Risks of Carbaryl Use to Federally Threatened

Delta Smelt (*Hypomesus transpacificus*)

Pesticide Effects Determinations
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Primary Authors:	**Thomas Steeger, Ph.D. Senior Biologist** **R. David Jones, Ph.D. Senior Agronomist** **Kris, Garber, Biologist**
Secondary Review:	**Melissa Panger, Ph.D., Biologist** **Charles Peck, Environmental Engineer**
Acting Branch Chief:	**Mark Corbin** **Environmental Risk Assessment Branch 4**

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List of Commonly Used Abbreviations and Nomenclature

µg/kg	Symbol for "micrograms per kilogram"
$\mu g \cdot L^{-1}$	Symbol for "micrograms per liter"
ºC	Symbol for "degrees Celsius"
AAPCO	Association of American Pesticide Control Officials
a.i.	Active Ingredient
AIMS	Avian Monitoring Information System
Acc#	Accession Number
amu	Atomic Mass Unit
BCF	Bioconcentration Factor
BEAD	Biological and Economic Analysis Division
Bw	Body Weight
CAM	Chemical Application Method
CARB	California Air Resources Board
CBD	Center for Biological Diversity
CDPR	California Department of Pesticide Regulation
CDPR-PUR	California Department of Pesticide Regulation Pesticide Use Reporting Database
CFWS	California Freshwater Shrimp
CI	Confidence Interval
CL	Confidence Limit
CTS	California Tiger Salamander
CTS-CC	California Tiger Salamander Central California Distinct Population Segment
CTS-SB	California Tiger Salamander Santa Barbara County Distinct Population Segment
CTS-SC	California Tiger Salamander Sonoma County Distinct Population Segment
DS	delta smelt
EC	emulsifiable concentrate
EC_{05}	5% Effect Concentration
EC_{25}	25% Effect Concentration
EC_{50}	50% (or Median) Effect Concentration
ECOTOX	EPA managed database of ECOTOXicology data
EEC	Estimated Environmental Concentration
EFED	Environmental Fate and Effects Division

e.g.	Latin *exempli gratia* ("for example")
EIM	Environmental Information Management System
EPI	Estimation Programs Interface
ESU	evolutionarily significant unit
et al.	Latin *et alii* ("and others")
Etc.	Latin *et cetera* ("and the rest" or "and so forth")
EXAMS	Exposure Analysis Modeling System
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
FQPA	Food Quality Protection Act
Ft	Feet
GENEEC	Generic Estimated Exposure Concentration model
HPLC	High Pressure Liquid Chromatography
IC_{05}	5% Inhibition Concentration
IC_{50}	50% (or median) Inhibition Concentration
i.e.	Latin for *id est* ("that is")
IECV1.1	Individual Effect Chance Model Version 1.1
KABAM	$\underline{K}_{OW}$ (based) Aquatic BioAccumulation Model
Kg	Kilogram(s)
kJ/mole	Kilojoules per mole
Km	Kilometer(s)
K_{AW}	Air-water Partition Coefficient
K_d	Solid-water Distribution Coefficient
K_f	Freundlich Solid-Water Distribution Coefficient
K_{OC}	Organic-carbon Partition Coefficient
K_{OW}	Octanol–water Partition Coefficient
LAA	Likely to Adversely Affect
lb a.i./A	Pound(s) of active ingredient per acre
LC_{50}	50% (or Median) Lethal Concentration
LD_{50}	50% (or Median) Lethal Dose
LOAEC	Lowest Observable Adverse Effect Concentration
LOAEL	Lowest Observable Adverse Effect Level
LOC	Level of Concern
LOD	Level of Detection
LOEC	Lowest Observable Effect Concentration
LOQ	Level of Quantitation
M	Meter(s)

MA	May Affect
MATC	Maximum Acceptable Toxicant Concentration
m^2/day	Square Meters per Days
ME	Microencapsulated
Mg	Milligram(s)
Mg/kg	Milligrams per kilogram (equivalent to ppm)
Mg/L	Milligrams per liter (equivalent to ppm)
Mi	mile(s)
mmHg	Millimeter of mercury
MRID	Master Record Identification Number
MW	Molecular Weight
n/a	Not applicable
NASS	National Agricultural Statistics Service
NAWQA	National Water Quality Assessment
NCOD	National Contaminant Occurrence Database
NE	No Effect
NLAA	Not Likely to Adversely Affect
NLCD	National Land Cover Dataset
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOAEC	No Observable Adverse Effect Concentration
NOAEL	No Observable Adverse Effect Level
NOEC	No Observable Effect Concentration
NRCS	Natural Resources Conservation Service
OPP	Office of Pesticide Programs
OPPTS	Office of Prevention, Pesticides and Toxic Substances
ORD	Office of Research and Development
PCE	Primary Constituent Element
pH	Symbol for the negative logarithm of the hydrogen ion activity in an aqueous solution, dimensionless
pK_a	Symbol for the negative logarithm of the acid dissociation constant, dimensionless
ppb	Parts per Billion (equivalent to µg/L or µg/kg)
ppm	Parts per Million (equivalent to mg/L or mg/kg)
PRD	Pesticide Re-Evaluation Division
PRZM	Pesticide Root Zone Model

ROW	Right of Way
RQ	Risk Quotient
SFGS	San Francisco Garter Snake
SJKF	San Joaquin Kit Fox
SLN	Special Local Need
SMHM	Salt Marsh Harvest Mouse
TG	Tidewater Goby
T-HERPS	Terrestrial Herpetofaunal Exposure Residue Program Simulation
T-REX	Terrestrial Residue Exposure Model
UCL	Upper Confidence Limit
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VELB	Valley Elderberry Longhorn Beetle
WP	Wettable Powder
Wt	Weight

1. Executive Summary

1.1. Purpose of Assessment

The purpose of this assessment is to evaluate potential direct and indirect effects on the delta smelt (*Hypomesus transpacificus*, DS) arising from FIFRA regulatory actions regarding use of carbaryl on agricultural and non-agricultural sites. In addition, this assessment evaluates whether these actions can be expected to result in modification of designated critical habitat for the DS. This assessment was completed in accordance with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998), procedures outlined in the Agency's Overview Document (USEPA, 2004a), and consistent with a stipulated injunction ordered by the Federal District Court for the Northern District of California in the case Center for Biological Diversity (CBD) vs. EPA *et al*. (Case No. 07-2794-JCS).

The DS was listed as threatened on March 5, 1993 (58 FR 12854) by the USFWS (USFWS, 2007a). DS are mainly found in the Suisun Bay and the Sacramento-San Joaquin estuary near San Francisco Bay. During spawning, the smelt move into freshwater.

1.2. Scope of Assessment

1.2.1. Uses Assessed

Carbaryl is registered for use as an insecticide on 115 sites, including agriculture, professional turf management and ornamental production, and residential settings. Carbaryl is used on many agricultural sites including root crops, fruit and nut tree, fruit and vegetable, and grain crops (including direct applications to water in rice production). Nationally, crops with the greatest annual use of carbaryl include apples, pecans, grapes, alfalfa, oranges, and corn. Carbaryl is also used by homeowners in residential settings for lawn care, gardening (vegetables and ornamentals), and pet care (pet collars, powders and dips, in kennels, and on pet sleeping quarters). Carbaryl is also used as an insecticide by nursery, landscape, and golf course industries on turf, annuals, perennials, and shrubs. Carbaryl also has forestry and rangeland uses and is used for control of grasshoppers, adult mosquitoes, ticks and fire ants. Additionally, carbaryl is used as a plant growth regulator to thin fruit (inducing abscission of flower buds) in orchards.

1.2.2. Environmental Fate Properties of Carbaryl

Carbaryl is an insecticide belonging to the N-methyl carbamate class of pesticides. It degrades rapidly via alkaline hydrolysis ($T_{1/2}$ = 3.1 h @ pH 9 and 12 d @ ph7) and aqueous photolysis ($T_{1/2}$ = 21 d). There is no evidence of degradation in acidic conditions. Under aerobic conditions, carbaryl degrades fairly rapidly in both soil and water with half-lives of less than 5 days. Its major degradation product by all routes is 1-naphthol which in turn degrades rapidly. Carbaryl does not appear to degrade by hydrolysis under acidic conditions and degrades less rapidly in aquatic systems under anaerobic conditions ($T_{1/2}$ = 71 d) than aerobic conditions. Carbaryl is considered moderately mobile in soils; sorption of carbaryl is dependent on soil organic matter. Because of the compound's low octanol-water partition coefficient (K_{ow} = 229), carbaryl is not expected to bioconcentrate to a significant extent. Potential transport mechanisms of carbaryl include runoff, spray drift, and secondary drift of volatilized or soil-bound residues leading to deposition onto nearby or more distant ecosystems. The magnitude of pesticide transport via secondary drift depends on the pesticide's ability to be mobilized into air and its eventual removal through wet and dry deposition of gases/particles and photochemical reactions in the atmosphere.

1.2.3. Evaluation of Degradates and Stressors of Concern

The primary degradation product of carbaryl is 1-naphthol. While carbaryl acts as a cholinesterase inhibitor in animals on contact and upon ingestion by competing for binding sites on the enzyme acetylcholine esterase, its 1-naphthol degradate does not inhibit acetylcholine esterase. Comparison of available toxicity information for 1-naphthol indicates roughly equivalent aquatic toxicity to that of the parent for the species tested; however, 1-naphthol degrades more rapidly and is less mobile than the parent. 1-Naphthol is a known plant auxin (Wood, 2010) and effects on plants are likely to be though this mode of action. Since 1-naphthol is less persistent and less mobile than the parent compound and acts through a different mode of action, this assessment focuses on the parent compound alone.

1.3. Assessment Procedures

A description of routine procedures for evaluating risk to the San Francisco Bay Species is provided in Attachment I.

1.3.1. Exposure Assessment

1.3.1.a. Aquatic Exposures

Tier 2 aquatic exposure models are used to estimate high-end exposures of carbaryl in aquatic habitats resulting from runoff and spray drift from different uses. The models used to predict aquatic EECs are the Pesticide Root Zone Model coupled with the Exposure Analysis Model System (PRZM/EXAMS). The Tier 1 rice model was used to estimate the concentrations due to application on rice. Default spray drift values of 5% of the application rate were used for aerial applications and 1% for ground applications. The associated default application efficiency for aerial and ground spray was 95% and 99% respectively. These loadings are then used as inputs to EXAMS. As estimated using PRZM and EXAMS, one-in-ten year peak EECs resulting from different carbaryl uses range from 0.47 µg/L for flowers around buildings to 166.8 for Brussels sprouts. In addition, a Tier 1 EEC of 2579 $\mu g \cdot L^{-1}$ was calculated for rice using the Tier 1 rice model. This estimate is much higher than the Tier 2 estimates as the rice model does not consider degradation of the pesticide. These estimates are supplemented with analysis of available California surface water monitoring data from U. S. Geological Survey's National Water Quality Assessment (NAWQA) program and the California Department of Pesticide Regulation. The maximum concentration of carbaryl reported by NAWQA for California surface waters with agricultural watersheds is 1.06 $\mu g \cdot L^{-1}$. It is, however within the range of Tier 2 estimates for the different crops evaluated. This value is approximately two orders of magnitude less than the maximum Tier 2 model-estimated environmental concentration. The maximum concentration of carbaryl reported by the California Department of Pesticide Regulation surface water database (0.31 $\mu g \cdot L^{-1}$) is roughly three orders of magnitude less than the highest peak Tier 2 model-estimated environmental concentration.

1.3.1.b. Terrestrial Exposures

Terrestrial plants are an important component in all four primary constituent elements (PCEs) of DS critical habitat, particularly for providing shade, and thus, temperature control, and in mitigating runoff and sedimentation, which also affects water quality. The TerrPlant model is used to estimate carbaryl exposures to plants inhabiting semi-aquatic and dry areas, resulting from uses involving foliar and granular carbaryl applications.

1.3.2. Toxicity Assessment

The assessment endpoints include direct toxic effects on survival, reproduction, and growth of individuals, as well as indirect effects, such as reduction of the food source and/or modification of habitat. Federally-designated critical habitat has been established for the DS. Primary PCEs were used to evaluate whether carbaryl has the potential to modify designated critical habitat. The Agency evaluated registrant-submitted studies and data from the open literature to characterize carbaryl toxicity. The most sensitive toxicity value available from acceptable or supplemental studies for each taxon relevant for estimating potential risks to the assessed species and/or their designated critical habitat was used.

Section 4 summarizes the ecotoxicity data available on carbaryl. Carbaryl is highly toxic to freshwater and estuarine/marine fish and highly to very highly toxic to aquatic invertebrates on an acute exposure basis. Chronic exposure to carbaryl resulted in decreased growth in freshwater fish and decreased reproduction in freshwater invertebrates. Carbaryl is highly toxic to nonvascular aquatic plants and is moderately toxic to vascular aquatic plants.

1.3.3. Measures of Risk

Acute and chronic risk quotients (RQs) are compared to the Agency's Levels of Concern (LOCs) to identify instances where carbaryl use has the potential to adversely affect the assessed species or adversely modify their designated critical habitat. When RQs for a particular type of effect are below LOCs, the pesticide is considered to have "no effect" on the species and its designated critical habitat. Where RQs exceed LOCs, a potential to cause adverse effects or habitat modification is identified, leading to a conclusion of "may affect". If carbaryl use "may affect" the assessed species, and/or may cause effects to designated critical habitat, the best available additional information is considered to refine the potential for exposure and effects, and distinguish actions that are Not Likely to Adversely Affect (NLAA) from those that are Likely to Adversely Affect (LAA).

Table 1-1. Effects Determination Summary for Effects of Carbaryl on the Delta Smelt

Species	Effects Determination	Basis for Determination

Species	Effects Determination	Basis for Determination
Delta smelt (*Hypomesus transpacificus*)	May Affect, Likely to Adversely Affect (LAA)	**Potential for Direct Effects** Using fish toxicity data for Atlantic salmon and modeled EECs and consideration of individual effects, risk could not be precluded for rice, Brussels sprouts, strawberries, lettuce, broccoli, horseradish, wasteland, peaches, olives, ornamentals, sweet potatoes, asparagus, citrus, almonds, potato, rural shelter belts, celery and lawns due acute effects and, in addition, apple, loquat, sweet corn, grapes, tomatoes, potato, rights-of-way, rural shelter belts and ticks due to chronic effects. **Potential for Indirect Effects** ***Aquatic prey items, aquatic habitat, cover and/or primary productivity*** Using toxicity data representing freshwater (stoneflies) and estuarine invertebrates (mysid shrimp) and modeled exposures, risks could not be precluded based effects to prey items for all use patterns except flowers around buildings. ***Terrestrial prey items, riparian habitat*** Based on known but unquantified reproductive effects on terrestrial plants, effects on riparian habitat cannot be precluded.

1.4. Summary of Conclusions

Based on the best available information, the Agency makes a May Affect, and Likely to Adversely Affect determination for the DS from the use of carbaryl. Additionally, the Agency has determined that there is the potential for modification of designated critical habitat for the DS from the use of the chemical. A summary of the risk conclusions and effects determinations for the DS and its designated critical habitat is presented in **Table 1-1** and **Table** 1-2. Use-specific determinations are provided in **Table 1-3**. Further information on the results of the effects determination is included as part of the Risk Description in Section 5.2. Given the LAA determination for the DS and potential modification of designated critical habitat for the smelt, a description of the baseline status and cumulative effects for DS is provided in Attachment II.

Table 1-2. Effects Determination Summary for the Critical Habitat Impact Analysis

Designated Critical Habitat for:	Effects Determination	Basis for Determination
Delta smelt (*Hypomesus transpacificus*)	Habitat Modification	Using toxicity data representing freshwater (stoneflies) and estuarine invertebrates (mysid shrimp) and modeled exposures, risks could not be precluded for effects to prey items for all use patterns except flowers around buildings. Based on known but unquantified reproductive effects on terrestrial plants, habitat modification though effects on riparian habitat cannot be precluded.

Table 1-3. Use Specific Summary of The Potential for Adverse Effects to Delta Smelt

Uses	Potential for Effects to Delta Smelt Found in the Aquatic Environment:									
	Delta Smelt and Estuarine/Marine Vertebrates[1]		Delta Smelt and Freshwater Vertebrates[1]		Freshwater Invertebrates[2]		Estuarine/Marine Invertebrates[2]		Vascular Plants[2]	Non-vascular Plants[2]
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic		
A: Home lawn	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
B: Flowers around buildings	No	No	No	No	No	No	No	No	No	No
C: Lawns	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
D: Ornamentals	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
E Parks	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
F: Citrus 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
F: Citrus 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
G Olives	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
H: almonds	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
I: flowers	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
J: peaches	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
K: asparagus	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
L: apple	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
M: loquat	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
N: sweet corn	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
O: grapes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
P: strawberries	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Q: tomatoes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
R peanuts	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
S broccoli	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
T Brussels sprouts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
U sweet potatoes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
V: Field corn	No	No	No	No	Yes	Yes	Yes	Yes	No	No
W: head lettuce	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
X: sorghum	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
Y: celery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Z: horse radish	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AA: potato	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AB: radish	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AC: rice	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	yes	yes

	Potential for Effects to Delta Smelt Found in the Aquatic Environment:									
	Delta Smelt and Estuarine/Marine Vertebrates[1]		**Delta Smelt and Freshwater Vertebrates[1]**		**Freshwater Invertebrates[2]**		**Estuarine/Marine Invertebrates[2]**			
AD: dry beans	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AE: okra	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AF: sugar beet	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AG: alfalfa	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AH: pasture	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AI: grass for seed	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AJ: rangeland	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AK: melons	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AL: roses	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AM: rights of way	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AN: wasteland	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AO: non-urban forests	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AP: rural shelter belts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AQ: Ticks	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AR: flea collars	No	No	No	No	No	No	No	No	No	No

1 A yes in this column indicates a potential for direct effects to Delta smelt.
2 A yes in this column indicates a potential for indirect effects to Delta smelt.

Based on the conclusions of this assessment, a formal consultation with the U. S. Fish and Wildlife Service under Section 7 of the Endangered Species Act should be initiated.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the listed species and its resources (*i.e*., food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of drift and downstream transport (*i.e*., attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the species and its resources (*i.e*., food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of drift and downstream transport (*i.e*., attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available. Examples of such information and methodology required for this type of analysis would include the following:

- Enhanced information on the density and distribution of DS life stages within the action area and/or applicable designated critical habitat. This information would allow for quantitative extrapolation of the present risk assessment's predictions of individual effects to the proportion of the population extant within geographical areas where those effects are predicted. Furthermore, such population information would allow for a more comprehensive evaluation of the significance of potential resource impairment to individuals of the assessed species.
- Quantitative information on prey base requirements for the assessed species. While existing information provides a preliminary picture of the types of food sources utilized by the assessed species, it does not establish minimal requirements to sustain healthy individuals at varying life stages. Such information could be used to establish biologically relevant thresholds of effects on the prey base, and ultimately establish geographical limits to those effects. This information could be used together with the density data discussed above to characterize the likelihood of adverse effects to individuals.
- Information on population responses of prey base organisms to the pesticide. Currently, methodologies are limited to predicting exposures and likely levels of direct mortality, growth or reproductive impairment immediately following exposure to the pesticide. The degree to which repeated exposure events and the inherent demographic characteristics of the prey population play into the extent to which prey resources may recover is not predictable. An enhanced understanding of long-term prey responses to pesticide exposure would allow for a more refined determination of the magnitude and duration of resource impairment, and together

with the information described above, a more complete prediction of effects to individual species and potential modification to critical habitat.

2. Problem Formulation

Problem formulation provides a strategic framework for the risk assessment. By identifying the important components of the problem, it focuses the assessment on the most relevant life history stages, habitat components, chemical properties, exposure routes, and endpoints. The structure of this risk assessment is based on guidance contained in U.S. EPA's *Guidance for Ecological Risk Assessment* (USEPA, 1998), the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998) and is consistent with procedures and methodology outlined in the Overview Document (USEPA, 2004a) and reviewed by the U.S. Fish and Wildlife Service and National Marine Fisheries Service (USFWS/NMFS/NOAA, 2004).

2.1. Purpose

The purpose of this endangered species assessment is to evaluate potential direct and indirect effects on individuals of the threatened DS arising from FIFRA regulatory actions regarding use of carbaryl on root crops, small fruits and berries, grapes, tree nuts, orchards, citrus, residential gardens (fruit and vegetable), turf (commercial and residential), forage crops, forests and rangeland. Carbaryl is also used as an insecticide on pets and for control of grasshoppers, adult mosquitoes, ticks and fire ants. On orchards, carbaryl is also used to thin fruit.

In this assessment, direct and indirect effects to the DS and potential modification to designated critical habitat for the DS were completed in accordance with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998), procedures outlined in the Agency's Overview Document (USEPA, 2004a), and consistent with a stipulated injunction ordered by the Federal District Court for the Northern District of California in the case *Center for Biological Diversity (CBD) vs. EPA* et al. (Case No. 07-2794-JCS).

The DS was listed as threatened on March 5, 1993 (58 FR 12854) by the USFWS (USFWS, 2007a). DS are mainly found in the Suisun Bay and the Sacramento-San Joaquin estuary near San Francisco Bay. During spawning DS move into freshwater.

In accordance with the Overview Document, provisions of the ESA, and the Services' *Endangered Species Consultation Handbook*, the assessment of effects associated with registrations of carbaryl is based on an action area. The action area is the area directly or indirectly affected by the federal action, as indicated by the exceedance of the Agency's Levels of Concern (LOCs). It is acknowledged that the action area for a national-level FIFRA regulatory decision associated with a use of carbaryl may potentially involve numerous areas throughout the United States and its Territories. However, for the purposes of this assessment, attention will be focused on relevant sections of the action area including those geographic areas associated with locations of the DS and their designated critical habitat within the state of California. As part of the "effects determination," one of the following three conclusions will be reached for the DS regarding the potential use of carbaryl in accordance with current labels:

- “No effect”;
- “May affect, but not likely to adversely affect”; or
- “May affect and likely to adversely affect”.

Additionally, for habitat and PCEs, a “No Effect” or a “Habitat Modification” determination is made.

A description of routine procedures for evaluating risk to the San Francisco Bay Species is provided in Attachment I.

2.2. Scope

The end result of the EPA pesticide registration process (*i.e.*, the FIFRA regulatory action) is an approved product label. The label is a legal document that stipulates how and where a given pesticide may be used. Product labels (also known as end-use labels) describe the formulation type (*e.g.*, liquid or granular), acceptable methods of application, approved use sites, and any restrictions on how applications may be conducted. Thus, the use or potential use of carbaryl in accordance with the approved product labels for California is “the action” relevant to this ecological risk assessment.

Carbaryl is a carbamate insecticide registered for control of a wide range of insect and other arthropod pests on over 100 agricultural and non-crop use sites, including home and garden uses. The chemical is also used to thin fruit in orchards.

Although current registrations of carbaryl allow for use nationwide, this ecological risk assessment and effects determination addresses currently registered uses of carbaryl in portions of the action area that are reasonably assumed to be biologically relevant to the DS and their designated critical habitat. Further discussion of the action area for the DS and their critical habitat is provided in Section 2.8.

2.2.1. Evaluation of Degradates and Other Stressors of Concern

This assessment quantitatively considers effects of exposures of carbaryl only. Carbaryl degrades into one notable degradate, 1-naphthol; however, 1-naphthol is a natural product and is also formed as a degradation product of naphthalene and other polycyclic aromatic hydrocarbons. Available environmental fate data indicate that 1-naphthol degrades more rapidly and is less mobile than the parent. Toxicity data indicate that 1-naphthol is roughly equal to or less toxic than the parent compound depending on the species tested. Since the degradate is no more toxic than the parent compound, the risk assessment is considered protective for non-target species as the toxicity endpoints are the most sensitive measured.

2.2.2. Evaluation of Mixtures

The Agency does not routinely include, in its risk assessments, an evaluation of mixtures of active ingredients, either those mixtures of multiple active ingredients in product formulations or those in the applicator’s tank. In the case of the product formulations of active ingredients (that is, a registered product containing more than one active ingredient), each active ingredient is subject to an individual risk assessment for regulatory decision regarding the active ingredient on a particular use site. If effects data are available for a formulated product containing more than one active ingredient, they may be used qualitatively or quantitatively in accordance with the Agency's Overview Document and the Services' Evaluation Memorandum (U.S., EPA 2004a; USFWS/NMFS 2004).

Carbaryl has registered products that contain multiple active ingredients. Analysis of the available acute oral mammalian LD_{50} data for multiple active ingredient products relative to the single active ingredient is provided in Appendix A. The results of this analysis show that an assessment based on the toxicity of the single active ingredient of carbaryl is appropriate.

2.3. Previous Assessments

2.3.1. Carbaryl Reregistration Eligibility Decision

In March 2003, a revised environmental fate and ecological risk assessment was published in support of the interim Reregistration Eligibility Decision (IRED) on carbaryl (USEPA 2004b). The chapter was revised to include additional ecological effect studies and to address issues raised during the public comment phase of the reregistration process. The baseline risk assessment concluded that for many of the registered uses of carbaryl, acute and chronic risk levels of concern were exceeded for mammals and chronic risk levels of concern were exceeded for birds. Citrus was the only use that exceeded the acute risk LOC for fish; however, most of the uses exceeded the acute and chronic risk LOCs for aquatic invertebrates. Based on a single acceptable study of green algae, none of the uses evaluated exceeded the acute risk LOC for aquatic plants. No data were available to assess the risk of carbaryl to terrestrial plants; however according to some labels, it may cause injury to tender foliage if applied to wet foliage or during periods of high humidity and incident data suggested that both ornamental and agricultural crops could be affected by carbaryl.

Beneficial insects were sensitive to carbaryl and incident data submitted subsequent to the publication of the ecological risk assessment indicate that a number of bee kills have been associated with the use of carbaryl. The use of carbaryl to thin fruit in orchards could serve as a source of exposure for honeybees to carbaryl. This may occur when subtle shifts in elevation or different varieties of fruit render adjacent orchards in different stages of bloom and overlap the application of carbaryl in one orchard for thinning purposes while bees are present in the adjacent orchard for pollination purposes.

As a result of the IRED, a number of measures have been implemented to mitigate the risks to wildlife, homeowners, and agricultural workers. This includes the cancellation of use on some crops and the use of some formulations for certain uses, restrictions on aerial application for some uses, and restrictions on application timing for some crops. This mitigation is considered in this assessment.

Because the Agency determined that carbaryl shares a common mechanism of toxicity with the structurally-related N-methyl carbamate insecticides, a cumulative human health risk assessment for the N-methyl carbamate insecticides was necessary before the Agency could make a final determination of reregistration eligibility of carbaryl (USEPA 2007b).

2.3.2. Carbaryl Endangered Species Assessments

As noted in the IRED on carbaryl (USEPA 2004b), EPA consulted with the U. S. Fish and Wildlife Service in 1989 regarding potential impacts on endangered species from certain uses of carbaryl (USFWS 1989). As a result, the U.S. Fish and Wildlife Service issued a formal Biological Opinion which identified reasonable and prudent measures (RPM) and alternatives (RPA) to mitigate potential effects of carbaryl use on endangered species.

EPA also consulted with the National Marine Fisheries Service concerning potential effects of carbaryl use on endangered salmon and steelhead in the Pacific Northwest. In its assessment, the Agency determined that the use of carbaryl may affect 20 salmon and steelhead evolutionarily significant units (ESUs), may affect but is not likely to adversely affect two ESUs and will have no effect on four ESUs (Turner 2003).

In September of 2007 EPA completed an endangered species assessment of carbaryl for the Barton Springs salamander (*Eurycea sosorum*) (USEPA 2007) and concluded that there was a potential to indirectly adversely affect the Barton Springs salamander through reductions in its invertebrate forage base. However, based on this assessment, carbaryl use in the Barton Springs segment of the Edwards Aquifer had no effect on the critical habitat of the Barton Springs salamander.

In October of 2007, EPA completed an assessment of carbaryl for the California red-legged frog (*Rana aurora draytonii*) (EFED 2007) and concluded that based on the potential for direct effects on *R. aurora* and indirect effects on its prey, carbaryl was likely to adversely affect the listed species and modify its designated critical habitat.

2.4. Aquatic Life Criteria

The Health and Ecological Criteria Division of the Office of Science and Technology within the Office of Water is in the process of drafting Ambient Aquatic Life Water Quality Criteria for carbaryl. This effort is being conducted under Section 304(a)(1) of the Clean Water Act requiring the EPA to publish water quality criteria that accurately reflect the latest scientific knowledge on the kind and extent of all identifiable effects on health and welfare that might be expected from the presence of pollutants in any body of water, including ground water. These values are intended to serve as guidance to states.

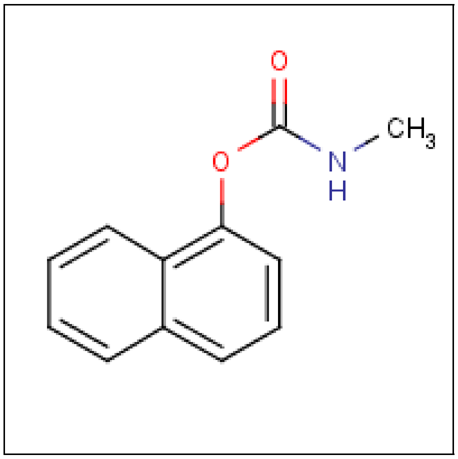


Figure 2-1. Chemical structure of carbaryl

2.5. Environmental Fate Properties

The following fate and transport description for carbaryl (**Figure 2-1**) is consistent with the information contained in the initial 2004 IRED (USEPA, 2004b).

Table 2-1 lists the physical-chemical properties of carbaryl. Environmental fate and transport data are summarized in **Table 2-2**. 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. The hydrolysis of carbaryl is pH dependent. There is no evidence of degradation at a pH of 5 and degradation occurs in neutral (pH 7) and alkaline (pH 9) systems with measured half-lives of 12 days and 0.13 days, respectively. The major degradation product was 1-naphthol which did not further degrade during the course of the 30 day experiment.

Carbaryl degraded rapidly by aqueous photolysis to 1-naphthol with a half-life of 1.8 days which in turn degraded very rapidly with a half-life of less than 1 hour. In aerobic soil and aquatic systems, carbaryl degrades fairly rapidly ($t_{½}$ =4.0 and 4.9 days respectively) but more slowly under anaerobic conditions ($t_{½}$ =72 days).

Carbaryl is considered to be moderately mobile in soils according to the FAO mobility classification (FAO, 2000). Based on measurement in batch sorption/ desorption studies, the compound has K_{oc} of 195 L·kg^{-1}. This was confirmed in a soil column leaching study which showed movement of carbaryl below 12 cm in each of 4 columns following elution with 20 cm of water. Because of the low octanol/water partition coefficient of 229 (Windholz *et al.*, 1976), carbaryl is not expected to bioconcentrate to a significant extent.

