Study Classification
Water flea (*Daphnia magna*)	49.0%	7.1	Very highly toxic	00150538 Nicholson and Surprenant (1985)	Supplemental
Water flea (*Daphnia magna*)	43.9%	13.0	Very highly toxic	00150540 Nicholson and Surprenant (1985)	Supplemental
Water flea (*Daphnia magna*)	47.3%	4.29	Very highly toxic	42432401 Lintott (1992)	Supplemental
Water flea (*Daphnia magna*)	43.7%	6.66	Very highly toxic	42397902 Lintott (1992)	Core
Water flea (*Daphnia magna*)	81.5%	7.2	Very highly toxic	42397903 Lintott (1992)	Core

In a series of studies (**Table 11**) to simulate the presence of sediment, technical grade carbaryl was evaluated for its toxicity to freshwater invertebrates including an amphipod (*Gammarus fossarum*), two cladocerans (*Chydorus sphaericus* and *Daphnia magna*), a clam (*Sphaerium corneum*), a Mayfly larvae (*Ephemera danica*), and a snail (*Planobarius corneus*). Exposure was based on mean-measured water column concentrations over the length of each study. Carbaryl was moderately toxic to both the clam and the snail (96-hr EC_{50} > 2200 :g/L) (ppb) while it was very highly toxic to the remainder of invertebrates studied.(48-hr EC_{50} range 5 - 15 :g/L).

Table 11. Acute toxicity of carbaryl in :g/L (ppb) to freshwater invertebrates using technical grade carbaryl in the presence of sediment

Species	% ai	48-hour EC50 (:g/L)	Toxicity category	MRID No. Author/Year	Study Classification
Pulmonate Snail *Planobarius corneus*	99.1%	96-hr EC_{50} > 2245	Moderately Toxic	458609-05 Schäfers (2002)	Supplemental
Freshwater clam *Sphaerium corneum*	99.1%	96-hr EC_{50} > 2467	Moderately Toxic	458609-06 Schäfers (2002)	Supplemental
Cladoceran *Chydorus sphaericus*	99.1%	48-hr EC_{50} = 7.25	Very Highly Toxic	458609-02 Schäfers (2002)	Supplemental
Amphipod *Gammarus fossarum*	99.1%	96-hr EC_{50} = 17.5	Very Highly Toxic	458609-04 Schäfers (2002)	Supplemental
Cladoceran *Daphnia magna*	99.1%	48-hr EC_{50} = 15	Very Highly Toxic	457848-01 Schäfers (2002)	Supplemental
Cladoceran *Daphnia longispina*	99.1%	48-hr EC_{50} = 4.9	Very Highly Toxic	4548609-01 Schäfers (2002)	Supplemental
Mayfly *Ephemera danica*	99.1%	48-hr EC_{50} = 4.9	Very Highly Toxic	458609-03 Schäfers (2002)	Supplemental

Field studies that evaluated populations of damselflies (*Xanthocnemis zealandica*) after exposure to 0.1 mg/L carbaryl showed a 90% reduction in emergence success after 10-12 days exposure (Hardersen and Wratten, 1998). Studying natural plankton communities in enclosed mesocosms, Havens (1995) reports a decline in total zooplankton biomass and numbers of individuals up to 0.100 mg/L. Furthermore, at carbaryl concentrations greater than 0.02 mg/L *Daphnia* was no longer found and that at concentrations above 0.050 mg/L all cladocerans were eliminated, resulting in an increase in algal biomass, representing a repartitioning of biomass from zooplankton to phytoplankton. Hanazato (1995) exposed *Daphnia ambigua* to carbaryl and a kairomone released by the predator *Chaoborus* (phantom midge) simultaneously. *Daphnia* developed helmets in response to the kairomone, but not in response to carbaryl at 0.001- 0.003 mg/L. However, carbaryl enhanced the development of high helmets and prolonged the maintenance period of the helmets in the presence of the kairomone, suggesting that at low concentrations carbaryl can alter predator-prey interactions by inducing helmet formation and vulnerability to predation in *Daphnia*. In related mesocosms studies, exposure to carbaryl at 1 mg/L killed all plankton species, including *Chaoborus* larvae (Hanazato, 1989). However, this concentration is well above the maximum EECs modeled for carbaryl, and is unlikely that such high levels of this chemical would be found under field conditions. Mora *et al.* (2000) studying the relationship between toxicokinetics of carbaryl and effects on acetylcholinesterase (ACHase) activity in the snail, *Pomaca patula,* observed increased enzyme inhibition, along with the bioconcentration of carbaryl, after 72 hours of exposure to sublethal levels (0.0032 mg/L). The transfer of snails to carbaryl-free water was followed by rapid monophasic elimination with a half-life of 1.0 hour, although ACHase activity levels never returned to control values.

Freshwater Invertebrate, Chronic

A 21-day toxicity study preformed with the water flea estimated a NOAEC and a LOAEC of 1.5 : g/L and 3.3 : g/L (ppb), respectively, based on affected reproduction (**Table 12**). Guideline 72-4(b) for freshwater invertebrates is fulfilled (MRID 00150901).

In a recent 28-day chronic (static) toxicity of carbaryl (technical; 99.1% purity) to the midge larvae *Chironomus riparius* (MRID 457848-02), organisms were exposed to negative control, solvent (acetone) control and test chemical at a single dosing of nominal concentration of 0.0625, 0.125, 0.25, 0.50, and 1.0 mg/L. Reduced emergence and development rates were the most sensitive endpoints (NOEC = 0.5 mg/L; LOEC = 1.0 mg/L) (ppm). The study is classified as supplemental since it is uncertain whether the use of dechlorinated tap water may have impacted the study's ability to differentiate treatment effects; however, the study provides information on the effects of carbaryl technical (99.1% purity) on benthic invertebrates based on a single exposure to carbaryl followed by a 28-day observation period. Analytical analysis of overlying water revealed that carbaryl and its primary degradate, 1-naphthol, had essentially dissipated by day 7.

Table 12. Summary of freshwater aquatic invertebrate life-cycle toxicity in µg/L (ppb) for technical grade carbaryl

Species	% ai	21-day NOAEC/ LOAEC (µg/L)	Endpoints Affected	MRID No. Author/Year	Study Classification
Water flea *(Daphnia magna)*	99.0%	1.5 / 3.3	Reproduction	00150901 Surprenant (1985)	Core
Midge *Chironomous riparius*	99.1%	500 / 1000	Emergence / developmental rate	457848-02 Ebeling & Radix (2002)	Supplemental

Toxicity to Estuarine and Marine Animals

Estuarine/Marine Fish, Acute

Since the minnow LC_{50} is 2.6 mg/L (ppm) (**Table 13**), carbaryl is categorized as moderately toxic to estuarine/marine fish on an acute basis. The guideline 72-3(a) is fulfilled (MRID 42372801).

Table 13. Summary of estuarine/marine fish acute toxicity for technical grade carbaryl

Species/Static	% ai	96-hour LC_{50} mg/L (nominal)	Toxicity Category	MRID No. Author/Year	Study Classification
Sheepshead Minnow *(Cyprinodon variegatus)*	99	2.2	Moderately Toxic	00150539 Sousa and Surprenant (1985)	Supplemental
Sheepshead Minnow *(Cyprinodon variegatus)*	99.7%	2.6	Moderately Toxic	42372801 Lintott (1992)	Core

Estuarine and Marine Fish, Chronic

An estuarine/marine fish early life-stage toxicity test using the TGAI is required for carbaryl because the end-use product is expected to be transported to this environment from the intended use site. The pesticide uses (e.g. turf) are such that its presence in water is likely to be continuous (multiple applications), and chronic concerns have been noted for freshwater and marine fish. At this point, the guideline 72-4(a) for estuarine/marine fish is not fulfilled.

Estuarine and Marine Invertebrates, Acute

As shown in **Table 14**, the 96-hour mysid shrimp LC_{50} for technical carbaryl falls is 5.7 µg/L (ppb) (MRID 42343401). Thus, this chemical is categorized as very highly toxic to estuarine/ marine shrimp species on an acute basis. By contrast, carbaryl is moderately toxicity to the oyster (LC_{50} = 2.7 mg/L (ppm; MRID 00148221). Guidelines 72-3(b) and 72-3(c) are fulfilled.

Table 14. Summary of estuarine/marine invertebrate acute toxicity for technical grade carbaryl

Species	% ai.	48-hour LC_{50} :g/L	Toxicity Category	MRID No. Author/Year	Study Classification
Brown Shrimp (*Penaeus aztecus*)	99.7	1.5	Very Highly Toxic	40228401 Mayer (1986)	Supplemental
Mysid (*Mysidopsis bahia*)	99	96 hr LC_{50} = 6.7	Very Highly Toxic	00150544 Hoberg and Surprenant (1985)	Supplemental
Mysid (*Mysidopsis bahia*)	99.7	96 hr LC_{50} = 5.7	Very Highly Toxic	42343401 Lintott (1992)	Core
Glass Shrimp (*Palaemonetes kadiakensis*)	99.5	5.6	Very Highly Toxic	40098001 Mayer & Ellersieck (1986)	Supplemental
Grass Shrimp (*Palaemonetes pugio*)	99.7	28	Very Highly Toxic	40228401 Mayer (1986)	Supplemental
Pink Shrimp (*Penaeus duorarum*)	99.7	32	Very Highly Toxic	40228401 Mayer (1986)	Supplemental
Eastern Oyster (*Crassostrea virginica*)	99.7	96 hr LC_{50}>2	Very Highly Toxic	40228401 Mayer (1986)	Core
Eastern Oyster (*Crassostrea virginica*)	99	2700	Moderately Toxic	00148221 Surprenant, *et al.* (1985)	Core
Blue Crab (*Callinectes sapidus*)	99.7	320	Highly Toxic	40228401 Mayer (1986)	Supplemental
Fairy Shrimp	95.3%	170	Highly toxic	40094602 Mayer (1986)	Supplemental
Eastern Oyster (*Crassostria virginica*)	95.0%	>1,000	Moderately toxic	40228401 Mayer (1986)	Supplemental

Results of toxicity testing using the typical end-use product are summarized in **Table 15.** Carbaryl TEPs are highly toxic to mysids, LC_{50} values ranging from 9.3 to 20.2 :g/L (ppb) (MRID #s 42397904, 42565601, and 42343402), and slightly toxic to oysters (LC_{50} = 23.6 mg/L (ppm), MRID 42597301). Guidelines 72-3(e) and 72-3(f) are fulfilled.

Table 15. Summary of estuarine/marine invertebrate acute toxicity for TEP

Species	% ai.	48-hour LC_{50} :g/L	Toxicity Category	MRID No. Author/Year	Study Classification
Mysid (*Mysidopsis bahia*)	81.5	9.6	Very Highly Toxic	42397904 Lintott (1992)	Core
Mysid (*Mysidopsis bahia*)	81.5	9.3	Very Highly Toxic	42565601 McElwee and Lintott (1992)	Core
Mysid (*Mysidopsis bahia*)	43.7%	96 hr LC_{50} = 20.2	Very Highly Toxic	42343402 Lintott (1992)	Core
Eastern Oyster (*Crassostrea virginica*)	43.3%	96 hr LC_{50} = 23,600	Slightly Toxic	42597301 Lintott (1992)	Supplemental

Estuarine and Marine Invertebrate, Chronic

There are no available chronic toxicity data for estuarine/marine invertebrates. The guideline 72-4(b) for estuarine/marine invertebrates is no fulfilled.

1-Naphthol Toxicity to Aquatic Organisms

Acute Toxicity

The major metabolite of carbaryl degradation by abiotic and microbially mediated processes is 1-naphthol. As summarized in **Table 16**, 1-naphthol is categorized as moderately to highly toxic to aquatic organisms on an acute exposure basis. LC_{50} values ranged from 0.75 to 1.6 mg/L for freshwater fish, from 1.2 to 1.8 mg/L for estuarine/marine fish, from 0.70 to 3.25 mg/L for freshwater invertebrates, and from 0.21 to 2.5 mg/L for estuarine/marine invertebrates.

Acute toxicity testing of 1-naphthol was also conducted using earthworms (*Eisenia fetida*). In a 14-day study, the LC_{50} was 441 mg/kg of soil (MRID 457848-06). Although the study was conducted for 14 days, no additional mortality was observed after day 7 suggesting that naphthol had likely degraded. The study is classified as supplemental since EPA does not currently require earthworm testing..

Table 16 Summary of aquatic organisms acute toxicity in mg/L (ppm) for the carbaryl degradate 1-naphthol.

Species	96-hour LC_{50} (mg/L) (nominal)	Toxicity Category	MRID No. Author/Year	Study Classification
Rainbow Trout (*Onchorynchus mykiss*)	1.4	Moderately Toxic	40955204 Surprenant (1988)	Core
Rainbow Trout *(Onchorynchus mykiss)*	1.6	Moderately Toxic	00164307 Surprenant (1986)	Supplemental
Bluegill Sunfish *(Lepomis macrochirus)*	0.76	Highly Toxic	40955203 Surprenant (1988)	Core
Bluegill Sunfish *(Lepomis macrochirus)*	0.75	Highly Toxic	00164305 Surprenant (1986)	Supplemental
Sheepshead Minnow *(Cyprinodon variegatus)*	1.2	Moderately Toxic	40955201 Surprenant (1988)	Core
Sheepshead Minnow *(Cyprinodon variegatus)*	1.8	Moderately Toxic	00164306 Surprenant (1986)	Supplemental
Waterflea (*Daphnia magna*)	48 hr EC_{50} = 0.73	Highly Toxic	40955205 Surprenant (1988)	Core
Waterflea (*Daphnia magna*)	48 hr EC_{50} = 0.70	Highly Toxic	00164310 Surprenant (1986)	Supplemental
Waterflea (*Daphnia magna*)	48 hr EC_{50} = 3.25	Moderately toxic	457854-05 Ebeling & Nguyen (2002)	Supplemental
Mysid *(Mysidopsis bahia)*	0.21	Highly Toxic	40955202 Surprenant (1988)	Core
Mysid *(Mysidopsis bahia)*	0.20	Highly Toxic	00164309 Surprenant (1986)	Supplemental
Eastern Oyster *(Crassostrea virginica)*	48 hr LC_{50} = 2.1	Moderately Toxic	00164308 Surprenant (1986)	Core

Chronic Toxicity

Chronic (32-day) exposure to the 1-naphthol degradate of carbaryl at mean-measured concentrations of 200 :g/L resulted in reduced larval survival and reduced body weight and length **Table 17.** Approximately 75% of the fish exposed to the 200 µg/L exhibited deformed jaw, *i.e.*, mouth appeared abnormally small and the lower jaw appeared extended. The guideline requirement 72-4(a) for freshwater fish using 1-naphthol is fulfilled.

Table 17. Chronic toxicity testing of the carbaryl degradate 1-naphthol.

Species	% ai	NOEC/LOEC (mg/L)	Endpoints Affected	MRID No. Author/Year	Study Classification
Fathead Minnow (*Pimephales promelas*)	99	0.10 / 0.20	Larval survival/growth	457848-04 Sousa (2002)	Core

Terrestrial Plants

Toxicity testing of terrestrial plants is required for non-herbicide pesticides when the label warns that nontarget plants could be adversely affected. Carbaryl can be used as a fruit thinning agent on apples and pears. However, the label cautions that the product may result in fruit deformity under certain environmental conditions. The label also cautions that application to wet foliage or during periods of high humidity may cause injury to tender foliage. Label language indicates that carbaryl should not be used on Boston ivy, Virginia creeper, and maidenhair fern due to potential injury. Incidents have also been recorded for vegetable crops (tomatoes, potatoes, cabbage, broccoli, pumpkin, squash, cucumbers) in New York and Pennsylvania (#1009262-128; #1009305-001).

Tier 1 terrestrial plant vegetative vigor testing was conducted for 6 plant species (4 dicots and 2 monocots) after application of Sevin® XLR Plus, soluble concentrate (Carbaryl, 44.35% w/w) at a single field application rate of 900 g a.i./ha (0.803 lbs a.i./acre), equivalent to the TEP of 4.059 g/L per ha (0.014 lbs/gal per acre). Response at this level was compared to response in a negative control group. Test species included cabbage, cucumber, onion, ryegrass, soybean, and tomato. No species were sensitive to Sevin® XLR Plus, soluble concentrate (Carbaryl, 44.35% w/w) because no reductions exceeded 25%. The study (MRID 457848-07) is classified as supplemental and does not fulfill the guideline requirements for a Tier I vegetative vigor study (Subdivision J, §122-1b) because fewer species than recommended (6 dicot and 4 monocot species) were tested and the species tested did not include corn and a dicot root crop species. Furthermore, plant height was (a recommended endpoint) not evaluated Guideline 122-1 is not fulfilled.

Incidents Involving Terrestrial Plants

Of all of the incidents associated with carbaryl, the greatest number (11) have affected terrestrial plants. In Minnesota, Sevin XLR Plus damaged all 15 acres of a cucumber crop (I012089-008). In Florida, Bug-B-Gon Garden dust killed two tomato plants (I010017-016). In California, the use of Sevin 80W (9.3 lbs/acre) in conjunction with SunSpray 6E (petroleum distillate) on olives resulted in pitting, slight burn and leaf drop (I009846-003). In North Carolina, the use of Sevin XLR Plus was alleged to have damaged an orchard; however, the application rate and crop is not reported (I009412-001). In Pennsylvania, the use of Garden Tech Ready-to-Use bug killer to control flea beetles resulted in burning of vegetables (potatoes, cabbage, broccoli and tomatoes) in a homeowner's garden (I009305-001). In New York, Bub-B-Gon Dust killed tomatoes, cucumbers, pumpkins and squash two weeks after application by a home gardener (I009262-128). In California, application of two different formulations of carbaryl (Sevin 50W and Sevin 80 WSP) over 4 consecutive months resulted in 50% of a 43-acre quince crop being spotted (I008034-004 / I008034-003). Also in California, 60% of the fruit from 8-acre quince orchard was spotted following application of Sevin 50W (I008034-002). In Oregon where two orchards applied Sevin XLR, pear harvest was reduced by low fruit set and malformations in fruit shape (I002276-002); the certainty factor was classified as "unlikely" since the reviewer felt there was no indication that carbaryl had damaged plants at registered use rates. In California, following the use of Greensweep, a homeowner's lawn was damaged (I001556-002); the certainty factor however, was classified as unlikely since the reviewer did not believe carbaryl had ever been implicated in causing plant damage. Finally, in Florida use of Greesweep Weed damaged a homeowner's lawn (I001358-002); the certainty factor was classified as unlikely since the reviewer felt there was insufficient information contained within the incident report to link carbaryl directly to the damage.

Based on the available incident data related to carbaryl use, it appears that many of the reports were generated by homeowner use of the pesticides. Insufficient detail is provided to determine whether the homeowner followed label instructions for the application of carbaryl on plants. The large scale damage inflicted to orchard crops is a greater concern. The limited terrestrial plant data available on carbaryl does not indicate the likelihood of phytotoxic effects; however, the incident data imply that phytotoxic effects are possible.

Aquatic Plants

Aquatic plant testing is recommended for all pesticides having outdoor uses (Keehner. July 1999). The tests are performed on species from a cross-section of the nontarget aquatic plant population. The preferred test species are duckweed (*Lemna gibba*), marine diatom (*Skeletonema costatum*), freshwater blue-green algae (*Anabaena flos-aquae*), freshwater green alga (*Selenastrum capricornutum*), and a freshwater diatom. Toxicity testing for aquatic plant species is required for carbaryl because of its registered forestry uses.

To date, the Agency has received data on only one aquatic plant species, i.e., a green algae *Pseudokirchneria subcapitata* (formerly *Selenastrum capricornutum*). I n one study of green algae the LC_{50} and NOAEC are 1.1 ppm and 0.37 ppm, respectively (MRID #42372802); the study is classified as core.

In a recent 96-hour acute toxicity study (MRID 457848-03), cultures of *Pseudokirchneriella subcapitata* were exposed to carbaryl at nominal concentrations of 1.0, 1.8, 3.2, 5.6, 10, and 18mg a.i/L under static. The EC_{05} and EC_{50}/IC_{50} values based on cell density were 0.287 and 1.27 mg a.i/L, respectively. The percent growth inhibition in the treated algal culture as compared to the control ranged from 27 to 98%. Other than inhibition of cell growth (in terms of numbers of cells), there were no compound related phytotoxic effects. This toxicity study is classified as supplemental because tap water was used as a source of dilution water and the levels of residual chlorine are not reported; it is uncertain whether this deficiency may have impacted the ability of the study to detect treatment effects.

In a similar 96-hr acute toxicity study (MRID 457848-08), cultures of *Pseudokirchneriella subcapitata* were exposed to SEVIN XLR PLUS (carbaryl extra long residue formulated product) at nominal concentrations of 0, 1.0, 1.8, 3.2, 5.6,1 and 10 mg a.i/L under static conditions. The NOAEC is 1.8 mg a.i./L and EC_{50}/IC_{50} values based on cell count was 3.2 mg a.i/L. The percent growth inhibition in the treated algal culture as compared to the control ranged from 0 to 97%. No abnormalities in cell morphology were observed at any of the test concentrations. The study is classified as scientifically sound and is suitable for use in estimating the risk of carbaryl formulated end-product to aquatic plants.

