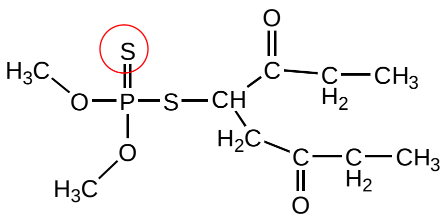
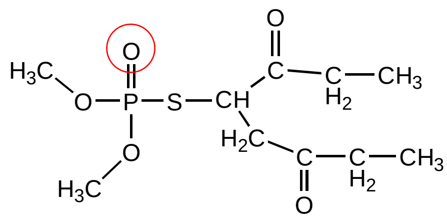
Risks of Malathion Use to the Federally Threatened Delta Smelt (*Hypomesus transpacificus*) and California Tiger Salamander (*Ambystoma californiense*), Central California Distinct Population Segment, and the Federally Endangered California Tiger Salamander, Santa Barbara County and Sonoma County Distinct Population Segments



Malathion (Parent Compound)



Maloxon (Degradate of Concern)

Pesticide Effects Determinations
PC Code: 057701
CAS Number: 121-75-5

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

September 29, 2010

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List of Commonly Used Abbreviations and Nomenclature

µg/kg	Symbol for "micrograms per kilogram"
µg/L	Symbol for "micrograms per liter"
ºC	Symbol for "degrees Celsius"
AAPCO	Association of American Pesticide Control Officials
a.i.	Active Ingredient
AIMS	Avian Monitoring Information System
Acc#	Accession Number
amu	Atomic Mass Unit
BCB	Bay Checkerspot Butterfly
BCF	Bioconcentration Factor
BEAD	Biological and Economic Analysis Division
bw	Body Weight
CAM	Chemical Application Method
CARB	California Air Resources Board
CAW	California Alameda Whipsnake
CBD	Center for Biological Diversity
CCR	California Clapper Rail
CDPR	California Department of Pesticide Regulation
CDPR-PUR	California Department of Pesticide Regulation Pesticide Use Reporting Database
CFWS	California Freshwater Shrimp
CI	Confidence Interval
CL	Confidence Limit
CTS	California Tiger Salamander
CTS-CC	Central Valley DPS of the California Tiger Salamander
CTS-SB	Santa Barbara County DPS of the California Tiger Salamander
CTS-SC	Sonoma County DPS of the California Tiger Salamander
DPS	Distinct population segment
DS	Delta Smelt
EC	Emulsifiable Concentrate
EC_{05}	5% Effect Concentration
EC_{25}	25% Effect Concentration
EC_{50}	50% (or Median) Effect Concentration
ECOTOX	EPA managed database of Ecotoxicology data

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

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

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

1. Executive Summary

1.1. Purpose of Assessment

The purpose of this assessment is to evaluate potential direct and indirect effects on the delta smelt (*Hypomesus transpacificus*) (DS) and California tiger salamander (*Ambystoma californiense*) (CTS) arising from FIFRA regulatory actions regarding use of malathion (PC code: 057701) on agricultural and non-agricultural sites. In addition, this assessment evaluates whether these actions can be expected to result in modification of designated critical habitat for the DS and CTS. The CTS is comprised of three threatened or endangered distinct population segments (DPS's): Central California (CTS-CC), Santa Barbara County (CTS-SB), and Sonoma County (CTS-SC). Except where noted, this assessment addresses risk to all three DPSs jointly. This assessment was completed in accordance with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998) procedures outlined in the Agency's Overview Document (USEPA, 2004) and is consistent with a suit in which malathion was alleged to be of concern to the DS and CTS (Center for Biological Diversity (CBD) vs. EPA et al. (Case No. 07-2794-JCS)).

The DS was listed as threatened on March 5, 1993 (58 FR 12854) by the USFWS (USFWS, 2007). DS are mainly found in slightly brackish water of the Suisun Bay and the Sacramento-San Joaquin Delta Estuary near San Francisco Bay. During spawning DS move upstream into freshwater habitats.