Table 2-1. Physical-chemical Properties of Carbaryl

Property	Parent Compound	
	Value and units	**MRID or Source**
Molecular Weight	201.22 g/mole	calculated
Chemical Formula	$C_{12}H_{11}NO_2$	calculated
Density	1.21 kg·L^{-1}	45400104
Bulk Density	0.744 kg·L^{-1}	45400104
Vapor Pressure	1.36 x 10^{-6} torr @ 25^{o} C	Ferreira and Seiber, 1981
Henry's Law Constant	1.28 x 10^{-8} atm·m^{3}·mol^{-1}	Suntio *et al.*, 1988
Water Solubility	32 mg·L^{-1} at 20^{o} C	Suntio *et al.*, 1988
Octanol – water partition coefficient (K_{OW})	229	Windholz *et al.*, 1976
UV/visible light	220 nm: 8.27 x 10^{4} L·mol^{-1}·cm^{-1}	46771301

Property	Parent Compound	
	Value and units	MRID or Source
absorption	270 nm: 5.74 x 10^3 $L\cdot mol^{-1}\cdot cm^{-1}$ 278 nm: 6.43 x 10^3 $L\cdot mol^{-1}\cdot cm^{-1}$ 291 nm: 4.21 x 10^3 $L\cdot mol^{-1}\cdot cm^{-1}$	

Table 2-2. Summary of Carbaryl Environmental Fate Properties

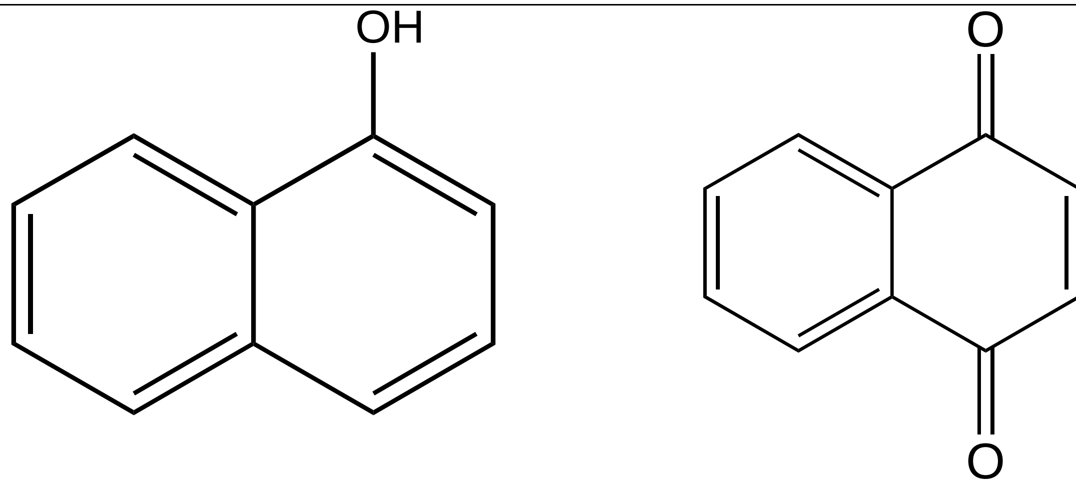
Study	Value and unit	MRID # or Citation	Study Classification, Comment
Abiotic Hydrolysis	Half-life[1] = pH 5: no evidence of degradation pH 7: 12 days pH 9: 0.13 days	00163847, 44759301	
Direct Aqueous Photolysis	Half-life[1] = 21 days	41982603	
Aerobic Soil Metabolism	Half-life[1] = 4 days, unidentified sandy loam	42785101	
Aerobic Aquatic Metabolism half life[1,2]	4.9 d (clay loam) 101.4 d (clay loam) 92.3 (sand)	43143401 46580701 46580701	
Anaerobic Aquatic Metabolism[1,2]	72 days	42785102	
Foliar Dissipation Half-life[3]	3.71 d	D288376	
Foliar Washoff Rate	0.91 cm^{-1}	D288376	
Batch Equilibrium	K_f =1.74 - sandy loam 2.04clay loam sediment 3.00- silt loam 3.52 - silty clay loam 1/n values ranged from 0.78-0.84 K_{oc} =196 $L\cdot kg_{oc}^{-1}$	43259301	
Soil Column Leaching	slightly mobile in columns (30-cm length) of sandy loam, silty clay loam, silt loam, and loamy sand soils	43320701	
Forestry Dissipation Study	Foliar $t_{1/2}$ = 21 days Leaf Litter $t_{1/2}$ = 75 days Soil $t_{1/2}$ = 65 days	43439801	supplemental
Bioconcentration Factor (BCF)- Species Name	NA		not expected due to low K_{ow}

Abbreviations: wt=weight, NA – not available

1Half-lives were calculated using the single-first order equation and nonlinear regression, unless otherwise specified.

2 Total system half-life

3The value may reflect both dissipation and degradation processes.



1-naphthol **1,4-napthoquinone**

Figure 2-2**.** Chemical structures of primary environmental degradates of carbaryl.

Degradation products from the laboratory fate studies are in **Table 2-3.** Carbon dioxide was found to form in both aerobic and anaerobic metabolism studies and was still increasing at the end of all three studies. As noted above, 1-naphthol (Figure 2-2) was the primary degradate in all the degradation studies, but was only formed transiently, in most cases having completely degraded by the end of each study. The only other major degradate was 1, 4-napthoquinone (Figure 2-2) which was found at 17.3% on the third day after study initiation in the aerobic aquatic metabolism study. Data on the primary degradate, 1-naphthol are limited; however, 1-naphthol appears to be less mobile than the parent and is not likely to persist due to fairly rapid degradation. Since 1-naphthol can occur from a variety of natural and anthropogenic processes, its presence cannot be considered indicative of carbaryl use.

Table 2-3. The Maximum Amount of Degradates Formed in Laboratory Degradation Studies by Carbaryl and the Time When the Maximum Occurred.

Degradate	Hydrolysis	Aqueous Photolysis	Aerobic Soil Metabolism	Aerobic Aquatic Metabolism	Anaerobic Aquatic Metabolism
CO_2			59.7%@14d*	18.5%@101d*	12.3%@a26d*
1-naphthol	pH 7 77%@30 d pH 9: 95%@ 1d	67% @ 14d	34.5%@1d	24.7%@1d	24.9%@4d
1,4-naphthoquinone				17.6%@3d	2.5%@4d
napthalene-1,5-diol				5.6%@4d	0.4%@126d*
phthalic acid				6.6%@60d	
4-hydroxycarbaryl				3.3%@30d	
1-napthylhydroxymethylcarbamate			0.3%@4d		1.6%@126d*
5-hydroxy-1-napthylmethylcarbamate			0.9%@1d		1.1%@94d

* The time of maximum occurrence of the degradate was at the termination of the study.

2.5.1. Environmental Transport Mechanisms

Potential transport mechanisms include pesticide surface water runoff, spray drift, and secondary drift of volatilized or soil-bound residues leading to deposition onto nearby or more distant ecosystems. The magnitude of pesticide transport via secondary drift depends on the pesticide's ability to be mobilized into air and its eventual removal through wet and dry deposition of gases/particles and photochemical reactions in the atmosphere. A number of studies have documented atmospheric transport and redeposition of pesticides from the Central Valley to the Sierra Nevada Mountains (Fellers *et al*., 2004, Sparling *et al*., 2001, LeNoir *et al*., 1999, and McConnell *et al*., 1998). Prevailing winds blow across the Central Valley eastward to the Sierra Nevada Mountains, transporting airborne industrial and agricultural pollutants into Sierra Nevada ecosystems (Fellers *et al*., 2004, LeNoir *et al*., 1999, and McConnell *et al*., 1998). Therefore, physicochemical properties of the pesticide that describe its potential to enter the air from water or soil (*e.g*., Henry's Law constant and vapor pressure), pesticide use, modeled estimated concentrations in water and air, and available air monitoring data from the Central Valley and the Sierra Nevada Mountains are considered in evaluating the potential for atmospheric transport of carbaryl to habitat for the DS. In general though, given carbaryl's relatively rapid degradation, its potential for long-range atmospheric transport is limited.

Several sections of the range and critical habitat for the DS are located east of the Central Valley. The magnitude of transport via secondary drift depends on carbaryl's ability to be mobilized into air and its eventual removal through wet and dry deposition of gases/particles and photochemical reactions in the atmosphere. Carbaryl has been detected in both fog and rainfall in California (Majewski *et al*. 2006; Schomburg *et al.* 1991). This data is discussed in Section 3.2.4 below. In addition an evaluation of the potential additional exposure to carbaryl from rainfall has been included in the Risk Characterization

In general, deposition of drifting or volatilized pesticides is expected to be greatest close to the site of application. For aquatic exposure, drift was estimated using default values which represent drift associated with various application methods (*i.e.* aerial, air blast, ground spray) Spray drift assessment for terrestrial exposure was not performed as there is only one terrestrial assessment endpoint (habitat modification through effects on terrestrial plants) and there is no measurement endpoint for this effect with which to compare the terrestrial exposure assessment values.

2.5.2. Mechanism of Action

Carbaryl is an insecticide belonging to the N-methyl carbamate class of pesticides. Carbaryl is a cholinesterase inhibitor that acts on animals on contact and upon ingestion by competing for binding sites on the enzyme acetylcholine esterase, thus preventing the breakdown of the neurotransmitter acetylcholine. The primary degradate, 1-naphthol does not inhibit acetyl cholinesterase. Carbaryl is also used to thin fruit in orchards; its activity in the abscission of flower buds may be related to its structural similarity to plant auxins, such as α-naphthalene acetic acid. The carbaryl degradate 1-naphthol is a known plant auxin[1].

[1] http://chemicalland21.com/lifescience/agro/1-NAPHTHALENEACETIC%20ACID.htm

2.5.3. Use Characterization

Analysis of labeled use information is the critical first step in evaluating the federal action. The current labels for carbaryl represent the FIFRA regulatory action; therefore, labeled use and application rates specified on the label form the basis of this assessment. The assessment of use information is critical to the development of the action area and selection of appropriate modeling scenarios and inputs.

Carbaryl is nationally registered for over 115 uses in agriculture, professional turf management, ornamental production, and residential settings (See **Appendix D**). Included in the registered uses is carbaryl use as a mosquito adulticide. Agricultural uses include tree fruit, nuts, fruit and vegetable, and grain crops. Carbaryl is used by homeowners in residential settings for lawn care, gardening (vegetables and ornamentals), and pet care (pet collars, powders, and dips, in kennels, and on pet sleeping quarters). Carbaryl also is used by nursery, landscape, and golf course industries on turf, annuals, perennials, and shrubs. Additionally, carbaryl is used to thin fruit in orchards to enhance fruit size and enhance repeat bloom.[2]

For assessment purposes, specific uses of carbaryl were grouped by similarity of crops and application rates. Crop groups are given an alphabetic identification and a title. The crop groups used in this assessment, as well as the specific uses which apply to the groups and their application rate information, are available in **Table 2-4.**

Table 2-4. Carbaryl Uses Assessed for California

Crop Group	Specific crops included in this group	Max. App. Rate (lb a.i./acre)	Max. No. of Apps.	Application Intervals (days)	Application Method
A: Home lawn	Home lawn (includes mosquito adulticide use	9.1	2	7	ground
B: Flower beds around buildings	Flower beds around buildings and lawns, building perimeter treatment	8	25	3	Drop/broadcast spreader
C: Lawns	Lawns	7.8	4	7	ground
D: Ornamentals	Ornamentals	7.8	4	7	ground
E: Parks	Parks, recreation areas, golf courses, sod farms, commercial lawns	4	2	7	ground
F: Citrus	Oranges, lemons, grapefruit, tangerines, etc.	16	1	NA	aerial
G: Olives	Olives	7.5	2	14	aerial
H: Almonds	Almonds, chestnuts, pecans, filberts, walnuts, pistachio	5	3	7	aerial
I: Flowers	Flowers and shrubs	4.3	3	7	ground
J: Peaches	Peaches, apricots, cherries, nectarines, plums, prunes	4 (5 dormant)	2 + 1 dormant	15	aerial
K: Asparagus*	Asparagus	Pre: 2 Post: 4	Pre:3 Post: 1	Pre:3 Post: NA	aerial
L: Apple	Apple, pear, crabapple, oriental pears	3	5	14	aerial
M: Loquat	loquat	3	5	14	aerial

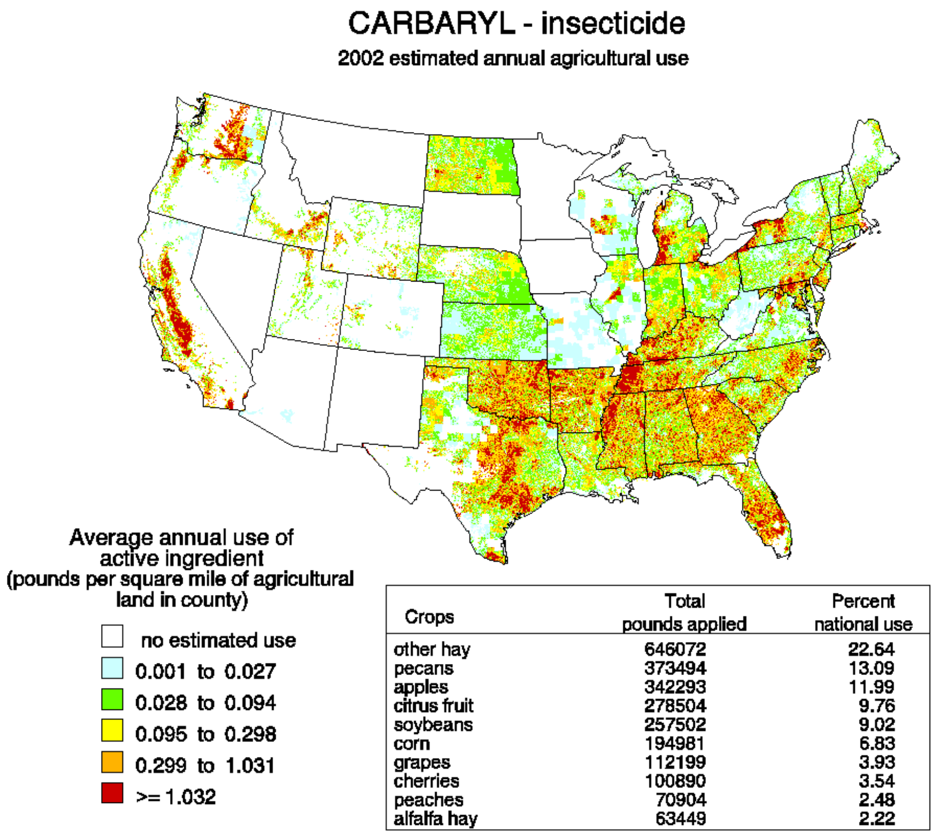
[2] (http://www.umass.edu/fruitadvisor/NEAPMG/145-149.pdf).

Crop Group	Specific crops included in this group	Max. App. Rate (lb a.i./acre)	Max. No. of Apps.	Application Intervals (days)	Application Method
N: Sweet corn	Sweet corn	2	8	3	aerial
O: Grapes	Grapes, caneberries, blueberries	2	5	7	aerial
P: Strawberries	strawberries	2	5	7	aerial
Q: Tomatoes	Tomatoes, peppers, eggplant	2	4	7	aerial
R: Peanuts	peanuts	2	4	7	aerial
S: Broccoli	Broccoli, cauliflower, cabbage, kohlrabi, Chinese cabbage, collards, kale, mustard greens	2	4	6	aerial
T: Brussels sprouts	Brussels sprouts and Hanover salad	2	4	6	aerial
U: Sweet potato	Sweet potato	2	4	7	aerial
V: Field corn	Field corn, popcorn	2	4	14	aerial
W: Lettuce, head	Head and leaf lettuce, dandelion, endive, parsley, spinach, Swiss chard	2	3	7	aerial
X: Sorghum	sorghum	2	3	7	aerial
Y: Celery	Celery, prickly pear, garden beets, carrots	2	3	7	aerial
Z: Horseradish	Horseradish	2	3	7	aerial
AA: Potato	Potato, parsnip, rutabaga, turnip (root)	2	3	7	aerial
AB: Radish	radish	2	3	7	aerial
AC: Rice	Rice	1.5	2	7	aerial
AD: Beans	Dry beans, fresh peas, dry peas, cow peas, southern peas (fresh)	1.5	4	7	aerial
AE: Okra	Okra	1.5	4	6	ground
AF: Sugar beet	Sugar beet	1.5	2	14	aerial
AG: Alfalfa	Alfalfa, birds foot trefoil, clover	1.5	7	30	aerial
AH: Pasture	Pasture	1.5	2	14	aerial
AI: Grass for seed	Grass for seed	1.5	2	14	aerial
AJ: Rangeland	Rangeland	1	1	NA	aerial
AK: Melon	Melon, cucumber, pumpkin, squash	1	6	7	aerial
AL: Roses	Roses, herbaceous plants, woody plants	1	6	7	aerial
AM: Rights-of-way	Rights-of-way, hedgerows, ditch banks, roadsides	1	2	14	aerial
AN: Wasteland	wasteland	1	2	14	aerial
AO: Non-urban forests	Non-urban forests, tree plantations, Christmas trees, parks, rangeland trees	1	2	7	aerial
AP: Rural shelter belts	Rural shelter belts	1	2	7	aerial
AQ: Ticks	Ticks, grasshoppers	1	25	3	ground
AR: Flea collars	dogs, cats	NA	NA	NA	NA

NA – not applicable

* There are different pre-harvest and post-harvest application patterns that can be applied to asparagus in the same year.

Information from EPA's Biological and Economic Analysis Division (BEAD) indicates that many crops can be grown more than one time/year in California (USEPA 2007b). Of the crops for which carbaryl is registered, 18 can have more than one cropping cycle per year: broccoli, cauliflower, cabbage, kohlrabi, Chinese cabbage, collards, kale, mustard greens, both head and leaf lettuce, Hanover salad, dandelion, endive, parsley, Swiss chard, celery, beets, and radish. In most cases, fields that are double or triple cropped will be rotated among crops, however, given the wide variety of crops onto which carbaryl can be applied, it is possible for carbaryl to be applied to three different crops in the same field in the same year. Most carbaryl product labels specify application rates on a per crop cycle basis (not on a per year basis). Since standard PRZM scenarios only consist of one crop per year, applications to only one crop per year were modeled. If carbaryl is applied for multiple cropping cycles within a year, EECs presented in this assessment may under-predict exposures. For carbaryl, this under-prediction is likely to be small as it degrades quickly and only small amounts will carryover from cropping cycle to cropping cycle. For all other labeled uses, it was assumed that a maximum seasonal application rate specified on the label was equivalent to a maximum annual application.



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

Figure 2-3. Carbaryl Use in Total Pounds per County
(Source: http://ca.water.usgs.gov/pnsp/pesticide_use_maps/show_map.php?year=02&map=m6006)

As noted in the carbaryl IRED (USEPA 2004b), approximately 3.9 million pounds of carbaryl active ingredient are sold annually in the U. S.; with about half used in agriculture and half in non-agricultural settings (per 1998 data). The amount of carbaryl usage in agriculture has declined from an average of 1.9 million pounds of active ingredient per year from 1992 through 2001, to 1 to 1.5 million pounds of active ingredient in 2001. Figure 2-3 depicts the extent of estimated annual carbaryl use nationally as of 2002. As of 2002, a total of 2,440,288 pounds of carbaryl were applied annually; the highest (646,072 lbs) was applied to hay. Pecans (373,494 lbs) and apples (342,293 lbs) represented the second and third highest total pounds of carbaryl applied, respectively. It is clear from Figure 2-3 that the use of carbaryl exceeds 1 lb per square mile for large parts of the Central Valley of California.

BEAD provides an analysis of both national- and county-level usage information (USEPA, 2010) using state-level usage data obtained from USDA-NASS[3], Doane (www.doane.com;) the full dataset is not provided due to its proprietary nature) and the California's Department of Pesticide Regulation Pesticide Use Reporting (CDPR PUR) database[4]. CDPR PUR is considered a more comprehensive source of usage data than USDA-NASS or EPA proprietary databases, and, thus, the usage data reported for carbaryl by county in this California-specific assessment were generated using CDPR PUR data. Three years (2003-2005) of usage data were included in this analysis. Data from CDPR PUR were obtained for every agricultural pesticide application made on every use site at the section level (approximately one square mile) of the public land survey system.[5] BEAD summarized these data to the county level by site, pesticide, and unit treated. Calculating county-level usage involved summarizing across all applications made within a section and then across all sections within a county for each use site and for each pesticide. The county level usage data that were calculated include: average annual pounds applied, average annual area treated, and average and maximum application rate across all three years. The units of area treated are also provided where available.

From 2003-2005 according to CDPR PUR data, the percentage of total carbaryl use in California was highest on oranges (21.2% of total use), apples (8.2%), landscape maintenance (7.8%), rice (5.9%) olives (4.5%), pistachios (4.4%), peaches (4.4%) and tomatoes (4.1%). The total annual average for reported uses over this three year period was 211,645 lbs. Distribution of the carbaryl uses from 2003-2005 on orchards and vineyards (including nuts and fruit), agricultural crops and non-agricultural uses is depicted in **Figure 2-4**. Data are unavailable for residential uses of carbaryl, since these data are not reported to the state. See **Appendix C** for more details on uses of carbaryl in California over 2003-2005.

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[3] United States Depart of Agriculture (USDA), National Agricultural Statistics Service (NASS) Chemical Use Reports provide summary pesticide usage statistics for select agricultural use sites by chemical, crop and state. See http://www.pestmanagement.info/nass/app_usage.cfm.

[4] The California Department of Pesticide Regulation's Pesticide Use Reporting database provides a census of pesticide applications in the state. See http://www.cdpr.ca.gov/docs/pur/purmain.htm.

[5] Most pesticide applications to parks, golf courses, cemeteries, rangeland, pastures, and along roadside and railroad rights of way, and postharvest treatments of agricultural commodities are reported in the database. The primary exceptions to the reporting requirement are home-and-garden use and most industrial and institutional uses (http://www.cdpr.ca.gov/docs/pur/purmain.htm).

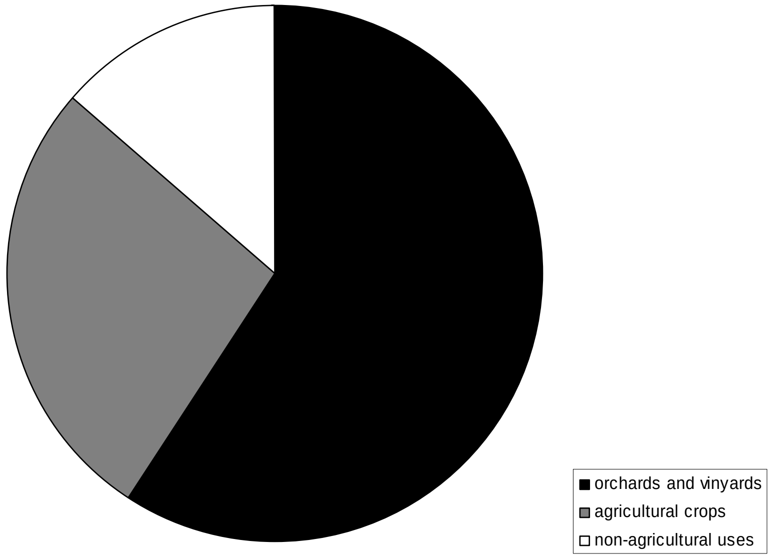

Figure 2-4. Distribution of Reported Mass of Carbaryl Applied During 2003-2005 in California by Crop Group.

A comprehensive list of current uses of carbaryl, along with the methods and rates associated with applications of carbaryl is included in **Appendix D**. Uses that could be modeled using the same application practices on the same scenario (for aquatic exposure estimation) have been modeled as a group with one crop serving as a surrogate for the group. The crop groups and their application practices are in **Table 2-4**. Rationales for the choices of surrogates and groups are provided in **Appendix D**. Since only the use rates (*i.e.*, pounds of active ingredient applied, number of applications and reapplication interval) and not the scenario (*e.g.*, crop-specific soil types and application dates and weather data) are considered for terrestrial exposure estimation, crop groupings need not be split out by scenario.

For some use patterns, no limit was placed the maximum number of applications, the maximum seasonal/annual rate or minimum application interval. Since these values are necessary for a use pattern to be assessable, values for two of these parameters must be assumed when they are not specified on the label. The use patterns, as assessed, are in **Table 2-4.**

There are 13 use patterns for which carbaryl is registered that were not explicitly evaluated. These are flax, home fruits and vegetables, cranberries, proso millet, lentils, soybeans, dry southern peas, sunflower, tobacco, transplants, wheat, and adult mosquitoes. Cranberries, dry southern peas, tobacco, and soybeans are not grown in California. Current carbaryl labels specifically prohibit use on flax, home fruits and vegetables, oysters, proso millet, sunflowers, and wheat in California. The transplants use pattern could not be evaluated because the label use pattern could not be reduced to an areal (pounds per acre) rate.

The mosquito adulticide use pattern was not evaluated separately because it is identical to the home lawn use pattern and is thus included in use pattern A in **Table 2-4**. The treatment is intended to kill mosquitoes resting on foliage in the lawn and is not an aerosol application intended to kill mosquitoes across a wide area.

The uses considered in this risk assessment represent all currently registered uses according to a review of all current labels. No other uses are relevant to this assessment. Any other reported use, such as may be seen in the CDPR PUR database, represent either historic uses that have been cancelled, misreported uses, or misuse. Historical uses, misreported uses, and misuse are not considered part of the federal action and, therefore, are not considered in this assessment.

2.6. Assessed Species

Attachment II provides a summary of the current distribution, habitat requirements, and life history parameters for the listed species being assessed. More detailed life-history and distribution information can be found in Attachment III. See Figure 2-6 for a map of the current range and designated critical habitat of the assessed listed species.

The DS was listed as threatened on March 5, 1993 (58 FR 12854) by the USFWS (USFWS, 2007a). DS are mainly found in the Suisun Bay and the Sacramento-San Joaquin estuary near San Francisco Bay. During spawning DS move into freshwater.

Figure 2-5. Summary of Current Distribution, Habitat Requirements, and Life History Information for the Assessed Listed Species

Assessed Species	Size	Current Range	Habitat Type	Designated Critical Habitat?	Reproductive Cycle	Diet
Delta Smelt (*Hypomesus transpacificus*)	Up to 120 mm in length	Suisun Bay and the Sacramento-San Joaquin estuary (known as the Delta) near San Francisco Bay, CA	The species is adapted to living in fresh and brackish water. They typically occupy estuarine areas with salinities below 2 parts per thousand (although they have been found in areas up to 18ppt). They live along the freshwater edge of the mixing zone (saltwater-freshwater interface).	Yes	They spawn in fresh or slightly brackish water upstream of the mixing zone. Spawning season usually takes place from late March through mid-May, although it may occur from late winter (Dec.) to early summer (July-August). Eggs hatch in 9 – 14 days.	They primarily eat planktonic copepods, cladocerans, amphipods, and insect larvae. Larvae feed on phytoplankton; juveniles feed on zooplankton.

[1] For more detailed information on the distribution, habitat requirements, and life history information of the assessed listed species, see Attachment II.

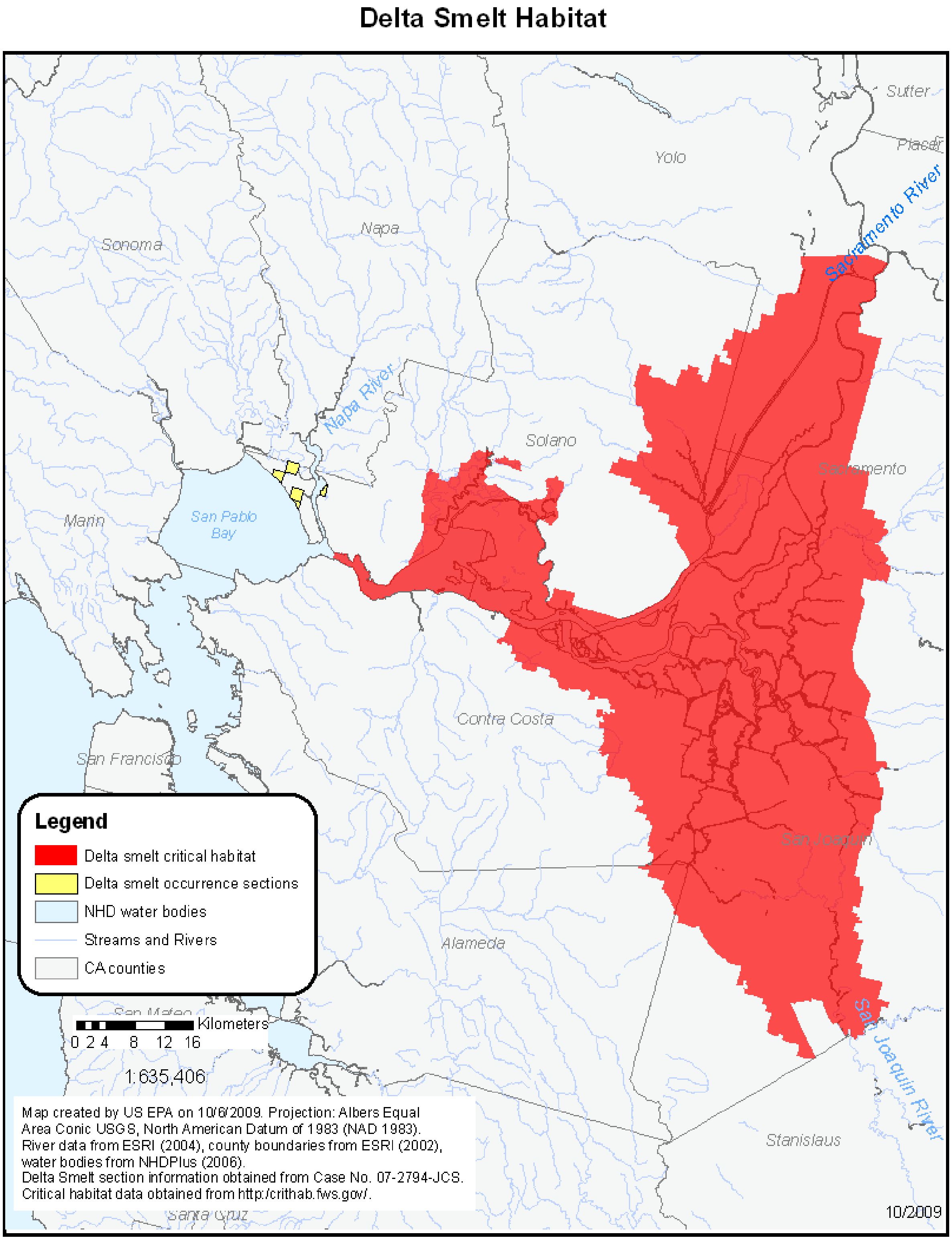

Figure 2-6. Delta Smelt Critical Habitat and Occurrence Sections outside of the critical habitat identified in Case No. 07-2794-JCS.

2.7. Designated Critical Habitat

Critical habitat has been designated for the DS. Risk to critical habitat is evaluated separately from risk to effects on the species. 'Critical habitat' is defined in the ESA as the geographic area occupied by the species at the time of the listing where the physical and biological features necessary for the conservation of the species exist, and there is a need for special management to protect the listed species. It may also include areas outside the occupied area at the time of listing if such areas are 'essential' to the conservation of the species. Critical habitat designations identify, to the extent known using the best scientific and commercial data available, habitat areas that provide essential life cycle needs of the species or areas that contain certain primary constituent elements (PCEs) (as defined in 50 CFR 414.12(b)). **Table 2-5** describes the PCEs for the critical habitats designated for the DS.

