Risks of Carbaryl Use to the Federally-Listed California Red Legged Frog
(*Rana aurora draytonii*)

Pesticide Effects Determination

Environmental Fate and Effects Division
Office of Pesticide Programs
Washington, D.C. 20460

October 19, 2007

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Acknowledgement

The carbaryl chemical team would like to acknowledge the contribution of the California red-legged frog Steering Committee in compiling detailed information on the threatened species. Additionally, the Steering Committee has provided invaluable guidance toward achieving greater consistency in format and content between chemicals being assessed. We acknowledge the contribution of Ms. Michelle Thawley, Mr. Kurt Pluntke, Ms. Megan Thynge in providing the Geographic Information System analysis used to define the potential overlap between California red-legged frog and their designated critical habitat with the action area.

Table of Contents

Appendices

Attachments

List of Figures

List of Tables

1. Executive Summary

The purpose of this assessment is to evaluate potential direct and indirect effects on the California red-legged frog *(Rana aurora draytonii*) (CRLF) 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 the destruction or modification of the species' designated critical habitat. 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) and procedures outlined in the Agency's Overview Document (U.S. EPA, 2004).

The CRLF was listed as a threatened species by USFWS in 1996. The species is endemic to California and Baja California (Mexico) and inhabits both coastal and interior mountain ranges. A total of 243 streams or drainages are believed to be currently occupied by the species, with the greatest numbers in Monterey, San Luis Obispo, and Santa Barbara counties (USFWS 1996) in California.

Carbaryl is registered for use as an insecticide on over 400 sites, including agriculture, professional turf management and ornamental production, and residential settings. Carbaryl is used on many agricultural sites including fruit and nut tree, fruit and vegetable, and grain crops (including direct applications to water in rice production). 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. Additionally, carbaryl is used to thin fruit (inducing abscission of flower buds) in orchards.

The environmental fate properties of carbaryl along with monitoring data identifying its presence in surface waters and precipitation in California indicate that carbaryl has the potential to be transported to non-target areas. In this assessment, transport of carbaryl from initial application sties through runoff and spray drift are considered in deriving quantitative estimates of carbaryl exposure to CRLF, its prey and its habitats.

Since CRLFs exist within aquatic and terrestrial habitats, exposure of the CRLF, its prey and its habitats to carbaryl are assessed separately for the two habitats. Tier-II exposure models (PRZM and EXAMS) are used to estimate high-end exposures to aquatic habitats resulting from runoff and spray drift from different uses. The Tier-I Rice model is used to estimate high-end exposure to aquatic habitats resulting from the direct application of carbaryl to rice production paddies. Peak model-estimated environmental concentrations, resulting from different carbaryl uses, range from 0.47 to 2579 µg/L. 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 from 1999-2005 for California surface waters is 1.06 µg/L. This value is three orders of magnitude less than the maximum model-estimated environmental concentration, but is within the range of environmental concentrations estimated for different uses. The maximum concentration of carbaryl reported by the California Department of Pesticide Regulation surface water database from 1999-2005 (0.31 µg/L) is four orders of magnitude less than the highest peak model-estimated environmental concentration.

To estimate carbaryl exposures to terrestrial-phase CRLF, its potential prey and its habitat resulting from uses involving foliar applications, the T-REX model is used. To further characterize exposures of terrestrial-phase CRLF to dietary and dose-based exposures of carbaryl resulting from foliar applications, T-HERPS is used. AgDRIFT and AGDISP are also used to estimate deposition of carbaryl on terrestrial habitats from spray drift.

The assessment endpoints for the CRLF include direct toxic effects on the survival, reproduction, and growth of the CRLF itself, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. Direct effects to the CRLF in the aquatic habitat are based on toxicity information for freshwater fish, which are generally used as a surrogate for aquatic-phase amphibians. In the terrestrial habitat, direct effects are based on toxicity information for birds, which are used as a surrogate for terrestrial-phase amphibians. Given that the CRLF's prey items and designated critical habitat requirements in the aquatic habitat are dependant on the availability of freshwater aquatic invertebrates and aquatic plants, toxicity information for these taxonomic groups is also discussed. In the terrestrial habitat, indirect effects due to depletion of prey are assessed by considering effects to terrestrial insects, small terrestrial mammals and frogs. Indirect effects due to modification of the terrestrial habitat could not be quantitatively characterized since measurement endpoints were indiscreet (*i.e*, median effects concentrations were less than the highest concentration tested) for terrestrial monocotyledenous and dicotyledonous plants; however, indirect effects to the terrestrial habitat are qualitatively characterized.

Carbaryl's primary mode of action as an insecticide is through inhibition of acetylcholine esterase. Carbaryl is highly toxic to freshwater fish and very highly toxic to freshwater invertebrates on an acute exposure basis. Toxicity categories for aquatic plants have not been defined. If classification for animals were applied to aquatic plants, carbaryl would be classified as moderately toxic to unicellular and vascular plants. The acute-to-chronic ratio (ACR) adjusted no observed adverse effect concentrations (NOAECs) for the Atlantic salmon and stonefly are 0.0068 and 0.0014 mg a.i./L, respectively. Carbaryl is practically nontoxic to birds and moderately toxic to mammals on an acute exposure basis. Carbaryl is also very highly toxic to honey bees on an acute exposure basis. Chronic exposures of mallard ducks to carbaryl in reproduction studies indicate reproductive effects (decreased number of eggs) with a NOAEC of 300 mg/kg-diet/day. Chronic exposures of rats to carbaryl in a reproduction study indicate a NOAEL for decreased pup survival of 75 mg/kg-diet/day. Plant toxicity testing with six terrestrial plant species failed to provide a definitive toxicity endpoint at treatment levels equivalent to a carbaryl application rate of to 0.8 lbs a.i./A (limit test EC_{25}>0.8 lbs a.i./A); however, carbaryl is used to thin fruit in orchards, and the chemical's structural similarity to the plant auxin α-naphthalene acetic acid suggests it could affect terrestrial plants through its potential activity as a plant auxin.

Degradates of carbaryl include 1-naphthol. 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. There are no data to indicate that 1-naphthol acts through the same mechanism of action as the parent compound. Therefore, in this assessment, risks are determined based on carbaryl only.

Risk quotients (RQs) are derived as quantitative estimates of potential high-end risk. Acute and chronic RQs are compared to the Agency's levels of concern (LOCs) for Federally-listed threatened (listed) species to identify if carbaryl use within the action area has any direct or indirect effect on the CRLF. Based on estimated environmental concentrations for the currently registered uses of carbaryl, RQ values exceed the Agency's LOC for direct acute and chronic effects on the CRLF; this represents a "may affect" determination. RQs exceed the LOC for acute and chronic exposures to aquatic invertebrates and for acute exposures to terrestrial invertebrates. Therefore, there is a potential to indirectly affect juvenile and adult CRLF due to effects to the invertebrate prey base in aquatic and terrestrial habitats. The effects determination for indirect effects to the CRLF due to effects to its prey base is "may affect." When considering the prey of larger CRLF in aquatic and terrestrial habitats (*e.g.* frogs, fish and small mammals), RQs for these taxa also exceed the LOC for acute and chronic exposures, resulting in a "may affect" determination. RQ values for plants in aquatic habitats do not exceed the LOC, with the exception of the direct application of carbaryl to water for use on rice. Risk of carbaryl use on riparian and terrestrial vegetation cannot be discounted given the structural similarity of the compound to a plant auxin, the chemical's use in abscission of flower buds in orchard crops and reported ecological incidents involving terrestrial plants. Therefore, indirect effects to the CRLF through effects to its habitat is a "may affect" determination.

All "may affect" determinations are further refined using available evidence to determine whether they are "not likely to adversely affect" (NLAA) or "likely to adversely affect" (LAA) the CRLF. Additional evidence is employed to distinguish between NLAA and LAA determinations. This evidence includes available monitoring data and likelihood of individual mortality analysis.

Refinement of all "may affect" determinations results in a "LAA" determination based on direct effects to the CRLF, a "LAA" determination for indirect effects to the CRLF based on effects to its prey and an "LAA" determination for indirect effects to the CRLF based on effects to its habitat (**Table 1**). Use-specific determinations are defined in **Tables 2 and 3**. Consideration of CRLF critical habitat indicates a determination of "habitat modification" for aquatic and terrestrial habitats. **The overall CRLF effects determination for carbaryl use is "LAA."**

Table 1. Carbaryl Effects Determination Summary for the California Red-legged Frog.

Assessment Endpoint	Effects Determination[1]	Basis for Determination
Direct effects to CRLF	LAA	-Table 2 contains use specific determinations for acute and chronic exposures of the CRLF to carbaryl in aquatic and terrestrial habitats. -Based on LOC exceedances, likelihood of individual effects analysis, and consideration of genus sensitivity distributions, there is potential for mortality to CRLF based on acute exposures resulting from some uses of carbaryl. -Consideration of LOC exceedances results in potential for reproductive effects in aquatic-phase CRLF resulting from chronic exposures from some uses. -Consideration of LOC exceedances in the context of refined exposure modeling results in potential for reproductive effects in terrestrial-phase CRLF resulting from chronic exposures from some uses.
Indirect effects to tadpole CRLF via reduction of prey (*i.e.*, algae)	NE for all uses except rice; LAA for rice	-applications of carbaryl are not expected to affect this food source except for use on rice -For rice, estimated exposure concentrations are 2X the level where 50% effects (to cell density) were observed in a laboratory study where algae were exposed to carbaryl.
Indirect effects to juvenile CRLF via reduction of prey (*i.e.*, invertebrates)	LAA	- Acute (RQ range: 0.3 – 1517) and chronic risk (RQ range: 6.2 – 5158) estimates for aquatic invertebrates and acute risk estimates for terrestrial invertebrates (RQ range 2 – 293) indicate that all uses of carbaryl can potentially result in effects to invertebrates serving as prey to terrestrial-phase CRLFs. -Likelihood of individual mortality in aquatic and terrestrial invertebrates is 12-100% for all uses of uses. - Table 3 contains use specific determinations.
Indirect effects to adult CRLF via reduction of prey (*i.e.*, invertebrates, fish, frogs, mice)	LAA	-There is potential for effects to aquatic and terrestrial invertebrates due to acute and chronic exposures of carbaryl. -Based on likelihood of individual analysis and species sensitivity distribution data for fish, and acute and chronic RQs, some uses of carbaryl have the potential to indirectly affect the CRLF by influencing populations of fish and aquatic phase amphibians which serve as prey to the CRLF. -The likelihood of individual mortality to mice ranges 20-100% for acute exposures to carbaryl. Acute and chronic exposures of carbaryl are likely to affect mice. -For some uses of carbaryl, chronic effects are possible for terrestrial-phase amphibians representing prey of CRLF. -Overall, exposures of carbaryl have the potential to decrease populations of several types of prey of the CRLF, indicating that it is likely that uses of carbaryl can adversely affect the CRLF through indirect effects to its prey. - Table 3 contains use specific determinations.
Indirect effects to CRLF via reduction of habitat and/or primary productivity (*i.e.*, plants)	LAA	-Based on RQs for unicellular and vascular plants inhabiting aquatic habitats, applications of carbaryl are not expected to affect these plants, except in cases where there are direct applications to water for rice production. -There are several reported incidents involving effects of carbaryl to plants. - Carbaryl is used for fruit thinning, indicating that it has potential reproductive effects to plants; carbaryl is structurally related to the plant auxin α-naphthalene acetic acid. -Risks of carbaryl to riparian and terrestrial plants cannot be discounted. -Risks of carbaryl to riparian and terrestrial plants cannot be quantified.

[1]LAA = likely to adversely affect; NLAA = not likely to adversely affect; NE = no effect

Table 2. Carbaryl use-specific direct effects determinations[1] for the Aquatic- and Terrestrial-phase CRLF (shading added to indicate use where there is any LAA determination).

Use(s)	Aquatic-Phase CRLF		Terrestrial-Phase CRLF	
	Acute	Chronic	Acute	Chronic
Home lawn	NLAA	NE	NLAA	LAA
Flower beds around buildings and lawns	NE	NE	NLAA	LAA
Lawns	LAA	LAA	NLAA	LAA
Ornamentals	LAA	LAA	NLAA	LAA
Parks, recreation areas, golf courses, sod farms, commercial lawns	NE	NE	NLAA	LAA
Oranges, lemons, grapefruit, tangerines, etc.	LAA	LAA	NLAA	LAA
Olives	LAA	LAA	NLAA	LAA
Almonds, chestnuts, pecans, filberts, walnuts, pistachio	LAA	LAA	NLAA	LAA
Flowers and shrubs	NLAA	NE	NLAA	LAA
Peaches, apricots, cherries, nectarines, plums, prunes	LAA	LAA	NLAA	LAA
Asparagus	LAA	LAA	NLAA	LAA
Apple, pear, crabapple, oriental pears	NLAA	LAA	NLAA	LAA
loquat	NLAA	LAA	NLAA	LAA
Sweet corn	NLAA	LAA	NLAA	LAA
Grapes, caneberries, blueberries	NLAA	LAA	NLAA	LAA
strawberries	LAA	LAA	NLAA	LAA
Tomatoes, peppers, eggplant	NLAA	LAA	NLAA	LAA
peanuts	NLAA	NE	NLAA	LAA
Broccoli, cauliflower, cabbage, kohlrabi, Chinese cabbage, collards, kale, mustard greens	LAA	LAA	NLAA	LAA
Brussels sprouts and Hanover salad	LAA	LAA	NLAA	LAA
Sweet potato	LAA	LAA	NLAA	LAA
Field corn, popcorn	NE	NE	NLAA	LAA
Head and leaf lettuce, dandelion, endive, parsley, spinach, Swiss chard	LAA	LAA	NLAA	LAA
sorghum	NLAA	NE	NLAA	LAA
Celery, prickly pear, garden beets, carrots	LAA	LAA	NLAA	LAA
Horseradish	LAA	LAA	NLAA	LAA
Potato, parsnip, rutabaga, turnip (root)	LAA	LAA	NLAA	LAA
radish	NLAA	NE	NLAA	LAA
Rice	LAA	LAA	NLAA	NLAA
Dry beans, fresh peas, dry peas, cow peas, southern peas (fresh)	NE	NE	NLAA	LAA
Okra	NE	NE	NLAA	LAA
Sugar beet	NLAA	NE	NLAA	NLAA
Alfalfa, birds foot trefoil, clover	NE	NE	NLAA	NLAA
Pasture	NE	NE	NLAA	NLAA
Grass for seed	NE	NE	NLAA	NLAA
Rangeland	NLAA	NE	NLAA	NLAA
Melon, cucumber, pumpkin, squash	NE	NE	NLAA	NLAA
Roses, herbaceous plants, woody plants	NLAA	NE	NLAA	NLAA
Rights-of-way, hedgerows, ditch banks, roadsides	NLAA	LAA	NLAA	NLAA
wasteland	LAA	LAA	NLAA	NLAA
Non-urban forests, tree plantations, Christmas trees, parks, rangeland trees	NLAA	NE	NLAA	NLAA
Rural shelter belts	LAA	LAA	NLAA	NLAA
Ticks, grasshoppers	NLAA	LAA	NLAA	LAA

[1]LAA = likely to adversely affect; NLAA = not likely to adversely affect; NE = no effect

Table 3. Carbaryl use-specific indirect effects determinations[1] based on indirect effects of aquatic-phase and terrestrial-phase CRLF from effects to prey (shading added to indicate use where there is any LAA determination).

Use	Algae	Aquatic Invertebrates		Terrestrial Invertebrates (Acute)	Aquatic-phase frogs and fish		Terrestrial-phase frogs		Small Mammals	
		Acute	Chronic		Acute	Chronic	Acute	Chronic	Acute	Chronic
Home lawn	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
Flower beds around buildings and lawns	NE	LAA	NE	LAA	NE	NE	NLAA	LAA	LAA	LAA
Lawns	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Ornamentals	NE	LAA	LAA	LAA	LAA	LAA	NLAA	LAA	LAA	LAA
Parks, recreation areas, golf courses, sod farms, commercial lawns	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
Oranges, lemons, grapefruit, tangerines, etc.	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Olives	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Almonds, chestnuts, pecans, filberts, walnuts, pistachio	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Flowers and shrubs	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
Peaches, apricots, cherries, nectarines, plums, prunes	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Asparagus	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Apple, pear, crabapple, oriental pears	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
loquat	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Sweet corn	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Grapes, caneberries, blueberries	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
strawberries	NE	LAA	LAA	LAA	LAA	LAA	NLAA	LAA	LAA	LAA
Tomatoes, peppers, eggplant	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
peanuts	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
Broccoli, cauliflower, cabbage, kohlrabi, Chinese cabbage, collards, kale, mustard greens	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Brussels sprouts and Hanover salad	NE	LAA	LAA	LAA	LAA	LAA	NLAA	LAA	LAA	LAA
Sweet potato	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Field corn, popcorn	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
Head and leaf lettuce, dandelion, endive, parsley, spinach, Swiss chard	NE	LAA	LAA	LAA	LAA	LAA	NLAA	LAA	LAA	LAA
sorghum	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
Celery, prickly pear, garden beets, carrots	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA

Use	Algae	Aquatic Invertebrates		Terrestrial Invertebrates (Acute)	Aquatic-phase frogs and fish		Terrestrial-phase frogs		Small Mammals	
		Acute	Chronic		Acute	Chronic	Acute	Chronic	Acute	Chronic
Horseradish	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Potato, parsnip, rutabaga, turnip (root)	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
radish	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
Rice	LAA	LAA	LAA	LAA	LAA	LAA	NLAA	NLAA	LAA	LAA
Dry beans, fresh peas, dry peas, cow peas, southern peas (fresh)	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
Okra	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
Sugar beet	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
Alfalfa, birds foot trefoil, clover	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
Pasture	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
Grass for seed	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
Rangeland	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
Melon, cucumber, pumpkin, squash	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
Roses, herbaceous plants, woody plants	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
Rights-of-way, hedgerows, ditch banks, roadsides	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	NLAA	LAA	LAA
wasteland	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	NLAA	LAA	LAA
Non-urban forests, tree plantations, Christmas trees, parks, rangeland trees	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
Rural shelter belts	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	NLAA	LAA	LAA
Ticks, grasshoppers	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA

[1]LAA = likely to adversely affect; NLAA = not likely to adversely affect; NE = no effect

When evaluating the significance of this risk assessment's direct/indirect and 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 CRLF life stages within specific recovery units and/or designated critical habitat within the action area. 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 species.
- Quantitative information on prey base requirements for individual aquatic- and terrestrial-phase frogs. While existing information provides a preliminary picture of the types of food sources utilized by the frog, 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 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 frogs 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* (U.S. EPA 1998), the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS 1998) and procedures outlined in the Overview Document (U.S. EPA 2004).

2.1 Purpose

The purpose of this endangered species assessment is to evaluate potential direct and indirect effects on individuals of the federally threatened California red-legged frog *(Rana aurora draytonii*) (CRLF) 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 addition, this assessment evaluates whether these actions can be expected to result in the modification of the species' critical habitat. Key biological information for the CRLF is included in Section 2.5, and designated critical habitat information for the species is provided in Section 2.6 of this assessment. This ecological risk assessment has been prepared as part of the *Center for Biological Diversity (CBD) vs. EPA et al*. (Case No. 02-1580-JSW(JL)) settlement agreement entered in the Federal District Court for the Northern District of California on October 20, 2006.

In this endangered species assessment, direct and indirect effects to the CRLF and potential modification to its critical habitat are evaluated in accordance with the methods (both screening level and species-specific refinements, when appropriate) described in the Agency's Overview Document (U.S. EPA 2004) and evaluated by the U. S. Fish and Wildlife Service (Williams and Hogarth 2004).

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 are based on an action area. The action area is considered to be the area directly or indirectly affected by the federal action, as indicated by the exceedance of Agency Levels of Concern (LOCs) used to evaluate direct or indirect effects. 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 CRLF and its designated critical habitat within the state of California.

As part of the "effects determination," one of the following three conclusions will be reached regarding the potential for registration of carbaryl at the use sites described in this document to affect CRLF individuals and/or result in the modification of designated CRLF critical habitat:

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

Designated critical habitat identifies specific areas that have the physical and biological features, (known as primary constituent elements or PCEs) essential to the conservation of listed species. The PCEs for CRLFs are aquatic and upland areas where suitable breeding and non-breeding aquatic habitat is located, interspersed with upland foraging and dispersal habitat (Section 2.6).

If the results of initial screening-level assessment methods show no direct or indirect effects (no LOC exceedances) upon individual CRLFs or upon the PCEs of the species' designated critical habitat, a "no effect" determination is made for the FIFRA regulatory action regarding carbaryl as it relates to this species and its designated critical habitat. If, however, direct or indirect effects to individual CRLFs are anticipated and/or effects may impact the PCEs of the CRLF's designated critical habitat, a preliminary "may affect" determination is made for the FIFRA regulatory action regarding carbaryl.

If a determination is made that use of carbaryl within the action area(s) associated with the CRLF "may affect" this species and/or its designated critical habitat, additional information is considered to refine the potential for exposure and for effects to the CRLF and other taxonomic groups upon which these species depend (*e.g.,* aquatic and terrestrial vertebrates and invertebrates, aquatic plants, riparian vegetation, etc.). Additional information, including spatial analysis (to determine the overlay of CRLF habitat with carbaryl use) and further evaluation of the potential impact of carbaryl on the PCEs is also used to determine whether modification to designated critical habitat may occur. Based on the refined information, the Agency uses the best available information to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that "may affect and are likely to adversely affect" the CRLF and/or the PCEs of its designated critical habitat. This information is presented as part of the Risk Characterization in Section 5 of this document.

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 (defined in Section 2.7), 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 (*i.e.*, the biological resource requirements for the listed species associated with the critical habitat or important physical aspects of the habitat that may be reasonably influenced through biological processes). Activities that may 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 CRLF's critical habitat form the basis of the critical habitat impact analysis. Actions that may affect the CRLF's designated critical habitat have been identified by the Services and are discussed further in Section 2.6.

2.2 Scope

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.

The end result of the EPA pesticide registration process (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" being assessed.

This ecological risk assessment is for currently registered uses of carbaryl in portions of the action area that are reasonably assumed to be biologically relevant to the CRLF and its designated critical habitat. Further discussion of the action area for the CRLF and its critical habitat is provided in Section 2.7.

This assessment quantitatively considers effects of exposures to carbaryl only. Carbaryl degrades into one notable degradate, 1-naphthol. 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 focused on carbaryl is considered protective for non-target species as the toxicity endpoints for carbaryl are the most sensitive measured.

This assessment considers only the single active ingredient of carbaryl. However, the assessed species and their environments may be exposed to multiple pesticides simultaneously. Interactions of other toxic agents with carbaryl could result in additive effects, synergistic effects or antagonistic effects. Evaluation of pesticide mixtures is beyond the scope of this assessment because of the myriad factors that cannot be quantified based on the available data. Those factors include identification of other possible co-contaminants and their concentrations, differences in the pattern and duration of exposure among contaminants, and the differential effects of other physical/chemical characteristics of the receiving waters (*e.g.* organic matter present in sediment and suspended water). Evaluation of factors that could influence additivity/synergism is beyond the scope of this assessment and is beyond the capabilities of the available data to allow for an evaluation. However, it is acknowledged that not considering mixtures could over- or under-estimate risks depending on the type of interaction and factors discussed above. This assessment has however, analyzed the toxicity of formulated products (including formulations involving more than one active ingredient) and determined that none of the formulated products evaluated were more toxic than the technical grade active ingredient data used for assessing both direct and indirect risks.

2.3 Previous Assessments

In March 2003, a revised environmental fate and ecological risk assessment was published in support of the interim reregistration eligibility decision on carbaryl (USEPA 2004). The chapter was revised to include additional ecological effect studies and to address concerns received 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.

Although freshwater fish are typically used as surrogates for assessing the sensitivity of aquatic-phase amphibians to chemicals, carbaryl has a relatively large amount of data available on the effects of carbaryl on larval amphibians. These data were captured qualitatively in the baseline assessment and the data indicate that across the species tested, amphibians are less sensitive to carbaryl than fish. However, studies examining the interaction of carbaryl with aquatic communities indicated that in some cases, carbaryl exposure could enhance the growth of larval amphibians (tadpoles) through the elimination of zooplankton that compete with tadpoles for food.

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).

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

EPA also consulted with the National Marine Fisheries Service concerning carbaryl effects on endangered salmon and steelhead to determine the best processes to assess pesticide impacts on endangered species. 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).

2.4 Stressor Source and Distribution

2.4.1 Environmental Fate and Transport Assessment

The following fate and transport description for carbaryl is consistent with the information contained in the initial 2004 IRED (U.S. EPA, 2004b).

2.4.1.1 Hydrolysis

Carbaryl hydrolysis is strongly pH dependent. The compound is stable under acidic conditions (pH 5) and degrades 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 was stable to further hydrolysis. (MRID 44759301; **Figure 1**). The registrant-submitted hydrolysis data were used to generate the model input parameters.

Chapman and Cole (1982) measured half-lives of 14 days (pH 7.0) and 0.49 days (pH 8). Wolfe *et al*. (1978) reported half-life values in natural pond waters of 30 days (pH 6.7) and 12 days (pH 7.2). They also estimated a minimum hydrolysis half-life in acidic conditions of 1600 days. Armbrust and Crosby (1991) reported hydrolysis half-lives in filtered seawater of 1 day (pH 7.9) and 0.96 day (pH 8.3).

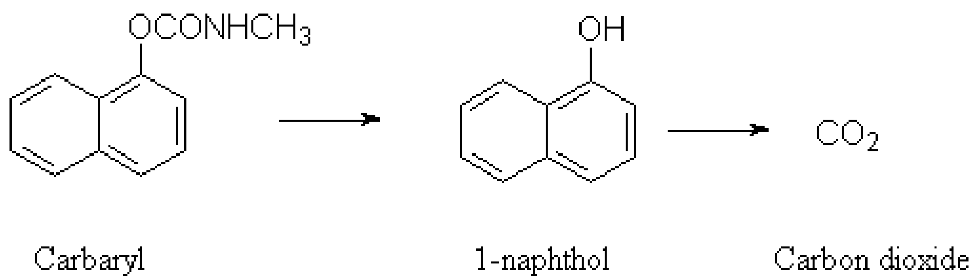


Figure 1. Generalized degradation pathway of carbaryl.

2.4.1.2 Photolysis

The photolysis half-life is 45 hours in distilled water at pH 5.5. In filtered seawater, carbaryl degraded rapidly to 1-naphthol under artificial sunlight (290-360 nm) with a half-life of 5 hours. The degradation product, 1-naphthol, was degraded very rapidly with half-life of less than 1 hour (Armbrust and Crosby, 1991). The data from the study submitted by the registrant (MRID 41982603) was used to generate the model input parameters.

Table 4. Summary of Environmental Chemistry and Fate Parameters For Carbaryl.

Parameter	Value	Reference
Selected Physical/Chemical Parameters		
Molecular Weight	201.22 g/mol	
Water Solubility	32 mg/L (ppm) at 20° C	Suntio, et al., 1988
Vapor pressure	1.36 10^{-7} mm Hg (25° C)	Ferrira and Seiber, 1981
Henry's Law Constant	1.28 x 10^{-8} atm m^3 mol^{-1}	Suntio, et al., 1988
Octanol/Water Partition Coefficient (Kow)	229	Windholz et al., 1976
Persistence		
Hydrolysis $t_{1/2}$ pH 5 pH 7 pH 9	stable 12 days 3.2 hours	MRIDs 00163847, 44759301
Aqueous Photolysis $t_{½}$	21 days	MRID 41982603
Soil photolysis $t_{½}$	assumed stable	No valid data submitted
Aerobic Soil metabolism t½	4 days in one sandy loam soil	MRID 42785101
Anaerobic Soil metabolism t½	72 days	MRID 42785102
Aerobic Aquatic metabolismt½	4.9 days	MRID 43143401
Anaerobic Aquatic metabolism t½	$t_{1/2}$ = 72 days	MRID 42785102
Mobility/Adsorption-Desorption		
Batch Equilibrium	K_{foc}) =1.74 (207) - sandy loam 2.04 (249) - clay loam sediment 3.00 (211) - silt loam 3.52 (177) - silty clay loam 1/n values ranged from 0.78-0.84	MRID 43259301
Column Leaching	slightly mobile in columns (30-cm length) of sandy loam, silty clay loam, silt loam, and loamy sand soils	MRID 43320701
Field Dissipation		
Forestry Dissipation	Foliar $t_{1/2}$ = 21 days Leaf Litter $t_{1/2}$ = 75 days Soil $t_{1/2}$ = 65 days	MRID 43439801

2.4.1.3 Microbially-mediated processes

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

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

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

2.4.1.4 Mobility

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

Batch Adsorption/Desorption

Based on batch equilibrium experiments (*MRID* 43259301), carbaryl is mobile in soils. In silty clay loam, sandy loam, loamy sand, and silt loam soils and clay loam sediment, mobility decreased with increasing soil organic matter content. K_f values were 1.74 for the sandy loam soil, 2.04 for the clay loam sediment, 3.00 for the silt loam soil, and 3.52 for the silty clay loam soil. An adsorption K_{oc} of 144 was estimated when a regression with a y-intercept was used.

When this model is used, there is a residual adsorption of 0.7 L kg^{-1} when there is no organic matter present. This implies carbaryl has some ability to sorb directly to clay. This model has a r^2 of 0.94 and is significant at $p<0.05$. A model with no-intercept was also fit, and the K_{oc} calculated using this was 195; however, the r^2 is only 0.81 and p = 0.069. Values of 1/n ranged from 0.78-0.84; the closer this value is to 1, K_d is equivalent to $K_{f.}$, relative to sorption. Sorption showed significant hysteresis with Freundlich desorption constants ($K_{f(des)}$) values of 6.72 for sandy loam soil, 6.78 for clay loam sediment, 6.89 for silt loam soil, and 7.66 for silty clay loam soil. Values of 1/n ranged from 0.86-1.02. Literature data confirms that carbaryl is mobile. Nkedi-Kizza and Brown (1998) reported K_f of 4.72 (1/n = 0.80) for soil with an organic content of 590 mg/Kg. They found that sorption was lower on subsoils and attributed this to a lower organic content. The K_{oc} estimated using the no-intercept (195) was used for modeling as this is how K_{oc} is handled internally in both PRZM and EXAMS.

Column Leaching

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

2.4.1.5 Field Dissipation

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

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

Terrestrial Field Dissipation

Results of two field dissipation studies conducted in California and North Carolina were submitted (MRID 41982605).

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

North Carolina site: Carbaryl dissipated with an observed initial half-life of <7 days from the upper 0.15 m of a plot of Norfolk sandy loam soil planted to sweet corn in North Carolina, following one application at 7.11 kg a.i./ha of carbaryl on May 1, 1990. In the 0- to 0.15-m soil depth, carbaryl was 3.72-7.30 μg/g immediately after treatment, 0.145-0.379 μg/g at 7 days, 0.036-0.105 μg/g at 16 days, 0.017-0.043 μg/g at 30 days, and <0.013 μg/g at 62 days. Carbaryl was sporadically detected at <0.015 ug/g in the 0.15- to 0.60-m soil depths, except carbaryl was O.D6 ug/g in one of four samples from the 0.30- to 0.45-m depth at 7 days. Carbaryl was not detected in the 0.60- to 0.90-m soil depths at any sampling interval. The formation and decline of carbaryl degradates were not investigated. Rainfall plus irrigation totaled 53.1 mm through 7 days post-treatment (May 1-May 8, 1990), and 174 mm throughout the remainder of the study (May I-July 2).

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

Aquatic Field Dissipation

Results of aquatic field dissipation studies conducted on rice in Texas and Mississippi were submitted (MRID 43263001). The studies were evaluated and found to provide supporting data. Frozen storage stability data were provided for only 6 months, although the water samples were stored for up to 14 months and the soil samples were stored for up to 17.5 months prior to analysis. In the six months of storage, carbaryl degraded an average of 34% in Texas water and 39% in water from Mississippi. The primary degradate, 1-naphthol, further degraded 50% in water from Texas and 69% from Mississippi.

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

Forestry Field Dissipation

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

2.4.1.6 Foliar Dissipation/Foliar Wash-off

Based on thirty acceptable studies (MRID 45860501), the mean foliar half-life of carbaryl was determined to be 3.2 d. These studies were predominantly magnitude of residue studies used to support the setting of tolerances for food as well as some other data from the open literature. A set of criterion (described in detail in the EFED RED chapter, 2004b) for data quality and study appropriateness were established to select those studies which were appropriate for making the estimate. A value of 3.7 d was used for foliar degradation in estimating for terrestrial, aquatic and drinking water exposure estimates. This value is the upper 90% confidence bound on the mean value and is used as a model input parameter.

Two studies (Willis *et al,* 1988, Willis *et al,* 1996) were submitted by the registrant which could be used to estimate the foliar wash-off rate which is an input parameter for PRZM. In the absence of data, this parameter is usually set to 0.5. Wash-off coefficients estimated from these two studies were 0.83 and 0.98 respectively with a mean of 0.91. In both these cases, the wash-off coefficient was estimated from only two points, so no error could be estimated. The mean of 0.91 was used in the modeling.

2.4.1.7 Bioconcentration in Fish

Because of the low octanol/water partition coefficient, carbaryl is not expected to bioconcentrate to a significant extent. Reported K_{ow} values range from 65 to 229 (Bracha, and O'Brian, 1966; Mount and Oehme, 1981; Windholz *et al.*, 1976). A fish bioconcentration study (Chib, 1986, Fiche/Master ID 00159342) suggested that bioconcentration factors (BCFs) were 14x in edible tissue, 75x in visceral tissue and 45x in whole fish. Though the study does not meet current acceptable standards, it does support the conclusion that significant bioconcentration is not expected.

2.4.1.8 Atmospheric Transport

Potential transport mechanisms of carbaryl in air include spray drift, and secondary drift of volatilized or soil-bound residues leading to deposition onto nearby or more distant ecosystems. 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 CRLF.

Carbaryl has been shown to be transported and deposited by atmospheric processes (Waite, *et al.*, 1995; Foreman, *et al.*, 2000; Sanusi *et al.*, 2000). As with all chemicals applied by aerial or ground spray, spray drift can cause exposure to non-target organisms downwind. Vapor-phase transport and particulate transport may carry the compound far from the area of application. In the atmosphere, partitioning between particulate and gas phase is a function of temperature, atmospheric transport distance and deposition are therefore a function of temperature. In general though, given carbaryl's relatively rapid degradation, its potential for long-range atmospheric transport is limited.