As mentioned earlier, there are data suggesting that amphibians growth has actually increased in carbaryl-treated waters (Bridges and Boone 2003). In this study, chlorophyll a concentrations in ponds treated with carbaryl at 5 mg/L increased 347% compared to controls. The authors suggest that the increased phytoplankton productivity may have been due to reduced grazing by zooplankton sensitive to carbaryl. It is also possible though that since the carbaryl degradate 1-naphthol is a plant auxin, carbaryl treatment may have stimulated the growth of certain algae. Therefore, EFED is uncertain regarding the potential effects of carbaryl on aquatic plants. Since only one species of aquatic plant has been tested, the Guideline 122-2 is not fulfilled.

APPENDIX D2. REVIEW OF LITERATURE ON EFFECTS OF CARBARYL ON AMPHIBIANS

Bridges, C. M. 1999. Effects of a Pesticide on Tadpole Activity and Predator Avoidance Behavior. Journal of Herpetology 33 (2): 303 - 306

Gray treefrog (*Hyla versicolor*) tadpoles (0.025 ± 0.008 g) at stage 25 were housed with red-spotted newts (Notophthalmus viridescens) and exposed to carbaryl at either 1.25 or 2.50 mg/L, dilution (well water) water control, or solvent (0.06 ml acetone/L) control. Three replicates of eight 3.78-L glass jars filled with 2 L of well water at 22ºC and exposed for 24 hours under static conditions. Testing chambers consisted of 18-L plastic tubs (45 x 25 x 15 cm) willed with 10 L well water. A small plastic plant was secured 15 cm from one end. At the other end was a 1-L (8 x 8 x 15 cm) plastic container to hold the newt. The containers had plastic mesh sides to facilitate the dissemination of visual, tactile, and chemical cues, but precluded attack by the newt. Following the 24-hr carbaryl exposure, each group of three tadpoles was placed in testing chamber containing the confined newt. After a 5-minute acclimation, tadpole activity (swimming, resting and feeding) and position within the chamber (*i.e.*, in refugia, in open, near edge) were recorded every 3 minutes for 1 hour. Activity of all three tadpoles was pooled.

Tadpoles exposed to carbaryl at 2.5 mg/L were active an average of 45% less of the time than control tadpoles. The responses of tadpoles to carbaryl were not considered adaptive [to the presence of predators]. Carbaryl-exposed tadpoles spent less time in refugia compared to controls when predators were present and also spent more time in refugia when no predator was present.

Both in the presence of predators and carbaryl exposure significantly reduced the amount of time tadpoles spent active. Tadpoles spending too much time resting may not acquire adequate resources to achieve metamorphosis or to outgrow gape-limited predators. Although carbaryl-exposed tadpoles spent less time active with predators were present, a greater proportion of that active time was spent feeding, thereby minimizing the costs associated with the trade-off between time spent foraging and predator avoidance. The author concludes that tadpoles in carbaryl contaminated sites may experience longer larval periods or a smaller size at metamorphosis, both of which can negatively affect adult fitness.

Boone, M. D. and C. M. Bridges. 1998. The Effect of Temperature on the Potency of Carbaryl for Survival of Tadpoles of the Green Frog (Rana clamitans). Environmental Toxicology and Chemistry 18 (7): 1482 - 1484.

Green frog (*Rana clamitans*) tadpoles weighing an average of 80 mg (± 15 mg) were exposed to one of nine chemical treatments, *i.e.*, water control, solvent (acetone 0.5 mL/L), 3.5, 5.0, 7.2, 10.3, 14.7, 21.0 and 30.0 mg carbaryl/L, and to one of three temperature treatments, *i.e.*, 17, 22, or 27ºC, in a 96-hr static test. The tests were conducted in 3.8-L glass jars containing 2 L of well water (ph 7.8, hardness 286 mg/L as $CaCO_3$). Each treatment was replicated three times. Ten tadpoles were randomly assigned to each glass jar and the percent mortality was determined at 12, 24, 48, and 96 hours. Tadpoles were not fed during the exposure.

Average survival was significantly different at each temperature treatment. At 24 hours survival was significantly lower at 27ºC. Lower concentrations (3.5, 5.0, 7.2 and 10.3 mg/L) were not significantly different from controls (survival > 96%). The two greatest concentrations (21 and 30 mg/L) were significantly different from controls at all times and had an average survival below 42%, with no tadpoles surviving in the 30 mg/L group for 96 hours.. Tadpoles at 17 and 22ºC had greater survival at higher concentrations than tadpoles at 27ºC. At 48 hours, the LC_{50} at 27ºC was 16.17 mg/L and at 17ºC the LC_{50} was 26.01 mg/L. By 96 hours, the LC_{50} at 27ºC (11.32 mg/L) was twice as large as at 17ºC (22.02 mg/L); that is, a smaller amount of carbaryl was needed to induce mortality at a high temperature.

Bridges, C. M. and R. D. Semlitsch. 2001. Genetic Variation in Insecticide Tolerance in a Population of Southern Leopard Frogs (*Rana sphenocephala*): Implications for Amphibian Conservation. Copeia 1: 7 - 13

In a study investigating the amount of genetic variability in tolerance to carbaryl within a single population of southern leopard frogs (*Rana sphenocephala*), time to death was measured in tadpoles exposed to carbaryl at 30 mg/L. Mortality was determined at 3, 6, 9, 12, 18, 24, 36 and 48 hours among 10 replicates of full- and half-sibling families. Tadpoles were housed in 250-mL glass beakers containing 200 mL. Control, solvent (acetone 0.5 mL/L) and carbaryl treated solutions were prepared using well water (pH 7.8, hardness 286 mg/L as $CaCO_3$). The results of the study indicated that significant differences in time to death were attributed to family with some families significantly more sensitive than others. The study found a significant amount of genetic variation for tolerance to carbaryl among half-sibling famines suggesting that this population may have the ability to persist in the presence of carbaryl contamination. The data also indicated that smaller tadpoles were more tolerant of carbaryl

Boone, M. D. and R. D. Semlitsch. 2002. Interactions of an Insecticide with Competition and Pond Drying in Amphibian Communities. Ecological Applications 12 (1): 307 - 316.

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 early in the larval period. The study units consisted of fifty 1480-L polyethylene ponds (1.85 m in diameter) containing 1000 L of well water and 1 kg of leaf litter. 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). Frogs species included: Southern leopard frog (*Rana sphenocephala*), plains leopard frog (*R. blairi*), and the Woodhouse toad (*Bufo woodhousii*). The results suggest that for Woodhouse toads, carbaryl exposure actually increased the survival of the frogs by roughly 30% in the highest treatment. Toads in the high-density ponds showed greater survival than those in low-density ponds at the highest carbaryl level.

For Southern and plains leopard frogs, carbaryl treatment did not have a significant or profound influence on either species. For green frogs, carbaryl exposure had a significant effect on days to metamorphosis with tadpoles in the chemical treatments generally having longer larval periods.

The study concluded that both leopard frog species may be less affected by carbaryl than Woodhouse 's toad.. Toads show a dramatic increase in survival with carbaryl treatment. The authors speculate that the increase in survival could have resulted from decreased predation by newts exposed to carbaryl, or more likely, a competitive release from zooplankton in the presence of carbaryl. In general, the three species studied showed no direct negative effect when exposed to carbaryl; however, poor survival in the control ponds may have confounded the test's ability to detect carbaryl treatment effects. Additionally, the authors speculate that since the test animals were collected from agricultural areas, the animals may have been more tolerant to carbaryl.

Bridges, C. M. 2000. Long-term Effects of Pesticide Exposure at Various Life Stages of the Southern Leopard Frog (*Rana sphenocephala*). Arch. Environ. Contam. Toxicol. 39: 91 - 96.

In a study to determine whether chronic exposure of tadpoles to carbaryl affected responses at metamorphosis and whether the effects are dependent on the life stage at which individuals are exposed, Southern leopard frogs (*Rana sphenocephala*) eggs, embryos and tadpoles were exposed to control, solvent control (0.25 mL acetone/L), 0.16, 0.40 and 1.0 mg carbaryl/L. Each treatment combination was replicated 10 times (total n = 250 tadpoles) in individual 1.5-L plastic containers filled with 1 L of well water (pH 7.8, hardness 286 mg/L as $CaCO_3$; temperature 21 ± 1.5°C). The results indicated that metamorphs exposed throughout the tadpole stage and throughout development (egg, embryo, tadpole) experienced significant mortality at all chemical levels. Additionally, metamorphs exposed during the egg stage were smaller than their corresponding controls. Nearly 18% of individuals exposed to carbaryl during development exhibited some type of developmental deformity (including visceral and limb malformations) compared to less than 1% in controls.

Bridges, C. M., F. J. Dwyer, D. K. Hardesty, and D. W. Whites. 2002. Comparative Contaminant Toxicity: Are Amphibian Larvae More Sensitive than Fish? Bull. Enviorn. Contam. Toxicol. 69: 562 - 569.

In a study designed to determine the LC_{50} of Southern leopard frog (*Rana sphenocephala*) tadpoles and determine whether amphibians are more sensitive to contaminants than fish, three replicates (containing 10 tadpoles per replicate) for each of six test concentrations were tested. Tadpole (0.05 mg ± 0.008 mg) mortality was recorded after 6, 12, 24, 48, 72 and 96 hours. The 96-hr LC50 was then compared to similar values on rainbow trout (*Onchorynchus mykiss*), fathead minnow (*Pimephales promelas*), bluegill sunfish (*Lepomis macrochirus*) and boreal toad tadpoles (*Bufo boreas*). In this study, tadpoles (96-hr LC_{50} = 8.4 mg/L) were relatively tolerant to carbaryl compared to the bluegill sunfish (96-hr LC_{50} = 6.2 mg/L), fathead minnow ((96-hr LC_{50} = 5.21 mg/L) and rainbow trout (96-hr LC_{50} = 1.88 mg/L). The only species that was less sensitive than the leopard frog was the Boreal toad (96-hr LC_{50} = 12.31 mg/L). In fact, of the 5 compounds tested (4 nonylphenol, carbaryl, copper, pentachlorophenol and permethrin) only copper exhibited enhanced toxicity to the leopard frog. For the remaining organic compounds, the toxicity estimates obtained for fish proved to be protective for amphibians. The report notes that correlations obtained from surrogate species and leopard frogs suggest that rainbow trout may be the most appropriate surrogate fish species for making reference to anuran tadpoles as their LC_{50} values for many contaminants are most similar.

Bridges, C. M. 1997. Tadpole Swimming Performance and Activity Affected by Acute Exposure to Sublethal Levels of Carbaryl. Environ. Toxicol. and Chem. 16(9): 1935 - 1939.

In a study to determine the effects of sublethal concentrations of carbaryl on activity level and swimming performance (*i.e.*, sprint speed and distance) of plains leopard frog (*Rana blairi*) tadpoles, two replicate groups of five 3.8-L glass jars each filled with 2 L of well water were used to test single tadpoles (approximately 20 mg) to control, solvent (0.5 mL acetone/L), 3.5, 5.0 and 7.5 mg carbaryl/L. Tadpoles were not fed 24 hours up to study or during study. Well water was characterized at having pH of 7.8, water hardness of 286 mg/L as $CaCO_3$ and a temperature of 22 ± 1^{o}C. Each tadpole was observed for 5 seconds every 4 minutes to determine swimming activity or resting activity for a total of 20 times per jar initially. Activity was also examined at 24, 48, 72 and 96 hours after which time, the tadpoles were transferred to clean water and their activity monitored for 24- and 48-hr post-exposure.

Carbaryl concentration significantly affected the time tadpoles spent being active. At 48-hrs post exposure, activity of tadpoles in the control and 3.5 mg/L treatments were not significantly difference. Some recovery of tadpoles, although not significant, was noted in all treatments except the 7.2 mg/L group. Additionally, control tadpoles exhibited greater sprint speed than carbaryl-treated tadpoles and the controls swam greater distances than their carbaryl-treated counterparts.

Bridges, C. M. and M. D. Boone 2003. The Interactive Effects of UV-B and Insecticide Exposure on Tadpole Survival, Growth and Development. Biological Conservation *In Press*.

In a study of the Southern leopard frog (*Rana sphenocephala*), the interaction of three ultraviolet B (UV-B) radiation levels and carbaryl exposure was explored. Artificial ponds (1480 L) consisting of polyethylene cattle tanks were willed with 1000 L of well water and 1 kg of leaf litter and inoculated with algae from a local pond. Ponds were allowed to equilibrate for 45 days. One day prior to the start of the study, 45 tadpoles were added to each pond. Dissolved oxygen (range 2.5 - 4.9 mg/L), pH (range 6.9 - 7.1) and temperature (16.4 - 16.9oC) were monitored the day of Sevin (22.5% carbaryl) application; the nominal carbaryl concentration was 5 mg/L. Differing pond lids (plastic wrap, Mylar D and Polycarbonate) served as filters to provide, high (ambient), medium (roughly 50%) and low (roughly10%) UV-B exposure intensities. Control ponds were uncovered (ambient UV-B).

UV-B intensity significantly increased survival to metamorphosis. The presence of carbaryl significantly increased the mass at metamorphosis; tadpoles in tanks containing carbaryl were 20% larger than those in tanks without carbaryl. Chlorophyll concentrations in ponds with carbaryl was 347% greater than in control ponds.

Bridges C. M. and R. D. Semlitsch. 1999. Variation in Pesticide Tolerance of Tadpoles Among and Within Species of Ranidae and Patterns of Amphibian Decline. Conservation Biology14(5): 1490 - 1499.

In a series of studies designed to assess the degree of variation in response to carbaryl among and within species of frogs in the family Ranidae, the tolerance to carbaryl was tested among nine species and among Southern leopard frogs. The study was conducted over 3 years by collecting species (red-legged frog (*Rana aurora*), yellow-legged frog (*R. boylii)*, spotted frog (*R. pretiosa*), wood frog (*R. sylvatica*), Pickeral frog (*R. palustris*), plains leopard frog *(R. blairi)*, northern leopard frog (*R. clamitans*) , and crayfish frog (*R. areolata*) from across the United States. At least three egg masses from each species. To examine variation in response among populations of southern leopard frogs (*R. sphenocephala*), 10 populations were sampled. Tadpoles from separate egg masses from each population were tested to determine the within-population, i.e., among-family, variation on all but two (Illinois and Texas) collection sites. Time-to-death assays were conducted by placing individual tadpoles in 250-mL glass beakers containing 200 ml of 30 mg/L carbaryl in well water with 0.1 ml acetone as a co-solvent. All beakers were held at 22 ±1°C and tadpoles were not fed during exposure. Each family was replicated 10 times except in three cases. Mortality was determined at 3, 6, 9, 12, 18, 24, 36, 48 and 60 hours. Activity changes were also tested using 2.5 mg/L carbaryl. Each family was replicated 10 times with one tadpole per replicate except in three cases where there were too few animals. Activity (presence or absence of tail movement) was monitored after 24 hours of exposure. Each observation was made for 5 seconds and a total of 20 observations were recorded per tadpole.

There were significant differences ($p < 0.0001$) in time to death among the nine ranid species. From most to least sensitive: *Rana sylvatica* > *R. areolata* > *R. boyii* > *R. clamitans* > *R. blairi* > *R. sphenocephala* > *R. palustris* > *R. pretiosa* > *R. aurora*. Mean time to death varied from 5 to 34 hours. R. sylvatica was significantly more sensitive than all other species.

There were significant differences among species with respect to overall activity ($P < 0.0002$); however, there was no significant interaction of treatment and species; the lack of interaction indicated that all species were equally sensitive to carbaryl exposure.

Time to death significantly differed among southern leopard frog populations in each of the 3 years. Populations in Texas, Mississippi, South Carolina, and one from Missouri were most tolerant, whereas populations from Virginia and Illinois and three from Missouri were most sensitive. In two of the years there was a significant population by treatment interaction indicating that populations were differentially sensitive to carbaryl exposure

APPENDIX D3. REVIEW OF RELYEA AND MILLS PAPER

U. S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

OFFICE OF
PREVENTION, PESTICIDES
AND TOXIC SUBSTANCES

MEMORANDUM **PC Code No.** 129106
DP Barcode:
D283014

SUBJECT: EFED Review of Relyea Paper Entitled "Predator-induced stress makes the pesticide carbaryl more deadly to gray treefrog tadpoles (*Hyla versicolor*) "

TO: Anthony Britten, Chemical Review Manager
Betty Shackleford, Product Manager
Special Review and Reregistration Division

FROM: Thomas M. Steeger, Ph.D., Senior Biologist
Environmental Risk Branch IV/EFED (7507C)

Through: Betsy Behl, Branch Chief
Environmental Risk Branch IV/EFED (7507C)

The Environmental Fate and Effects Division (EFED) has completed its review of the research article entitled *"Predator-induced stress makes the pesticide carbaryl more deadly to gray treefrog tadpoles* (*Hyla versicolor*)" published in the February 2001 issue of the Proceedings of the National Academy of Science. The paper, authored by Rick Relyea and Nathan Mills (Department of Biology, University of Pittsburgh) provides data demonstrating that prolonged sub-acute exposure of gray treefrog tadpoles to carbaryl at 3 to 4% of the reported LC50 (2.5 - 20.6 mg/L) killed 10 to 60% of the tadpoles. Furthermore, the paper claims that in the presence of "predatory cues" carbaryl was 2 to 4 times more lethal to tadpoles. The authors conclude that "under more realistic conditions of increased exposure times and predatory stress [simulated in their study], current application rates for carbaryl can potentially devastate gray treefrog populations" and that given the common mechanism of action, *i.e.*, acetylcholinesterase inhibition, of carbaryl with other widely used pesticides (carbamates and organophosphates), the "negative impacts may be widespread in nature."

While EFED concurs that biotic and abiotic effects do impact the toxicity of chemicals, we do not concur with the author's contention that their protocol is indicative of "more realistic ecological conditions" than EFED's current battery of acute and chronic toxicity tests; all of these studies are conducted under rigidly controlled laboratory conditions and are not intended to be representative of all of the variables that may affect the toxicity of a compound in the field. Furthermore, the EFED environmental fate and ecological risk assessment chapter on carbaryl submitted in support of the re-registration eligibility decision does attempt to account for carbaryl's risk to amphibians and is to some extent protective to amphibians at the concentrations discussed in the Relyea and Mills paper. However, while the authors are correct that a cumulative assessment of the effects of all chemicals acting through a similar mode of action may be more realistic, the logistics of conducting such an evaluation would require additional resources than are currently available in EFED.

The EFED environmental fate and ecological risk assessment chapter on carbaryl contains both acute and chronic amphibian toxicity data (see **Attachment 1** for excerpt on amphibians from chapter). Although bullfrogs *(Rana catesbeiana*) are relatively inured (LD50 > 4,000 mg/Kg) to carbaryl on an acute oral exposure basis, leopard frog tadpoles *(Rana blairi*) exhibited a 90% reduction in swimming activity at carbaryl concentrations in the 3.5 - 7.2 mg/L range. The chapter notes that such an impairment would likely render the tadpoles [prey] vulnerable to predation provided the predators were not similarly impaired. Furthermore, the chapter notes that chronic exposure of southern leopard frogs *(Rana sphenocephala)* to carbaryl led to developmental and growth effects and that the long-term effects of short-term carbaryl exposures to amphibians during critical life stages was uncertain and could potentially lead to population-level effects. Therefore, the EFED risk assessment does discuss qualitatively the potential susceptibility of amphibians following both acute and chronic exposure to carbaryl.

EFED does not typically evaluate risk to aquatic animals on a species-by-species or class-by-class basis but rather relies on surrogate species as representatives of broad ranges of aquatic organisms. As with most screening-level risk assessments conducted by EFED, the carbaryl chapter used fish toxicity data as a surrogate for amphibians. Toxicity values for freshwater fish ranged from 0.25 to 20 mg/L; the most sensitive species, *i.e.*, Atlantic salmon (*Salmo salar*) with a 96-hour LC50 value of 0.25 mg/L, was selected for calculating risk quotient (RQ) values used in EFED's assessment of ecological risk to freshwater vertebrates. The salmon LC50 value represents roughly 10% of the lower LC50 range (2.5 to 20.6 mg/L) for amphibians reported in Relyea and Mills paper. Given that EFED's levels of concern (LOC), *i.e.*, the ratio of expected environmental concentrations (EEC) to the LC50 value, for endangered is 0.05, if the EEC was greater than 0.01 mg/L, it would exceed EFED's LOC. Therefore, the ecological risk assessment for aquatic vertebrates is protective for species with 96-hour LC50 values greater than 0.01 mg/L. (0.04% of the range reported by Relyea and Mills).

EFED concurs with the study authors that biotic and abiotic effects can impact the toxicity of pesticides and that it is difficult to account for these effects on the basis of the limited laboratory tests that are typically available for evaluating the effects of pesticides. EFED also concurs with the authors that chemicals with similar modes of action may have additive toxicities and that commutative assessments may better account for toxicity; however, the practicality of implementing such evaluations is limited for screening-level assessments.