Table 2-5. Designated Critical Habitat PCEs for the Delta Smelt[1].

Species	PCEs	Reference
Delta Smelt	Spawning Habitat—shallow, fresh or slightly brackish backwater sloughs and edge waters to ensure egg hatching and larval viability. Spawning areas also must provide suitable water quality (*i.e.*, low "concentrations of pollutants) and substrates for egg attachment (*e.g.*, submerged tree roots and branches and emergent vegetation).	59 FR 65256 65279, 1994
	Larval and Juvenile Transport—Sacramento and San Joaquin Rivers and their tributary channels must be protected from physical disturbance and flow disruption. Adequate river flow_is necessary to transport larvae from upstream spawning areas to rearing habitat in Suisun Bay. Suitable water quality must be provided so that maturation is not impaired by pollutant concentrations.	
	Rearing Habitat—Maintenance of the 2 ppt isohaline and suitable water quality (low concentrations of pollutants) within the Estuary is necessary to provide delta smelt larvae and juveniles a shallow protective, food-rich environment in which to mature to adulthood.	
	Adult Migration— Unrestricted access to suitable spawning habitat in a period that may extend from December to July. Adequate flow and suitable water quality_may need to be maintained to attract migrating adults in the Sacramento and San Joaquin River channels and their associated tributaries. These areas also should be protected from physical disturbance and flow disruption during migratory periods.	

[1] These PCEs are in addition to more general requirements for habitat areas that provide essential life cycle needs of the species such as, space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing (or development) of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species.
[2] PCEs that are abiotic, including, physical-chemical water quality parameters such as salinity, pH, and hardness are not evaluated.

More detail on the designated critical habitat applicable to this assessment can be found in Attachment II. Activities that may destroy or adversely modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the species. Evaluation of actions related to use of carbaryl that may alter the PCEs of the designated critical habitat for the DS form the basis of the critical habitat impact analysis.

As previously noted in Section 2.1, the Agency believes that the analysis of direct and indirect effects to listed species provides the basis for an analysis of potential effects on the designated critical habitat. Because carbaryl is expected to directly impact living organisms within the action area, critical habitat analysis for carbaryl is limited in a practical sense to those PCEs of critical habitat that are biological or that can be reasonably linked to biologically mediated processes.

2.8. Action Area and LAA Effects Determination Area

2.8.1. Action Area

The action area is used to identify areas that could be affected by the Federal action. The Federal action is the authorization or registration of pesticide use or uses as described on the label(s) of pesticide products containing a particular active ingredient. The action area is defined by the Endangered Species Act as, "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 CFR §402.2). Based on an analysis of the federal action, the action area is defined by the actual and potential use of the pesticide and areas where that use could result in effects. Specific measures of ecological effect for the assessed species that define the action area include any direct and indirect toxic effect to the assessed species and any potential modification of its critical habitat, including reduction in survival, growth, and fecundity as well as the full suite of sub-lethal effects available in the effects literature. It is recognized that the overall action area for the national registration of carbaryl is likely to encompass considerable portions of the United States based on the large array of agricultural and/or non-agricultural uses. However, the scope of this assessment limits consideration of the overall action area to those portions that may be applicable to the protection of the DS and their designated critical habitat within the state of California.

For this assessment, the entire state of California is considered the action area. The purpose of defining the action area as the entire state of California is to ensure that the initial area of consideration encompasses all areas where the pesticide may be used now and in the future, including the potential for off-site transport via spray drift and downstream dilution that could influence the San Francisco Bay Species. Additionally, the concept of a state-wide action area takes into account the potential for direct and indirect effects and any potential modification to critical habitat based on ecological effect measures associated with reduction in survival, growth, and reproduction, as well as the full suite of sub-lethal effects available in the effects literature.

It is important to note that the state-wide action area does not imply that direct and/or indirect effects and/or critical habitat modification are expected to or are likely to occur over the full extent of the action area, but rather to identify all areas that may potentially be affected by the action. The Agency uses more rigorous analysis including consideration of available land cover data, toxicity data, and exposure information to determine areas where DS and designated critical habitat may be affected or modified via endpoints associated with reduced survival, growth, or reproduction.

2.8.2. LAA Effects Determination Area

A stepwise approach is used to define the Likely to Adversely Affect (LAA) Effects Determination Area. An LAA effects determination applies to those areas where it is expected that the pesticide's use will directly or indirectly affect the species and/or modify its designated critical habitat using EFED's standard assessment procedures (see Attachment I) and effects endpoints related to survival, growth, and reproduction. This is the area where the "Potential Area of LAA Effects" (initial area of concern + drift distance or downstream dilution distance) overlaps with the range and/or designated critical habitat for the species being assessed. If there is no overlap between the potential area of LAA effects and the habitat or occurrence areas, a no effect determination is made. The first step in defining the LAA Effects Determination Area is to understand the federal action. The federal action is defined by the currently labeled uses for carbaryl. An analysis of labeled uses and review of available product labels was completed. Several of the currently labeled uses are special local needs (SLN) uses not specified for use in California or are restricted to specific states and are excluded from this assessment. In addition, a distinction has been made between food use crops and those that are non-food/non-agricultural uses. For those uses relevant to the assessed species, the analysis indicates that, for carbaryl, the following agricultural uses are considered as part of the federal action evaluated in this assessment: citrus, olives, almonds, flowers, peaches, asparagus, apples, loquat, sweet and field corn, grapes, strawberries, tomatoes, eggplant, peanuts, broccoli, Brussels sprouts, sweet potato, sorghum, celery, horseradish, potato, radish, rice, beans, okra, sugar beets, alfalfa, pasture, grass for seed, rangeland, melons, and roses while the following non-agricultural uses have also been assessed: home lawns and gardens, parks, rights-of-way, wasteland, non-urban forests, rural shelter belts and ticks.

Following a determination of the assessed uses, an evaluation of the potential "footprint" of carbaryl use patterns (*i.e.*, the area where pesticide application may occur) is determined. This "footprint" represents the initial area of concern, based on an analysis of available land cover data for the state of California. The initial area of concern is defined as all land cover types and stream reaches within the land cover areas that represent the labeled uses described above. For carbaryl, these land cover types include 1) agricultural land covers, which are assumed to represent vegetable and non-orchard fruit crops as well as ornamental crops; 2) orchard and vineyard land covers; (3) residential; (4) pasture; (5) non-urban forests. This would cover essentially all land uses so the footprint would co-occur with the whole watershed (Figure 2-6).

Once the initial area of concern is defined, the next step is to define the potential boundaries of the Potential Area of LAA Effects by determining the extent of offsite transport via spray drift and runoff where exposure of one or more taxonomic groups to the pesticide will result in exceedances of the listed species LOCs.

An evaluation of usage information was conducted to determine the area where use of carbaryl may impact the assessed species. This analysis is used to characterize where predicted exposures are most likely to occur, but does not preclude use in other portions of the action area. A more detailed review of the county-level use information was also completed. These data indicate that carbaryl has historically been used on a wide variety of agricultural and non-agricultural uses throughout the watershed).

2.9. Assessment Endpoints and Measures of Ecological Effect

For more information on the assessment endpoints, measures of ecological effect, see **Attachment I**.

2.9.1. Assessment Endpoints

A complete discussion of all the toxicity data available for this risk assessment, including resulting measures of ecological effect selected for each taxonomic group of concern, is included in Section 4 of this document. Table 2-6 identifies the taxon used to assess the potential for direct and indirect effects from the uses of carbaryl for each listed species assessed here. The specific assessment endpoints used to assess the potential for direct and indirect effects to each listed species are provided in Table 2-7.

Table 2-6. Taxa Used in the Analyses of Direct and Indirect Effects for the Assessed Listed Species

Listed Species	Terrestrial Plants	FW Fish	FW Inverts.	Estuarine/Marine Fish	Estuarine/Marine Inverts.	Aquatic Plants
Delta smelt	Indirect (habitat)	Direct*	Indirect (prey)	Direct*	Indirect (prey)	Indirect (food/ habitat)

Abbreviations: n/a = Not applicable; Invert. = Invertebrate; FW = Freshwater

*The most sensitive fish species across freshwater and estuarine/marine environments is generally used to assess effects for these species because they may be found in freshwater or estuarine/marine environments. In this case both freshwater and saltwater acute test results were very similar.

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Table 2-7. Taxa and Assessment Endpoints Used to Evaluate the Potential for Use of Carbaryl to Result in Direct and Indirect Effects to the Assessed Listed Species or Modification of Critical Habitat.

Taxa Used to Assess Direct and Indirect Effects to Assessed Species and/or Modification to Critical Habitat or Habitat	Direct or Indirect Affect Delta Smelt	Assessment Endpoints	Measures of Ecological Effects
1. Freshwater Fish and Aquatic-Phase Amphibians	Direct Effect	Survival, growth, and reproduction of individuals via direct effects	1a. Atlantic salmon acute *LC_{50} = 0.22 mg·L^{-1} (guideline)* 1b. Atlantic salmon chronic *NOAEC = 0.0068 mg·L^{-1} (guideline)*
2. Freshwater Invertebrates	Indirect Effect (prey)	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on aquatic prey food supply (*i.e.*, freshwater invertebrates)	2a. freshwater invertebrate acute EC_{50} *stonefly EC_{50} = 0.0017 mg·L^{-1}* 2b. freshwater invertebrate chronic stonefly NOAEC = 0.0005 *mg·L^{-1}*
3. Estuarine/Marine Fish	Direct Effect	Survival, growth, and reproduction of individuals via direct effects	3a. Atlantic salmon acute *LC_{50} = 0.22 mg·L^{-1} (guideline)* 3b. Atlantic salmon chronic *NOAEC = 0.0068 mg·L^{-1} (guideline)l*
4. Estuarine/Marine Invertebrates	Indirect Effect (prey)	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on aquatic prey food supply (*i.e.*, estuarine/marine invertebrates)	4a. mysid shrimp acute EC_{50} = 0.0057 *mg·L^{-1}* 4b. estuarine/marine invertebrate chronic *No data*
5. Aquatic Plants (freshwater/marine)	Indirect Effect (food/habitat)	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on habitat, cover, food supply, and/or primary productivity (*i.e.*, aquatic plant community)	5a. Vascular plant acute Duckweed EC_{50} = 1.5 *mg·L^{-1}* (duckweed guideline test or ECOTOX vascular plant) 5b. Non-vascular plant acute EC_{50} *Navicula EC_{50} = 0.66 mg·L^{-1}*
9. Terrestrial Plants	Indirect Effect (food/habitat) (non-obligate relationship)	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on food and habitat (*i.e.*, riparian and upland vegetation)	9a. NOAEC for monocots: *vegetative vigor NOAEC: 0.8 lb-a.i./acre* 9b. NOAEC for dicots *vegetative vigor NOAEC: 0.8 lb-a.i./acre*

Abbreviations: SF=San Francisco
*The most sensitive fish species across freshwater and estuarine/marine environments is used to assess effects for these species because they may be found in freshwater or estuarine/marine environments.

2.9.2. Assessment Endpoints for Designated Critical Habitat

As previously discussed, designated critical habitat is assessed to evaluate actions related to the use of carbaryl that may alter the PCEs of the assessed species' designated critical habitat. PCEs for the assessed species were previously described in Section 2.7. Actions that may modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the assessed species. Therefore, these actions are identified as assessment endpoints. It should be noted that evaluation of PCEs as assessment endpoints is limited to those of a biological nature (*i.e.*, the biological resource requirements for the listed species associated with the critical habitat) and those for which carbaryl effects data are available.

Assessment endpoints used to evaluate potential for direct and indirect effects are equivalent to the assessment endpoints used to evaluate potential effects to designated critical habitat. If a potential for direct or indirect effects is found, then there is also a potential for effects to critical habitat. Some components of these PCEs are associated with physical abiotic features (*e.g.*, presence and/or depth of a water body, or distance between two sites), which are not expected to be measurably altered by use of pesticides.

2.10. Conceptual Model

2.10.1. Risk Hypotheses

Risk hypotheses are specific assumptions about potential adverse effects (*i.e.*, changes in assessment endpoints) and may be based on theory and logic, empirical data, mathematical models, or probability models (USEPA, 1998). For this assessment, the risk is stressor-linked, where the stressor is the release of carbaryl to the environment. The following risk hypotheses are presumed in this assessment:

The labeled use of carbaryl within the action area may:

- directly affect DS by causing mortality or by adversely affecting growth or fecundity;
- indirectly affect DS and/or modify their designated critical habitat by reducing or changing the composition of food supply;
- indirectly affect DS and/or modify their designated critical habitat by reducing or changing the composition of the aquatic plant community in the species' current range, thus affecting primary productivity and/or cover;
- indirectly affect DS and/or modify their designated critical habitat by reducing or changing the composition of the terrestrial plant community in the species' current range;
- indirectly affect DS and/or modify their designated critical habitat by reducing or changing aquatic habitat in their current range (via modification of water quality parameters, habitat morphology, and/or sedimentation).

2.10.2. Diagrams

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the carbaryl release mechanisms, biological receptor types, and effects endpoints of potential concern. The conceptual models for DS and the conceptual models for the aquatic and terrestrial PCE components of critical habitat are shown in **Figure 2-7** and **Figure 2-8.** Although the conceptual models for direct/indirect effects and modification of designated critical habitat PCEs are shown on the same diagrams, the potential for direct/indirect effects and modification of PCEs will be evaluated separately in this assessment. Exposure routes shown in dashed lines are not quantitatively considered because the contribution of those potential exposure routes to potential risks to the DS and modification to designated critical habitat is expected to be negligible.

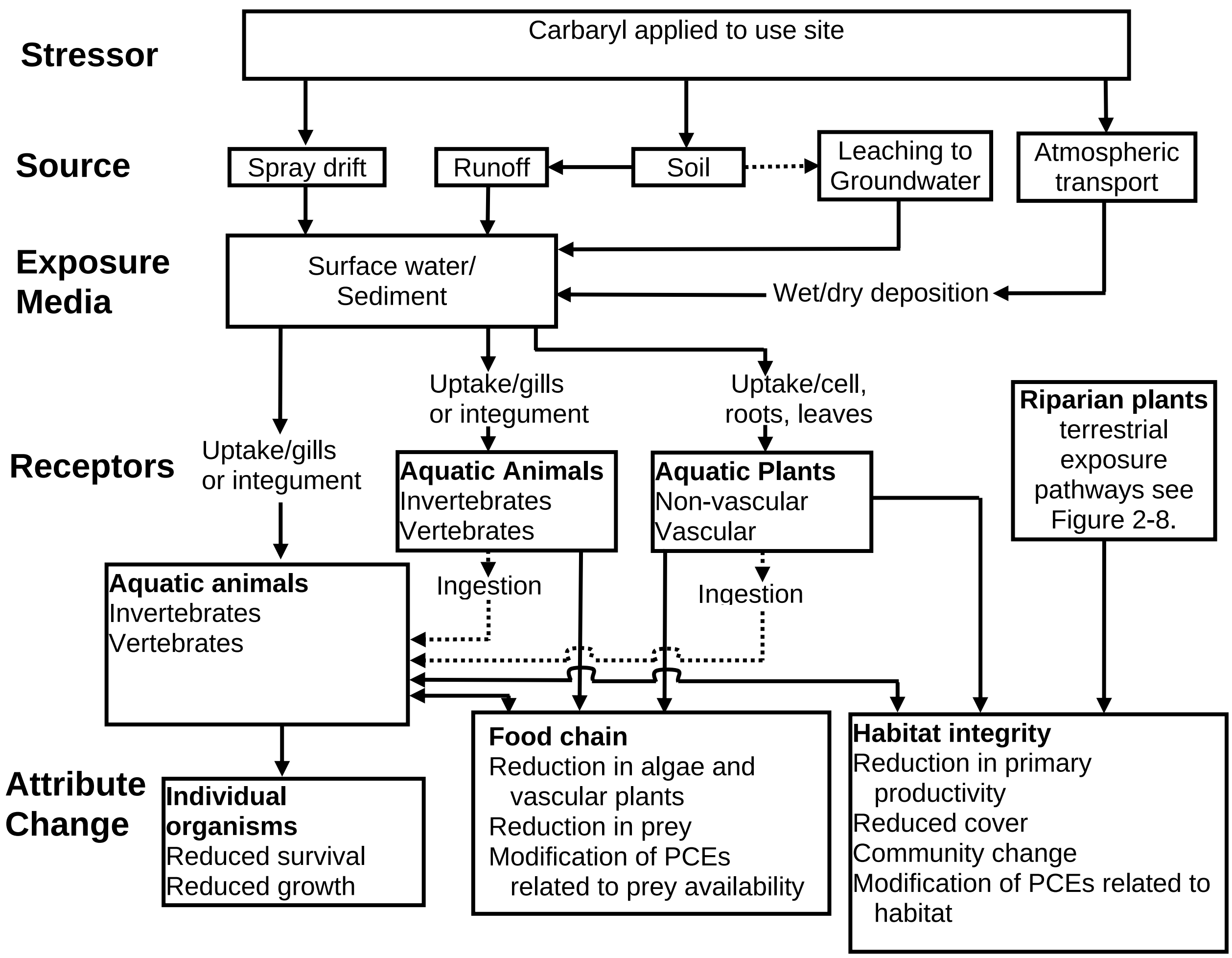

Figure 2-7. Conceptual Model Depicting Stressors, Exposure Pathways, and Potential Effects to Aquatic Organisms from the Use of Carbaryl.
Dotted lines indicate exposure pathways that have a low likelihood of contributing to ecological risk for the Delta smelt.

For carbaryl, atmospheric transport (other than spray drift) is expected to be limited by carbaryl's short environmental half-life. However, air monitoring data (discussed in Section 3.2.6) shows that carbaryl can occur in fog and rain. An assessment of the potential additional exposure due rainfall is included in the uncertainties section, 6.1.1.b. Tools to evaluate the potential additional exposure due to dry deposition are not available and consequently, this route was not assessed.

For terrestrial exposure, only the effects on habitat integrity as mediated through potential affects on terrestrial plants which border the stream are considered as DS dietary items do not include terrestrial sources.

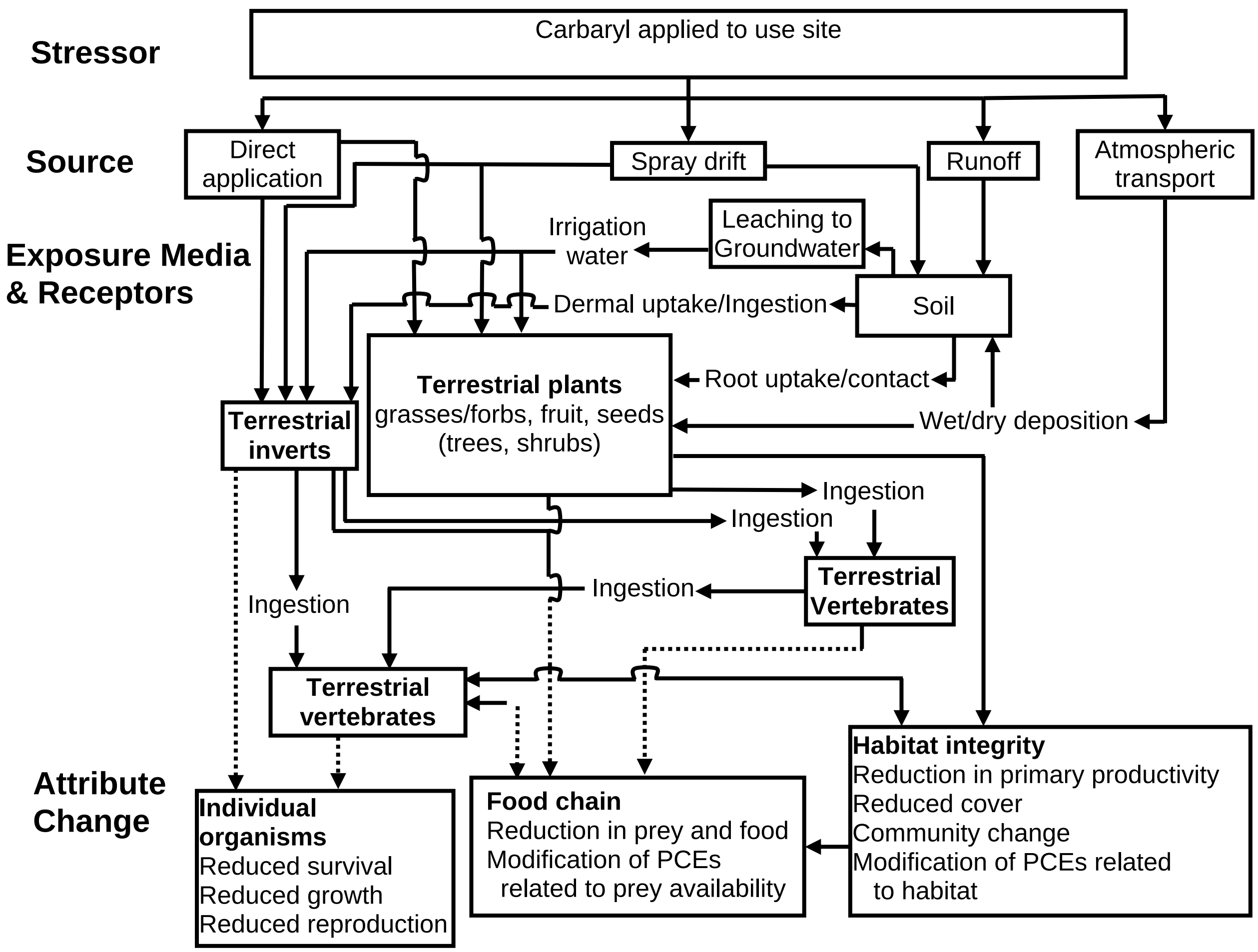

Figure 2-8. Conceptual Model Depicting Stressors, Exposure Pathways, and Potential Effects to Terrestrial Organisms from the Use of Carbaryl.
Dotted lines indicate exposure pathways that have a low likelihood of contributing to ecological risk for the Delta smelt.

2.11. Analysis Plan

In order to address the risk hypothesis, the potential for direct and indirect effects to the assessed species, prey items, and habitat is estimated based on a taxon-level approach. In the following sections, the use, environmental fate, and ecological effects of carbaryl are characterized and integrated to assess the risks. This is accomplished using a risk quotient (ratio of exposure concentration to effects concentration) approach. Although risk is often defined as the likelihood and magnitude of adverse ecological effects, the risk quotient-based approach does not provide a quantitative estimate of likelihood and/or magnitude of an adverse effect. However, as outlined in the Overview Document (USEPA, 2004a), the likelihood of effects to individual organisms from particular uses of carbaryl is estimated using the probit dose-response slope and either the level of concern (discussed below) or actual calculated risk quotient value. An overview of the risk quotient method and the associated levels of concern are in **Appendix E**.

Descriptions of routine procedures for evaluating risk to the San Francisco Bay Species are provided in Attachment I.

2.11.1. Measures of Exposure

The environmental fate properties of carbaryl along with monitoring data identifying its presence in surface water, in air and in precipitation in California indicate that spray drift, volatilization, atmospheric transport and subsequent deposition represent potential transport mechanisms of carbaryl to the aquatic and terrestrial habitats. In this assessment, transport of carbaryl through runoff and spray drift is considered in deriving quantitative estimates of carbaryl exposure to DS, its prey and its habitats. Although volatilization of carbaryl from treated areas resulting in atmospheric transport and deposition represent relevant transport pathways leading to exposure of the DS and its habitats, adequate tools are unavailable at this time to quantify exposures through these pathways. However, monitoring data for carbaryl occurrence in rainfall was used to estimate the contribution of carbaryl in precipitation to aquatic exposure. (See 6.1.1.b).

Measures of exposure are based on aquatic and terrestrial models that predict estimated environmental concentrations (EECs) of carbaryl using *maximum* labeled application rates and methods. The models used to predict aquatic EECs are the Pesticide Root Zone Model coupled with the Exposure Analysis Model System (PRZM/EXAMS). These models were parameterized using relevant reviewed registrant-submitted environmental fate data. Contributions to exposure from carbaryl groundwater were assessed using SCIGROW for the maximum application practice crops, lawn and ornamental gardens, only. These models are parameterized using relevant reviewed registrant-submitted environmental fate data. More information on these models is available in **Attachment I**.

2.11.1.a. Estimating Exposure in the Aquatic Environment

PRZM (v3.12beta, May 24, 2001) and EXAMS (v2.98.04, August 8, 2002) are screening simulation models coupled with the input shell pe4v01.pl (August 8, 2003) to generate daily exposures and 1-in-10 year EECs of carbaryl that may occur in surface water bodies adjacent to application sites receiving carbaryl through runoff and spray drift. PRZM simulates pesticide application, movement and transformation on an agricultural field and the resultant pesticide loadings to a receiving water body via runoff, erosion and spray drift. EXAMS simulates the fate of the pesticide and resulting concentrations in the water body. The standard scenario used for ecological pesticide assessments assumes application to a 10-hectare agricultural field that drains into an adjacent 1-hectare water body, 2 meters deep (20,000 m^3 volume) with no outlet. PRZM/EXAMS was used to estimate screening-level exposure of aquatic organisms to carbaryl. The measure of exposure for aquatic species is the 1-in-10 year return peak or rolling mean concentration. The 1-in-10 year peak is used for estimating acute exposures of direct effects to the DS, as well as indirect effects to the DS through effects to potential prey items, including: algae, aquatic invertebrates, fish and frogs. The 1-in-10-year 60-day mean is used for assessing chronic exposure to the DS and its prey items; the 1-in-10-year 21-day mean is used for assessing chronic exposure for aquatic invertebrates, which are also potential prey items.

The Tier I Rice Model (Version 1.0) is used for estimating surface water exposure from the use of carbaryl in rice paddies. This model relies on an equilibrium partitioning concept to provide conservative estimates of environmental concentrations resulting from application of pesticides to rice paddies. When a pesticide is applied to a rice paddy, the model assumes that it will instantaneously partition between a water phase and a sediment phase (USEPA, 2007c).

The SCIGROW model (version 2.3) is used to assess pesticide concentration in vulnerable ground water. The model provides an exposure value which is used to determine the potential risk to the environment The SCI-GROW estimate is based on environmental fate properties of the pesticide (aerobic soil degradation half-life and linear adsorption coefficient normalized for soil organic carbon content), the maximum seasonal application rate, and existing data from small-scale prospective ground-water monitoring studies at sites with sandy soils and shallow ground water.

Pesticide concentrations estimated by SCI-GROW represent conservative or high-end exposure values because the model is based on ground-water monitoring studies which were conducted by applying pesticides at maximum allowed rates and frequency to vulnerable sites (*i.e.*, shallow aquifers, sandy, permeable soils, and substantial rainfall and/or irrigation to maximize leaching). In most cases, a large majority of the use areas will have ground water that is less vulnerable to contamination than the areas used to derive the SCI-GROW estimate. For the purposes of this assessment, SCIGROW is being used to estimate the potential relative contribution to carbaryl in DS habitat from ground water recharge.

2.11.1.b. Estimating Exposure in the Riparian Environment

For this assessment, there is only limited toxicity data, No Observable Effects Levels for a vegetative vigor study, for assessing risks to riparian vegetation from carbaryl. Based on this limited effects data, only spray drift effects can be assessed. The TerrPlant model is used to estimate the exposures from this route to riparian vegetation.

2.11.2. Measures of Effect

Data identified in Section 2.9 are used as measures of effect for direct and indirect effects. Data were obtained from registrant submitted studies or from literature studies identified by ECOTOX. More information on the ECOTOXicology (ECOTOX) database and how toxicological data is used in assessments is available in Attachment I.

2.11.2.a. Integration of Exposure and Effects

Risk characterization is the integration of exposure and ecological effects characterization to determine the potential ecological risk from agricultural and non-agricultural uses of carbaryl, and the likelihood of direct and indirect effects to the assessed species in aquatic and terrestrial habitats. The exposure and toxicity effects data are integrated in order to evaluate the risks of adverse ecological effects on non-target species. The risk quotient (RQ) method is used to compare exposure and measured toxicity values. EECs are divided by acute and chronic toxicity values. The resulting RQs are then compared to the Agency's levels of concern (LOCs) (USEPA, 2004) (see **Appendix E**). More information on standard assessment procedures is available in **Attachment I**.

2.11.3. Data Gaps

The environmental fate database for carbaryl is nearly complete. However, while there is one acceptable study for the aerobic soil metabolism of the pesticide, additional data would allow a more robust assessment given that the pesticide is used on multiple crops in various regions of the U.S. in which the soils differ.

The effects data base is somewhat less complete than the fate data base as it relates to the assessment of risks to the DS. 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, particular effects that may impact plant reproduction; it is uncertain regarding the extent to which carbaryl use may impact non-target plants. Since no data have been provided on the chronic effects of carbaryl on estuarine/marine fish and invertebrates, we are unable to assess the chronic risks to these taxa. However, 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.

3. Exposure Assessment

Carbaryl is formulated as a dust, dispersible granule, liquid, wettable powder and emulsifiable concentrate and bait. Because of the wide variety of uses, formulations and use application scenarios, a great variety of application equipment could be used for carbaryl. These would include but would not be limited to ground boom sprayer, aerial application, air blast, hand held sprayers, and spreaders for granular applications. For this assessment, it has been assumed that there are no effects on exposure due to formulation and that all formulations are equivalent, including dusts and baits. Given the nature of the application practices for all these formulations, this assumption likely has little effect on the accuracy of the exposure assessment.

Risks from ground boom and aerial applications are considered in this assessment because they are expected to result in the highest off-target levels of carbaryl due to generally higher spray drift levels. In general aerial application has been assumed for agricultural application when this application is not specifically restricted from use on the crop as this method generally results in the greatest off-site drift. For residential uses, ground spray has been assumed unless the only available formulation for that use is granular.

3.1. Label Application Rates and Intervals

Carbaryl labels may be categorized into two types: labels for manufacturing uses (including technical grade carbaryl and its formulated products) and end-use products. While technical products, which contain carbaryl of high purity, are not used directly in the environment, they are used to make formulated products, which can be applied in specific areas to control insects and to thin fruit. The formulated product labels legally limit carbaryl's potential use to only those sites that are specified on the labels.

Currently registered agricultural and non-agricultural uses of carbaryl within California are listed in **Table 2-4** along their maximum application practices in the state. Crops which have the same use pattern and can be modeled using the same scenario are grouped together and modeled using a single crop as surrogate for the whole group. The uses being assessed are summarized in **Appendix D**.

3.2. Aquatic Exposure Assessment

3.2.1. Modeling Approach

The EECs are calculated using the EPA Tier II PRZM (Pesticide Root Zone Model) and EXAMS (Exposure Analysis Modeling System) with the EFED Standard Pond environment. PRZM is used to simulate pesticide transport as a result of runoff and erosion from an agricultural field, and EXAMS estimates environmental fate and transport of pesticides in surface water. Aquatic exposure is modeled for the parent alone.