At this time, EFED does not have an approved model for estimating atmospheric transport of pesticides and resulting exposure to aquatic organisms in areas receiving pesticide deposition from the atmosphere. Potential mechanisms of transport of carbaryl to the atmosphere, such as volatilization, wind erosion of soil, and spray drift, can only be discussed qualitatively. The extent to which carbaryl will be deposited from the air to the action area is unknown. Potential deposition of carbaryl in precipitation is discussed in section **5.2.6.1.3** of this assessment, but based on the chemical's environmental fate characteristics wet deposition is expected to be minimal.

2.4.2 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.

2.4.3 Use Characterization

Carbaryl is nationally registered for over 115 uses in agriculture, professional turf management, ornamental production, and residential settings (See **Appendix A**). Carbaryl also is registered for 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 (http://www.umass.edu/fruitadvisor/NEAPMG/145-149.pdf).

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 5**.

Table 5. Methods and rates of application of currently registered used of carbaryl in 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	9.1	2	7	ground
B: Flower beds around buildings	Flower beds around buildings and lawns	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
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	NS	aerial
AK: Melon	Melon, cucumber, pumpkin, squash	1	6	7	aerial

Crop Group	Specific crops included in this group	Max. App. Rate (lb a.i./acre)	Max. No. of Apps.	Application Intervals (days)	Application Method
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

As noted in the carbaryl IRED (USEPA 2004b), approximately 3.9 millions 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 form 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** 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.

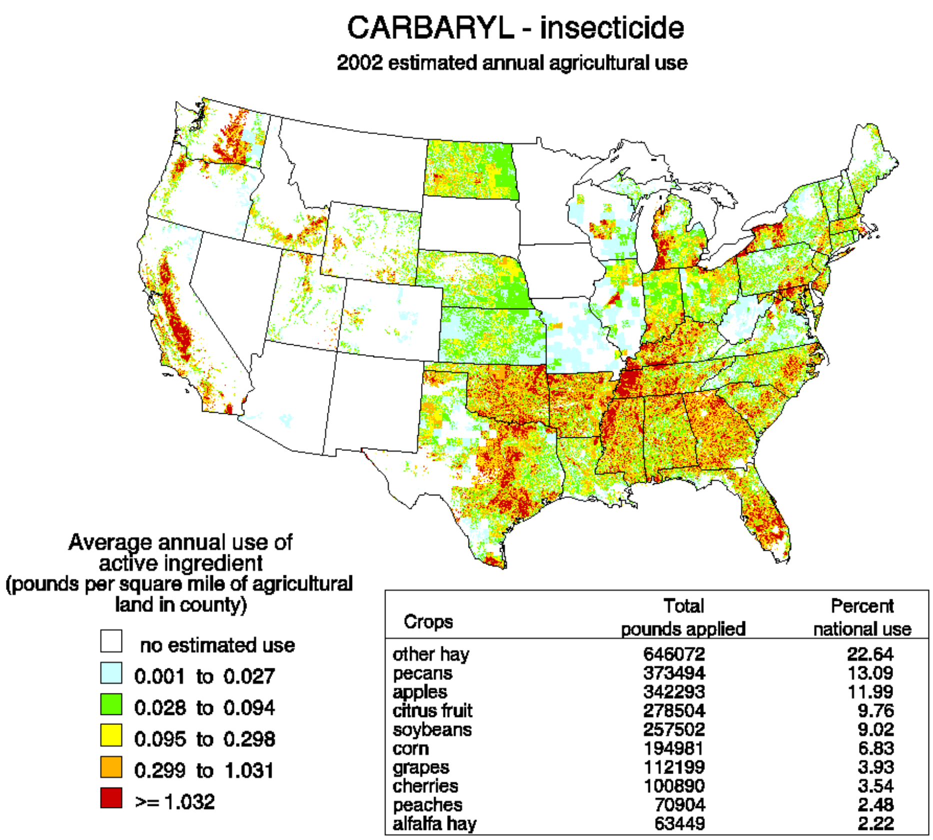


Figure 2. Historical Extent (2002) of carbaryl usage.
(Source http://ca.water.usgs.gov/pnsp/pesticide_use_maps/show_map.php?year=02&map=m6006)

From 2003-2005, 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%) (CDPR 2007a). 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 3**. Data are unavailable for residential uses of carbaryl, since these data are not reported to the state. See **Appendix B** for more details on uses of carbaryl in California over 2003-2005.

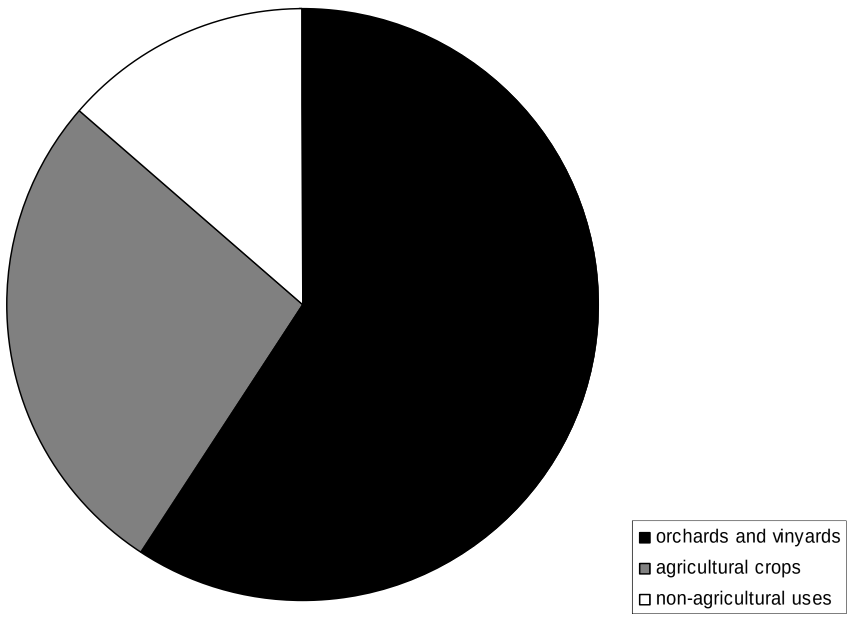


Figure 3. Distribution of reported mass of carbaryl applied during 2003-2005 in California by crop group.

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. A comprehensive list of current uses of carbaryl, along with the methods and rates associated with applications of carbaryl is included in **Appendix A**. 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 5**. Rationales for the choices of surrogates and groups are provided in **Appendix A**. 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. Crop groups (*i.e.* similar application rates) for terrestrial assessment are indicated by the code in parentheses in Table 3. For spray drift assessment, since only the single application rate and the application method (ground, air blast, or aerial) are considered, some of the terrestrial groupings can be placed together. The groupings for spray drift assessment are in brackets.

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 these two parameters must be assumed when they are not specified on the label. If the minimum interval is not specified, three days has been used and when maximum seasonal rate or number of application has not been specified, 25 applications have been assumed. The use patterns, as assessed are in **Table 5**.

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 aerial (pounds per acre) rate.

The mosquito adulticide use pattern was not evaluated separately because it is applied as an aerosol. Since current assessment tools are expected to underestimate the distance aerosols will actually drift, this use was not assessed separately. The absolute concentration at an any point in the environment for this use pattern are not likely to exceed those for 1 $lb \cdot acre^{-1}$ application patterns such as non-urban forests and wasteland, although the dispersion in the environment may be greater as aerosols may have some increased propensity to drift as compared to non-aerosol spray particles. Greater detail on the rationale for not considering these use patterns is provided in **Appendix A.** Effects determinations associated with non-urban forests and wasteland are assumed to be representative of carbaryl use as a mosquito adulticide.

The uses considered in this risk assessment represent all currently registered used according to a review of all current labels. No other uses are relevant to this assessment. Any 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.

2.5 Assessed Species

The CRLF was federally listed as a threatened species by USFWS effective June 24, 1996 (USFWS 1996). It is one of two subspecies of the red-legged frog and is the largest native frog in the western United States (USFWS 2002). A brief summary of information regarding CRLF distribution, reproduction, diet, and habitat requirements is provided in Sections 2.5.1 through 2.5.4, respectively. Further information on the status, distribution, and life history of and specific threats to the CRLF is provided in **Attachment 1.**

Final critical habitat for the CRLF was designated by USFWS on April 13, 2006 (USFWS 2006; 71 FR 19244-19346). Further information on designated critical habitat for the CRLF is provided in Section 2.6.

2.5.1 Distribution

The CRLF is endemic to California and Baja California (Mexico) and historically inhabited 46 counties in California including the Central Valley and both coastal and interior mountain ranges (USFWS 1996). Its range has been reduced by about 70%, and the species currently resides in 22 counties in California (USFWS 1996). The species has an elevational range of near sea level to 1,500 meters (5,200 feet) (Jennings and Hayes 1994); however, nearly all of the known CRLF populations have been documented below 1,050 meters (3,500 feet) (USFWS 2002).

Populations currently exist along the northern California coast, northern Transverse Ranges (USFWS 2002), foothills of the Sierra Nevada (5-6 populations), and in southern California south of Santa Barbara (two populations) (Fellers 2005a). Relatively larger numbers of CRLFs are located between Marin and Santa Barbara Counties (Jennings and Hayes 1994). A total of 243 streams or drainages are believed to be currently occupied by the species, with the greatest numbers in Monterey, San Luis Obispo, and Santa Barbara counties (USFWS 1996). Occupied drainages or watersheds include all bodies of water that support CRLFs (i.e., streams, creeks, tributaries, associated natural and artificial ponds, and adjacent drainages), and habitats through which CRLFs can move (i.e., riparian vegetation, uplands) (USFWS 2002).

The distribution of CRLFs within California is addressed in this assessment using four categories of location including recovery units, core areas, designated critical habitat, and known occurrences of the CRLF reported in the California Natural Diversity Database (CNDDB) that are not included within core areas and/or designated critical habitat (see Figure 3). Recovery units, core areas, and other known occurrences of the CRLF from the CNDDB are described in further detail in this section, and designated critical habitat is addressed in Section 2.6. Recovery units are large areas defined at the watershed level that have similar conservation needs and management strategies. The recovery unit is primarily an administrative designation, and land area within the recovery unit boundary is not exclusively CRLF habitat. Core areas are smaller areas within the recovery units that comprise portions of the species' historic and current range and have been determined by USFWS to be important in the preservation of the species. Designated critical habitat is generally contained within the core areas, although a number of critical habitat units are outside the boundaries of core areas, but within the boundaries of the recovery units. Additional information on CRLF occurrences from the CNDDB is used to cover the current range of the species not included in core areas and/or designated critical habitat, but within the recovery units.

Recovery Units

Eight recovery units have been established by USFWS for the CRLF. These areas are considered essential to the recovery of the species, and the status of the CRLF "may be considered within the smaller scale of the recovery units, as opposed to the statewide range" (USFWS 2002). Recovery units reflect areas with similar conservation needs and population statuses, and therefore, similar recovery goals. The eight units described for the CRLF are delineated by watershed boundaries defined by US Geological Survey hydrologic units and are limited to the elevational maximum for the species of 1,500 m above sea level. The eight recovery units for the CRLF are listed in Table 3 and shown in Figure 3.

Core Areas

USFWS has designated 35 core areas across the eight recovery units to focus their recovery efforts for the CRLF (see **Figure 4**). **Table 6** summarizes the geographical relationship among recovery units, core areas, and designated critical habitat. The core areas, which are distributed throughout portions of the historic and current range of the species, represent areas that allow for long-term viability of existing populations and reestablishment of populations within historic range. These areas were selected because they: 1) contain existing viable populations; or 2) they contribute to the connectivity of other habitat areas (USFWS 2002). Core area protection and enhancement are vital for maintenance and expansion of the CRLF's distribution and population throughout its range.

For purposes of this assessment, designated critical habitat, currently occupied (post-1985) core areas, and additional known occurrences of the CRLF from the CNDDB are considered. Each type of locational information is evaluated within the broader context of recovery units. For example, if no labeled uses of carbaryl occur (or if labeled uses occur at predicted exposures less than the Agency's LOCs) within an entire recovery unit, that particular recovery unit would not be included in the action area and a "no effect" determination would be made for all designated critical habitat, currently occupied core areas, and other known CNDDB occurrences within that recovery unit. Historically occupied sections of the core areas are not evaluated as part of this assessment because the USFWS Recovery Plan (USFWS 2002) indicates that CRLFs are extirpated from these areas. A summary of currently and historically occupied core areas is provided in Table 3 (currently occupied core areas are bolded). While core areas are considered essential for recovery of the CRLF, core areas are not federally-designated critical habitat, although designated critical habitat is generally contained within these core recovery areas. It should be noted, however, that several critical habitat units are located outside of the core areas, but within the recovery units. The focus of this assessment is currently occupied core areas, designated critical habitat, and other known CNDDB CRLF occurrences within the recovery units. Federally-designated critical habitat for the CRLF is further explained in Section 2.6.

Other Known Occurrences from the CNDBB

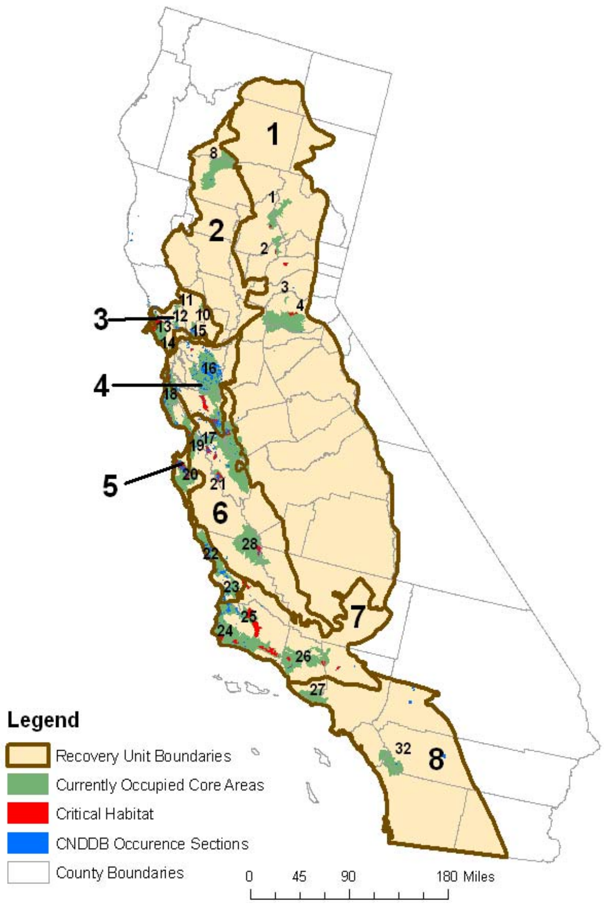
The CNDDB provides location and natural history information on species found in California. The CNDDB serves as a repository for historical and current species location sightings. Information regarding known occurrences of CRLFs outside of the currently occupied core areas and designated critical habitat is considered in defining the current range of the CRLF. See: http://www.dfg.ca.gov/bdb/html/cnddb_info.html for additional information on the CNDDB.

Table 6. California Red-legged Frog Recovery Units with Overlapping Core Areas and Designated Critical Habitat.

Recovery Unit [1] (Figure 4)	Core Areas [2,7] (Figure 4)	Critical Habitat Units [3]	Currently Occupied (post-1985) [4]	Historically Occupied [4]
Sierra Nevada Foothills and Central Valley (1) (eastern boundary is the 1,500m elevation line)	**Cottonwood Creek (partial) (8)**	--	✓	
	Feather River (1)	BUT-1A-B	✓	
	Yuba River-S. Fork Feather River (2)	YUB-1	✓	
	--	NEV-1[6]		
	Traverse Creek/Middle Fork American River/Rubicon (3)	--	✓	
	Consumnes River (4)	ELD-1	✓	
	S. Fork Calaveras River (5)	--		✓
	Tuolumne River (6)	--		✓
	Piney Creek (7)	--		✓
	East San Francisco Bay (partial)(16)	--	✓	
North Coast Range Foothills and Western Sacramento River Valley (2)	**Cottonwood Creek (8)**	--	✓	
	Putah Creek-Cache Creek (9)	--		✓
	Jameson Canyon – Lower Napa Valley (partial) (15)	--	✓	
	Belvedere Lagoon (partial) (14)	--	✓	
	Pt. Reyes Peninsula (partial) (13)	--	✓	
North Coast and North San Francisco Bay (3)	Putah Creek-Cache Creek (partial) (9)	--		✓
	Lake Berryessa Tributaries (10)	NAP-1	✓	
	Upper Sonoma Creek (11)	--	✓	
	Petaluma Creek-Sonoma Creek (12)	--	✓	
	Pt. Reyes Peninsula (13)	MRN-1, MRN-2	✓	
	Belvedere Lagoon (14)	--	✓	
	Jameson Canyon-Lower Napa River (15)	SOL-1	✓	
South and East San Francisco Bay (4)	--	CCS-1A[6]		
	East San Francisco Bay (partial) (16)	ALA-1A, ALA-1B, STC-1B	✓	
	--	STC-1A[6]		
	South San Francisco Bay (partial) (18)	SNM-1A	✓	
Central Coast (5)	**South San Francisco Bay (partial) (18)**	SNM-1A, SNM-2C, SCZ-1	✓	
	Watsonville Slough- Elkhorn Slough (partial) (19)	SCZ-2 [5]	✓	
	Carmel River-Santa Lucia (20)	MNT-2	✓	
	Estero Bay (22)	--	✓	
	--	SLO-8[6]		
	Arroyo Grande Creek (23)	--	✓	
	Santa Maria River-Santa Ynez River (24)	--	✓	
Diablo Range and Salinas Valley (6)	**East San Francisco Bay (partial) (16)**	MER-1A-B, STC-1B	✓	
	--	SNB-1[6], SNB-2[6]		
	Santa Clara Valley (17)	--	✓	
	Watsonville Slough- Elkhorn	MNT-1	✓	

	Slough (partial)(19)			
	Carmel River-Santa Lucia (partial)(20)	--	✓	
	Gablan Range (21)	SNB-3	✓	
	Estrella River (28)	SLO-1A-B	✓	
Northern Transverse Ranges and Tehachapi Mountains (7)	--	SLO-8[6]		
	Santa Maria River-Santa Ynez River (24)	STB-4, STB-5, STB-7	✓	
	Sisquoc River (25)	STB-1, STB-3	✓	
	Ventura River-Santa Clara River (26)	VEN-1, VEN-2, VEN-3	✓	
	--	LOS-1[6]		
Southern Transverse and Peninsular Ranges (8)	**Santa Monica Bay-Ventura Coastal Streams (27)**	--	✓	
	San Gabriel Mountain (29)	--		✓
	Forks of the Mojave (30)	--		✓
	Santa Ana Mountain (31)	--		✓
	Santa Rosa Plateau (32)	--	✓	
	San Luis Rey (33)	--		✓
	Sweetwater (34)	--		✓
	Laguna Mountain (35)	--		✓

[1] Recovery units designated by the USFWS (USFWS 2000, pg 49).
[2] Core areas designated by the USFWS (USFWS 2000, pg 51).
[3] Critical habitat units designated by the USFWS on April 13, 2006 (USFWS 2006, 71 FR 19244-19346).
[4] Currently occupied (post-1985) and historically occupied core areas as designated by the USFWS (USFWS 2002, pg 54).
[5] Critical habitat unit where identified threats specifically included pesticides or agricultural runoff (USFWS 2002).
[6] Critical habitat units that are outside of core areas, but within recovery units.
[7] Currently occupied core areas that are included in this effects determination are bolded.



Recovery Units

1. Sierra Nevada Foothills and Central Valley
2. North Coast Range Foothills and Western Sacramento River Valley
3. North Coast and North San Francisco Bay
4. South and East San Francisco Bay
5. Central Coast
6. Diablo Range and Salinas Valley
7. Northern Transverse Ranges and Tehachapi Mountains
8. Southern Transverse and Peninsular Ranges

Core Areas

1. Feather River
2. Yuba River- S. Fork Feather River
3. Traverse Creek/ Middle Fork/ American R. Rubicon
4. Cosumnes River
5. South Fork Calaveras River*
6. Tuolumne River*
7. Piney Creek*
8. Cottonwood Creek
9. Putah Creek – Cache Creek*
10. Lake Berryessa Tributaries
11. Upper Sonoma Creek
12. Petaluma Creek – Sonoma Creek
13. Pt. Reyes Peninsula
14. Belvedere Lagoon
15. Jameson Canyon – Lower Napa River
16. East San Francisco Bay
17. Santa Clara Valley
18. South San Francisco Bay
19. Watsonville Slough-Elkhorn Slough
20. Carmel River – Santa Lucia
21. Gablan Range
22. Estero Bay
23. Arroyo Grange River
24. Santa Maria River – Santa Ynez River
25. Sisquoc River
26. Ventura River – Santa Clara River
27. Santa Monica Bay – Venura Coastal Streams
28. Estrella River
29. San Gabriel Mountain*
30. Forks of the Mojave*
31. Santa Ana Mountain*
32. Santa Rosa Plateau
33. San Luis Ray*
34. Sweetwater*
35. Laguna_Mountain

* Core areas that were historically occupied by the California red-legged frog are not included in the map

Figure 4. Recovery Unit, Core Area, Critical Habitat, and Occurrence Designations for CRLF.

2.5.2 Reproduction

CRLFs breed primarily in ponds; however, they may also breed in quiescent streams, marshes, and lagoons (Fellers 2005a). According to the Recovery Plan (USFWS 2002), CRLFs breed from November through late April. Peaks in spawning activity vary geographically; Fellers (2005b) reports peak spawning as early as January in parts of coastal central California. Eggs are fertilized as they are being laid. Egg masses are typically attached to emergent vegetation, such as bulrushes (*Scirpus* spp.) and cattails (*Typha* spp.) or roots and twigs, and float on or near the surface of the water (Hayes and Miyamoto 1984). Egg masses contain approximately 2000 to 6000 eggs ranging in size between 2 and 2.8 mm (Jennings and Hayes 1994). Embryos hatch 10 to 14 days after fertilization (Fellers 2005a) depending on water temperature. Egg predation is reported to be infrequent and most mortality is associated with the larval stage (particularly through predation by fish); however, predation on eggs by newts has also been reported (Rathburn 1998). Tadpoles require 11 to 28 weeks to metamorphose into juveniles (terrestrial-phase), typically between May and September (Jennings and Hayes 1994, USFWS 2002); tadpoles have been observed to over-winter (delay metamorphosis until the following year) (Fellers 2005b, USFWS 2002). Males reach sexual maturity at 2 years, and females reach sexual maturity at 3 years of age; adults have been reported to live 8 to 10 years (USFWS 2002). **Figure 5** depicts CRLF annual reproductive timing.

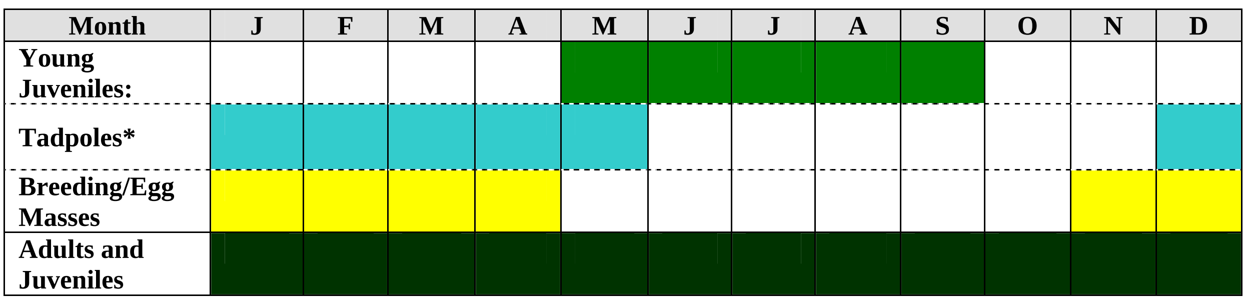


Figure 5. CRLF Reproductive Events by Month.

2.5.3 Diet

Although the diet of CRLF aquatic-phase larvae (tadpoles) has not been studied specifically, it is assumed that their diet is similar to that of other frog species, with the aquatic phase feeding exclusively in water and consuming diatoms, algae, and detritus (USFWS 2002). Tadpoles filter and entrap suspended algae (Seale and Beckvar, 1980) via mouthparts designed for effective grazing of periphyton (Wassersug, 1984, Kupferberg *et al.*; 1994; Kupferberg, 1997; Altig and McDiarmid, 1999).

Juvenile and adult CRLFs forage in aquatic and terrestrial habitats, and their diet differs greatly from that of larvae. The main food source for juvenile aquatic- and terrestrial-phase CRLFs is thought to be aquatic and terrestrial invertebrates found along the shoreline and on the water surface. Hayes and Tennant (1985) report, based on a study examining the gut content of 35 juvenile and adult CRLFs, that the species feeds on as many as 42 different invertebrate taxa, including Arachnida, Amphipoda, Isopoda, Insecta, and Mollusca. The most commonly observed prey species were larval alderflies (*Sialis* cf. *californica*), pillbugs (*Armadilliadrium vulgare*), and water striders (*Gerris* sp). The preferred prey species, however, was the sowbug (Hayes and Tennant, 1985). This study suggests that CRLFs forage primarily above water, although the authors note other data reporting that adults also feed under water, are cannibalistic, and consume fish. For larger CRLFs, over 50% of the prey mass may consists of vertebrates such as mice, frogs, and fish, although aquatic and terrestrial invertebrates were the most numerous food items (Hayes and Tennant 1985). For adults, feeding activity takes place primarily at night; for juveniles feeding occurs during the day and at night (Hayes and Tennant 1985).

2.5.4 Habitat

CRLFs require aquatic habitat for breeding, but also use other habitat types including riparian and upland areas throughout their life cycle. CRLF use of their environment varies; they may complete their entire life cycle in a particular habitat or they may utilize multiple habitat types. Overall, populations are most likely to exist where multiple breeding areas are embedded within varying habitats used for dispersal (USFWS 2002). Generally, CRLFs utilize habitat with perennial or near-perennial water (Jennings et al. 1997), and dense vegetation close to water and shading water of moderate depth are habitat features that appear especially important for CRLF (Hayes and Jennings 1988).

Breeding sites include streams, deep pools, backwaters within streams and creeks, ponds, marshes, sag ponds (land depressions between fault zones that have filled with water), dune ponds, and lagoons. Breeding adults have been found near deep (0.7 m) still or slow moving water surrounded by dense vegetation (USFWS 2002); however, the largest number of tadpoles have been found in shallower pools (0.26 – 0.5 m) (Reis, 1999). Data indicate that CRLFs do not frequently inhabit vernal pools, as conditions in these habitats generally are not suitable (Hayes and Jennings 1988).

CRLFs also frequently breed in artificial impoundments such as stock ponds, although additional research is needed to identify habitat requirements within artificial ponds (USFWS 2002). Adult CRLFs use dense, shrubby, or emergent vegetation closely associated with deep-water pools bordered with cattails and dense stands of overhanging vegetation (http://www.fws.gov/endangered/features/rl_frog/rlfrog.html#where).

In general, dispersal and habitat use depends on climatic conditions, habitat suitability, and life stage. Adults rely on riparian vegetation for resting, feeding, and dispersal. The foraging quality of the riparian habitat depends on moisture, composition of the plant community, and presence of pools and backwater aquatic areas for breeding. CRLFs can be found living within streams at distances up to 3 km (2 miles) from their breeding site and have been found up to 30 m (100 feet) from water in dense riparian vegetation for up to 77 days (USFWS 2002).

During dry periods, the CRLF is rarely found far from water, although it will sometimes disperse from its breeding habitat to forage and seek other suitable habitat under downed trees or logs, industrial debris, and agricultural features (UWFWS 2002). According to Jennings and Hayes (1994), CRLFs also use small mammal burrows and moist leaf litter as habitat. In addition, CRLFs may also use large cracks in the bottom of dried ponds as refugia; these cracks may provide moisture for individuals avoiding predation and solar exposure (Alvarez 2000).

2.6 Designated Critical Habitat

In a final rule published on April 13, 2006, 34 separate units of critical habitat were designated for the CRLF by USFWS (USFWS 2006; FR 51 19244-19346). A summary of the 34 critical habitat units relative to USFWS-designated recovery units and core areas (previously discussed in Section 2.5.1) is provided in Table 2.a.

'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.' All designated critical habitat for the CRLF was occupied at the time of listing. Critical habitat receives protection under Section 7 of the ESA through prohibition against destruction or adverse modification with regard to actions carried out, funded, or authorized by a federal Agency. Section 7 requires consultation on federal actions that are likely to result in the modification of critical habitat.

To be included in a critical habitat designation, the habitat must be '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)). PCEs include, but are not limited to, 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. The designated critical habitat areas for the CRLF are considered to have the following PCEs that justify critical habitat designation:

- Breeding aquatic habitat;
- Non-breeding aquatic habitat;
- Upland habitat; and
- Dispersal habitat.

Please note that a more complete description of these habitat types is provided in **Attachment 1**.

Occupied habitat may be included in the critical habitat only if essential features within the habitat may require special management or protection. Therefore, USFWS does not include areas where existing management is sufficient to conserve the species. Critical habitat is designated outside the geographic area presently occupied by the species only when a designation limited to its present range would be inadequate to ensure the conservation of the species. For the CRLF, all designated critical habitat units contain all four of the PCEs, and were occupied by the CRLF at the time of FR listing notice in April 2006. The FR notice designating critical habitat for the CRLF includes a special rule exempting routine ranching activities associated with livestock ranching from incidental take prohibitions. The purpose of this exemption is to promote the conservation of rangelands, which could be beneficial to the CRLF, and to reduce the rate of conversion to other land uses that are incompatible with CRLF conservation. Please see **Attachment 1** for a full explanation on this special rule.

USFWS has established modification standards for designated critical habitat (USFWS 2006). Activities that may 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 CRLF's critical habitat form the basis of the critical habitat impact analysis. According to USFWS (2006), activities that may affect critical habitat and therefore result in effects to the CRLF include, but are not limited to the following:

(1) Significant alteration of water chemistry or temperature to levels beyond the tolerances of the CRLF that result in direct or cumulative effects to individuals and their life-cycles.
(2) Significant increase in sediment deposition within the stream channel or pond or disturbance of upland foraging and dispersal habitat that could result in elimination or reduction of habitat necessary for the growth and reproduction of the CRLF by increasing the sediment deposition to levels that would affect their ability to complete their life cycles.
(3) Significant alteration of channel/pond morphology or geometry that may lead to changes to the hydrologic functioning of the stream or pond and alter the timing, duration, water flows, and levels that would degrade or eliminate the CRLF and/or its habitat. Such an effect could also lead to increased sedimentation and degradation in water quality to levels that are beyond the CRLF's tolerances.
(4) Elimination of upland foraging and/or aestivating habitat or dispersal habitat.
(5) Introduction, spread, or augmentation of non-native aquatic species in stream segments or ponds used by the CRLF.
(6) Alteration or elimination of the CRLF's food sources or prey base (also evaluated as indirect effects to the CRLF).

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.

2.7 Action Area

For listed species assessment purposes, the action area is considered to be the area affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). 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 its 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 CRLF and its designated critical habitat within the state of California. Deriving the geographical extent of this portion of the action area is the product of consideration of the types of effects that carbaryl may be expected to have on the environment, the exposure levels to carbaryl that are associated with those effects, and the best available information concerning the use of carbaryl and its fate and transport within the state of California.

The definition of action area requires a stepwise approach that begins with an understanding of 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. This analysis indicates that the following uses are considered as part of the federal action evaluated in this assessment: home lawns and gardens, parks, 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, roses, rights-of-way, wasteland, non-urban forests, rural shelter belts and ticks.

After determination of which uses will be assessed, an evaluation of the potential "footprint" of the use pattern is determined. This "footprint" represents the initial area of concern and is typically based on available land cover data. Local land cover data available for the state of California were analyzed to refine the understanding of potential carbaryl uses. The initial area of concern is defined as all land cover types that represent the labeled uses described above. The initial area of concern is represented by 1) agricultural landcovers, which are assumed to represent vegetable and non-orchard fruit crops as well as ornamental crops; 2) orchard and vineyard landcovers; (3) residential; (4) pasture; (5) non-urban forests. The specific uses which correspond to each of these landcovers are depicted in **Table 7**. Maps representing the land cover types that make up the initial areas of concern for these separate uses are depicted in **Figures 6-10**. These maps represent the areas that may be directly affected by the federal action.

Table 7. Carbaryl uses and their respective GIS landcovers used to depict the initial carbaryl action area for this assessment.

GIS Landcover	Uses
Orchard/vineyard	citrus, olives, almonds, chestnuts, pecans, filberts, walnuts, pistachios, peaches, apricots, cherries, nectarines, plums, prunes, pears, crabapples, oriental pears, apple, loquat, grapes
agricultural lands	asparagus, corn, strawberries, tomatoes, eggplant, peanuts, broccoli, Brussels sprouts, sweet potato, corn, lettuce, dandelion, endive, parsley, spinach, Swiss chard, sorghum, celery, horseradish, potato, parsnip, rutabaga, turnip, radish, rice, dry beans, fresh peas, dry peas, cow peas, southern peas, okra, sugar beet, alfalfa, birds foot trefoil, clover, melon, cucumber, pumpkin, squash, grass for seed, rural shelter belts, ornamentals, flowers, roses, peppers, cauliflower, cabbage, kohlrabi, Chinese cabbage, collards, kale, mustard greens, Hanover salad
residential (urban)	flower beds around buildings, roses, home lawn, lawns, parks, recreational areas, golf courses, sod farms, commercial lawns, rights-of-way, hedgerows, ditch banks, roadsides, ticks, grasshoppers
pasture	pasture, rangeland
non-urban forests	Forestry, tree plantations, Christmas trees, parks, rangeland trees

Once the initial area of concern is defined, the next step is to compare the extent of that area with the results of the screening level risk assessment. In this assessment, transport of carbaryl through runoff and spray drift is considered in deriving quantitative estimates of carbaryl exposure to CRLF, its prey and its habitats.

Since this screening level risk assessment defines taxa that are predicted to be exposed through runoff and drift to carbaryl at concentrations above the Agency's Levels of Concern (LOC), there is need to expand the action area to include areas that are affected indirectly by this federal action. Two methods are employed to define the areas indirectly affected by the federal action, and thus the total action area. These are the down stream dilution assessment for determining the extent of the affected lotic aquatic habitats (flowing water) and the spray drift assessment for determining the extent of the affected terrestrial habitats. In order to define the final action areas relevant to uses of carbaryl, it is necessary to combine areas directly affected, as well as aquatic and terrestrial habitats indirectly affected by the federal action. It is assumed that lentic (standing water) aquatic habitats (*e.g.* ponds, pools, marshes) overlapping with the terrestrial areas are also indirectly affected by the federal action. **The analysis of areas indirectly affected by the federal action, as well as the determination of the final action area for carbaryl is described in the risk discussion (Section 5.2.5).** Additional analysis related to the intersection of the carbaryl action area and CRLF habitat used in determining the final action area is described in A**ppendix C**.