EFED is uncertain regarding how representative the Relyea and Mills article is of field effects though or of the direct effects of carbaryl and predatory cues. The experimental design included 10 tadpoles in 10-liter polyethylene tubs containing filtered tapwater. In a 10-day static renewal study, they changed water on days 3 and 7. In 16-day static-renewal exposures, they changed water every

4 days. Water quality parameters (dissolved oxygen, temperature, pH and ammonia) were measured midway through the 16-day exposure studies. Predator treatments consisted of a larval salamander (*Ambystoma maculatum*) housed within a 250-ml plastic cup, covered with a fiberglass window screening, in each of the exposure tanks; controls consisted of the plastic cup alone. Nominal carbaryl concentrations ranged from 0.045 to 0.54 mg/L; both negative and solvent (acetone) controls were run concurrently. The results demonstrate that increased ammonia concentrations were associated ($P< 0.0001$, range of means = 0.21 - 0.99 mg/L) with carbaryl concentration, an effect attributed to the presence of dead tadpoles and excess unconsumed food. A regression analysis of survival against ammonia was significant ($P < 0.001$, but not particularly predictive ($R^2 = 0.395$). Predators had no effect on ammonia ($P > 0.1$) and only had small effects on oxygen and pH (9% decrease in oxygen, $P < 0.0001$; 5% decrease in pH, $P = 0.019$). Given that water quality parameters were only measured midway through the study and that both tadpoles and thus feeding rates were likely increasing throughout the study, ammonia levels may have been considerably higher toward the end of the studies. Thus it is unclear whether ammonia, pH and dissolved oxygen had an effect on the toxicity of carbaryl to tadpoles. It is noteworthy that the Relyea and Mills data showed precipitous declines in tadpole survival after 5 days of exposure.

Although it is difficult to design a study that can accurately reflect field conditions and particularly predator-prey relationships, EFED is not convinced that the Relyea and Mills study could be interpreted as more representative of field conditions. Typically, prey demonstrate predator avoidance behavior in the presence of a perceived threat. In this study, tadpoles were unable to escape their perceived threat; predatory cues, *i.e.*, seeing a predator (visual cues) may have protracted their response well beyond the chemical cues released following the salamander's consumption of tadpoles. It is questionable whether tadpoles would have remained in view of a potential predator under more realistic conditions.

In refined ecological assessments, EFED oftentimes has mesocosm study data available to assess the risk of pesticides under "field conditions". These studies, while considerably more expensive that the Relyea and Mills protocol, may represent the most accurate reflection of controlled field studies. It is interesting to note though that while mesocosm studies may yield LC50 values similar to laboratory studies, they rarely provide LC50 values showing enhanced toxicity. Test species within these studies are better able to rely on compensatory mechanism to shield themselves from the toxic effects of chemicals.

In addition, the environmental fate of pesticides is often different under field conditions. Under alkaline conditions, *i.e.*, pH > 7, carbaryl undergoes hydrolysis with half-lives ranging from 0.15 to 12 days. While Relyea and Mills accurately note carbaryl's susceptibility to hydrolysis, they fail to mention that under aerobic conditions, carbaryl is also microbially degraded in the aquatic environment with a half life of approximately 5 days. It is likely that gray treefrogs in the Relyea and Mills study were exposed to carbaryl concentrations considerably lower than nominal after 3 to 4 days. Thus the actual exposure regime may have been more representative of pulsed exposures to declining concentrations of carbaryl and increasing concentrations of ammonia. While it is clear that predators had an effect on the response of tadpoles to the exposure regime, EFED does not concur that the test results are representative of the effects of predation on carbaryl toxicity alone.

EFED concurs with Relyea and Mills that both biotic and abiotic factors impact the toxicity of pesticides and that current screening methods do not account for the full range of these effects nor do screening level assessments take into account aggregate effects from exposure to chemicals with similar modes of action. Screening-level assessments attempt to identify where EFED's LOCs are exceeded and where EFED has uncertainties regarding risk. With respect to amphibians, the chapter discusses the likelihood of acute and chronic effects from current uses of carbaryl.

Attachment 1. Excerpt on Amphibians from the Initial Draft Environmental Fate and Ecological Risk Assessment for the Reregistration of Carbaryl Chapter

According to an available supplemental study with a 50% carbaryl formulation, the LD_{50} for the bullfrog (*Rana catesbeiana*) is greater than 4,000 mg/kg, or practically nontoxic (MRID 00160000). A single acute exposure of plains leopard frog tadpoles (*Rana blairi*) to carbaryl concentrations in the 3.5 - 7.2 mg/L range led to a 90% reduction in swimming activity, including sprint speed and sprint distance, activity ceasing completely at 7.2 mg/L (Bridges 1997). This reduction in activity and swimming performance may result in increased predation rates and, because activity is closely associated with feeding, may result in slowed growth that could lead to failure to complete metamorphosis. Acute exposure to low carbaryl levels may not only affect immediate survival of tadpoles but also impact critical life history functions.

On a chronic basis, carbaryl has been shown to have the potential to adversely affect amphibians. In a recent study, nearly 18% of southern leopard frog (*Rana sphenocephala*) tadpoles exposed to carbaryl during development exhibited some type of developmental deformity, including both visceral and limb malformations, compared to a single deformed (< 1%) control tadpole demonstrating that carbaryl exposure can result in amphibian deformities (Bridges, 2000). Although the length of the larval period was the same for all experimental groups, tadpoles exposed throughout the egg stage were smaller than their corresponding controls. Because exposure to nonpersistent chemicals may last for only a short period of time, it is important to examine the long-term effects that short-term exposure has on larval amphibians and the existence of any sensitive life stage. Any delay in metamorphosis or decrease in size at metamorphosis can impact demographic processes of the population, potentially leading to declines or local extinction.

APPENDIX E1. SECTION 24c USE OF CARBARYL TO CONTROL BURROWING SHRIMP

Although Texas recently applied for a Section 24c (Supplemental Label of the Amended Federal Insecticide, Fungicide and Rodenticide Act) for use of carbaryl in shrimp culture ponds which drain into estuaries along the Gulf of Mexico, Washington is currently the only state sanctioning the use of carbaryl in estuarine/marine waters for control of burrowing shrimp on mud flats used for oyster culture. The use of carbaryl to control burrowing shrimp has generated concern regarding the effects of the chemical in the immediate application area and the movement (drift) and potential subsequent effects of carbaryl to nontarget sites.

The commercial oyster fishery in Willapa Bay has been in existence since the 1800's. Originally sustained by the indigenous Olympia oyster, *Ostrea lurida*, the fishery now relies on the Pacific oyster (*Crassostrea gigas*). Over the years, increasing numbers of indigenous burrowing shrimp (ghost shrimp, *Callianassa sp.*, and mud shrimp *Upogebia pugettensis*) have rendered tidal mud flats in the bay less amenable to traditional oyster culture methods. The activity of burrowing shrimp results in mud too soft to support oysters and as a consequence oysters settle into the mud and suffocate. Since 1963 Washington has issued permits to oyster growers to apply carbaryl to sheltered tidal areas and since 1994 carbaryl has been sprayed annually on 600 acres in Willapa Bay and 200 acres in Grays Harbor at a rate of 7.5 - 8 lbs/acre. Although lower application rates have been attempted, they were not effective at penetrating tidal muds to a sufficient depth to kill burrowing shrimp and thus retreatment was required in subsequent years. Carbaryl is applied as a wettable powder to tidelands at low low [Spring] tide primarily by helicopter; however, hand spraying is used in some instances. The label restricts aerial applications within 200 feet of a channel or slough; hand spraying is prohibited within 50 feet of a channel or slough.

Willapa Bay is located on the Pacific coast of Washington State and encompasses 79,000 acres at mean high tide representing a volume of 56.6 million ft^3 of water. The tidal range in Willapa Bay is from 14 to 16 feet and roughly 45% (25.4 million ft^3) of the water in the bay is exchanged into the Pacific Ocean during a complete tidal cycle. The relatively shallow bay has more than 50% its acreage exposed at low tide with much of the remaining surface area, except for channels, covered by 1 to 6 feet of water. Channel depths range from 30 to 50 feet with maximum depths 75- to 77-ft below mean low water. Willapa Bay opens to the Pacific Ocean at its northwestern corner through a broad shallow pass about 6 miles wide between Cape Shoalwater and Leadbetter Point. Major tributaries to the bay include the Willapa River to the north and the Naselle River to the south, together draining an area of 461,280 acres in Pacific County, Washington . Rainfall in the Willapa Bay area ranges from 85 - 100 inches per year resulting in mean annual runoff for the entire basin of 3.4 million acre-feet; mean maximum discharge at the mouth of Willapa Bay is estimated at 1.6 million ft^3/second. Mean daily runoff is estimated to be about 0.004% of the total volume of the bay (Hedgpeth, J. W. and S. Obrebski 1981. Willapa Bay: A Historical Perspective and a Rationale for Research. Coastal Ecosystems Project, Office of Biological Services, U. S. Fish and Wildlife Service FWS/OBS-81/03).

The entrance of Willapa Bay is approximately 28 miles north of the mouth of the Columbia River and approximately 11 miles south of the entrance to Grays Harbor. Flushing rates (tidal prism) in Willapa Bay are influenced by conditions in the ocean. During the summer, strong northwesterly winds bring upwelled water from the ocean into the bay and promotes rapid turnover. Strong Pacific storms also promote mixing. At other times though, freshwater outflow from the Columbia River acts as a discrete water mass moving northward along the Pacific coast and may prevent mixing from occurring in the bay (Hedgpeth and Obrebski 1981).

To address concerns regarding the mobility/persistence of carbaryl and it effects on nontarget animals, a series of studies were undertaken as a requirement of the permitting process. These studies have been reviewed by EFED (**APPENDIX E1**). Except for more recent studies conducted by Washington State University and the Washington Department of Ecology, much of the older (pre-1996) data had procedural problems that limited the utility of the data. The more recent data indicate that carbaryl residues in the water column were generally at or below Washington state's projected effect threshold of 0.1 µg/L Although large carbaryl applications can affect water quality in areas distant from spray sites, the Washington Department of Ecology concluded that "no widespread effects from carbaryl would be expected in Willapa Bay after the end of the [carbaryl] application period.".

Additional studies have also been submitted examining potential drift and long-term effects of carbaryl in Willapa Bay (**APPENDIX E2**). Studies have been undertaken to examine recovery of treated sediments (Mazzone and McNamara); however, the data underscore the difficulty in conducting well-designed field studies that account for the many sources of variability that can affect a study's ability to establish causality. Insufficient detail is provided in the Mazzone and McNamare study to suggest though that carbaryl applications to control burrowing shrimp in selected sites in the bay are likely to exhaust aquatic life within the bay. Given that the reapplication interval is roughly six years and the current study at best demonstrates that after two years a similar range of species exist in treated and untreated sites (that may or may not be comparable), there is no conclusive evidence to support concerns that carbaryl treatments are reducing the overall "natural productivity" of Willapa Bay. Although a report by Felsot and Ruppert (2002) suggests that carbaryl residues may partition to sediment, persist there for extended periods of time, and serve as a sink for carbaryl re-entering the water column for as much as year post-application, these data are not consistent with previous studies in Willapa Bay nor the environmental fate data reported in this document. Therefore, the source of preapplication carbaryl residues as high as 0.7 µg/L is uncertain.

In 2002, a total of 810.5 acres and 186 acres were treated in Willapa Bay and Grays Harbor, respectively. As part of the National Pollutant Discharge Elimination System (NPDES) permit program, established under Section 402 of the Clean Water Act prohibiting unauthorized discharge of pollutants from point sources, monitoring was conducted to document acute and chronic exposure potential. Acute samples were collected at the first falling tide at least 24 hours following the final treatment within a sample area and samples for chronic analysis were taken at the first falling tide at least 30 days after final treatments. Acute monitoring data revealed carbaryl concentration as high as 5.3 µg/L while 3 out of 22 (14%) of the chronic monitoring samples had carbaryl levels (range 0.58 - 1.25 µg/L) exceeding detection limits (Booth *et al.* 2002). Based on 2002 monitoring data collected by the Shoalwater Bay Environmental Research Laboratory (docket number OPP-2002-0138-052), carbaryl residues outside of application areas peaked at 1.4 µg/L on July 26 and again at 1.6 µg/L three days later following carbaryl applications on July 25 and July 27. These data are consistent with a Washington Department of Ecology study showing that carbaryl is frequently detected up to 4 days after application to oyster beds and that carbaryl is transported several miles from the site of application.

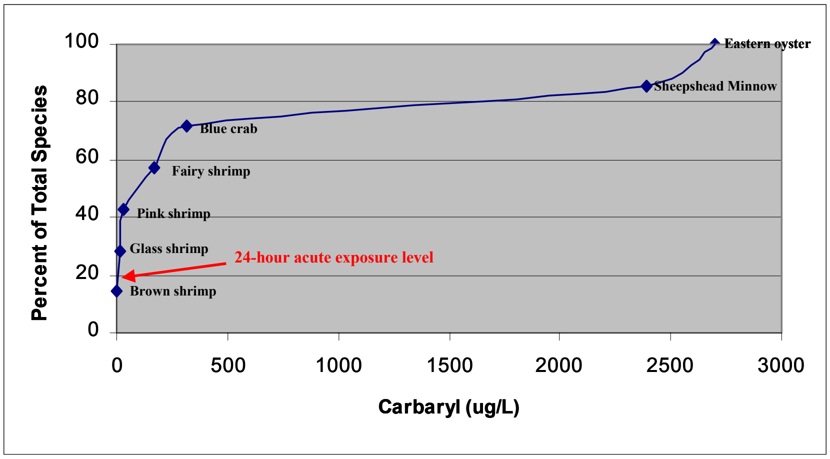


Figure 11. Cumulative percent distribution of acute LC_{50} values in µg/L (ppb) for estuarine marine fish and invertebrate exposed to carbaryl. The red arrow shows point along curve for an exposure of 5 ug/L.

Based on a cumulative effects distribution of acute LC_{50} values for estuarine/marine species (**Figure 11**), at maximum reported peak values (5.3 µg/L) after 24 hours, less than 28% of the total species would likely be affected in terms of acute mortality. Although 24-hr post-application mortality is expected to be low in treatments sites, aquatic animals (fish and invertebrates) entrapped in shallow pools by the outgoing tide and in the immediate treatment area are likely to experience 100% mortality the day of treatment. Observations by members of the Shoalwater Bay Indian Tribe (personal communication Gary Burns, Environmental Programs Director, Shoalwater Bay Environmental Research Laboratory 2003) on the day of treatment report extensive mortality of crustaceans and in particular crabs, which constitute a subsistence-level fishery for the Shoalwater Bay Indian reservation members. These observations are consistent with data (Stonic 1999) indicating that Dungeness crab (*Cancer magister*) larvae would be particularly sensitive to carbaryl exposure and that the number of crabs killed by carbaryl in treated areas has increased as the number of acres treated each year has increased (Washington Department of Ecology 1987). Total crab landings per year from Willapa Bay (**Figure 12**) appear to fluctuate on a 10 to 15 year cycle and have ranged from 169 thousand pounds to 1.4 million pounds; on average, 515 thousand pounds are harvested annually. Since a precipitous (83%) decline in harvest in 1997, subsequent years have yielded a steady increase in annual harvest. Harvest in 2002 (976,870 lbs) was roughly double the annual

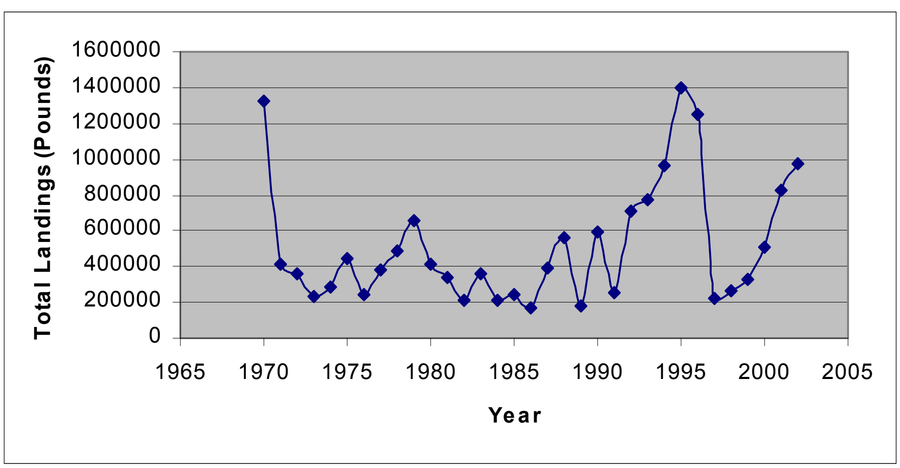


Figure 12. Total landings of crab in pounds harvested by year from Willapa Bay, Washington. Source: Washington Department of Fish and Wildlife 2003.

average. Given that carbaryl application to the bay have been relatively consistent over the years, the information on crab harvest suggests that crab recruitment is not well correlated with carbaryl applications.

Furthermore, age 0+ crabs placed on mud flats 24-hrs after application of carbaryl and monitored for 14 days did not differ in mortality rate from controls (Feldman *et al.* 2000); the study indicated that young crabs were capable of recolonizing oyster grounds shortly after treatment. The risks to crabs age 1+ and 2+ foraging on animals immobilized by carbaryl treatments appeared to be greatest during the first 24 hours then declined rapidly; this is consistent with data showing carbaryl residues in tissues of burrowing shrimp treated with carbaryl declined by 90% after 24 hours.

In general, although some species are adversely affected by carbaryl treatments on a short-term basis, re-colonization by bedload transport and rapid reproduction is viewed as largely offsetting impacts resulting from carbaryl application (Feldman *et al.* 2002). Ironically, the productive oyster culture in the bay is viewed by some as actually improving environmental conditions through the filter-feeding activity of these animals, the refuge that the oyster shells provide for attachment of epibionts and protection for juvenile fish and invertebrates. Juvenile crab densities have been shown to be significantly higher in these habitats compared to areas occupied by large populations of burrowing shrimp (Dumbauld *et al.* 1998).

With an application rate of 8 lbs to the acre and assuming that the tidal flats are eventually covered by 6 feet of water at high tide, carbaryl would be theoretically diluted in 1.96×10^6 gallons of water corresponding to a carbaryl concentration of approximately 0.5 parts per million (0.5 mg/L). Based on the environmental fate properties of carbaryl, the chemical is expected to undergo relatively rapid hydrolysis ($t_{½}$ = 10 hrs at pH 8.4) in an estuarine/marine environment while undergoing considerable dilution from successive tides. The fact that on-site monitoring 24 hours post-application indicates carbaryl concentrations were detected at a maximum of 5 parts per billion (0.005 mg/L) suggests that carbaryl is rapidly dissipating from application sites and that its potential to exert ecological effects is diminished. While EFED recognizes that acute mortality in the immediate application site may be near 100% for aquatic animals trapped in tide pools and/or living in benthic sediments, the potential for off-site effects and overall impact to Willapa Bay as a whole appears limited. This is based on the fact that roughly 1% of the total acres (79,000 acres) of the bay are treated during any given year, the treatments are dispersed over several months depending on low low tide schedules and that during a complete tidal cycle (low low tide to high high tide), as much as 25.4 million ft^3 of water (up to 45% of the bay's total volume) may be exchanged. Thus, the opportunity for dilution alone is significant. Although this discussion has focused primarily on Willapa Bay, it is believed that the same potential for dissipation exists for Grays Harbor where less than 1% of the total acreage is treated.

Although preliminary research (personal communication Nat Scholz, National Marine Fisheries Service 2002) suggests that salmonid fish exposed to carbaryl in olfactory perfusion assays are not able to detect the chemical, *i.e.*, the chemical does not elicit an electrical response from olfactory cells, the relevancy of these data is uncertain. Concern has been raised though that the animal's inability to detect carbaryl would render the fish incapable of avoiding a chemical plume; however, no evidence has been provided that for fish other than those trapped in tide pools and directly in a chemical treatment site, that the Section 24c use of carbaryl has resulted in fish kills. Studies have been proposed though (personal communication Christian Grue, University of Washington Cooperative Fish and Wildlife Unit, 2003) that are designed to answer whether salmonids frequent active carbaryl application sites, the extent to which they consume prey containing carbaryl residues and whether the residues have any impact on brain acetylcholinesterase activity in the fish.

Concern has also been raised over the potential effects of carbaryl on birds feeding opportunistically on immobilized aquatic animals in treated areas; however, based on the available information, carbaryl is practically nontoxic to birds on an acute exposure basis (LD_{50} > 2,000 mg/Kg) and a subacute dietary basis (LC_{50} > 5,000 mg/kg of diet). No data are available to suggest that birds are adversely affected on an acute exposure basis from the use of carbaryl to control burrowing shrimp. Furthermore, the data suggest that the likelihood of chronic exposure to birds is low.