For this assessment, estimates of carbaryl concentrations in surface water were calculated using PRZM and EXAMS. These models were run in the shell, pe4. The shell processed the output from EXAMS to estimate the 1 in 10 year return values reported here. For this modeling effort, PRZM scenarios designed to represent different crops and geographic areas of California are used in conjunction with the standard pond environment in EXAMS. Use-specific and chemical-specific parameters for the PE4 shell as well as PRZM scenarios are described below. Two use patterns, peaches and asparagus had PRZM and EXAMS run outside the PE4 shell so that applications patterns could be split into different times of the year. The **Table 20** processor, dated March 2, 1998 was used to analyze the output from these two simulations. The rice use was modeled with the rice model rather than PE4. For this model, the input parameters include an organic carbon content of 0.01 to translate K_{oc} (**Table 3-2**) to K_d and application rate (**Table**

3-3). For the ground water assessment, the SciGrow model version 2.3, dated July 29, 2003 was used for this assessment. A table listing of the input files used for this assessment is in **Appendix F.**

3.2.1.a. PRZM Scenarios

Scenarios used for each use pattern as well as the date for the first application each year are in **Table 3-1.** In general, a first application date of March 15 was used since it corresponds to the beginning of spring growing season in central California. In cases where specific information for a crop was available, a more appropriate date was selected. A justification for the scenario selection and any use-specific rationales for application date selections are provided below.

Use-specific management practices for all of the assessed uses of carbaryl were used for modeling, including application rates, number of applications per year, application intervals, and the first application date for each use. The date of first application was developed based on several sources of information including data provided by BEAD, a summary of individual applications from the CDPR PUR data, and Crop Profiles maintained by the USDA. For example, a sample of the distribution of carbaryl applications to oranges from the CDPR PUR data for 2006 used to pick application dates is shown in **Figure 3-1**. Similar tables for the different uses reported in the CDPR PUR database are available in **Appendix C**.

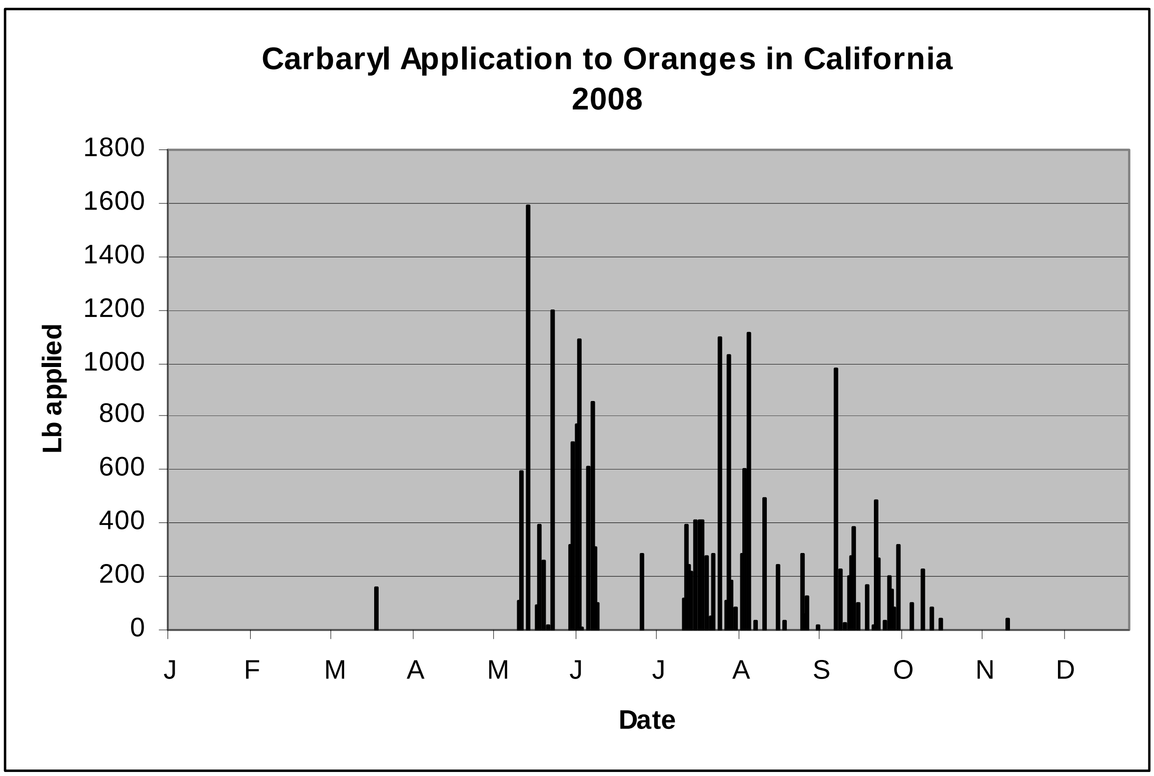

Figure 3-1. Summary of Applications of Carbaryl to Oranges in 2008 from CDPR PUR Data.

Home lawns (Group A): Estimating the aquatic exposure from the use of carbaryl on home lawns involves the use of two scenarios, one for California residential turf and one for California impervious surfaces. EECs are derived for both scenarios, and then combined by assuming that 50% of the watershed is treated lawn and the remainder is impervious surface. It is also assumed that 1.68% of the impervious surface gets over-sprayed during treatment of the lawns. A detailed description of the rationale for these values is provided in **Appendix G**. This use pattern is being used as a surrogate for the mosquito adulticide use which is restricted to kills from immediate contact from the spray and does not include wide area broadcast spraying.

Flower beds around buildings (Group B): The California residential scenario was used with this use pattern as it was thought that this scenario is most representative of flower beds around buildings. The label indicates that a drop or broadcast spreader should be used for this use. It was assumed that the dust from a dry application was approximately the same size distribution as the droplets from a ground application, so applications were modeled as ground methods. Because the use pattern is only for a six foot wide swath around buildings, it was assumed that only 4.4% of the watershed was treated. A detailed description of the rationale for this value is provided in **Appendix H**. This use pattern serves as a surrogate for the use on nuisance insects around buildings which is a mosquito adulticide use.

Lawns (Group C): This scenario is distinct from the home lawn scenario in that it could include lawns other than residential lawns, so the more generic California turf scenario was used for this simulation.

Ornamentals (Group D): The California nursery scenario was specifically designed for commercially grown outdoor ornamentals which would be included in this very general use pattern. The use group also includes residential, public, and commercial gardens.

Parks (Group E): This group includes recreation areas, golf courses, sod farms, and commercial lawns. The California turf scenario, which was specifically designed for sod farms, is most representative of this group of uses and was specifically designed for sod farms in particular. The use pattern that would produce the greatest EECs for parks could not be determined from labels. Therefore, applications to parks were modeled using two approaches: with one application of 8 lb acre^{-1} and with two applications of 4 lb acre^{-1} applied 7 days apart. The second use pattern gave the highest EEC's and is the one reported in Table 3-3.

Citrus (Group F): The California citrus scenario is a standard scenario that was specifically designed to represent citrus in that state. The use pattern that would produce the greatest EECs for citrus could not be determined from the label and was modeled two ways: with one application of 16 lb acre^{-1} and with three applications of 7 lb acre^{-1} applied 14 days apart. The first use pattern gave the highest EECs and is the one reported in Table 3-3. April 1 represents an early season application of carbaryl to citrus crops and was the value used in the previous aquatic exposure assessment (USEPA, 2003).

Olives (Group G): The California olive scenario was specifically designed for simulating that crop in California.

Almonds (Group H): The California almond scenario is a standard scenario that was specifically designed to represent almonds in that state and on a national basis. Almonds serve as surrogate for the other nut crops: almonds, chestnuts, pecans, filberts, walnuts, and pistachios.

Flowers (Group I): This use pattern is for commercially grown flowers and is different from Group B, flower beds around buildings which is a residential use and has a limited coverage in the landscape. The California nursery scenario was specifically designed to represent commercially grown, outdoor ornamentals, including flowers. Flowers serve as a surrogate for the use of carbaryl on shrubs.

Peaches (Group J): The California fruit scenario is a standard scenario that was specifically designed to represent deciduous fruit trees in that state, including the stone fruits. Peaches serve as a surrogate crop for the other stone fruits in this assessment, including: apricots, cherries, nectarines, plums, and prunes. There are two application seasons for peaches; during the growing season and during the dormant season. Two applications of 4 lb acre^{-1} were made 15 days apart starting on March 15 with a dormant application of 5 lb acre^{-1} made on December 15.

Asparagus (Group K): The California row crop scenario is a generic scenario for vegetables that are grown in the Coastal Valley other than leafy vegetables (lettuce scenario), and the cole crops (cole crop scenario). Since asparagus is neither a leafy vegetable nor a cole crop, and is grown in the Coastal Valley, the row crop scenario is appropriate for simulation of asparagus culture.
Asparagus is a perennial crop for which the stem is harvested. Multiple harvests, typically three, will be made from the same field each year in the spring followed by period where the plant is allowed to mature so that rhizomes can be filled to allow growth the following year. Spears are allowed to grow about a week after emergence before harvest. Fields can produce for years if they are well maintained. Carbaryl has different application patterns during the harvest period and after harvest during which vegetative growth is allowed. Three applications of 2 lb were modeled at 3-d intervals during harvest starting January 1, while a single application of 4 lb/acre was modeled post-harvest on June 15.

Apple (Group L): The California fruit scenario is a standard scenario that was specifically designed to represent deciduous fruit trees in that state, including the pome fruits. Apples serves as a surrogate for the pome fruits other than loquat, including pears, oriental pears, and crabapples.

Loquat (Group M): Loquats are an evergreen pome fruit and were thus simulated using the California citrus scenario rather the California fruit scenario which is used for other pome fruits.

Sweet corn (Group N): Sweet corn was simulated using the California corn scenario designed for the organophosphate cumulative assessment (USEPA 2006) as it was designed specifically for corn in California. The first application date to sweet corn was June 15 after the start of ear development.

Grapes (Group O): There are two grape scenarios for California, one scenario represents wine grapes in Sonoma County and the other scenario represents California grapes in the Central

Valley for table and raisin grapes. Since the carbaryl labels do not specify grape type, the wine grape scenario was used as it produces higher EECs. Grapes serve as a surrogate for two other berry crops: blueberries and caneberries. Caneberries are blackberries, raspberries, dewberries and other related crops are more commonly known collectively as brambles.

Strawberries (Group P): The California no-plastic strawberry scenario was used for this assessment. Strawberries can be a winter crop in coastal California, so a January 15 first application date was used for these simulations, as this is also the rainy season in California.

Tomatoes (Group Q): The California tomato scenario was used for this assessment and was designed for assessing tomatoes in California. Tomatoes serve as a surrogate for peppers.

Peanuts (Group R): The California row crop scenario was used for peanuts because it is a legume similar to dry beans which is one of the crops the row crop scenario was designed to represent. Peanuts are grown in sandier soils than that in the row crop scenario so these estimates may be somewhat conservative. A first application date of May 1 is used as peanuts are a spring crop and would be expected to have emerged by this date.

Broccoli (Group S): The California cole crop scenario was used for this assessment since broccoli is a type of cole crop. Broccoli serves as surrogate for most of the cole crops and some related vegetables, including: cauliflower, cabbage, kohlrabi, Chinese cabbage, collards, and mustard greens. Broccoli and the other cole crops can be a winter crop in coastal California, which is also the rainy season in California. Selection of an application date during the rainy season is likely to result in more pesticide runoff and higher EECs. A January 15 first application date was used for these simulations.

Brussels sprouts (Group T): The California lettuce scenario was used for simulating Brussels sprouts since Brussels sprouts are a leafy vegetable crop with similar cultural practices as lettuce. Brussels sprouts serve as surrogate for Hanover salad, which is also leafy vegetable crop. Brussels sprouts can be a winter crop in coastal California, so a January 15 application date was used for these simulations.

Sweet potato (Group V): The California potato scenario was used for simulating sweet potatoes as they are both tuber crops with somewhat similar production practices. The first application date was set to two weeks after the expected crop emergence on May 1.

Field corn (Group U): Sweet corn was simulated using the California corn scenario designed for the organophosphate cumulative assessment (USPEA 2006) as it was designed specifically for corn in California. Field corn also serves as a surrogate for popcorn. The first application date to sweet corn was June 15, after the start of ear development.

Lettuce, head (Group W): The California lettuce scenario is a standard scenario that was specifically designed to represent head lettuce in California and on a national basis. Head lettuce serves as a surrogate for several leafy vegetables: leaf lettuce, dandelion, endive, parsley, spinach, and Swiss chard. Lettuce is usually a winter crop in coastal California, so a January 15 first application date was used for these simulations.

Sorghum (Group X): The California corn scenario was used for sorghum as it closely resembles corn in agricultural management practices. Like corn, sorghum is a non-tillering grain that is planted in and grown in rows. Grains grown in rows tend to a have higher (much higher) tendency to generate eroded sediment, than the small grains, like wheat, that tiller extensively and tend to cover the soil surface much more completely at maturity. Sorghum is grown in the place of corn, in places where there is too little moisture, or it is not reliable enough to grow corn. The first application date to sweet corn was June 15 after the start of grain development.

Celery (Group Y): The California row crop scenario is a generic scenario for vegetables that are grown in the Coastal Valley other than leafy vegetables (lettuce scenario), and the cole crops (cole crop scenario). This scenario is specifically designed for celery. This group includes several vegetable crops grown in the Coastal Valley of California: celery, prickly pear, garden beets, and carrots. Celery is usually a winter crop in coastal California, so a January 15 first application date was used for these simulations.

Horseradish (Group Z): The California cole crop scenario was used for horseradish because it is in the same botanical family as the cole crops (Brassicaceae). It is expected that horseradish has similar cultivation practices and environmental requirements as other members of the cole crop group. January 15 was selected for an application date to derive conservative EECs.

Potato (Group AA): The California potato scenario was used for this assessment. This group includes several other root and tuber vegetables: parsnip, rutabaga, salsify, and turnip (root).

Radish (Group AB): The California onion scenario, which is a standard scenario used for onions in California, serves a suitable scenario for radish as they are both bulb crops grown in the Central Valley. The first application date was set to 15 days after emergence in the scenario, March 21.

Rice (Group AC): As discussed above, rice was not modeled with PRZM and EXAMS but rather, using the Tier I rice model. Therefore, no PRZM scenario was used.

Beans (Group AD): Beans, including fresh beans, are one of the crops for which the California row crop scenario was designed and has been used for that purpose in this assessment. This group includes a variety of leguminous crops: dry beans, fresh peas, dry peas, cowpeas, and fresh southern peas. A first application date of May 1 was selected as beans are a spring crop and would be expected to have emerged by this date.

Okra (Group AE): Okra is a bushy annual crop somewhat similar to tomatoes. The California tomato scenario was used to simulate okra for this assessment.

Sugar beet (Group AF): The California sugar beet scenario was designed for assessing aquatic exposure from sugar beet culture in California and has been used for that crop for these simulations. The first application date was set to February 15 as this is the earliest date, and hence most vulnerable to runoff inducing rain storms, at which sugar beets are planted in California

Alfalfa (Group AG): The California alfalfa scenario was designed for the organophosphate cumulative assessment (USEPA 2006) and has been used to simulate alfalfa culture for these assessments. This group includes other surrogate forage crops, including: birdsfoot trefoil and clover. Stands of alfalfa are maintained for as long as five years before replanting. Several cuttings per year are taken from each alfalfa field and carbaryl can be applied once per cutting. For this assessment, it was assumed there were 7 applications at 30 day intervals starting in April 15 which appears to be typical number of cuttings for California.

Pasture (Group AH): The California rangeland and hay scenario was used for this assessment and was specifically designed for assessing rangeland, hay and pasture crops for CRLF assessments.

Grass for seed (Group AI): The California turf scenario was thought to best represent this use and was specifically designed for sod farms, which somewhat resembles grass grown for seed. The first application date was set to February 15 to reflect that grass will be dormant during the winter months.

Rangeland (Group AJ): The California rangeland and hay scenario was used for this assessment and was specifically designed for assessing rangeland, hay and pasture crops. The first application date was set to February 15 to reflect that grass will be dormant during the winter months.

Melon (Group AK): The California melon scenario was used for this assessment and was specifically designed for assessing melons for CRLF assessments. This group represents other cucurbits: cucumber, pumpkin, and squash.

Roses (Group AL): The California nursery scenario was specifically designed the CRLF assessment to represent commercially grown outdoor ornamentals including roses and other flowers.

Rights-of-way (Group AM): The California rights-of-way scenario was specifically designed for this use pattern for the CRLF. Rights-of-way serve as a surrogate for several other use patterns of perennial vegetation that are along borders or paths: hedgerow, ditch banks, roadsides, CRP acreage, and set-aside acreage. The application date was set for two weeks after the emergence date in the scenario on October 1. A more detailed discussion of how the EECs were estimated for the rights-of-way scenario is in **Appendix I**.

Wasteland (Group AN): Wasteland is a vague, poorly-defined use pattern which could be any poorly maintained area which had some prior, now-abandoned usage. Since this use could conceivably include abandoned parking lots, the California impervious scenario was used to represent wasteland for this assessment. The first application date of January 15 reflects the fact that applications can be made at any time, including the rainy season, which occurs in January. Applications made during the rainy season result in more runoff and thus, more conservative EECs.

Non-urban forests (Group AO): 'Non-urban forests' serves as surrogate for other maintained and unmaintained groups of trees not used for fruit production. This group includes tree plantations, Christmas trees, parks, and rangeland trees. Since urban forests are considered to be parks, this use pattern, along with its surrogates, covers any group of trees other than fruit trees. It does not include those planted along the edge of fields (see rural shelter belt use pattern). The first application date of January 15 was selected as a conservative application data because evergreen forests may have pest pressure year round.

Rural shelter belts (Group AP): The California rights-of-way scenario was used to simulate rural shelterbelts as this rural shelter belts are long and narrow with perennial vegetation similar to rights-of-way. The first application date of January 15 was selected as a conservative application date because evergreen forests may have pest pressure year round.

Ticks (Group AQ): The turf scenario was used to simulate carbaryl applications to treat ticks. It is expected that turf and turf-like scenarios would serve as the most common type of land cover to which this application would be made. Since ticks can be found at any time in California, a first application date of January 15 during the wettest part of the year was selected.

Flea collars (Group AR): There are two flea collar products registered for cats (Reg No. 2724-272) and dogs (Reg. No. 2724-273). Little or no aquatic exposure is expected due to this use and the exposure was not quantitatively assessed.

Table 3-1. PRZM Scenario Assignments and First Application Dates for the Uses of Carbaryl Simulated for the Aquatic Exposure Assessment for the Delta Smelt Ecological Risk Assessment.

Crop group[1]	Scenario	First Application Date
A: Home lawn	CAresidential no_irrig CAImpervious	March 15
B: Flower beds around buildings	CAresidential no_irrig	March 15
C: Lawns	CaTurf no_irrig	March 15
D: Ornamentals	CANursery no_irrig	March 15
E: Parks	CaTurf no_irrig	March 15
F: Citrus	CAcitrus_NirrigC	April 1
G: Olives	CaTurf no_irrig	March 15
H: Almonds	CAalmond_NirrigC	March 15
I: Flowers	CANursery no_irrig	March 15
J: Peaches	CAfruit_NirrigC	March 15, December 15
K: Asparagus	CARowCrop no_irrig	January 1, June 15
L: Apple	CAfruit_NirrigC	March 15
M: Loquat	CAcitrus_NirrigC	March 15
N: Sweet corn	CAcornOP	June 15
O: Grapes	CAwinegrapes no_irrig	March 15
P: Strawberries	CAStrawberry_noplastic no_irrig	January 15
Q: Tomatoes	CAtomato_NirrigC	March 15
R: Peanuts	CARowCrop no_irrig	May 1
S: Broccoli	CAColeCrop no_irrig	January 15
T: Brussels sprouts	CAlettuceC	January 15
U: Sweet potato	CAPotato no_irrig	May 1

Crop group[1]	Scenario	First Application Date
V: Field corn	CAcornOP	June 15
W: Lettuce, head	CAlettuceC	January 15
X: Sorghum	CAcornOP	June 15
Y: Celery	CARowCrop no_irrig	January 15
Z: Horseradish	CAColeCrop no_irrig	January 15
AA: Potato	CAPotato no_irrig	March 15
AB: Radish	CAonion_NirrigC	March 21
AC: Rice	NA (Rice model used)	NA
AD: Beans	CARowCrop no_irrig	May 1
AE: Okra	CAtomato_NirrigC	March 15
AF: Sugar beet	Casugarbeet_NirrigOP	February 15
AG: Alfalfa	Caalfalfa_NirrigOP	April 15
AH: Pasture	CARangelandHay	March 15
AI: Grass for seed	CaTurf no_irrig	February 15
AJ: Rangeland	CARangelandHay	February 15
AK: Melon	CAMelons No_irrig	March 15
AL: Roses	CANursery no_irrig	March 15
AM: Rights-of-way	Carightofway	October 1
AN: Wasteland	CAImpervious	January 15
AO: Non-urban forests	CAForestry	January 15
AP: Rural shelter belts	Carightofway	January 15
AQ: Ticks	CaTurf no_irrig	January 15

NA = not applicable

[1]For specific uses associated with each crop grouping, see **Table 5**.

More detail on the crop profiles and the previous assessments may be found at:

http://www.ipmcenters.org/CropProfiles/

3.2.2. Model Inputs

The input parameters used to describe the chemical properties of carbaryl are in Table 3-2. In most cases these parameters were selected in accordance with guidance (USEPA, 2002). In this assessment, an organic carbon partition coefficient (K_{oc}) was estimated by regressing the adsorption K_f values against the organic carbon content. K_f was significantly correlated with organic carbon content at $p < 0.1$. The K_f values were assumed to be linear, *i.e.*, equal to K_d. This will result in some underestimation of the binding (and overestimation of carbaryl mobility) at low soil organic carbon contents, but greater accuracy over all scenarios. This is described in more detail in the revised environmental fate and ecological risk assessment which was published in support of the interim reregistration eligibility decision on carbaryl (USEPA 2004a).

Metabolism was estimated from three single studies for aerobic soil, 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 aerobic aquatic metabolism value was set to the upper confidence bound on the mean of three values.

The original assessment of carbaryl for reregistration (USEPA, 2003) assumed that carbaryl did not undergo degradation by the foliar route for the aquatic assessment and the default foliar degradation rate of 35 d was used for the terrestrial assessment. The registrant has provided data (MRID 45860501) indicating that carbaryl degrades on foliage at a substantially faster rate than default foliar degradation rate 35 d used for terrestrial assessments. The data discussed in the submission provided by the registrant were reviewed and analyzed (D288376). Based on that analysis, a value of 3.71 days was used for the foliar degradation half-life. This represents an upper 90% confidence bound on the mean from 30 foliar dissipation studies.

Table 3-2. Carbaryl Chemical Input Parameters for PE4 for Carbaryl for the Delta Smelt Assessment.

Parameter	Value	Comments
Molecular weight	201.22 g mol^{-1}	
Solubility	32 mg L^{-1}	
Henry's Law Constant	1.28 x 10^{-8} atm-m^{-3} mol^{-1}	
K_{oc}	196 L kg^{-1}	
Vapor Pressure	1.36 x 10^{-7} torr	
Aerobic soil metabolism half-life	12 d	3 x a single value
Aerobic aquatic metabolism half-life	124.2 d	Upper 90% CI on 3 values
Anaerobic aquatic metabolism half-life	216.6 d	3 x a single value
Hydrolysis half-life	pH 5 - assumed stable pH 7 - 12 d pH 9 - 0.133 d	
Aqueous photolysis	21 d	
Foliar Degradation Rate	0.187 d^{-1}	Upper 90% CI on 3 values
Foliar Wash-off Coefficient	3.70 cm^{-1}	

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 wash-off coefficient. In the absence of data, current EFED policy recommends a wash-off coefficient 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 a wash-off coefficient of 0.91 is more appropriate. However, the estimates for both studies were based on two point estimates, 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 the report titled *Review and Estimation of Foliar Dissipation Half-life of Carbaryl* (DP Barcode D288376).

i. Use-specific parameters

Use-specific parameters include application methods and rates (**Table 2-4**). Application methods, maximum rates per application and maximum number of applications per year are based on current label directions (**Table 2-4**). For each simulated crop, the maximum single application rate was simulated, with the maximum number of applications per year, with the minimum application interval. In several cases, both a maximum number of applications and a maximum seasonal rate were specified. In some of these cases, the maximum application rate multiplied by the maximum number of applications was greater than the maximum seasonal application rate. In these cases, the maximum seasonal rate was used to limit the number of applications. In general, this approach produces the greatest aquatic exposure estimates for each crop. In cases where it was not clear that this would be the case, more than one use scenario was modeled. These cases are discussed in the crop-specific use pattern descriptions below.

Table 3-3. Management Practice Input Parameters for the Assessment of Aquatic Exposure from Carbaryl to the Delta Smelt.

Crop Group[5]	IPSCND[1]	Max. App. Rate (lb a.i./ acre)	Max. No. of Apps.	Application Intervals (days)	Application Method
A: Home lawn	3	9.1	2	7	ground
B: Flower beds around buildings[2]	1	8	25	3	Drop/broadcast spreader
C: Lawns[3]	3	7.8	4	7	ground
D: Ornamentals[4]	1	7.8	4	7	ground
E: Parks	3	4	2	7	ground
F: Citrus	3	16	1	NA	aerial
G: Olives	3	7.5	2	14	aerial
H: Almonds	1	5	3	7	aerial
I: Flowers	1	4.3	3	7	ground
J: Peaches	1	4 (dormant=5)	2 + 1 dormant	15	aerial
K: Asparagus	1	Pre: 2; Post: 4	Pre:3; Post: 1	Pre:3; Post: NA	aerial
L: Apple	1	3	5	14	aerial
M: Loquat	3	3	5	14	aerial
N: Sweet corn	1	2	8	3	aerial
O: Grapes	1	2	5	7	aerial
P: Strawberries	1	2	5	7	aerial
Q: Tomatoes	1	2	4	7	aerial
R: Peanuts	1	2	4	7	aerial
S: Broccoli	1	2	4	6	aerial
T: Brussels sprouts	1	2	4	6	aerial
U: Sweet potato	1	2	4	7	aerial
V: Field corn	1	2	4	14	aerial
W: Lettuce, head	1	2	3	7	aerial
X: Sorghum	1	2	3	7	aerial
Y: Celery	1	2	3	7	aerial
Z: Horseradish	1	2	3	7	aerial
AA: Potato	1	2	3	7	aerial
AB: Radish	1	2	3	7	aerial
AC: Rice	1	1.5	2	7	aerial
AD: Beans	1	1.5	4	7	aerial
AE: Okra	1	1.5	4	6	ground
AF: Sugar beet	1	1.5	2	14	aerial
AG: Alfalfa	2	1.5	7	30	aerial
AH: Pasture	3	1.5	2	14	aerial

Crop Group[5]	IPSCND[1]	Max. App. Rate (lb a.i./ acre)	Max. No. of Apps.	Application Intervals (days)	Application Method
AI: Grass for seed	2	1.5	2	14	aerial
AJ: Rangeland	3	1	1	NA	aerial
AK: Melon	1	1	6	7	aerial
AL: Roses[3]	1	1	6	7	aerial
AM: Rights-of-way	1	1	2	14	aerial
AN: Wasteland	3	1	2	14	aerial
AO: Non-urban forests	3	1	2	7	aerial
AP: Rural shelter belts	3	1	2	7	aerial
AQ: Ticks	3	1	25	3	ground

NA: not applicable

[1]IPSCND: condition for disposition of foliar pesticide after harvest. 1 = surface applied, 2 = complete removal, 3 = left alone.

[2] uniform 6 ft band around building, water in lightly after application; [3]does not include pre-plant dip of 1.2 lb/acre for sweet potatoes

[4]Labels do not provide information for aerial spray applications but do not restrict the products for aerial application. [5]For specific uses associated with each crop group see Table 5.

Each of the 115 use patterns of carbaryl in California has either been simulated, or has been assigned a surrogate. Justifications for surrogate selection are provided in **Appendix D**. Surrogate crops covered by each modeled scenario are listed in the use specific descriptions below.

In most cases, at least one carbaryl label allowed aerial application to the crop. In some cases, the label did not make reference to aerial application, but neither was the practice prohibited and it was assumed that these products could legally be used as an aerial spray. An exception to this was for uses in and around residential settings where aerial application was not assumed. For aerial applications, the application efficiency and spray drift input parameters were set at 0.95 and 0.05, respectively, in accordance with current input parameter guidance (USEPA 2002). For ground sprays, the application efficiency and spray drift input values were 0.99 and 0.01.

For all use patterns in this assessment, except those applied to impervious surfaces, a foliar application was assumed (This is set with the CAM variable in PRZM; CAM=2). For applications to uses with an impervious surface (home lawns and wasteland) a broadcast application was used (CAM = 1). For foliar applications, the disposition of foliar pesticide after harvest, the IPSCND variable, must also be set. The IPSCND variable has three possible values: 1- the pesticide is surface applied; 2- the pesticide is completely removed; and 3- the pesticide is left alone. In most agricultural crops, the pesticide is surface applied on the assumption the crop residue other than the fruit or grain itself is left in the field. For evergreen trees and turf, a value of 3 was used as it would be assumed the pesticide remains on the vegetation. In a few cases, *e.g.* sod farms, a value of 2 was used as it would be expected that the foliar pesticide would be removed as the crop was removed.

3.2.2.b. Post-Processing approach for rights-of-way and residential scenarios

In a standard PRZM scenario, it is assumed that an entire 10 ha field is composed only of the identified crop, and that the field has uniform surface properties throughout the field. In a right-of-way or residential area, this is not a reasonable assumption, since these areas contain both impervious and pervious surfaces. Since the two surfaces have different properties (especially different curve numbers influencing the runoff from the surfaces) and different masses of applied carbaryl, the standard approach for deriving aquatic EECs is revised using the following approach:

a. Aquatic EECs are derived for the pervious portion of the right-of-way and residential, using the maximum use rates of carbaryl on the CA right-of-way and CA residential scenarios, respectively. At this point, it is assumed that 100% of the area is composed of pervious surface.
b. Aquatic EECs are derived for the impervious portions of the right-of-way and residential area, using 1% and 5.68%, respectively, of the maximum use rates of carbaryl on the CA impervious scenario. At this point, it is assumed that 100% of the areas are each composed of impervious surface.
c. The daily aquatic EECs (contained in the PRZM/EXAMS output file with the suffix "TS") are input separately into a Microsoft® Excel worksheet to post process the right-of-way and residential EECs.
d. Daily aquatic EECs for the impervious surface are multiplied by 50%. Daily aquatic EECs for the pervious surface are multiplied by 50%. The resulting EECs for impervious and pervious surfaces are added together to get an adjusted EEC for each day of the 30-year simulation period (**Equation 1**).

$$1)\quad \text{Revised EEC} = (imperviousEEC * 50\%) + (perviousEEC * 50\%)$$

e. Rolling averages for the relevant durations of exposure (21-day, and 60-day averages) are calculated. The 1-in-10 year peak, 21-day and 60-day values are used to define the acute and chronic EECs for the aquatic habitat.

In this approach, it is assumed that a right-of-way and a residential area are composed of equal parts pervious and impervious surfaces (*i.e.* in steps 4, the EECs of both surfaces are multiplied by 50%). For rights-of-way, this is more likely to be representative of a highway or road right-of-way. It is likely that rights-of-way contain different ratios of the two surfaces. In general, incorporation of impervious surfaces into the exposure assessment results in increasing runoff volume in the watershed, which tends to reduce overall pesticide exposure (when assuming 1% overspray to the impervious surface). For residential areas, the rational for the post-processing approach is described in **Appendix G**.