There are currently three CTS Distinct Population Segments (DPSs): the Sonoma County (SC) DPS, the Santa Barbara (SB) DPS, and the Central California (CC) DPS. Each DPS is considered separately in the risk assessment as they occupy different geographic areas. The CTS-SB and CTS-SC were downlisted from endangered to threatened in 2004 by the USFWS, however, the downlisting was vacated by the U.S. District Court. Therefore, the Sonoma and Santa Barbara DPSs are currently listed as endangered while the CTS-CC is listed as threatened. CTS utilize vernal pools, semi-permanent ponds, and permanent ponds, and the terrestrial environment in California. The aquatic environment is essential for breeding and reproduction and mammal burrows are also important habitat for estivation.

1.2. Scope of Assessment

1.2.1. Uses Assessed

Malathion is one of the most widely used insecticides in the U. S. for residential as well as agricultural pest control. It is used throughout the state of California. Historically a predominant agricultural use was cotton for the Boll Weevil Eradication Program. Currently, it is applied to a large number of other agricultural commodities, including various vegetable, grain, fruit, nut crops, and stored grains. Malathion is also used extensively in non-agricultural settings for adult mosquito control by municipal vector control programs. Several uses of malathion were removed during the recent reregistration process either because the uses were not supported or were discontinued as part of the implementation of risk mitigation (see Appendix B, *Verification*

Memorandum for Malathion for SF Bay Species). The remaining registered uses of malathion in the United States are listed below.

<u>*Agricultural Uses*</u>
Alfalfa
Apricot
Asparagus
Avocado
Barley
Beans, dry, snap, lima
Beets, garden
Blueberry
Broccoli, Chinese broccoli, broccoli rabb
Brussels sprouts
Cabbage
Cantaloupe
Caneberries
Carrots
Cucumber
Cauliflower
Celery
Cherries, sweet
Cherries, tart
Citrus fruits
Clover
Collards
Corn, field
Corn, sweet and pop
Chayote fruit
Chayote root
Chinese greens
Clover
Cotton
Currant
Dandelion
Dates
Eggplant
Eggplant, oriental
Endive (escarole)
Fig
Flax
Garlic
Grains, stored
Grapes, raisin, table, wine
Grass, forage, hay
Grasses, Bermuda,
Guava
Hops
Horseradish
Kale
Kohlrabi
Kumquats
Leeks
Lespedeza
Lettuce, head
Lettuce, leaf
Lupine
Macadamia nut
Mango
Melons
Mint
Mushrooms
Mustard greens
Nectarines
Oats
Okra
Onions, bulb, and green
Papaya
Parsley
Parsnip
Passion fruit
Pasture and rangeland
Peaches
Pears
Peas, dried
Peas, green
Pecans
Peppers
Pineapple
Potatoes
Pumpkins
Radish
Rutabagas
Rice
Rye
Salsify
Shallot
Sorghum
Spinach
Squash, summer
Squash, winter
Strawberry
Sweet potatoes
Swiss chard
Tomatoes, Tomatillos
Trefoil, birdsfoot
Turnips
Vetch
Walnuts
Watercress
Watermelons
Wheat, spring and winter
Wild Rice
Yams
Agricultural, uncultivated areas

<u>*Non-agricultural Uses*</u>
Christmas tree plantations
Cull piles
Fence rows/hedge rows
Grain/cereal/flour bins
Grain/cereal/flour elevators
Household/ domestic dwellings
Intermittently flooded areas
Non-agricultural rights-of-way/fencerows
Non-agricultural uncultivated areas/soil
Ornamental and/or shade trees
Ornamental herbaceous plants
Ornamental non-flowering plants
Ornamental woody shrubs and vines
Pine seed orchards
Refuse/solid waste containers
Refuse/solid waste sites
Swamps/marshes/ stagnant water
Wide Area – Public Health Use

Malathion is registered for use to control a wide variety of insects and arachnids. Most malathion products are formulated as an emulsifiable concentrate (EC) spray, ultralow-volume (ULV) concentrate, or a dust. A few products are formulated as a powder or wettable powder.