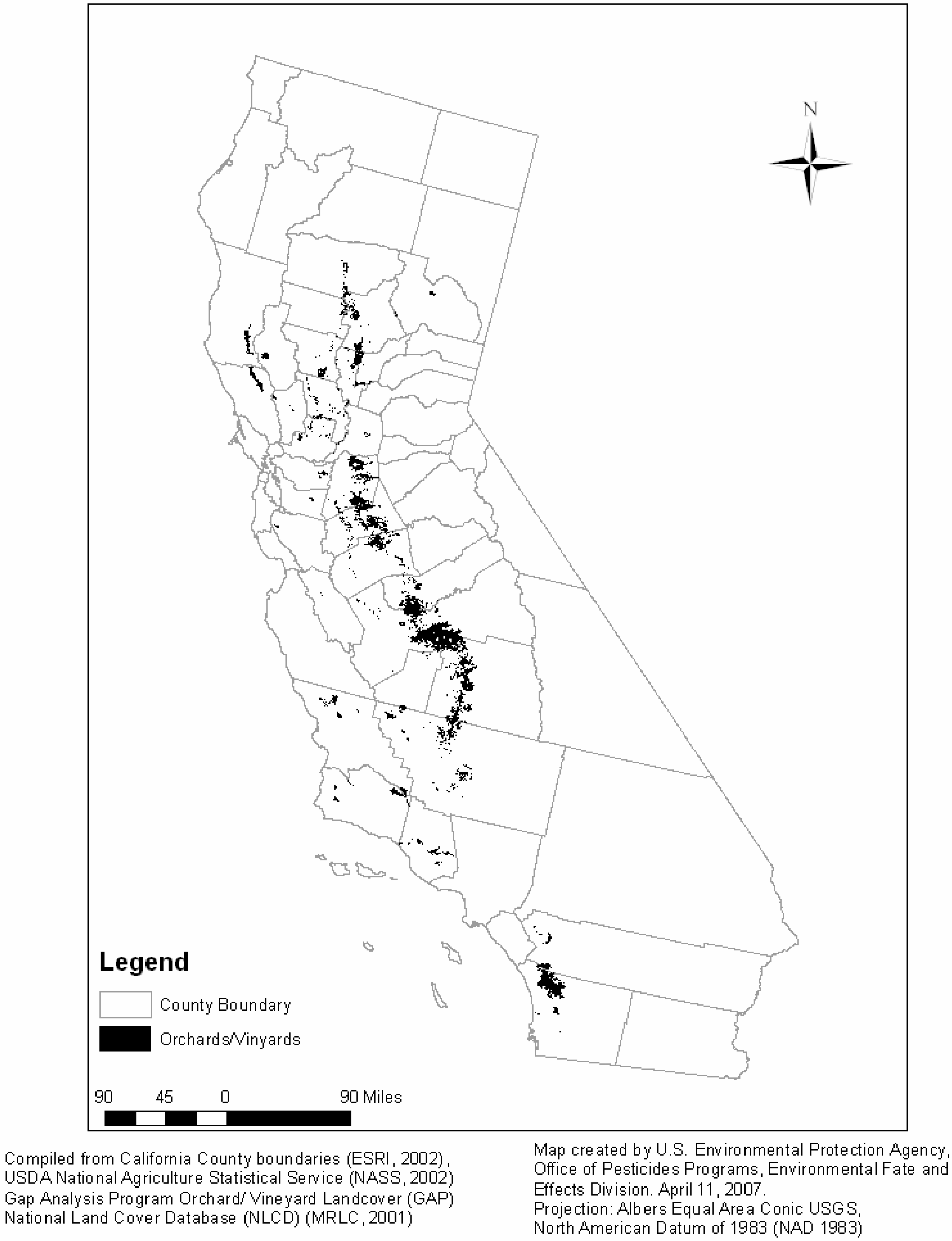


Figure 6. Initial action area for crops described by orchard/vineyard landcover which corresponds to potential carbaryl use sites. This map represents the area potentially directly affected by the federal action.

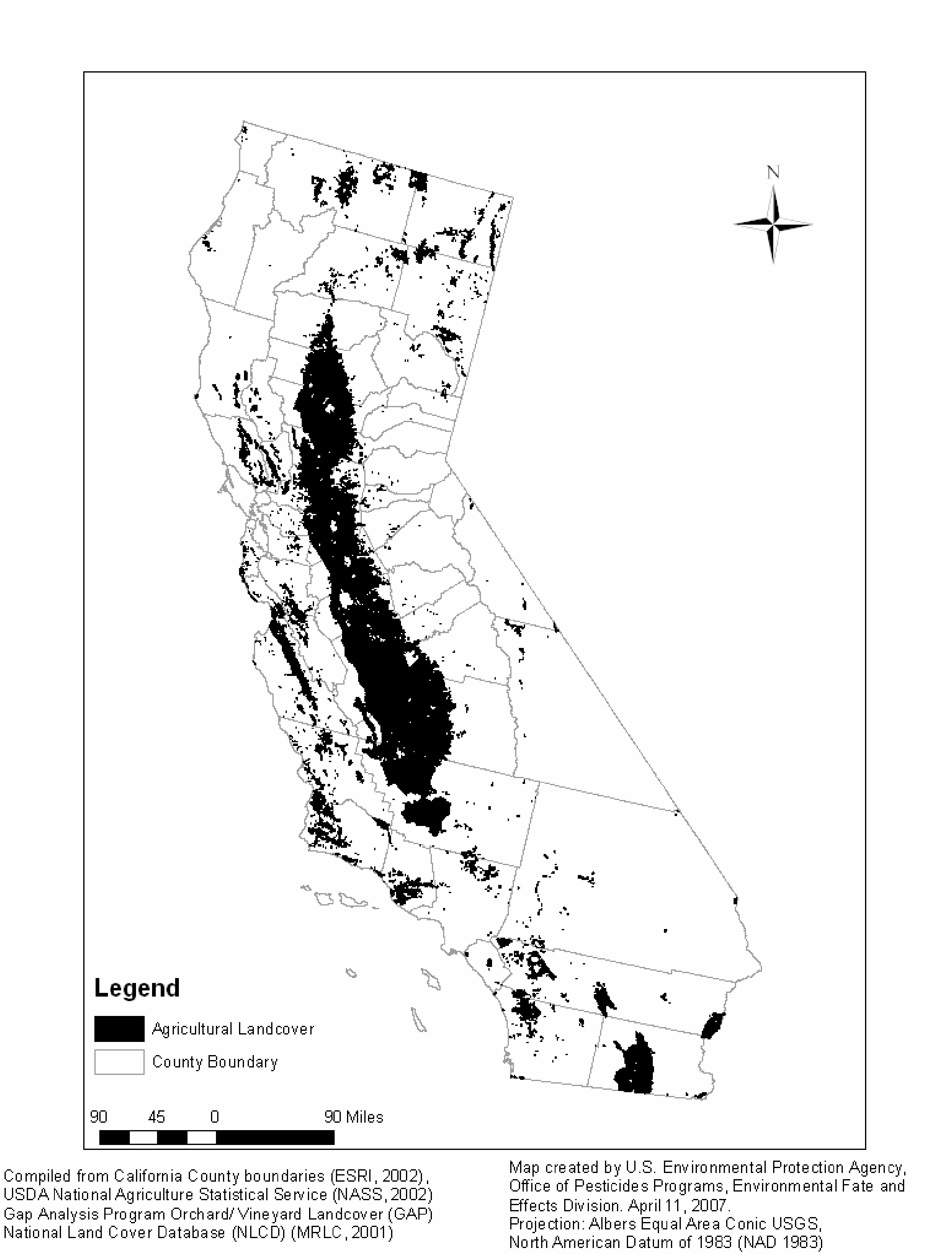


Figure 7. Initial action area for crops described by agricultural landcover which corresponds to potential carbaryl lithium use sites. This map represents the area potentially directly affected by the federal action.

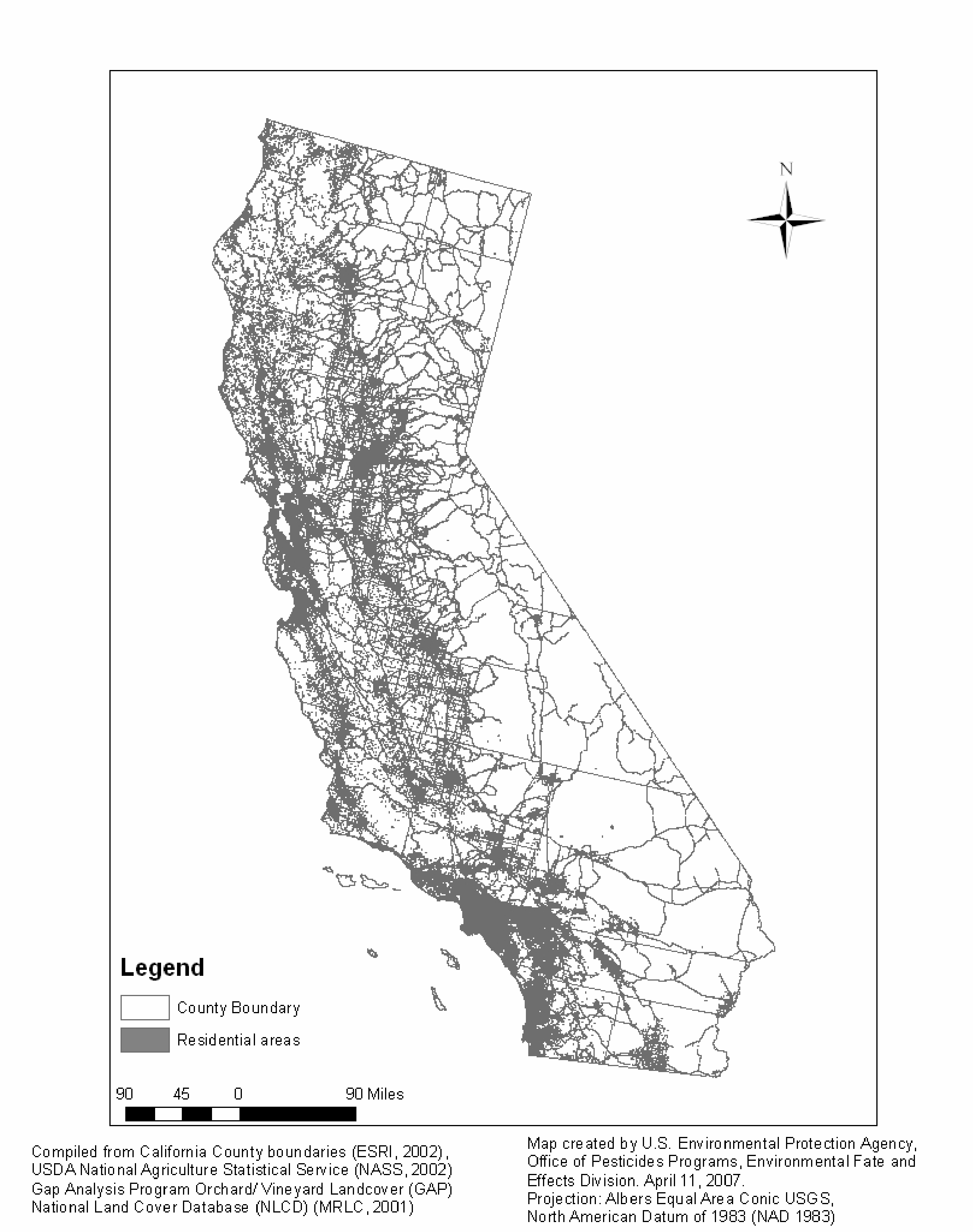
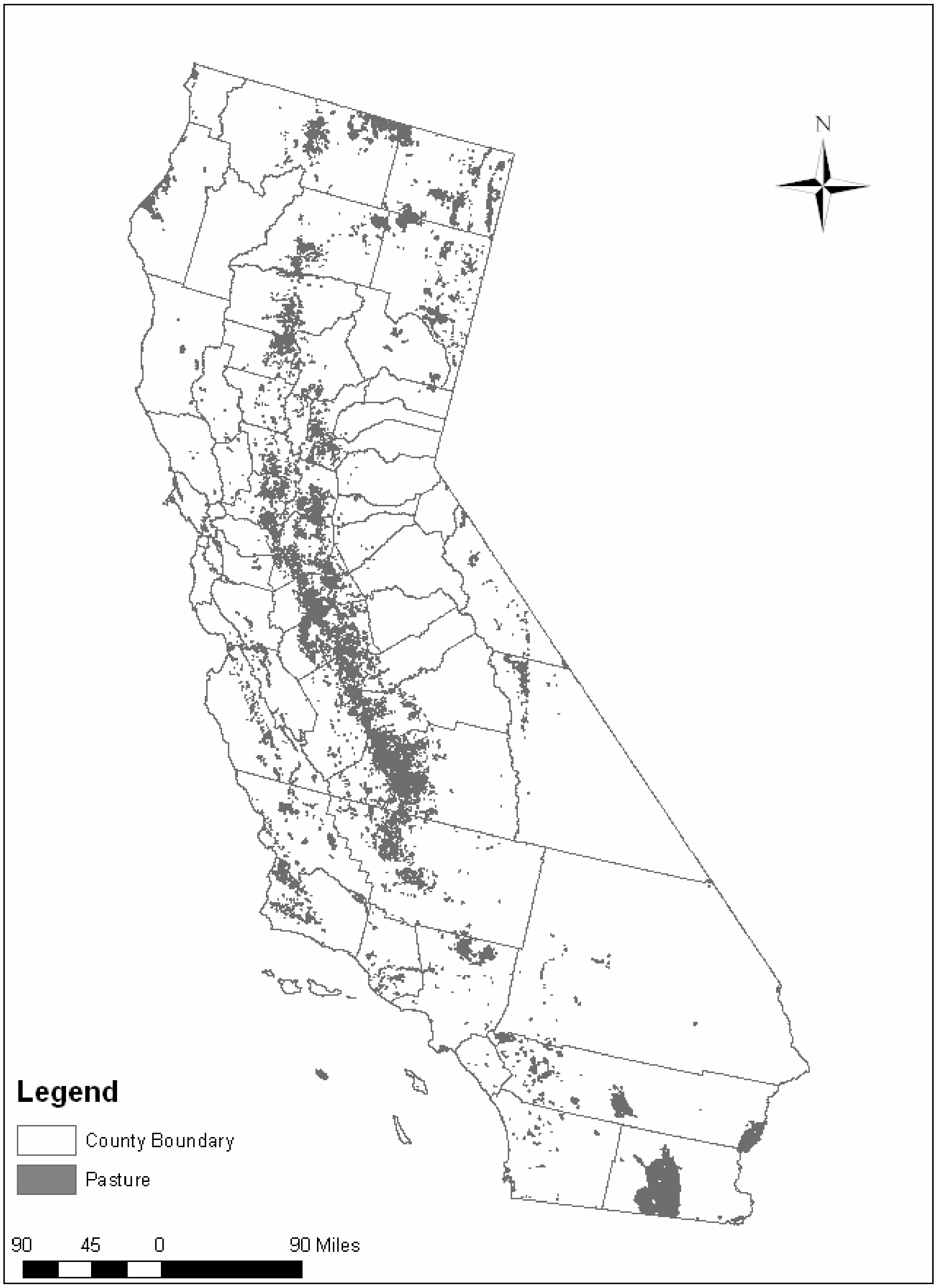


Figure 8. Initial action area for crops described by residential landcover which corresponds to potential carbaryl use sites. This map represents the area potentially directly affected by the federal action.



Compiled from California County boundaries (ESRI, 2002),
USDA National Agriculture Statistical Service (NASS, 2002)
Gap Analysis Program Orchard/ Vineyard Landcover (GAP)
National Land Cover Database (NLCD) (MRLC, 2001)

Map created by U.S. Environmental Protection Agency,
Office of Pesticides Programs, Environmental Fate and
Effects Division. April 11, 2007.
Projection: Albers Equal Area Conic USGS,
North American Datum of 1983 (NAD 1983)

Figure 9. Initial action area for crops described by pasture landcover which corresponds to potential carbaryl use sites. This map represents the area potentially directly affected by the federal action.

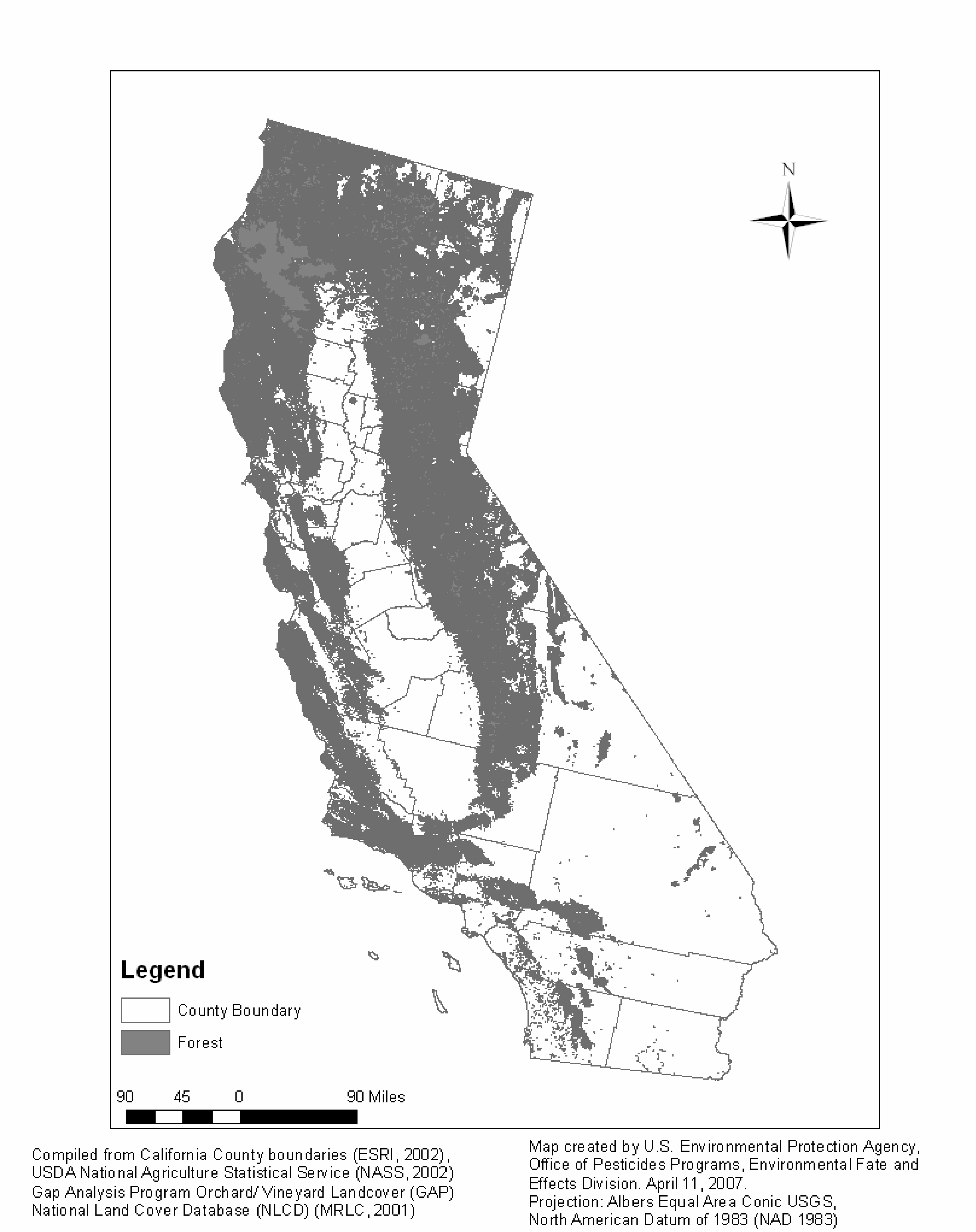


Figure 10. Initial action area for crops described by non-urban forest landcover which corresponds to potential carbaryl use sites. This map represents the area potentially directly affected by the federal action.

2.8 Assessment Endpoints and Measures of Ecological Effect

Assessment endpoints are defined as "explicit expressions of the actual environmental value that is to be protected" (USEPA 1992). Selection of the assessment endpoints is based on valued entities (*e.g*., CRLF, organisms important in the life cycle of the CRLF, and the PCEs of its designated critical habitat), the ecosystems potentially at risk (e.g,. water bodies, riparian vegetation, and upland and dispersal habitats), the migration pathways of carbaryl (*e.g.,* runoff, spray drift, *etc*.), and the routes by which ecological receptors are exposed to the pesticide (e.g., direct contact, *etc*).

2.8.1 Assessment Endpoints for the CRLF

Assessment endpoints for the CRLF include direct toxic effects on the survival, reproduction, and growth of the CRLF, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. In addition, potential modification of critical habitat is assessed by evaluating potential effects to PCEs, which are components of the habitat areas that provide essential life cycle needs of the CRLF. Each assessment endpoint requires one or more "measures of ecological effect," defined as changes in the attributes of an assessment endpoint or changes in a surrogate entity or attribute in response to exposure to a pesticide. Specific measures of ecological effect are generally evaluated based on acute and chronic toxicity information from registrant-submitted guideline tests that are performed on a limited number of organisms. Additional ecological effects data from the open literature are also considered.

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. A summary of the assessment endpoints and measures of ecological effect selected to characterize potential assessed direct and indirect CRLF risks associated with exposure to carbaryl is provided in **Table 8**.

Table 8. Summary of Assessment Endpoints and Measures of Ecological Effects for Direct and Indirect Effects of Carbaryl on the California Red-legged Frog.

Assessment Endpoint	Measures of Ecological Effects
Aquatic Phase (eggs, larvae, tadpoles, juveniles, and adults)[a]	
1. Survival, growth, and reproduction of CRLF individuals via direct effects on aquatic phases	1a. Atlantic salmon LC_{50} 1b. Atlantic salmon NOAEC[d]
2. Survival, growth, and reproduction of CRLF individuals via effects to food supply (*i.e.,* freshwater invertebrates, non-vascular plants)	2a. Stonefly acute EC_{50} 2b. Stonefly chronic NOAEC[d] 2c. Algae EC_{50}
3. Survival, growth, and reproduction of CRLF individuals via indirect effects on habitat, cover, and/or primary productivity (*i.e.,* aquatic plant community)	3a. Non-vascular plant acute EC_{50} (freshwater algae or diatom, or ECOTOX non-vascular)
4. Survival, growth, and reproduction of CRLF individuals via effects to riparian vegetation, required to maintain acceptable water quality and habitat in ponds and streams comprising the species' current range.	4a. Tier 1 vegetative vigor studies used qualitatively in conjunction with incident data and the use of carbaryl to intentionally affect the growth of plants.
Terrestrial Phase (Juveniles and adults)	
5. Survival, growth, and reproduction of CRLF individuals via direct effects on terrestrial phase adults and juveniles	5a. Mallard acute LD_{50} 5b. Mallard subacute LC_{50} 5b. Mallard chronic NOAEC
6. Survival, growth, and reproduction of CRLF individuals via effects on prey (*i.e.,* terrestrial invertebrates, small terrestrial vertebrates, including mammals and terrestrial phase amphibians)	6a. Honeybee acute contact LD_{50} 6b. Most sensitive terrestrial mammal acute LD_{50} 6c. Most sensitive terrestrial mammal chronic NOAEC 6d. Mallard acute LD_{50} 6e. Mallard subacute LC_{50} 6f. Mallard chronic NOAEC
7. Survival, growth, and reproduction of CRLF individuals via indirect effects on habitat (*i.e.,* riparian vegetation)	7a. Tier 1 vegetative vigor studies used qualitatively in conjunction with incident data and the use of carbaryl to intentionally affect the growth of plants.

[a] Adult frogs are no longer in the "aquatic phase" of the amphibian life cycle; however, submerged adult frogs are considered "aquatic" for the purposes of this assessment because exposure pathways in the water are considerably different that exposure pathways on land.
[b] Birds are used as surrogates for terrestrial phase amphibians.
[c] Although the most sensitive toxicity value is initially used to evaluate potential indirect effects, sensitivity distribution is used (if sufficient data are available) to evaluate the potential impact to food items of the CRLF.
[d] Estimated using acute-to-chronic ratio.

2.8.2 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 CRLF's critical habitat. PCEs for the CRLF were previously described in Section 2.6. Actions that may modify critical habitat are those that alter the PCEs and may jeopardize the continued existence of the CRLF. 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 and measures of ecological effect selected to characterize potential modification to designated critical habitat associated with exposure to carbaryl are provided in **Table 9**. Adverse modification to the critical habitat of the CRLF includes the following, as specified by USFWS (2006) and previously discussed in Section 2.6:

1. Alteration of water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs.
2. Alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs.
3. Significant increase in sediment deposition within the stream channel or pond or disturbance of upland foraging and dispersal habitat.
4. Significant alteration of channel/pond morphology or geometry.
5. Elimination of upland foraging and/or aestivating habitat, as well as dispersal habitat.
6. Introduction, spread, or augmentation of non-native aquatic species in stream segments or ponds used by the CRLF.
7. Alteration or elimination of the CRLF's food sources or prey base.

Measures of such possible effects by labeled use of carbaryl on critical habitat of the CRLF are described in **Table 9**. 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. Assessment endpoints used for the analysis of designated critical habitat are based on the modification standard established by USFWS (2006).

Table 9. Summary of Assessment Endpoints and Measures of Ecological Effect for Primary Constituent Elements of Designated Critical Habitat.

<table>
<tr><th>Assessment Endpoint</th><th>Measures of Ecological Effect</th></tr>
<tr><td colspan="2">Aquatic-Phase PCEs
(Aquatic Breeding Habitat and Aquatic Non-Breeding Habitat)</td></tr>
<tr><td>Alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond: aquatic habitat (including riparian vegetation) provides for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs.</td><td>a. Most sensitive aquatic plant EC_{50}
b. Tier 1 vegetative vigor studies used qualitatively in conjunction with incident data and the use of carbaryl to intentionally affect the growth of plants.</td></tr>
<tr><td>Alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food source.*</td><td>a. Non-vascular plant acute EC_{50} (freshwater algae)
b. Tier 1 vegetative vigor studies used qualitatively in conjunction with incident data and the use of carbaryl to intentionally affect the growth of plants.</td></tr>
<tr><td>Alteration of other chemical characteristics necessary for normal growth and viability of CRLFs and their food source.</td><td>a. Atlantic salmon acute LC_{50}
b. Atlantic salmon chronic NOAEC**
c. Stonefly acute EC_{50}
d. Stonefly chronic NOAEC**</td></tr>
<tr><td>Reduction and/or modification of aquatic-based food sources for pre-metamorphs (e.g., algae)</td><td>a. Algae EC_{50}</td></tr>
<tr><td colspan="2">Terrestrial-Phase PCEs
(Upland Habitat and Dispersal Habitat)</td></tr>
<tr><td>Elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs: Upland areas within 200 ft of the edge of the riparian vegetation or dripline surrounding aquatic and riparian habitat that are comprised of grasslands, woodlands, and/or wetland/riparian plant species that provides the CRLF shelter, forage, and predator avoidance</td><td rowspan="4">a. Distribution of EC_{25} values for monocots (seedling emergence, vegetative vigor)
b. Distribution of EC_{25} values for dicots (seedling emergence, vegetative vigor)
c. Most sensitive food source acute EC_{50}/LC_{50} and NOAEC values for terrestrial vertebrates (mammals) and invertebrates, birds or terrestrial-phase amphibians, and freshwater fish.</td></tr>
<tr><td>Elimination and/or disturbance of dispersal habitat: Upland or riparian dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal</td></tr>
<tr><td>Reduction and/or modification of food sources for terrestrial phase juveniles and adults</td></tr>
<tr><td>Alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs and their food source.</td></tr>
</table>

- Physico-chemical water quality parameters such as salinity, pH, and hardness are not evaluated because these processes are not biologically mediated and, therefore, are not relevant to the endpoints included in this assessment.

2.9 Conceptual Model

2.9.1 Risk Hypotheses

Risk hypotheses are specific assumptions about potential effects (*i.e.*, changes in assessment endpoints) and may be based on theory and logic, empirical data, mathematical models, or probability models (U.S. EPA, 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 for this endangered species assessment:

- Labeled uses of carbaryl within the action area may directly affect the CRLF by causing mortality or by affecting growth or fecundity;

- Labeled uses of carbaryl within the action area may indirectly affect the CRLF by reducing or changing the composition of food supply;
- Labeled uses of carbaryl within the action area may indirectly affect the CRLF and/or modify designated critical habitat by reducing or changing the composition of the aquatic plant community in the ponds and streams comprising the species' current range and designated critical habitat, thus affecting primary productivity and/or cover;
- Labeled uses of carbaryl within the action area may indirectly affect the CRLF and/or modify designated critical habitat by reducing or changing the composition of the terrestrial plant community (*i.e.*, riparian habitat) required to maintain acceptable water quality and habitat in the ponds and streams comprising the species' current range and designated critical habitat;
- Labeled uses of carbaryl within the action area may modify the designated critical habitat of the CRLF by reducing or changing breeding and non-breeding aquatic habitat (via modification of water quality parameters, habitat morphology, and/or sedimentation);
- Labeled uses of carbaryl within the action area may modify the designated critical habitat of the CRLF by reducing the food supply required for normal growth and viability of juvenile and adult CRLFs;
- Labeled uses of carbaryl within the action area may modify the designated critical habitat of the CRLF by reducing or changing upland habitat within 200 ft of the edge of the riparian vegetation necessary for shelter, foraging, and predator avoidance.
- Labeled uses of carbaryl within the action area may modify the designated critical habitat of the CRLF by reducing or changing dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal.
- Labeled uses of carbaryl within the action area may modify the designated critical habitat of the CRLF by altering chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs.

2.9.2 Diagram

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the stressor (carbaryl), release mechanisms, biological receptor types, and effects endpoints of potential concern. The conceptual models for aquatic and terrestrial phases of the CRLF are shown in **Figures 11** and **12**, and the conceptual models for the aquatic and terrestrial PCE components of critical habitat are shown in **Figures 13** and **14**. Exposure routes shown in dashed lines are not quantitatively considered because the resulting exposures are expected to be so low as not to cause effects to the CRLF.

The environmental fate properties of carbaryl along with monitoring data identifying its presence in surface waters, air and precipitation in California indicate that runoff, spray drift, volatilization and limited atmospheric transport and deposition represent potential transport mechanisms of carbaryl to the aquatic and terrestrial habitats of the CRLF. These transport properties (*e.g.* sources) are depicted in the conceptual models below (**Figures 11-14**) along with the receptors of concern and the potential attribute changes in the receptors due to exposures to carbaryl.

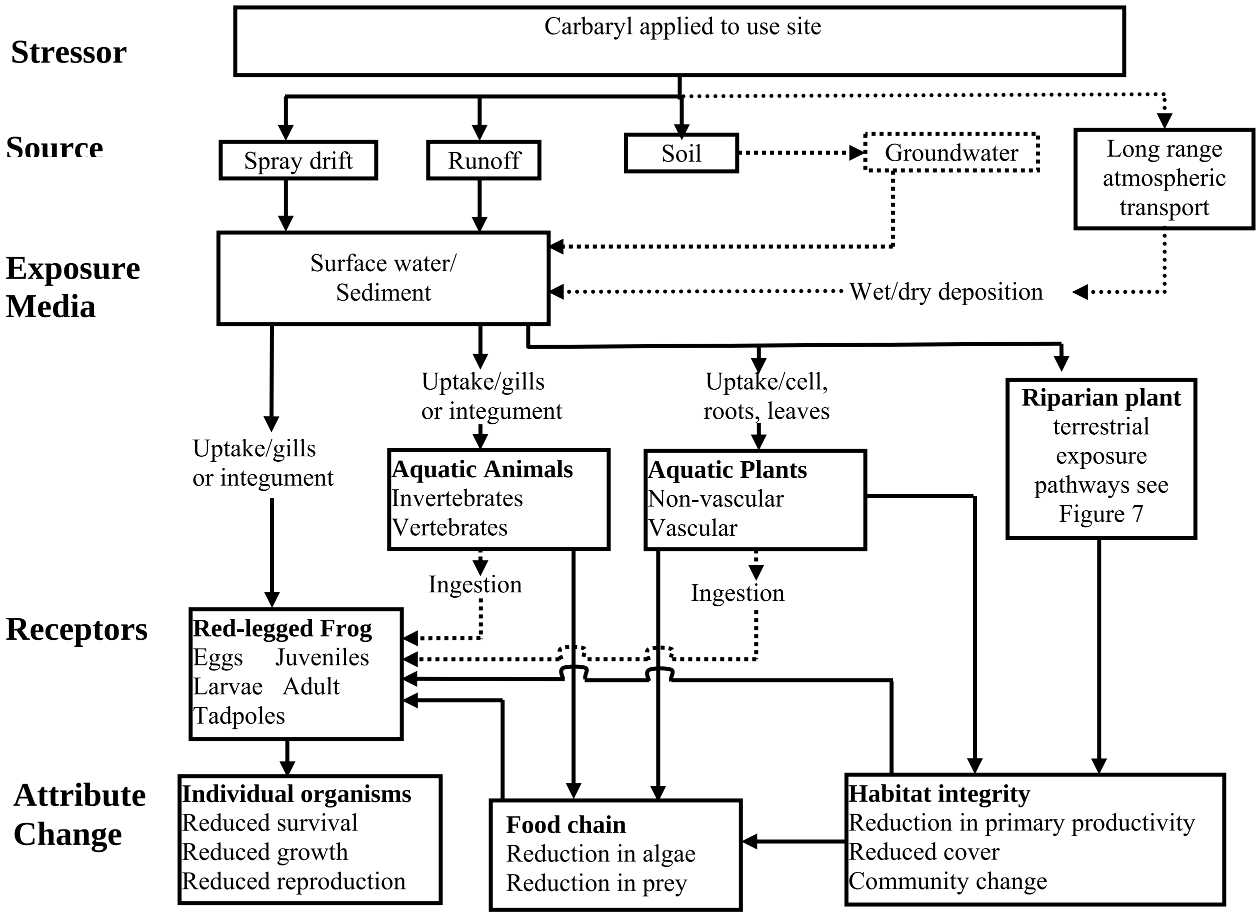


Figure 11. Conceptual model for potential effects of carbaryl on the aquatic phase of the California red-legged frog.