3.2.2.c. Groundwater Modeling

The input parameters for the groundwater exposure assessment are in Table 3-4. For the ground water assessment, the maximum seasonal application rate among all use label use patterns was used. This pattern was 4 applications of 7.1 lb·acre^{-1} applied four times a year to home lawns (Group C) and Ornamental Garden (Group D).

Table 3-4. Carbaryl Input Parameters and Results for Sci-Grow for Carbaryl on Lawns and Ornamental Gardens for the Delta Smelt Assessment.

Parameter	Value	Comments
K_{oc}	196 $L \cdot kg^{-1}$	mean K_{oc}
Aerobic soil metabolism half-life	4 d	single value
Maximum Application Rate	7.1 $lb \cdot acre^{-1}$	lawns and ornamentals
Number of Applications	4	lawns and ornamentals
Estimated Ground water Concentration	0.1 $\mu g \cdot L^{-1}$	

3.2.2.d. Riparian Plant Exposure

Based on the availability of vegetative vigor studies with NOECs for plants in the riparian zone around DS habitat, it is possible to assess risks to plants from the spray drift route of exposure only. The management practice input parameters for TerrPlant are in **Table 3-5**. Only three use patterns have been considered, for the highest and second highest single application rates with aerial application (Group F: citrus and Group G: olives), and the highest single application rate for ground application (Group A: home lawn). Only one chemical input parameter is necessary to run TerrPlant, the solubility of 32 $mg \cdot L^{-1}$.

Table 3-5. Management Practice Input Parameters for the Assessment of Exposure from Carbaryl to Riparian Plants the Delta Smelt.

Crop Group	Max. App. Rate (lb a.i./ acre)	Application Method[1]
A: Home lawn	9.1	ground
F: Citrus	16	aerial
G: Olives	7.5	aerial
1) For ground application, spray drift fraction of 0.1 is assumed; for aerial application a spray drift fraction of 0.05 is assumed		

3.2.3. Results

3.2.3.a. Surface Water

Tier 2 EECs representing 1-in-10 year peak, 21-day, and 60-day concentrations of carbaryl in the aquatic environment are located in Table 3-6. The highest EECs are for the rice use which is a reflection of the lower tier assessment used for that crop. The next highest EECs are for Brussels sprouts which had a 1-in-ten year peak EEC of 167 µg/L. In general, crops grown in coastal scenarios had higher EECs than those in the Central Valley; and those where an application was made in the winter had higher EECs than those in the spring and summer. Example output files are included in **Appendix J**.

Table 3-6. Aquatic EECs (µg/L) for Carbaryl Uses in California

Crop Group[1]	Peak (µg/L)	21 Day EEC (µg/L)	60 Day EEC (µg/L)
A: Home lawn	14.6	8.7	5.25
B: Flowers around buildings	0.47	0.29	0.15
C: Lawns	25.4	19.0	12.4
D: Ornamentals	51.2	29.3	16.0
E: Parks 1	9.3	6.5	3.6
E Parks 2	10.0	6.3	3.7
F: Citrus 1	33.2	22.0	15.4
F: Citrus 2	44.7	25.2	11.8
G Olives	52.6	31.4	18.9
H: almonds	43.3	29.1	17.5
I: flowers	21.4	13.0	6.7
J: peaches	56.8	32.1	17.0
K: asparagus	47.2	26.5	13.4
L: apple	16.3	10.7	9.3
M: loquat	13.0	8.7	7.5
N: sweet corn	24.8	18.7	10.7
O: grapes	22.4	18.2	11.9
P: strawberries	100.2	72.7	39.7
Q: tomatoes	24.5	17.1	11.0
R: peanuts	12.9	9.0	5.6
S: broccoli	73.0	47.5	26.4
T: Brussels sprouts	166.8	108.3	55.8
U: sweet potatoes	49.7	32.0	19.6
V: corn	9.1	6.2	5.0
W: head lettuce	93.5	62.7	34.6
X: sorghum	11.4	7.4	4.1
Y: celery	37.9	22.4	11.6
Z: horse radish	71.8	43.2	22.8
AA: potato	42.0	24.2	12.5
AB: radish	13.3	8.6	4.8
AC: rice	2579	2579	2579
AD: dry beans	9.7	6.8	4.2
AE: okra	5.6	3.1	1.8
AF: sugar beet	13.6	9.6	5.4
AG: alfalfa	9.1	5.0	3.2
AH: pasture	10.9	7.8	4.3
AI: grass for seed	7.1	4.7	3.1
AJ: rangeland	12.8	7.7	2.6
AK: melons	7.2	5.4	4.0
AL: roses	14.9	8.9	4.7
AM: rights of way	19.0	12.2	7.6
AN: wasteland	68.0	40.0	26.1
AO: non-urban forests	11.5	8.2	4.2
AP: rural shelter belts	41.0	28.7	14.9
AQ: ticks	17.7	15.1	13.2

[1]For specific uses associated with each crop group see Table 5.

3.2.3.b. Ground Water

For the ground water assessment, the maximum seasonal application rate was used among all use label use patterns. This pattern was 4 applications of 7.1 lb·acre^{-1} applied four times a year to home lawns (Group C) and Ornamental Garden (Group D). The resulting ground water EEC was 0.1 µg·L^{-1} (**Table 3-4**). Since this value is small compared to the EECs due to runoff and spray drift, the contribution of carbaryl from ground water recharge to aquatic environments is expected to be minimal. An example output files are included in **Appendix J**.

3.2.3.c. Terrestrial Plants

Table 3-7. Estimated Environmental Concentrations Estimated by TerrPlant for Spray Drift from Carbaryl to Riparian Plants in the Habitat of Delta Smelt.

Crop Group	EEC (lb·acre^{-1})
A: Home lawn	0.091
F: Citrus	0.8
G: Olives	0.375

3.2.4. Existing Monitoring Data

A critical step in the process of characterizing EECs is comparing the modeled estimates with available surface water monitoring data. EFED finalized the Environmental Fate and Ecological Risk assessment for carbaryl in 2003 (USEPA 2003). The IRED document for carbaryl (USEPA 2004b) was published for comment in 2004, and EFED completed a response to those comments in 2005 (USEPA 2005). Since that time, additional carbaryl monitoring data were obtained and are summarized below. Data specific to California are described. These data include United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) and the CDPR Surface Water Database. In addition, observed trends in carbaryl concentrations in national surface waters are discussed.

3.2.4.a. USGS NAWQA Surface Water Data

In 2003, EFED (USEPA 2003) reported that carbaryl was the second most widely detected insecticide in surface water in the U. S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) monitoring program (US Geological Survey 2007). Although this monitoring does not target specific chemicals, carbaryl was detected in 46% of 36 NAWQA study units from 1991 - 1998. Much of the data in the NAWQA database are amended with an "E" qualifier to indicate uncertainty found in the analysis. Typically this uncertainty is because the concentration is beyond the limit of the calibration curve for the analytical instrumentation; thus, a high reported concentration is in fact *high;* however, it is a less precise estimate than those concentrations that lie within the calibration curve. In the 2003 assessment of NAQWA data, 1,067 (21%) out of 5,198 surface water samples had detections greater than the minimum detectable limit. The maximum reported carbaryl concentration was 5.5 µg·L^{-1} across all sites. For samples with positive detections the mean concentration was 0.11 µg·L^{-1}, with a standard deviation of 0.43 μg/L. In a summary of pesticide occurrence and concentrations for 40 NAWQA stream sites within primarily agricultural basins, carbaryl was detected in 11% of the samples (N = 1,001) with a maximum concentration of 1.5 $\mu g \cdot L^{-1}$.

In a report released in 2006 summarizing pesticide results from NAWQA from 1992 – 2001 (Gilliom *et al.,* 2006), carbaryl is listed as one of the 14 most frequently detected pesticide compounds in surface water and one of the 3 most frequently detected insecticides. Carbaryl was detected in 50% of urban samples over this time period. The majority of carbaryl concentrations detected were low with 35% of the urban samples (and 70% of the detections) less than 0.1 $\mu g \cdot L^{-1}$. Detection frequencies in agricultural and mixed-land use streams were lower (10% and 17%, respectively), and concentrations associated with those land uses were almost all less than 0.1 $\mu g \cdot L^{-1}$.

For this assessment NAWQA carbaryl data in the USGS data warehouse from 1999 – 2005 were specifically reviewed. A total of 11,732 samples were collected in US waters in that timeframe and analyzed for carbaryl, with 29% of all samples reporting a detection greater than the minimum detection limit. For samples with detections, the mean carbaryl concentration reported was 0.058 $\mu g \cdot L^{-1}$. The maximum concentration reported was 33.5 $\mu g \cdot L^{-1}$ at a location associated with agricultural land (mean in agricultural areas: 0.094 $\mu g \cdot L^{-1}$). The detection frequency associated with agricultural uses was lower (19%) than that associated with urban uses (50%). The highest concentration reported in urban areas was 16 $\mu g \cdot L^{-1}$ in Denver, CO (concentration confirmed by Bret Bruce USGS South Platte). The higher detection frequency in urban streams (versus agricultural or mixed land uses) is consistent with data summarized in the 2003 assessment (USEPA, 2003). The concentrations detected in urban streams (mostly low concentrations, a few detections in the multiple ppb range) are also consistent with earlier data. The relatively high reported concentration associated with agricultural uses (33.5 $\mu g \cdot L^{-1}$), is unusual but not outside of the range predicted by modeling.

3.2.4.b. NAWQA Data (1999-2005) for California

NAWQA monitoring data are available for carbaryl from California surface waters (USGS 2007) (Figure 3-2). Samples were analyzed for carbaryl using gas chromatography coupled with mass spectroscopy (GCMS) and high pressure liquid chromatography (HPLC) techniques. Although this monitoring does not target specific chemicals, carbaryl was detected in 41.6% of all samples analyzed by GCMS and 28.3% of all samples analyzed by HPLC, with a maximum concentration of 1.06 µg/L. NAQWA data are defined by the land cover composition of the watershed of the surface waters from which samples were taken. Available NAWQA data from surface waters with watershed land covers defined as agricultural, mixed, other and urban are defined separately in **Table 3-8**.

Of the NAWQA monitoring data from California surface waters (including detected concentrations, non-detections and estimated concentrations), none of the 1492 analyzed samples contained levels of carbaryl sufficient to exceed the LOC for acute exposures to the DS (*i.e.* 11 $\mu g \cdot L^{-1}$). Of the 1393 total samples analyzed by GCMS, 1.1 percent (15 samples) contained levels of carbaryl sufficient to exceed the LOC for acute exposures to aquatic invertebrates (*i.e.* 0.085 $\mu g \cdot L^{-1}$).

Detections of carbaryl in water bodies with urban land covers were 54.1-76.7% of analyzed samples. These detection rates were greater when compared to all other types of watershed land covers. Concentrations of carbaryl in waters with urban watersheds were sufficient to exceed the LOC for acute exposures to aquatic invertebrates in 4.5% of samples analyzed by GCMS (**Table 3-8**).

Table 3-8. NAWQA 1999 - 2005 Data for Carbaryl Detections in CA Surface Waters with Watersheds with Different Land Cover Compositions. Data are Distinguished by Method of Analysis.

Statistics	Agricultural	Mixed	Other	Urban	Total
GCMS					
Number of Samples	322	805	109	157	1393
% Detects[1]	47.2	39.0	25.7	54.1	41.6
Number of sites	14	20	15	13	62
Maximum Concentration ($\mu g \cdot L^{-1}$)	0.657	0.750	0.041	1.060	**1.060**
% Samples with concentrations sufficient to exceed LOC for acute exposures to Delta smelt [2]	0	0	0	0	0
% Samples with concentrations sufficient to exceed LOC for acute exposures to aquatic invertebrates [3]	1.2	0.5	0	4.5	1.1
HPLC					
Number of Samples	20	47	2	30	99
% Detects[1]	25.0	0	0	76.7	28.3
Number of sites	1	3	1	2	7
Maximum Concentration ($\mu g \cdot L^{-1}$)	0.222	<0.0628	<0.0284	0.1922	**0.1922**
% Samples with concentrations sufficient to exceed LOC for acute exposures to Delta smelt [2]	0	0	0	0	0
% Samples with concentrations sufficient to exceed LOC for acute exposures to aquatic invertebrates [3]	0	0	0	0	0

[1]Method detection limit = 0.003 $\mu g \cdot L^{-1}$
[2]Based on an LC_{50} of 220 $\mu g \cdot L^{-1}$ for Atlantic salmon, the concentration required to exceed the acute exposure LOC of 0.05 is 11 µg/L.
[3]Based on an EC_{50} of 1.7 $\mu g \cdot L^{-1}$ for stonefly, the concentration required to exceed the acute exposure LOC of 0.05 is 0.085 µg/L.

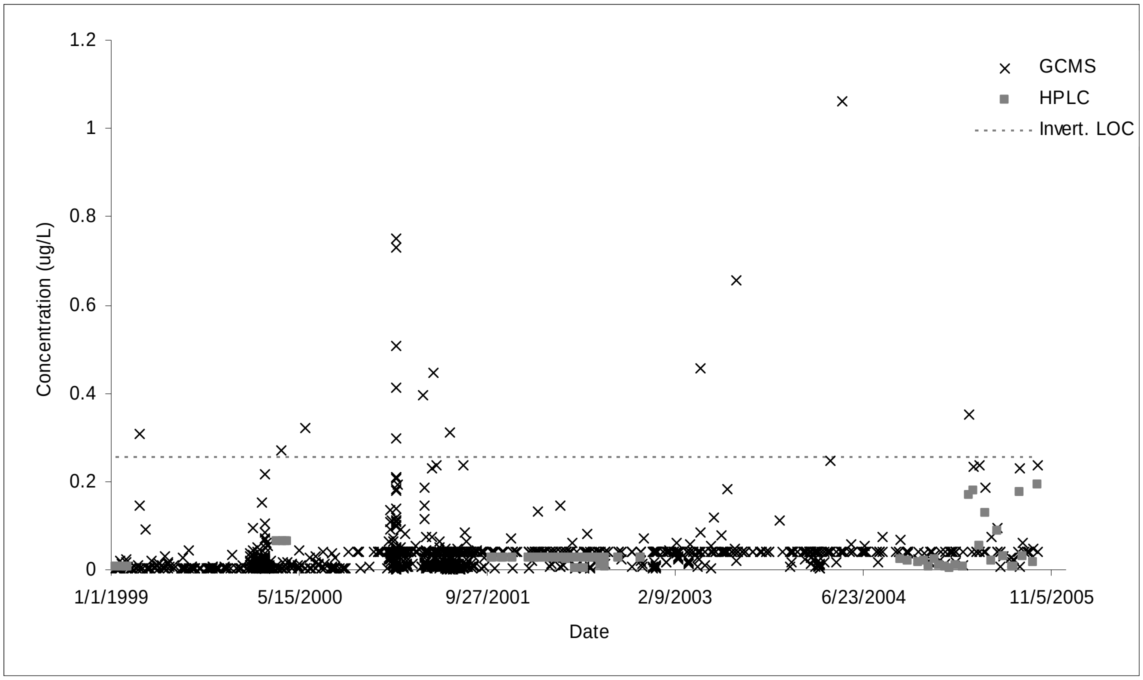

Figure 3-2. Concentrations of Carbaryl Reported by NAWQA in CA Surface Waters from 1999-2005.

3.2.4.c. USGS NAWQA Groundwater Data

In 905 groundwater samples taken at 321 sites by the by the United States Geological Survey's NAWQA program in California between 1991 and 2009, two samples had detectable concentrations of carbaryl: One from August, 1993 taken in Fresno County of 0.013 $\mu g \cdot L^{-1}$and one of 0.004 $\mu g \cdot L^{-1}$from San Bernardino County in August, 2000. Neither of these counties is in the Critical Habitat of the DS.

3.2.4.d. California Department of Pesticide Regulation (CDPR) Data

CDPR maintains a database of monitoring data of pesticides in CA surface waters. The sampled water bodies include rivers, creeks, urban streams, agricultural drains, the San Francisco Bay delta region and storm water runoff from urban areas. The database contains data from 51 different studies by federal (including the USGS NAWQA program), state and local agencies as well as groups from private industry and environmental interests. Data are available from 1990-2005 for 27 counties for several pesticides and their degradates. Data for carbaryl are included in this database (CDPR 2007). Data included in this database are not necessarily related to targeted monitoring efforts. For the purpose of this assessment, carbaryl monitoring data from 1999-2005 were accessed from the CDPR database and are discussed below.

From 1999-2005, 1641 samples from CA surface waters were analyzed for carbaryl. Of these, carbaryl was detected in 0.6% (10 samples), with a maximum concentration of 0.31 µg/L. These samples included 83 different sites from 15 counties; including counties where DS species and critical habitat are located. When considering all samples analyzed during this time period (including non-detections), carbaryl was detected at concentrations sufficient to exceed the invertebrate LOC (*i.e*., >0.255 µg/L) in 1 sample, which represents 0.06% of samples.

Some data reported in this database are also reported by USGS in NAWQA; therefore, there is some overlap between these two data sets. Unlike NAWQA data, the land use (*e.g*. agriculture, urban) associated with the watershed of the sampled surface waters is not defined in the CDPR database; therefore, the available data do not allow for a link of the general use pattern and the individual data.

3.2.4.e. Environmental Monitoring of Carbaryl Applied in Urban Areas to control the Glassy-Winged Sharpshooter in California (Walters et al., 2003)

The Environmental Monitoring Branch of CDPR conducted monitoring of carbaryl and other selected insecticides to provide information on concentrations in various environmental media, including surface water, resulting from ground applications to control glassy-winged sharpshooter (*Homalodisca coagulata*) infestations in California. Carbaryl insecticide was applied to plants in urban areas to control a serious insect pest, the glassy-winged sharpshooter, newly introduced in California. To assure there were no impacts to human health and the environment from the carbaryl applications, carbaryl was monitored in air, surface water, foliage and backyard fruits and vegetables. CDPR reported:

> *"There were three detections of carbaryl in surface water near application sites: 0.125 ppb (parts per billion) from a water treatment basin; 6.94 ppb from a gold fish pond; and 1737 ppb in a rain runoff sample collected from a drain adjacent to a sprayed site."*

DPR concluded that results from the five urban areas showed there were no significant human exposures or impacts on the environment.

3.2.5. National Trends in Carbaryl Concentrations in Urban Areas

This section discusses trends that have been observed in carbaryl concentrations in urban areas since the announcement of the phase out of two other insecticides widely used in urban areas—diazinon and chlorpyrifos. There was speculation that with diazinon and chlorpyrifos no longer available, homeowners would use more carbaryl, and that carbaryl concentrations in streams in urban areas would increase. The residential use of liquid broadcast formulations of carbaryl on turf was restricted in 2005 to areas less than 1000 ft^2. Risk managers concluded that this restriction may help reduce potential runoff of carbaryl in urban environments; however the labels for granular formulations were not modified. How the carbaryl label changes impact the extent of the area treated and how that would affect carbaryl concentrations in urban streams is unclear at this time.

The timing of the phase-out decisions is important in understanding trends in pesticide concentrations in the environment. On one hand, the date of the announcement of a phase out initiates a multi-year process stipulating a "stop sale" date and some additional time for pesticide applicators to use products they have purchased. On the other hand, the market and pesticide applicators may react quickly to such an announcement. EPA announced the agreement to phase out and eliminate all residential uses of the insecticide diazinon on December 5, 2000. The terms of the four-year phase-out stipulated that technical registrants reduce the amount of diazinon produced by 50% or more by 2003. As of December 31, 2004, it was unlawful to sell diazinon outdoor, non-agricultural products in the United States (the "stop sale" date for all outdoor diazinon home, lawn, and garden products). According to existing stocks provisions, it remained legal for consumers to use products bearing labeling that allowed these uses after that date. On June 8, 2000, EPA announced an agreement with pesticide registrants to phase out and cancel nearly all indoor and outdoor residential uses of chlorpyrifos within 18 months, effectively eliminating use by homeowners. Those uses that posed the most immediate potential risks to children (home lawn, indoor crack and crevice treatments, uses in schools, parks) were canceled first, ending as of December 12, 2001. The last remaining residential use, products used for pre-construction termite control, was cancelled as of December 31, 2005.

Based on the studies described below, the longer term impact of the phase-out on carbaryl concentrations in urban areas is not clear and may vary by region due to differences in pest pressure and perhaps marketing of different products. Unlike the clear downward trend in concentrations observed within a few years for the phased-out compounds (diazinon and chlorpyrifos), the environmental outcome of this registration decision may take longer to discern. However, based on the available data, there does not appear to be a steady upward trend to carbaryl concentrations in urban areas following the phase-out of diazinon and chlorpyrifos.

In a poster, Embrey and Moran (2004), summarized data collected by the NAWQA program over a decade in the Puget Sound Basin and included data on diazinon and carbaryl collected in Thornton Creek. During the first cycle, the insecticide diazinon was often detected in samples from Thornton Creek; some samples were at concentrations greater than 0.1 $\mu g \cdot L^{-1}$. **Figure 3-3**, which was taken from the poster, shows a decrease in diazinon detections and concentrations following the announcement of the phase out in 2000. There is also an increase in carbaryl detection frequency and concentrations in the years following the announcement of the phase out of diazinon. The data also appear to show that carbaryl concentrations began to decline toward the end of the study period in 2005, rarely exceeding 0.1 $\mu g \cdot L^{-1}$.

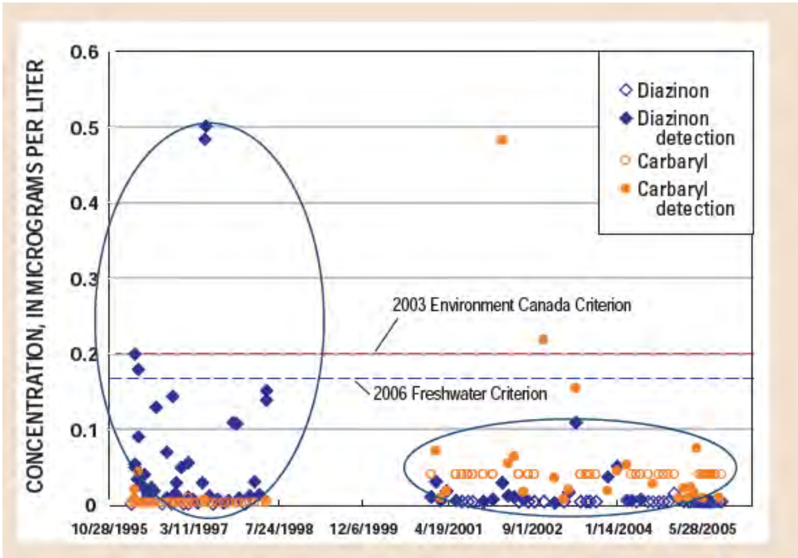

Figure 3-3. Temporal Changes in Surface-water Insecticide Concentrations after the Phase-out of Diazinon and Chlorpyrifos.

A recently published paper by USGS scientists evaluated trends in concentrations of carbaryl in the Northeast and Mid-West after the phase-out of diazinon and chlorpyrifos insecticides in urban environments. They compared concentrations of these pesticides in samples collected from 20 streams by the USGS between 1992 and 2004 and determined that 16 of these streams met criteria established for assessing trends of carbaryl in urban streams. Sample collection and analysis followed standard NAWQA procedures for collection and analysis. Using seasonal step trend analysis they evaluated the data to identify trends in summer, fall/winter, and winter/spring. Results showed a decrease in diazinon and chlorpyrifos concentrations following the announcement of the phase out in 2000. In contrast, trends were not observed in carbaryl concentrations in these regions during the same time period.

3.2.6. Atmospheric Monitoring Data

Carbaryl's vapor pressure (1.36×10^{-6} torr) and Henry's law constant (1.28×10^{-8} atm-m^{-3} mol^{-1}) are consistent with compounds which are found at least occasionally in the atmosphere. Other than near-field spray drift studies, carbaryl was only measured in a two studies. Carbaryl was found in fog in concentrations as high as 69 ng·L^{-1} in six samples (**Table 3-9**) collected at three sites along the Pacific Coast in Monterey County, CA (Shomburg *et al.*, 1991). Carbaryl has been also detected in precipitation samples in California (Majewski *et al*, 2006). Out of 137 rain samples, 93 had detectable carbaryl with a maximum concentration of 0.756 µg·L^{-1}. Based on these data, it is possible that carbaryl can be deposited on land and aquatic environments in precipitation.

Table 3-9. Carbaryl detections in fog and precipitation samples taken in California.

Location	Year	Sample type	Maximum Conc (µg/L)	Detection frequency (number samples)	Source
San Joaquin Valley, CA	2002-2004	Rain	0.756	68% (n = 137)	Majewski *et al.* 2006
Monterey, CA	1987	Fog	4.0	100% (n = 6)	Schomburg *et al.* 1991

In air samples collected during a forestry spray application study (Segawa *et al.*, 1991), air concentrations during the application event ranged from 0.118 to 7.95 $\mu g \cdot m^3$ in three samples collected on the application site after an application made at a release height of 80 feet. In a second trial with a release height at 50 ft, the concentrations ranged from 0.397 to 6.18 $\mu g \cdot m^3$. In samplers placed downwind of the application, a sampler found detectable carbaryl concentrations of 0.199 $\mu g \cdot m^3$ from the 180 ft-release height application at 80 m from the application site. A sampler at 550 m downwind did not measure detectable carbaryl. A single measurement from the 50 ft release height found 4.52 $\mu g \cdot m^3$ at 310 m downwind. Carbaryl was found in concentrations of 2 to 4 $\mu g \cdot L^{-1}$ in a river immediately abutting the spray site in samples taken just after the applications were made.

3.3. Riparian Plant Exposure Assessment

Based on the availability of vegetative vigor studies with NOECs for plants in the riparian zone around delta smelt habitat, it is possible to assess risks to plants from the spray drift route of exposure only. The management practice input parameters for TerrPlant are Table 3-10. Only three use patterns have been considered, for the highest and second highest single application rates with aerial application (Group F: citrus and Group G: olives), and the highest single application rate for ground application (Group A: home lawn). Only one chemical input parameter is necessary to run TerrPlant, the solubility of 32 $mg \cdot L^{-1}$.

Table 3-10. Management Practice Input Parameters for the Assessment of Exposure from Carbaryl to Riparian Plants in the Habitat of the Delta Smelt.

Crop Group	Max. App. Rate (lb a.i./ acre)	Application Method[1]
A: Home lawn	9.1	ground
F: Citrus	16	aerial
G: Olives	7.5	aerial
1) For ground application, spray drift fraction of 0.1 is assumed; for aerial application a spray drift fraction of 0.05 is assumed		

4. Effects Assessment

This assessment evaluates the potential for carbaryl to directly or indirectly affect DS or modify their designated critical habitat. Assessment endpoints for the effects determination for each assessed species include direct toxic effects on the survival, reproduction, and growth, as well as indirect effects, such as reduction of the prey base or modification of its habitat. In addition, potential modification of critical habitat is assessed by evaluating effects to the PCEs, which are components of the critical habitat areas that provide essential life cycle needs of each assessed species. Direct effects to the DS are based on toxicity information for freshwater fish (which are more sensitive to carbaryl than estuarine/marine fish based on available data).

As described in the Agency's Overview Document (USEPA, 2004), the most sensitive endpoint for each taxon is used for risk estimation. For this assessment, evaluated taxa include freshwater fish, marine/estuarine fish, freshwater invertebrates, marine/estuarine invertebrates, and aquatic and terrestrial plants. Acute (short-term) and chronic (long-term) toxicity information is characterized based on registrant-submitted studies and a comprehensive review of the open literature on carbaryl.

4.1. Ecotoxicity Study Data Sources

Toxicity endpoints are established based on data generated from guideline studies submitted by the registrant, and from open literature studies that meet the criteria for inclusion into the ECOTOX database maintained by EPA/Office of Research and Development (ORD) (U.S. EPA, 2004). Open literature data presented in this assessment were obtained from the 2003 carbaryl IRED (U.S. EPA, 2004b) as well as information obtained from ECOTOX on December 14, 2006. The December 2006 ECOTOX search included all open literature data for carbaryl and 1-naphthol (*i.e*., pre- and post-IRED). In order to be included in the ECOTOX database, papers must meet the following minimum criteria:

(1) the toxic effects are related to single chemical exposure;
(2) the toxic effects are on an aquatic or terrestrial plant or animal species;
(3) there is a biological effect on live, whole organisms;
(4) a concurrent environmental chemical concentration/dose or application rate is reported; and
(5) there is an explicit duration of exposure.

Open literature toxicity data for other 'target' insect species (not including bees, butterflies, beetles, and non-insect invertebrates including soil arthropods and worms), which include efficacy studies, are not currently considered in deriving the most sensitive endpoint for terrestrial insects. Efficacy studies do not typically provide endpoint values that are useful for risk assessment (*e.g*., NOAEC, EC_{50}, *etc*.), but rather are intended to identify a dose that maximizes a particular effect (*e.g*., EC_{100}). Therefore, efficacy data and non-efficacy toxicological target insect data are not included in the ECOTOX open literature data summaries provided in **Appendix K**. For the purposes of this assessment, 'target' insect species are defined as all terrestrial insects with the exception of bees, butterflies, beetles, and non-insect invertebrates (*i.e*., soil arthropods, worms, *etc*.) which are included in the ECOTOX data presented in **Appendix K**. The list of citations including toxicological and/or efficacy data on target insect species not considered in this assessment is provided in.

Data that pass the ECOTOX screen are evaluated along with the registrant-submitted data, and may be incorporated qualitatively or quantitatively into this endangered species assessment. In general, effects data in the open literature that are more conservative than the registrant-submitted data are considered. The degree to which open literature data are quantitatively or qualitatively characterized for the effects determination is dependent on whether the information is relevant to the assessment endpoints (*i.e.*, survival, reproduction, and growth) identified in Section 2.9. For example, endpoints such as behavior modifications are likely to be qualitatively evaluated, because quantitative relationships between modifications and reduction in species survival, reproduction, and/or growth are not available. Although the effects determination relies on endpoints that are relevant to the assessment endpoints of survival, growth, or reproduction, it is important to note that the full suite of sub-lethal endpoints potentially available in the effects literature (regardless of their significance to the assessment endpoints) are considered, as they are relevant to the understanding of the area with potential effects, as defined for the action area.

Citations of all open literature not considered as part of this assessment because they were either rejected by the ECOTOX screen or accepted by ECOTOX but not used (*e.g.*, the endpoint is less sensitive) are included in **Appendix L.** This appendix also includes a rationale for rejection of those studies that did not pass the ECOTOX screen and those that were not evaluated as part of this endangered species risk assessment.

In addition to registrant-submitted and open literature toxicity information, other sources of information, including use of the acute probit dose response relationship to establish the probability of an individual effect and reviews of ecological incident data, are considered to further refine the characterization of potential ecological effects associated with exposure to carbaryl. A summary of the available aquatic and terrestrial ecotoxicity information and the incident information for carbaryl are provided in Sections 4.1 through 4.4.