1.2.2. Environmental Fate Properties of Malathion

Several open literature studies (Mulla *et al* 1981, Howard 1991) are consistent with data presented by the registrant showing that malathion degradation is much slower under acidic conditions compared to alkaline conditions. This is likely due to the extreme variation in malathion hydrolysis rates with pH (hydrolysis $T_{1/2}$ = 107, 6, and 0.5 days at pH 5, 7, and 9, respectively). Malathion is stable to aqueous photolysis ($T_{1/2}$ = 98 and 143 days, corrected for dark control) and soil photolysis ($T_{1/2}$ = 173 days). It is likely that malathion can be metabolized by soil microorgaisms, but the rate at which this occurs is somewhat uncertain due to the necessary presence of water and the complications of factoring out the effects of hydrolysis. Additional open literature studies suggest persistence on soil is longer under dry, sandy, low nitrogen, low carbon, and acidic conditions (Walker and Stojanovic 1973).

The importance of other dissipation pathways must consider the conditions of use. For example, volatilization (≤5.1% of applied volatilized after 16 days) would be an important dissipation pathway under dry and/or acidic conditions (urban environment or acidic soils), but would be much less important under wet and basic conditions (typical of agricultural use). A complete discussion of the environmental fate properties of malathion is given in Section 2.4.

1.2.3. Evaluation of Degradates and Stressors of Concern

The hydrolysis, metabolism, demethylation reactions that malathion undergoes under most use conditions are similar to the biological reactions used by most biological entities to breakdown and detoxify malathion. Therefore, the majority of malathion degradates are less toxic than the parent. The major exception is the oxidation reaction that produces maloxon, which is more toxic than malathion. (Maloxon is the active cholinesterase inhibiting metabolite of malathion.)

Other stressors of potential concern are impurities (chemicals that are not intentionally included in the technical pesticide formulation). In general, impurity concentrations tend to decrease as pesticide formulation methods improve over time. Because malathion has a long history extending back to the 1950s, impurities have been reported in relatively high concentrations (see section 2.2.1). However, EFED assumes modern malathion formulations contain much lower concentrations of impurities.

Therefore, EFED considers maloxon, produced directly through oxidation of malathion, to be the only degradate of concern. Maloxon has not been observed to form during any of the registrant-submitted fate studies. However, it has been observed in urban surface runoff monitoring data associated with the USDA's Medfly Eradication Program, and has been found to occur in California rainwater (Vogel *et al.*, 2008) and fog (Schomburg *et al.*, 1991). Additionally, California Department of Pesticide Regulation has measured maloxon production on dry, microbially-inactive surfaces (steel plates) of up to 10%.

A potential explanation of these observations is that malathion oxidation to maloxon in the environment is slower than hydrolysis or metabolism. Therefore, under the environmental conditions typical for agricultural uses and most nonagricultural uses (presence of water and microorganisms), malathion is converted to hydrolysis or metabolism products before it can be oxidized to maloxon. However under environmental conditions in which hydrolysis and/or metabolism are not favored, EFED believes there may be potential for maloxon production (*i.e.*, on dry, microbially-inactive surfaces such as the steel plates in the CDPR study or concrete, glass or metal surfaces in malathion-treated urban and suburban areas). As part of the agency's registration review process, a data call-in was issued for a study of maloxon production on dry surfaces. This study has not been completed at this time.

Because EFED does not have the maloxon production estimates yet, and inclusion of maloxon exposure would not alter the endangered species affect determination made by this assessment, EFED has chosen to include maloxon in the risk assessment qualitatively, rather than to consider it quantitatively. Therefore for those uses in which malathion is or may be applied to dry, microbially-inactive surfaces (most notably, mosquito adulticide and refuse/solid waste containers), the Estimated Environmental Concentrations (EECs) and Risk Quotients (RQs) should be considered as low estimates as they do not account for the potential additional impact of maloxon. However, for most uses on wet and microbially-active surfaces (most agricultural and non-agricultural uses), little maloxon production is expected.

1.3. Assessment Procedures

A description of routine procedures for evaluating risk to the San Francisco Bay Species is provided in Attachment 1.