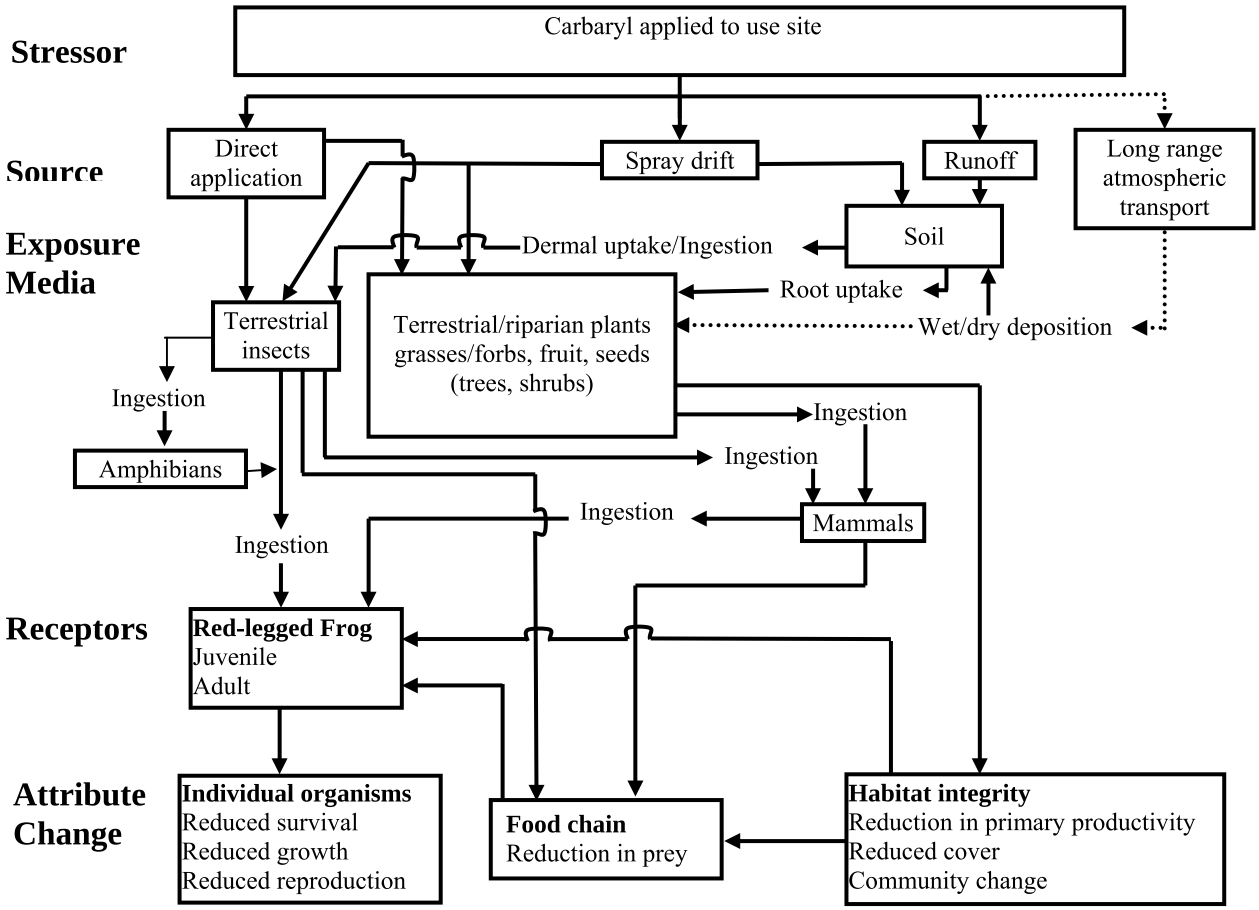


Figure 12. Conceptual model for the potential effects of carbaryl on the terrestrial phase of the California red-legged frog.

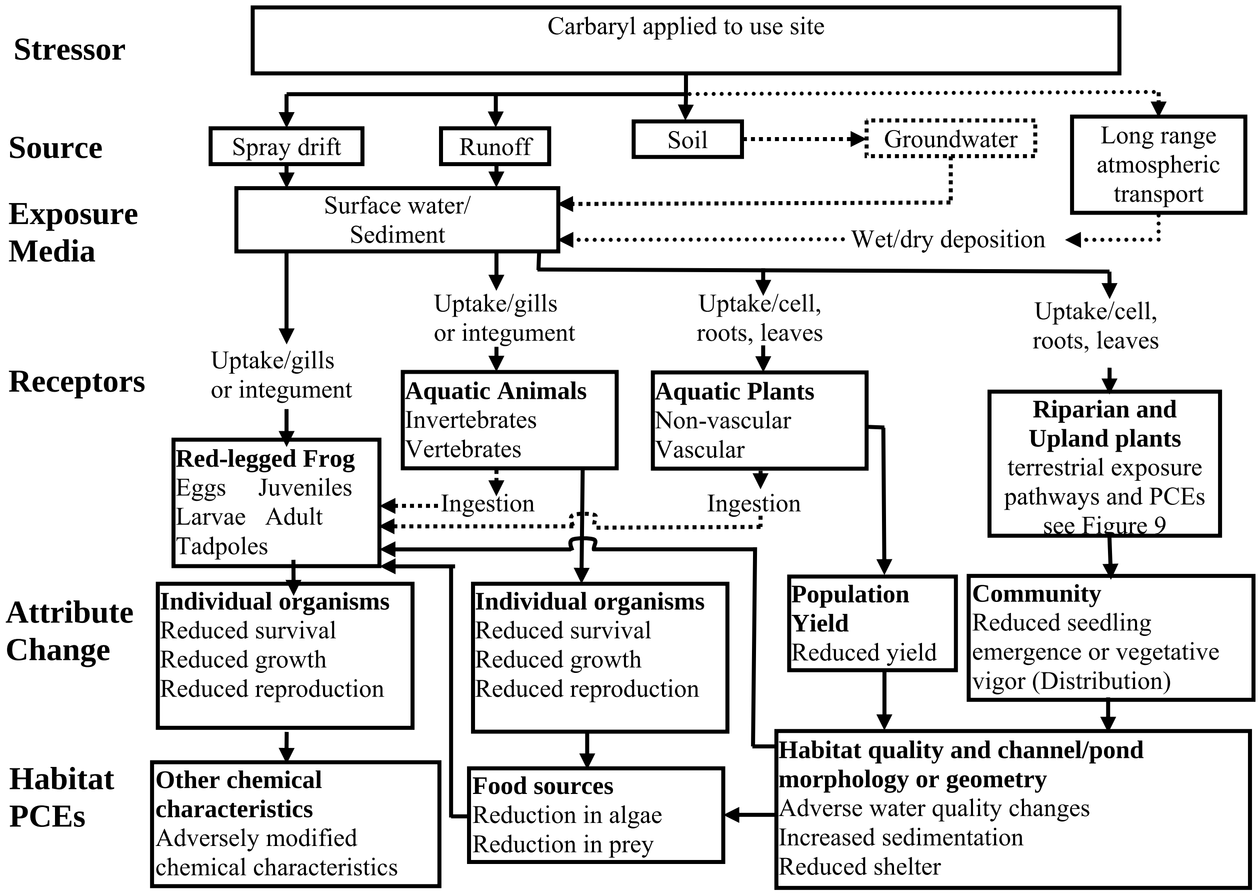


Figure 13. Conceptual model for the potential effects of carbaryl on aquatic components of the California red-legged frog critical habitat.

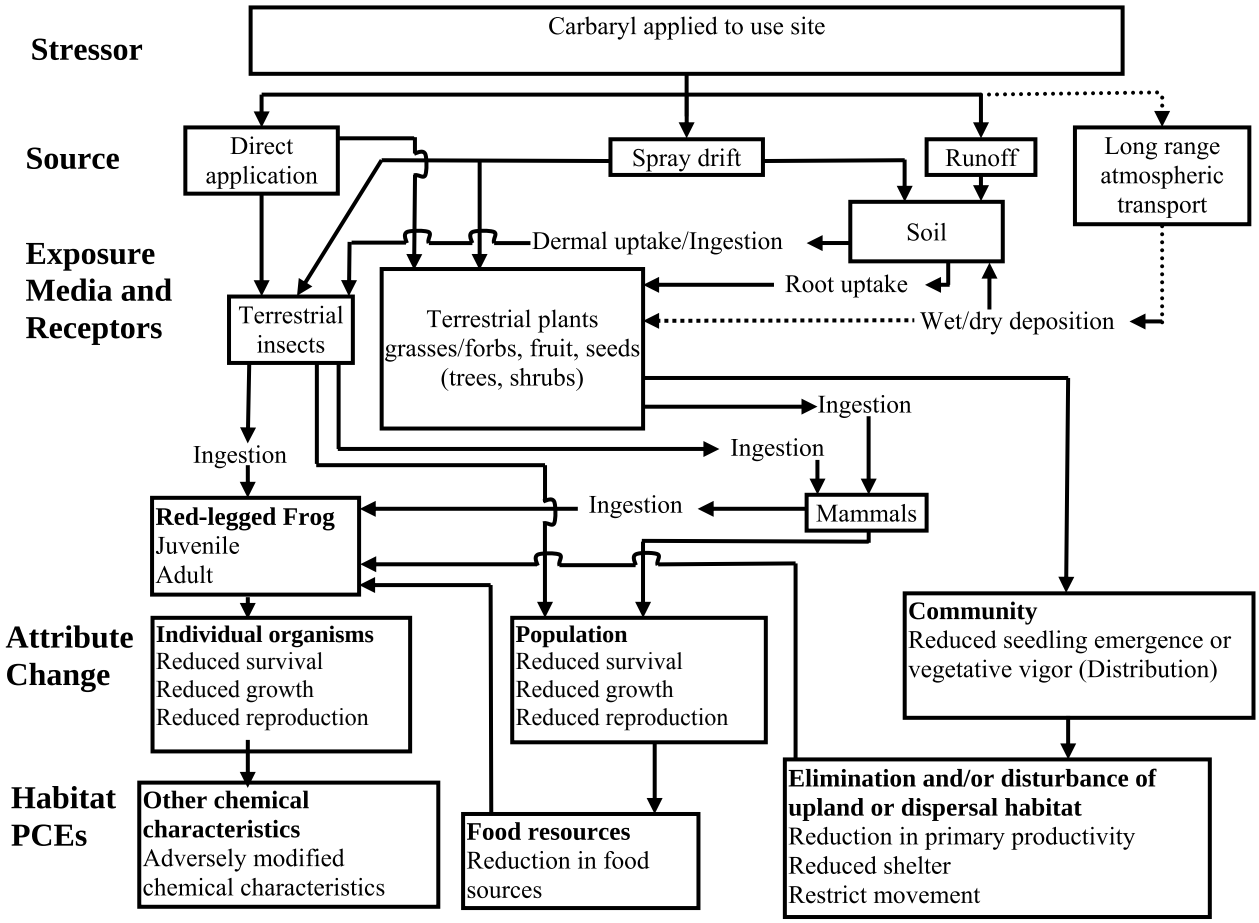


Figure 14. Conceptual model for the potential effects of carbaryl on terrestrial components of the California red-legged frog critical habitat.

2.10 Analysis Plan

In order to address the risk hypothesis, the potential for effects on the CRLF, its prey and its habitat is estimated. In the following sections, the use, environmental fate, and ecological effects of carbaryl are characterized and integrated to assess the risks. This was accomplished using a risk quotient (ratio of exposure concentration to effects concentration) approach. Although risk is often defined as the likelihood and magnitude of ecological effects, the risk quotient-based approach does not provide a quantitative estimate of likelihood and/or magnitude of an effect. However, as outlined in the Overview Document (USEPA 2004), 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.

2.10.1. Measures to Evaluate the Risk Hypothesis and Conceptual Model

2.10.1.1. 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 of the CRLF. In this assessment, transport of carbaryl through runoff and spray drift is considered in deriving quantitative estimates of carbaryl exposure to CRLF, 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 CRLF and its habitats, adequate tools are unavailable at this time to quantify exposures through these pathways. Therefore, volatilization, atmospheric transport and wet and dry deposition from the atmosphere are only discussed qualitatively in this assessment.

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). The model used to predict terrestrial EECs on food items was T-REX. These models were parameterized using relevant reviewed registrant-submitted environmental fate data.

PRZM (v3.12beta, May 24, 2001) and EXAMS (v2.98.04, Aug. 18, 2002) are screening simulation models coupled with the input shell pe4v01.pl (Aug.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 CRLF, as well as indirect effects to the CRLF 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 CRLF and fish and frogs serving as 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 (Orrick and Young 2007).

Exposure estimates for terrestrial phase CRLF and terrestrial invertebrates and mammals (serving as potential prey) assumed to be in the target area or in an area exposed to spray drift are derived using the T-REX model (version 1.3.1, 12/07/2006). This model incorporates the Kenega nomograph, as modified by Fletcher *et al.* (1994), which is based on a large set of actual field residue data. The upper limit values from the nomograph represented the 95th percentile of residue values from actual field measurements (Hoerger and Kenega, 1972). The Fletcher *et al.* (1994) modifications to the Kenega nomograph are based on measured field residues from 249 published research papers, including information on 118 species of plants, 121 pesticides, and 17 chemical classes. These modifications represent the upper bound of the expanded data set. For modeling purposes, direct exposures of the CRLF to carbaryl through contaminated food are estimated using the EECs for the small bird (20 g) which consumes small insects. Dietary-based and dose-based exposures of potential prey (small mammals) are assessed using the small mammal (15 g) which consumes short grass. The small bird (20g) consuming small insects and the small mammal (15g) consuming short grass were used because these categories represent the largest RQs of the size and dietary categories in T-REX that are appropriate surrogates for the CRLF and one of its prey items. Estimated exposures of terrestrial insects to carbaryl are bound by using the dietary based EECs for small insects and large insects.

Birds are currently used as surrogates for terrestrial-phase CRLF. However, amphibians are poikilotherms (body temperature varies with environmental temperature) while birds are homeotherms (temperature is regulated, constant, and largely independent of environmental temperatures). Therefore, amphibians tend to have much lower metabolic rates and lower caloric intake requirements than birds or mammals. As a consequence, birds are likely to consume more food than amphibians on a daily dietary intake basis, assuming similar caloric content of the food items. Therefore, the use of avian food intake allometric equation as a surrogate to amphibians is likely to result in an over-estimation of exposure and risk for reptiles and terrestrial-phase amphibians. Therefore, T-REX (version 1.3.1) has been refined to the T-HERPS model (v. 1.0), which allows for an estimation of food intake for poikilotherms using the same basic procedure as T-REX to estimate avian food intake.

Two spray drift models, AGDISP and AgDRIFT were used to assess exposures of terrestrial phase CRLF and its prey to carbaryl deposited in spray drift. AGDisp (version 8.13; dated 12/14/2004) (Teske and Curbishley, 2003) is used to simulate aerial and ground applications using the Gaussian far-field extension. AgDrift (version 2.01; dated 5/24/2001) is used to simulate spray blast applications to orchard crops.

2.10.1.2. Measures of Effect

Data identified in Section 2.8 are used as measures of effect for direct and indirect effects to the CRLF. Data were obtained from registrant submitted studies or from literature studies identified by ECOTOX. The ECOTOXicology database (ECOTOX) was searched in order to provide more ecological effects data and in an attempt to bridge existing data gaps. ECOTOX is a source for locating single chemical toxicity data for aquatic life, terrestrial plants, and wildlife. ECOTOX was created and is maintained by the USEPA, Office of Research and Development, and the

National Health and Environmental Effects Research Laboratory's Mid-Continent Ecology Division (ECOTOX, 2006).

The assessment of risk for direct effects to the CRLF makes the assumption that avian toxicity is similar to terrestrial-phase CRLF. The same assumption is made for fish and aquatic-phase CRLF. Aquatic invertebrates and algae represent potential prey of the CRLF in the aquatic habitat. Aquatic plants and semi-aquatic plants represent habitat of CRLF. Terrestrial invertebrates and small mammals represent potential prey of the CRLF in the terrestrial habitat.

The acute measures of effect used for animals in this assessment are the LD_{50}, LC_{50} and EC_{50}. The acronym “LD” stands for "Lethal Dose", and LD_{50} is the amount of a material, given all at once, that is estimated to cause the death of 50% of the test organisms. The acronym “LC” stands for “Lethal Concentration” and LC_{50} is the concentration of a chemical that is estimated to kill 50% of the test organisms. The acronym “EC” stands for “Effective Concentration” and the EC_{50} is the concentration of a chemical that is estimated to produce a specific effect in 50% of the test organisms. Endpoints for chronic measures of exposure for listed and non-listed animals are the NOAEL/NOAEC and NOEC. The acronym “NOAEL” stands for “No Observed-Adverse-Effect-Level” and refers to the highest tested dose of a substance that has been reported to have no harmful (adverse) effects on test organisms. The NOAEC (*i.e.*, “No-Observed-Adverse-Effect-Concentration”) is the highest test concentration at which none of the observed effects were statistically different from the control. The NOEC is the No-Observed-Effects-Concentration. For non-listed plants, only acute exposures are assessed (*i.e.*, EC_{25} for terrestrial plants and EC_{50} for aquatic plants).

2.10.1.3. Integration of Exposure and Effects

Risk characterization is the integration of exposure and ecological effects characterization to determine the potential ecological risk from the use of carbaryl on fruits, nuts, vegetables and ornamentals, and the likelihood of direct and indirect effects to CRLF in aquatic and terrestrial habitats. The exposure and toxicity effects data are integrated in order to evaluate the risks of ecological effects on non-target species. For the assessment of carbaryl risks, 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 **Table 10**). These criteria are used to indicate when carbaryl’s uses, as directed on the label, have the potential to cause direct or indirect effects to the CRLF.

Table 10. Agency risk quotient (RQ) metrics and levels of concern (LOC) per risk class.

Risk Class	Description	RQ	LOC
Aquatic Habitats			
Acute Listed Species	CRLF may be potentially affected by use by direct or indirect effects.	Peak EEC/EC_{50}[1]	0.05
Chronic Listed Species	Potential for chronic risk to CRLF through direct or indirect effects. Indirect effects represented by effects to invertebrates, which represent potential prey.	60-day EEC/NOEC (CRLF) 21-day EEC/NOEC (invertebrates)	1
Non-Listed	Potential for effects in non-listed plants.	Peak EEC/ EC_{50}	1
Terrestrial Habitats			
Acute Listed Species	CRLF may be potentially affected by use by direct or indirect effects.	Dietary EEC [2]/LC_{50} Or Dose EEC [2]/LD_{50}	0.1
Acute Listed Species	Potential effects to terrestrial invertebrates. CRLF may be potentially affected by use by direct or indirect effects.	EEC [2]/LD_{50}	0.05
Chronic Listed Species	Potential for chronic risk to CRLF through direct or indirect effects. Indirect effects represented by effects to small mammals, which represent potential prey.	EEC [2]/NOAEC	1
Non-Listed	Potential for effects in non-listed plants.	Peak EEC/ EC_{25}	1

[1] LC_{50} or EC_{50}.
[2] Based on upper-bound Kenaga values.

3. Exposure Assessment

3.1 Aquatic Exposure Assessment

3.1.1 Existing Water Monitoring Data for California

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. In addition, 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.

3.1.1.1. National NAWQA Data (2000-2005)

In 2003, EFED 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 (USGS 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 concentration 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 across all sites. For samples with positive detections the mean concentration was 0.11 µg/L, with a standard deviation of 0.43 µg/L. In a summary of pesticide occurrence and concentrations for 40 NAWQA stream sites within primarily agricultural basins, carbaryl was detected in 11% of the samples (N = 1,001) with a maximum concentration of 1.5 µg/L.

In a report released in 2006 summarizing pesticide results from NAWQA from 1992 – 2001 (USGS 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 µg/L. Detection frequencies in agricultural and mixed-land use streams were lower (10% and 17%, respectively), and concentrations associated with those land uses were almost all less than 0.1 µg/L.

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 µg/L. The maximum concentration reported was 33.5 µg/L at a location associated with agricultural land (mean in agricultural areas: 0.094 μg/L). The detection frequency associated with agricultural uses was lower (19%) than that associated with urban uses (50%). The highest concentration reported in urban areas was 16 μg/L 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. The concentrations detected in urban streams (mostly low concentrations, a few detections in the multiple ppb range), is also consistent with earlier data. The relatively high concentration reported associated with agricultural uses (33.5 μg/L), is unusual but not outside of the range predicted by modeling.

3.1.1.2. NAWQA Data (1999-2005) for California

NAWQA monitoring data are available for carbaryl from California surface waters (USGS 2007) (**Table 1, Figure 15**). 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 landcover composition of the watershed of the surface waters from which samples were taken. Available NAWQA data from surface waters with watershed landcovers defined as agricultural, mixed, other and urban are defined separately in **Table 11**.

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 CRLF (i.e. 12.5 μg/L). 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. 0.255 μg/L); while none of the 99 total samples analyzed by HPLC contained levels sufficient to exceed the LOC for aquatic invertebrates.

Detections of carbaryl in water bodies with urban landcovers were 54.1-76.7% of analyzed samples. These detection rates were greater when compared to all other types of watershed landcovers. 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 11**).

Table 11. NAWQA 1999 - 2005 data for carbaryl detections in CA surface waters with watersheds with different landcover 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 (µg/L)	0.657	0.750	0.041	1.060	**1.060**
% Samples with concentrations sufficient to exceed LOC for acute exposures to CRLF [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 (µg/L)	0.222	<0.0628	<0.0284	0.1922	**0.1922**
% Samples with concentrations sufficient to exceed LOC for acute exposures to CRLF [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 µg/L
[2]Based on an LC_{50} of 220 µg/L 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 5.1 µg/L for stonefly, the concentration required to exceed the acute exposure LOC of 0.05 is 0.255 µg/L.

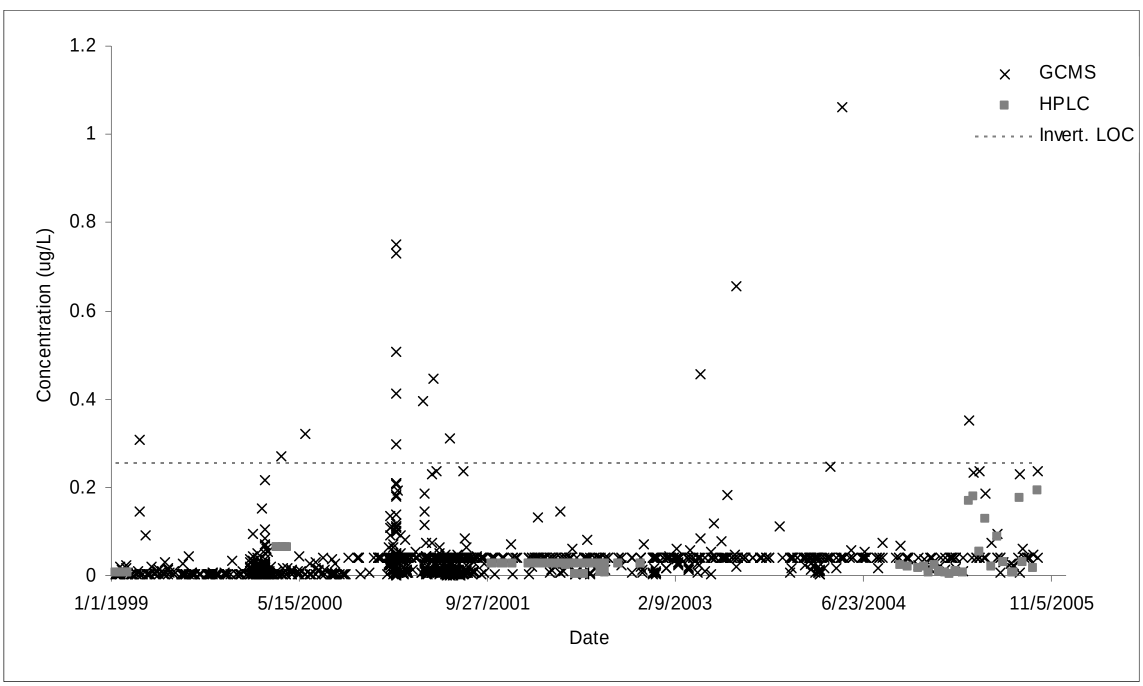


Figure 15. Concentrations of carbaryl reported by NAWQA in CA surface waters from 1999-2005.

3.1.1.3. California Department of Pesticide Regulation Surface Water Database

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 CRLF core areas 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.

3.1.1.4. 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 tank mixtures, 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.

3.1.1.5. 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 of 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 µg /L. **Figure 16**, 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 µg /L.

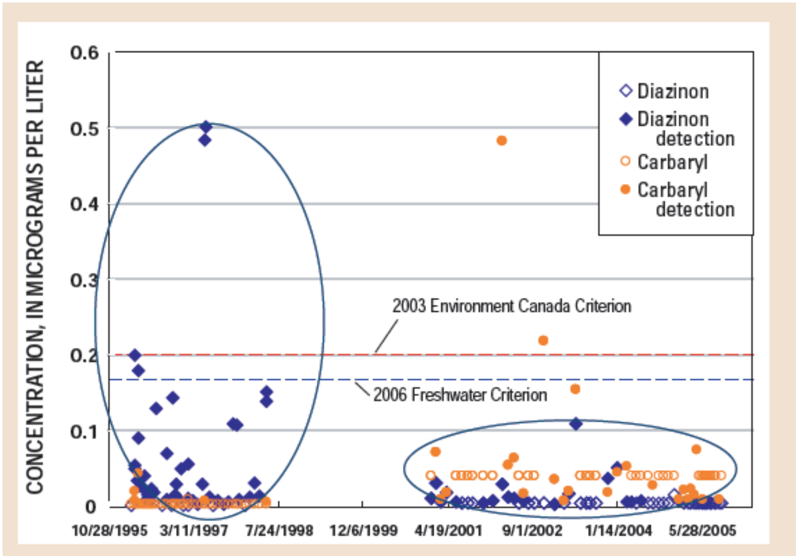


Figure 16. Temporal Changes in Surface-water Insecticide Concentrations after the phase-out of diazinon and chlorpyrifos (Phillips et al., 2007).

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.

3.1.2. Modeling Approach

For this assessment, estimates of carbaryl concentrations in surface water were calculated using PRZM version 3.12 dated May 24, 2001 and EXAMS version 2.98.04 dated July 18, 2002. These models were run in the EFED PRZM EXAMS shell, PE4 version 1.2, dated October 15, 2002. The shell also processed the output from EXAMS to estimate the 1 in 10 year return values reported here. 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 **Table20** 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 a organic carbon content of 0.01 to translate Koc (**Table 13**) to K_d and application rate (**Table 14**). At table listing of the input files used for this assessment is in **Appendix D**.

3.1.2.1. PRZM scenarios

Scenarios used for each use pattern as well as the date for the first application each year are in **Table 12.** 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.

Table 12. PRZM scenario assignments and first application dates for the uses of carbaryl simulated for the aquatic exposure assessment for the California CRLF 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
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	January 1
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**.

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 E**.

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 F.**

Lawns (Group C): This scenario is distinct from the home lawn scenario in that in 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 14**.

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 to 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 14**. April 1 represents an early season application of carbaryl to citrus crops and was the value used in the previous aquatic exposure assessment (Jones 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): 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 two peaches, during the growing season and during the dormant season. Two applications of four 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 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 made at 3-d intervals during harvest starting January 1, while a single application of 4 lb/acre was made 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.

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 Brussel 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 on 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 as beans is 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.

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 grass grown for seed somewhat resembles. 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 G**.

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 data 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.

3.1.2.2. Input Parameters

Chemical-specific parameters

The input parameters used to describe the chemical properties of carbaryl are in **Table 13**. In most cases these parameters were selected in accordance with guidance (Environmental Fate and Effects Division, 2002). In some cases though, no guidance exists, *e.g.*, selection of wash-off ratios; in these cases, the method used to select the input parameter is described more thoroughly below. Data quality descriptions for each parameter were derived as follows. The descriptor "Excellent" is used to describe parameters which are very well know and had little or no error associated with them (*e.g.* molecular weight) or when there is an abundance of high quality data available. The descriptor "Very good" is used to describe parameters from high quality studies and the study is generally reproducible (*e.g.* hydrolysis), or when there is substantial background variability (*e.g.* aerobic soil metabolism) there are multiple high quality studies used to develop the input parameter. The descriptor "Good" is used where the data is expected to be reproducible, but is more uncertain than normal, or if metabolism parameters are based on two high quality studies, or where there are multiple studies which are usable but not high quality. The descriptor "Fair" is used to describe metabolism parameters based on a single study, or where the data set is significantly flawed but still provide some usable information. The descriptor "Poor" is used describe input parameters based on surrogate data.

In the previous modeling for aquatic exposure, soil-water partitioning used K_d values which were keyed to soil texture. Since texture is usually only a factor of secondary importance, this method of parameter selection would not be expected to result in great accuracy. In this assessment, an organic carbon partition coefficient (K_{oc}) was estimated by regressing the adsorption K_f values against the organic carbon content. 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 2004).

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.

In the original science chapter in support of the reregistration eligibility decision for carbaryl (USEPA 2003), the foliar degradation half-life was set to 35 days based OPP policy for terrestrial exposure assessments in the absence of measured foliar degradation rates. Current guidance is to use a rate constant of zero for aquatic assessments in the absence of data. Bayer CropScience, provided data (MRID 45860501) indicating that carbaryl degrades on foliage at substantially faster rate than 35 d. The data discussed in the submission provided by the registrant was reviewed and analyzed (Jones 2003b). 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 13. Carbaryl chemical input parameters for PE4 for carbaryl for the CRLF assessment.

Parameter	Value	Quality
Molecular weight	201.22 g mol^{-1}	excellent
Solubility	32 mg L^{-1}	good
Henry's Law Constant	1.28 x 10^{-8} atm-m^{-3} mol^{-1}	fair
K_{oc}	196 L kg^{-1}	good
Vapor Pressure	1.36 x 10^{-7} torr	good
Aerobic soil metabolism half-life	12 d	fair
Aerobic aquatic metabolism half-life	124.2 d	fair
Anaerobic aquatic metabolism half-life	216.6 d	fair
Hydrolysis half-life	pH 5 - assumed stable pH 7 - 12 d pH 9 - 0.133 d	good
Aqueous photolysis	21 d	good
Foliar Degradation Rate	0.187 d^{-1}	excellent
Foliar Washoff Coefficient	3.70 cm^{-1}	fair

As part of the data submitted for consideration in estimating the foliar degradation rate, the registrant also submitted data which supported a revised estimate of the foliar washoff coefficient. In the absence of data, current EFED policy recommends a washoff 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).

Use-specific parameters

Use-specific parameters include application methods and rates (**Table 5**). Application methods, maximum rates per application and maximum number of applications per year are based on current label directions (**Table 14)**. 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 use scenario was modeled. These cases are discussed in the crop-specific use pattern descriptions below.

Table 14. Use patterns for the assessment of aquatic exposure from carbaryl to the CRLF.

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
AI: Grass for seed	2	1.5	2	14	aerial
AJ: Rangeland	3	1	1	NS	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

[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 112 use patterns of carbaryl in California has either been simulated, or has been assigned a surrogate. Justifications for surrogate selection are provided in **Appendix A**. 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 an 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 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.

3.1.2.3. 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**).

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

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 step 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 E**.

3.1.3. Aquatic Modeling Results

PRZM/EXAMS EECs representing 1-in-10 year peak, 21-day, and 60-day concentrations of carbaryl in the aquatic environment are located in **Table 15**. 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 166 µg/L. In general, crops grown in coastal scenarios had higher EECs than those in the Central Valley; and those where application was made in the winter had higher EECs than those in the spring and summer.

Table 15. One-in-ten-year carbaryl EECs for aquatic environments from the application of carbaryl to 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.

An adjustment factor was applied to the EECs for the "flower beds around buildings" use pattern to account for the portion of the watershed that is on the perimeter of buildings and could be treated. This approach is modeled after an approach which has been previously used for Fipronil® and naphthalene (Corbin, 2007; USEPA 2007). According to the 2000 United States Census, the average lot size is ¼ of an acre or 10,890 square feet and the typical house has a foot print of 1000 square feet. If the house is square, there would be 31.6 ft on each side. If there is a garden 3-feet wide all the way around the house, the total length of that garden would be 138.5 feet, and the total area of the garden would be 415 square feet. In the standard 10 ha (107,640 sq. ft) watershed, there would be 58 houses or a total area of 24,070 sq feet of perimeter garden which is equivalent 2.24% of the watershed. This Crop Area Factor was applied to the flower beds around buildings use pattern (Pattern B) to calculate the EECs

3.2. Terrestrial Exposure Assessment

3.2.1. Modeling Approach

T-REX (version 1.3.1) is used to calculate dietary and dose-based EECs of carbaryl for the terrestrial-phase CRLF and its potential prey (*e.g.* terrestrial invertebrates, small mammals) inhabiting terrestrial areas. EECs used to represent exposure to CRLF are also used to represent exposure values for frogs serving as potential prey of terrestrial-phase CRLF adults. T-REX simulates a 1-year time period. A foliar dissipation half-life of 3.71 days is used based on data reported by Jones 2003b. The Mineau scaling factor of 1.55 is used to improve interspecies extrapolation of dose-based toxicity data for birds (surrogate for the CRLF) exposed to carbaryl (Mineau *et al*. 1996). Specific input values, including number of applications, application rate and application interval used in the analyses are located in **Table 16**. Use specific input values are consistent with those used in aquatic exposure modeling (**Table 14**). An example output from T-REX v.1.3.1 is available in **Appendix H**.

For residential use of carbaryl on flowers around buildings, labels indicate a maximum application rate equivalent to 8 lb a.i./A. The total number of applications per year is not specified on the label. Therefore, with the 3-day reapplication interval, the maximum number of applications possible per year is assumed to be 25.

Table 16. Input parameters for foliar applications used to derive terrestrial EECs for carbaryl with T-REX.