4.2. Toxicity of Carbaryl to Aquatic Organisms

Table 4-1 summarizes the most sensitive aquatic toxicity endpoints, based on an evaluation of both the submitted studies and the open literature, as previously discussed. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment for the DS is presented below. Additional information is provided in **Appendix K**. All endpoints are expressed in terms of the active ingredient unless otherwise specified. The available information indicates that aquatic organisms are more sensitive to the technical grade (TGAI) than the formulated products of carbaryl (Section 4.3 and **Appendix M**); therefore, the focus of this assessment is on the TGAI of carbaryl. Based on the most sensitive toxicity endpoints for each of the taxa evaluated, carbaryl is classified as very highly toxic to aquatic invertebrates and moderately to highly toxic to fish on an acute exposure basis. Chronic exposure to carbaryl resulted in reduced growth in fish and reproductive effects in aquatic invertebrates. Aquatic nonvascular plants were more sensitive to carbaryl than vascular aquatic plants.

Table 4-1. Summary of Acute and Chronic Aquatic Toxicity Estimates using Technical Grade Carbaryl.

Species	Acute Toxicity		Chronic Toxicity		
	96-hr LC_{50} (mg/L)	MRID	NOEC / LOEC (mg/L)	Affected Endpoint	MRID
Atlantic Salmon *Salmo salar*	0.220	40098001	0.0068[1]	--	--
Fathead Minnow *Pimephales promelas*	7.7	--	0.21 / 0.68	reduced growth	TOUCAR05
Stonefly *Chloroperla grammatica*	0.0017	40098001	0.0005[2]		
Water flea *Daphnia magna*	0.0056	--	0.0015 / 0.0033	reproduction	00150901
Sheepshead Minnow *Cyprinodon variegatus*	2.6	42372801	0.071[1]		
Mysid shrimp *Americamysis bahia*	0.0057	42343401	0.0015[2]		
Freshwater diatom *Navicula spp.*	14-day EC_{50}=0.66	--	--	--	--
Duckweed *Lemna gibba*	14-day EC_{50}=1.5	--	--	--	--

[1] Estimated NOEC using acute-to-chronic ratio for fathead minnow of 36.7.
[2] Estimated NOEC using acute-to-chronic ratio for *Daphnia magna* of 3.73

Toxicity to fish and aquatic invertebrates is categorized using the system shown in **Table 4.2** (USEPA, 2004a). Toxicity categories for aquatic plants have not been defined.

Table 4-2. Categories of Acute Toxicity for Fish and Aquatic Invertebrates

LC_{50} (mg/L)	Toxicity Category
< 0.1	Very highly toxic
> 0.1 - 1	Highly toxic
> 1 - 10	Moderately toxic
> 10 - 100	Slightly toxic
> 100	Practically nontoxic

4.2.1. Toxicity to Freshwater Fish

A summary of acute and chronic freshwater fish data, including data from the open literature, is provided below in Sections 4.2.1a and 4.2.1b.

4.2.1.a. Freshwater Fish: Acute Exposure (Mortality) Studies

On an acute exposure basis, technical grade (purity > 90%) carbaryl ranged in toxicity from highly to slightly toxic (LC_{50} = 0.22 - 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*).

Acute, 96-h LC_{50} values are available for 19 studies, which include data for 17 species and 11 fish genera. A quantitative distribution is established for this set of data; including studies classified acceptable or supplemental. The average of the Log_{10} values of the LC_{50} values for a species is calculated. Then, the geometric means of the values of the genera are calculated. A semi-lognormal distribution is used to estimate the sensitivity distribution by considering the mean and standard deviation of all genus mean values. A full description of the data and results used to derive these distributions is included in **Appendix N**. The lower 95th percentile of the fish distribution (472 µg/L) indicates that the use of the lowest available toxicity value (220 µg/L) is likely a conservative estimate of the toxicity of carbaryl to freshwater vertebrates (Figure 4-1).

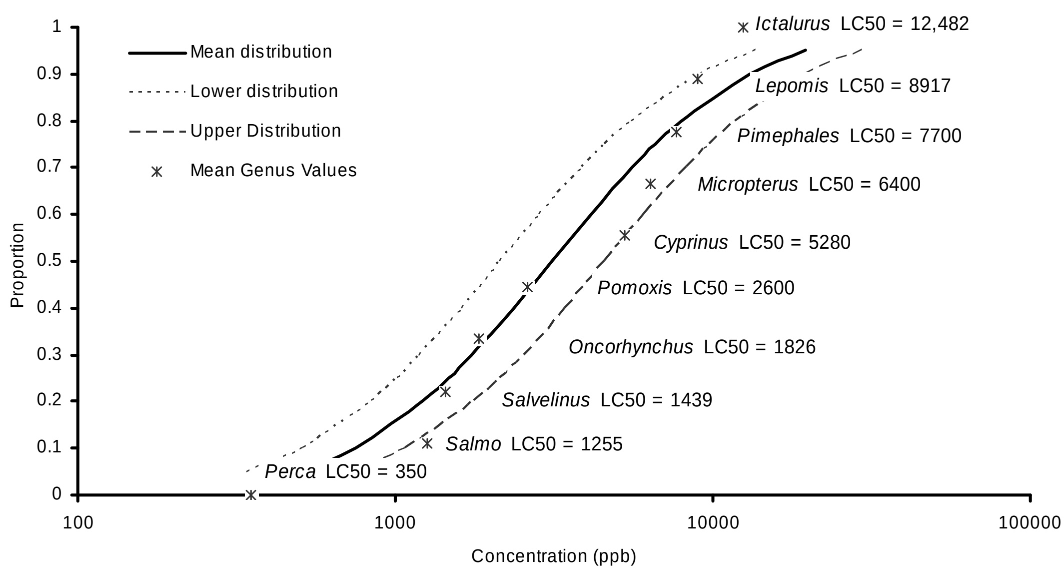

Figure 4-1. Fish Sensitivity Distribution based 96-h LC_{50} Values from Acute Exposures of Fish to Carbaryl.

4.2.1.b. Freshwater Fish: Chronic Exposure (Growth/Reproduction) Studies

Similar to the acute data, chronic freshwater fish toxicity studies are used to assess potential direct effects to the DS. Chronic exposure of fathead minnows (*Pimephales promelas*) to carbaryl resulted in reduced survival and reproductive effects (NOEC = 0.210 mg·L^{-1}) including reduced number of eggs per female and reduced number of eggs spawned. However, since Atlantic salmon are the most sensitive species on an acute exposure basis and no chronic toxicity data are available, an acute-to-chronic ratio was used to estimate the chronic toxicity of carbaryl to Atlantic salmon. Based on the information contained in the carbaryl IRED (USEPA 2004b), the 96-hr acute LC_{50} value for fathead minnows is 7.7 $mg{\cdot}L^{-1}$. With an acute LC_{50} of 7.7 $mg{\cdot}L^{-1}$ and a chronic NOEC of 0.21, the acute-to-chronic ratio (ACR) for fathead minnow is 36.7 (7.7÷0.21). When the ACR is applied to the Atlantic salmon data (LC_{50} = 0.22 $mg{\cdot}L^{-1}$), the resulting estimated NOAEC is 0.0068 $mg{\cdot}L^{-1}$.

4.2.2. Toxicity to Freshwater Invertebrates

A summary of acute and chronic freshwater invertebrate data, including data published in the open literature, is provided below in Sections 4.2.2.a through 4.2.2.b.

4.2.2.a. Freshwater Invertebrates: Acute Exposure Studies

Technical grade carbaryl is very highly toxic to aquatic invertebrates with EC_{50} values ranging from 0.0017 - 0.026 $mg{\cdot}L^{-1}$ on an acute exposure basis. Stoneflies (*Isoperla grammatica*) are the most sensitive freshwater invertebrate in an acute toxicity study (96-hr LC_{50} = 0.0017 $mg{\cdot}L^{-1}$). In general, freshwater invertebrates exhibited the same sensitivity (EC_{50} range: 0.007 - 0.013 $mg{\cdot}L^{-1}$) to formulated end-use 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 $mg{\cdot}L^{-1}$) suggesting that a tendency of carbaryl and its hydrolysis degradate 1-naphthol to partition to sediment may limit their bioavailability and hence reduce toxicity under more natural exposure conditions.

Sensitivity distributions were developed for aquatic invertebrates using acute toxicity data in a similar manner as described above for the freshwater fish distribution. Acute, EC_{50} values are available for 12 studies, which include data for 9 species and 7 genera of aquatic invertebrates. The lower 95^{th} percentile of the invertebrate distribution (0.7) indicates that the use of the lowest available toxicity value (1.7 $mg{\cdot}L^{-1}$) may not be as conservative as the value used for vertebrates (Figure 4-2). Data supporting the development of this distribution are in **Appendix N**.

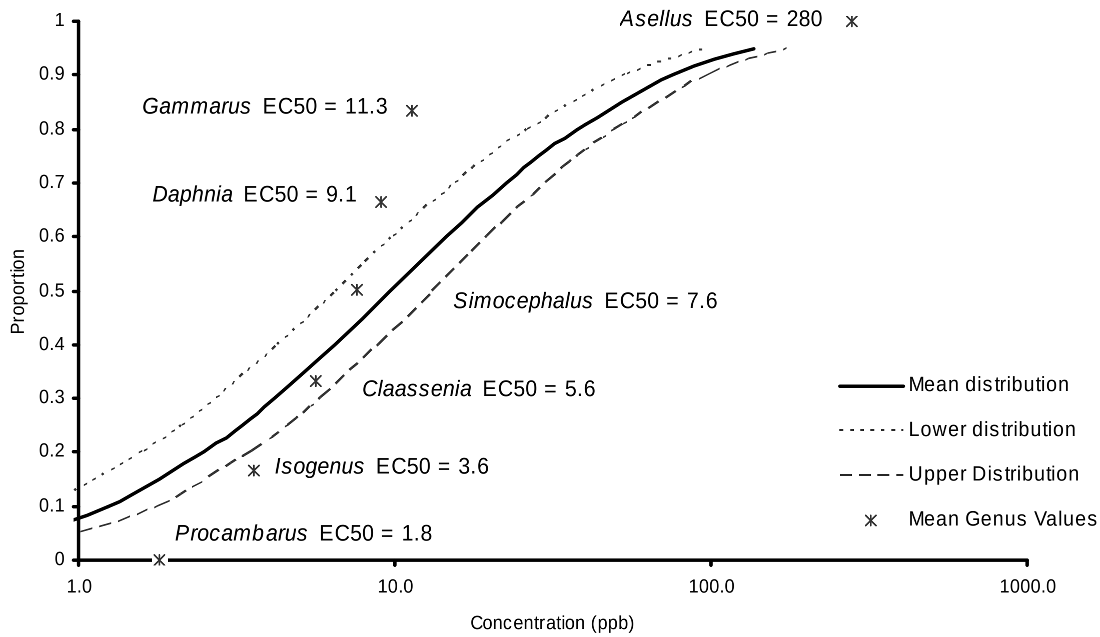

Figure 4-2. Invertebrate Sensitivity Distribution based 48-h and 96-h LC_{50} Values from Acute Exposures of Invertebrates to Carbaryl.

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 (Boone and James 2003).

4.2.2.b. Freshwater Invertebrates: Chronic Exposure Studies

On a chronic exposure basis, carbaryl affected reproduction (NOEC = 0.0015 $mg \cdot L^{-1}$) in water fleas (*Daphnia magna).* However, since stoneflies are the most sensitive invertebrate species on an acute exposure basis and no chronic toxicity data are available, an acute-to-chronic ratio was used to estimate the chronic toxicity of carbaryl to stoneflies. Based on the information contained in the carbaryl IRED (USEPA 2004b), the 48-hr acute LC_{50} value for *Daphnia magna* is 0.0056 mg/L. With an acute LC_{50} of 0.0056 $mg \cdot L^{-1}$and a chronic NOEC of 0.0015, the acute-to-chronic ratio (ACR) for *D. magna* is 3.73 (0.0056÷0.0015). When the ACR is applied to the stonefly data (LC_{50} = 0.0017 $mg \cdot L^{-1}$), the resulting estimated NOAEC is 0.0005 $mg \cdot L^{-1}$.

4.2.3. Toxicity to Estuarine/Marine Fish

A summary of acute and chronic E/M fish data, including data published in the open literature is provided below in Sections 4.2.3.a through 4.2.3.b.

4.2.3.a. Estuarine/Marine Fish: Acute Exposure Studies

Acute toxicity testing with the sheepshead minnow (*Cyprinodon variegatus*) resulted in a 96-hr LC_{50} of 2.6 mg a.i.$\cdot L^{-1}$; carbaryl is categorized as moderately toxic to estuarine/marine fish on an acute exposure basis. However, since the acute toxicity endpoint for Atlantic salmon (LC_{50}=0.22 mg/L) is more sensitive than that of the sheepshead minnow and since Atlantic salmon are an anadromous species, the acute toxicity value for the Atlantic salmon will be used to represent the acute sensitivity of estuarine/marine as well as freshwater fish to carbaryl.

4.2.3.b. Estuarine/Marine Fish: Chronic Exposure Studies

At this time, chronic toxicity data for carbaryl are not available for estuarine/marine fish. However, using the acute-to-chronic ratio of 36.7 derived for freshwater fish, the chronic estimated NOAEC for sheepshead minnow is 0.071 mg ai$\cdot L^{-1}$. This value is less sensitive than that derived for Atlantic salmon (NOAEC=0.0068 mg$\cdot L^{-1}$); therefore, the chronic toxicity value for Atlantic salmon will be used to represent estuarine/marine fish as well as freshwater fish chronic toxicity.

4.2.4. Toxicity to Estuarine/Marine Invertebrates

A summary of acute and chronic E/M invertebrate data, including data published in the open literature, is provided below in Sections 4.2.4.a through 4.2.4.b.

4.2.4.a. Estuarine/Marine Invertebrates: Acute Exposure Studies

The 96-hour mysid shrimp (*Americamysis bahia)* LC_{50} for technical carbaryl is 0.0057 mg/L (MRID 42343401). Thus, this chemical is categorized as very highly toxic to estuarine/ marine shrimp species on an acute basis.

4.2.4.b. Estuarine/Marine Invertebrates: Chronic Exposure Studies

There are no available chronic toxicity data for estuarine/marine invertebrates. Similar to what was done for estuarine/marine fish, an acute-to-chronic ratio for freshwater invertebrates, ACR=3.73, is used to estimate the chronic toxicity value for mysid shrimp, *i.e.*, 0.0015 mg$\cdot L^{-1}$.

4.2.5. Toxicity to Aquatic Plants

Aquatic plant toxicity studies are used as one of the measures of effect to evaluate whether carbaryl may affect primary production. Aquatic plants may also serve as dietary items of DS. In addition, freshwater vascular and non-vascular plant data are used to evaluate a number of the PCEs associated with the critical habitat impact analysis.

Two types of studies are used to evaluate the potential of carbaryl to affect primary productivity. Laboratory studies are used to determine whether carbaryl may cause direct effects to aquatic plants. In addition, the threshold concentrations, described in Section 4.2.5.a and 4.2.5.b, are used to further characterize potential community level effects to DS resulting from potential effects to aquatic plants in 4.2.6.

4.2.5.a. Toxicity to Freshwater Non-vascular Plants

Only two studies of the filamentous green algae *Pseudokirchneriella subcaptitata* were available to assess the toxicity of carbaryl to non-vascular aquatic plants. With technical grade carbaryl the concentration inhibiting plant growth (in terms of number of algal cells) by 50% (IC_{50}) was 1.27 $mg \cdot L^{-1}$. The most sensitive freshwater aquatic plant is the freshwater diatom *Navicula* with an EC_{50} of 0.66 $mg \cdot L^{-1}$.

Carbaryl was roughly similar to the endpoint for formulated end-use product (IC_{50} = 3.2 $mg \cdot L^{-1}$). 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 carbaryl's similarity to the plant auxin α-naphthalene acetic acid is unclear.

4.2.5.b. Toxicity to Freshwater Vascular Plants

In a supplemental study (MRID 42372102) with duckweed (*Lemna gibba*), the 14-day EC_{50} was 1.5 $mg \cdot L^{-1}$ based on reduced number of fronds. ECOTOX provided limited information on the toxicity of carbaryl to aquatic plants. In a study by Peterson *et al*. 1994, a single concentration of carbaryl (3.67 $mg \cdot L^{-1}$) resulted in 33% inhibition of *L. gibba* growth after 7-days static exposure (**Appendix K**). Although the study suggests that carbaryl has an effect on vascular aquatic plant growth, the study does not provide any information on dose response given that only a single concentration was tested.

4.2.6. Aquatic Field/Mesocosm Studies

Mesocosm studies with carbaryl provide measurements of primary productivity that incorporate the aggregate responses of multiple species in aquatic communities. Because various aquatic species vary widely in their sensitivity to carbaryl, the overall response of the aquatic community may be different from the responses of the individual species measured in laboratory toxicity tests. Mesocosm studies allow observation of population and community recovery from carbaryl effects and of indirect effects on higher trophic levels. In addition, mesocosm studies, especially those conducted in outdoor systems, incorporate partitioning, degradation, and dissipation, factors that are not usually accounted for in laboratory toxicity studies, but that may influence the magnitude of ecological effects.

The baseline risk assessment science chapter in support of the reregistration eligibility decision for carbaryl (USEPA 2003) reviewed several mesocosm studies of carbaryl and demonstrated that overall the results of these studies are highly variable. Studying natural plankton communities in enclosed mesocosms, Havens (1995) reports a decline in total zooplankton biomass and individuals across the range of carbaryl treatments (0 - 100 $ug \cdot L^{-1}$). Furthermore, at carbaryl concentrations greater than 20 $ug \cdot L^{-1}$, *Daphnia* were no longer found and at concentrations above 50 $ug \cdot L^{-1}$,, all cladocerans were eliminated, resulting in an increase in algal biomass. This represents 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 1-3 µg/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).

In some cases, mesocosms exposed to carbaryl exhibited transitory effects. In a study by Boone *et al.* 2003, carbaryl exposure significantly reduced chlorophyll concentrations 12-days after exposure; however, by the end of the study, there was no difference between carbaryl treated and control groups.

4.3. Toxicity of Carbaryl to Terrestrial Organisms

Based on an evaluation of both the submitted studies and the open literature, a brief summary of submitted and open literature data considered relevant to this ecological risk assessment is presented below. Additional information is provided in Appendix J. Input and Output files for Simulation Modeling of Exposure for the Delta Smelt
Appendix K.

4.3.1. Toxicity to Terrestrial Plants

Plant toxicity data from both registrant-submitted studies and studies in the scientific literature were reviewed for this assessment. Registrant-submitted studies are conducted under conditions and with species defined in EPA toxicity test guidelines. Sublethal endpoints such as plant growth, dry weight, and biomass are evaluated for both monocots and dicots, and effects are evaluated at both seedling emergence and vegetative life stages. Guideline studies generally evaluate toxicity to ten crop species. These tests are conducted on herbaceous crop species only, and extrapolation of effects to other species, such as the woody shrubs and trees and wild herbaceous species, contributes uncertainty to risk conclusions.

Commercial crop species have been selectively bred, and may be more or less resistant to particular stressors than wild herbs and forbs. The direction of this uncertainty for specific plants and stressors, including carbaryl, is largely unknown. Homogenous test plant seed lots also lack the genetic variation that occurs in natural populations, so the range of effects seen from tests is likely to be smaller than would be expected from wild populations.

The results of the Tier II seedling emergence and vegetative vigor toxicity tests on non-target plants are summarized below in Table 4-3**.** There are no identified seedling emergence studies for carbaryl. In a Tier I vegetative vigor study involving 6 plant species (cabbage, cucumber, soybean, tomato, onion and ryegrass), no effects to survival or dry weight were observed after a single treatment of 0.8 lbs a.i./A (MRID 45784807), which is below the maximum application rate allowed for carbaryl.

Table 4-3. Non-target Terrestrial Plant Seedling Emergence and Vegetative Vigor Toxicity (Tier II) for Carbaryl

Crop	Type of Study Species	NOAEC (lb a.i./A)	EC_{25} (lb a.i./A)	Most sensitive parameter	Slope
Vegetative Vigor					
Monocots	ryegrass	0.8	NA	NA	NA
Dicots	cabbage	0.8	NA	NA	NA
	cucumber	0.8	NA	NA	NA
	soybean	0.8	NA	NA	NA
	tomato	0.8	NA	NA	NA
	onion	0.8	NA	NA	NA

4.4. Toxicity of Chemical Mixtures

As discussed previously, toxicity testing of carbaryl formulated product with aquatic animals has indicated that none of the formulations tested were more toxic than the technical grade active ingredient (**Table 4-4**). A review of formulated product testing conducted with rats indicates that none of the formulated products (including those involving a second active ingredient, *i.e.*, metaldehyde, were more toxic than the technical grade (Sevin Technical LD_{50}=614 mg·kg^{-1} body weight).

Table 4-4. Rat acute 96-hr Oral Toxicity Test Data for Formulated Products of Carbaryl.

Formulated Product	Percent Active Ingredient	Rat Acute Oral LD_{50} (mg/kg body weight)
Sevin Brand 85 Sprayable Insecticide	85% Carbaryl	>50
Sevin Technical	99.45%	614
Sevin XLR Plus Carbaryl Insecticide	44.1%	698.5
Sevin Brand Granular Insecticide	7%	3240
Sevin 5 Bait	5%	3129
Sevin 10% Granules	10%	3620
Turf Pride Fertilizer with 2% Sevin	2%	3129
Corry's Slug, Snail and Insect Killer	5% carbaryl 2% metaldehyde	>5000
Anderson's 8% Granular	8%	1750
GrubTox Lawn Grub and Insect Killer	4.6%	3129
Bonide Slug, Snail and Sowbug Bait	5% carbaryl 2% metaldehyde	>5000
Sevin 4% Plus Fertilizer	4%	5000
Sevin Brand Granular Insecticide	6.3%	>5000

4.4. Evaluation of Aquatic Ecotoxicity Studies for 1-Naphthol

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 $mg \cdot L^{-1}$). These data indicate that 1-naphthol is of equal or less toxicity than parent carbaryl whose acute toxicity to fish ranges from 0.220 to 12,000 $mg \cdot L^{-1}$. Chronic exposure of fathead minnows to 1-naphthol reduced larval growth and survival (NOEC = 0.1 $mg \cdot L^{-1}$. For freshwater invertebrates, 1-naphthol ranged from moderately to highly toxic (EC_{50} range: 0.2 - 3.3 $mg \cdot L^{-1}$).

4.5. Incident Database Review

A review of the Ecological Incident Information System (EIIS, version 2.1), the 'Aggregate Incident Reports' (v. 1.0) database, and the Avian Monitoring Information System (AIMS) for ecological incidents involving carbaryl was completed on May 4, 2010. There were 101 incidents in the EIIS systems. No additional bird incidents beyond those already included in the EIIS were reported in AIMS. The Aggregate Incident Report database contains information on 7 'minor' fish and wildlife incidents, 172 'minor' plant incidents, and 10 'minor' 'other non-target' incidents. The results of this review for plant, and aquatic incidents are discussed below in Sections 4.5.1 through 4.5.2. A complete list of the incidents involving carbaryl including terrestrial incidents not considered in this assessment is included as **Appendix P**.

4.5.1. Plant Incidents

Of all of the incidents in EIIS associated with carbaryl, the greatest number, 15, have affected terrestrial plants. These incidents include effects on orchard and vegetable crops, and lawns. Specific crops include cucumbers, tomato, olive, pumpkin, squash, potato, cabbage, and quince. 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. Most of these incidents involved surface damage to the fruit or leaves of the plant. 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 toxicity data available for carbaryl does not indicate the likelihood of phytotoxic effects; however, the incident data imply that phytotoxic effects are possible.

4.5.2. Aquatic Incidents

With respect to ecological incidents involving fish reported in the EIIS, a total of six fish-kill incidents were reported for carbaryl. Only one of those incidents, report #B0000-501-92, could be credibly associated with a specific carbaryl use, *i.e.*, to control gypsy moth in New Jersey in 1980. No data on residues were provided.

In an incident (I000910-001) in Louisiana, a fish kill was reported to have occurred 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 $mg{\cdot}L^{-1}$) and iprodione (LC_{50} = 3.1 $mg{\cdot}L^{-1}$) 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.

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 (B0000-246-01). 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 $\mu g{\cdot}L^{-1}$ and 0.32 $\mu g{\cdot}L^{-1}$, respectively, it is likely that they are more credible candidates for having caused the fish kill than carbaryl.

In 2001, a large fish (several thousand fish) occurred in the San Joaquin River in California (I013436-001). The fish were primarily threadfin shad and small catfish (< 3 in). A variety of pesticides were found in the river water and in discharges to the river including demeton-S, diazinon, naled (dibrom), disulfoton and azinphos methyl. Dioxathion, carbaryl, carbofuran, fenuron, methomyl, and monuron were found in the gill tissue of the fish. Carbaryl was found only in the fish tissue and 1.75 $mg{\cdot}L^{-1}$. Azinphos methyl was found at 16 $\mu g{\cdot}L^{-1}$ in water from an agricultural drain entering the river and 0.2 to 0.8 $\mu g{\cdot}L^{-1}$ in the San Joaquin River itself. Given azinphos methyl's known ability to result in large fish kills in this concentration, it is likely that it was the cause of the fish kill rather than carbaryl. The certainty of the second incident is also low because of lack of evidence.

For two other incidents in Texas in 1994 (I001297-011) and 2004 (I015419-664) insufficient information was provided in the report to allow any evaluation of a cause and effect relationship with carbaryl.

4.6. Use of Probit Slope Response Relationship to Provide Information on the Endangered Species Levels of Concern

The Agency uses the probit dose response relationship as a tool for providing additional information on the potential for acute direct effects to individual listed species and aquatic animals that may indirectly affect the listed species of concern (USEPA, 2004a). As part of the risk characterization, an interpretation of acute RQs for listed species is discussed. This interpretation is presented in terms of the chance of an individual event (*i.e.*, mortality or immobilization) should exposure at the EEC actually occur for a species with sensitivity to carbaryl on par with the acute toxicity endpoint selected for RQ calculation. To accomplish this interpretation, the Agency uses the slope of the dose response relationship available from the toxicity study used to establish the acute toxicity measures of effect for each taxonomic group that is relevant to this assessment. The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship. In addition to a single effects probability estimate based on the mean, upper and lower estimates of the effects probability are also provided to account for variance in the slope, if available.

Individual effect probabilities are calculated based on an Excel spreadsheet tool IECV1.1 (Individual Effect Chance Model Version 1.1) developed by the U.S. EPA, OPP, Environmental Fate and Effects Division (June 22, 2004). The model allows for such calculations by entering the mean slope estimate (and the 95% confidence bounds of that estimate) as the slope parameter for the spreadsheet. In addition, the acute RQ is entered as the desired threshold.

5. Risk Characterization

Risk characterization is the integration of the exposure and effects characterizations. Risk characterization is used to determine the potential for direct and/or indirect effects to the DS or for modification to their designated critical habitat from the use of carbaryl in California. The risk characterization provides an estimation (Section 5.1) and a description (Section 5.2) of the likelihood of adverse effects; articulates risk assessment assumptions, limitations, and uncertainties; and synthesizes an overall conclusion regarding the likelihood of adverse effects to the assessed species or their designated critical habitat (*i.e.*, “no effect,” “likely to adversely affect,” or “may affect, but not likely to adversely affect”). In the risk estimation section, risk quotients are calculated using standard EFED procedures and models. In the risk description section, additional analyses may be conducted to help characterize the potential for risk.

5.1. Risk Estimation

Risk is estimated by calculating the ratio of exposure to toxicity. This ratio is the risk quotient (RQ), which is then compared to pre-established acute and chronic levels of concern (LOCs) for each category evaluated (**Appendix E**). For acute exposures to the aquatic animals, the LOC is 0.05. The LOC for chronic exposures to animals, as well as acute exposures to plants, is 1.0.

Acute and chronic risks to aquatic organisms are estimated by calculating the ratio of exposure to toxicity using 1-in-10 year EECs in Table 3-6 and Table 3-7 based on the label-recommended carbaryl usage scenarios summarized in **Table 3-1** and the appropriate aquatic toxicity endpoint from **Table 4-1**. Acute risks to terrestrial plants are estimated based the appropriate toxicity endpoint from **Table 4-3**.

5.1.1. Exposures in the Aquatic Habitat

5.1.1.a. Freshwater Fish

Acute risk to fish is based on 1-in-10-year peak EECs in the standard pond and the lowest acute toxicity value for freshwater fish. Chronic risk is based on the 1-in-10 year 60-day EECs and the lowest chronic toxicity value for freshwater fish. Risk quotients for freshwater fish are shown in Table 5-1.

Resulting acute RQs exceed the acute listed species LOC (0.05) across all of the uses modeled except applications to flowers around buildings, field corn, dry beans, okra, alfalfa, grass for seed and melons. RQs exceed the chronic risk LOC (1.0) for carbaryl applications to lawns, ornamentals, citrus, olives, almonds, peaches, asparagus, apples, loquat, sweet corn, grapes, strawberries, tomatoes, broccoli, Brussels sprouts, sweet potatoes, head lettuce, celery, horse radish, potatoes, rice, rights-of-way, wasteland, rural shelter belts, and ticks (**Table 5-1**).