1.3.1. Exposure Assessment

1.3.1.a. Aquatic Exposures

Aquatic exposure assessments were conducted to predict exposure of malathion to the delta smelt, the California tiger salamander, and aquatic prey of these species. Tier-II aquatic exposure models were used to estimate high-end exposures of malathion in aquatic habitats resulting from runoff and spray drift. The models used to predict aquatic EECs for all uses except aquatic agriculture (rice, wild rice, and water cress) are the Pesticide Root Zone Model coupled with the Exposure Analysis Model System (PRZM/EXAMS). The AgDRIFT and AGDISP models were used to estimate deposition of malathion on aquatic habitats from spray drift. Peak PRZM/EXAMS estimated environmental concentrations (EECs) resulting from malathion uses ranged from 0.614 to 89.8 µg/L. EECs for aquatic agriculture were estimated using the Tier-I Rice Model which calculates the upper limit of concentrations on a flooded field based on direct application. This model does not account for degradation. Since malathion degrades rapidly in soil and water, these estimates are likely overestimates of actual exposure. The maximum peak EEC estimated for aquatic agriculture was 1120 µg/L.

These model estimates were 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 (Section 3.2.3.a). The maximum concentration of malathion reported by monitoring of surface waters in agricultural watersheds since 1991 was 6.00 µg/L (Gorder *et al*., 1996). This value is approximately 15 times less than the maximum non-rice model-estimated environmental concentration. Because these samples were not specifically targeted to malathion use areas and were not collected at sites similar to the standard EXAMS pond (which is designed to present a high EEC scenario), these detections are not expected to be directly comparable to PRZM/EXAMS EECs.

Monitoring targeted specifically to malathion applications was available from the various monitoring and pest eradication efforts (Section 3.2.3.b). The highest concentrations measured were in runoff samples associated with medfly eradication efforts in California, which resulted in maximum concentrations of 583 µg/L for malathion and 328 µg/L for maloxon. This malathion concentration is 6.5 times the highest PRZM/EXAMS EEC and approximately half the highest Rice Model concentration estimate. Again because the application rates and use characteristics vary between these studies and currently allowed applications, these targeted monitoring values cannot be directly compared to the model estimates and non-targeted monitoring values. However, the similarity in measured and modeled values should dispel any notion that the modeled values are biased by orders of magnitude in one direction or another.

A number of studies have documented atmospheric transport and re-deposition of pesticides, including malathion, from the Central Valley to the Sierra Nevada Mountains (Fellers *et al.*, 2004; LeNoir *et al.*, 1999; McConnell *et al.*, 1998; Sparling *et al.*, 2001). Prevailing winds blow across the Central Valley eastward to the Sierra Nevada Mountains, transporting airborne industrial and agricultural pollutants into the Sierra Nevada ecosystems, where they are deposited in rain and snow. Thus, long range transport may be an additional source of exposure to CTS that breed in ponds which are located in higher elevations, especially in the foothills of the Sierra Nevada Mountains to the east of the intensive use areas of the Central Valley.

1.3.1.b. Terrestrial Exposures

Terrestrial exposure assessments were conducted to estimate malathion exposures to the terrestrial stage of the CTS and its terrestrial prey (small birds and mammals). The T-REX model (ver. 1.4.1) was used for estimating exposure for screening level risk assessments, using small mammals and birds as surrogates for amphibians. The T-HERP model (ver. 1.1) was used to refine the exposure assessment for the CTS and to characterize dietary exposures of terrestrial-phase salamander relative to the bird and mammal surrogates. The AgDisp model was also used to estimate deposition of malathion on terrestrial habitats from aerial ULV spraying done for adult mosquito control and other wide-area public health uses. For these uses, maximum deposition rates estimated from aerial ULV spraying were input into the T-REX and T-HERPS models in place of the typical application rates. The TerrPlant model was not used in this assessment.