Crop Group[1]	Max. App. Rate (lb a.i./ acre)	Number of applications/ year	Application Interval (days)
A: Home lawn	9.1	2	7
B: Flower beds around buildings[2]	8	25	3
C: Lawns[3]	7.8	4	7
D: Ornamentals[4]	7.8	4	7
E: Parks	4	2	7
F: Citrus	16	1	NA
G: Olives	7.5	2	14
H: Almonds	5	3	7
I: Flowers	4.3	3	7
J: Peaches	4[2]	3	15
K: Asparagus	2[3]	4	3
L: Apple	3	5	14
M: Loquat	3	5	14
N: Sweet corn	2	8	3
O: Grapes	2	5	7
P: Strawberries	2	5	7
Q: Tomatoes	2	4	7
R: Peanuts	2	4	7
S: Broccoli	2	4	6
T: Brussels sprouts	2	4	6
U: Sweet potato	2	4	7
V: Field corn	2	4	14
W: Lettuce, head	2	3	7
X: Sorghum	2	3	7
Y: Celery	2	3	7
Z: Horseradish	2	3	7
AA: Potato	2	3	7
AB: Radish	2	3	7
AC: Rice	1.5	2	7
AD: Beans	1.5	4	7
AE: Okra	1.5	4	6
AF: Sugar beet	1.5	2	14
AG: Alfalfa	1.5	7	30
AH: Pasture	1.5	2	14
AI: Grass for seed	1.5	2	14
AJ: Rangeland	1	1	NS
AK: Melon	1	6	7
AL: Roses	1	6	7
AM: Rights-of-way	1	2	14
AN: Wasteland	1	2	14
AO: Non-urban forests	1	2	7
AP: Rural shelter belts	1	2	7
AQ: Ticks	1	25	3

[1]For specific uses associated with each crop group see Table 5.
[2]The maximum application scenario for peaches is 2 seasonal applications of 4 lbs a.i./A with one dormant season application of 5 lbs a.i./A. For modeling purposes, EECs were derived assuming 3 annual applications of 4 lbs a.i./A each.
[3]The maximum application scenario for asparagus is 3 preseason applications of 2 lbs a.i./A with one post season application of 4 lbs a.i./A. For modeling purposes, EECs were derived assuming 5 annual applications of 2 lbs a.i./A each.

3.2.2. Terrestrial Animal Exposure Modeling Results

For modeling purposes, exposures of the CRLF to carbaryl through contaminated food are estimated using the EECs for the small bird (20 g) which consumes small insects. Dietary-based and dose-based exposures of potential prey are assessed using the small mammal (15 g) which consumes short grass. Upper-bound Kenaga nomogram values reported by T-REX for these two organism types are used for derivation of EECs for the CRLF and its potential prey (**Table 17**). T-REX reported, dietary-based EECs used for small and large insects are available in **Table 17**. An example output from T-REX v. 1.3.1 is available in **Appendix H**.

Table 17. Upper-bound Kenaga nomogram EECs for dietary- and dose-based exposures of the CRLF and its prey to carbaryl.

Crop Group[1]	EECs for CRLF (and terrestrial-phase amphibians serving as prey)		EECs for large terrestrial invertebrates (ppm)	EECs for small mammals (prey)	
	Dose-based EEC (mg/kg-bw)	Dietary-based EEC (ppm)[2]		Dose-based EEC (mg/kg-bw)	Dietary-based EEC (ppm)
A: Home lawn	1777	1560	173	2645	2774
B: Flower beds around buildings	2866	2516	280	4265	4473
C: Lawns	1635	1435	159	2432	2551
D: Ornamentals	1635	1435	159	2432	2551
E: Parks	781	686	76	1162	1219
F: Citrus	2460	2160	240	3661	3840
G: Olives	1237	1086	121	1841	1931
H: Almonds	1033	907	101	1537	1612
I: Flowers	888	780	87	1579	1386
J: Peaches	1160	575	64	971	1018
K: Asparagus	640	562	62	953	1000
L: Apple	498	437	49	741	777
M: Loquat	498	437	49	741	777
N: Sweet corn	708	622	69	1054	1106
O: Grapes	421	369	41	626	657
P: Strawberries	421	369	41	626	657
Q: Tomatoes	419	368	41	624	654
R: Peanuts	419	368	41	624	654
S: Broccoli	451	396	44	671	704
T: Brussels sprouts	451	396	44	671	704
U: Sweet potato	419	368	41	624	654
V: Field corn	332	291	32	494	518
W: Lettuce, head	413	363	40	615	645
X: Sorghum	413	363	40	615	645
Y: Celery	413	363	40	615	645
Z: Horseradish	413	363	40	615	645
AA: Potato	413	363	40	615	645
AB: Radish	413	363	40	615	645
AC: Rice	293	257	29	436	457
AD: Beans	314	276	31	468	491
AE: Okra	338	297	33	503	528
AF: Sugar beet	247	217	24	368	386
AG: Alfalfa	231	203	23	343	360
AH: Pasture	247	217	24	368	386
AI: Grass for seed	247	217	24	368	386
AJ: Rangeland	154	135	15	229	240
AK: Melon	211	185	21	313	329
AL: Roses	211	185	21	313	329
AM: Rights-of-way	165	145	16	246	258
AN: Wasteland	165	145	16	246	258
AO: Non-urban forests	195	171	19	291	305
AP: Rural shelter belts	195	171	19	291	305
AQ: Ticks	358	315	35	533	559

[1]For specific uses associated with each crop group see **Table 5**. [2]Also represent EECs for small terrestrial invertebrates.

3.2.3. Spray Drift Modeling

In order to determine terrestrial habitats of concern due to carbaryl exposures through spray drift, it is necessary to estimate the distance spray applications can drift from the treated field and still be greater than the level of concern. For this assessment, the level of concern for the most sensitive endpoint and exposure duration is used. When this is expressed as an equivalent rate per unit area, it is 5×10^{-4} lb a.i./A. This assessment used the AgDisp model. AgDisp (version 8.13; dated 12/14/2004) (Teske and Curbishley, 2003) It was used to simulate both aerial and ground applications. For simulation requiring estimates of drift beyond 2400 ft, the Gaussian farfield extension mode in AgDisp was used.

Scenario and management practice input parameters for AgDisp fall into three categories. First are parameters for which there is current guidance. In all cases, there was no information from carbaryl labels relevant to these parameters so they have been set to the default values recommended by the current draft EFED Guidance for AgDisp (EFED 2005). Second are the default input values for AgDisp that do not affect the results of these calculations, or are reference variables whose value would only be changed under special circumstances. “Wind speed” is an example of the former and “Height for wind speed measurement” is an example of the latter. These parameters have ‘NA’ for not applicable in the quality column. Third are the parameters for which no current guidance is available and the default value for AgDisp was used for the input parameter for this set of simulations. The justification for these parameters is “program default” in **Table 18**.

The quality column in **Table 18** provides some qualitative characterization regarding the confidence in the accuracy of that input parameter. When little or no information is available to support the value of a particular input parameter, the characterization in the quality column is poor. In many cases, when this occurs, the variable is set to a value that will produce drift values greater than those than that would actually occur, so the results will likely be conservative and protective. When the amount of information supporting a parameter value is typical, the characterization is ‘good’ and the characterization is ‘very good’ or ‘excellent’ when several measurements of high quality support the value for the parameter.

Table 18. Scenario and standard management input parameters for simulation of carbaryl in spray drift using AgDisp with Gaussian far-field extension.

Parameter	Value	Justification	Quality
Nozzle type[1]	Flat fan	Program default	Poor
Boom Pressure[1]	60 lb	Program default	Poor
Spray lines	20	Program default	Poor
Nozzles	42	None available	Poor
Droplet Size Distribution (DSD)	Fine to very fine	Default; draft guidance	NA
Swath Width	60 ft	Program default	good
Wind Speed	15 mph	Default; draft guidance	good
Wind direction	- 90°	Default	NA
Air temperature	65° F	Program default	poor
Relative Humidity	50%	Program default	poor
Spray Material	Water	Program default	good
Fraction of active solution that is non-volatile	0.1	Program default	poor
Fraction of additive solution that is non-volatile	0.1	Program default	poor
Upslope angle	0°	Assume flat surface	good
Side slope angle	0°	Assume flat surface	god
Canopy type	none	Default from guidance	por
Surface roughness	0.0246 ft	Program default, none provided	poor
Transport	0 ft	Program default	poor
Height for wind peed measurement	6.56 ft	Program default	Good
Maximum comp. Time	600 sec	Program default	NA
Maximum downwind distance	2608.24 ft	Program default	NA
Vortex decay rate OGE	0.03355	Program default	NA
Vortex decay rate IGE	1.25	Program default	NA
Aircraft drag coefficient	0.1	Program default	NA
Propeller efficiency	0.8	Program default	NA
Ambient pressure	29.91	Program default	NA
Ground reference	0 ft	Program default	NA
Evaporation rate	84.76 $\mu g \cdot (K \cdot s)^{-1}$	Program default	NA
Specific Gravity (non-volatile)	1.0	Program default	poor

[1] parameter for ground spray only

AgDrift input parameters that vary with the crop and application type are in **Table 19**. These use patterns serve as surrogates for all the use patterns in the assessment. Surrogacy relations are detailed in **Appendix A**. The ground spray for carbaryl is a foliar spray made directly to the plant canopy. For this application, a height of 6 inches is the most appropriate as the spray is usually made close to the ground surface; however, AgDisp does not produce reliable values for these simulations when the spray height was set at less than 3 ft. The default release height of 15 ft is used for aerial applications in the absence of other label directions. Spray volumes are the minimum spray volumes from carbaryl labels for each crop. The non-volatile fraction, active fraction and specific gravity were calculated from label information according to current guidance (EFED 2005). The default ½ swath displacement was used with the aerial spray for lettuce as it is standard practice for aerial sprays, but was not used with the ground sprays.

Table 19. AgDrift Input parameters that vary with crop and formulation.

Crop Grouping	App method	Release Height	Swath Displacement	Spray Volume (gal)	Non-volatile Fraction	Active Fractio n	Specific Gravity of Carrier
A: home lawn	Ground	4 ft	None	2.28	1	.43	1.089
B, D: parks	Ground	4 ft	None	2	1	.43	1.089
C: lawns 2	Ground	4 ft	None	2	0.98	0.42	1.089
F: citrus	Aerial	15 ft	½ swath	10	0.4	0.17	1.089
G: olives	Aerial	15 ft	½ swath	10	0.188	0.081	1.089
H: almonds	Aerial	15 ft	½ swath	10	0.125	0.054	1.089
I: flowers	Aerial	15 ft	½ swath	2	0.53	0.23	1.089
J: peaches	Aerial	15 ft	½ swath	10	0.125	0.081	1.089
K: asparagus	Aerial	15 ft	½ swath	2	.5	0.22	1.089
L: apple	Aerial	15 ft	½ swath	10	0.075	0.032	1.089
N: sweet corn	Aerial	15 ft	½ swath	2	0.25	0.11	1.089
O: grapes	Aerial	15 ft	½ swath	10	0.05	0.022	1.089
AD: rice	Aerial	15 ft	½ swath	2	0.19	0.081	1.089
AF: okra	Ground	4 ft	None	2	0.19	0.081	1.089
AL: rangeland	Aerial	15 ft	½ swath	2	0.125	0.054	1.089
AR: ticks	Ground	4 ft	None	2	0.250	0.108	1.089

Carbaryl labels do not indicate a minimum volume for ground sprays, only to 'Apply in sufficient volume for adequate coverage of all crops and sites.' For these simulations, a volume of 2 gal/acre was used as this was the minimum recommendation for aerial application, since no value for ground spray could otherwise be established. In most cases, it would be expected that a larger volume would be used for ground sprays and this would be expected to reduce drift distances. A volume of 2.28 rather than 2 gal/acre was used for home lawns as this was the minimum volume that contained the application rate.

Table 20 presents the results of the AGDISP modeling and shows the minimum distance, for selected surrogate crops, where the area-based concentration of carbaryl is below the LOC of 3.81 $x10^{-2}$ $kg \cdot ha^{-1}$. This value was estimated using TREX as the greatest single application rate that would not exceed the RQ at the endangered species (listed species) level of concern of 0.1 for birds eating insects which is being used as a surrogate for terrestrial-phase CRLF. It is important to note that this particular value is based on a study where no effect was seen for mallard duck, so it only indicates that the toxicity is greater than the highest value measured in the study. This makes these overestimates of the drift buffer needed for protection of the CRLF, but shorter distances cannot be established as the level which an effect would be expected to occur has not been established.

As would be expected, the distance from the aerial application to lettuce is considerably larger than for the ground spray uses. Most drift events would be expected to have shorter distances due to lower wind speed. In addition, a fine to very-fine spray has been assumed for the ground sprays and ground equipment generally produces a coarser spray. However, there is no language restricting the spray quality on the carbaryl labels so the fine to very spray was used as it is the default in the absence of other label instructions.

Table 20. Distance from the edge of the treated field to get below LOC for crops with aerial or ground spray application of carbaryl.

Use Pattern	App Rate (lb·acre^{-1})	Distance, 15 mph wind speed
A: Home lawn (ground)	9	2260 ft
B, D: parks (ground)	8	2205 ft
C: lawns 2 (ground)	7.8	2216 ft
F: Citrus (air)	16	10920 ft
G: olives (aerial)	7.5	7836 ft
H: almonds (aerial)	5	6184 ft
I: flowers (aerial)	4.3	6293 ft
K: asparagus (aerial)	4	6238 ft
L: apples (aerial)	3	4451 ft
N: sweet corn (aerial)	2	4827 ft
O: grapes (aerial)	2	3521 ft
AD: rice (aerial)	1.5	4159 ft
AF: okra (ground)	1.5	1725 ft
AL: rangeland (aerial)	1	3293 ft
AR: ticks (ground)	2	2159 ft

4. Effects Assessment

This assessment evaluates the potential for carbaryl to affect the CRLF. As previously discussed in Section 2.7, assessment endpoints for the CRLF include direct toxic effects on the survival, reproduction, and growth of the CRLF itself, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat leading to effects on survival, growth or reproduction. Direct effects to the CRLF in aquatic habitats are based on toxicity information for freshwater vertebrates, including fish, which are generally used as a surrogate for amphibians, as well as available amphibian toxicity data from the open literature. Direct effects to the CRLF in terrestrial habitats are based on toxicity information for birds, which are generally used as a surrogate for terrestrial-phase amphibians. Given that the CRLF's prey items and habitat requirements are dependent on the availability of freshwater aquatic invertebrates and aquatic plants, fish, frogs, terrestrial invertebrates and terrestrial mammals, toxicity information for these organisms is also discussed. 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. A summary of the available freshwater ecotoxicity information, use of the probit dose response relationship, and the incident information for carbaryl are provided in Sections 4.1 through 4.4, respectively. A detailed summary of the available ecotoxicity information for carbaryl formulated products is presented in **Appendix M.**

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.

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:

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

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, open literature effects data that are more conservative than the registrant-submitted data are considered. Studies relevant to carbaryl that were accepted by ECOTOX and/or OPPTS are identified in **Appendix N**, as well as carbaryl studies that were rejected by ECOTOX and/or OPPTS.

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

4.1. Evaluation of Aquatic Ecotoxicity Studies for Carbaryl

As described in the Agency's Overview Document (U.S. EPA, 2004), the most sensitive endpoint for each taxon is evaluated. For this assessment, evaluated taxa relevant to the aquatic habitat of the CRLF include freshwater fish, freshwater aquatic invertebrates, and freshwater aquatic plants. Currently, no guideline tests exist for frogs. Therefore, surrogate species are used as described in the Overview Document (U.S. EPA, 2004). In addition, aquatic-phase amphibian ecotoxicity data from the open literature are qualitatively discussed. **Table 21** summarizes the most sensitive ecological toxicity endpoints for the CRLF, its prey and its habitat, 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 CRLF is presented below. Additional information is provided in **Appendix I**

Table 21. 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	400980-01	0.0005[2]		
Water flea *Daphnia magna*	0.0056	--	0.0015 / 0.0033	reproduction	00150901
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.
[2] Estimated NOEC using acute to chronic ratio for *Daphnia magna*

Acute toxicity to aquatic fish and invertebrates is categorized using the system shown in **Table 22** (U.S. EPA, 2004). Toxicity categories for aquatic plants have not been defined. Based on these categories, at most, carbaryl is classified highly toxic to freshwater fish and very highly toxic to invertebrates on an acute exposure basis.

Table 22. Categories of Acute Toxicity for Aquatic Organisms.

LC_{50} (µg/L)	Toxicity Category
< 100	Very highly toxic
> 100 – 1,000	Highly toxic
> 1,000 – 10,000	Moderately toxic
> 10,000 – 100,000	Slightly toxic
> 100,000	Practically nontoxic

4.1.1. Toxicity to Freshwater Fish

The available open literature information on carbaryl toxicity to aquatic-phase amphibians, which is provided in **Section 4.1.2**, shows that acute and chronic ecotoxicity endpoints for amphibians are generally less sensitive than fish. Therefore, endpoints based on freshwater fish ecotoxicity data are assumed to be protective of potential direct effects to aquatic-phase amphibians, including the CRLF. A summary of acute and chronic freshwater fish data, including sub-lethal effects, is provided below.

4.1.1.1. 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 average of the Log_{10} 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 L**. 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 17**).

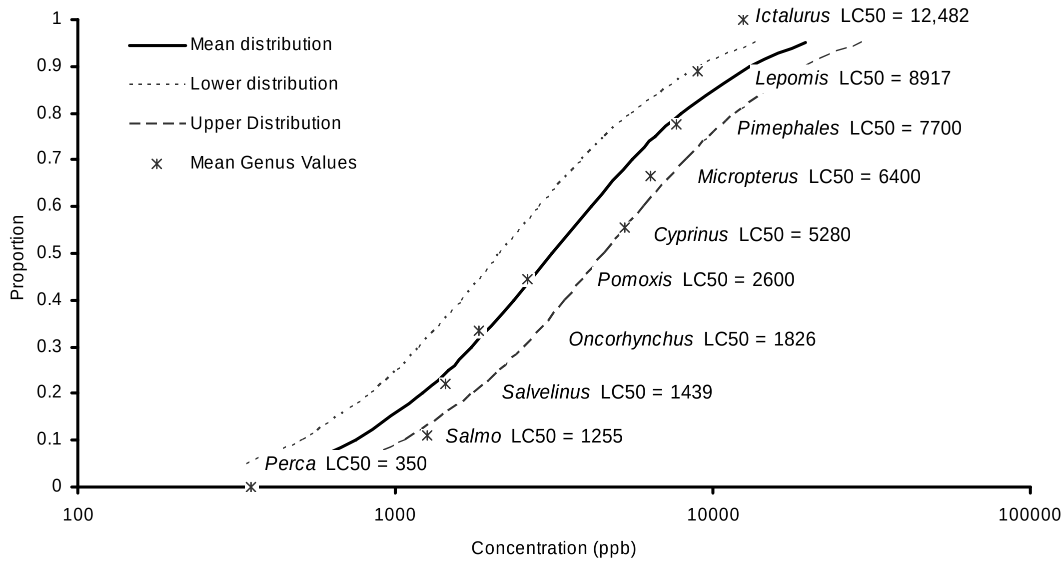


Figure 17. Fish sensitivity distribution based 96-h LC50 values from acute exposures of fish to carbaryl.

4.1.1.2. 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 CRLF because direct chronic toxicity guideline data for frogs do not exist. Chronic exposure of fathead minnows (*Pimephales promelas*) to carbaryl resulted in reduced survival and reproductive effects (NOEC = 0.210 mg/L) including reduced number of eggs per female and reduced number of eggs spawned. 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/L. With an acute LC_{50} of 7.7 mg/L 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, the resulting estimated NOAEC is 0.0068 mg/L.

With respect to ecological incidents involving fish reported in the Ecological Incident Information System, a total of three 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.

4.1.2. Toxicity to Aquatic-phase Amphibians

Available toxicity information on potential carbaryl-related mortality and sub-lethal effects to aquatic-phase amphibians from the open literature is summarized below in **Sections 4.1.2.1 and 4.1.2.2**, respectively. Although useful for characterization purposes, amphibian specific data were not considered useful for quantification of RQs for direct effects to the CRLF. Guideline ecotoxicity studies for amphibians are not available.

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

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

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

Several studies have suggested that carbaryl exposure impairs predator avoidance behavior in frogs (Bridges 1997; Bridges 1999), affects the length of time required for tadpoles to complete metamorphosis into adults (Boone and Semlitsch 2002), and affected the weight of animals undergoing metamorphosis. Carbaryl concentrations greater than 3.5 mg/L significantly affected the time tadpoles spent being active where control animals exhibited greater sprint speeds and were able to swim greater distances (Bridges 1997). Slower swimming speeds, altered activity patterns and prolonged juvenile stages have been suggested as increasing the vulnerability of frogs to predation (Bridges 1997; Bridges 1999; Relyea and Mills 2001) and/or that the threat of predation renders the animals more susceptible to the direct toxicity of carbaryl (Relyea and Mills 2001). While the Relyea and Mills paper indicates that carbaryl was 2 to 4 times more lethal to gray treefrogs (*Hyla versicolor*) in the presence of a predator, the study is confounded by the potential effects of water quality on mortality (**Appendix I**).

Increased vulnerability to predation assumes that only the prey species are incapacitated by carbaryl. The Bridges (1999) study indicates however, the predators may also be impacted and that gray treefrogs actually spent less time being active, but that the active times were primarily spent foraging. However, in some cases, it is unclear whether the effects of carbaryl on amphibians have been entirely adverse. For example, Southern leopard frogs exposed to carbaryl at 5 mg/L exhibited a 20% increase in weight at metamorphosis (Bridges and Boone, 2003) and that at concentrations as high as 7 mg/L, Woodhouse's toad (*Bufo woodhousii*) survival was roughly 30% higher than controls (Boone and Semlitsch, 2002). The increase in weight of leopard frogs was attributed to the indirect effect of carbaryl in reducing zooplankton that would normally have competed with tadpoles for phytoplankton. With zooplankton numbers reduced by carbaryl treatments, phytoplankton increased thereby increasing the amount of food available to tadpoles. However, aquatic-phase amphibians such as salamander that forage on zooplankton would not likely benefit since their food source would be diminished.

Additionally, open literature suggests that the toxicity of carbaryl to amphibians is enhanced in the presence of light (Zaga *et al*. 1998); the study reports that in the absence of simulated sunlight, the 96-hr LC_{50} for larval African clawed frogs (*Xenopus laevis*) and gray treefrogs (*Hyla versiocolor*) are 1.73 and 2.47 mg/L, respectively (**Appendix I**). In the presence of simulated light, the number of mortalities was higher; however, the study did not provide revised 96-hr LC_{50} estimates for the combination of carbaryl plus simulated sunlight. The extent to which sunlight can increase the sensitvity of aquatic-phase amphibians to carbaryl is uncertain.

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

None of the amphibian toxicity data reviewed in the open literature was considered sufficiently robust to use quantitatively for risk assessment purposes. The available lines of evidence suggest however, that both aquatic and terrestrial-phase amphibians are less sensitive to carbaryl than the most sensitive fish discussed in the preceding sections. The open literature is useful in characterizing potential indirect effects of carbaryl that may impact aquatic-phase amphibians, particularly as they relate to reductions in zooplankton (Bridges and Boone 2003).

4.1.3. Toxicity to Freshwater Invertebrates

Freshwater aquatic invertebrate toxicity data are used to assess potential indirect effects of carbaryl to the CRLF. Direct effects to freshwater invertebrates resulting from exposure to carbaryl may indirectly affect the CRLF via reduction in available food. As discussed in **Attachment 1**, the diet of CRLF aquatic-phase larvae (tadpoles) has not been studied specifically; it is assumed that their diet is similar to that of other frog species, with the tadpoles feeding exclusively in water and consuming diatoms, algae, and detritus (USFWS 2002). Postmetamorphic terrestrial-phase CRLFs feed on aquatic and terrestrial invertebrates found along the shoreline and on the water surface. Based on stomach content analysis, adults feed on a variety of invertebrates with larger-sized frogs feeding on small fish, frogs, and small mammals (Hayes and Tennant 1985).

A summary of acute and chronic freshwater invertebrate data, including published data in the open literature since completion of the IRED (USEPA 2004b), is provided below in **Sections 4.1.3.1 through 4.1.3.3**.

4.1.3.1. 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/L on an acute exposure basis. . Stoneflies (*Isoroperla grammatica*) are the most sensitive freshwater invertebrate in an acute toxicity study (96-hr LC_{50}=0.0017 mg/L). In general, freshwater invertebrates exhibited the same sensitivity (EC_{50} range: 0.007 - 0.013 mg/L) 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/L) 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 geniuses of aquatic invertebrates. The lower 95^{th} percentile of the invertebrate distribution (0.7 µg/L) indicates that the use of the lowest available toxicity value (1.7 µg/L) is not as conservative as the value used for vertebrates (**Figure 18**).

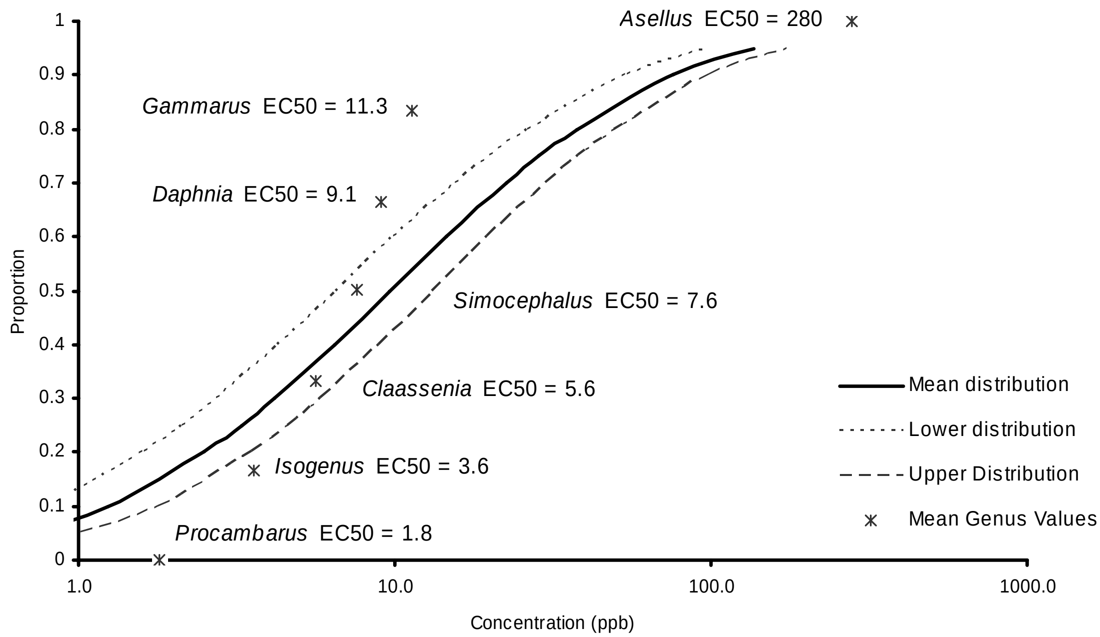


Figure 18. Invertebrate sensitivity distribution based 48-h and 96-h LC50 values from acute exposures of invertebrates to carbaryl.

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 (Bridges and Boone 2003). As discussed previously, though, while decreases in zooplankton can benefit aquatic-phase amphibians that depend on phytoplankton, decreased zooplankton can reduce growth and survival of those aquatic animals, such as salamanders, that forage on zooplankton and that, in turn, serve as prey for adult CRLFs.

4.1.3.2. Freshwater Invertebrates: Chronic Exposure Studies

On a chronic exposure basis, carbaryl affected reproduction (NOEC = 0.0015 mg/L) 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/L 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/L), the resulting estimated NOAEC is 0.0005 mg/L.

4.1.4. 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. Primary productivity is essential for indirectly supporting the growth and abundance of the CRLF. In addition to providing cover, aquatic plants harbor a variety of aquatic invertebrates that aquatic-phase CRLF eat.

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**, are used to further characterize potential community level effects to CRLF resulting from potential effects to aquatic plants. A summary of the laboratory data for aquatic plants is provided in **Section 4.1.4.1**.

4.1.4.1. 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 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/L. The most sensitive freshwater aquatic plant is the freshwater diatom *Navicula* with an EC_{50} of 0.66 mg/L.

Carbaryl was roughly similar to the endpoint for formulated end-use product (IC_{50} = 3.2 mg/L). In neither study were abnormalities in cell morphology or signs of phytotoxic effects observed. As reported earlier, carbaryl use has been associated with increases in phytoplankton numbers. Whether this is due to reduced predation by zooplankton as a result of their greater susceptibility to carbaryl and/or a response to carbaryl's similarity to the plant auxin α-naphthalene acetic acid is unclear.

4.1.4.1. Toxicity to Freshwater Vascular Plants

In a supplemental study (MRID 423721-02) with duckweed (*Lemna gibba*), the 14-day EC_{50} was 1.5 mg/L 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/L) resulted in 33% inhibition of *L. gibba* growth after 7-days static exposure (**Appendix I**). 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.

4.1.5. Freshwater Field 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/L). Furthermore, at carbaryl concentrations greater than 20 µg/L *Daphnia* were no longer found and at concentrations above 50 µg/L all cladocerans were eliminated, resulting in an increase in algal biomass, representing a repartitioning of biomass from zooplankton to phytoplankton. Hanazato (1995) exposed *Daphnia ambigua* to carbaryl and a kairomone released by the predator *Chaoborus* (phantom midge) simultaneously. *Daphnia* developed helmets in response to the kairomone, but not in response to carbaryl at 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 ppm killed all plankton species, including *Chaoborus* larvae (Hanazato, 1989). However, this concentration is well above the maximum EECs modeled for carbaryl, and it is unlikely that such high levels of this chemical would be found under field conditions.

In some cases, mesocosms exposed to carbaryl exhibited transitory effects. In a study by Boone *et al.* 2003 (**Appendix I**), 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. While these studies demonstrate that a range of factors, *e.g.*, hyrdroperiod and larval density, can influence the effects of carbaryl alone or in combination with other pesticides, *e.g.*, atrazine, the sensitivity of the amphibians in these studies is less than the surrogate fish species reported earlier.

4.2. Evaluation of Terrestrial Ecotoxicity Studies for Carbaryl

As described in the Agency's Overview Document (U.S. EPA, 2004), the most sensitive endpoint for each taxon is evaluated. For this assessment, evaluated taxa include birds, mammals, terrestrial invertebrates and terrestrial plants. Currently, no guideline tests exist for frogs and thus, no toxicity data are currently required on amphibians. Therefore, surrogate taxa (birds) were used as described in the Overview Document (U.S. EPA, 2004). **Table 23** summarizes the most sensitive ecological toxicity endpoints for terrestrial-phase CRLF, 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 CRLF are presented below. Additional information is provided in **Appendix I.**

Table 23. Summary of acute and chronic toxicity data for terrestrial organisms exposed to carbaryl.

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

Similar to toxicity categories for aquatic organisms, categories of acute toxicity ranging from "practically nontoxic" to "very highly toxic" have been established for terrestrial organisms based on LD_{50} values (**Table 24**), and avian species based on LD_{50} values (**Table 25**). Subacute dietary toxicity for avian species is based on the LC_{50} values (**Table 26**). Based on these categories, carbaryl is practically nontoxic to birds and moderately toxic to mammals on an acute exposure basis.

Table 24. Categories for mammalian acute toxicity based on median lethal dose in mg per kilogram body weight (parts per million).

LD_{50} (mg a.i./kg)	Toxicity Category
<10	Very highly toxic
10–50	Highly toxic
51–500	Moderately toxic
501–2000	Slightly toxic
>2000	Practically non-toxic

Table 25. Categories of avian acute oral toxicity based on median lethal dose in milligrams per kilogram body weight (parts per million).

LD_{50} (ppm)	Toxicity Category
<10	Very highly toxic
10-50	Highly toxic
51-500	Moderately toxic
501-2000	Slightly toxic
>2000	Practically non-toxic

Table 26. Categories of avian subacute dietary toxicity based on median lethal concentration in milligrams per kilogram diet per day (parts per million).

LC_{50} (ppm)	Toxicity Category
<50	Very highly toxic
50–500	Highly toxic
501–1000	Moderately toxic
1001–5000	Slightly toxic
>5000	Practically non-toxic

4.2.1. Toxicity to Birds

Carbaryl is practically nontoxic to birds on both an acute oral exposure (LD_{50} >2,000 mg/kg) and subacute dietary exposure basis (LC_{50} >5,000 mg/kg of diet).

Acute oral toxicity estimates as low as 16 mg/kg and 56 mg/kg have been reported for starlings (*Sturnus vulgaris*) and red-winged black birds (*Agelaius phoeniceus*), respectively (Schafer *et al.* 1983) and it is uncertain whether smaller passerine species may be more sensitive to the effects of carbaryl. Although useful for characterization purposes, these data were not considered useful for quantification of RQs for direct effects to the CRLF.

Exposure to carbaryl on a chronic basis resulted in adverse reproductive effects including decreased number of eggs produced and decreased fertility (NOAEC = 300 mg/kg of diet).

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

4.2.2. Toxicity to Terrestrial-phase Amphibians

The EFED ecotoxicity database reports an LD_{50} of greater than 2000 mg/kg for terrestrial-phase bullfrogs (*R. catesbeiana*).

4.2.3. Toxicity to Mammals

Carbaryl is moderately toxic (LD_{50} = 301 mg/kg) to mammals on an acute oral exposure basis (Accession Number 00148500). Chronic exposure to carbaryl resulted in decreased second-generation pup survival (NOEC = 75 mg/kg of diet; MRID 447329-01).

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

4.2.4. Toxicity to Terrestrial Invertebrates

Carbaryl is highly toxic to honey bees (*Apis mellifera*) on an acute contact exposure basis (LD_{50} = 0.0011 mg/bee; Accession Number 05004151); however, acute contact toxicity testing of carbaryl® SC indicates bees are less sensitive to the formulated product (LD_{50} = 0.0040 mg/bee). Acute oral toxicity studies with carbaryl reveal that technical grade carbaryl (LD_{50} = 0.0001 mg/bee) is roughly ten times more toxic than the formulated soluble concentrate (Carbaryl® SC LC_{50} = 0.0016 mg/bee). Carbaryl ranged from being moderately to highly toxic to predacious insects, mites and spiders.

For RQ derivation, the LD_{50} for honeybees (1.1 μg a.i./bee) is used. This toxicity value is converted to units of μg a.i./g (of bee) by multiplying by 1 bee/0.128 g thereby resulting in an LD_{50} = 8.6 μg a.i./g.

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

A total of 5 incidents related to carbaryl are reported in the EIIS database. Two of the reports (I005855-001 and B0000-300-03) do not contain any data but rather reflect general concerns expressed by the American Beekeeper Federation and the Honey Industry Council on the role of pesticides in bee kills. The Honey Industry Council sited the specific use of carbaryl on alfalfa during the day. In North Carolina (incident #I003826-021), a bee mortality was associated with 0.8 ppm carbaryl residues; however, in a second incident (#I003826-0090 in North Carolina, bee mortality was more likely attributed to methyl parathion than carbaryl. Only in one incident (I001611-002) was the use of carbaryl on a specific crop, *i.e.*, asparagus in Washington, clearly associated with carbaryl residues in dead bees. Subsequent to the publication of the ecological risk assessment chapter in support of the reregistration eligibility decision on carbaryl, a number of beekill incidents associated with the use of carbaryl have been identified. The majority of these incidents (40+) had been reported in Washington State and were associated with a range of carbaryl uses. Additional incidents have been reported in Minnestota and were associated with the use of carbaryl on poplar tree plantations.