As part of a memorandum of agreement (**APPENDIX E2**) between the oyster growers and the state of Washington, an integrated pest management plan has been developed in Willapa Bay. The agreement acknowledges that additional data on the environmental fate and effects of carbaryl are necessary and that alternative methods of control should be explored to mitigate adverse effects. As part of these efforts, the shellfish growers are actively engaged in exploring both chemical, biological (*e.g*., parasites, predation), and mechanical (*e.g*., surface/vertical barriers, compaction, harrowing/discing) alternatives along with different methods of oyster culture (*e.g.*, long-lining). Although both chemical and mechanical methods of controlling burrowing shrimp have been had mixed results, an effort is underway to reduce the potential for adverse effects from carbaryl. It is clear from the data that considerable variability exists in estimates on the extent to which carbaryl /naphthol residues persist in both the water column and treated sediments and EFED encourages more refined studies to address this issue. Proposals have been submitted to study the fate and transport of carbaryl in Willapa Bay and to better define the sediment impact zone. Based on the available data, acute mortality is likely for animals in the immediate application area; however, off-site acute mortality is not expected to be significant. Additionally, the potential for adverse chronic effects is not expected to be significant due to a combination of relatively rapid degradation and dilution in this tidal environment.

EFED acknowledges that there are uncertainties regarding the use of carbaryl in Willapa Bay/Grays Harbor and its potential effect on nontarget animals. Maintaining a constructive dialog between shellfish growers, Washington state representatives and other stakeholders within the Willapa Bay/Grays Harbor communities can only serve to promote the necessary research to address various concerns and uncertainties.

APPENDIX E2. REVIEW OF DATA SUBMITTED ON SECTION 24c USE OF CARBARYL TO CONTROL BURROWING SHRIMP

U. S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

OFFICE OF
PREVENTION, PESTICIDES
AND TOXIC SUBSTANCES

MEMORANDUM

PC Code No. 129106
DP Barcode: D279109

SUBJECT: EFED Review of Documents Relative to Section 24c Special Local Needs Registration of Carbaryl for Use on Oyster Beds.

TO: Anthony Britten, Chemical Review Manager
Betty Shackleford, Product Manager
Special Review and Reregistration Division

FROM: Thomas M. Steeger, Ph.D., Senior Biologist
Environmental Risk Branch IV/EFED (7507C)

Through: Betsy Behl, Branch Chief
Environmental Risk Branch IV/EFED (7507C)

The Environmental Fate and Effects Division (EFED) has completed its review of the materials submitted relative to the Section 24c Special Local Needs registration of carbaryl for use on oyster beds in Willapa Bay and Grays Harbor, Washington, to control ghost shrimp *(Callianassa californiensis*) and mud shrimp (*Upogebia pugettensis*). The documents included **1)** a report on concentrations of carbaryl and its degradate (1-naphthol) in marine sediments from sites treated with or adjacent areas treated with Sevin (Stonic 1999); **2)** a fact sheet on chemicals of special concern in Washington State; **3)** a memo from the State of Washington's Department of Ecology's review of data relevant to the environmental effects of applying Sevin™ to control burrowing shrimp in Willapa Bay and Grays Harbor oyster beds; **4)** a copy of the memorandum of agreement between the Washington State Department of Ecology, the Willapa/Grays Harbor Oyster Growers' Association and other state government and private organizations; and **5)** a Washington State Department of Ecology publication entitled Carbaryl Concentrations in Willapa Bay and Recommendations for Water Quality Guidelines (Johnson 2001). Except for more recent studies conducted by Washington State University and the Washington Department of Ecology, much of the older (pre-1996) data had procedural problems that limited the utility of the data. The more recent data indicate that carbaryl residues in the water column were generally at or below an effect threshold of 0.1 ug/L Although large carbaryl applications can affect water quality in areas distant from spray sites, the Washington Department of Ecology concluded that "no widespread effects from carbaryl would be expected in Willapa Bay after the end of the [carbaryl] application period."

Carbaryl has been used on approximately 600 acres of Willapa Bay and 200 acres of Grays Harbor at a rate of 7.5 to 10 lbs/acre/year since the 1960's. Carbaryl is applied as a wettable powder to tidelands at low low [Spring] tide primarily by helicopter; however, hand spraying is used in some instances. The label restricts aerial applications within 200 feet of a channel or slough; hand spraying is prohibited within 50 feet of a channel or slough.

The data collected and/or reviewed by the Washington Department of Ecology indicate that carbaryl residues drop below the level of quantitation (< 0.004 ug/L) approximately 6 weeks after application. While concentrations in nontarget areas immediately following the carbaryl application period are likely to inflict mortality to aquatic organisms, no data are provided to demonstrate that threatened and/or endangered species (*e.g.* salmonids) are adversely affected by the treatments to oyster beds.

While these documents provide additional information on the environmental fate and effects of carbaryl in estuarine/marine environments, EFED's review of Washington's Section 24c petition was based on the required guideline fate and effects data provided by the registrant in support of the reregistration of carbaryl. Although the EFED reregistration eligibility document (RED) for carbaryl does not estimate environmental concentrations for applications directly to tidelands for control of burrowing shrimp in oyster culture, it does discuss the use. Data submitted in support of reregistration (MRID 419826-06) indicate that estuarine/marine invertebrates will likely be impacted by this route of exposure and that certain species, *e.g.*, Dungeness crab (*Cancer magister*), may experience 100% mortality in the application area. However, the assessment goes on to note that effects on aquatic invertebrates will likely be temporary as most populations show signs of recovery within 2 months. Additionally, the chapter suggests that carbaryl applications that reduce the potential for drift to nontarget sites, such as direct injection of carbaryl into the sediment, may help mitigate nontarget effects.

Review of Submitted Literature

1) Screening Survey of Carbaryl (Sevin) and 1-naphthol Concentrations in Willapa Bay Sediments

The study was undertaken to determine the long-term persistence of carbaryl and 1-naphthol; more specifically, the study objectives were to:

- Determine if there are residues of carbaryl and its degradate 1-naphthol in the marine sediments at historically sprayed sites and unsprayed adjacent sites
- Monitor the depletion of these compounds in sediments following applications of Seven™.
- Measure concentrations of carbaryl in centrifuged sediment pore water.
- Determine drift potential.

The study was divided into two phases, pre-spray and post-spray. Sampling was conducted in Willapa Bay in areas deemed to be conducive to carbaryl persistence. Thus, areas with muddy and/or fine sediments were selected since they were believed to be more likely to retain both carbaryl and 1-naphthol. Sandy sediments were not believed to provide sufficient clay or organic material with which carbaryl and/or its degradate could sorb.

Pre-spray samples were collected from areas that had been sprayed in previous years or were adjacent to areas that had been sprayed in previously. A reference site, Nemah Oyster Reserve, was sampled as an area that had never been sprayed.

Post-spray samples were collected immediately following carbaryl treatment and also included areas adjacent to spray sites. Treated sites included areas that had been sprayed in years past in addition to the recent treatment. Sampling was typically conducted 2, 30 and 60 days after treatment (DAT). Sediment samples were collected using a stainless steel 17-cm diameter device that allowed sediment samples to be stratified into 0 - 2 cm, 2 - 7.5 cm, and 7.5 - 15 cm depths. Total organic carbon (TOC) and sediment size were also analyzed. Carbaryl and 1-naphthol residues were measured both in whole sediment and in centrifuged pore water. Quality assurance spiked sediment samples suggest considerable amount of variability in recovery of standards. The results may be negatively biased.

Based on the pre-spray study results, all of the historically sprayed sites, adjacent unsprayed sites and the reference site showed no carbaryl or 1-naphthol residues above the detection limit range of 21 to 58 ppb. One sample representing the shallowest area adjacent to historically sprayed beds had trace (29 ppb) residues of carbaryl.

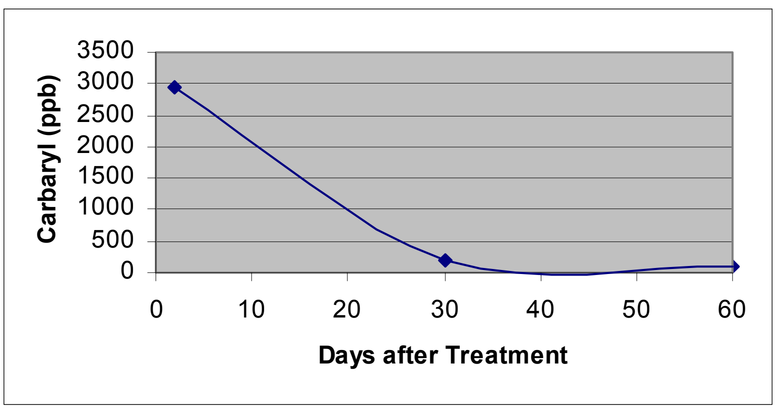


Figure 1 Average carbaryl concentrations in sediment collected from Willapa Bay at 2, 30 and 60 days after treatment.

Post-spray study results indicate that carbaryl concentrations at sprayed sites ranged from 2,000 to 3,400 ppb by 2 DAT, 180 to 220 ppb by 30 DAT, and 86 - 120 ppb by 60 DAT (**Figure 1**). Although, adjacent sites contained as much as 2,000 ppb 2 DAT, residues in sediment at all adjacent sites at 60 DAT were close to detection limits and ranged from 27 to 32 ppb.

Residues for the 1-naphthol ranged from detection limits to as high as 170 ppb at 2 DAT and by 30 DAT all samples had dropped to detection limits (22 to 33 ppb); one sample at 60 DAT contained naphthol at 34 ppb. The report concluded that once carbaryl degrades to 1-naphthol, the degradate appears to readily leave the sediment. It did not however, allow for the fact that the degradate could have been present in deeper reaches of the sediment. At adjacent sites, 1 naphthol ranged as high as 120 ppb 2 DAT and then dropped to below detection limits for the remaining sample periods.

Carbaryl residues in pore water were only detected 60 DAT and ranged from 0.57 to 1.15 ppb. It is difficult to understand though how the limit of detection for pore water was so much lower than that for sediment. Carbaryl was only detected in one sediment pore water sample collected from an adjacent site; the residue was close to the limit of detection at 0.05 ppb.

Analyses of sediment grain size and total organic carbon revealed that the clay-silt fraction of the post spray sites ranged from 25% to 73% while TOC ranged from 0.58% to 2.07%. Grain size and TOC were strongly correlated (Pearson R^2 range 0.89 - 0.96); however, there was no correlation between carbaryl residues and TOC.

The study concludes that carbaryl is clearly persistent in treatment areas with residues being detected up to 60 DAT. Additionally, residues in sites adjacent to treated areas indicate that drift does occur. Drift to nontarget sites was attributed to wind, depth of water sampled, and both surface and bottom water currents. Additionally, sediment pore water concentrations exceeded the National Academy of Sciences and Engineering water quality recommendation for carbaryl of 0.06 ppb. Additionally, historic sampling revealed that water column concentrations prior to application ranged as high as 9.2 ppb. The report notes that QA/QC standards suggested that actual pore water concentrations may be higher than those reported. It is uncertain how much naphthol was present in the water column; however, given that naphthol is more toxic than the parent, the potential affect of the residues on aquatic animals is a legitimate concern.

Finally the report compares the sediment residue data to available toxicity data on carbaryl and concludes that Dungeness crab larvae exposed to carbaryl at concentrations ranging from 0.1 to 10 ppb for 25-days exhibited both molting effects and mortality. Although no formal data were provided on the numbers of organisms affected; the author reports that marine fish and invertebrate mortality was observed 2 DAT. The author proposes that the incidental kills could serve as forage for other fish and foraging birds that would then bioaccumulate carbaryl in their tissues. The report further suggests that indirect effects, such as endocrine disruption and mutagenicity, are not sufficiently characterized and that coupled with direct effects and the potential for bioaccumulation in the food chain, carbaryl and 1-naphthol have the potential to impact threatened and/or endangered salmon stocks.

The study would have been more thorough had water column concentrations of carbaryl been measured. Given that the compound was applied using both aerial and hand-held sprayers, it is difficult to assess the affect of drift relative to application method. It would have also been helpful to know how representative the areas sampled were of the total areas treated in terms of TOC and grain size. Additionally, the limit of detection (25 - 35 ppb) was not sufficiently low to document residues in sediment and pore water that may have been sufficiently high to effect benthic invertebrates.

2) Chemicals of Special Concern in Washington State

Report published by the Washington Department of Ecology provides a brief overview of the environmental fate and effects of carbaryl. Although the overview has footnote numbers, no references were provided; therefore, data supporting carbaryl's characterization could not be verified. The report implies that carbaryl is relatively persistent and that recoveries of aquatic systems exposed to carbaryl have taken as long as 3 years. According to the overview, carbaryl is teratogenic, immunosuppressive, and degrades to carcinogenic compounds.

3) Washington Department of Ecology Review of Data Relevant to the Environmental Effects of Applying Carbaryl to Control Burrowing Shrimp in Willapa Bay and Grays Harbor Oyster Beds (1987).

The object of the Washington Department of Ecology review was to answer the following questions:

- How long do carbaryl and its primary hydrolysis product 1-naphthol persist in the water column?
- What concentrations of carbaryl and 1-naphthol in water are toxic to marine organisms?
- How long do carbaryl and 1-naphthol persist in the sediments?
- What concentrations of carbaryl and 1-naphthol in sediment are toxic to marine organisms?
- What are the effects on abundance and diversity of infauna?
- What are the effects on abundance and diversity of epifauna?
- What mortality is experienced by Dungeness crab and how does this affect the fishery?
- What mortality is experienced by fish?
- Are birds adversely affected?
- What are the potential ecological impacts of Sevin applications?

While the environmental fate studies on water column and sediment concentrations during and after application of carbaryl showed a decline in carbaryl and 1-naphthol concentrations, much of the data were discounted due to poor detection limits and procedural deficiencies. Open literature reviews of ecological effects revealed that carbaryl is more toxic to crustaceans than to molluscs or fish; however, the degradate 1-naphthol is less toxic to crustaceans than carbaryl but more toxic than the parent to molluscs and fish. Subacute effects of carbaryl were reported at concentrations below the detection limit (1 mg/L) of most of the monitoring studies reported; the report states that circumstantial evidence suggests the potential for toxic effects at or below 0.1 mg/L in sediment. Sublethal effects included reduced development of oysters and delayed molting of crab larvae, malformations in fish eggs and adults. Toxicity of carbaryl is reported to increase with temperature.

Although the report fails to conclusively resolve whether carbaryl and its 1-naphthol degradate are sufficiently persistent to effect aquatic life, it notes that the target population of burrowing shrimp take a number of years to recover. However, failure of a treated area to recover may be due to a number of factors and may not result exclusively on the toxicity of carbaryl or its degradate.

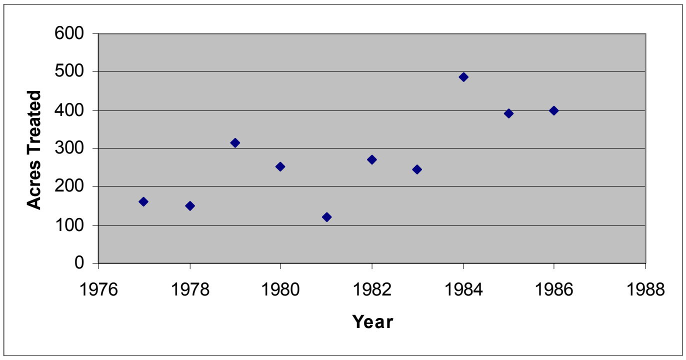


Figure 2. Number of acres treated with carbaryl in Willapa Bay over years.

Fisheries data collected on Willapa Bay from 1977 to 1986 show (**Figure 2**) that the number of acres treated with carbaryl increased each year. And that the number of crabs killed by carbaryl treatment also increased (**Figure 3**) as the number of acres treated increased. The number of crabs killed was significantly correlated (Pearson Correlation coefficient = 0.72; $p > rho = 0.0187$) with the number of acres treated. Over the observation period an average of 53 crabs (standard error = 13) were killed per acre. Follow-up studies by the University of Washington that [Dungeness] crab in treated areas are impacted but that further studies are required to establish population-level effects in Willapa Bay.

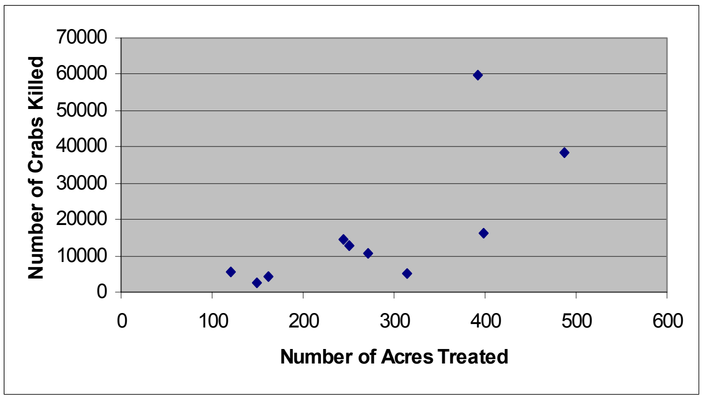


Figure 3. Number of crabs killed versus number of acres treated with carbaryl in Willapa Bay.

Mortalities to fish were limited to small specimens which were entrapped in shallow pools by the outgoing tide and directly exposed to carbaryl during treatment; however, the reviewed literature did not address the potential for indirect mortality.

Although no studies were conducted, the report concluded that likelihood of acute or chronic effects of carbaryl on birds was remote.

Whether there are broad ecological impacts associated with the use of carbaryl to control burrowing shrimp in Willapa Bay remains an uncertainty. The Environmental Impact Statement concluded that the use of carbaryl by the commercial oyster industry was not expected to cause significant impacts on the estuarine ecosystem when applied at current levels. It based this conclusion on the fact that:

- Carbaryl is not accumulated by any food chain component or transmitted to higher levels in the food chain.
- No chemically active radical group remains to contaminate the estuarine environment.
- Only a small percentage of the total intertidal lands are treated annually; 0.8% in Willapa Bay and 0.3% in Grays Harbor.

The report recommends though that further work be conducted to evaluate the persistence of carbaryl and 1-naphthol in sediment and to better document the effects of nontarget mortality.

4) Burrowing Shrimp Integrated Pest Management Memorandum of Agreement

The memorandum of agreement (MOA) was established between the Washington State Department of Ecology, Washington State Department of Agriculture, the Washington State Commission on Pesticide Registration, the Washington Department of Fish and Wildlife, the Willapa/Grays Harbor Oyster Growers Association, the Pacific Coast Shellfish Growers Association and the Pacific Shellfish Institute. The agreement acknowledges that while carbaryl and its 1-naphthol degradate affect nontarget species, are likely transported several hundred yards offsite by tidal action, and may persist for several weeks in the water column and sediments within Willapa Bay/Grays Harbor, treatment for burrowing shrimp is necessary if economic losses due to diminished oyster harvests are to be avoided. The agreement acknowledges that additional data on the environmental fate and effects of carbaryl are necessary and that alternative methods of control should be explored to mitigate adverse effects especially on threatened/endangered salmonids. The MOA establishes a process and time for the development of a "sustainable site-specific, environmentally sound and ecologically based [integrated] pest management plan for the control of burrowing." The MOA outlines criteria to be met, i.e., demonstration that burrowing shrimp populations have reached a size sufficient to inflict economic losses, before which carbaryl can be applied.

5) Carbaryl Concentrations in Willapa Bay and Recommendations for Water Quality Guidelines.

In the summer of 2000, the Washington State Department of Ecology initiated a study of Willapa Bay. The study was a follow-up on the Stonic (1999) study from 1996 to 1997 and concern that carbaryl persisted at a level of 0.7 ug/L. The objectives of the study were to:

- determine if there is a carbaryl background that persists in Willapa Bay water outside the July to August spray period;
- analyze carbaryl in other potential sources to Willapa Bay;
- achieve quantitation limits for carbaryl sufficiently low to evaluate the potential for causing toxicity to sensitive marine organisms;
- review the literature on carbaryl's effects on marine organisms and evaluate appropriate water quality guidelines for carbaryl in Willapa Bay.

Results from the study show that carbaryl was frequently detected in Willapa Bay up to 4 days after application to oyster beds and that carbaryl was transported several miles from the site of application. However, the study showed no evidence of carbaryl background in the Willapa Bay water column. Additionally, tributaries and cranberry bog drainages were not significant carbaryl sources. Carbaryl had dropped to levels below quantitation (0.004 ug/L) approximately 1 month after application

Based on a review of toxicity data on 35 marine species, the report recommended 0.06 ug/L as a probable safe level for marine organisms and a range of 0.1 to 0.7 ug/L as a potential effects threshold. The value of 0.06 ug/L was based on a National Academy of Science approach using an EC50 of 6 ug/L for inhibiting molting in Dungeness crab larvae divided by a 100X safety factor. The data collected from open literature suggests that carbaryl is more toxic to crustaceans and echinoderms than to fish, molluscs, or polychaetes. The study notes that while similar information was not collected on the 1 naphthol degradate, one study has shown it to be roughly twice as toxic to fish as the parent compound but less toxic to crustaceans. Carbaryl was detected at concentrations within the proposed potential effects threshold several miles from treatment areas up to several days following application. The report recommended that future water quality monitoring focus on the period during or immediately after carbaryl applications and that data are collected on carbaryl's 1-naphthol transformation product. Additionally, the report recommends that future effects testing include more sensitive test species and indigenous aquatic species that serve as prey for endangered/threatened species

References

Stonic, Cynthia. 1999. Screening Survey of Carbaryl (Sevin™) and 1-naphthol Concentrations in Willapa Bay Sediments. Washington State Department of Ecology. Publication No. 99-323.