Table 5-1. Acute and Chronic RQs for Both Freshwater and Estuarine Fish

Crop Group[1]	Peak EEC (µg/L)	60-d EEC (µg/L)	Acute RQ[2]	Chronic RQ[5]
A: Home lawn	14.6	5.25	**0.07**[3]	0.77
B: Flowers around buildings	0.47	0.15	0.002	0.02
C: Lawns	25.4	12.4	**0.12**[3]	**1.82**[4]
D: Ornamentals	51.2	16	**0.23**[3]	**2.35**[4]
E Parks 1	9.3	3.6	0.04	0.53
E Parks 2	10	3.7	**0.05**	0.54
F: Citrus 1	33.2	15.4	**0.15**[3]	**2.26**[4]
F: Citrus 2	44.7	11.8	**0.20**[3]	**1.74**[4]
G Olives	52.6	18.9	**0.24**[3]	**2.78**[4]
H: almonds	43.3	17.5	**0.20**[3]	**2.57**[4]
I: flowers	21.4	6.7	**0.10**[3]	0.99
J: peaches	56.8	17	**0.26**[3]	**2.50**[4]
K: asparagus	47.2	13.4	**0.21**[3]	**1.97**[4]
L: apple	16.3	9.3	**0.07**[3]	**1.37**[4]
M: loquat	13	7.5	**0.06**[3]	**1.10**[4]
N: sweet corn	24.8	10.7	**0.11**[3]	**1.57**[4]
O: grapes	22.4	11.9	**0.10**[3]	**1.75**[4]
P: strawberries	100.2	39.7	**0.46**[3]	**5.84**[4]
Q: tomatoes	24.5	11	**0.11**[3]	**1.62**[4]
R peanuts	12.9	5.6	**0.06**[3]	0.82
S broccoli	73	26.4	**0.33**[3]	**3.88**[4]
T Brussels sprouts	166.8	55.8	**0.76**[3]	**8.21**[4]
U sweet potatoes	49.7	19.6	**0.23**[3]	**2.88**[4]
V: Field corn	9.1	5	0.04	0.74
W: head lettuce	93.5	34.6	**0.43**[3]	**5.09**[4]
X: sorghum	11.4	4.1	**0.05**[3]	0.60
Y: celery	37.9	11.6	**0.17**[3]	**1.71**[4]

Z: horse radish	71.8	22.8	**0.33**[3]	**3.35**[4]
AA: potato	42	12.5	**0.19**[3]	**1.84**[4]
AB: radish	13.3	4.8	**0.06**[3]	0.71
AC: rice	2579	2579	**11.7**[3]	**379**[4]
AD: dry beans	9.7	4.2	0.04	0.62
AE: okra	5.6	1.8	0.03	0.26
AF: sugar beet	13.6	5.4	**0.06**[3]	0.79
AG: alfalfa	9.1	3.2	0.04	0.47
AH: pasture	10.9	4.3	**0.05**	0.63
AI: grass for seed	7.1	3.1	0.03	0.46
AJ: rangeland	12.8	2.6	**0.06**[3]	0.38
AK: melons	7.2	4	0.03	0.59
AL: roses	14.9	4.7	**0.07**[3]	0.69
AM: rights of way	19	7.6	**0.09**[3]	**1.12**[4]
AN: wasteland	68	26.1	**0.31**[3]	**3.84**[4]
AO: non-urban forests	11.5	4.2	**0.05**[3]	0.62
AP: rural shelter belts	41	14.9	**0.19**[3]	**2.19**[4]
AQ: Ticks	17.7	13.2	**0.08**[3]	**1.94**[4]

[1]For specific uses associated with each crop group see Table 3-3.
[2] Based on 96-h LC_{50} = 0.220 mg/L for Atlantic salmon
[3] Exceeds listed species acute risk level of concern (RQ≥0.05)
[4] Exceeds listed species chronic risk level of concern (RQ>1.0)
[5] Based on Chronic NOEC of 0.0068 mg/L for Atlantic salmon

5.1.1.b. Freshwater Invertebrates

For assessing risks of indirect acute effects to the DS through effects to prey (invertebrates) in freshwater aquatic habitats, 1-in-10 year peak EECs in the standard pond are used with the lowest acute toxicity value for invertebrates. For chronic risks, 1-in-10 year peak 21-day EECs and the lowest chronic toxicity value for invertebrates are used to derive RQs. Acute and chronic RQs exceed the LOCs (RQ≥0.05 and RQ≥1.0, respectively) for applications to all use groups with the exception of carbaryl applications to flowers around buildings; for this one use, the chronic RQ value is below the chronic risk LOC (**Table 5-2**).

Table 5-2. Risk Quotient (RQ) Values for Acute and Chronic Exposures to Aquatic Invertebrates in Aquatic Habitats.

Crop Group[1]	Peak EEC (µg/L)	21-d EEC (µg/L)	Acute RQ[2]	Chronic RQ[3]
A: Home lawn	14.6	8.7	**8.6[4]**	**17.4[5]**
B: Flowers around buildings	0.47	0.29	**0.3**	0.6
C: Lawns	25.4	19	**14.9[4]**	**38.0[5]**
D: Ornamentals	51.2	29.3	**30.1[4]**	**58.6[5]**
E: Parks 2	9.3	6.5	**5.5[4]**	**13[5]**
E: Parks 2	10	6.3	**5.9[4]**	**12.6[5]**
F: Citrus 1	33.2	22	**19.5[4]**	**44.0[5]**
F: Citrus 2	44.7	25.2	**26.3[4]**	**50.4[5]**
G Olives	52.6	31.4	**30.9[4]**	**62.8[5]**
H: almonds	43.3	29.1	**25.5[4]**	**58.2[5]**
I: flowers	21.4	13	**12.6[4]**	**26.0[5]**
J: peaches	56.8	32.1	**33.4[4]**	**64.2[5]**
K: asparagus	47.2	26.5	**27.8[4]**	**53.0[5]**
L: apple	16.3	10.7	**9.6[4]**	**21.4[5]**
M: loquat	13	8.7	**7.6[4]**	**17.4[5]**
N: sweet corn	24.8	18.7	**14.6[4]**	**37.4[5]**
O: grapes	22.4	18.2	**13.2[4]**	**36.4[5]**
P: strawberries	100.2	72.7	**58.9[4]**	**145.4[5]**
Q: tomatoes	24.5	17.1	**14.4[4]**	**34.2[5]**
R: Peanuts	12.9	9	**7.6[4]**	**18.0[5]**
S: Broccoli	73	47.5	**42.9[4]**	**95.0[5]**
T: Brussels sprouts	166.8	108.3	**98.1[4]**	**216.6[5]**
U: Sweet potato	49.7	32	**29.2[4]**	**64.0[5]**
V: Field corn	9.1	6.2	**5.4[4]**	**12.4[5]**
W: Lettuce, head	93.5	62.7	**55.0[4]**	**125.4[5]**
X: Sorghum	11.4	7.4	**6.7[4]**	**14.8[5]**
Y: Celery	37.9	22.4	**22.3[4]**	**44.8[5]**
Z: Horseradish	71.8	43.2	**42.2[4]**	**86.4[5]**
AA: Potato	42	24.2	**24.7[4]**	**48.4[5]**
AB: Radish	13.3	8.6	**7.8[4]**	**17.2[5]**
AC: Rice	2579	2579	**1517[4]**	**5158[5]**
AD: Beans	9.7	6.8	**5.7[4]**	**13.6[5]**
AE: Okra	5.6	3.1	**3.3[4]**	**6.2[5]**
AF: Sugar beet	13.6	9.6	**8.0[4]**	**19.2[5]**
AG: Alfalfa	9.1	5	**5.4[4]**	**10.0[5]**
AH: Pasture	10.9	7.8	**6.4[4]**	**15.6[5]**
AI: Grass for seed	7.1	4.7	**4.2[4]**	**9.4[5]**
AJ: Rangeland	12.8	7.7	**7.5[4]**	**15.4[5]**
AK: Melon	7.2	5.4	**4.2[4]**	**10.8[5]**
AL: Roses	14.9	8.9	**8.8[4]**	**17.8[5]**
AM: Rights-of-way	19	12.2	**11.2[4]**	**24.4[5]**
AN: Wasteland	68	40	**40.0[4]**	**80.0[5]**
AO: Non-urban forests	11.5	8.2	**6.8[4]**	**16.4[5]**
AP: Rural shelter belts	41	28.7	**24.1[4]**	**57.4[5]**
AQ: Ticks	17.7	15.1	**10.4[4]**	**30.2[5]**

[1]For specific uses associated with each crop group see Table 3-3
[2] Based on 96-h LC_{50} = 0.0017 mg/L for Stonefly
[3] Based on estimated chronic NOEC of 0.0005 mg/L for Stonefly
[4] Exceeds listed species acute risk level of concern (RQ≥0.05)
[5] Exceeds listed species chronic risk level of concern (RQ>1.0)

5.1.1.c. Estuarine/Marine Fish

Acute risk to estuarine/marine fish is based on 1-in-10 year peak EECs in the standard pond and the lowest acute toxicity value for estuarine/marine fish. Chronic risk is based on 1 in 10 year 60-

day EECs and the lowest chronic toxicity value for estuarine/marine fish. Risk quotients are shown in **Table 5-1**. Since both the exposure and toxicity metrics for estuarine/marine fish and freshwater fish are identical, the risks for estuarine and marine fish will be the same as those identified in section 5.1.1.a for freshwater fish.

5.1.1.d. Estuarine/Marine Invertebrates

For assessing risks of indirect acute effects to the DS through effects to prey (invertebrates) in estuarine habitats, 1-in-10 year peak EECs in the standard pond are used with the lowest acute toxicity value for invertebrates. For chronic risks, 1-in-10 year peak and 21-day EECs and the lowest chronic toxicity value for invertebrates are used to derive RQs. Acute and chronic RQs exceed the LOCs (RQ≥0.05 and RQ≥1.0, respectively) for applications to all use groups with the exception of carbaryl applications to flowers around buildings; for this one use, the chronic RQ value is below the chronic risk LOC. Risk quotients for all uses are shown in **Table 5-3**.

Table 5-3. Risk Quotient (RQ) Values for Acute and Chronic Exposures to Marine and Estuarine Invertebrates, Prey of Delta Smelt, in Aquatic Habitats.

Crop Group[1]	Peak EEC (µg/L)	21-d EEC (µg/L)	Acute RQ[2]	Chronic RQ[3]
A: Home lawn	14.6	8.7	**2.56[4]**	**5.8[5]**
B: Flowers around buildings	0.47	0.29	**0.08**	**0.19**
C: Lawns	25.4	19	**4.46[4]**	**12.7[5]**
D: Ornamentals	51.2	29.3	**8.98[4]**	**19.5[5]**
E: Parks 2	9.3	6.5	**1.63[4]**	**4.3[5]**
E: Parks 2	10	6.3	**1.75[4]**	**4.2[5]**
F: Citrus 1	33.2	22	**5.82[4]**	**14.7[5]**
F: Citrus 2	44.7	25.2	**7.84[4]**	**16.8[5]**
G Olives	52.6	31.4	**9.23[4]**	**20.9[5]**
H: almonds	43.3	29.1	**7.59[4]**	**19.4[5]**
I: flowers	21.4	13	**3.75[4]**	**8.7[5]**
J: peaches	56.8	32.1	**9.96[4]**	**21.4[5]**
K: asparagus	47.2	26.5	**8.28[4]**	**5.5[5]**
L: apple	16.3	10.7	**2.86[4]**	**7.1[5]**
M: loquat	13	8.7	**2.28[4]**	**5.8[5]**
N: sweet corn	24.8	18.7	**4.35[4]**	**12.5[5]**
O: grapes	22.4	18.2	**3.93[4]**	**12.1[5]**
P: strawberries	100.2	72.7	**17.58[4]**	**48.4[5]**
Q: tomatoes	24.5	17.1	**4.30[4]**	**11.4[5]**
R: Peanuts	12.9	9	**2.3[4]**	**6.0[5]**
S: Broccoli	73	47.5	**12.8[4]**	**31.7[5]**
T: Brussels sprouts	166.8	108.3	**29.3[4]**	**72.2[5]**
U: Sweet potato	49.7	32	**8.7[4]**	**20.0[5]**
V: Field corn	9.1	6.2	**1.6[4]**	**4.1[5]**
W: Lettuce, head	93.5	62.7	**16.4[4]**	**41.8[5]**
X: Sorghum	11.4	7.4	**2.0[4]**	**4.9[5]**
Y: Celery	37.9	22.4	**6.6[4]**	**14.9[5]**
Z: Horseradish	71.8	43.2	**12.6[4]**	**28.8[5]**
AA: Potato	42	24.2	**7.4[4]**	**16.1[5]**
AB: Radish	13.3	8.6	**2.3[4]**	**8.9[5]**
AC: Rice	2579	2579	**452[4]**	**1719[5]**
AD: Beans	9.7	6.8	**1.7[4]**	**4.5[5]**
AE: Okra	5.6	3.1	**0.98[4]**	**2.1[5]**
AF: Sugar beet	13.6	9.6	**2.4[4]**	**6.4[5]**
AG: Alfalfa	9.1	5	**1.6[4]**	**3.3[5]**
AH: Pasture	10.9	7.8	**1.9[4]**	**5.2[5]**
AI: Grass for seed	7.1	4.7	**1.2[4]**	**3.1[5]**

AJ: Rangeland	12.8	7.7	**2.2**[4]	**5.1**[5]
AK: Melon	7.2	5.4	**1.3**[4]	**3.6**[5]
AL: Roses	14.9	8.9	**2.6**[4]	**5.9**[5]
AM: Rights-of-way	19	12.2	**3.3**[4]	**8.1**[5]
AN: Wasteland	68	40	**11.9**[4]	**26.7**[5]
AO: Non-urban forests	11.5	8.2	**2.0**[4]	**5.5**[5]
AP: Rural shelter belts	41	28.7	**7.2**[4]	**19.1**[5]
AQ: Ticks	17.7	15.1	**3.1**[4]	**10.1**[5]

[1] For specific uses associated with each crop group see Table 3-3.
[2] Based on 96-h LC_{50} = 0.0057 mg/L for mysid shrimp
[3] Based on estimated chronic NOEC of 0.0015 mg/L for mysid shrimp
[4] Exceeds listed species acute risk level of concern (RQ≥0.05)
[5] Exceeds listed species chronic risk level of concern (RQ>1.0)

5.1.1.e. Aquatic Plants

Risk to aquatic vascular and non-vascular plants is based on 1-in-10-year peak EECs in the standard pond and the lowest toxicity value. Risk quotients are shown in **Table 5-4**. For assessing risks of indirect effects of carbaryl to the DS through effects to its habitat on aquatic non-vascular plants, 1-in-10 year peak EECs from the standard pond are used with the lowest acute toxicity value for aquatic unicellular and vascular plants to derive 2 sets of RQs used to represent the aquatic habitat. Resulting RQs do not exceed the acute risk LOC (RQ≥1.0) for aquatic plants from carbaryl applications to any of the uses modeled except rice.

Table 5-4. Summary of Acute RQs for Aquatic Plants.

Crop Group[1]	Peak EEC (μg/L)	Indirect effects RQ (unicellular plants)[2]	Indirect effects RQ (vascular plants)[3]
A: Home lawn	14.6	0.02	0.01
B: Flowers around buildings	0.47	<0.01	<0.01
C: Lawns	25.4	0.04	0.02
D: Ornamentals	51.2	0.08	0.03
E: Parks 1	9.3	0.01	0.01
E: Parks 2	10	0.02	0.01
F: Citrus 1	33.2	0.05	0.02
F: Citrus 2	44.7	0.07	0.03
G: Olives	52.6	0.08	0.04
H: almonds	43.3	0.07	0.03
I: flowers	21.4	0.03	0.01
J: peaches	56.8	0.09	0.04
K: asparagus	47.2	0.07	0.03
L: apple	16.3	0.02	0.01
M: loquat	13	0.02	0.01
N: sweet corn	24.8	0.04	0.02
O: grapes	22.4	0.03	0.01
P: strawberries	100.2	0.15	0.07
Q: tomatoes	24.5	0.04	0.02
R: Peanuts	12.9	0.02	0.01
S: Broccoli	73	0.11	0.05
T: Brussels sprouts	166.8	0.25	0.11
U: Sweet potato	49.7	0.08	0.03
V: Field corn	9.1	0.01	0.01
W: Lettuce, head	93.5	0.14	0.06
X: Sorghum	11.4	0.02	0.01
Y: Celery	37.9	0.06	0.03
Z: Horseradish	71.8	0.11	0.05
AA: Potato	42	0.06	0.03
AB: Radish	13.3	0.02	0.01
AC: Rice	2579	**3.91**[4]	**1.72**[4]
AD: Beans	9.7	0.01	0.01
AE: Okra	5.6	0.01	<0.01
AF: Sugar beet	13.6	0.02	0.01
AG: Alfalfa	9.1	0.01	0.01
AH: Pasture	10.9	0.02	0.01
AI: Grass for seed	7.1	0.01	<0.01
AJ: Rangeland	12.8	0.02	0.01
AK: Melon	7.2	0.01	<0.01
AL: Roses	14.9	0.02	0.01
AM: Rights-of-way	19	0.03	0.01
AN: Wasteland	68	0.10	0.05
AO: Non-urban forests	11.5	0.02	0.01
AP: Rural shelter belts	41	0.06	0.03
AQ: Ticks	17.7	0.03	0.01

[1]For specific uses associated with each crop group see Table 3-3.
[2] Based on EC_{50} = 0.66 mg/L for green algae
[3] Based on EC_{50} = 1.5 mg/L for duckweed
[4] Exceeds risk level of concern (RQ≥1.0)

5.1.2. Exposures in the Terrestrial Habitat

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5.1.2.a. Terrestrial Plants

Insufficient data are available to fully characterize the toxicity of carbaryl to riparian and terrestrial plants. A tier 1 vegetative vigor study is available for 6 species of terrestrial plants exposed to carbaryl at levels below the maximum single application rate allowed for carbaryl. This study showed no effects. Since carbaryl is used for fruit thinning, carbaryl has potential for reproductive effects to plants. The potential for phytotoxic effects is also supported by the available incident data. No data are available to assess potential reproductive effects of carbaryl on plants. Based on the available toxicity data, only the assessment of vegetative vigor via the spray drift route can be assessed.

Based on this limited data, the risks from spray drift in plants in the riparian zone around DS habitat can be assessed by comparing the NOAEC (0.8 lb-ai·acre^{-1}) from the vegetative vigor studies to the spray drift EECs from TerrPlant. The use with the highest single application rate with aerial application allowed on the label (Group F: citrus) is at the level of concern with a risk quotient of 1. The second highest aerial use pattern, olives, is below the level of concern. The highest application rate with ground spray application (Group A: home lawns) is also below the level of concern. However, because the runoff route could not be assessed with this data, the absence of seedling emergence data, and incidence data, risks to DS from secondary effects through effects on riparian vegetation cannot be precluded.

Table 5-5. Summary of Risk Quotients for both Riparian Monocots and Dicots in Delta Smelt Habitat from Selected Uses of Carbaryl.

Crop Group		RQ
A: Home lawn	0.091	0.11
F: Citrus	0.8	**1**[1]
G: Olives	0.375	0.49
1) Exceeds risk level of concern (RQ≥1.0)		

5.1.3. Primary Constituent Elements of Designated Critical Habitat

For carbaryl use, the assessment endpoints for designated critical habitat PCEs involve the same endpoints as those being assessed relative to the potential for direct and indirect effects to the listed species assessed here. Therefore, the effects determinations for direct and indirect effects are used as the basis of the effects determination for potential modification to designated critical habitat.

5.2. Risk Description

The risk description synthesizes overall conclusions regarding the likelihood of adverse impacts leading to a preliminary effects determination (*i.e.*, “no effect,” “may affect, but not likely to adversely affect,” or “likely to adversely affect”) for the assessed species and the potential for modification of their designated critical habitat based on analysis of risk quotients and a comparison to the Level of Concern. The final No Effect/May Affect determination is made after the spatial analysis is completed at the end of the risk description, 5.2.3 In this section, a discussion of any potential overlap between areas where potential usage may result in LAA effects and areas where species are expected to occur (including any designated critical habitat) is presented. If there is no overlap of the species habitat and occurrence sections with the Potential Area of LAA Effects a No Effect determination is made.

If the RQs presented in the Risk Estimation (Section 5.1) show no direct or indirect effects for the assessed species, and no modification to PCEs of the designated critical habitat, a preliminary "no effect" determination is made, based on carbaryl's use within the action area. However, if LOCs for direct or indirect effect are exceeded or effects may modify the PCEs of the critical habitat, the Agency concludes a preliminary "may affect" determination for the FIFRA regulatory action regarding carbaryl. Based on the LOC exceedances identified above, a preliminary determination of 'may effect' is made for carbaryl usage relative to the DS and its associated critical habitat. A summary of the risk estimation results are provided in Table 5-6 for direct and indirect effects to the listed species assessed here and in Table 5-7 for the PCEs of their designated critical habitat.

Table 5-6. Risk Estimation Summary for Carbaryl Direct and Indirect Effects on Delta Smelt

Taxa	LOC Exceedances (Yes/No)	Description of Results of Risk Estimation	Assessed Species Potentially Affected
Freshwater Fish	Listed Species **Yes**	**acute:** LOCs for 34 of 43 crops modeled are exceeded **chronic**: LOCs for 26 of 43 crops modeled are exceeded	Direct Effects
Freshwater Invertebrates	Non-listed Species **Yes**	all acute LOCs and all chronic LOCs are exceeded except flower beds around buildings	Indirect Effects
Estuarine/Marine Fish	Listed Species **Yes**	**acute:** LOCs for 34 of 43 crops modeled are exceeded **chronic**: LOCs for 26 of 43 crops modeled are exceeded	Direct Effects
Estuarine/Marine Invertebrates	Non-listed Species **Yes**	acute and chronic LOCs are exceeded for all uses except flower beds around buildings	Indirect Effects
Vascular Aquatic Plants	Non-listed Species **Yes**	LOCs are exceeded for rice only	Indirect Effects
Non-Vascular Aquatic Plants	Non-listed Species **Yes**	LOCs are exceeded for rice only	Indirect Effects
Terrestrial Plants – Monocots	Non-listed Species **Yes**	LOCs are exceeded based on an absence of a quantitative endpoint	Indirect Effects
Terrestrial Plants – Dicots	Non-listed Species **Yes**	LOCs are exceeded based on an absence of a quantitative endpoint	Indirect Effects

Table 5-7. Risk Estimation Summary for Carbaryl – Effects to Designated Critical Habitat for Delta Smelt. (PCEs)

Taxa	LOC Exceedances (Yes/No)	Description of Results of Risk Estimation
Freshwater Invertebrates	Non-listed Species **Yes**	all acute LOCs and all chronic LOCs are exceeded except for flower beds around buildings and flea collars
Estuarine/Marine Invertebrates	Non-listed Species **Yes**	acute and chronic LOCs are exceeded for all uses except flower beds around buildings and flea collars
Vascular Aquatic Plants	Non-listed Species **Yes**	LOCs are exceeded for rice only
Non-Vascular Aquatic Plants	Non-listed Species **Yes**	LOCs are exceeded for rice only
Terrestrial Plants - Monocots	Non-listed Species[1] **Yes**	LOCs are exceeded based on an absence of a quantitative endpoint
Terrestrial Plants - Dicots	Non-listed Species[1] **Yes1**	LOCs are exceeded based on an absence of a quantitative endpoint

1- Only non-listed LOCs were evaluated because none of the assessed species have an obligate relationship with terrestrial monocots and dicots.

Following a preliminary "may affect" determination, additional information is considered to refine the potential for exposure at the predicted levels based on the life history characteristics (*i.e.*, habitat range, feeding preferences, *etc.*) of the assessed species. Based on the best available information, the Agency uses the refined evaluation to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that are "likely to adversely affect" the assessed species and its designated critical habitat.

The criteria used to make determinations that the effects of an action are "not likely to adversely affect" the assessed species or modify its designated critical habitat include the following:

- Significance of Effect: Insignificant effects are those that cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where "take" occurs for even a single individual. "Take" in this context means to harass or harm, defined as the following:
    - Harm includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering.

- Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering.

- Likelihood of the Effect Occurring: Discountable effects are those that are extremely unlikely to occur.
- Adverse Nature of Effect: Effects that are wholly beneficial without any adverse effects are not considered adverse.

A description of the risk and effects determination for each of the established assessment endpoints for the assessed species and their designated critical habitat is provided in Sections 5.2.1 through 5.2.3. Discussion will start with the potential for direct effects, followed by a discussion of the potential for indirect effects. These discussions do not consider the spatial analysis. The section will end with a discussion on the potential for modification to the critical habitat from the use of carbaryl. Finally, in Section 5.3, a discussion of any potential overlap between areas of concern and the species (including any designated critical habitat) is presented. If there is no overlap of the species habitat and occurrence sections with the Potential Area of LAA Effects a No Effect determination is made.

5.2.1. Delta Smelt

5.2.1.a. Direct Effects

Acute exposures

All modeled uses except applications to flowers around buildings, field corn, dry beans, okra, alfalfa, grass for seed and melons exceed the acute risk to listed species LOC by factors ranging from 1 to 240X for direct effects to DS.

A source of uncertainty in the derivation of RQs is the estimation of exposure. As discussed above (section 3.2.1) concentrations of carbaryl have been detected in California surface waters; however, the detections ($\leq$1.06 µg/L) were not at levels sufficient to exceed the LOC for direct acute effects to the DS. Since the NAWQA monitoring data are not targeted to actual carbaryl application times and/or sites, it is uncertain whether concentration in surface waters is sufficient to exceed either acute or chronic risk LOCs for the DS.

An analysis of the likelihood of individual direct mortality (**Table 5-8**) for each assessed use indicates that based on the highest RQ value (12) for direct effects on the DS and with a dose-response slope of 4.62, the likelihood is 1 in 1. At the endangered species LOC, *i.e.*, RQ=0.05, the likelihood of individual mortality is 1 in 1.1 x $10^{9;}$ however, at an RQ of 0.3, the likelihood of individual mortality increases to 1 in 127. Although many of the current uses are estimated to exceed the acute risk to listed species LOC for DS, the likelihood of individual mortality may be is significantly lower for some of the uses. Methods for calculating the likelihood of individual direct mortality are in **Appendix O**.

Table 5-8. Likelihood of Individual Effect for Each Use of Carbaryl for the Delta Smelt.

Crop Group[1]	Acute RQ	Likelihood of individual acute effect (1 in….)
A: Home lawn	0.07	2.10E+07
B: Flowers around buildings	0.002	1.82E+35
C: Lawns	0.12	95300
D: Ornamentals	0.23	62.7
E: Parks 1	0.04	1.89E+10
E Parks 2	0.05	1.08E+09
F: Citrus 1	0.15	14200
F: Citrus 2	0.20	1610
G Olives	0.24	477
H: almonds	0.20	1610
I: flowers	0.10	5.21E+05
J: peaches	0.26	370
K: asparagus	0.21	1510
L: apple	0.07	2.10E+07
M: loquat	0.06	1.21E+08
N: sweet corn	0.11	2.11E+05
O: grapes	0.10	5.21E+05
P: strawberries	0.46	16.8
Q: tomatoes	0.11	2.11E+05
R: Peanuts	0.06	1.21E+08
S: Broccoli	0.33	76.6
T: Brussels sprouts	0.76	3.44
U: Sweet potato	0.23	627
V: Field corn	0.04	1.89E+10
W: Lettuce, head	0.43	22.1
X: Sorghum	0.05	1.08E+09
Y: Celery	0.17	5300
Z: Horseradish	0.33	76.6
AA: Potato	0.19	2320
AB: Radish	0.06	1.21E+08
AC: Rice	11.7	1
AD: Beans	0.04	1.89E+10
AE: Okra	0.03	1.01E+12
AF: Sugar beet	0.06	1.21E+08
AG: Alfalfa	0.04	1.89E+10
AH: Pasture	0.05	1.08E+09
AI: Grass for seed	0.03	1.01E+12
AJ: Rangeland	0.06	1.21E+08
AK: Melon	0.03	1.01E+12
AL: Roses	0.07	2.10E+07
AM: Rights-of-way	0.09	47100
AN: Wasteland	0.31	107
AO: Non-urban forests	0.05	1.08E+09
AP: Rural shelter belts	0.19	2320
AQ: Ticks	0.08	4.97E+06

[1]For specific uses associated with each crop group see **Table 5**.

In order to characterize the conservativeness of the endpoint selected to represent direct effects to DS (*e.g*. Atlantic salmon LC_{50} = 220 $\mu g \cdot L^{-1}$) a genus sensitivity distribution is derived using the available acute toxicity data for freshwater fish. This distribution is described in the effects characterization of this assessment. The lower 95th percentile of the fish distribution (472 $\mu g \cdot L^{-1}$) indicates that the use of the lowest available toxicity value (220 $\mu g \cdot L^{-1}$) is likely a conservative estimate of the toxicity of carbaryl to freshwater vertebrates. When considering estimated aquatic exposure concentrations, use on carbaryl on rice is sufficient to exceed the LOC for 100% of the fish sensitivity distribution. Estimated aquatic concentrations resulting from uses on Brussels sprouts, strawberries, lettuce, broccoli, horseradish, wasteland and peaches are at levels sufficient to exceed the LOC for 20-55% of fish species. Uses of carbaryl on olives, ornamentals, sweet potatoes, asparagus, citrus, almonds, potato, rural shelter belts, celery and lawns are sufficient to exceed the LOC for 5-20% of fish species. Estimates of carbaryl concentrations in surface waters resulting from all other uses are sufficient to exceed the LOC for <5% of fish species.

Based on the above information, there is a potential for acute direct effects to the DS for carbaryl uses on rice, Brussels sprouts, strawberries, lettuce, broccoli, horseradish, wasteland, peaches, olives, ornamentals, sweet potatoes, asparagus, citrus, almonds, potato, rural shelter belts, celery and lawns.

Chronic exposures

All of the uses modeled except for home lawns, flowers around buildings, parks, flowers, peanuts, corn, sorghum, radish, dry beans, okra, sugar beets, alfalfa, pasture, grass for seed, rangeland, melons, roses and non-urban forests exceed the chronic risk LOC for direct effects to the DS. .

RQs for chronic exposures are based on the level where no effects were observed (the NOAEC) in laboratory exposure tests. As discussed in section 4.1.1.b, chronic toxicity data are unavailable for the most sensitive species (Atlantic salmon) used to assess acute risk. Therefore, an acute-to-chronic ratio was used to estimate the NOAEC for carbaryl exposures to Atlantic salmon. This same approach can be applied to approximate the lowest concentration where effects (LOAEC) would be expected to be observed. Based on the information contained in the carbaryl IRED (USEPA 2004b), the 96-hr acute LC_{50} value for fathead minnows is 7.7 mg/L. With an acute LC_{50} of 7.7 mg/L and a chronic LOAEC of 0.68, the acute to chronic ratio (ACR) for fathead minnow is 11.3 (7.7÷0.68). When the ACR is applied to the Atlantic salmon data (LC_{50} = 0.22 mg/L), the resulting estimated LOAEC is 0.0195 mg/L.

Direct comparison of 60-d EECs to this estimated LOAEC for the Atlantic salmon indicates that EECs are sufficient to exceed this LOAEC for carbaryl uses on strawberries, broccoli, Brussels sprouts, sweet potatoes, head lettuce, horse radish, rice and wasteland.

For several uses the LOC is exceeded by RQs derived using the NOAEC but the EECs are insufficient to exceed the ACR-derived LOAEC. These uses include: lawns, ornamentals, citrus, olives, almonds, peaches, asparagus, apple, loquat, sweet corn, grapes, tomatoes, celery, potato, rights-of-way, rural shelter belts and ticks. In this assessment, the NOAEC is used to derive RQs representing risks of chronic exposures of the DS to carbaryl. There are two significant uncertainties regarding the potential for direct effects for these uses. First, it is assumed that the actual exposure concentration where effects are exhibited lies somewhere between the NOAEC and the LOAEC. Given the uncertainty associated with the actual level where effects occur, risks of chronic exposures of the DS to carbaryl cannot be discounted. Second, it has been acknowledged in this assessment that 1-naphthol, which is a major degradate of toxicological concern, is not included in the estimation of exposures. In an early life cycle study involving fathead minnows exposed to 1-naphthol, the NOAEC was 0.102 mg/L, with the LOAEC defined as 0.203 mg/L based on effects to larval survival and growth (MRID 45784804). This LOAEC is similar to the NOAEC (0.21 mg/L; MRID 40644801) reported in a long term study with fathead minnows exposed to carbaryl. There is uncertainty associated with the extent of the exposure of the DS to 1-naphthol in the aquatic environment. Therefore, there is uncertainty associated with the increased risk that could be attributed to these exposures. Based on the LOC exceedances and the two uncertainties described above, there is a potential for direct effects to the DS from chronic exposure in aquatic habitat resulting from carbaryl use on lawns, ornamentals, citrus, olives, almonds, peaches, asparagus, apple, loquat, sweet corn, grapes, tomatoes, celery, potato, rights-of-way, rural shelter belts and ticks.