1.3.2. Toxicity Assessment

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

Section 4 summarizes the ecotoxicity data available on malathion. In general, malathion is extremely toxic to fish, aquatic invertebrates, and terrestrial invertebrates, but is less toxic to terrestrial vertebrates. Malathion is classified as very highly toxic to all freshwater and estuarine/marine fish and invertebrates on an acute exposure basis. With chronic exposure, the NOAEL and LOAEL for sublethal effects to freshwater invertebrates were determined to be 0.060 ppb and 0.10 ppb, respectively. Chronic toxicity levels for fish were higher (NOAEL = 8.6 ppb and LOAEL = 11 ppb). Malathion is classified as moderately toxic to birds on an acute oral basis and slightly toxic to birds on a subacute dietary exposure basis. On a chronic basis, the NOAEL and LOAEL for sublethal effects to birds are 110 mg/kg and 350 mg/kg, respectively. For mammals, malathion is also classified as slightly toxic on an acute oral exposure basis. On a chronic basis, the NOAEL and LOAEL for sublethal effects to mammals are 240 mg/kg and 1000 mg/kg, respectively. Malathion is classified as very highly toxic to honey bees on an acute contact exposure basis. Data available from the open literature indicate that malathion has low toxicity to plants.

1.3.3. Measures of Risk

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

1.4. Summary of Conclusions

Based on the best available information, the Agency makes a May Affect and Likely to Adversely Affect determination for the Delta smelt (DS) and for all three DPSs of the California tiger salamander (CTS) from the use of malathion. All uses of malathion are predicted to have potential to cause mortality of aquatic and terrestrial invertebrates, thereby reducing the availability of prey to both the DS and the CTS. For the DS, most uses of malathion are also predicted to have the potential to cause direct adverse effects by way of acute and chronic toxicity. For the CTS, all uses of malathion are also predicted to have the potential to cause direct adverse effects by way of acute toxicity, and most uses are predicted to have the potential to cause chronic effects as well. Additionally, the Agency has determined that there is the potential for modification of designated critical habitat of the DS and CTS from the use of this pesticide. Malathion is predicted to have the potential to adversely affect the habitat of the DS by contributing to degradation of water quality and by reducing prey availability. Malathion is predicted to have the potential to adversely affect the habitat of the CTS by reducing prey availability and potentially causing acute and chronic toxic effects on small mammals, thereby potentially reducing the availability of small mammal burrows that the CTS uses for refugia. A summary of the risk conclusions and effects determinations for each listed species assessed and their designated critical habitat is presented in Table 1-1 and Table 1-2. Use-specific determinations are provided in Table 1-3. Further information on the results of the effects determination is included as part of the Risk Description in Section 5.2. Given the LAA determination for the DS and the CTS, and the potential modification of designated critical habitat for the DS and CTS, a description of the baseline status and cumulative effects for these two species is provided in Attachment 2.

Table 1-1. Effects Determination Summary for Effects of Malathion on the Delta Smelt and California Tiger Salamander

Species	Effects Determination	Basis for Determination
Delta Smelt (*Hypomesus transpacificus*)	Likely to Adversely Affect (LAA)	**Potential for Direct Effects**
		Aquatic-phase (Eggs, Larvae, and Adults): Exposure from uses of malathion is expected to occur throughout the entire range of the DS. Risk quotients exceed the Agency LOCs for listed species. Mortality was observed in the rainbow trout (a freshwater fish) and the sheepshead minnow (an estuarine/marine fish) with acute exposure to malathion at concentrations less than one-twentieth the malathion EEC, and reproductive impairment was observed in the flagfish (a freshwater fish) and the bullhead (an estuarine/marine fish) with chronic exposure to malathion at concentrations less than the chronic EEC. In addition, numerous fish kills have been linked to malathion use.
		Potential for Indirect Effects
		Aquatic prey items, aquatic habitat, cover and/or primary productivity Exposure from uses of malathion is expected to occur throughout the entire range of the DS. Risk quotients exceed the Agency LOCs for taxa that comprise the prey of the DS and indicate that use of malathion is likely to reduce abundance of prey of the DS. Mortality was observed in the water flea (a freshwater crustacean) and the mysid (an estuarine/marine crustacean) with acute exposure to malathion at concentrations much less than less than one-tenth the malathion EEC. Reproductive impairment was predicted in the water flea (a freshwater crustacean) and the mysid (an estuarine/marine crustacean) with chronic exposure to malathion at concentrations much less than the chronic EEC and less than some malathion concentrations from surface water samples taken within the range of the DS.
California Tiger Salamander (*Ambystoma*	Likely to adversely affect (LAA)	**Potential for Direct Effects**
		Aquatic-phase (Eggs, Larvae, and Adults):