4.2.5. Toxicity to Terrestrial Plants

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).

4.3. Toxicity of formulated products containing carbaryl

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 16**). 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 body weight).

Table 27. 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
GrubTo®x 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/L). Chronic exposure of fathead minnows to 1-naphthol reduced larval growth and survival (NOEC = 0.1 mg/L). No data are available on the acute or chronic toxicity of 1-naphthol to amphibians. For freshwater invertebrates, 1-naphthol ranged from moderately to highly toxic (EC_{50} range: 0.2 - 3.3 mg/L).

5. Risk Characterization

Risk characterization is the integration of the exposure and effects characterizations to determine the potential ecological risk from varying carbaryl use scenarios within the action area and likelihood of direct and indirect effects on the CRLF. The risk characterization provides an estimation and description of the likelihood of effects; it articulates risk assessment assumptions, limitations, and uncertainties; and synthesizes an overall conclusion regarding the effects determination (*i.e.*, "no effect," "likely to adversely affect," or "may affect, but not likely to adversely affect") for the CRLF.

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 established acute and chronic levels of concern (LOCs) for each category evaluated (**Appendix J**). For acute exposures to the CRLF and its animal prey in aquatic habitats, as well as terrestrial invertebrates, the LOC is 0.05. For acute exposures to the CRLF and mammals, the LOC is 0.1. The LOC for chronic exposures to CRLF and its prey, as well as acute exposures to plants is 1.0.

Screening-level RQs are based on the most sensitive endpoints and modeled EECs in **aquatic systems** from the following scenarios for carbaryl:

- Multiple applications to urban environments (home gardens, lawns, parks) at rates equivalent to 4 to 9 lbs a.i./A.
- Applications to citrus with single applications up to 16 lbs a.i./A
- Applications to nurseries at 4.3 lbs a.i./A
- Multiple applications to peaches and asparagus at up to 4 lbs a.i/A) and a single dormant application to peaches at 5 lbs a.i./A
- Multiple applications to orchards at up to 3 lbs a.i./A
- Multiple applications to vegetable crops, grapes, strawberries and peanuts at up to 2 lbs a.i./A
- Multiple applications to rice at 1.5 lbs a.i./A
- Multiple applications to pasture, alfalfa, grass for seed, sugar beets, tomatoes and row crops at 1.5 lbs a.i./A
- Multiple applications to rangeland, melons, roses, rights-of-way, wastelands, non-urban forests and rural shelters at 1 lb a.i./A.

For developing RQs for the **terrestrial-**phase CRLF and its prey (e.g. terrestrial insects and small mammals), exposures to carbaryl resulting from foliar applications of carbaryl are modeled. These included applications to turf, outdoor ornamentals, olives, fruit and nut orchards, vineyards, vegetables, grains, melons, trees and range/pasture lands. Maximum application rates and numbers of application for each crop were modeled according to the list above.

While exposures of terrestrial plants inhabiting dry and semi-aquatic habitats, single maximum applications of each use could be modeled, including applications involving foliar and soil-incorporation methods; however, no toxicity data are available with which to evaluate potential risk.

5.1.1. Exposures in the Aquatic Habitat

5.1.1.1. Direct Effects to CRLF

For assessing acute risks of direct effects to the CRLF, 1-in-10 year peak EECs in the standard pond are used with the lowest acute toxicity value for fish. For chronic risks, 1-in-10 year peak 60-day EECs and the lowest chronic toxicity value for fish are used. Resulting acute RQs exceed the acute listed species LOC (0.05) across all of the uses modeled except applications to flowers around buildings, ornamentals, parks, peaches, asparagus, 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, corn, head lettuce, celery, horse radish, potatoes, rice, rights-of-way, wasteland and rural shelter belts (**Table 28**).

Table 28. Risk Quotient values for acute and chronic exposures directly to the CRLF in aquatic habitats.

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	10	3.7	0.045	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	6	0.04	0.88
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	0.049	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 5**.
[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

5.1.1.2 Indirect Effects to CRLF through effects to prey

For assessing risks of indirect effects of carbaryl to the aquatic-phase CRLF (tadpoles) through effects to its diet, 1-in-10 year peak EECs from the standard pond are used with the lowest acute toxicity value for aquatic unicellular plants to derive RQs. 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 29**).

For assessing risks of indirect acute effects to the aquatic-phase CRLF through effects to prey (invertebrates) in 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 homes; for this one use, the chronic RQ value is below the chronic risk LOC (**Table 30**).

Fish and frogs also represent prey of CRLF. These RQs are represented by those used for direct effects to the CRLF in aquatic habitats (**Table 28**). RQs exceed the acute risk LOC (0.05) across all of the uses modeled except applications to flowers around buildings, ornamentals, parks, peaches, asparagus, 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, corn, head lettuce, celery, horse radish, potatoes, rice, rights-of-way, wasteland and rural shelter belts

5.1.2.3. Indirect Effects to CRLF through effects to habitat (plants)

For assessing risks of indirect effects of carbaryl to the aquatic-phase CRLF through effects to its habitat, 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 31**).

Table 29. RQ values for exposures to unicellular aquatic plants (diet of CRLF in tadpole life stage).

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

[1]For specific uses associated with each crop group see Table 5.
[2] Based on EC_{50} = 0.66 mg/L for green algae
[3] exceeds risk level of concern (RQ≥1.0)

Table 30. Risk Quotient (RQ) values for acute and chronic exposures to aquatic invertebrates (prey of CRLF juveniles and adults) 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[4]**	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	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 5**.
[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)

Table 31. Risk Quotient (RQ) values for exposures to aquatic plants (representing aquatic habitat).

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	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 5**.
[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$\geq$1.0)

5.1.2. Exposures in the Terrestrial Habitat

5.1.2.1. Direct Effects to CRLF

As described above, to assess risks of carbaryl to terrestrial-phase CRLF, dietary-based and dose-based exposures modeled in T-REX for a small bird (20g) consuming small invertebrates are used. Acute, subacute and chronic effects are estimated using the lowest available toxicity data for birds. EECs are divided by toxicity values to estimate acute and chronic dietary-based RQs as well as dose-based RQs. The only acute and subacute avian studies that were deemed acceptable for quantitative use indicated that that median lethal dose and median lethal concentration exceeded the maximum level tested; therefore, all of the resulting acute dietary-based and dose-based RQ values are less than the calculated value. Dose-based RQ values exceed the acute risk to endangered species LOC ($RQ \geq 0.1$) by factors ranging between 8 to 158X. Whether definitive median lethal doses would actually be high enough to remain below the acute risk LOC is uncertain. Chronic RQ values exceed the chronic risk LOC for home lawns, flower beds around buildings, parks, citrus, olives, almonds, flowers, peaches, asparagus, apples sweet corn, tomatoes, and lettuce (**Table 32**).

Table 32. Acute and chronic, dietary-based RQs and dose-based RQs for direct effects to the terrestrial-phase CRLF. RQs calculated using T-REX.

Crop Group[1]	Acute Dose-Based RQ[2]	Dietary - Based, acute RQ[3]	Dietary-based, chronic RQ[5]
A: Home lawn	**<9.04[4]**	**<0.29[4]**	**4.78[6]**
B: Flower beds around buildings	**<15.8[4]**	**<0.50[4]**	**8.39[6]**
C: Lawns	**<9.04[4]**	**<0.29[4]**	**4.78[6]**
D: Ornamentals	**<9.04[4]**	**<0.29[4]**	**4.78[6]**
E: Parks	**<4.32[4]**	**<0.14[4]**	**2.29[6]**
F: Citrus	**<13.60**	**<0.43[4]**	**7.20[6]**
G: Olives	**<6.84[4]**	**<0.22[4]**	**3.62[6]**
H: Almonds	**<3.02[4]**	**<0.18[4]**	**5.71[6]**
I: Flowers	**<4.91[4]**	**<0.16[4]**	**2.60[6]**
J: Peaches	**<3.62[4]**	**<0.11[4]**	**1.92[6]**
K: Asparagus	**<3.54**	**<0.11[4]**	**1.87[6]**
L: Apple	**<2.75[4]**	<0.09	**1.46[6]**
M: Loquat	**<2.75[4]**	<0.09	**1.46[6]**
N: Sweet corn	**<3.92[4]**	**<0.12[4]**	**2.07[6]**
O: Grapes	**<2.33[4]**	<0.07	**1.23[6]**
P: Strawberries	**<2.33[4]**	<0.07	**1.23[6]**
Q: Tomatoes	**<8.0[4]**	<0.07	**1.23[6]**
R: Peanuts	**<8.0[4]**	<0.07	**1.23[6]**
S: Broccoli	**<2.49[4]**	<0.08	**1.32[6]**
T: Brussels sprouts	**<2.49[4]**	<0.08	**1.32[6]**
U: Sweet potato	**<8.0[4]**	<0.07	**1.23[6]**
V: Field corn	**<1.83[4]**	<0.06	**0.97[6]**
W: Lettuce, head	**<2.28[4]**	<0.07	**1.21[6]**
X: Sorghum	**<2.28[4]**	<0.07	**1.21[6]**
Y: Celery	**<2.28[4]**	<0.07	**1.21[6]**
Z: Horseradish	**<2.28[4]**	<0.07	**1.21[6]**
AA: Potato	**<2.28[4]**	<0.07	**1.21[6]**
AB: Radish	**<2.28[4]**	<0.07	**1.21[6]**
AC: Rice	**<1.62[4]**	<0.05	0.86
AD: Beans	**<1.74[4]**	<0.06	0.92
AE: Okra	**<1.87[4]**	<0.06	0.99
AF: Sugar beet	**<1.37[4]**	<0.04	0.72
AG: Alfalfa	**<1.28[4]**	<0.04	0.68
AH: Pasture	**<1.37[4]**	<0.04	0.72
AI: Grass for seed	**<1.37[4]**	<0.04	0.72
AJ: Rangeland	**<0.85[4]**	<0.03	0.45
AK: Melon	**<1.16[4]**	<0.04	0.62
AL: Roses	**<1.16[4]**	<0.04	0.62
AM: Rights-of-way	**<0.91[4]**	<0.03	0.48
AN: Wasteland	**<0.91[4]**	<0.03	0.48
AO: Non-urban forests	**<1.08[4]**	<0.03	0.57
AP: Rural shelter belts	**<1.08[4]**	<0.03	0.57
AQ: Ticks	**<1.98[4]**	<0.06	**1.05[6]**

[1]For specific uses associated with each crop group see **Table 5**.
[2]Based on LD_{50} >2000 ppm (for mallard duck)
[3] Based on LC_{50} >5000 ppm (for mallard duck)
[4]Potentially exceeds acute listed species LOC (RQ≥0.1)
[5]Based on NOAEC = 300 ppm (for mallard duck)
[6]Exceeds chronic listed species LOC (RQ≥1.0)

5.1.2.2. Indirect Effects to CRLF through effects to prey

In order to assess the risks of foliar applications of carbaryl to terrestrial invertebrates, which are considered prey of CRLF in terrestrial habitats, the honey bee is used as a surrogate for terrestrial invertebrates. EECs (µg a.i./g of bee) calculated by T-REX for small and large insects are divided by the calculated toxicity value for terrestrial invertebrates, which is 8.6 µg a.i./g of bee. The resulting RQ values for large insect and small insect exposures bound the potential range of exposures for terrestrial insects to carbaryl. For all uses, RQ values exceed the acute risk LOC ($RQ \geq 0.05$) for both large and small terrestrial insects (**Table 33**).

As described above, to assess risks of carbaryl to prey (small mammals) of larger terrestrial-phase CRLF, dietary-based and dose-based exposures modeled in T-REX for a small mammal (15g) consuming small invertebrates are used. Subacute and chronic effects are estimated using the most sensitive mammalian toxicity data. EECs are divided by the toxicity value to estimate acute and chronic dietary-based RQs as well as acute dose-based RQs. Across all uses, acute dose-based RQ values exceed the listed species acute risk LOC; except for use on melons, rights-of-way/wasteland, non-urban forests and rural shelter belts, rangeland and for uses to control ticks, RQ values exceed the acute risk to non-listed species LOC as well for mammals considered as potential prey items for the CRLF. Dietary-based chronic RQ values exceed the chronic risk LOC for mammals considered as potential prey species for CRLF (**Table 34**).

An additional prey item of the adult CRLF is other species of frogs. In order to assess risks to these organisms, dietary-based and dose-based exposures modeled in T-REX for a small bird (20g) consuming small invertebrates are used. These are the same EECs, toxicity values and RQs used to assess direct effects to the CRLF. Acute, dietary-based RQ values, dietary-based chronic RQ values and dose-based RQ values exceed the LOC for listed species for all uses (**Table 32**).

Table 33. RQs for determining indirect effects to the terrestrial-phase CRLF through effects to potential prey items (terrestrial invertebrates).

Crop group[1]	Small invertebrate RQ[2,3]	Large Invertebrate RQ[2,3]
A: Home lawn	**181**	**20**
B: Flower beds around buildings	**293**	**33**
C: Lawns	**167**	**18**
D: Ornamentals	**167**	**18**
E: Parks	**80**	**9**
F: Citrus	**251**	**28**
G: Olives	**126**	**14**
H: Almonds	**105**	**12**
I: Flowers	**91**	**10**
J: Peaches	**67**	**7**
K: Asparagus	**65**	**7**
L: Apple	**51**	**6**
M: Loquat	**51**	**6**
N: Sweet corn	**72**	**8**
O: Grapes	**43**	**5**
P: Strawberries	**43**	**5**
Q: Tomatoes	**43**	**5**
R: Peanuts	**43**	**5**
S: Broccoli	**46**	**5**
T: Brussels sprouts	**46**	**5**
U: Sweet potato	**43**	**5**
V: Field corn	**34**	**4**
W: Lettuce, head	**42**	**5**
X: Sorghum	**42**	**5**
Y: Celery	**42**	**5**
Z: Horseradish	**42**	**5**
AA: Potato	**42**	**5**
AB: Radish	**42**	**5**
AC: Rice	**30**	**3**
AD: Beans	**32**	**4**
AE: Okra	**35**	**4**
AF: Sugar beet	**25**	**3**
AG: Alfalfa	**24**	**3**
AH: Pasture	**25**	**3**
AI: Grass for seed	**25**	**3**
AJ: Rangeland	**16**	**2**
AK: Melon	**22**	**2**
AL: Roses	**22**	**2**
AM: Rights-of-way	**17**	**2**
AN: Wasteland	**17**	**2**
AO: Non-urban forests	**20**	**2**
AP: Rural shelter belts	**20**	**2**
AQ: Ticks	**37**	**4**

[1]For specific uses associated with each crop group see **Table 5**.
[2]Based on LD_{50} = 8.6 µg a.i./bee
[3]Exceeds LOC of 0.05.

Table 34. Acute and chronic, acute dose-based RQs and chronic dietary-based RQs for prey items (small mammals) of terrestrial-phase CRLF.

Crop Group[1]	Acute Dose-Based RQ[2]	Chronic Dietary-based RQ[5]
A: Home lawn	3.68[3]	34.02[4]
B: Flower beds around buildings	6.45[3]	55.9[4]
C: Lawns	3.68	34.02[4]
D: Ornamentals	3.68	34.02[4]
E: Parks	1.76[3]	16.26[4]
F: Citrus	5.53[3]	61.2[4]
G: Olives	2.78[3]	24.1[4]
H: Almonds	2..32[3]	20.2[4]
I: Flowers	2.00[3]	17.3[4]
J: Peaches	1.47[3]	13.62[4]
K: Asparagus	1.44[3]	13.33[4]
L: Apple	1.12[3]	9.71[4]
M: Loquat	1.12[3]	9.71[4]
N: Sweet corn	1.59[3]	13.8[4]
O: Grapes	4.14[3]	2.19[4]
P: Strawberries	4.14[3]	2.19[4]
Q: Tomatoes	0.94[3]	8.18[4]
R: Peanuts	0.94[3]	8.18[4]
S: Broccoli	1.01[3]	8.80[4]
T: Brussels sprouts	1.01[3]	8.80[4]
U: Sweet potato	0.94[3]	8.18[4]
V: Field corn	0.75[3]	6.47[4]
W: Lettuce, head	0.93[3]	8.06[4]
X: Sorghum	0.93[3]	8.06[4]
Y: Celery	0.93[3]	8.06[4]
Z: Horseradish	0.93[3]	8.06[4]
AA: Potato	0.93[3]	8.06[4]
AB: Radish	0.93[3]	8.06[4]
AC: Rice	0.66[3]	5.72[4]
AD: Beans	0.71[3]	6.54
AE: Okra	0.76[3]	6.60[4]
AF: Sugar beet	0.56[3]	4.83[4]
AG: Alfalfa	0.52[3]	4.50[4]
AH: Pasture	0.56[3]	4.83[4]
AI: Grass for seed	0.56[3]	4.83[4]
AJ: Rangeland	0.35[3]	3.00[4]
AK: Melon	0.47[3]	4.11[4]
AL: Roses	0.47[3]	4.11[4]
AM: Rights-of-way	0.37[3]	3.22[4]
AN: Wasteland	0.37[3]	3.22[4]
AO: Non-urban forests	0.44[3]	4.06[4]
AP: Rural shelter belts	0.44[3]	4.06[4]
AQ: Ticks	0.81[3]	7.45[4]

[1]For specific uses associated with each crop group see **Table 5**.
[2] Based on LD_{50} = 301 ppm (for laboratory rat)
[3]exceeds acute listed species LOC (RQ≥0.1)
[4]Exceeds chronic listed species LOC (RQ≥1.0)
[5]Based on NOAEC = 75 ppm (for laboratory rat)

5.1.2.3. Indirect Effects to CRLF through effects to habitat (plants)

Insufficient data are available to 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. Since carbaryl is used for fruit thinning, carbaryl has potential for reproductive effects to plants. No data are available to assess potential reproductive effects of carbaryl on plants. Therefore, RQs could not be quantified for describing risks of uses of carbaryl to riparian and terrestrial vegetation.

5.2. Risk Description

The risk description synthesizes an overall conclusion regarding the likelihood of impacts leading to an effects determination (*i.e.*, "no effect," "may affect, but not likely to adversely affect," or "likely to adversely affect") for the CRLF.

If the RQs presented in the Risk Estimation (**Section 5.1**) show no indirect effects and LOCs for the CRLF are not exceeded for direct effects, a "no effect" determination is made, based on use of carbaryl within the action area. If, however, indirect effects are anticipated and/or exposure exceeds the LOCs for direct effects, the Agency concludes a preliminary "may affect" determination for the CRLF. Following a "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 CRLF and potential community-level effects to aquatic plants. 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 CRLF.

The criteria used to make determinations that the effects of an action are "not likely to adversely affect" the CRLF 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. For example, use of dose-response information to estimate the likelihood of effects can inform the evaluation of some discountable effects.

- 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 CRLF is provided below.

5.2.1. Direct Effects

5.2.1.1. Aquatic-phase

Acute exposures

All modeled uses except applications to flowers around buildings, ornamentals, parks, peaches, asparagus, dry beans, okra, alfalfa, grass for seed and melons exceed the acute risk to listed species LOC by factors ranging 1 to 240X for direct effects to aquatic-phase CRLF. A “no effect” determination is made for the uses that do not exceed the acute LOC. A “may affect” determination is made based on potential acute mortality of aquatic-phase amphibians for all carbaryl uses that exceed the LOC (See **Table 28**).

A source of uncertainty in the derivation of RQs is the estimation of exposure. As discussed above (section 3.1.1.4) concentrations of carbaryl have been detected in California surface waters; however, the detections (≤1.06 µg/L) were not at levels sufficient to exceed the LOC for direct acute effects to the CRLF. 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 CRLF.

An analysis of the likelihood of individual direct mortality (**Appendix K**) indicates that based on the highest RQ value (12) for direct effects on the aquatic-phase CRLF 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 aquatic-phase CRLF, the likelihood of individual mortality may be is significantly lower for some of the uses.

Table 35. Likelihood of individual effect for each use of carbaryl for the aquatic-phase CRLF.

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	11.72	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	0.13	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**.

Consistent with the process identified in the Overview Document (USEPA 2004) evaluated by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (Williams and Hogarth 2004), the potential for carbaryl to result in direct acute mortality of aquatic-phase CRLF is based on toxicity data for the most sensitive fish. However, if risk estimates were based on available acute amphibian toxicity data for carbaryl (see section 4.1.2), only the RQ value for rice would exceed the acute risk LOC. The determination would be that current uses of carbaryl, with the exception of rice, have "no effect" on the aquatic-phase CRLF. Similarly, had the assessment for indirect effects to CRLF based on effects to its forage base of other frogs been based on amphibian toxicity data, a no effect determination would have been reached.

In order to characterize the conservativeness of the endpoint selected to represent direct effects to aquatic-phase CRLF (*e.g*. Atlantic salmon LC_{50} = 220 µg/L) 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 95^{th} 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. 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, the determination for acute direct effects to the aquatic-phase CRLF is "LAA" 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. The determinations for the remaining uses originally designated as "may affect" are "NLAA."

Chronic exposures

All of the uses modeled except for home lawns, flowers around buildings, parks, flowers, eggplant, 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 aquatic-phase CRLF. A "No Effect" determination is made for the uses that do not exceed the chronic LOC. For the remaining uses, the chronic risk LOC is exceeded by factors ranging 1 – 379X (See **Table 28**). A "may affect" determination is made based on potential chronic reproductive effects on aquatic-phase amphibians.

RQs for chronic exposures are based on the level where no effects were observed (the NOAEC) in laboratory exposure tests. As discussed in section 4.1.1.2, 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, 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, heat lettuce, horse radish, rice and wasteland. For these uses, the determination is “LAA” for chronic effects to the CRLF in aquatic habitats.

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 CRLF to carbaryl. There are two significant uncertainties that prevent making a determination of “NLAA” 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 CRLF 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 457848-04). This LOAEC is similar to the NOAEC (0.21 mg/L; MRID 406448-01) reported in a long term study with fathead minnows exposed to carbaryl. There is uncertainty associated with the extent of the exposure of the CRLF 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, the determination is “LAA” for chronic effects to the CRLF 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.

5.2.1.2. Terrestrial-phase

Acute-dose based, indiscreet RQs potentially exceed the LOC, resulting in a “may affect” determination for all uses. Acute, dietary-based RQs, which are also indiscreet, also potentially exceed the LOC for several uses. Chronic, dietary based RQs, which are discreet, exceed the LOC for the majority of carbaryl uses. In order to explore influences of amphibian specific food intake equations on potential dose-based and dietary-based exposures of the terrestrial phase CRLF to carbaryl, T-HERPS was used. Modeling with T-HERPS incorporates the same application rates, intervals and number of applications for each use as defined for modeling using T-REX (**Table 16**). Since applications of carbaryl for many uses result in exposures sufficient to exceed the LOC for direct effects to the CRLF, this model was used to estimate EECs and subsequent risks to the CRLF based on amphibian specific equations. These refined EECs and RQs were used to distinguish “NLAA” and “LAA” determinations.

RQs are calculated for the terrestrial-phase CRLF on the basis of dose and diet. It should be noted that although dietary-based RQ values are considerably lower than dose-based RQ values, the former do not take into account that different-sized animals consume differing amounts of food and that depending on the forage item, an animal has to consume varying amounts due to differing nutrition levels in the food item. If dietary-based RQ values are adjusted to account for differential food consumption, the adjusted RQ value would likely approximate the dose-based RQ value.

Acute exposures

Refined dose based RQs for small sized (1.4 g) CRLF do not exceed the acute listed species LOC for any use (**Table 36**), resulting in a no effect determination. Refined dose based RQs for medium (37 g) and large (238 g) sized CRLF feeding on small and large insects, small insectivore mammals and small terrestrial-phase amphibians do not exceed the acute listed species LOC for any use, resulting in a no effect determination (**Tables 37 and 38**).

Refined dose-based RQs indicate that, for some carbaryl uses, there is potential for direct mortality to medium (37 g) and large (238 g) sized CRLF feeding on small herbivore mammals (**Tables 37** and **38**). Carbaryl is classified as practically nontoxic to birds on an acute oral exposure basis with the acute oral LD_{50} (>2000 mg/kg bw) exceeding the maximum concentration tested. All of the estimated RQ values are less than the calculated value, resulting in uncertainty in whether or not the values should exceed the listed species LOC. Direct comparison of the limit dose of the available avian acute oral test (2000 mg/kg-bw) to dose-based EECs indicates that EECs are insufficient to reach this level (i.e. acute dose-based RQs are less than 1). Therefore, EECs are insufficient to reach levels where less than 50% mortality was observed in laboratory tests. The only exceptions to this are for medium sized CRLF consuming small herbivore mammals in fields where carbaryl was applied to citrus and flowers and beds around buildings. Overall, based on dose-based exposure estimates, the risk of acute mortality of carbaryl to terrestrial-phase CRLF is low.

Refined dietary-based RQs indicate that, for some carbaryl uses, there is potential for direct mortality to CRLF feeding on small insects or small herbivore mammals. RQs do not exceed the acute LOC for CRLF feeding on large insects, small insectivore mammals and small terrestrial phase amphibians (**Table 39**). Carbaryl is classified as practically nontoxic to birds on a subacute dietary exposure basis with the subacute dietary LC_{50} (>5000 mg/kg diet) exceeding the maximum concentration tested. All of the estimated RQ values are less than the calculated value, resulting in uncertainty in whether or not the values should exceed the listed species LOC. Direct comparison of the limit dose of the available avian acute oral test (5000 mg/kg-diet) to acute dietary-based EECs indicates that EECs are insufficient to reach this level (i.e. acute dietary-based RQs are less than 1). Therefore, EECs are insufficient to reach levels where less than 50% mortality was observed in laboratory tests. Overall, based on dietary-based exposure estimates, the risk of acute mortality of carbaryl to terrestrial-phase CRLF is low.

Based on the refined estimates of exposures to terrestrial-phase CRLF, the effects determinations for acute effects resulting from all uses of carbaryl is "NLAA."

Table 36. Revised dose-based RQs for 1.4 g CRLF consuming different food items. EECs calculated using T-HERPS.

Crop Group[1]	Small Insects	Large Insects
A: Home lawn	<0.03	<0.01
B: Flower beds around buildings	<0.05	<0.01
C: Lawns	<0.03	<0.01
D: Ornamentals	<0.03	<0.01
E: Parks	<0.01	<0.01
F: Citrus	<0.04	<0.01
G: Olives	<0.02	<0.01
H: Almonds	<0.02	<0.01
I: Flowers	<0.02	<0.01
J: Peaches	<0.01	<0.01
K: Asparagus	<0.01	<0.01
L: Apple	<0.01	<0.01
M: Loquat	<0.01	<0.01
N: Sweet corn	<0.01	<0.01
O: Grapes	<0.01	<0.01
P: Strawberries	<0.01	<0.01
Q: Tomatoes	<0.01	<0.01
R: Peanuts	<0.01	<0.01
S: Broccoli	<0.01	<0.01
T: Brussels sprouts	<0.01	<0.01
U: Sweet potato	<0.01	<0.01
V: Field corn	<0.01	<0.01
W: Lettuce, head	<0.01	<0.01
X: Sorghum	<0.01	<0.01
Y: Celery	<0.01	<0.01
Z: Horseradish	<0.01	<0.01
AA: Potato	<0.01	<0.01
AB: Radish	<0.01	<0.01
AC: Rice	<0.01	<0.01
AD: Beans	<0.01	<0.01
AE: Okra	<0.01	<0.01
AF: Sugar beet	<0.01	<0.01
AG: Alfalfa	<0.01	<0.01
AH: Pasture	<0.01	<0.01
AI: Grass for seed	<0.01	<0.01
AJ: Rangeland	<0.01	<0.01
AK: Melon	<0.01	<0.01
AL: Roses	<0.01	<0.01
AM: Rights-of-way	<0.01	<0.01
AN: Wasteland	<0.01	<0.01
AO: Non-urban forests	<0.01	<0.01
AP: Rural shelter belts	<0.01	<0.01
AQ: Ticks	<0.01	<0.01

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

Table 37. Revised dose-based RQs for 37 g CRLF consuming different food items. EECs calculated using T-HERPS.

Crop Group	Small Insects	Large Insects	Small herbivore mammals[2]	Small insectivore mammals	Small terrestrial-phase amphibian
A: Home lawn	<0.03	<0.01	**<0.86**	<0.06	<0.01
B: Flower beds around buildings	<0.05	<0.01	**<1.39**	<0.09	<0.01
C: Lawns	<0.03	<0.01	**<0.80**	<0.05	<0.01
D: Ornamentals	<0.03	<0.01	**<0.80**	<0.05	<0.01
E: Parks	<0.01	<0.01	**<0.38**	<0.02	<0.01
F: Citrus	<0.04	<0.01	**<1.20**	<0.07	<0.01
G: Olives	<0.02	<0.01	**<0.60**	<0.04	<0.01
H: Almonds	<0.02	<0.01	**<0.50**	<0.03	<0.01
I: Flowers	<0.01	<0.01	**<0.43**	<0.03	<0.01
J: Peaches	<0.01	<0.01	**<0.32**	<0.02	<0.01
K: Asparagus	<0.01	<0.01	**<0.31**	<0.02	<0.01
L: Apple	<0.01	<0.01	**<0.24**	<0.02	<0.01
M: Loquat	<0.01	<0.01	**<0.24**	<0.02	<0.01
N: Sweet corn	<0.01	<0.01	**<0.34**	<0.02	<0.01
O: Grapes	<0.01	<0.01	**<0.20**	<0.01	<0.01
P: Strawberries	<0.01	<0.01	**<0.20**	<0.01	<0.01
Q: Tomatoes	<0.01	<0.01	**<0.20**	<0.01	<0.01
R: Peanuts	<0.01	<0.01	**<0.20**	<0.01	<0.01
S: Broccoli	<0.01	<0.01	**<0.22**	<0.01	<0.01
T: Brussels sprouts	<0.01	<0.01	**<0.22**	<0.01	<0.01
U: Sweet potato	<0.01	<0.01	**<0.20**	<0.01	<0.01
V: Field corn	<0.01	<0.01	**<0.16**	<0.01	<0.01
W: Lettuce, head	<0.01	<0.01	**<0.20**	<0.01	<0.01
X: Sorghum	<0.01	<0.01	**<0.20**	<0.01	<0.01
Y: Celery	<0.01	<0.01	**<0.20**	<0.01	<0.01
Z: Horseradish	<0.01	<0.01	**<0.20**	<0.01	<0.01
AA: Potato	<0.01	<0.01	**<0.20**	<0.01	<0.01
AB: Radish	<0.01	<0.01	**<0.20**	<0.01	<0.01
AC: Rice	<0.01	<0.01	**<0.14**	<0.01	<0.01
AD: Beans	<0.01	<0.01	**<0.15**	<0.01	<0.01
AE: Okra	<0.01	<0.01	**<0.16**	<0.01	<0.01
AF: Sugar beet	<0.01	<0.01	**<0.12**	<0.01	<0.01
AG: Alfalfa	<0.01	<0.01	**<0.11**	<0.01	<0.01
AH: Pasture	<0.01	<0.01	**<0.12**	<0.01	<0.01
AI: Grass for seed	<0.01	<0.01	**<0.12**	<0.01	<0.01
AJ: Rangeland	<0.01	<0.01	<0.07	<0.01	<0.01
AK: Melon	<0.01	<0.01	<0.10	<0.01	<0.01
AL: Roses	<0.01	<0.01	<0.10	<0.01	<0.01
AM: Rights-of-way	<0.01	<0.01	<0.08	<0.01	<0.01
AN: Wasteland	<0.01	<0.01	<0.08	<0.01	<0.01
AO: Non-urban forests	<0.01	<0.01	<0.10	<0.01	<0.01
AP: Rural shelter belts	<0.01	<0.01	<0.10	<0.01	<0.01
AQ: Ticks	<0.01	<0.01	**<0.17**	<0.01	<0.01

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

[2]bold values potentially exceed the acute listed species LOC (0.10)

Table 38. Revised dose-based RQs for 238 g CRLF consuming different food items. EECs calculated using T-HERPS.

Crop Group	Small Insects	Large Insects	Small herbivore mammals[2]	Small insectivore mammals	Small terrestrial-phase amphibian
A: Home lawn	<0.02	<0.01	**<0.13**	<0.01	<0.01
B: Flower beds around buildings	<0.03	<0.01	**<0.22**	<0.01	<0.01
C: Lawns	<0.02	<0.01	**<0.12**	<0.01	<0.01
D: Ornamentals	<0.02	<0.01	**<0.12**	<0.01	<0.01
E: Parks	<0.01	<0.01	<0.06	<0.01	<0.01
F: Citrus	<0.03	<0.01	**<0.19**	<0.01	<0.01
G: Olives	<0.01	<0.01	<0.09	<0.01	<0.01
H: Almonds	<0.01	<0.01	<0.08	<0.01	<0.01
I: Flowers	<0.01	<0.01	<0.07	<0.01	<0.01
J: Peaches	<0.01	<0.01	<0.05	<0.01	<0.01
K: Asparagus	<0.01	<0.01	<0.05	<0.01	<0.01
L: Apple	<0.01	<0.01	<0.04	<0.01	<0.01
M: Loquat	<0.01	<0.01	<0.04	<0.01	<0.01
N: Sweet corn	<0.01	<0.01	<0.05	<0.01	<0.01
O: Grapes	<0.01	<0.01	<0.03	<0.01	<0.01
P: Strawberries	<0.01	<0.01	<0.03	<0.01	<0.01
Q: Tomatoes	<0.01	<0.01	<0.03	<0.01	<0.01
R: Peanuts	<0.01	<0.01	<0.03	<0.01	<0.01
S: Broccoli	<0.01	<0.01	<0.03	<0.01	<0.01
T: Brussels sprouts	<0.01	<0.01	<0.03	<0.01	<0.01
U: Sweet potato	<0.01	<0.01	<0.03	<0.01	<0.01
V: Field corn	<0.01	<0.01	<0.03	<0.01	<0.01
W: Lettuce, head	<0.01	<0.01	<0.03	<0.01	<0.01
X: Sorghum	<0.01	<0.01	<0.03	<0.01	<0.01
Y: Celery	<0.01	<0.01	<0.03	<0.01	<0.01
Z: Horseradish	<0.01	<0.01	<0.03	<0.01	<0.01
AA: Potato	<0.01	<0.01	<0.03	<0.01	<0.01
AB: Radish	<0.01	<0.01	<0.03	<0.01	<0.01
AC: Rice	<0.01	<0.01	<0.02	<0.01	<0.01
AD: Beans	<0.01	<0.01	<0.02	<0.01	<0.01
AE: Okra	<0.01	<0.01	<0.03	<0.01	<0.01
AF: Sugar beet	<0.01	<0.01	<0.02	<0.01	<0.01
AG: Alfalfa	<0.01	<0.01	<0.02	<0.01	<0.01
AH: Pasture	<0.01	<0.01	<0.02	<0.01	<0.01
AI: Grass for seed	<0.01	<0.01	<0.02	<0.01	<0.01
AJ: Rangeland	<0.01	<0.01	<0.01	<0.01	<0.01
AK: Melon	<0.01	<0.01	<0.02	<0.01	<0.01
AL: Roses	<0.01	<0.01	<0.02	<0.01	<0.01
AM: Rights-of-way	<0.01	<0.01	<0.01	<0.01	<0.01
AN: Wasteland	<0.01	<0.01	<0.01	<0.01	<0.01
AO: Non-urban forests	<0.01	<0.01	<0.01	<0.01	<0.01
AP: Rural shelter belts	<0.01	<0.01	<0.01	<0.01	<0.01
AQ: Ticks	<0.01	<0.01	<0.03	<0.01	<0.01

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

[2]bold values potentially exceed the acute listed species LOC (0.10)

Table 39. Revised acute dietary-based RQs for CRLF consuming different dietary items. EECs calculated using T-HERPS.