Johnson, Art. 2001. Carbaryl Concentrations in Willapa Bay and Recommendations for Water Quality Guidelines. Washington State Department of Ecology. Environmental Assessment Program. Publication No. 01-03-005.

APPENDIX E3. REVIEW OF LITERATURE SUBMITTED TO REBUT THE USE OF CARBARYL TO CONTROL BURROWING SHRIMP IN WILLAPA BAY/GRAYS HARBOR.

In a study entitled "*Benthic Organisms State of Regeneration Two Years after Carbaryl Application in Willapa Bay*" conducted by Scott Mazzone and Michael McNamara (no date; no journal) to determine whether there are any statistical differences between regeneration of species in sprayed sites and the productivity of species in unsprayed sites, three sampling areas (A, B, C) in Willapa Bay, Washington, were selected. At each site, 25 m X 25 m square areas were identified and divided into 0.5 m square intervals. Twenty random sites of 0.5-m square were selected from area A (control) and 10 sampling sites each were selected from areas B and C (previously sprayed sites). All benthic organisms were identified and counted at each site. Burrow openings were also counted at each site to determine the relationship between the openings and the number of organisms present. Total number of species present (species richness) and their population sizes (abundance) were compared. A Shannon-Weiner index and a Species Evenness Index were also calculated. Results were compared using a two-tailed t-test. Additionally, the depth of the anoxic layer was noted at each site by collecting 10 measurements at each site. The number of species within the sprayed areas were averaged and then compared to the control.

According to the results "the control site was at a natural state of productivity. The benthic organisms were observed as having high levels of biodiversity and population. Evidence of generational succession existed in the control site. The indicator species (lugworms) showed a sustainable level of productivity, while littleneck clams (*Protothaca staminea*) and Orange Nemertean (*Tubulanus polymorphus*) were the dominant species. .

Both treated areas (B and C) "contained similar biodiversity to that of site A. The specific species populations were significantly lower with no evidence of generational succession. The indicator species showed a non-sustainable level of production; orange Nemertean were [sic] the dominant species." Species found in the control site were consistently more abundant than that of the sprayed sites and there did not appear to be any indication that the burrow openings reflect the amount of organisms for at each sample point. The Shannon-Wiener Index for treated versus control sites were significantly different ($P = 2.002 \times 10^{-7}$); the Species Evenness Index for the two sites were significantly different ($P=0.00001$), and the depth of the anoxic layer at the treated versus the control sites was significantly different ($P= 2.455 \times 10^{-15}$). Based on the study results, the authors conclude that the rate of regeneration of the areas that have been treated "does not support the current belief that regeneration of the affected organisms are approaching natural levels of productivity" and that "relatively low populations of the organisms again exposed to carbaryl will be exhausted throughout Willapa Bay.

In reviewing this study, it is unclear whether the control site (A) was similar to either of the treated sites. The authors used both salinity and temperature to determine the similarity; however, given that the study is examining benthic organisms, a more likely measure of comparability may have been sediment type and morphology. Based on the map that was provided, the reference site appears to be facing open ocean while the treated sites appear to be on a sheltered inlet of the bay. Furthermore, the distance of the study sites from the shore and the depth of water over each site is not reported. Although the report states that freshwater inputs, currents, winds, and sediment composition were also noted and found to be similar between sites, no data are provided to support this conclusion statistically.

Additionally, the study intends to compare three sites; however, the authors use a two-sample t-test to compare results. Also, it is not clear from the study whether the authors tested to see whether parametric statistics applied and/or whether it was appropriate to pool data from the treated sites. While the study purports to measure species richness and abundance, the authors make conclusions about sustainable levels of productivity and generational succession in the study sites and conclude that repeated applications of carbaryl will "exhaust" already compromised populations in the Willapa Bay as a whole.

Although the authors state that both treated areas (B and C) "contained similar biodiversity to that of site A" they report that the Shannon-Wiener Diversity Index was significantly different between the sites. According to the report figures, 5 different groups of animals (clams, ghost shrimp, lug worms, orange Nemertean, and a goby) were identified in the control area; 5 different groups of animals were also identified in the combined sites B and C (clams, ghost shrimp, lug worms, orange Nemerteans and mud shrimp). The apparent difference between the two sites appears to be in the number (abundance) of each organism. Since most of these are filter feeding organisms, it suggests that the availability of food (primary productivity) may have been a critical factor; however, the authors do not provide any information on plankton counts between the sampling areas.

Carbaryl had not been applied to the treated sites for 2 years and analyses of both water and sediment revealed no carbaryl residues; therefore, it cannot be concluded that repopulation of the sites was affected by carbaryl residues. Since insufficient information is provided to demonstrate the similarity of the sites to facilitate comparing treated versus untreated, it isn't possible to conclude that the reported differences in species diversity and abundance are a result of carbaryl treatment. It is clear though that based on the carbaryl reapplication intervals required by oyster growers in the bay, it requires roughly 6 years for burrowing shrimp populations to fully recover. However, this is not to say that carbaryl-treated areas remain a biological wasteland over those years. It is likely that recovery occurs in stages and that sere progression over the years accounts for differences in species diversity.

This report underscores the difficulty in conducting well-designed field studies that account for the many sources of variability that can affect a study's ability to establish causality. Insufficient detail is provided in the current study to suggest though that carbaryl applications to control burrowing shrimp in selected sites in the bay are likely to exhaust aquatic life within the bay. Given that the reapplication interval is roughly six years and the current study at best demonstrates that after two years a similar range of species exist in treated and untreated sites (that may or may not be comparable), there is no conclusive evidence to support concerns that carbaryl treatments are reducing the overall "natural productivity" of Willapa Bay.

In a second study entitled "*Imidacloprid Residues in Willapa Bay (Washington State) Water and Sediment Following Application for Control of Burrowing Shrimp*" by A. S. Felsot and J. R. Ruppert (Journal of Agric. food Chem 2002, 50, 4417 - 4423), imidacloprid residues were monitored after application to mudflats in Willapa Bay and sorption studies of bay sediments were conducted to test the hypothesis that fluctuations in water volumes associated with tidal changes dispersed residues to levels below detection limits. The residue monitoring was part of an efficacy study intended to compare imidacloprid (0.28, 0.56, 1.12 kg a.i./ha) with carbaryl (4.48 and 8.96 kg a.i./ha) after spraying with different rates and volumes of water (93.5 and 468 L/ha) applied by ground hand-boom sprayer. The study utilized a stratified random-block design with four replications; 10 possible insecticide treatments and 1 untreated control were randomly assigned to one of 11 plots (6.1 m x 6.1 m) in each of 4 blocks. Adjacent plots in each block were separated from one another by an untreated 6.1-m buffer.. The four experimental blocks were arranged in a line that ran parallel to the shoreline approximately m offshore. Tidal flow was approximately perpendicular to the long axis of the blocks. Water (collected as tide was coming in) and sediment (collected during low tide) were collected immediately after application and days 14 and 28 post-application from at various distances (0, 30, 61, 122 and 244 m) along a westerly transect from the plots. Sorption studies were conducted for C^{14}-labeled imidacloprid alone.

According to the paper, on the day following application, residues of both pesticides had dropped by greater than 96%. Within the next two weeks, both pesticides were recovered from the plots with levels close to the detection limits. Imidacloprid was still detected at 28 days after application, but carbaryl residues were below the detection limit. Residues on neither pesticide were detected in any sediment samples collected along the transect away from the plots in the direction of tidal flow. Comparing their results to those of the Department of Ecology (DOE) study, the authors note that the DOE had documented a 73% decline in carbaryl residues after 2 days and carbaryl residues were still detectable 60 days after application even though the Felsot and Ruppert studies had more sensitive detection limits.

In the water column, carbaryl residues peaked 10 minutes after application and could still be detected at concentrations ranging from 0.4 to 0.7 : g/L 28 days post-application. The report states however, that prior to application, carbaryl residues in the water were at 0.7 : g/L and suggests that the residues may have persisted from spraying in the previous year. Although the study does not specifically state that carbaryl residues persist because of the compound's ability to sorb to sediment, it claims that imidacloprid dissipates rapidly due to its low sorption potential. It is unclear however, that if carbaryl residues in sediment at the application site were close to the level of detection 2-weeks after application and were below levels of detection 28-days post-application, what exactly is serving as a source for the carbaryl. The report notes that the limit of detection for carbaryl (6 : g/Kg) in sediment may have been sufficiently high not to detect a potential sink for the compound; however, the dissipation half life of carbaryl in water and soil, based on laboratory studies, does not support the contention that carbaryl residues of 0.7 : g/L in the water column were a result of the previous years application. Although, the carbaryl residues detected in the water are an order-of-magnitude greater than reported detection limits (0.06 - 0.09 : g/L) for the study, the source of the carbaryl remains speculative.

In reviewing this study, it is unclear why carbaryl residues were detected in the treatment area prior to treatment. The results of this study are inconsistent with the results of the DOE study (2000) showing that carbaryl had dropped to levels below quantitation (0.004 : g/L) approximately 1 month after application. Therefore, it is uncertain how background levels of carbaryl reported in this study can be accounted for.

APPENDIX F. ECOLOGICAL RISK ASSESSMENT

Risk characterization integrates the results of exposure and ecotoxicity data to evaluate the likelihood of adverse ecological effects, using for this purpose the risk quotient (RQ) method. RQs are calculated by dividing estimated environmental concentrations (EECs) of the pesticide by acute and chronic toxicity values. Although EECs are primarily based on the maximum label application rates for that pesticide, EECs based on a Quantitative Use Assessment (QUA) average and maximum reported (Doane data) use rates were also considered in this assessment. The 74 carbaryl registered uses and application specifications (methods, maximum label use rates, number of applications, and interval between applications) used in the risk assessment for terrestrial organisms are summarized in **Table 1**.

The ecotoxicity test values (*i.e.*, measurement endpoints) used in the acute and chronic risk quotients are derived from the results of required studies. Examples of ecotoxicity values derived from the results of short-term laboratory studies that assess acute effects are: (1) LC_{50} (fish and birds) (2) LD_{50} (birds and mammals) (3) EC_{50} (aquatic plants and aquatic invertebrates) and (4) EC_{25} (terrestrial plants). Examples of toxicity test effect levels derived from the results of long-term laboratory studies that assess chronic effects are: (1) NOEC (birds, fish, and aquatic invertebrates) (2) NOEC (birds, fish and aquatic invertebrates) and (3) MATC (fish and aquatic invertebrates). For birds, mammals, and all aquatic organisms, the NOEC is the ecotoxicity test value used in assessing chronic risk. Other values may be used when justified. **Table 2** lists the measurement endpoints used for assessing the risk associated with the use of carbaryl to terrestrial and aquatic nontarget organisms. In addition, the Agency considers any incident data that are submitted concerning adverse effects on nontarget species to further characterize risk.

RQs are compared to levels of concern (LOC) criteria used by OPP for determining potential risk to nontarget organisms and the subsequent need for possible regulatory action. The criteria indicate that a pesticide used as directed has the potential to cause adverse effects on nontarget organisms. Levels of concern currently address the following risk presumption categories: (1) acute, *i.e.*, potential for acute risk; regulatory action may be warranted in addition to restricted use classification, (2) acute restricted use, *i.e.*, potential for acute risk, but may be mitigated through restricted use classification; (3) acute endangered species, *i.e.*, potential for acute risk to endangered species; regulatory action may be warranted; (4) chronic risk, *i.e.*, the potential for chronic risk is high, and regulatory action may be warranted. Currently, EFED does not perform assessments for chronic risk to plants, acute or chronic risks to nontarget insects, or chronic risk from granular/bait formulations to birds or mammals. Risk presumptions and the corresponding risk quotients and levels of concern are summarized in **Tables 3a** through **3c**.

Table 1. Uses, application rates, and application intervals used in the risk assessment for carbaryl[1]

Uses	Non-granular Formulations				Granular/ Bait
Use/Crop	Appl Rate (lb ai/A)	No. Appl	Interval (days)	Max lb/ year	Rate (lb ai/A)
Asparagus	2	5	3	10	2
Broccoli, Brussels sprouts, cauliflower, collards, cabbage, mustard greens, lettuce, parsley, spinach, celery, Swiss chard, (beets, carrots, potato, radish, horseradish, parsnip, rutabaga, salsify	2	3	7	6	2
Corn (field, pop)	2	4	14	8	-----
Sorghum	2	3	7	6	-----
Rice (tadpole shrimp)	1.5	2	7	4	-----
Corn (sweet)	2	8	3	16	2
Flax, millet, wheat, pasture, grasses, noncropland,	1.5	2	14	3	-----
Cucurbits (melons, cucumbers, squash, pumpkin)	1	6	7	6	-----
Alfalfa, clover	1.5	8	30	12	-----
Rangeland	1	1	----	1	-----
Solanaceous crops (tomato, pepper, eggplant), tobacco	2	4	7	8	2
Legumes (beans, peas, lentils, cowpeas, soybean)	1.5	4	7	6	-----
Peanuts, sweet potatoes	2	4	7	8	-----
Sugar beets	1.5	2	14	4	1.5
Small fruits & berries (grape, blueberry, caneberry, cranberry, strawberry)	2	5	7	10	-----
Strawberry	----	----	----	-----	2
Sunflower	1.5	2	7	3	-----
Citrus (orange, lemon, grapefruit)	5, 16	4	14	20	-----
Olives	7.5	2	14	15	-----
Pome fruits (apple, pear)	3	5	14	15	-----
Stone fruits (peach, apricot, cherry, nectarine, plum/prune)	4	3	14	14	-----
Tree nuts (almond, chestnut, filbert, pecan, pistachios, walnut)	5	3	7	15	-----
Forested areas (non-urban)	1	2	7	2	-----
Trees and ornamentals	1	6	7	6	9.1
Turfgrass	8	2	7	16	9.1
Ticks	-----		-----		9.1
Oyster beds	1		-----	10	

[1] Aerial and ground application methods for all uses

Table 2. Terrestrial and aquatic measurement endpoints used in determining risk of carbaryl to nontarget organisms.

Measurement Endpoint	Toxicity Value
Avian acute oral LD_{50}	No assessment done since carbaryl is practically nontoxic to birds on an acute exposure basis
Avian subacute dietary LC_{50}	No assessment done since carbaryl is practically nontoxic to birds on a subacute dietary exposure basis
Avian chronic (reproduction) NOAEC	mallard duck = 300 ppm
Mammalian acute oral LD50	rat = 301 mg/kg
Mammalian chronic (reproduction) NOAEC	rat = 75 ppm
Freshwater fish acute LC_{50}	salmon = 0.25 ppm
Freshwater fish acute (TEP) LC_{50}	trout = 1.2 ppm
Freshwater fish chronic NOAEC	minnow = 0.21 ppm
Freshwater invertebrate acute LC_{50}	stonefly = 5.1 ppb
Freshwater invertebrate chronic NOAEC	waterflea = 1.5 ppb
Estuarine/marine fish acute LC_{50}	minnow = 2.6 ppm
Estuarine/marine mollusc acute EC_{50}	oyster = 2.7 ppm
Estuarine/marine shrimp EC_{50}	mysid = 5.7 ppb
Estuarine/marine fish chronic NOAEC	no data
Estuarine/marine aquatic invertebrate chronic NOAEC	no data

Table 3a. Risk presumptions for terrestrial animals

Risk Presumption	Risk Quotient (RQ)	Level of Concern (LOC)
	Birds	
Acute Risk	EEC[1]/LC_{50} or LD_{50}/sqft[2] or LD_{50}/day[3]	0.5
Acute Restricted Use	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day (or LD_{50} < 50 mg/kg)	0.2
Acute Endangered Species	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day	0.1
Chronic Risk	EEC/NOAEC	1
	Wild Mammals	
Acute Risk	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day	0.5
Acute Restricted Use	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day (or LD_{50} < 50 mg/kg)	0.2
Acute Endangered Species	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day	0.1
Chronic Risk	EEC/NOAEC	1

[1] abbreviation for Estimated Environmental Concentration (ppm) on avian/mammalian food items

[2] $\frac{mg/ft^2}{LD_{50} * \text{wt. of bird}}$ [3] $\frac{\text{mg of toxicant consumed/day}}{LD_{50} * \text{wt. of bird}}$

Table 3b. Risk presumptions for aquatic animals

Risk Presumption	RQ	LOC
Acute Risk	EEC[1]/LC_{50} or EC_{50}	0.5
Acute Restricted Use	EEC/LC_{50} or EC_{50}	0.1
Acute Endangered Species	EEC/LC_{50} or EC_{50}	0.05
Chronic Risk	EEC/NOAEC	1

[1] EEC = (ppm or ppb) in water

Table 3c. Risk presumptions for plants

Risk Presumption	RQ	LOC
Plant Inhabiting Terrestrial and Semi-Aquatic Areas		
Acute Risk	EEC[1]/EC_{25}	1
Acute Endangered Species	EEC/EC_{05} or NOAEC	1
Aquatic Plants		
Acute Risk	EEC[2]/EC_{50}	1
Acute Endangered Species	EEC/EC_{05} or NOAEC	1

[1] EEC = lbs a.i./A
[2] EEC = (ppb or ppm) in water

Exposure and Risk to Nontarget Terrestrial Animals

For nongranular pesticide applications (*e.g.*, liquid, dust), the estimated environmental concentrations (EECs) on food items following product application are compared to LC_{50} values to assess risk. The predicted 0-day maximum and mean residues of a pesticide that may be expected to occur on selected avian or mammalian food items immediately following a direct single application at 1 lb a.i./A are tabulated in **Table 4**.

Table 4. Estimated environmental concentrations (EECs) on avian and mammalian food items (ppm) following a single application at 1 lb a.i./A)

Food Items	EEC (ppm) Predicted Maximum Residue[1]	EEC (ppm) Predicted Mean Residue[1]
Short grass	240	85
Tall grass	110	36
Broadleaf/forage plants and small insects	135	45
Fruits, pods, seeds, and large insects	15	7

[1] Predicted maximum and mean residues are for a 1 lb a.i./a application rate and are based on Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994).

Avian Acute and Chronic Risk

Risk from Exposure to Nongranular Products

Based on an avian subacute dietary LC_{50} of greater than 5,000 ppm (**Appendix D1**), with zero mortality observed at this concentration for the four avian species tested, carbaryl is classified as practically nontoxic to birds. Since the acute toxicity measurement endpoint exceeded the highest required test dose, *i.e.*, 5000 ppm, acute risk quotient values have not been calculated and acute risk to birds is assumed to lie below the established level of concern, *i.e.*, RQ < 0.1.

Based on an avian NOAEC of 300 ppm and maximum label application rates, for birds feeding on short grasses the avian chronic risk LOC is exceeded for all nongranular uses (**Table 5a**) except rangeland. For tall grass feeders, the avian chronic LOC is exceeded for 55% of the modeled use categories. For birds feeding on broadleaf/forage plants and small insects the avian chronic LOC is exceeded for 60% of the use categories. The chronic LOC for birds feeding on fruits, pods, seeds, and large insects is not exceeded for any of the carbaryl uses.

In addition to maximum label use rates, avian chronic RQs were also calculated for nongranular carbaryl using QUA average use rates (**Table 5b**) for 70 use sites, as well as maximum reported (Doane data) use rates for 42 use sites (**Table 5c**). When RQs are based on average application rates, the chronic risk LOC is exceeded for 34 of 70 (49%) uses. For RQs based on maximum reported use rates, the chronic risk LOC is met or exceeded for 81% of the uses.

Table 5a. Avian chronic RQs for multiple applications of nongranular carbaryl (broadcast) based on a mallard duck NOAEC of 300 ppm, and maximum label application rates.