Species	Effects Determination	Basis for Determination
californiense), including Central, Santa Barbara, and Sonoma County distinct population segments		Aquatic exposure from uses of malathion is expected to occur throughout the entire range of the CTS, including all DPSs. Risk quotients exceed the Agency LOCs for listed species. Mortality was observed in the rainbow trout (a freshwater fish, surrogate for freshwater amphibians) with acute exposure to malathion at concentrations less than one-twentieth the malathion EEC, and reproductive impairment was observed in the flagfish (a freshwater fish, surrogate for freshwater amphibians) with acute exposure to malathion at concentrations less than less than the chronic malathion EEC.
		Terrestrial-phase (Juveniles and Adults): Terrestrial exposure from uses of malathion is expected to occur throughout the entire range of the CTS, including all DPSs. Risk quotients exceed the Agency LOCs for listed species. Mortality was predicted for CTS (based on acute toxicity data for the ring-neck pheasant and Japanese quail, surrogates for the CTS) at dietary concentrations less than one-tenth the acute EEC, and reproduction impairment was predicted for CTS (based on reproduction toxicity data for the northern bobwhite) at dietary concentrations less than the chronic EEC.
		Potential for Indirect
		Aquatic prey items, aquatic habitat, cover and/or primary productivity Aquatic exposure from uses of malathion is expected to occur throughout the entire range of the CTS, including all DPSs. Risk quotients exceed the Agency LOCs for taxa that comprise the prey of the CTS and indicate that use of malathion is likely to reduce abundance of prey of the CTS. Mortality was observed in the water flea (a freshwater crustacean) with acute exposure to malathion at concentrations much less than less than one-tenth the malathion EEC. Reproductive impairment was predicted in the water flea (a freshwater crustacean) with chronic exposure to malathion at concentrations much less than the chronic EEC.
		Terrestrial prey items, riparian habitat Terrestrial exposure from uses of malathion is expected to occur throughout the entire range of the CTS, including all DPSs. Risk quotients exceed the Agency LOCs for taxa that comprise the prey of the CTS. Mortality was observed in the honey bee and the rat (surrogates for terrestrial prey of the CTS) at concentrations less than one-tenth the acute EEC. Reproduction impairment was observed in the rat at concentrations less than the chronic EEC.

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

Designated Critical Habitat for:	Effects Determination	Basis for Determination
Delta Smelt (*Hypomesus transpacificus*)	Habitat Modification	Use of malathion has the potential to cause degradation of water quality in the estuarine and freshwater habitats used by the DS.
California Tiger Salamander (*Ambystoma californiense*),	Habitat Modification	Use of malathion has the potential to cause acute and chronic effects to small mammals, thereby potentially reducing the availability of burrows on which the CTS depends for underground refugia.

including Central, Santa Barbara, and Sonoma County distinct population segments		

Table 1-3. Malathion Use-specific Risk Summary for Delta Smelt and California Tiger Salamander

Use(s)	Species Effects Determination[1]	Critical Habitat Modification	Potential for Effects	
			Direct	**Indirect**
Delta Smelt				
All uses except passion fruit, ULV application on citrus, and ULV application for adult mosquito control	LAA	Yes	Acute toxicity (all uses) and chronic toxicity (some uses)	Acute and chronic toxicity, reduced prey abundance, and degradation of water quality
Passion fruit, ULV application on citrus, and ULV application for adult mosquito control	LAA	Yes	None	Acute and chronic toxicity, reduced prey abundance, and degradation of water quality
California Tiger Salamander				
All uses except ULV application on citrus, and ULV application for adult mosquito control	LAA	Yes	Acute toxicity and chronic toxicity	Acute toxicity to insects, chronic toxicity to mammals, acute toxicity to mammals (some uses), reduced prey abundance, and reduction of mammal burrows
ULV application on citrus, and ULV application for adult mosquito control	LAA	Yes	Acute toxicity	Acute toxicity to insects and reduced prey abundance