Crop Group[1]	Small Insects[2]	Large Insects	Small herbivore mammals[2]	Small insectivore mammals	Small terrestrial-phase amphibian
A: Home lawn	**<0.31**	<0.03	**<0.37**	<0.02	<0.01
B: Flower beds around buildings	<0.05	<0.06	**<0.59**	<0.04	<0.02
C: Lawns	**<0.29**	<0.03	**<0.34**	<0.02	<0.01
D: Ornamentals	**<0.29**	<0.03	**<0.34**	<0.02	<0.01
E: Parks	**<0.14**	<0.02	**<0.16**	<0.01	<0.01
F: Citrus	**<0.43**	<0.05	**<0.51**	<0.03	<0.01
G: Olives	**<0.22**	<0.02	**<0.25**	<0.02	<0.01
H: Almonds	**<0.18**	<0.02	**<0.21**	<0.01	<0.01
I: Flowers	**<0.16**	<0.02	**<0.18**	<0.01	<0.01
J: Peaches	**<0.11**	<0.01	**<0.13**	<0.01	<0.01
K: Asparagus	**<0.11**	<0.01	**<0.13**	<0.01	<0.01
L: Apple	<0.09	<0.01	<0.10	<0.01	<0.01
M: Loquat	<0.09	<0.01	<0.10	<0.01	<0.01
N: Sweet corn	**<0.12**	<0.01	**<0.15**	<0.01	<0.01
O: Grapes	<0.07	<0.01	<0.09	<0.01	<0.01
P: Strawberries	<0.07	<0.01	<0.09	<0.01	<0.01
Q: Tomatoes	<0.07	<0.01	<0.09	<0.01	<0.01
R: Peanuts	<0.07	<0.01	<0.09	<0.01	<0.01
S: Broccoli	<0.08	<0.01	<0.09	<0.01	<0.01
T: Brussels sprouts	<0.08	<0.01	<0.09	<0.01	<0.01
U: Sweet potato	<0.07	<0.01	<0.09	<0.01	<0.01
V: Field corn	<0.06	<0.01	<0.07	<0.01	<0.01
W: Lettuce, head	<0.07	<0.01	<0.08	<0.01	<0.01
X: Sorghum	<0.07	<0.01	<0.08	<0.01	<0.01
Y: Celery	<0.07	<0.01	<0.08	<0.01	<0.01
Z: Horseradish	<0.07	<0.01	<0.08	<0.01	<0.01
AA: Potato	<0.07	<0.01	<0.08	<0.01	<0.01
AB: Radish	<0.07	<0.01	<0.08	<0.01	<0.01
AC: Rice	<0.05	<0.01	<0.06	<0.01	<0.01
AD: Beans	<0.06	<0.01	<0.06	<0.01	<0.01
AE: Okra	<0.06	<0.01	<0.07	<0.01	<0.01
AF: Sugar beet	<0.04	<0.01	<0.05	<0.01	<0.01
AG: Alfalfa	<0.04	<0.01	<0.05	<0.01	<0.01
AH: Pasture	<0.04	<0.01	<0.05	<0.01	<0.01
AI: Grass for seed	<0.04	<0.01	<0.05	<0.01	<0.01
AJ: Rangeland	<0.03	<0.01	<0.03	<0.01	<0.01
AK: Melon	<0.04	<0.01	<0.04	<0.01	<0.01
AL: Roses	<0.04	<0.01	<0.04	<0.01	<0.01
AM: Rights-of-way	<0.03	<0.01	<0.03	<0.01	<0.01
AN: Wasteland	<0.03	<0.01	<0.03	<0.01	<0.01
AO: Non-urban forests	<0.03	<0.01	<0.04	<0.01	<0.01
AP: Rural shelter belts	<0.03	<0.01	<0.04	<0.01	<0.01
AQ: Ticks	<0.06	<0.01	<0.07	<0.01	<0.01

[1]For specific uses associated with each crop group see **Table 5**.
[2]bold values potentially exceed the acute listed species LOC (0.10)

Chronic exposures

Refined dietary-based RQs indicate that, for some carbaryl uses, there is potential for chronic effects to CRLF feeding on small insects or small herbivore mammals. Chronic RQs for these feeding groups are exceeded by factors ranging 1.05X to 9.82X. RQs do not exceed the acute LOC for CRLF feeding on large insects, small insectivore mammals and small terrestrial phase amphibians (**Table 40**). In the available chronic study where mallard ducks were exposed to carbaryl, the NOAEC was 300 ppm, and the LOAEC was 600 ppm, based on decreased number of eggs. Comparison of the LOAEC directly to chronic dietary-based EECs indicate that several EECs are sufficient to exceed the concentration were reproductive effects were observed in the laboratory. Some EECs are insufficient to exceed the LOAEC. As discussed above, 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 CRLF to carbaryl cannot be discounted. Therefore, for all uses where the chronic RQ exceeds the LOC (Table x5), the effects determination for chronic effects to the terrestrial phase CRLF is "LAA" based on potential reproductive effects. For all uses where <u>none</u> of the chronic RQs for the CRLF exceed the LOC, the effects determination is "NLAA" for chronic effects to the terrestrial-phase CRLF.

Table 40. Revised chronic dietary-based RQs for CRLF consuming different dietary items. EECs calculated using T-HERPS.

Crop Group	Small Insects[2]	Large Insects	Small herbivore mammals[2]	Small insectivore mammals	Small terrestrial-phase amphibian
A: Home lawn	**5.20**	0.58	**6.09**	0.38	0.18
B: Flower beds around buildings	**8.39**	0.93	**9.82**	0.61	0.29
C: Lawns	**4.78**	0.53	**5.60**	0.35	0.17
D: Ornamentals	**4.78**	0.53	**5.60**	0.35	0.17
E: Parks	**2.29**	0.25	**2.68**	0.17	0.08
F: Citrus	**7.20**	0.80	**8.43**	0.53	0.25
G: Olives	**3.62**	0.40	**4.24**	0.27	0.13
H: Almonds	**3.02**	0.34	**3.54**	0.22	0.10
I: Flowers	**2.60**	0.29	**3.04**	0.19	0.09
J: Peaches	**1.92**	0.21	**2.24**	0.14	0.07
K: Asparagus	**1.87**	0.21	**2.20**	0.14	0.07
L: Apple	**1.46**	0.16	**1.71**	0.11	0.05
M: Loquat	**1.46**	0.16	**1.71**	0.11	0.05
N: Sweet corn	**2.07**	0.23	**2.43**	0.15	0.07
O: Grapes	**1.23**	0.14	**1.44**	0.09	0.04
P: Strawberries	**1.23**	0.14	**1.44**	0.09	0.04
Q: Tomatoes	**1.23**	0.14	**1.44**	0.09	0.04
R: Peanuts	**1.23**	0.14	**1.44**	0.09	0.04
S: Broccoli	**1.32**	0.15	**1.55**	0.10	0.05
T: Brussels sprouts	**1.32**	0.15	**1.55**	0.10	0.05
U: Sweet potato	**1.23**	0.14	**1.44**	0.09	0.04
V: Field corn	0.97	0.11	**1.14**	0.07	0.03
W: Lettuce, head	**1.21**	0.13	**1.42**	0.09	0.04
X: Sorghum	**1.21**	0.13	**1.42**	0.09	0.04
Y: Celery	**1.21**	0.13	**1.42**	0.09	0.04
Z: Horseradish	**1.21**	0.13	**1.42**	0.09	0.04
AA: Potato	**1.21**	0.13	**1.42**	0.09	0.04
AB: Radish	**1.21**	0.13	**1.42**	0.09	0.04
AC: Rice	0.86	0.10	1.00	0.06	0.03
AD: Beans	0.92	0.10	**1.08**	0.07	0.03
AE: Okra	0.99	0.11	**1.16**	0.07	0.03
AF: Sugar beet	0.72	0.08	0.85	0.05	0.03
AG: Alfalfa	0.68	0.08	0.79	0.05	0.02
AH: Pasture	0.72	0.08	0.85	0.05	0.03
AI: Grass for seed	0.72	0.08	0.85	0.05	0.03
AJ: Rangeland	0.45	0.05	0.53	0.03	0.02
AK: Melon	0.62	0.07	0.72	0.05	0.02
AL: Roses	0.62	0.07	0.72	0.05	0.02
AM: Rights-of-way	0.48	0.05	0.57	0.04	0.02
AN: Wasteland	0.48	0.05	0.57	0.04	0.02
AO: Non-urban forests	0.57	0.06	0.67	0.04	0.02
AP: Rural shelter belts	0.57	0.06	0.67	0.04	0.02
AQ: Ticks	**1.05**	0.12	**1.23**	0.08	0.04

[1]For specific uses associated with each crop group see **Table 5**.
[2]bold values potentially exceed the chronic listed species LOC (1.0)

5.2.1.3. Summary of determinations for direct effects of CRLF resulting from Carbaryl exposures

When considering acute and chronic exposures to the CRLF in its aquatic and terrestrial habitats, estimates of exposure are sufficient to be of concern for effects based on acute or chronic exposures for the majority of carbaryl uses. The overall effects determination for the CRLF is "LAA" for 36 of the 44 assessed use groups of carbaryl. For the remaining 8 use groups, the effects determination is "NLAA" (**Table 41**).

Table 41. Carbaryl use-specific direct effects determinations[1] for the CRLF (shading added to indicate use where there is any LAA determination).

Crop Group[2]	Aquatic-Phase CRLF		Terrestrial-Phase CRLF	
	Acute	Chronic	Acute	Chronic
A: home lawn	NLAA	NE	NLAA	LAA
B: flowers beds around buildings	NE	NE	NLAA	LAA
C: lawns	LAA	LAA	NLAA	LAA
D: ornamentals	LAA	LAA	NLAA	LAA
E: parks	NE	NE	NLAA	LAA
F: citrus	LAA	LAA	NLAA	LAA
G: olives	LAA	LAA	NLAA	LAA
H: almonds	LAA	LAA	NLAA	LAA
I: flowers	NLAA	NE	NLAA	LAA
J: peaches	LAA	LAA	NLAA	LAA
K: asparagus	LAA	LAA	NLAA	LAA
L: apple	NLAA	LAA	NLAA	LAA
M: loquat	NLAA	LAA	NLAA	LAA
N: sweet corn	NLAA	LAA	NLAA	LAA
O: grapes	NLAA	LAA	NLAA	LAA
P: strawberries	LAA	LAA	NLAA	LAA
Q: tomatoes	NLAA	LAA	NLAA	LAA
R: Peanuts	NLAA	NE	NLAA	LAA
S: Broccoli	LAA	LAA	NLAA	LAA
T: Brussels sprouts	LAA	LAA	NLAA	LAA
U: Sweet potato	LAA	LAA	NLAA	LAA
V: Field corn	NE	NE	NLAA	LAA
W: Lettuce, head	LAA	LAA	NLAA	LAA
X: Sorghum	NLAA	NE	NLAA	LAA
Y: Celery	LAA	LAA	NLAA	LAA
Z: Horseradish	LAA	LAA	NLAA	LAA
AA: Potato	LAA	LAA	NLAA	LAA
AB: Radish	NLAA	NE	NLAA	LAA
AC: Rice	LAA	LAA	NLAA	NLAA
AD: Beans	NE	NE	NLAA	LAA
AE: Okra	NE	NE	NLAA	LAA
AF: Sugar beet	NLAA	NE	NLAA	NLAA
AG: Alfalfa	NE	NE	NLAA	NLAA
AH: Pasture	NE	NE	NLAA	NLAA
AI: Grass for seed	NE	NE	NLAA	NLAA
AJ: Rangeland	NLAA	NE	NLAA	NLAA
AK: Melon	NE	NE	NLAA	NLAA
AL: Roses	NLAA	NE	NLAA	NLAA
AM: Rights-of-way	NLAA	LAA	NLAA	NLAA
AN: Wasteland	LAA	LAA	NLAA	NLAA
AO: Non-urban forests	NLAA	NE	NLAA	NLAA
AP: Rural shelter belts	LAA	LAA	NLAA	NLAA
AQ: Ticks	NLAA	LAA	NLAA	LAA

[1]LAA = likely to adversely affect; NLAA = not likely to adversely affect; NE = no effect
[2]For specific uses associated with each crop group see Table 5.

5.2.2. Indirect Effects (through effects to prey)

As discussed in section 2.5.3, the diet of tadpole CRLF is composed primarily of unicellular aquatic plants and detritus. Juvenile CRLF consume primarily aquatic and terrestrial invertebrates. The diet of adult CRLF is composed of aquatic and terrestrial invertebrates, fish, frogs and mice. These prey groups are considered in determining indirect effects to the CRLF caused by direct effects to its prey.

Unicellular plants

Based on RQs for algae (**Table 29**), applications of carbaryl are not expected to affect this food source except for use on rice. Therefore, indirect effects of carbaryl to CRLF tadpoles by reductions in phytoplankton are not expected based on the animal's diet during this life stage for all of the use except rice. However, the use of carbaryl on rice "may affect" tadpoles through the reduction in phytoplankton (RQ=2.0). Since EECs associated with use of carbaryl on rice exceed the level where 50% reduction in algal cells were observed in the laboratory, the determination for indirect effects to the CRLF due to effects to algae is "LAA."

Aquatic invertebrates

(RQ range: 0.3 – 1517) and chronic (RQ range: 0.6-5158) risk estimates for aquatic invertebrates indicate that all uses of carbaryl can potentially result in effects to invertebrates serving as prey to aquatic-phase CRLFs. Based on RQ exceedances of the acute or chronic LOC for listed species, all carbaryl uses "may affect" the CRLF due to effects to aquatic invertebrates, which compose its diet.

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.

When considering chronic exposures, EECs exceed the estimated NOAEC for stoneflies for all uses except flowers around buildings.

In order to characterize the conservativeness of the endpoint selected to represent indirect effects to the CRLF through direct effects to its aquatic prey (*e.g*. Stonefly EC_{50} = 1.7 µg/L) 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 95^{th} percentile of the invertebrate distribution (0.69 µg/L) indicates that the use of the lowest available toxicity value (1.7 µg/L) is not as conservative as the lower 95^{th} 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 exceeds 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) is sufficient to exceed the invertebrate LOC for approximately 65% of available geneses.

Based on acute and chronic RQ exceedances, likelihood of individual mortality analysis and genus sensitivity distribution information for aquatic invertebrates, the determination for indirect effects to the CRLF due to effects to aquatic invertebrates is "LAA" for all uses of carbaryl.

Terrestrial invertebrates

RQ values representing acute exposures to terrestrial invertebrates indicate that all uses of carbaryl can potentially result in effects to invertebrates. Therefore, indirect effects are possible to CRLF juveniles and adults, through decreases in prey. When considering the level where carbaryl causes 50% mortality in honey bees, EECs are sufficient to exceed this level by factors of 2x-293x (**Table 33**). Based on an analysis of the likelihood of individual mortality using the lowest RQ value for terrestrial invertebrates (RQ=2) and a probit dose-response of 4.5 (default value), the likelihood of individual mortality is 91%. All other RQ values result in an estimation of approximately 100% likelihood of individual mortality in terrestrial invertebrates. Therefore, the determination for indirect effects to the CRLF due to effects to terrestrial invertebrates is "LAA" for all uses of carbaryl.

Fish and aquatic-phase amphibians

RQs representing direct exposures of carbaryl to aquatic-phase CRLF can also be used to represent exposures of carbaryl to fish and frogs in aquatic habitats. Based on estimated exposures resulting from use of carbaryl, acute (RQ range: 0.05 – 12) risk to fish and frogs serving as prey to CRLF is possible across all of the uses evaluated except for use of carbaryl on flowers around buildings, corn, dray beans, okra, alfalfa, grass for seed and melons. Based on an analysis of the likelihood of individual acute mortality, RQ values of less than 0.4 represent less than a 1 in 30 chance of prey mortality which is not considered significant. The low significance of a 1/30 likelihood of acute mortality is based on the use of a conservative toxicity endpoint (Atlantic salmon LC_{50}=220 μg/L) in estimating risks and the likelihood of alternative prey items for the CRLF. Based on the species sensitivity distribution for fish, the lower 95th percentile of the distribution is 472 μg/L. Thus it is likely that a number of less sensitive vertebrate prey items would be available for consumption. Therefore, only carbaryl uses on ornamentals, strawberries, Brussels sprouts, head lettuce and rice are determined to likely adversely affect the CRLF through indirect effects on aquatic vertebrate prey items.

Chronic risks (RQ range: 1.1 – 379) to fish and frogs are possible for carbaryl uses on 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 for control of ticks (**Table 28**). These uses of carbaryl are determined to likely adversely affect the CRLF through indirect chronic effects on aquatic vertebrate prey items.

Small terrestrial mammals

Acute dose-based RQ values (RQ range 0.37 – 6.5) representing carbaryl exposures to mice (small mammals) indicate potential for indirect effects to CRLF from all uses of carbaryl modeled through decreased availability of prey. Chronic dietary-based RQ values (RQ range 3 – 56) indicate chronic risk to small vertebrates serving as prey to terrestrial-phase CRLF for all carbaryl uses (**Table 34**). Based on the highest dose-based RQ (RQ=6.5) for terrestrial mammals, the likelihood of individual mortality is 100% (based on default slope of 4.5; **Appendix K**). Even at the lowest RQ for mammals (RQ=0.35), the likelihood of individual mortality is 20%. Therefore, the determination for indirect effects to the CRLF due to effects to terrestrial mammals is "LAA" for all uses of carbaryl.

Small terrestrial-phase amphibians

In order to explore influences of amphibian-specific food intake equations on potential dose-based and dietary-based exposures of amphibians (prey of CRLF) to carbaryl, T-HERPS is used. The Pacific tree frog is used to represent the amphibian prey species. The weight of the animal was assumed to be 2.3 g, and its diet was assumed to be composed of small and large insects. Consideration of dose-based RQs calculated by T-HERPS for small (1.4g) and medium (37 g) sized CRLF which consume small and large invertebrates (**Tables 36** and **37**), indicates that amphibian specific EECs for frogs smaller and larger than the Pacific Tree frog are insufficient to reach levels where no mortality was observed in a laboratory study with birds (surrogates for terrestrial-phase frogs) (*i.e.* the RQs are <1). Acute dietary-based RQs for the CRLF, which do not account for the weight of the animal being assessed, can also be used to assess risks to the terrestrial frog prey (**Table 39**). Again, although dietary-based RQs potentially exceed the LOC, EECs for frogs are insufficient to reach levels where no mortality was observed in a laboratory study with birds (*i.e.* the RQs are <1). This indicates that mortality from acute carbaryl exposures to terrestrial frogs representing CRLF prey is unlikely.

Chronic dietary-based RQs for the CRLF, which do not account for the weight of the animal being assessed, can also be used to assess risks to the terrestrial frog prey (**Table 40**). Refined dietary-based RQs indicate that, for some carbaryl uses, there is potential for chronic effects to terrestrial frogs feeding on small insects. Chronic RQs are exceeded by factors ranging 1.05X to 8.4X. RQs do not exceed the chronic LOC for terrestrial frogs feeding on large insects, which also compose the diet of prey of the CRLF. Since frogs would be expected to consume both small and large insects, it seems likely that the actual EEC should fall somewhere between the extreme EECs representing diets composed only of small insects and diets composed only of large insects. Therefore, there is potential for estimates of exposure and s

In the available chronic study where mallard ducks were exposed to carbaryl, the NOAEC was 300 ppm, and the LOAEC was 600 ppm, based on decreased number of eggs. Comparison of the LOAEC directly to chronic dietary-based EECs indicate that several EECs are sufficient to exceed the concentration were reproductive effects were observed in the laboratory. Some EECs are insufficient to exceed the LOAEC. As discussed above, 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 terrestrial prey frogs to carbaryl cannot be discounted.

Therefore, for all uses where the chronic RQ exceeds the LOC, the determination for indirect effects to the CRLF due to chronic effects to terrestrial frogs representing its prey is "LAA." For uses where the chronic RQs for the do not exceed the LOC, the determination is "NLAA" for indirect effects to the CRLF due to chronic effects to frogs representing its prey.

Summary of indirect effects to the CRLF based on effects to prey

When considering indirect effects to the CRLF through effects to its prey, estimates of exposure are sufficient to be of concern for effects based on decreased prey for several taxa of the CRLF's prey for the majority of carbaryl uses. Although effects to the prey of the tadpole life stage are not expected for the majority of carbaryl's uses (with the exception of use on rice), effects to the prey of the juvenile and adult lifestages of the CRLF are of concern. The overall effects determination for the CRLF based on indirect effects due to effects due to prey is "LAA" for all uses of carbaryl (**Table 42**).

Table 42. Carbaryl use-specific indirect effects determinations[1] based on effects to prey (shading added to indicate use where there is any LAA determination).

Crop Group[2]	Algae	Aquatic Invertebrates		Terrestrial Invertebrates (Acute)	Aquatic-phase frogs and fish		Terrestrial-phase frogs		Small Mammals	
		Acute	Chronic		Acute	Chronic	Acute	Chronic	Acute	Chronic
A: home lawn	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
B: flowers beds around buildings	NE	LAA	NE	LAA	NE	NE	NLAA	LAA	LAA	LAA
C: lawns	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
D: ornamentals	NE	LAA	LAA	LAA	LAA	LAA	NLAA	LAA	LAA	LAA
E: parks	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
F: citrus	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
G: olives	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
H: almonds	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
I: flowers	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
J: peaches	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
K: asparagus	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
L: apple	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
M: loquat	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
N: sweet corn	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
O: grapes	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
P: strawberries	NE	LAA	LAA	LAA	LAA	LAA	NLAA	LAA	LAA	LAA
Q: tomatoes	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
R: Peanuts	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
S: Broccoli	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
T: Brussels sprouts	NE	LAA	LAA	LAA	LAA	LAA	NLAA	LAA	LAA	LAA
U: Sweet potato	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
V: Field corn	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
W: Lettuce, head	NE	LAA	LAA	LAA	LAA	LAA	NLAA	LAA	LAA	LAA
X: Sorghum	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
Y: Celery	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
Z: Horseradish	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
AA: Potato	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA
AB: Radish	NE	LAA	LAA	LAA	NLAA	NE	NLAA	LAA	LAA	LAA
AC: Rice	LAA	LAA	LAA	LAA	LAA	LAA	NLAA	NLAA	LAA	LAA
AD: Beans	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
AE: Okra	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
AF: Sugar beet	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
AG: Alfalfa	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
AH: Pasture	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
AI: Grass for seed	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
AJ: Rangeland	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
AK: Melon	NE	LAA	LAA	LAA	NE	NE	NLAA	NLAA	LAA	LAA
AL: Roses	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
AM: Rights-of-way	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	NLAA	LAA	LAA
AN: Wasteland	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	NLAA	LAA	LAA
AO: Non-urban forests	NE	LAA	LAA	LAA	NLAA	NE	NLAA	NLAA	LAA	LAA
AP: Rural shelter belts	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	NLAA	LAA	LAA
AQ: Ticks	NE	LAA	LAA	LAA	NLAA	LAA	NLAA	LAA	LAA	LAA

[1]LAA = likely to adversely affect; NLAA = not likely to adversely affect; NE = no effect. [2]For specific uses associated with each crop group see **Table 5**.

5.2.3. Indirect Effects (through effects to habitat)

As discussed in section 2.5.4, the habitat of the CRLF varies during its life cycle, with the CRLF surviving in aquatic, riparian and upland areas. Adults rely on riparian vegetation for resting, feeding, and dispersal. Egg masses are typically attached to emergent vegetation, such as bulrushes (*Scirpus* spp.) and cattails (*Typha* spp.) or roots and twigs, and float on or near the surface of the water (Hayes and Miyamoto 1984).

Based on RQs for unicellular and vascular plants inhabiting aquatic habitats (**Table 31**), 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 approximately 2, meaning that estimated exposure concentrations are twice the level where 50% effects have been observed in laboratory tests involving aquatic plants exposed to carbaryl.

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 (11) 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, 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, the determination for indirect effects to the CRLF caused by effects to riparian and terrestrial plants resulting from use of carbaryl is “likely to adversely affect.”

5.2.4. Primary Constituent Elements of Designated Critical Habitat

5.2.4.1. Aquatic-Phase (Aquatic breeding habitat and aquatic non-breeding habitat)

Two of the four assessment endpoints for the aquatic-phase primary constituent elements (PCEs) of designated critical habitat for the CRLF are related to potential effects to aquatic and/or riparian plants:

- Alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond: aquatic habitat (including riparian vegetation) provides for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs.
- Alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food source.

Due to potential effects to riparian vegetation caused by use of carbaryl, the determination is "habitat modification."

The third aquatic-phase PCE is "alteration of other chemical characteristics necessary for normal growth and viability of CRLFs and their food source." Carbaryl is not expected to alter the chemical characteristics of the water such that growth and viability of the CRLF or their habitat would not be a concern.

Another of the aquatic-phase PCE is: reduction and/or modification of aquatic-based food sources for pre-metamorphs (*e.g.,* algae). RQs do not exceed the LOC for algae for uses of carbaryl, with the exception of use on rice. Therefore, for all carbaryl uses, except rice, this PCE is not of concern.

5.2.4.2. Terrestrial-Phase (upland habitat and dispersal habitat)

Three of the four assessment endpoints for the terrestrial-phase PCEs of designated critical habitat for the CRLF are related to potential effects to terrestrial plants:

- Elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs: Upland areas within 200 ft of the edge of the riparian vegetation or drip line surrounding aquatic and riparian habitat that are comprised of grasslands, woodlands, and/or wetland/riparian plant species that provides the CRLF shelter, forage, and predator avoidance
- Elimination and/or disturbance of dispersal habitat: Upland or riparian dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal

- Alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs and their food source.

Potential risk of carbaryl to terrestrial plants resulting in the determination of "habitat modification."

The remaining terrestrial-phase PCE is "reduction and/or modification of food sources for terrestrial phase juveniles and adults." RQs for terrestrial invertebrates, which represent a food source for terrestrial phase CRLF, exceed the LOC. Therefore, the determination for this endpoint is "habitat modification."

5.2.5. Action Area

5.2.5.1. Areas indirectly affected by the federal action

The initial action area for carbaryl was previously discussed in Section 2.7 and depicted in **Figures 6-10** of the problem formulation. In order to determine the extent of the action area in lotic (flowing) aquatic habitats, the greatest ratios of the RQ to the LOC for any endpoint for aquatic organisms for each use category is used to determine the distance downstream for concentrations to be diluted below levels that would be of concern (*i.e.* result in RQs above the LOC). For this assessment, this applies to RQs for acute exposures of carbaryl to aquatic invertebrates. For all uses in a landcover category, the highest RQ/LOC ratio is used to define the action area for that group of uses (**Table 43**). The total stream kilometers within the action area that are estimated to be at levels of concern are defined in **Table 44**.

Table 43. Down stream dilution factors used to determine extent of lotic action area for uses of carbaryl.

Action area title	Uses	Down stream dilution factor (RQ/LOC ratio)	Specific use group defining down stream dilution factor
Orchard/vineyard	citrus, olives, almonds, chestnuts, pecans, filberts, walnuts, pistachios, peaches, apricots, cherries, nectarines, plums, prunes, pears, crabapples, oriental pears, apple, loquat, grapes	660	Peaches
agricultural lands	asparagus, corn, strawberries, tomatoes, eggplant, peanuts, broccoli, Brussels sprouts, sweet potato, corn, lettuce, dandelion, endive, parsley, spinach, Swiss chard, sorghum, celery, horseradish, potato, parsnip, rutabaga, turnip, radish, rice, dry beans, fresh peas, dry peas, cow peas, southern peas, okra, sugar beet, alfalfa, birds foot trefoil, clover, melon, cucumber, pumpkin, squash, grass for seed, rural shelter belts, ornamentals, flowers, roses, peppers, cauliflower, cabbage, kohlrabi, Chinese cabbage, collards, kale, mustard greens, Hanover salad	30340	Rice
residential (urban)	flower beds around buildings, roses, home lawn, lawns, parks, recreational areas, golf courses, sod farms, commercial lawns, rights-of-way, hedgerows, ditch banks, roadsides, ticks, grasshoppers	336	Rights-of-way
pasture	pasture, rangeland	150	Rangeland
non-urban forests	Forestry, tree plantations, Christmas trees, parks, rangeland trees	136	Forestry

Table 44. Quantitative results of spatial analysis of lotic aquatic action area relevant to carbaryl uses (in km).

Measure	Orchard/ vineyard	Agriculture	Residential	Pasture	Forest
Total Streams in CA	332,962				
Streams within initial area of concern	11,946	56,404	104,061	29,071	142,464
Downstream distance added	3,431	9,158	7,739	8,559	26,676
Streams in aquatic action area	15,377	65,562	111,800	37,630	169,140

When considering the terrestrial habitats of the CRLF, spray drift from use sites onto non-target areas could potentially result in exposures of the CRLF, its prey and its habitat to carbaryl. Therefore, it is necessary to estimate the distance from the application site where spray drift exposures do not result in LOC exceedances for organisms within the terrestrial habitat. To account for this, first, the carbaryl application rate which does not result in an LOC exceedance is calculated for each terrestrial taxa of concern. AgDISP was then used to determine the distance required to reach EECs not exceeding any LOCs. These values are defined for each use in **Table 45**.

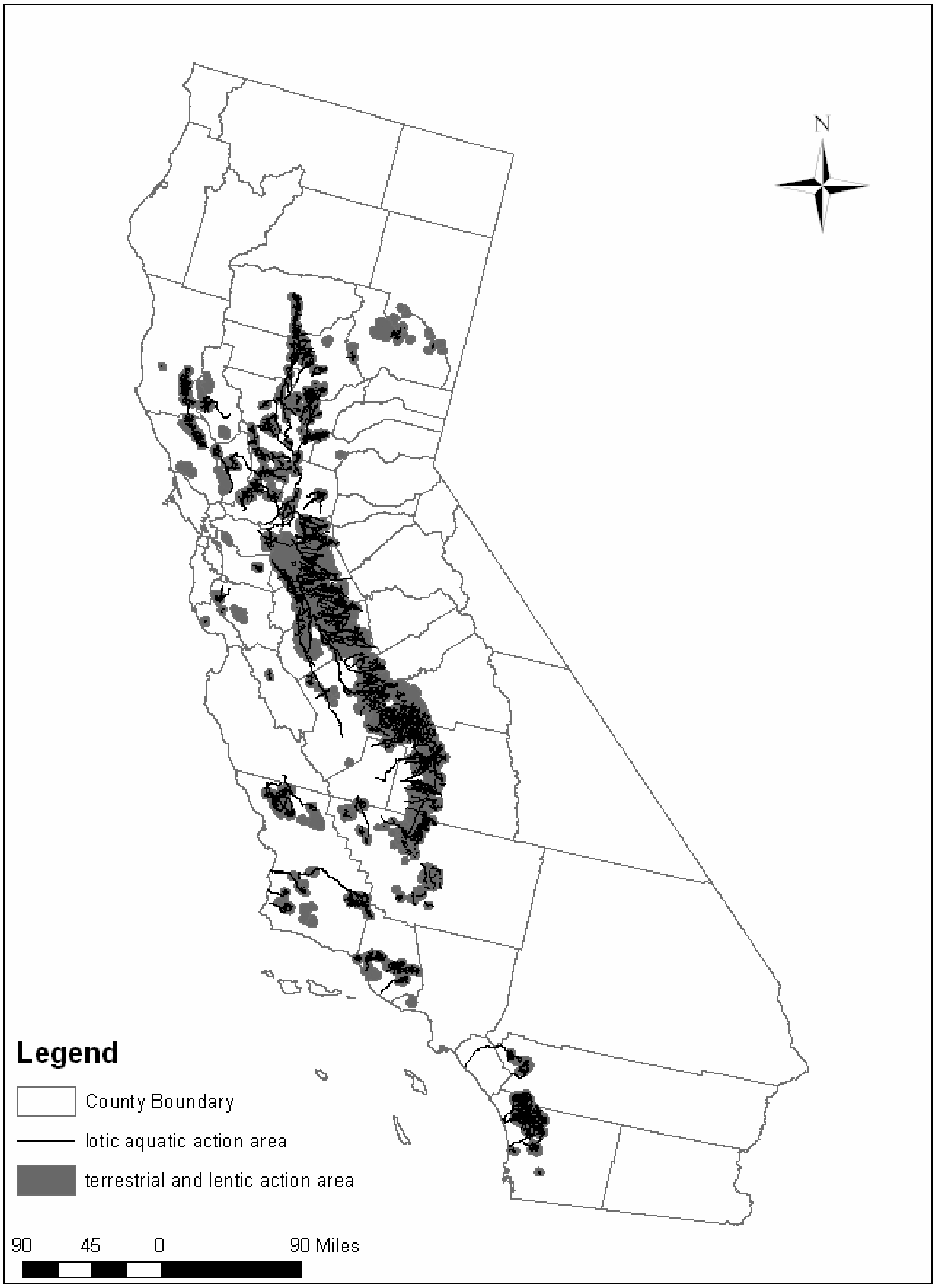
Table 45. Spray drift distances used to determine extent of terrestrial action area for uses of carbaryl.