Uses	Appl. Rate No. Appl. Interval	Food Items	Maximum EEC [a] (ppm)	NOAEC (ppm)	Chron. RQ (EEC/ NOAEC)
Citrus (orange, lemon, grapefruit)	5 lb ai/A 4 appl 14 days	Short grass Tall grass Broadleaf plants, sm. ins. Fruit, seeds, lg. insects	1294 593 728 81	300	4.31 [b] 1.98 [b] 2.42 [b] 0.27
Citrus (California)	16 lb ai/A 1 appl	Short grass Tall grass Broadleaf plants, sm. ins. Fruit, seeds, lg. insects	3840 1760 2160 240	300	12.8 [b] 5.87 [b] 7.20 [b] 0.80
Olives	7.5 lb ai/A 2 appl 14 days	Short grass Tall grass Broadleaf plants, sm. ins. Fruit, seeds, lg. insects	1931 885 1086 121	300	6.44 [b] 2.95 [b] 3.62 [b] 0.40
Pome fruits (apple, pear)	3 lb ai/A 5 appl 14 days	Short grass Tall grass Broadleaf plants, sm. ins. Fruit, seeds, lg. insects	777 356 437 49	300	2.59 [b] 1.19 [b] 1.46 [b] 0.16
Stone fruits (peaches, apricot, cherry, nectarine, plum/prune)	4 lb ai/A 3 appl 14 days	Short grass Tall grass Broadleaf plants, sm. ins. Fruit, seeds, lg. insects	1035 474 582 65	300	3.45 [b] 1.58 [b] 1.94 [b] 0.22

Uses	Appl. Rate No. Appl. Interval	Food Items	Maximum EEC [a] (ppm)	NOAEC (ppm)	Chron. RQ (EEC/ NOAEC)
Tree nuts (almond, chestnut, filbert, pecan, pistachios, walnut)	5 lb ai/A	Short grass	1612	300	5.37 [b]
	3 appl	Tall grass	739		2.46 [b]
	7 days	Broadleaf plants, sm. ins.	907		3.02 [b]
		Fruit, seeds, lg. insects	101		0.34
Corn (field, pop)	2 lb ai/A	Short grass	518	300	1.73 [b]
	4 appl	Tall grass	238		0.79
	14 days	Broadleaf plants, sm. ins.	291		0.97
		Fruit, seeds, lg. insects	32		0.11
Corn (sweet)	2 lb ai/A	Short grass	1106	300	3.69 [b]
	8 appl	Tall grass	507		1.69 [b]
	3 days	Broadleaf plants, sm. ins.	622		2.07 [b]
		Fruit, seeds, lg. insects	69		0.23
Rice, sunflower	1.5 lb ai/A	Short grass	457	300	1.52 [b]
	2 appl	Tall grass	210		0.70
	7 days	Broadleaf plants, sm. ins.	257		0.86
		Fruit, seeds, lg. insects	29		0.10
Sugar beets, wheat, millet, flax, pasture, grasses, noncropland	1.5 lb ai/A	Short grass	386	300	1.29 [b]
	2 appl	Tall grass	177		0.59
	14 days	Broadleaf plants, sm. ins.	217		0.72
		Fruit, seeds, lg. insects	24		0.08
Asparagus	2 lb ai/A	Short grass	1051	300	3.50 [b]
	5 appl	Tall grass	481		1.60 [b]
	3 days	Broadleaf plants, sm. ins.	591		1.97 [b]
		Fruit, seeds, lg. insects	66		0.22
Broccoli, Brussels sprouts, cabbage, cauliflower, collards, mustard greens, celery, lettuce, parsley, spinach, beets, potato, carrot, horseradish, parsnip, rutabaga, salsify, sorghum	2 lb ai/A	Short grass	645	300	2.15 [b]
	3 appl	Tall grass	296		0.99
	7 days	Broadleaf plants, sm. ins.	363		1.21 [b]
		Fruit, seeds, lg. insects	40		0.13
Cucurbits (cucumbers, melons, squash, pumpkin), trees and ornamentals	1 lb ai/A	Short grass	329	300	1.10 [b]
	6 appl	Tall grass	151		0.50
	7 days	Broadleaf plants, sm. ins.	185		0.62
		Fruit, seeds, lg. insects	21		0.07
Solanaceous (tomato, pepper, eggplant), peanuts, tobacco, sweet potato	2 lb ai/A	Short grass	654	300	2.18 [b]
	4 appl	Tall grass	300		1.00 [b]
	7 days	Broadleaf plants, sm. ins.	368		1.23 [b]
		Fruit, seeds, lg. insects	41		0.14
Legumes (beans, peas, lentils, cowpeas, soybeans)	1.5 lb ai/A	Short grass	491	300	1.64 [b]
	4 appl	Tall grass	225		0.75
	7 days	Broadleaf plants, sm. ins.	276		0.92
		Fruit, seeds, lg. insects	31		0.10
Small fruits & berries (grapes, blueberry, caneberry, cranberry, strawberry)	2 lb ai/A	Short grass	657	300	2.19 [b]
	5 appl	Tall grass	301		1.00 [b]
	7 days	Broadleaf plants, sm. ins.	369		1.23 [b]
		Fruit, seeds, lg. insects	41		0.14
Alfalfa, clover	1.5 lb ai/A	Short grass	361	300	1.20 [b]
	8 appl	Tall grass	166		0.55
	30 days	Broadleaf plants, sm. ins.	293		0.98
		Fruit, seeds, lg. insects	23		0.08
Rangeland	1 lb ai/A	Short grass	240	300	0.80
	1 appl	Tall grass	110		0.37
		Broadleaf plants, sm. ins.	135		0.45
		Fruit, seeds, lg. insects	15		0.05

Uses	Appl. Rate No. Appl. Interval	Food Items	Maximum EEC [a] (ppm)	NOAEC (ppm)	Chron. RQ (EEC/ NOAEC)
Forested areas (non-urban)	1 lb ai/A	Short grass	305	300	1.02 [b]
	2 appl	Tall grass	140		0.47
	7 days	Broadleaf plants, sm. ins.	171		0.57
		Fruit, seeds, lg. insects	19		0.06
Turfgrass	8 lb ai/A	Short grass	2439	300	8.13 [b]
	2 appl	Tall grass	1118		3.73 [b]
	7 days	Broadleaf plants, sm. ins.	1372		4.57 [b]
		Fruit, seeds, lg. insects	152		0.51

[a] Predicted maximum residues are for a 1 lb a.i./a application rate and are based on Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994).
[b] Exceeds chronic level of concern (RQ $ 1.0)

Table 5b. Avian chronic risk quotients[a] for multiple applications of nongranular carbaryl based on a mallard duck NOAEC of 300 ppm and QUA average application rates for 70 uses

Use site (Appl. Rate [lb ai/A], No. Applications, Interval)	Chronic RQ (EEC/NOAEC)	Use Site (Appl. Rate [lb ai/A], No. Applications, Interval)	Chronic RQ (EEC/NOAEC)
Alfalfa (1.1, 1)	0.89	Nectarines (3.8, 1)	3.04 [b]
Almonds (2.1, 1)	1.68 [b]	Okra (1.9, 1)	1.52 [b]
Apples (1.2, 1)	0.96	Olives (5.3, 1)	4.24 [b]
Asparagus (0.9, 1)	0.72	Oranges (3.4, 1)	2.72 [b]
Beans, Dry (0.5, 1)	0.40	Pasture (0.9, 1)	0.72
Beans, Lima, Fresh (0.9, 1)	0.72	Peaches (1.0, 3, 7)	1.07 [b]
Beans, Snap, Fresh (0.9, 2, 7)	0.91	Peanuts (0.8, 1)	0.64
Beans, Snap, Processed (0.7, 2, 7)	0.71	Pears (1.0, 1,2	0.80
Beets (0.5, 1)	0.40	Pears, Dry (1.0, 1)	0.80
Blackberries (1.7, 1)	1.36 [b]	Peas, Green (1.5, 1)	1.20 [b]
Blueberries (1.7, 1)	1.36 [b]	Pecans (1.4, 2)	2.10 [b]
Broccoli (0.8, 1)	0.64	Peppers, Bell (0.9, 2)	1.35 [b]
Brussels Sprouts (0.9, 1)	0.72	Peppers, Sweet (1.3, 1)	1.04 [b]
Chinese Cabbage (0.2, 1)	0.16	Pistachios (3.6, 1)	2.88 [b]
Fresh Cabbage (1.0, 2, 7)	1.02 [b]	Plums (3.8, 1)	3.04 [b]
Cantaloupes (0.8, 1)	0.64	Potatoes (0.8, 2)	1.20 [b]
Carrots (0.9, 2, 7)	0.91	Pumpkins (2.0, 2)	2.99 [b]
Cauliflower (1.1, 1)	0.88	Raspberries (2.8, 1)	2.24 [b]
Celery (1.0, 2, 7)	1.02 [b]	Rice (1.1, 1)	0.88
Cherries (1.9, 1)	1.52 [b]	Sorghum (1.1, 1)	0.88
Citrus, other (1.8, 2, 14)	1.55 [b]	Soybeans (0.9, 1)	0.72
Corn, Field (1.0, 1)	0.80	Squash (1.4, 1)	1.12 [b]
Cranberries (2.0, 1)	1.60 [b]	Strawberries (1.4, 2)	2.10 [b]
Cucumbers (1.1, 1)	0.88	Sugar Beets (1.3, 1)	1.04 [b]
Cucumbers, Processed (0.6, 2, 7)	0.61	Sunflower (0.7, 1)	0.32
Eggplant (1.0, 2, 7)	1.02 [b]	Sweet Corn, Fresh (1.3, 3, 3)	1.97 [b]
Flax (1.1, 1)	0.88	Sweet Potatoes (1.6, 1)	1.28 [b]
Grapefruit (1.4, 2, 14)	1.20 [b]	Tobacco (1.1, 2,7)	1.12 [b]
Grapes (1.4, 2, 7)	1.42 [b]	Tomatoes, Fresh (0.7, 3, 7)	0.75
Hay (0.8, 1)	0.64	Tomatoes, Processed (1.2, 1)	0.96
Hazelnuts (2.5, 1)	2.00 [b]	Walnuts (1.9, 1)	1.52 [b]
Lemons (2.7, 1)	2.16 [b]	Watermelons (0.5, 1)	0.40
Lettuce (1.1, 1)	0.88	Wheat, Spring (0.6, 1)	0.48
Lots/Farmsteads (0.4, 2, 14)	0.68	Wheat, Winter (0.8, 1)	0.64
Melons (0.7, 1)	0.56	Woodland (0.7, 1)	0.32

[a]Only the highest RQs -- i.e. those based on short grass EECs -- are included in this table. [b] Exceeds chronic level of concern (RQ $ 1.0)

Table 5c. Avian chronic risk quotients[1] for multiple applications of nongranular carbaryl based on a mallard duck NOAEC of 300 ppm, and maximum reported use rates (Doane data) for 42 use sites

Use site [appl.rate (lb ai/A), No. appl]	Chronic RQ (EEC/NOAEC)	Use Site [appl.rate (lb ai/A) No. appl]	Chronic RQ (EEC/NOAEC)
Alfalfa (1.5, 1)	1.2 [b]	Peaches (5,1)	4.0 [b]
Almonds (4, 1)	3.2 [b]	Peanuts (2, 1)	1.6 [b]
Apples (3.2, 1)	2.6 [b]	Pears (2, 1)	1.6 [b]
Apricots (4, 1)	3.2 [b]	Pecans (3, 2, 7)	3.1 [b]
Asparagus (4, 1)	3.2 [b]	Peppers (2, 1)	1.6 [b]
Beans, Lima, (1.3,1)	1.0 [b]	Pistachios (5, 1)	4.0 [b]
Beans, snap (1.6,1)	1.3 [b]	Plums (4, 1)	3.2 [b]
Cabbage (2,1)	1.6 [b]	Potatoes (1.5, 1)	1.2 [b]
Canola (0.5, 1)	0.4	Pumpkins (1.5, 1)	1.2 [b]
Cantaloupe (1.2, 1)	1.0 [b]	Rice (1.3, 1)	1.0 [b]
Carrots (0.8, 1)	0.6	Sorghum (0.5, 1)	0.4
Cauliflower (1, 1)	0.8	Squash (1.2, 1)	1.0 [b]
Celery (2, 1)	1.6 [b]	Sugar Beets (1.2, 1)	1.0 [b]
Cherries (5, 1)	4.0 [b]	Sunflower (1, 1)	0.8
Corn, Field (1.5, 2, 14)	1.3 [b]	Strawberries (2,1)	1.6 [b]
Cucumbers (1, 1)	0.8	Sweet Corn (1.5, 2, 3)	1.9 [b]
Grapefruit (12.8, 1)	10.2 [b]	Tobacco (2, 1)	1.6 [b]
Grapes (2.5,1)	2.0 [b]	Tomatoes (2,1)	1.6 [b]
Lemons (8,1)	6.4 [b]	Walnuts (4, 1)	3.2 [b]
Lettuce (1, 1)	0.8	Watermelons (2, 1)	1.6 [b]
Oranges (15, 1)	12.0 [b]	Wheat (1,1)	0.8

[a]Only the highest RQs -- i.e. those based on short grass EECs -- are included in this table.
[b] Exceeds chronic level of concern (RQ $ 1.0)

Risk from Exposure to Granular Products

Birds may be exposed to granular pesticides by ingesting granules when foraging for food or grit. Birds may also be exposed by other routes, such as by walking on exposed granules or by drinking water contaminated with granules. The number of lethal doses (LD_{50}) that are available within one square foot immediately after application (LD_{50}/ft^2) is used as the risk quotient for granular/bait products. Typically, risk quotients are calculated for birds in three separate weight classes: 1000 g (*e.g.* waterfowl), 180 g (*e.g.* upland gamebirds), and 20 g (*e.g.*, songbirds).

Based on a mallard LD_{50} greater than 2,000 mg/kg, technical carbaryl can be classified as slightly to practically nontoxic to birds on an acute exposure basis. LD_{50} values for carbaryl as low as 16.2 mg/kg and 56.2 mg/kg have been reported for the starling and the red-winged blackbird, respectively (Schafer *et al.*, 1983). Although these data are based on simple screening tests, and are therefore not reliable for risk assessment purposes, they do suggest that passerine birds may be significantly more sensitive to carbaryl exposure than non-passerine birds. The registrant is strongly encouraged to submit acute oral toxicity tests with passerine avian species. Because of the low acute oral toxicity of carbaryl to mallard ducks though, risk from exposure to granular products is expected to be minimal (RQ < 0.1).

Mammalian Acute and Chronic Risk

Estimating the potential for adverse effects to wild mammals is based upon EFED's draft 1995 SOP of mammalian risk assessments and methods used by Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994). The concentration of carbaryl in the diet that is expected to be acutely lethal to 50% of the test population (LC_{50}) is determined by dividing the LD_{50} value (usually rat LD_{50}) by the % (decimal of) body weight consumed. A risk quotient is then determined by dividing the EEC by the derived LC_{50} value. Risk quotients are calculated for three separate weight classes of mammals (15, 35, and 1000 g), each presumed to consume four different kinds of food (grass, forage, insects, and seeds). The acute risk quotients for broadcast applications of nongranular products are tabulated below.

Risk from Exposure to Nongranular Products

short grass

The mammalian acute risk LOC is exceeded for all registered nongranular carbaryl uses, at maximum label application rates, for short grass feeders with a daily food consumption equal to 95% and 66% of their body weight, with RQ values ranging from 0.76 to 12 and from 0.53 to 8.4, respectively (**Table 6**). The acute risk LOC for herbivores consuming daily 15% of their body weight are exceeded for 8 out of 20 (40%) of the use categories (RQs: 0.52 - 1.91). The acute endangered species LOC is exceeded for all herbivores.

Broadleaf/forage plants and small insects

The acute risk LOC is exceeded for all nongranular carbaryl uses except rangeland for small mammals feeding on broadleaf/forage plants and small insects, with RQs in the 0.54 - 6.82 range for mammals with a daily food consumption equal to 95% of their body weights (**Table 6**). Acute risk LOC is also exceeded for 75% of the use categories for mammals consuming 66% of their body weights (RQs: 0.56 to 4.74). For mammals consuming 15 % of their body weight, the acute risk LOC is reached or exceeded for olives and turfgrass (RQs: 0.54 - 0.68). RQs equal or exceed the acute restricted use or the endangered species LOCs for most other uses except cucurbits, trees, ornamentals, rangeland, and forested areas.

Fruit, pods, seeds, and large insects

The acute risk LOC is only exceeded in citrus for small mammals consuming 95% (RQ = 0.76) and 66% (RQ = 0.53) of these food items. For mammals that consume 15% of their body weight, the acute risk LOC is not exceeded for any use; however, the acute endangered species LOC is exceeded for citrus.

Table 6. Mammalian (herbivore/insectivore) acute risk quotients for multiple applications of nongranular carbaryl (broadcast) based on a rat LD_{50} of 301 mg/kg and maximum label use rates.

Uses, Application Rate, No. Applications, Interval	Body Wt (g)	% Body Weight Con_ sumed	LC_{50} (LD_{50}/% Body Wt Con_ sumed	EEC: Short Grass (ppm)	EEC: Forage & Small Insects (ppm)	EEC: Fruit, Seeds, Lg Insects (ppm)	Acute RQ: Short Grass	Acute RQ: Forage & Small Insects	Acute RQ: Large Insects
Citrus, 5 lb ai/A,	15	95	316.84				4.08 [a]	2.29 [a]	0.26 [b]
4 appl, 14 days	35	66	456.06	1294.49	728.15	80.91	2.83 [a]	1.60 [a]	0.18 [c]
	1000	15	2006.67				0.65 [a]	0.36 [b]	0.04
Citrus (California), 16 lb	15	95	316.84				12.1 [a]	6.82 [a]	0.76 [a]
ai/A, 1 appl	35	66	456.06	3840.00	2160.00	240.00	8.41 [a]	4.74 [a]	0.53 [a]
	1000	15	2006.67				1.91 [a]	1.08 [a]	0.12 [c]
Olives, 7.5 lb ai/A	15	95	316.84				6.10 [a]	3.43 [a]	0.38 [b]
2 appl, 14 days	35	66	456.06	1931.43	1086.43	120.71	4.24 [a]	2.38 [a]	0.26 [b]
	1000	15	2006.67				0.96 [a]	0.54 [a]	0.06
Pome fruits (apples, etc.), 3	15	95	316.84				2.45 [a]	1.38 [a]	0.15 [c]
lb ai/A, 5 appl,	35	66	456.06	776.71	436.90	48.54	1.70 [a]	0.96 [a]	0.11 [c]
14 days	1000	15	2006.67				0.39 [b]	0.22 [b]	0.02
Stone fruits (peaches, etc.), 4	15	95	316.84				3.26 [a]	1.84 [a]	0.20 [b]
lb ai/A, 3 appl,	35	66	456.06	1035.21	582.31	64.70	2.27 [a]	1.28 [a]	0.14 [c]
14 days	1000	15	2006.67				0.52 [a]	0.29 [b]	0.03
Tree nuts (pistachios, etc.), 5	15	95	316.84				5.09 [a]	2.86 [a]	0.32 [b]
lb ai/A, 3 appl, 7 days	35	66	456.06	1611.88	906.68	100.74	3.53 [a]	1.99 [a]	0.22 [b]
	1000	15	2006.67				0.80 [a]	0.45 [b]	0.05
Corn, field, 2 lb ai/A	15	95	316.84				1.63 [a]	0.92 [a]	0.10 [c]
4 appl, 14 days	35	66	456.06	517.79	291.26	32.36	1.14 [a]	0.64 [a]	0.07
	1000	15	2006.67				0.26 [b]	0.15 [c]	0.02
Corn, sweet, 2 lb ai/A	15	95	316.84				3.49 [a]	1.96 [a]	0.22 [b]
8 appl, 3 days	35	66	456.06	1105.64	621.93	69.10	2.42 [a]	1.36 [a]	0.15 [c]
	1000	15	2006.67				0.55 [a]	0.31 [b]	0.03
Rice (tadpole shrimp),	15	95	316.84				1.44 [a]	0.81 [a]	0.09
sunflower, 1.5 lb ai/A, 2 appl,	35	66	456.06	457.28	257.22	28.58	1.00 [a]	0.56 [a]	0.06
7 days	1000	15	2006.67				0.23 [b]	0.13 [c]	0.01
Sugar beets, wheat, millet,	15	95	316.84				1.22 [a]	0.69 [a]	0.08
flax, pasture, grasses,	35	66	456.06	386.29	217.29	24.14	0.84 [a]	0.48 [b]	0.05
noncropland 1.5 lb ai/A, 2 appl, 14 days	1000	15	2006.67				0.19 [c]	0.11 [c]	0.01
Asparagus, 2 lb ai/A, 5 appl,	15	95	316.84				3.32 [a]	1.87 [a]	0.21 [b]
3 days	35	66	456.06	1050.51	590.91	65.66	2.30 [a]	1.30 [a]	0.14 [c]
	1000	15	2006.67				0.52 [a]	0.29 [b]	0.03
Cucurbits (cucumbers melons, squash, etc.), trees &	15	95	316.84				1.04 [a]	0.58 [a]	0.06
ornamentals, 1 lb ai/A, 6	35	66	456.06	328.74	184.91	20.55	0.72 [a]	0.41 [b]	0.05
appl, 7 days	1000	15	2006.67				0.16 [c]	0.09	0.01
Solanaceous (peppers, tomatoes, eggplant), sweet	15	95	316.84				2.06 [a]	1.16 [a]	0.31 [b]
potatoes, peanuts, tobacco, 2	35	66	456.06	654.22	368.00	40.89	1.43 [a]	0.81 [a]	0.09
lb ai/A, 4 appl, 7 days	1000	15	2006.67				0.33 [b]	0.18 [c]	0.02

Leafy veg (celery, lettuce, etc.), *Brassica* (broccoli, cabbage, etc.), roots & tubers (carrots, potatoes, etc.), sorghum, 2 lb ai/A, 3 appl, 7 days	15 35 1000	95 66 15	316.84 456.06 2006.67	644.75	362.67	40.30	2.03 [a] 1.41 [a] 0.32 [b]	1.14 [a] 0.80 [a] 0.18 [c]	0.13 [c] 0.09 0.02
Legumes (beans, peas, lentils, cowpeas), 1.5 lb ai/A, 4 appl, 7 days	15 35 1000	95 66 15	316.84 456.06 2006.67	490.67	276.00	30.67	1.55 [a] 1.08 [a] 0.24 [b]	0.87 [a] 0.61 [a] 0.14 [c]	0.10 [c] 0.07 0.02
Small fruits & berries (grapes, strawberries, etc.), 2 lb ai/A, 5 appl 7 days	15 35 1000	95 66 15	316.84 456.06 2006.67	656.78	369.44	41.05	2.07 [a] 1.44 [a] 0.33 [b]	1.17 [a] 0.81 [a] 0.18 [c]	0.13 [c] 0.09 0.02
Alfalfa, clover, 1.5 lb ai/A, 10 appl, 30 days	15 35 1000	95 66 15	316.84 456.06 2006.67	361.33	203.25	22.58	1.14 [a] 0.79 [a] 0.18 [c]	0.64 [a] 0.45 [b] 0.10 [c]	0.07 0.05 0.01
Rangeland, 1 lb ai/A, 1 appl	15 35 1000	95 66 15	316.84 456.06 2006.67	240.00	135.00	15.00	0.76 [a] 0.53 [a] 0.12 [c]	0.43 [b] 0.30 [b] 0.07	0.05 0.03 <0.01
Forested areas (non-urban), 1 lb ai/A, 2 appl, 7 days	15 35 1000	95 66 15	316.84 456.06 2006.67	304.85	171.48	19.05	0.96 [a] 0.67 [a] 0.15 [c]	0.54 [a] 0.38 [b] 0.09	0.06 0.04 0.01
Turfgrass, 8 lb ai/A, 2 appl, 7 days	15 35 1000	95 66 15	316.84 456.06 2006.67	2438.82	1371.83	152.43	7.70 [a] 5.35 [a] 1.22 [a]	4.33 [a] 3.01 [a] 0.68 [a]	0.48 [b] 0.33 [b] 0.08

[a] Exceeds acute high risk (RQ $ 0.5), restricted use (RQ $ 0.2) and endangered species level of concern (RQ $0.1)
[b] Exceeds restricted use (RQ $ 0.2) and endangered species level of concern (RQ $0.1)
[c] Exceeds endangered species level of concern (RQ $0.1)

Although neither the acute risk nor the acute restricted use LOC is exceeded for granivores for any of the nongranular carbaryl uses, the acute endangered species LOC is reached or exceeded for citrus and turfgrass (RQs: 0.11 - 0.17), and for citrus alone (RQs = 0.12), for granivores with daily food consumption equal to 21% and 15% of their body weight, respectively (**Table 7**). No acute LOCs are exceeded for granivores which consume daily 3% of their body weight.