[1]LAA = Likely to adversely affect

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

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

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

2. Problem Formulation

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

2.1. Purpose

The purpose of this endangered species assessment is to evaluate potential direct and indirect effects on individuals of the DS and CTS arising from FIFRA regulatory actions regarding use of malathion for a wide variety of agricultural and non-agricultural uses. In addition, this assessment evaluates whether these actions can be expected to result in modification of designated critical habitat of the DS and CTS. For the California Tiger Salamander, the assessment jointly discusses the Central California, Santa Barbara County, and Sonoma County distinct population segments (DPS's) except where noted. This ecological risk assessment has been prepared consistent with the settlement of a suit in which malathion was alleged to be of concern to the DS and CTS (*Center for Biological Diversity (CBD) vs. EPA et al*. (Case No. 07-2794-JCS)).

In this assessment, direct and indirect effects to the DS and CTS and potential modification to designated critical habitat for the DS and CTS were evaluated in accordance with the methods described in the Agency's Overview Document (USEPA, 2004). Adverse effects to the Primary Constituent Elements (PCEs) of each species were considered.

The DS was listed as threatened on March 5, 1993 (58 FR 12854) by the USFWS (USFWS, 2007). DS are mainly found in the Suisun Bay and the Sacramento-San Joaquin estuary near San Francisco Bay. During spawning DS move into freshwater. The PCEs for DSs are shallow fresh or brackish backwater sloughs for egg hatching and larval viability, suitable water with adequate river flow for larval and juvenile transport, suitable rearing habitat, and unrestricted access to suitable spawning habitat.

There are currently three CTS Distinct Population Segments (DPSs): the Sonoma County (SC) DPS, the Santa Barbara (SB) DPS, and the Central California (CC) DPS. Each DPS is considered separately in the risk assessment as they occupy different geographic areas. The main difference in the assessment will be in the spatial analysis. The CTS-SB and CTS-SC were downlisted from endangered to threatened in 2004 by the USFWS, however, the downlisting was vacated by the U.S. District Court. Therefore, the Sonoma and Santa Barbara DPSs are currently listed as endangered while the CTS-CC is listed as threatened. CTS utilize vernal pools, semi-permanent ponds, and permanent ponds, and the terrestrial environment in California. The aquatic environment is essential for breeding and reproduction and mammal burrows are also important habitat for estivation. The PCEs for CTSs are standing bodies of freshwater sufficient for the species to complete the aquatic portion of its life cycle that are adjacent to barrier-free uplands that contain small mammal burrows. An additional PCE is upland areas between sites (as described above) that allow for dispersal of the species.

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 malathion is based on an action area. The action area is the area directly or indirectly affected by the federal action, as indicated by risk quotients exceeding of the Agency's Levels of Concern (LOCs). It is acknowledged that the action area for a national-level FIFRA regulatory decision associated with a use of malathion may potentially involve numerous areas throughout the United States and its Territories. However, for the purposes of this assessment, attention was focused on relevant sections of the action area including those geographic areas associated with locations of the DS and CTS and their designated critical habitat within the state of California. As part of this assessment, "effects determination" identified one of the following three conclusions for each of the assessed species in the lawsuits regarding the potential use of malathion in accordance with current labels:

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

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

A description of routine procedures for evaluating risk to the San Francisco Bay Species is provided in Attachment 1.

2.2. Scope

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

Historically, malathion has been one of the most widely used insecticides in the U. S. for residential as well as agricultural pest control. It is used throughout the state of California. A major historical use was on cotton in the boll weevil eradication program. However, it is also applied to a large number of other agricultural commodities, including various vegetable, grain, fruit, and nut crops, as well as stored grains. It has also been used extensively in non-agricultural settings for residential insect control and for adult mosquito control by municipal vector control programs.

Although current registrations of malathion allow for use nationwide, this ecological risk assessment and effects determination address currently registered uses of malathion in portions of the action area that are reasonably assumed to be biologically relevant to the DS and CTS and their designated critical habitat. Because of the wide variety of agricultural and nonagricultural uses of malathion, including residential uses, the action area for this assessment is considered to be the entire state of California. Thus the spatial scope of this assessment is limited only by the distribution of the DS and CTS, not by the action area for the use of malathion. Further discussion of the action area relative to the DS and CTS and their critical habitat is provided in Section 2.7.