Action area title	Uses	Spray drift distance not exceeding LOC (in feet)	Specific use group defining spray drift distance
Orchard/vineyard	citrus, olives, almonds, chestnuts, pecans, filberts, walnuts, pistachios, peaches, apricots, cherries, nectarines, plums, prunes, pears, crabapples, oriental pears, apple, loquat, grapes	10920	citrus
agricultural lands	asparagus, corn, strawberries, tomatoes, eggplant, peanuts, broccoli, Brussels sprouts, sweet potato, corn, lettuce, dandelion, endive, parsley, spinach, Swiss chard, sorghum, celery, horseradish, potato, parsnip, rutabaga, turnip, radish, rice, dry beans, fresh peas, dry peas, cow peas, southern peas, okra, sugar beet, alfalfa, birds foot trefoil, clover, melon, cucumber, pumpkin, squash, grass for seed, rural shelter belts, ornamentals, flowers, roses, peppers, cauliflower, cabbage, kohlrabi, Chinese cabbage, collards, kale, mustard greens, Hanover salad	6238	asparagus
residential (urban)	flower beds around buildings, roses, home lawn, lawns, parks, recreational areas, golf courses, sod farms, commercial lawns, rights-of-way, hedgerows, ditch banks, roadsides, ticks, grasshoppers	6293	turf
pasture	pasture, rangeland	3293	rangeland
non-urban forests	Forestry, tree plantations, Christmas trees, parks, rangeland trees	3293	forestry

To understand the area indirectly affected by the federal action due to spray drift from application areas of carbaryl, landcovers are considered as potential application areas. These areas are “buffered” using ArcGIS 9.2. In this process, the original landcover is modified by expanding the border of each polygon representing a field out to a designated distance, which in this case, is the distance estimated where carbaryl in spray drift does not exceed any LOCs. This effectively expands the action area relevant to terrestrial habitats so that it includes the area directly affected by the federal action, and the area indirectly affected by the federal action.

5.2.5.2. Final action area

In order to define the final action areas relevant to uses of carbaryl, it is necessary to combine areas directly affected, as well as aquatic and terrestrial habitats indirectly affected by the federal action. This is done separately for the 5 categories of action areas (i.e. agricultural, orchard/vineyard, residential, pasture and forests) using ArcGIS 9.2. Landcovers representing areas directly affected by carbaryl applications are overlapped with indirectly affected aquatic habitats (determined by down stream dilution modeling) and with indirectly affected terrestrial habitats (determined by spray drift modeling). It is assumed that lentic (standing water) aquatic habitats (*e.g.* ponds, pools, marshes) overlapping with the terrestrial areas are also indirectly affected by the federal action. The result is the final action area for carbaryl uses (**Figures 19-23**).



Compiled from California County boundaries (ESRI, 2002),
USDA National Agriculture Statistical Service (NASS, 2002)
Gap Analysis Program Orchard/ Vineyard Landcover (GAP)
National Land Cover Database (NLCD) (MRLC, 2001)

Map created by U.S. Environmental Protection Agency,
Office of Pesticides Programs, Environmental Fate and
Effects Division. April 11, 2007.
Projection: Albers Equal Area Conic USGS,
North American Datum of 1983 (NAD 1983)

Figure 19. Final action area for crops described by orchard/vineyard landcover which corresponds to potential carbaryl use sites. This map represents the area potentially directly and indirectly affected by the federal action.

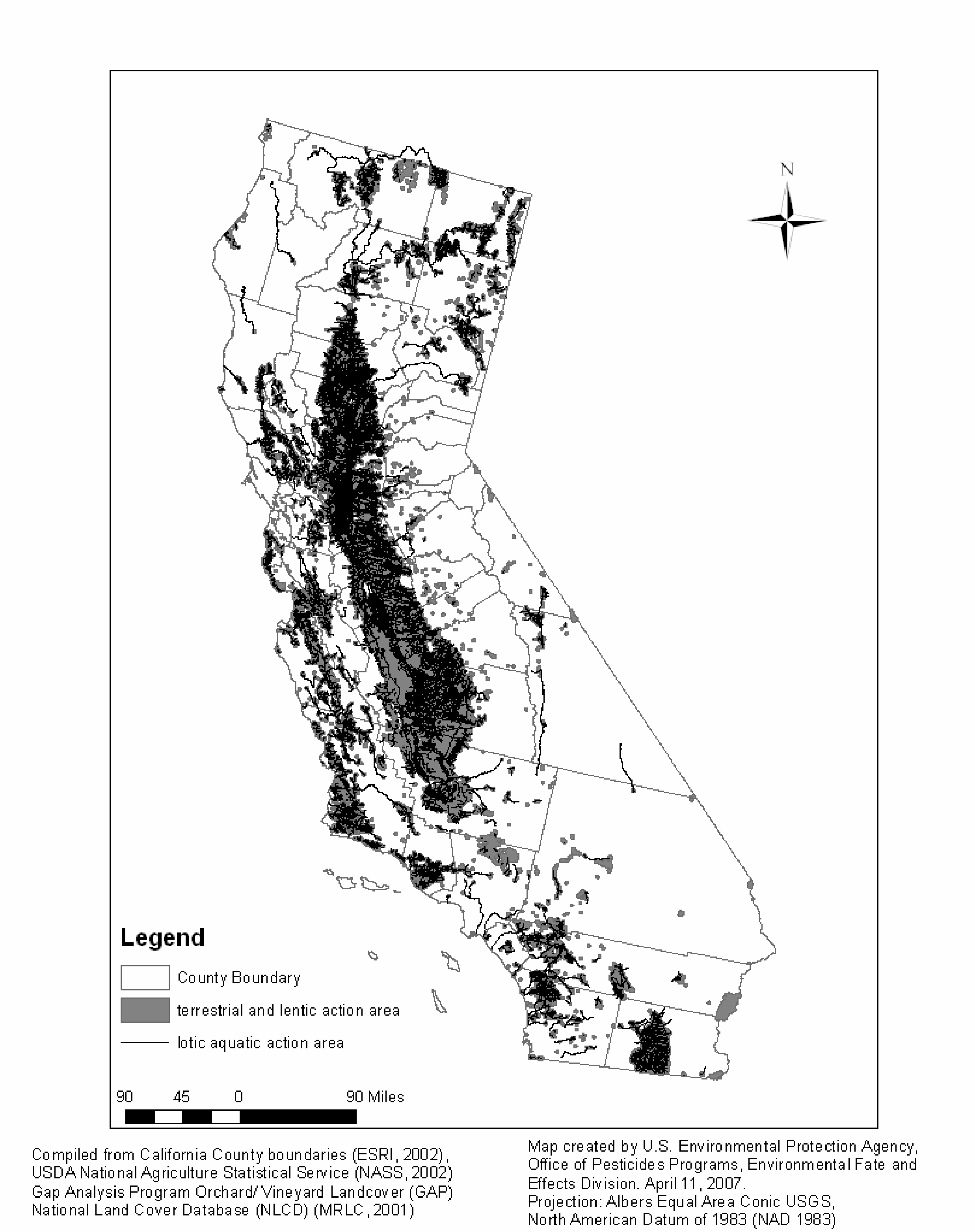


Figure 20. Final action area for crops described by agricultural landcover which corresponds to potential carbaryl lithium use sites. This map represents the area potentially directly and indirectly affected by the federal action.

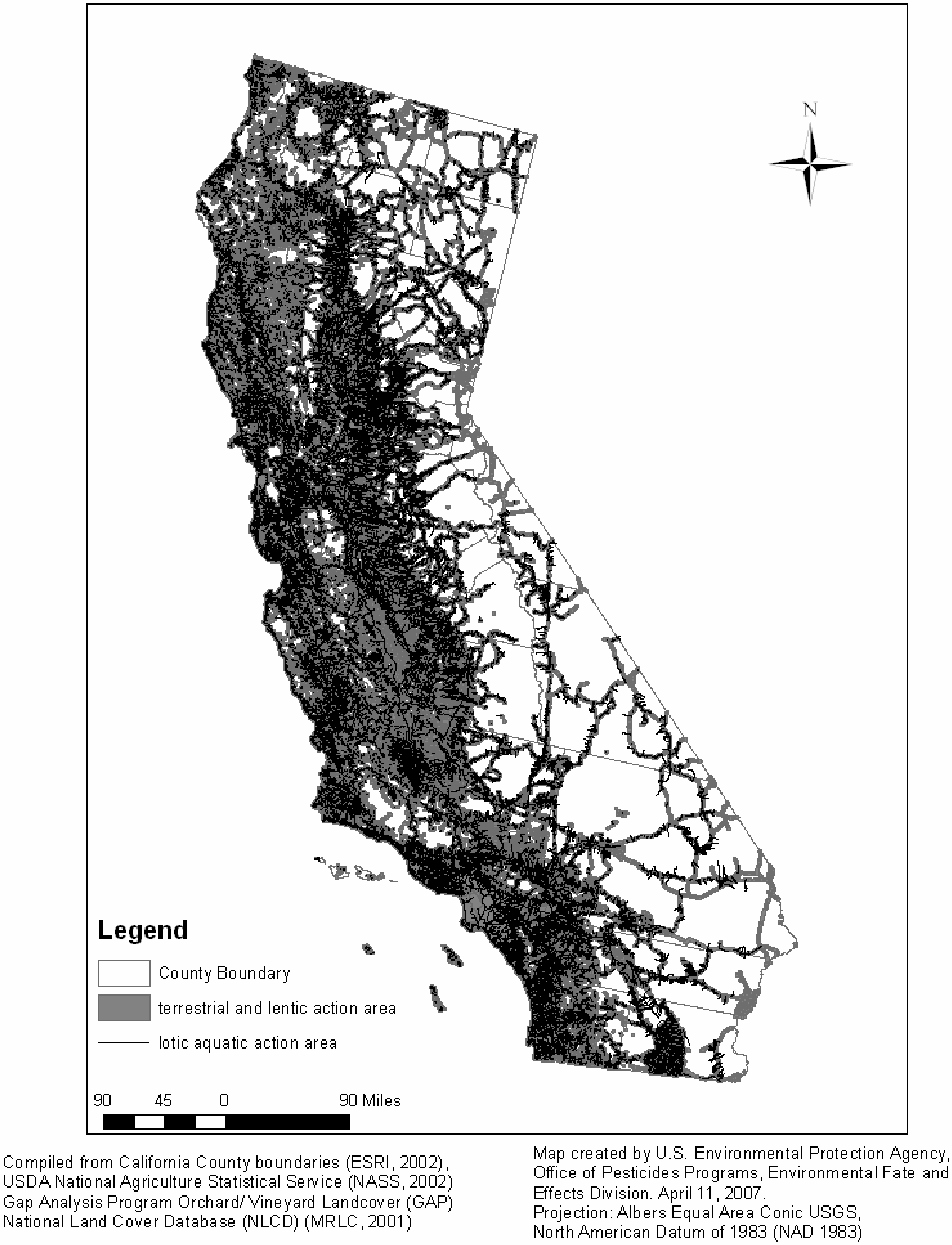
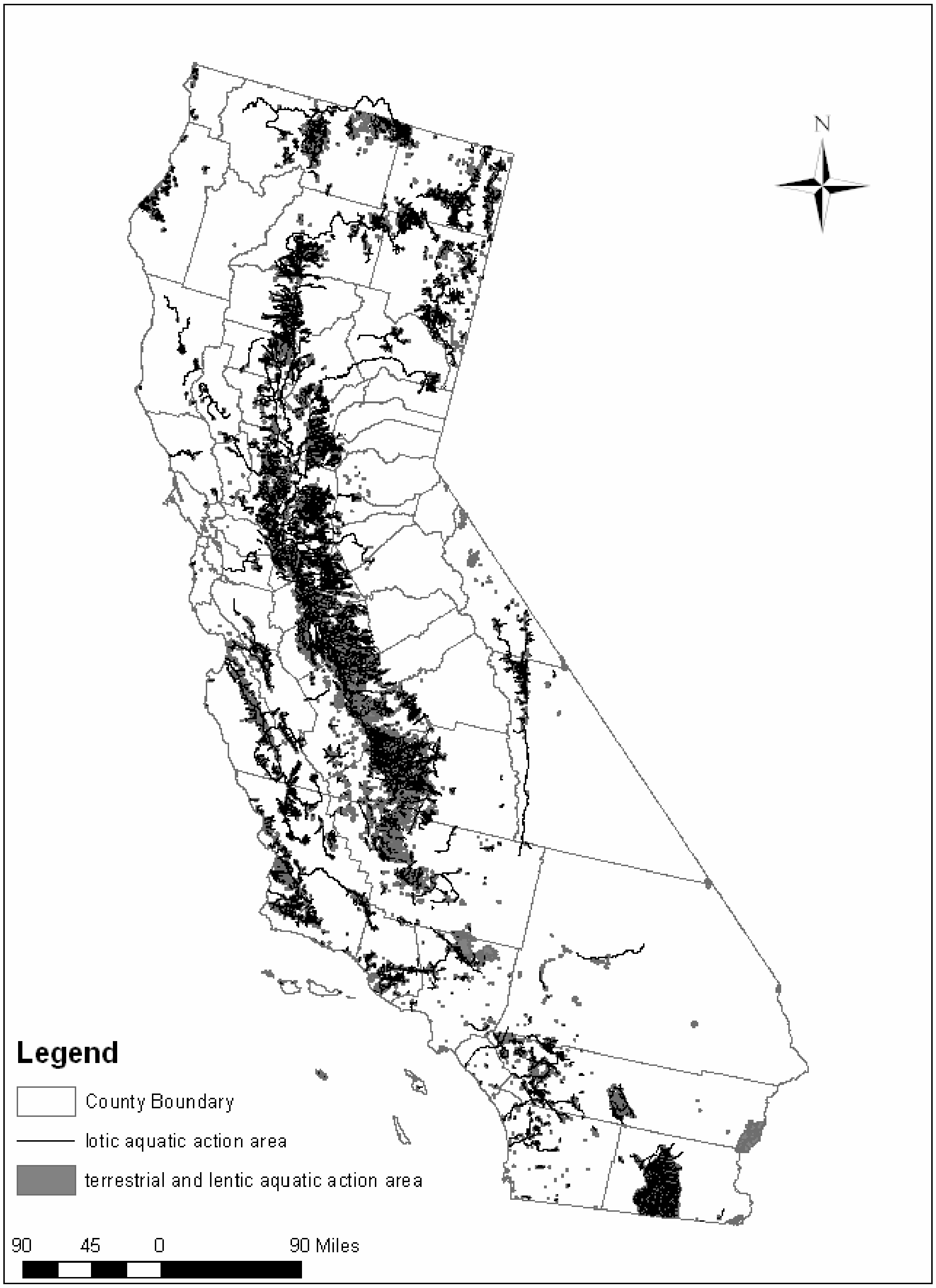


Figure 21. Final action area for crops described by residential landcover which corresponds to potential carbaryl use sites. This map represents the area potentially directly and indirectly affected by the federal action.



Compiled from California County boundaries (ESRI, 2002), USDA National Agriculture Statistical Service (NASS, 2002) Gap Analysis Program Orchard/ Vineyard Landcover (GAP) National Land Cover Database (NLCD) (MRLC, 2001)

Map created by U.S. Environmental Protection Agency, Office of Pesticides Programs, Environmental Fate and Effects Division. April 11, 2007. Projection: Albers Equal Area Conic USGS, North American Datum of 1983 (NAD 1983)

Figure 22. Final action area for crops described by pasture landcover which corresponds to potential carbaryl use sites. This map represents the area potentially directly and indirectly affected by the federal action.

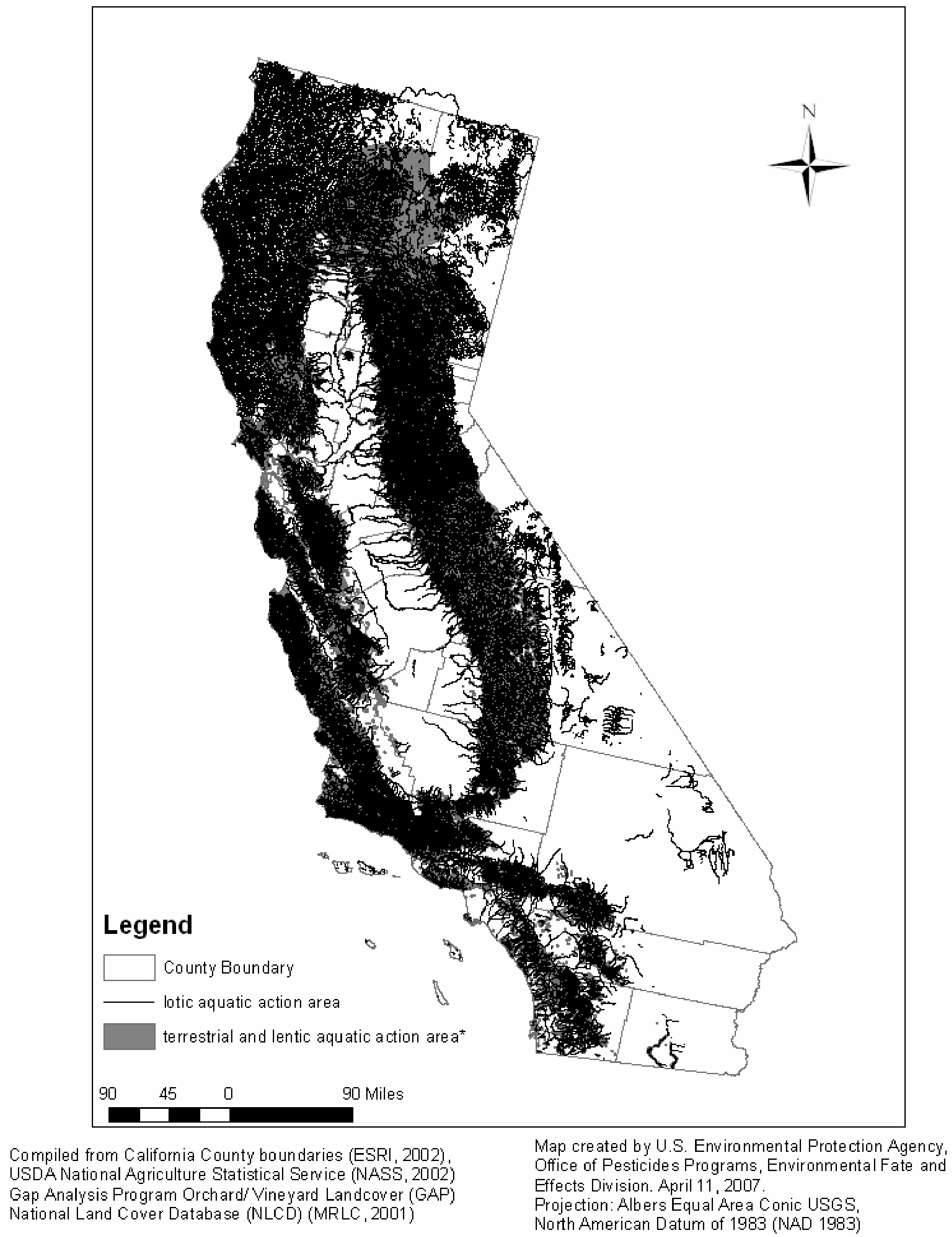


Figure 23. Final action area for crops described by non-urban forest landcover which corresponds to potential carbaryl use sites. This map represents the area potentially directly and indirectly affected by the federal action. *Within recovery units.

5.2.5.3. Overlap between CRLF habitat and final action area

In order to confirm that uses of carbaryl have the potential to affect CRLF through direct applications to target areas and runoff and spray drift to non-target areas, it is necessary to determine whether or not the final action areas for carbaryl uses overlap with CRLF habitats. Spatial analysis using ArcGIS 9.2 indicates that lotic aquatic habitats within the CRLF core areas and critical habitats potentially contain concentrations of carbaryl sufficient to result in RQ values that exceed LOCs. In addition, terrestrial habitats (and potentially lentic aquatic habitats) of the final action areas overlap with the core areas, critical habitat and available occurrence data for CRLF (**Tables 46-50**). Thus, uses of carbaryl could result in exposures of carbaryl to CRLF in aquatic and terrestrial habitats. Additional analysis related to the intersection of the carbaryl action areas and CRLF habitat is described in **Appendix C**.

Table 46. Overlap between CRLF habitat (core areas and critical habitat) and orchard/vineyard action area by recovery unit (RU#).

Measure	RU1	RU2	RU3	RU4	RU5	RU6	RU7	RU8	Total
CRLF habitat (km^2)*	3654	2742	1323	3279	3650	5306	4917	3326	28,197
Overlapping area of CRLF habitat and terrestrial/lentic aquatic action area (km^2)	126	285	27	218	76	354	906	745	2,736
% CRLF habitat overlapping with terrestrial/lentic aquatic Action Area	*3%*	*10%*	*2%*	*7%*	*2%*	*7%*	*18%*	*22%*	*10%*
# Occurrences overlapping with terrestrial/lentic aquatic action area (959 total)	0	0	2	53	11	4	23	4	97

*Area occupied by core areas and/or critical habitat.

Table 47. Overlap between CRLF habitat (core areas and critical habitat) and agricultural action area by recovery unit (RU#).

Measure	RU1	RU2	RU3	RU4	RU5	RU6	RU7	RU8	Total
CRLF habitat (km^2)*	3654	2742	1323	3279	3650	5306	4917	3326	28,197
Overlapping area of CRLF habitat and terrestrial/lentic aquatic action area (km^2)	447	289	189	1010	1571	1494	1940	616	7,555
% CRLF habitat overlapping with terrestrial/lentic aquatic Action Area	*12%*	*11%*	*14%*	*31%*	*43%*	*28%*	*39%*	*19%*	*27%*
# Occurrences overlapping with terrestrial/lentic aquatic action area (959 total)	0	0	18	141	208	48	70	3	488

*Area occupied by core areas and/or critical habitat.

Table 48. Overlap between CRLF habitat (core areas and critical habitat) and residential action area by recovery unit (RU#).

Measure	RU1	RU2	RU3	RU4	RU5	RU6	RU7	RU8	Total
CRLF habitat (km^2)*	3654	2742	1323	3279	3650	5306	4917	3326	28,197
Overlapping area of CRLF habitat and terrestrial/lentic aquatic action area (km^2)	2764	2154	1183	2614	3298	4168	3835	2895	22911
% CRLF habitat overlapping with terrestrial/lentic aquatic Action Area	*76%*	*79%*	*89%*	*80%*	*90%*	*79%*	*78%*	*87%*	*81%*
# Occurrences overlapping with terrestrial/lentic aquatic action area (959 total)	10	3	69	308	275	119	90	33	907

*Area occupied by core areas and/or critical habitat.

Table 49. Overlap between CRLF habitat (core areas and critical habitat) and pasture action area by recovery unit (RU#).

Measure	RU1	RU2	RU3	RU4	RU5	RU6	RU7	RU8	Total
CRLF habitat (km^2)*	3654	2742	1323	3279	3650	5306	4917	3326	28,197
Overlapping area of CRLF habitat and terrestrial/lentic aquatic action area (km^2)	82	273	24	89	382	499	977	139	2465
% CRLF habitat overlapping with terrestrial/lentic aquatic Action Area	*2%*	*10%*	*2%*	*3%*	*10%*	*9%*	*20%*	*4%*	*9%*
# Occurrences overlapping with terrestrial/lentic aquatic action area (959 total)	0	0	2	26	79	22	48	1	178

*Area occupied by core areas and/or critical habitat.

Table 50. Overlap between CRLF habitat (core areas and critical habitat) and forestry action area by recovery unit (RU#).

Measure	RU1	RU2	RU3	RU4	RU5	RU6	RU7	RU8	Total
CRLF habitat (km^2)*	3654	2742	1323	3279	3650	5306	4917	3326	28,197
Overlapping area of CRLF habitat and terrestrial/lentic aquatic action area (km^2)	3643	2222	1205	2665	3453	2782	4400	2315	22,688
% CRLF habitat overlapping with terrestrial/lentic aquatic Action Area	*100%*	*81%*	*91%*	*81%*	*95%*	*52%*	*89%*	*70%*	*80%*
# Occurrences overlapping with terrestrial/lentic aquatic action area (959 total)	5	3	33	205	240	78	68	10	642

*Area occupied by core areas and/or critical habitat.

5.2.6. Description of Assumptions, Limitations, Uncertainties, Strengths and Data Gaps

5.2.6.1. Exposure Assessment

Aquatic exposure modeling of carbaryl

The standard ecological water body scenario (EXAMS pond) used to calculate potential aquatic exposure to pesticides is intended to represent conservative estimates, and to avoid underestimations of the actual exposure. The standard scenario consists of application to a 10-hectare field bordering a 1-hectare, 2-meter deep (20,000 m^3) pond with no outlet. Exposure estimates generated using the EXAMS pond are intended to represent a wide variety of vulnerable water bodies that occur at the top of watersheds including prairie pot holes, playa lakes, wetlands, vernal pools, man-made and natural ponds, and intermittent and lower order streams. As a group, there are factors that make these water bodies more or less vulnerable than the EXAMS pond. Static water bodies that have larger ratios of pesticide-treated drainage area to water body volume would be expected to have higher peak EECs than the EXAMS pond. These water bodies will be either smaller in size or have larger drainage areas. Smaller water bodies have limited storage capacity and thus may overflow and carry pesticide in the discharge, whereas the EXAMS pond has no discharge. As watershed size increases beyond 10-hectares, it becomes increasingly unlikely that the entire watershed is planted with a single crop that is all treated simultaneously with the pesticide. Headwater streams can also have peak concentrations higher than the EXAMS pond, but they likely persist for only short periods of time and are then carried and dissipated downstream.

The Agency acknowledges that there are some unique aquatic habitats that are not accurately captured by this modeling scenario and modeling results may, therefore, under- or over-estimate exposure, depending on a number of variables. For example, aquatic-phase CRLFs may inhabit water bodies of different size and depth and/or are located adjacent to larger or smaller drainage areas than the EXAMS pond. The Agency does not currently have sufficient information regarding the hydrology of these aquatic habitats to develop a specific alternate scenario for the CRLF. As previously discussed in Section 2 and in Attachment 1, CRLFs prefer habitat with perennial (present year-round) or near-perennial water and do not frequently inhabit vernal (temporary) pools because conditions in these habitats are generally not suitable (Hayes and Jennings 1988). Therefore, the EXAMS pond is assumed to be representative of exposure to aquatic-phase CRLFs. In addition, the Services agree that the existing EXAMS pond represents the best currently available approach for estimating aquatic exposure to pesticides (USFWS/NMFS 2004a).

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. Peak EECs resulting from different carbaryl uses ranged 5.6 - 2579 μg/L. The maximum concentration of carbaryl reported by NAWQA (1999-2005) for California surface waters with agricultural watersheds (1.06 μg/L) is three orders of magnitude less than the maximum EEC, 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 μg/L) 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 μg/L) 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 μg/L) in a single sample. Carbaryl was not detected at concentrations sufficient to exceed the direct effects acute risk LOC (>12.5 μg/L) in any of the samples (**Figure 15**).

Differences between modeled EECs and monitoring results are generally attributable to three sources: 1) simulation modeling estimates are made using maximum label rates, monitoring data reflects typical use, 2) modeled values represent a small static water body, the vast majority of monitoring data is for streams and rivers which tend to be less vulnerable as high concentration tend to be of short duration as they pesticide is carried downstream more rapidly; 3) simulation modeling represents a small watershed near the area of application; 4) monitoring data usually represents higher order streams with large basins and multiple land uses; 5: modeled values are 1 in 10 year exceedance values. Since most monitoring data is from one or two year studies at any one site, it represents 1 in 2 year values. This is reflected in the simulation modeling as well. The 1 in 10 year peak EEC for carbaryl for lettuce was 93.5 $\mu g \cdot L^{-1}$ while the 1 in 2 year EEC is 23.1 $\mu g \cdot L^{-1}$.

Terrestrial exposure modeling of carbaryl

As indicated above, only similar foliar applications are considered when assessing EECs for terrestrial-phase CRLF and its prey (terrestrial invertebrates, small mammals and frogs), since T-REX. not appropriate for modeling soil applications with incorporation. Several of the uses, *e.g.* dormant applications to orchard crops and pre- versus post-emergent applications to asparagus, utilize different application rates.

Deposition of carbaryl in precipitation

Carbaryl has been detected in precipitation samples in California (**Table 51**). 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 51. 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 µg/L. 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 x10^7 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 52**). 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 52. 1-in-10 year peak estimates of carbaryl concentrations in aquatic and terrestrial habitats resulting from deposition of carbaryl at 0.756 µg/L carbaryl in rain.

Met Station	Scenario	Concentration in aquatic habitat (µg/L)	Deposition on terrestrial habitat (lbs a.i./A)
Sacramento	CA almond	0.141	0.0005
Santa Maria	CA lettuce	0.152	0.0004
San Francisco	CA wine grape	0.133	0.0004
Monterey Co.	CA row crop	0.122	0.0005
Fresno	CA fruit	0.055	0.0003
San Diego	CA nursery	0.102	0.0004
Bakersfield	CA onion	0.041	0.0002

To estimate deposition of carbaryl on the terrestrial habitat resulting from deposition in rain, the daily volume of water deposited in precipitation on 1 acre of land is estimated. This volume is multiplied by the maximum concentration of carbaryl in precipitation reported in monitoring data, which is 0.756 µg/L. The result is a mass load of carbaryl per acre (converted to units of lbs a.i./A). From the daily values, the 1-in-10 year peak estimate of the deposition of carbaryl on the terrestrial habitat is estimated for each PRZM scenario (**Table 52**). In this approach, it is assumed that the concentration of carbaryl in the rain event is spatially and temporally homogeneous (e.g. constant over the 1 A of terrestrial habitat for the entire rain event).

Additional uses not considered in quantitative EEC derivation

As discussed in the use characterization (Section 2.4.3) here 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. Greater detail on the rationale for not considering these use patterns is provided in **Appendix A.**

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.

Mixture Effects

This assessment considers only the single active ingredient of carbaryl. However, the assessed species and its environments may be exposed to multiple pesticides simultaneously. Interactions of other toxic agents with carbaryl could result in additive effects, synergistic effects or antagonistic effects. Evaluation of pesticide mixtures is beyond the scope of this assessment because of the myriad factors that cannot be quantified based on the available data. Those factors include identification of other possible co-contaminants and their concentrations, differences in the pattern and duration of exposure among contaminants, and the differential effects of other physical/chemical characteristics of the receiving waters (*e.g.* organic matter present in sediment and suspended water). Evaluation of factors that could influence additivity/synergism is beyond the scope of this assessment and is beyond the capabilities of the available data to allow for an evaluation. However, it is acknowledged that not considering mixtures could over- or under-estimate risks depending on the type of interaction and factors discussed above. This assessment has however, analyzed the toxicity of carbaryl formulated product mixtures (carbaryl formulations involving more than one active ingredient; **Appendix**

M) and has determined that none of the formulated products evaluated were more toxic than the technical grade active ingredient data used for assessing both direct and indirect risks in this document.

5.2.6.2. Effects Assessment

Direct Effects

As previously discussed, direct effects to aquatic-phase CRLF are based on freshwater fish data, which are used as a surrogate for aquatic-phase amphibians. While a limited amount of amphibian data are available, these studies either failed to establish an LC_{50} value or did not report measured concentration values, making them inappropriate for derivation of quantitative RQ values. If RQs are developed based on the nominal concentration LC_{50} value for the African clawed frogs exposed to carbaryl (96-hr LC50-1.73 mg/L; Zaga *et al.* 1998), estimated concentrations in the aquatic habitat would be insufficient to exceed the LOC for direct effects to the CRLF for all but four uses (strawberries, Brussel sprouts, head lettuce and rice).

Available data suggest that amphibians are considerably less sensitive to carbaryl than fish. To the extent to that amphibians are less sensitive than the surrogate species used in this assessment, the assessment is conservative.

Toxicity data for terrestrial-phase amphibians is not available for use in this assessment. Therefore, avian toxicity data are used as a surrogate for terrestrial-phase CRLF. There is uncertainty regarding the relative sensitivity of amphibians and birds to carbaryl. If birds are substantially more or less sensitive than the CRLF, then risk would be over or under estimated, respectively.

Sublethal Effects

Open literature is useful in identifying sublethal effects associated with exposure to carbaryl. However, no data are available to link the sublethal 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 sublethal effects have been associated with carbaryl exposure; however, at this point there are insufficient data to definitively link the measurement endpoints to assessment endpoints.

Indirect Effects

Indirect effects on the aquatic-phase CRLF are estimated based on the most sensitive invertebrate tested, *i.e.*, *Chloroperla grammatica*. Other, less sensitive, aquatic invertebrates may be part of the diet of the aquatic-phase CRLR. Therefore, risk to *C. grammatica*, may not be equivalent to risk to organisms comprising the diet of the CRLF and its use in this assessment may result in an overestimation of risk.

5.2.7. Addressing the Risk Hypotheses

In order to conclude this risk assessment, it is necessary to address the risk hypotheses defined in section 2.9.1. Based on the conclusions of this assessment, none of the hypotheses can be rejected, meaning that the stated hypotheses represent concerns in terms of effects of carbaryl on the CRLF.

6. Conclusions

Based on estimated environmental concentrations for the currently registered uses of carbaryl, RQ values are above the Agency's LOC for direct acute and chronic effects on the CRLF; this represents a "may affect" determination. RQs exceed the LOC for acute and chronic exposures to aquatic invertebrates and for acute exposures to terrestrial invertebrates. Therefore, there is a potential to indirectly affect juvenile and adult CRLF due to effects to the invertebrate forage base in aquatic and terrestrial habitats. The effects determination for indirect effects to the CRLF due to effects to its prey base is "may affect." When considering the prey of larger CRLF in aquatic and terrestrial habitats (e.g. frogs, fish and small mammals), RQs for these taxa also exceed the LOC for acute and chronic exposures, resulting in a "may affect" determination. RQ values for plants in aquatic habitats do not exceed the LOC, with the exception of use on rice. Risk of carbaryl use on riparian and terrestrial vegetation cannot be discounted due to lack of a definitive toxicity endpoint, incident data indicating that nontarget effects on plants have been recorded in the field and the known effects of carbaryl on abscission of flowers. Therefore, indirect effects to the CRLF through effects to its habitat is a "may affect" determination.

Refinement of all "may affect" determinations results in a "LAA" determination based on direct effects to the CRLF, a "LAA" determination for indirect effects to the CRLF based on effects to its prey and an "LAA" determination for indirect effects to the CRLF based on effects to its habitat. Consideration of CRLF critical habitat indicates a determination of "habitat modification" for aquatic and terrestrial habitats. **The overall CRLF effects determination for carbaryl use is "LAA."**

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. **Attachment 2**, which includes information on the baseline status and cumulative effects for the CRLF, can be used during this consultation to provide background information on past US Fish and Wildlife Services biological opinions associated with the CRLF.

When evaluating the significance of this risk assessment's direct/indirect and 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 CRLF life stages within specific recovery units and/or designated critical habitat within the action area. 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 species.
- Quantitative information on prey base requirements for individual aquatic- and terrestrial-phase frogs. While existing information provides a preliminary picture of the types of food sources utilized by the frog, 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 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 frogs and potential modification to critical habitat.

7. References

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