Table 7. Mammalian (granivore) acute risk quotients for multiple applications of nongranular carbaryl (broadcast) based on a rat LD_{50} of 301 mg/kg and maximum label use rates.

Uses, Application Rate, No. Applications, Interval	Body Weight (g)	% Body Weight Consumed	LC_{50} (LD_{50} ÷ % Body Weight Consumed)	EEC: Seeds (ppm)	Acute RQ: Seeds
Citrus, 5 lb ai/A, 4 appl, 14 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	80.91	0.06 0.04 0.01
Citrus (California), 16 lb ai/A, 1 appl	15 35 1000	21 15 3	1433.33 2000.67 10033.33	240.00	0.17 [a] 0.12 [a] 0.02
Olives, 7.5 lb ai/A, 2 appl, 14 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	120.71	0.08 0.06 0.01

Pome fruits (apple, pear, etc.), 3 lb ai/A, 3 appl, 14 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	48.53	0.03 0.02 <0.01
Stone fruits (peach, apricot, etc.), 4 lb ai/A, 3 appl, 14 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	64.70	0.05 0.03 0.01
Tree nuts (pistachios, etc.), 5 lb ai/A, 3 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	80.88	0.06 0.04 0.01
Corn, field, 2 lb ai/A, 4 appl, 14 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	32.36	0.02 0.02 <0.01
Corn, sweet, 2 lb ai/A, 8 appl, 3 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	69.10	0.05 0.03 0.01
Rice, sunflower, 1.5 lb ai/A, 2 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	28.58	0.02 0.01 <0.01
Sugar beets, wheat & millet, flax, pasture, grasses, noncropland, 1.5 lb ai/A, 2 appl, 14 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	21.14	0.02 0.01 <0.01
Asparagus, 4 lb ai/A, 2 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	76.21	0.05 0.04 0.01
Brassica crops (broccoli, cabbage, etc.), leafy veg (celery, lettuce, etc.), Roots & tubers (beets, carrot, potato, etc.), sorghum, 2 lb ai/A, 3 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	40.30	0.03 0.02 <0.01
Cucurbits (cucumbers, melons, squash, etc.), trees and ornamentals, 1 lb ai/A, 6 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	20.55	0.01 0.01 <0.01
Solanaceous (pepper, tomato, eggplant), sweet potato, peanuts, tobacco, 2 lb ai/A, 4 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	40.89	0.03 0.02 <0.01
Legumes (beans, peas, lentils, cowpeas), 1.5 lb ai/A, 4 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	30.67	0.02 0.02 <0.01
Small fruits & berries (grapes, strawberries, etc.), 2 lb ai/A, 5 appl 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	41.05	0.03 0.02 <0.01
Alfalfa, clover, 1.5 lb ai/A, 10 appl, 30 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	22.58	0.02 0.01 <0.01
Rangeland, 1 lb ai/A, 1 appl	15 35 1000	21 15 3	1433.33 2000.67 10033.33	15.0	0.01 0.01 <0.01
Forested areas (non-urban), 1 lb ai/A, 2 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	19.05	0.01 0.01 <0.01
Turfgrass, 8 lb ai/A, 2 appl, 7 days	15 35 1000	21 15 3	1433.33 2000.67 10033.33	152.43	0.11 [a] 0.08 0.02

[a] Exceeds acute risk to endangered species level of concern (RQ $0.1)

As summarized in **Table 8**, at maximum label application rates, the mammalian chronic LOC (RQ = 1) is exceeded on all registered uses of nongranular carbaryl for animals feeding on short grasses (RQ range: 3.0 - 51), forage/small insects (RQ range: 1.4 - 24), and fruits/large insects (RQ range: 1.7 - 29). The mammalian chronic LOC is exceeded for granivores on following uses: citrus, olives, stone fruits, tree nuts, and turfgrass (chronic RQs = 1.1 - 3.2).

Table 8. Mammalian chronic risk quotients for multiple applications of nongranular carbaryl (broadcast) based on a 2-generation rat reproductive study NOAEC of 75 ppm and maximum label application rates

Site, Application Rate, Number of Applications, Interval	Food Items	Peak Mean EEC (ppm)	Chronic RQ (EEC)/NOAEC)
Citrus, 5 lb ai/A, 4 appl, 14 days	Short Grass	1294.49	17.3 [a]
	Forage/sm insects	593.31	7.91 [a]
	Fruit/lg insects	728.15	9.71 [a]
	Seed Fruit	80.91	1.08 [a]
Citrus (California), 16 lb ai/A, 1 appl	Short Grass	3840.00	51.2 [a]
	Forage/sm insects	1760.00	23.5 [a]
	Fruit/lg insects	2160.00	28.8 [a]
	Seed Fruit	240.00	3.20 [a]
Olives, 7.5 lb ai/A, 2 appl, 14 days	Short Grass	1931.43	25.8 [a]
	Forage/sm insects	885.24	11.8 [a]
	Fruit/lg insects	1086.43	14.5 [a]
	Seed Fruit	120.71	1.61 [a]
Pome fruits (apples, etc.), 3 lb ai/A, 5 appl, 14 days	Short Grass	776.71	10.4 [a]
	Forage/sm insects	355.99	4.75 [a]
	Fruit/lg insects	436.90	5.83 [a]
	Seed Fruit	48.54	0.65
Stone fruits (peaches, etc.), 4 lb ai/A, 3 appl, 14 days	Short Grass	1035.21	13.8 [a]
	Forage/sm insects	474.47	6.33 [a]
	Fruit/lg insects	582.31	7.76 [a]
	Seed Fruit	64.70	6.86 [a]
Tree nuts (pistachios, etc.), 5 lb ai/A, 3 appl, 7 days	Short Grass	1611.88	21.5 [a]
	Forage/sm insects	738.78	9.85 [a]
	Fruit/lg insects	906.68	12.1 [a]
	Seed Fruit	100.74	1.34 [a]
Corn, field, 2 lb ai/A, 4 appl, 14 days	Short Grass	517.79	6.90 [a]
	Forage/sm insects	237.32	3.16 [a]
	Fruit/lg insects	291.26	3.88 [a]
	Seed Fruit	32.36	0.43
Corn, sweet, 2 lb ai/A, 8 appl, 3 days	Short Grass	1105.64	14.7 [a]
	Forage/sm insects	506.75	6.76 [a]
	Fruit/lg insects	621.93	8.29 [a]
	Seed Fruit	69.10	0.92
Rice, sunflower, 1.5 lb ai/A, 2 appl, 7 days	Short Grass	457.28	6.10 [a]
	Forage/sm insects	209.59	2.79 [a]
	Fruit/lg insects	257.22	3.43 [a]
	Seed Fruit	28.58	0.38

Site, Application Rate, Number of Applications, Interval	Food Items	Peak Mean EEC (ppm)	Chronic RQ (EEC)/NOAEC)
Asparagus, 2 lb ai/A, 5 appl, 3 days	Short Grass	1050.51	14.0 [a]
	Forage/sm insects	481.48	6.42 [a]
	Fruit/lg insects	590.91	7.88 [a]
	Seed Fruit	65.66	0.88
Brassica crops (broccoli, cabbage, etc.), leafy veg (celery, lettuce, etc.), roots & tubers (beets, carrots, potatoes, etc.), sorghum, 2 lb ai/A, 3 appl, 7 days	Short Grass	644.75	8.60 [a]
	Forage/sm insects	295.51	3.94 [a]
	Fruit/lg insects	362.67	4.84 [a]
	Seed Fruit	40.30	0.54
Cucurbits (cucumbers melons, squash, etc.), trees and ornamentals, 1 lb ai/A, 6 appl, 7 days	Short Grass	328.74	4.11 [a]
	Forage/sm insects	150.67	1.88 [a]
	Fruit/lg insects	184.91	2.31 [a]
	Seed Fruit	20.55	0.26
Solanaceous (peppers, tomatoes, eggplant), sweet potatoes, peanuts, tobacco, 2 lb ai/A, 4 appl, 7 days	Short Grass	654.22	8.18 [a]
	Forage/sm insects	299.85	3.75 [a]
	Fruit/lg insects	368.00	4.60 [a]
	Seed Fruit	40.89	0.51
Legumes (beans, peas, lentils, cowpeas), 1.5 lb ai/A, 4 appl, 7 days	Short Grass	490.67	6.13 [a]
	Forage/sm insects	224.89	2.81 [a]
	Fruit/lg insects	276.00	3.45 [a]
	Seed Fruit	30.67	0.38
Sugar beets, wheat, millet, flax, pasture, grasses, non-cropland, 1.5 lb ai/A, 2 appl, 14 days	Short Grass	386.29	4.83 [a]
	Forage/sm insects	177.05	2.21 [a]
	Fruit/lg insects	217.29	2.72 [a]
	Seed Fruit	24.14	0.30
Small fruits & berries (grapes, strawberries, etc.), 2 lb ai/A, 5 appl, 7 days	Short Grass	656.78	8.21 [a]
	Forage/sm insects	301.03	3.76 [a]
	Fruit/lg insects	369.44	4.62 [a]
	Seed Fruit	41.05	0.51
Alfalfa, clover, 1.5 lb ai/A, 8 appl, 30 days	Short Grass	361.33	4.52 [a]
	Forage/sm insects	165.61	2.07 [a]
	Fruit/lg insects	203.25	2.54 [a]
	Seed Fruit	22.58	0.28
Rangeland, 1 lb ai/A, 1 appl	Short Grass	240.00	3.00 [a]
	Forage/sm insects	110.00	1.38 [a]
	Fruit/lg insects	135.00	1.69 [a]
	Seed Fruit	15.00	0.19
Forested areas (non-urban), 1 lb ai/A, 2 appl, 7 days	Short Grass	304.85	3.81 [a]
	Forage/sm insects	139.72	1.75 [a]
	Fruit/lg insects	171.48	2.14 [a]
	Seed Fruit	19.05	0.24
Turfgrass, 8 lb ai/A, 2 appl, 7 days	Short Grass	2438.82	30.5 [a]
	Forage/sm insects	1117.79	14.0 [a]
	Fruit/lg insects	1371.83	17.2 [a]
	Seed Fruit	152.43	1.91 [a]

[a] Exceeds chronic risk level of concern (RQ ≥1.0)

In addition to maximum label use rates, mammalian acute and chronic RQs were also calculated for nongranular carbaryl using QUA average use rates data available for 70 uses (**Table 9a**) and maximum reported (Doane data) use rates data available for 42 uses (**Table 9b**).

As summarized in **Table 9a**, when RQs are based on QUA average rates, the acute risk LOC is exceeded for 62 (89%) of the uses, whereas the restricted use LOC is exceeded for 69 uses (not exceeded only for Chinese cabbage), and the endangered species LOC is exceeded for all 70 uses. The chronic risk LOC is exceeded for 69 uses (not exceeded only for Chinese cabbage).

Table 9a. Mammalian (herbivores) highest acute and chronic risk quotients[a] for nongranular carbaryl based on a rat LD_{50} of 301 mg/kg ppm, a developmental rat NOAEC of 75 ppm, and QUA average application rates for 70 uses

Use site	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOAEC)	Use Site	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOAEC)
Alfalfa	0.84 [b]	3.30 [e]	Nectarines	2.88 [b]	12.2 [e]
Almonds	1.59 [b]	6.72 [e]	Okra	1.44 [b]	6.08 [e]
Apples	0.91 [b]	3.84 [e]	Olives	4.02 [b]	17.0 [e]
Asparagus	0.68 [b]	2.88 [e]	Oranges	2.58 [b]	10.9 [e]
Beans, Dry	0.38 [c]	1.60 [e]	Pasture	0.68 [b]	2.88 [e]
Beans, Lima, Fresh	0.68 [b]	2.88 [e]	Peaches	1.02 [b]	4.29 [e]
Beans, Snap, Fresh	0.86 [b]	3.65 [e]	Peanuts	0.60 [b]	2.56 [e]
Beans, Snap, Processed	0.67 [b]	2.84 [e]	Pears	0.76 [b]	3.20 [e]
Beets	0.38 [c]	1.60 [e]	Pears, Dry	0.75 [b]	3.20 [e]
Blackberries	1.28 [b]	5.44 [e]	Peas, Green	1.13 [b]	4.80 [e]
Blueberries	1.28 [b]	5.44 [e]	Pecans	1.98 [b]	7.86 [e]
Broccoli	0.60 [b]	2.56 [e]	Peppers, Bell	1.28 [b]	5.05 [e]
Brussels Sprouts	0.68 [b]	2.88 [e]	Peppers, Sweet	0.99 [b]	4.16 [e]
	0.15 [d]	0.64	Pistachios	2.72 [b]	11.5 [e]
Chinese Cabbage	0.96 [b]	4.07 [e]	Plums	2.88 [b]	12.2 [e]
Fresh Cabbage	0.60 [b]	2.56 [e]	Potatoes	1.13 [b]	4.49 [e]
Cantaloupes	0.86 [b]	3.65 [e]	Pumpkins	2.84 [b]	11.2 [e]
Carrots	0.84 [b]	3.52 [e]	Raspberries	2.12 [b]	8.96 [e]
Cauliflower	0.96 [b]	4.07 [e]	Rice	0.84 [b]	3.52 [e]
Celery	1.44 [b]	6.08 [e]	Sorghum	0.84 [b]	3.52 [e]
Cherries	1.46 [b]	6.19 [e]	Soybeans	0.68 [b]	2.88 [e]
Citrus, other	0.75 [b]	3.20 [e]	Squash	1.06 [b]	4.48 [e]
Corn, Field	1.52 [b]	6.40 [e]	Strawberries	1.98 [b]	7.86 [e]
Cranberries	0.84 [b]	3.52 [e]	Sugar Beets	0.99 [b]	4.16 [e]
Cucumbers	0.58 [b]	2.44 [e]	Sunflower	0.31 [c]	2.24 [e]
Cucumbers, Processed	0.96 [b]	4.07 [e]	Sweet Corn, Fresh	1.87 [b]	7.89 [e]
Eggplant	0.84 [b]	3.52 [e]	Sweet Potatoes	1.21 [b]	5.12 [e]
Flax	1.14 [b]	4.81 [e]	Tobacco	1.06 [b]	4.47 [e]
Grapefruit	1.35 [b]	5.69 [e]	Tomatoes, Fresh	0.71 [b]	3.01 [e]
Grapes	0.60 [b]	2.56 [e]	Tomatoes, Processed	0.91 [b]	3.84 [e]
Hay	1.90 [b]	8.00 [e]	Walnuts	1.44 [b]	6.08 [e]
Hazelnuts	2.05 [b]	8.64 [e]	Watermelons	0.38 [c]	1.60 [e]
Lemons	0.84 [b]	3.52 [e]	Wheat, Spring	0.46 [c]	1.92 [e]
Lettuce	0.33 [c]	1.37 [e]	Wheat, Winter	0.60 [b]	2.56 [e]
Lots/Farmsteads	0.53 [b]	2.24 [e]	Woodland	0.31 [c]	2.24 [e]
Melons					

[a]Only the highest RQs -- i.e. those corresponding to 15 g mammals which have a daily food consumption equal to 95% of their body weight and based on short grass EECs -- are included in this table.
[b] Exceeds acute high risk (RQ $ 0.5), restricted use (RQ $ 0.2) and endangered species level of concern (RQ $0.1)
[c] Exceeds acute restricted use (RQ $ 0.2) and endangered species level of concern (RQ $0.1)
[d] Exceeds acute risk to endangered species level of concern (RQ $0.1)
[e] Exceeds chronic risk level of concern (RQ $1.0)

When RQs are calculated using maximum reported application rates, the acute risk LOC is exceeded for 40 of the 42 uses (RQs: 0.60 - 11). The acute restricted use and endangered species (RQ range 0.38 - 11) and chronic (RQs: 1.6 - 48) risk LOCs are exceeded for all 42 uses (**Table 9b**).

Table 9b. Mammalian (herbivores) highest acute and chronic risk quotients[a] for nongranular carbaryl based on a rat LD_{50} of 301 mg/kg ppm and, a developmental rat NOAEC of 75 ppm, and maximum reported use rates (Doane data) for 42 uses

Use site [appl.rate (lb ai/A), No. appl]	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOAEC)	Use Site [appl.rate (lb ai/A) No. appl]	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOAEC)
Alfalfa (1.5, 1)	1.13 [b]	4.8 [e]	Peaches (5, 1)	3.78 [b]	16.0 [e]
Almonds (4, 1)	3.03 [b]	12.8 [e]	Peanuts (2, 1)	1.52 [b]	6.4 [e]
Apples (3.2, 1)	2.43 [b]	10.2 [e]	Pears (2, 1)	1.52 [b]	6.4 [e]
Apricots (4, 1)	3.03 [b]	12.8 [e]	Pecans (3, 2, 7)	2.89 [b]	12.2 [e]
Asparagus (4, 1)	3.03 [b]	12.8 [e]	Peppers (2, 1)	1.52 [b]	6.4 [e]
Beans, Lima (1.3,1)	0.99 [b]	4.2 [e]	Pistachios (5, 1)	3.78 [b]	16.0 [e]
Beans, snap (1.6, 1)	1.21 [b]	4.8 [e]	Plums (4, 1)	3.03 [b]	12.8 [e]
Cabbage (2,1)	1.52 [b]	5.1 [e]	Potatoes (1.5, 1)	1.13 [b]	4.8 [e]
Canola (0.5, 1)	0.38 [c]	1.6 [e]	Pumpkins (1.5, 1)	1.13 [b]	4.8 [e]
Cantaloupe (1.2, 1)	0.91 [b]	3.8 [e]	Rice (1.3, 1)	0.99 [b]	4.2 [e]
Carrots (0.8, 1)	0.60 [b]	2.6 [e]	Sorghum (0.5, 1)	0.38 [c]	1.6 [e]
Cauliflower (1, 1)	0.75 [b]	3.2 [e]	Squash (1.2, 1)	0.91 [b]	3.8 [e]
Celery (2, 1)	1.53 [b]	6.4 [e]	Sugar Beets (1.2, 1)	0.91 [b]	3.8 [e]
Cherries (5, 1)	3.78 [b]	16.0 [e]	Sunflower (1, 1)	0.75 [b]	3.2 [e]
Corn, Field (1.5, 2, 14)	1.22 [b]	5.1 [e]	Strawberries (2,1)	1.52 [b]	6.4 [e]
Cucumbers (1, 1)	0.75 [b]	3.2 [e]	Sweet Corn (1.5, 2, 3)	1.78 [b]	7.5 [e]
Grapefruit (12.8, 1)	9.70 [b]	41.0 [e]	Tobacco (2, 1)	1.52 [b]	6.4 [e]
Grapes (2.5,1)	1.90 [b]	8.0 [e]	Tomatoes (2,1)	1.52 [b]	6.4 [e]
Lemons (8,1)	6.06 [b]	25.6 [e]	Walnuts (4, 1)	3.03 [b]	12.8 [e]
Lettuce (1, 1)	0.75 [b]	3.2 [e]	Watermelons (2, 1)	1.52 [b]	6.4 [e]
Oranges (15, 1)	11.36 [b]	48.0 [e]	Wheat (1,1)	0.75 [b]	3.2 [e]

[a] Only the highest RQs -- i.e. those corresponding to 15 g mammals which have a daily food consumption equal to 95% of their body weight and based on short grass EECs -- are included in this table.
[b] Exceeds acute high risk (RQ $ 0.5), restricted use (RQ $ 0.2) and endangered species level of concern (RQ $0.1)
[c] Exceeds acute restricted use (RQ $ 0.2) and endangered species level of concern (RQ $0.1)
[d] Exceeds acute risk to endangered species level of concern (RQ $0.1)
[e] Exceeds chronic risk level of concern (RQ $1.0)

Risk to Granular Products

Mammals also may be exposed to granular/bait pesticides through ingestion and by other routes, such as by walking on exposed granules or by drinking water contaminated with granules. The number of lethal doses (LD_{50}) that are available within one square foot immediately after application (LD_{50}/ft2) is used as the risk quotient for granular/bait products. Risk quotients are calculated for small mammals in three weight classes: 15 g, 35 g, and 1000 g.