5.2.1.b. Indirect Effects

i. Potential Loss of Prey

As discussed in section Attachment II, the diet of DS is composed primarily of zooplankton, particularly copepods. Therefore, freshwater and estuarine invertebrates as well as unicellular aquatic plants are considered as prey groups for determining indirect effects to the DS caused by direct effects to its prey.

Aquatic invertebrates

The range of RQs for acute (0.3 – 1517) and chronic (0.6-5158) risk estimates for freshwater aquatic invertebrates indicate that all uses of carbaryl can potentially result in effects to invertebrates serving as prey to DS when it resides in freshwater. For brackish waters, the corresponding ranges for estuarine invertebrates are 0.08 to 452 for acute and 0.19 to 1719 for chronic.

Based on an analysis of the likelihood of individual mortality using the highest RQ value for aquatic invertebrates (carbaryl use on rice; RQ=1517) and a probit dose-response of 4.30, the likelihood of individual mortality is 100%. At the lowest acute RQ value (*i. e*, RQ=0.3 for use on flowers around building), the likelihood of individual mortality is 1 in 8.2.

In order to characterize the conservativeness of the endpoint selected to represent indirect effects to the DS through direct effects to its aquatic prey (*e.g*. stonefly EC_{50} = 1.7 $\mu g \cdot L^{-1}$) genus sensitivity distributions are derived using the available acute toxicity data for freshwater fish and invertebrates, respectively. These distributions are described in the effects characterization of this assessment. The lower 95th percentile of the invertebrate distribution (0.69 $\mu g \cdot L^{-1}$) indicates that the use of the lowest available toxicity value (1.7 $\mu g \cdot L^{-1}$) is not as conservative as the lower 95th percentile of the distribution. When considering the distribution, estimated aquatic concentrations resulting from all uses except flowers around buildings are at levels sufficient to exceed the LOC for >90% of invertebrate species. EECs for flowers around buildings exceed for approximately 50% of the distribution. When considering invertebrate sensitivity distributions in the context of available monitoring data, the highest concentration of carbaryl observed in

California surface waters (1.06 μg·L^{-1}) is sufficient to exceed the invertebrate LOC for approximately 65% of available genera.

An analysis of the likelihood of individual direct mortality (**Table 5-9**) for each assessed use indicates that based on the RQ values for all but one use (flowers around buildings RQ=0.08) indirect effects, through loss of invertebrate forage items, on the DS and with a dose-response default slope of 4.5, the likelihood is 1 in 1, *i.e.*, 100%. At the endangered species LOC, *i.e.*, RQ=0.05, the likelihood of individual mortality is 1 in 4.18 x 10^8; at an RQ of 0.08, the likelihood of individual mortality increases to 1 in 2.5 x10^6. However, by the second lowest RQ value (okra RQ=0.98), the likelihood of individual mortality increases to 1 in 2. Consistent with the elevated RQ values for aquatic invertebrates and based on the use of a default dose-response slope of 4.5, the likelihood of individual effects on aquatic invertebrates across all but one of the uses evaluated are high. Methods for calculating the likelihood of individual indirect mortality to aquatic invertebrate forage organisms are in **Appendix O**.

Table 5-9. Likelihood of Individual Effect for Each Use of Carbaryl for Aquatic Invertebrates.

Crop Group[1]	Acute RQ[2]	Likelihood of individual acute effect (1 in . . .)
A: Home lawn	2.56	1
B: Flowers around buildings	0.08	2.5E+06
C: Lawns	4.46	1
D: Ornamentals	8.98	1
E: Parks 2	1.63	1
E: Parks 2	1.75	1
F: Citrus 1	5.82	1
F: Citrus 2	7.84	1
G Olives	9.23	1
H: almonds	7.59	1
I: flowers	3.75	1
J: peaches	9.96	1
K: asparagus	8.28	1
L: apple	2.86	1
M: loquat	2.28	1
N: sweet corn	4.35	1
O: grapes	3.93	1
P: strawberries	17.58	1
Q: tomatoes	4.30	1
R: Peanuts	2.3	1
S: Broccoli	12.8	1
T: Brussels sprouts	29.3	1
U: Sweet potato	8.7	1
V: Field corn	1.6	1
W: Lettuce, head	16.4	1
X: Sorghum	2.0	1
Y: Celery	6.6	1
Z: Horseradish	12.6	1
AA: Potato	7.4	1
AB: Radish	2.3	1
AC: Rice	452	1
AD: Beans	1.7	1
AE: Okra	0.98	2
AF: Sugar beet	2.4	1
AG: Alfalfa	1.6	1
AH: Pasture	1.9	1
AI: Grass for seed	1.2	1.5

AJ: Rangeland	**2.2**	**1**
AK: Melon	**1.3**	**1.4**
AL: Roses	**2.6**	**1**
AM: Rights-of-way	**3.3**	**1**
AN: Wasteland	**11.9**	**1**
AO: Non-urban forests	**2.0**	**1**
AP: Rural shelter belts	**7.2**	**1**
AQ: Ticks	**3.1**	**1**

Based on acute and chronic LOC exceedances, likelihood of individual mortality analysis and genus sensitivity distribution information for aquatic invertebrates, there is a potential for indirect effects to the DS from loss of prey items for all uses of carbaryl except for use on flowers around buildings.

Unicellular plants

Based on RQs for algae (**Table 5-4**), applications of carbaryl are not expected to affect this food source except for use on rice. Therefore, indirect effects of carbaryl to DS by reductions in phytoplankton are not expected based on the animal's diet during this life stage for all of the uses except rice. However, the use of carbaryl on rice may adversely impact the DS through the reduction in phytoplankton (RQ=3.9). Since EECs associated with use of carbaryl on rice exceed the level where 50% reduction in algal cells was observed in the laboratory, there is a potential for indirect effects to the DS due to effects to algae. It is worth noting, however, the EECs for rice were calculated using a Tier 1 model that does not account for the degradation of carbaryl. Since carbaryl degrades relatively quickly ($T_{1/2}$ = 4.9 d) in water, the rice use EECs are likely to substantially overestimate exposures, a more sophisticated estimate of the rice EEC would likely be substantially lower.

ii. Potential Modification of Habitat

Aquatic plants serve several important functions in aquatic ecosystems. Non-vascular aquatic plants are primary producers and provide the autochthonous energy base for aquatic ecosystems. Vascular plants provide structure, rather than energy, to the system, as attachment sites for many aquatic invertebrates, and refugia for juvenile organisms. Emergent plants help reduce sediment loading and provide stability to near-shore areas and lower stream banks. In addition, vascular aquatic plants are important as attachment sites for egg masses of DS.

Based on RQs for unicellular and vascular plants inhabiting aquatic habitats (**Table 5-4**), applications of carbaryl are not expected to affect these plants, except in cases where applications are made to rice. RQs for rice exceed the LOC for aquatic plants by a factor of 1.7, meaning that estimated exposure concentrations are approximately twice the level where 50% effects have been observed in laboratory tests involving aquatic plants exposed to carbaryl. While this risk cannot be dismissed, it is worth noting that the rice EECs are Tier 1 values estimated without consideration of the degradation rate of carbaryl which is relatively fast ($T_{1/2}$ = 4.9 d in aquatic environments). EECs which were calculated for rice at the same level of sophistication as the other EECs would likely be less than LOC.

Terrestrial plants serve several important habitat-related functions for the listed assessed species. In addition to providing habitat and cover for invertebrate and vertebrate prey items of the listed assessed species, terrestrial vegetation also provides shelter and cover from predators while foraging. Riparian vegetation helps to maintain the integrity of aquatic systems by providing bank and thermal stability, serving as a buffer to filter out sediment, nutrients, and contaminants before they reach the watershed, and serving as an energy source.

One available study is useful for defining the toxicity of carbaryl to riparian and terrestrial plants. In this tier 1 vegetative vigor study, less than 25% effects to dry weight or survival were observed when plants were treated with 0.8 lbs a.i./A of carbaryl (MRID 45784807). For some uses, the potential concentrations of carbaryl in the environment exceed this application rate, leaving uncertainty regarding whether or not the higher applications of carbaryl can result in effects to riparian and terrestrial habitat.

According to the baseline ecological risk assessment chapter in support of the reregistration eligibility decision for carbaryl (USEPA 2003), there are carbaryl labels stating that it may cause injury to tender foliage if applied to wet foliage or during periods of high humidity. In addition, carbaryl, which acts as an auxin (plant hormone), can be used for fruit thinning, which indicates that it has potential for reproductive effects to plants.

The greatest number of incidents (15) for carbaryl has involved terrestrial plants. While the majority of these incident 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.

Although aquatic RQs indicate that aquatic plants are unlikely to be affected by carbaryl use, with the exception of use on rice (aquatic) and citrus (terrestrial), potential risks of carbaryl to riparian and terrestrial vegetation cannot be discounted. Carbaryl is known to affect plants and is used to thin fruit in orchards According to the carbaryl label (Sevin 50WP; EPA Reg. No. 769-972), the recommended rate for thinning apples is 0.5 – 1 lbs a.i./A and is higher than the maximum rate tested in the terrestrial plant studies; thus, the likelihood of effects on terrestrial plants at the higher application rate is uncertain; however, treatment at this rate is known to result in abscission of flowers. Additionally, several incidents involving plant damage are associated with the use of carbaryl. As a result, the extent of risk of carbaryl for plants cannot be quantified. Therefore, there is a potential for indirect effects to the DS caused by effects to riparian and terrestrial plants resulting from use of carbaryl.

5.2.2. Modification of Designated Critical Habitat

Based on the weight-of-evidence there is a potential for the modification of designated critical habitat based on the potential affects on prey base and aquatic and terrestrial plants.

5.2.3. Spatial Extent of Potential Effects

Since LOCs are exceeded, analysis of the spatial extent of potential LAA effects is needed to determine where effects may occur in relation to the treated site. If the potential area of usage and subsequent Potential Area of LAA Effects overlaps with DS habitat or areas of occurrence and/or critical habitat, a likely to adversely affect determination is made. If the Potential Area of LAA Effects and the DS habitat and areas of occurrence and/or critical habitat do not overlap, a no effect determination is made.

To determine this area, the footprint of carbaryl's use pattern is identified, using corresponding land cover data, see Section 2.8. Because of the broad spectrum of uses it is expected that the footprint of carbaryl's use could include the entire state of California. Therefore, no GIS mapping has been conducted. Actual usage is expected to occur in a smaller area as the chemical is only expected to be used on a portion of the identified area. The spatial extent of the effects determination also includes areas beyond the initial area of concern that may be impacted by runoff and/or spray drift (use footprint + distance downstream or downwind from use sites where organisms relevant to the assessed species may be affected. Because of the spatial extent of the use patterns of carbaryl, essentially all DS habitat could be affected by the pesticide.

5.3. Effects Determinations for Delta Smelt

In summary, based on the above information, the determination for effects to the DS is "LAA" for all carbaryl uses. For effects through habitat modification through effects on terrestrial plants, all uses are LAA based on known but unquantified effects on the reproduction of terrestrial plant by carbaryl.

Therefore, the Agency makes a "**may affect, and likely to adversely affect**" determination for the DS and a "**habitat modification determination"** for their designated critical habitat based on the potential for direct and indirect effects and effects to the PCEs of critical habitat.

5.3.1. Addressing the Risk Hypotheses

In order to conclude this risk assessment, it is necessary to address the risk hypotheses defined in Section 2.10.1. Based on the conclusions of this assessment, none of the hypotheses can be rejected, meaning that the stated hypotheses represent concerns in terms of direct and indirect effects of carbaryl on the DS and its designated critical habitat.

The labeled use of carbaryl may:

- …directly affect DS by causing acute mortality or by adversely affecting chronic growth or fecundity;
- … indirectly affect the DS and/or affect their designated critical habitat by reducing or changing the composition of the food supply;
- … indirectly affect the DS and/or affect their designated critical habitat by reducing or changing the composition of the aquatic plant community in the species' current range, thus, affecting primary productivity and/or cover;
- … indirectly affect the DS and affect their designated critical habitat by reducing or changing the composition of the terrestrial plant community in the species' current range;

- … indirectly affect the DS and affect their designated critical habitat by reducing or changing aquatic habitat in their current range (via modification of water quality parameters, habitat morphology, and/or sedimentation).

6. Uncertainties

Uncertainties that apply to most assessments completed for the San Francisco Bay Species are discussed in Attachment I. This section describes additional uncertainties specific to this assessment.

6.1. Exposure Assessment Uncertainties

6.1.1. Aquatic Exposure Modeling of Carbaryl

6.1.1.a. Rice Model

The concentration in water due to the use on rice was estimated using the rice model (EFED, 2007) rather than PRZM and EXAMS as these models cannot simulate the flooding and release of water on an agricultural field. The rice model simulates the concentration in water as it released from the paddy. It considers partitioning of the pesticide to the paddy soil, but does not consider degradation, particularly when the pesticide degrades fairly quickly as is the case with carbaryl which has an aerobic aquatic metabolism half-life of 4.9 d. While there is substantial rice culture in the San Francisco Bay estuary, most of this is above the city of Sacramento along the Sacramento River, and there is likely to be substantial dilution and degradation of carbaryl by the time it reaches the habitat of the DS. However, the extent of this attenuation is not known with certainty as is not considered in this risk assessment.

6.1.1.b. Additional Exposure Due to Rainfall

Carbaryl has been detected in precipitation samples in California (See Section 3.2.6)(**Table 6-1**). Based on these data, it is possible that carbaryl can be deposited on land in precipitation. Estimates of exposure of the CRLF, its prey and its habitat to carbaryl included in this assessment are based only on transport of carbaryl through runoff and spray drift from application sites. Current estimates of exposures of CRLF and its prey to carbaryl through runoff and spray drift, which are already sufficient to exceed the LOC, would be expected to be greater due to deposition in precipitation.

Table 6-1. Carbaryl detections in air and precipitation samples taken in California.

Location	Year	Sample type	Maximum Conc (µg/L)	Detection frequency (number samples)	Source
San Joaquin Valley, CA	2002-2004	Rain	0.756	68% (n = 137)	Majewski *et al.* 2006
Monterey, CA	1987	Fog	4.0	100% (n = 5)	Schomburg *et al.* 1991

In an attempt to estimate the amount of carbaryl deposited into aquatic and terrestrial habitats, carbaryl concentrations measured in rain samples taken in California (Majewski *et al*. 2005) were considered in combination with California specific precipitation data and runoff estimates from PRZM. Precipitation and runoff data associated with the PRZM scenarios used to model aquatic EECs were used to determine relevant 1-in-10 year peak runoff and rain events. The scenarios included were: CA almond, CA lettuce, CA wine grape, CA row crop, CA fruit, CA nursery, and CA onion. The corresponding meteorological data were from the following locations: Sacramento, Santa Maria, San Francisco, Monterey County, Fresno, San Diego, and Bakersfield, respectively.

To estimate concentrations of carbaryl in the aquatic habitat resulting from deposition in rain, the daily PRZM-simulated volume of runoff from a 10 ha field is combined with an estimate of daily precipitation volumes over the 1 ha farm pond relevant to the EXAMS environment. This volume is multiplied by the maximum concentration of carbaryl in precipitation reported in monitoring data, which is 0.756 $\mu g \cdot L^{-1}$. The result is a daily mass load of carbaryl into the farm pond. This mass is then divided by the volume of water in the farm pond (2.0 $\times 10^{7}$ L) to achieve a daily estimate of carbaryl concentration in the farm pond, which represents the aquatic habitat. From the daily values, the 1-in-10 year peak estimate of the concentration of carbaryl in the aquatic habitat is determined for each PRZM scenario (**Table 6-2**). There are several assumptions associated with this approach, including: 1) the concentration of carbaryl in the rain event is spatially and temporally homogeneous (e.g. constant over the 10 ha field and 1 ha pond for the entire rain event); 2) the entire mass of carbaryl contained in the precipitation runs off of the pond or is deposited directly into the pond; 3) there is no degradation of carbaryl between the time it leaves the air and the time it reaches the pond.

Table 6-2. 1-in-10 year peak estimates of carbaryl concentrations in aquatic habitats resulting from deposition of carbaryl at 0.756 $\mu g \cdot L^{-1}$ carbaryl in rain.

Met Station	Scenario	Concentration in aquatic habitat (μg/L)
Sacramento	CA almond	0.141
Santa Maria	CA lettuce	0.152
San Francisco	CA wine grape	0.133
Monterey Co.	CA row crop	0.122
Fresno	CA fruit	0.055
San Diego	CA nursery	0.102
Bakersfield	CA onion	0.041

6.1.1.c. Chemistry Input Parameters for Models

The environmental chemistry data for carbaryl is relatively complete. The greatest uncertainty is associated with the input parameter for the aerobic soil degradation of carbaryl which has a single measured half-life of 4 d. This has been tripled to account for the uncertainty associated with a single measurement for use as a model input parameter to 12 d. When the soil metabolism rate is relatively fast, as it is for carbaryl, the exposure estimates are sensitive to this value and consequently to the uncertainty that has been factored into the input parameter estimate.

6.1.2. Exposure in Estuarine/Marine Environments

PRZM-EXAMS modeled EECs are intended to represent exposure of aquatic organisms in relatively small ponds and low-order streams. Therefore it is likely that EECs generated from the PRZM-EXAMS model will over-estimate potential concentrations in larger receiving water bodies such as estuaries, embayments, and coastal marine areas because chemicals in runoff water (or spray drift, etc.) should be diluted by a much larger volume of water than would be found in the 'typical' EXAMS pond. However, as chemical constituents in water draining from freshwater streams encounter brackish or other near-marine-associated conditions, there is potential for important chemical transformations to occur. Many chemical compounds can undergo changes in mobility, toxicity, or persistence when changes in pH, E_h (redox potential), salinity, dissolved oxygen (DO) content, or temperature are encountered. For example, desorption and re-mobilization of some chemicals from sediments can occur with changes in salinity (Jordan *et al.*, 2008; Means, 1995; Swarzenski *et al.*, 2003), changes in pH (*e.g.*, Wood and Baptista 1993; Parikh *et al*. 2004), E_h changes (Velde and Church, 1999; Wood and Baptista, 1993), and other factors. Thus, although chemicals in discharging rivers may be diluted by large volumes of water within receiving estuaries and embayments, the hydrochemistry of the marine-influenced water may negate some of the attenuating impact of the greater water volume; for example, the effect of dilution may be confounded by changes in chemical mobility (and/or bioavailability) in brackish water. In addition, freshwater contributions from discharging streams and rivers do not instantaneously mix with more saline water bodies. In these settings, water will commonly remain highly stratified, with fresh water lying atop denser, heavier saline water – meaning that exposure to concentrations found in discharging stream water may propagate some distance beyond the outflow point of the stream (especially near the water surface). Therefore, it is not assumed that discharging water will be rapidly diluted by the entire water volume within an estuary, embayment, or other coastal aquatic environment. The PRZM and EXAMS model results should be considered consistent with concentrations that might be found near the head of an estuary unless there is specific information – such as monitoring data – to indicate otherwise. Conditions nearer to the mouth of a bay or estuary, however, may be closer to a marine-type system, and thus more subject to the notable buffering, mixing, and diluting capacities of an open marine environment. Conversely, tidal effects (pressure waves) can propagate much further upstream than the actual estuarine water, so discharging river water may become temporarily partially impounded near the mouth (discharge point) of a channel, and resistant to mixing until tidal forces are reversed.

The Agency does not currently have sufficient information regarding the hydrology and hydrochemistry of estuarine aquatic habitats to develop alternate scenarios for assessed listed species that inhabit these types of ecosystems. The Agency acknowledges that there are unique brackish and estuarine habitats that may not be accurately captured by PRZM-EXAMS modeling results, and may, therefore, under- or over-estimate exposure, depending on the aforementioned variables.

6.1.3. Modeled Versus Monitoring Concentrations

Modeling versus monitoring is not an appropriate way to describe how the Agency uses these two methods of characterizing exposure in the environment, as the two information sources complement each other. Each has different strengths and weaknesses. Modeling can generate estimates every day and simulate locations that are likely to be vulnerable from the use of a pesticide. Simulations for pesticide in the Agency are generally run for 30 years whereas the duration of monitoring data at any one site seldom exceeds two or three years. Currently modeling is used to characterize a few vulnerable sites well in time whereas monitoring data tends to provide a better spatial representation of how the pesticide concentration varies in the environment, but is less well defined in time. Robust monitoring datasets will have samples collected once a week. All this is to say that monitoring data and modeling provide complementary approaches to assessing exposure.

In order to account for this uncertainty, available monitoring data were compared to PRZM/EXAMS estimates of peak EECs for the different uses. As discussed above, several data values were available from NAWQA for carbaryl concentrations measured in surface waters receiving runoff from agricultural areas. The specific use patterns (e.g. application rates and timing, crops) associated with the agricultural areas are unknown; however, they are assumed to be representative of potential carbaryl use areas. One-in-ten-year peak EECs estimate using tier 2 modeling resulting from different carbaryl uses ranged 5.6 – 166.8 $\mu g \cdot L^{-1}$. The maximum concentration of carbaryl reported by NAWQA (1999-2005) for California surface waters with agricultural watersheds (1.06 $\mu g \cdot L^{-1}$) is two orders of magnitude less than the maximum EEC calculate using the Tier 2 models but within the range of EECs estimated for different uses. The maximum concentration of carbaryl reported by the California Department of Pesticide Regulation surface water database (1999-2005) (0.31 $\mu g \cdot L^{-1}$) is roughly four orders of magnitude lower than the highest peak EEC.

When considering 2000-2005 NAWQA monitoring data for California in the context of the effects data, 1.1% of samples (15 out of 1393) contained concentrations of carbaryl at levels (>0.085 $\mu g \cdot L^{-1}$) sufficient to exceed the LOC for aquatic invertebrates. In CDPR surface water monitoring data from 2000-2005, carbaryl was detected at concentrations sufficient to result in RQ values that exceed the invertebrate acute risk LOC (*i.e.*, >0.085 $\mu g \cdot L^{-1}$) in a single sample. Carbaryl was not detected at concentrations sufficient to exceed the direct effects acute risk LOC (>12.5 $\mu g \cdot L^{-1}$) in any of the samples (**Figure 3-2**).

Effects Assessment Uncertainties

6.1.4. Data Gaps and Uncertainties

i. Degradates

As previously discussed in the effects assessment, the toxicity of the primary degradate of carbaryl, i.e., 1-naphthol, is assumed to equivalent to or less than the parent compound; therefore, RQ values are not derived for exposures to this degradate.

As discussed in the screening-level ecological risk assessment of carbaryl (USEPA 2003), 1-naphthol is subject to both biotic and abiotic routes of degradation and laboratory studies suggest that the compound degrades more rapidly than the parent. Additionally, 1-naphthol is less mobile than carbaryl; therefore, 1-naphthol is not expected to contribute significantly to exposure relative to the parent compound.

6.1.5. Use of Surrogate Species Effects Data

Guideline toxicity tests and open literature data on carbaryl are not available for DS; therefore, other fish are used as surrogate species for assessing risks to the target species. Efforts are made to select the organisms most likely to be affected by the type of compound and usage pattern; however, there is an inherent uncertainty in extrapolating across phyla. In addition, the Agency's LOCs are intentionally set very low, and conservative estimates are made in the screening level risk assessment to account for these uncertainties.

6.1.6. Sublethal Effects

Open literature is useful in identifying sub-lethal effects associated with exposure to carbaryl. However, no data are available to link the sub-lethal measurement endpoints to direct mortality or diminished reproduction, growth and survival that are used by OPP as assessment endpoints. OPP acknowledges that a number of sub-lethal effects (*e.g.*, behavioral) have been associated with carbaryl exposure; however, at this point there are insufficient data to definitively link the measurement endpoints to assessment endpoints.

When assessing acute risk, the screening risk assessment relies on the acute mortality endpoint as well as a suite of sub-lethal responses to the pesticide, as determined by the testing of species response to chronic exposure conditions and subsequent chronic risk assessment. Consideration of additional sub-lethal data in the effects determination is exercised on a case-by-case basis and only after careful consideration of the nature of the sub-lethal effect measured and the extent and quality of available data to support establishing a plausible relationship between the measure of effect (sub-lethal endpoint) and the assessment endpoints. However, the full suite of sub-lethal effects from valid open literature studies is considered for the characterization purposes. However, no data are available to link the sub-lethal measurement endpoints to direct mortality or diminished reproduction, growth and survival that are used by OPP as assessment endpoints. OPP acknowledges that a number of sub-lethal effects have been associated with carbaryl exposure; however, at this point there are insufficient data to definitively link the measurement endpoints to assessment endpoints.

6.1.7. Lack of Terrestrial Plant Data

While incident data clearly shows that some effects on terrestrial plants are seen due to carbaryl use, the nature and extent of these impacts are not known, and in particular whether these effects could be extensive enough to see indirect effects relevant to the DS. Additional data clarifying the nature and magnitude of these effects, and what plant taxa are susceptible would substantially reduce the uncertainty this assessment.

7. Risk Conclusions

In fulfilling its obligations under Section 7(a)(2) of the Endangered Species Act, the information presented in this endangered species risk assessment represents the best data currently available to assess the potential risks of carbaryl to DS and their designated critical habitat.

Based on the best available information, the Agency makes a 'Likely to Adversely Affect' determination for the DS. Additionally, the Agency has determined that there is the potential for modification of the designated critical habitat for the DS from the use of the chemical. Given the LAA determination for DS and potential modification of designated critical habitat for this species, a description of the baseline status and cumulative effects is provided in Attachment III.

A summary of the risk conclusions and effects determinations for DS and their critical habitat, given the uncertainties discussed in Section 6 and Attachment I, is presented in Table 7-1 and Table 7-2. Use specific effects determinations are provided in Table 7-3.

Table 7-1. Effects Determination Summary for Effects of Carbaryl on the Delta Smelt

Species	Effects Determination	Basis for Determination
Delta smelt (*Hypomesus transpacificus*)	May Affect, Likely to Adversely Affect (LAA)	**Potential for Direct Effects** Using fish toxicity data for Atlantic salmon and modeled EECs and consideration of individual effects, risk could not be precluded for rice, Brussels sprouts, strawberries, lettuce, broccoli, horseradish, wasteland, peaches, olives, ornamentals, sweet potatoes, asparagus, citrus, almonds, potato, rural shelter belts, celery and lawns due acute effects and, in addition, apple, loquat, sweet corn, grapes, tomatoes, potato, rights-of-way, rural shelter belts and ticks due to chronic effects. **Potential for Indirect Effects** ***Aquatic prey items, aquatic habitat, cover and/or primary productivity*** Using toxicity data representing freshwater (stoneflies) and estuarine invertebrates (mysid shrimp) and modeled exposures, risks could not be precluded based effects to prey items for all use patterns except flowers around buildings. ***Terrestrial prey items, riparian habitat*** Based on known but unquantified reproductive effects on terrestrial plants, effects on riparian habitat cannot be precluded.

Table 7-2. Effects Determination Summary for the Critical Habitat Impact Analysis for the Delta Smelt

Designated Critical Habitat for:	Effects Determination	Basis for Determination
Delta smelt (*Hypomesus transpacificus)*	Habitat Modification	Using toxicity data representing freshwater (stoneflies) and estuarine invertebrates (mysid shrimp) and modeled exposures, risks could not be precluded for effects to prey items for all use patterns except flowers around buildings. Based on known but unquantified reproductive effects on terrestrial plants, habitat modification though effects on riparian habitat cannot be precluded.

Table 7-3. Use Specific Summary of The Potential for Adverse Effects to Delta Smelt.

Uses	Potential for Effects to Identified Taxa Found in the Aquatic Environment:									
	Delta smelt and Estuarine/Marine Vertebrates[1]		Delta smelt and Freshwater Vertebrates[2]		Freshwater Invertebrates[3]		Estuarine/Marine Invertebrates[4]		Vascular Plants[5]	Non-vascular Plants[5]
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic		
A: Home lawn	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
B: Flowers around buildings	No	No	No	No	No	No	No	No	No	No
C: Lawns	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
D: Ornamentals	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
E Parks	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
F: Citrus 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
F: Citrus 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
G Olives	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
H: almonds	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
I: flowers	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
J: peaches	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
K: asparagus	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
L: apple	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
M: loquat	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
N: sweet corn	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
O: grapes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
P: strawberries	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Q: tomatoes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
R peanuts	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
S broccoli	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
T Brussels sprouts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
U sweet potatoes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
V: Field corn	No	No	No	No	Yes	Yes	Yes	Yes	No	No
W: head lettuce	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
X: sorghum	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
Y: celery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Z: horse radish	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AA: potato	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AB: radish	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AC: rice	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	yes	yes
AD: dry beans	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AE: okra	No	No	No	No	Yes	Yes	Yes	Yes	No	No

	Potential for Effects to Identified Taxa Found in the Aquatic Environment:									
	Delta smelt and Estuarine/Marine Vertebrates[1]		**Delta smelt and Freshwater Vertebrates[2]**		**Freshwater Invertebrates[3]**		**Estuarine/Marine Invertebrates[4]**			
AF: sugar beet	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AG: alfalfa	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AH: pasture	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AI: grass for seed	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AJ: rangeland	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AK: melons	No	No	No	No	Yes	Yes	Yes	Yes	No	No
AL: roses	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AM: rights of way	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AN: wasteland	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AO: non-urban forests	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
AP: rural shelter belts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AQ: Ticks	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
AR: Flea collars	No	No	No	No	No	No	No	No	No	No

1 A yes in this column indicates a potential for direct effects to DS.
2 A yes in this column indicates a potential for direct effects to DS.
3 A yes in this column indicates a potential for indirect effects to DS.
4 A yes in this column indicates a potential for indirect effects to DS.
5 A yes in this column indicates a potential for indirect effects to DS.

Based on the conclusions of this assessment, a formal consultation with the U. S. Fish and Wildlife Service under Section 7 of the Endangered Species Act should be initiated.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the listed species and its resources (*i.e.*, food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of drift and downstream transport (*i.e.*, attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the species and its resources (*i.e.*, food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of drift and downstream transport (*i.e.*, attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available. Examples of such information and methodology required for this type of analysis would include the following:

- Enhanced information on the density and distribution of DS life stages within the action area and/or applicable designated critical habitat. This information would allow for quantitative extrapolation of the present risk assessment's predictions of individual effects to the proportion of the population extant within geographical areas where those effects are predicted. Furthermore, such population information would allow for a more comprehensive evaluation of the significance of potential resource impairment to individuals of the assessed species.
- Quantitative information on prey base requirements for the assessed species. While existing information provides a preliminary picture of the types of food sources utilized by the assessed species, it does not establish minimal requirements to sustain healthy individuals at varying life stages. Such information could be used to establish biologically relevant thresholds of effects on the prey base, and ultimately establish geographical limits to those effects. This information could be used together with the density data discussed above to characterize the likelihood of adverse effects to individuals.
- Information on population responses of prey base organisms to the pesticide. Currently, methodologies are limited to predicting exposures and likely levels of direct mortality, growth or reproductive impairment immediately following exposure to the pesticide. The degree to which repeated exposure events and the inherent demographic characteristics of the prey population play into the extent to which prey resources may recover is not predictable. An enhanced understanding of long-term prey responses to pesticide exposure would allow for a more refined determination of the magnitude and duration of resource impairment, and together

with the information described above, a more complete prediction of effects to individual species and potential modification to critical habitat.

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