The acute level of concern is exceeded for mammals in the 15 g and 35 g categories for all 40 registered granular uses (**Table 10**). For 1000 g mammals, the restricted use and endangered species LOCs are exceeded for applications to trees and ornamentals, turfgrass, and tick control.

Table 10. Mammalian acute risk quotients[a] for granular carbaryl (broadcast, unincorporated) based on a rat LD_{50} of 301 mg/kg

Uses	Rate in lb ai/A	Body Weight (g)	Acute RQ[a] (LD_{50}/ft^2)
Asparagus, *Brassica* crops (broccoli, cabbage, cauliflower, collards, etc.), corn (field, sweet), sorghum, solanaceous crops (tomato, pepper, eggplant), leafy vegetables (celery, lettuce, parsley, spinach, etc.), roots & tubers (beets, carrots, radishes, potatoes, etc.), strawberries	2	15	4.61[b]
		35	1.98[b]
		1000	0.07
Cucurbits (cucumber, melon, pumpkin, squash)	1	15	2.30[b]
		35	0.99[b]
		1000	0.03
Legumes (beans, peas, lentils, cowpeas, southern peas), Wheat, millet, Sugar beets	1.5	15	3.45[b]
		35	1.48[b]
		1000	0.05
Trees and ornamentals, turfgrass, tick control	9.15	15	21.10[b]
		35	9.04[b]
		1000	0.32[c]

[a] RQ = Appl. rate (lb ai/a) * (453,590 mg/lb/43,560 ft^2/a) / LD_{50} mg/kg * weight of animal (kg)

[b] Exceeds acute high risk (RQ ≥ 0.5), restricted use (RQ ≥ 0.2) and endangered species level of concern (RQ ≥0.1)

[c] Exceeds acute restricted use (RQ ≥ 0.2) and endangered species level of concern (RQ ≥0.1)

Insects

Currently EFED does not assess risk to nontarget insects. However, data from acceptable studies are used to recommend appropriate label precautions. Carbaryl, is highly toxic to domestic and wild bees and should be applied only under the conditions specified by the latest pollinator protection label language. Carbaryl has also been shown to be from moderately to highly toxic to predaceous and parasitic arthropods, including lace bugs, big eyed bugs, lady beetles, carabid ground beetles, hymenopterous parasitoids, predaceous mites, and spiders.

Terrestrial Plants

Based on the single vegetative vigor study of Sevin XLR Plus at a single field application rate (0.803 lbs a.i./Acre), the inhibitory concentration (IC_{25}) exceeded the highest dose tested. Therefore, no terrestrial plant risk quotients are calculated. However, based on precautionary label language about potential injury to several crop plants and the limited range of plants tested in the Tier I vegetative vigor study (MRID 457848-07), the registrant needs to submit a more comprehensive tier I and, if necessary, tier II Seed Germination and Seedling Emergence and Vegetative Vigor studies.

Exposure and Risk to Nontarget Aquatic Animals

EFED calculates estimated environmental concentrations (EECs) using the PRZM/ EXAMS model. The EECs are used for assessing acute and chronic risks to aquatic organisms. Acute risk assessments are performed using peak EEC values for single and multiple applications. Chronic risk assessments are performed using the 21-day EECs for invertebrates and 56-day EECs for fish.

The PRZM/EXAMS program uses basic environmental fate data and pesticide label application information to estimate the expected EECs following treatment of 10 hectares. The model calculates the concentration (EEC) of a pesticide in a one hectare, two meter deep pond, taking into account the following: (1) adsorption to soil or sediment, (2) soil incorporation, (3) degradation in soil before washoff to a water body, and (4) degradation within the water body. The model also accounts for direct deposition of spray drift into the water body (assumed to be 1% and 5% of the application rate for ground and aerial applications, respectively). The environmental fate parameters used in the model for this pesticide are contained in Table 6 of the preceding main environmental fate and effects chapter. EECs are tabulated below in **Table 11.**

Table 11. Tier II surface water estimated environmental concentration (EEC) values derived from PRZM/ EXAMS modeling for use in ecological risk assessment (Calculated using standard pond.)

Use Site, Application Method	Use Rates	Number of Applications Per Year	Application Rate (Pounds A.I. per Application)	Surface Water Acute (ppb) (1 in 10 year peak single day concentration)	21 day (ppb) (1 in 10 year)	60 day (ppb) (1 in 10 year)
Sweet Corn (OH), air/ground	Maximum "Average" Maximum Reported	8 2 3	2 3.4 1	53 46 23	30 25 12	19 13 7
Field Corn (OH), air/ground	Maximum "Average" Maximum Reported	4 2 2	2 1 1.5	47 13 20	25 7 11	14 4 7
Apples (PA), air/ground	Maximum "Average" Maximum Reported	5 2 2	2 1.2 1.6	31 12 16	15 5 6	7 2 2
Sugar Beets (MN), air/ground	Maximum "Average" Maximum Reported	2 1 1	1.5 1.5 1.2	23 7 5	13 3 3	6 2 2
Citrus (FL), air/ground	Maximum "Average" Maximum Reported	4 2 3	5 3.4 4.3	153 100 131	82 51 68	41 23 31

Freshwater Animals

Fish

Acute and chronic risk quotients for freshwater fish, based on maximum label (Maximum), QUA average ("Average"), and maximum reported (Max Rep;Doane data) use rates are tabulated in **Table 12**. The acute risk LOC is exceeded only for the citrus scenario, for all three use rates modeled, whereas the endangered species LOC is met or exceeded for all of the crops modeled except sugar beets, for all three use rates. For sugar beets, none of the acute risk LOCs is exceeded at either average or maximum reported application rate. The chronic risk LOC is not exceeded for any uses modeled, at any of the use rates.

Table 12. Risk quotients for freshwater fish based on an Atlantic salmon LC_{50} of 250 ppb and a fathead minnow NOAEC of 210 ppb, at maximum label use rates, QUA average use rates, and maximum reported use rates

Site/Appl. Method	Use Rates	LC_{50} (ppb)	NOAEC (ppb)	EEC Initial/ Peak (ppb)	EEC 60-Day Ave. (ppb)	Acute RQ (EEC/LC_{50})	Chronic RQ (EEC/NOAEC)
Sweet Corn (OH), air/ground	Maximum	250	210	53	19	0.21 [b]	0.09
	"Average"			46	13	0.18 [b]	0.06
	Max Rep			23	7	0.09 [c]	0.03
Field Corn (OH) air/ground	Maximum	250	210	47	14	0.19 [b]	0.07
	"Average"			13	4	0.05 [c]	0.02
	Max Rep			20	7	0.08 [c]	0.03
Apples (PA) air/ground	Maximum	250	210	31	7	0.12 [b]	0.03
	"Average"			12	2	0.05 [c]	0.01
	Max Rep			16	2	0.06 [c]	0.01
Sugar Beets (MN) air/ground	Maximum	250	210	23	6	0.09 [c]	0.03
	"Average"			7	2	0.03	0.01
	Max Rep			5	2	0.02	0.01
Citrus (FL) air/ground	Maximum	250	210	153	41	0.61 [a]	0.20
	"Average"			100	23	0.40 [b]	0.11
	Max Rep			131	31	0.52 [a]	0.15

[a] Exceeds acute high risk (RQ $ 0.5), restricted use (RQ $ 0.1) and endangered species level of concern (RQ $0.05)
[b] Exceeds acute restricted use (RQ $ 0.1) and endangered species level of concern (RQ $0.05)
[c] Exceeds acute risk to endangered species level of concern (RQ $0.05)

Invertebrates

The risk quotients for freshwater invertebrates exceed both the acute and chronic LOCs for all five uses modeled, at maximum label use rates, QUA average rates, and maximum reported (Doane data) use rates (**Table 13**).

Table 13. Risk quotients for freshwater invertebrates based on a stonefly EC_{50} of 5.1 ppb and a water flea NOAEC of 1.5 ppb, at maximum label use rates, QUA average use rates, and maximum reported use rates

Site/Appl. Method	Use Rates	EC_{50} (ppb)	NOAEC (ppb)	EEC Initial/ Peak (ppb)	EEC 21-Day Ave. (ppb)	Acute RQ (EEC/EC_{50})	Chronic RQ (EEC/NOAEC)
Sweet Corn (OH)	Maximum	**5.1**	1.5	53	30	10.4 [a]	20 [b]
	"Average"			46	25	9.0 [a]	17 [b]
	Max Rep			23	12	4.5 [a]	8 [b]
Field Corn (OH)	Maximum	**5.1**	1.5	47	25	9.2 [a]	17 [b]
	"Average"			13	7	2.5 [a]	4.7 [b]
	Max Rep			20	11	3.9 [a]	7.3 [b]
Apples (PA)	Maximum	**5.1**	1.5	31	15	6.1 [a]	10 [b]
	"Average"			12	5	2.4 [a]	3.3 [b]
	Max Rep			16	6	3.1 [a]	4.0 [b]
Sugar Beets (MN)	Maximum	**5.1**	1.5	23	13	4.5 [a]	8.7 [b]
	"Average"			7	3	1.4 [a]	2.0 [b]
	Max rep			5	3	1.0 [a]	2.0 [b]
Citrus (FL)	Maximum	**5.1**	1.5	153	82	30 [a]	55 [b]
	"Average"			100	51	20 [a]	34 [b]
	Max Rep			131	68	26 [a]	45 [b]

[a] Exceeds acute high risk (RQ $ 0.5), restricted use (RQ $ 0.1) and endangered species level of concern (RQ $0.05)
[b] Exceeds chronic risk level of concern (RQ $1.0)

Estuarine and Marine Animals

Fish

The acute risk LOC is not exceeded for any of the five uses modeled using maximum label use rates, QUA average rates, and maximum reported rates (**Table 14**). The acute endangered species LOC is minimally exceeded at maximum label and maximum reported rates on citrus alone. Due to the unavailability of core chronic toxicity data, it is not possible to evaluate chronic risk to estuarine/ marine fish at this time.

Table 14. Acute risk quotients for estuarine/marine fish based on a sheepshead minnow LC_{50} of 2.6 ppm and label maximum and QUA average use rates, at maximum label use rates, QUA average use rates, and maximum reported use rates

Site/Appl. Method	Use Rates	LC_{50} (ppb)	EEC Initial/Peak (ppb) (Max Rates)	Acute RQ (EEC/EC_{50})
Sweet Corn (OH)	Maximum	2600	53	0.02
	"Average"		46	0.02
	Max Rep		23	0.01
Field Corn (OH)	Maximum	2600	47	0.02
	"Average"		13	0.01
	Max Rep		20	0.01
Apples (OR)	Maximum	2600	31	0.01
	"Average"		12	<0.01
	Max Rep		16	0.01
Sugar Beets (MN)	Maximum	2600	23	0.01
	"Average"		7	<0.01
	Max rep		5	<0.01
Citrus (FL)	Maximum	2600	153	0.06[a]
	"Average"		100	0.04
	Max Rep		131	0.06 [a]

[a] Exceeds acute risk to endangered species level of concern (RQ $\geq$0.05)

Invertebrates

The acute risk LOC for estuarine/marine invertebrates is exceeded for all five carbaryl uses modeled at maximum label use rates, QUA average rates, and maximum reported (Doane data) rates (**Table 15**). Due to the unavailability of core chronic toxicity data, it is not possible to evaluate chronic risk to estuarine/ marine fish or invertebrates at this time.

Table 15. Acute risk quotients for estuarine/marine invertebrates based on a mysid LC_{50} of 5.7 ppb and three sets of use rates, at maximum label use rates, QUA average use rates, and maximum reported use rates

Site/Appl. Method	Use Rates	LC_{50} (ppb)	EEC Initial/Peak (ppb) (Max Rates)	Acute RQ (EEC/EC_{50}) (Max Rates)
Sweet Corn (OH)	Maximum	5.7	53	9.3 [a]
	"Average"		46	8.1 [a]
	Max Rep		23	4.0 [a]
Field Corn (OH)	Maximum	5.7	47	8.2 [a]
	"Average"		13	2.3 [a]
	Max Rep		20	3.5 [a]
Apples (OR)	Maximum	5.7	31	5.4 [a]
	"Average"		12	2.1 [a]
	Max Rep		16	2.8 [a]
Sugar Beets (MN)	Maximum	5.7	23	4.0 [a]
	"Average"		7	1.2 [a]
	Max rep		5	0.9 [a]
Citrus (FL)	Maximum	5.7	153	27 [a]
	"Average"		100	18 [a]
	Max Rep		131	23 [a]

[a] Exceeds acute high risk (RQ $\geq$ 0.5), restricted use (RQ $\geq$ 0.1) and endangered species level of concern (RQ $\geq$0.05)

Aquatic Plants

Exposure to nontarget aquatic plants may occur through runoff or spray drift from adjacent treated sites or directly from such uses as aquatic weed or mosquito larvae control. An aquatic plant risk assessment for acute risk is usually made for aquatic vascular plants from the surrogate duckweed *Lemna gibba*. Non-vascular acute risk assessments are performed using either algae or a diatom, whichever is the most sensitive species. An aquatic plant risk assessment for acute-endangered species is usually made for aquatic vascular plants from the surrogate duckweed *Lemna gibba*. To date, there are no known non-vascular plant species on the endangered species list. Runoff and drift exposure is computed from PRZM/EXAMS. The risk quotient is determined by dividing the pesticide's initial or peak concentration in water by the plant EC_{50} value.

Based on a single core aquatic plant toxicity study available, neither the acute risk nor the endangered species LOC is exceeded for any of the five use scenarios modeled, at maximum label, QUA average, and maximum reported use rates (**Table 16**). However, to fully assess carbaryl risk to aquatic plants, it is recommended that toxicity studies with *Lemna gibba, Anabaena flos-aquae, Skeletonema costatum,* and a freshwater diatom be submitted.

Table 17. Risk quotients for aquatic plants based on a green alga (*Pseudokirchneriella subcapitata*) EC_{50} of 1.3 ppm and a NOAEC of 0.29 ppm, at maximum label use rates, QUA average use rates, and maximum reported use rates.

Site/Appl. Method	Use Rates	EC_{50} (ppb)	NOAEC (ppb)	EEC Initial/ Peak (ppb)	Acute RQ (EEC/EC_{50})	Acute Endangered Species RQ (EEC/NOAEC)
Sweet Corn (OH)	Maximum	1300	290	53	0.04	0.18
	"Average"			46	0.04	0.16
	Max Rep			23	0.02	0.08
Field Corn (OH)	Maximum	1300	290	47	0.04	0.16
	"Average"			13	0.01	0.04
	Max Rep			20	0.02	0.07
Apples (OR)	Maximum	1300	290	31	0.02	0.11
	"Average"			12	0.01	0.04
	Max Rep			16	0.01	0.06
Sugar Beets (MN)	Maximum	1300	290	23	0.02	0.08
	"Average"			7	0.01	0.02
	Max rep			5	<0.01	0.02
Citrus (FL)	Maximum	1300	290	153	0.12	0.53
	"Average"			100	0.08	0.34
	Max Rep			131	0.10	0.45

APPENDIX G. GRASSHOPPER AND MORMON CRICKET SUPPRESSION PROGRAM

Carbaryl has been used as part of the U. S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS) Grasshopper and Mormon Cricket Suppression Program. According to the USDA, carbaryl is considered unique in providing satisfactory results under cool, wet conditions. It is also more persistent than other chemical alternatives, e.g., malathion or diflubenzuron, in the program and it is more effective in dense vegetation and on rough terrain (Docket Number OPP-2002-0138-0043). A single application of carbaryl is applied by ultra low volume sprayers at rates ranging from 0.25 to 0.50 lbs a.i./A. In the past, the entire affected area has been treated; however, under a Reduced Agent Area Treatment (RAAT) approach to grasshopper suppression, carbaryl will, in the future, be applied to alternating swaths. The number of acres treated in the past has increased (Figure 13) by roughly a factor of four.

Risk to Terrestrial Animals

Based on estimated environmental concentrations derived using EL-FATE model (APPENDIX C) at the maximum single application rate of 0.5 lbs a.i./acre, risk quotients do not exceed either acute or chronic levels of concern for birds. However, for small and intermediate-sized mammals feeding on short grasses and for small mammals feeding on large insects, acute restricted use and endangered species LOCs are exceeded (RQ range: 0.21 - 0.38). For small and intermediate-sized mammals feeding on broadleaf plants/small insects and for intermediate-sized mammals feeding on large insects, acute endangered species LOCs are exceeded (RQ range: 0.15 - 0.17). No acute LOC is exceeded for large-sized mammals. The chronic risk LOC is exceeded (RQ = 1.60) for animals feeding on short grasses alone. At an application rate of 0.25 lbs a.i./A, the acute endangered species LOC is exceeded for small and intermediate-sized mammals feeding on short grasses and for small-sized mammals feeding on large insects; the chronic risk LOC was not exceeded at the lower application rate.

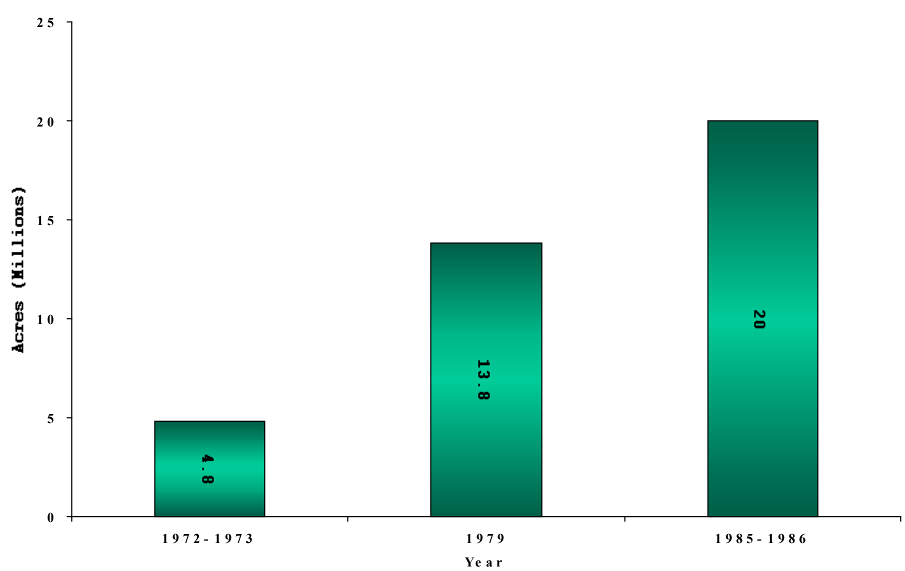


Figure 13. Combined acreage of private, State, and Federal rangeland treated to suppress grasshopper outbreaks. (Source: USDA APHIS 2003)

Risk to Aquatic Animals

Estimated environmental concentrations for determining aquatic exposure were derived using a North Dakota wheat scenario with PRZM/EXAMS. While this scenario may not be completely representative of the actual use area, it is believed to provide a conservative estimate of exposure. Assuming 5% drift, peak, 21-day and 56-day average concentrations in water are estimated at 1.05, 0.55 and 0.32 µg/L, respectively. At these concentrations, acute restricted use and endangered species LOCs are exceeded (RQ = 0.21) for freshwater invertebrates alone. If 95% spraydrift is assumed for direct overspray of aquatic environments, peak, 21-day and 56-day average concentrations in water are estimated at 12.8, 6.5 and 2.8 µg/L, respectively. Acute endangered species LOC is exceed (RQ = 0.05) for fish while the acute high risk LOC (RQ= 2.5) and chronic risk LOC (RQ= 4.3) are exceeded for freshwater invertebrates at these estimated residue levels.

The Grasshopper Suppression Program has undergone Section 7 consultation with the U. S. Fish and Wildlife Service and the National Marine Fisheries Service and a Biological Opinion was issued in 1995. It was concluded that APHIS or the land manager will consult locally with the USFWS and/or NMFS to develop protective mitigations, if threatened or endangered species are in areas targeted for treatment (Carl Bausch, Deputy Director, Environmental Services, USDA Policy and Program Development).