2.2.1. Evaluation of Degradates and Other Stressors of Concern

Malathion degrades and transforms into a large number of chemicals (Table 2-1). Additionally, technical malathion has historically contained impurities that account for up to 5% of the insecticide. California Department of Food and Agriculture reported 15 impurities (Table 2-1) in a representative ultra low volume malathion formulation (CalEPA 1981).

Table 2-1. Impurities and Degradates Reported in Technical Malathion (CalEPA 1981)

Impurity as Listed in CalEPA (1981)	% in Technical	Synonym as in Appendix Table D-1
Diethyl fumarate	0.90	Diethylfumarate (DEF)
Diethylhydroxysuccinate	0.05	Diethylmaleate
O,O-dimethylphosphorothioate	0.05	Ion not in Appendix
O,O,O-trimethyl phosphorothioate	0.45	CAS No. 1186-09-0 Not in Appendix
O,O,S-trimethyl phosphorodithioate	1.20	CAS No. 2953-29-9 Not in Appendix
Ethyl nitrite	0.03	Not in Appendix
Diethyl-bis (ethoxycarbonyl) mercaptosuccinate	0.15	Cannot Identify[1]
S-1,2-ethyl-O,S-dimethyl phosphorodithioate	0.20	Isomalathion
S-(1-methoxycarbonyl-2-ethoxycarbonyl)ethyl-O,O-dimethyl phosphorodithioate	0.60	Cannot Identify[1]
Bis-(O,O-dimethyl thionophosphoryl) sulfide	0.30	Cannot Identify[1]
Diethyl methylthiosuccinate	1.00	Cannot Identify[1]
S-ethyl-O,O-dimethyl phosphorodithioate	0.10	Cannot Identify[1]
S-1,2-bis (ethoxycarbonyl) ethyl-O,O-dimethyl phosphorothioate	0.10	Maloxon
Diethyl ethylthiosuccinate	0.10	Cannot Identify[1]
Sulfuric acid	0.05	Not in Appendix

1 Web-based searches for chemical synonyms only returned quotations of the original document (no synonyms).

Some malathion (and other organophosphate) impurities can potentiate malathion toxicity and also are toxic alone, but there is almost no data available on their environmental fate. The persistence of a phosphorothioate impurity (O,O,S-trimethyl phosphorothioate) was shown to be 18.7 times longer than malathion in an aerobic soil metabolism study (Miles and Takashima 1991). Some phosphorothioates and -dithioates have been intensively studied and induce a delayed toxic effect to mammals at much lower levels than pure malathion (Ali Fouad and Fukuto 1982, Umetsu *et al* 1977, Fukuto 1983, Aldridge *et al* 1979, Toia *et al* 1980). A phosophorothioate and -dithioate impurity identified by CalEPA (1981) is of lower toxicity than impurities reported in older formulations (Toia *et al* 1980). One hydrolysis product, diethyl fumarate, which is also present as an impurity in technical malathion is approximately three times more toxic to fathead minnows than malathion (Bender 1969). No guideline studies have been conducted and little open literature data exist to define the fate and persistence of impurities of malathion; however, most of the highly toxic impurities identified in past studies on malathion (Ali Fouad and Fukuto 1982, Umetsu *et al* 1977, Fukuto 1983, Aldridge *et al* 1979, Toia *et al* 1980) have not been identified or are present only at low levels in more recently produced technical malathion (CaEPA 1981 and confidential information provided by the registrant).

The relative concentration of malathion impurities can vary dramatically depending not only on manufacturing processes but also storage conditions. Umetsu *et al* (1977) concluded "Storage of technical malathion for 3 to 6 months at 40 degrees C resulted in materials which were noticeably more toxic to mice." Therefore, the composition and toxicological properties of the technical malathion are not only affected by initial purity, but also by storage conditions.

Similar to several other organophosphate insecticides, malathion degrades and is metabolized into an oxon product that is more toxic than the parent compound. The oxon product of malathion is called maloxon in this document, but also called mal**a**oxon elsewhere. Chemically, the only difference between malathion and maloxon is the substitution of oxygen for sulfur at its double bond to phosphorous (Structures provided in Table D-1 of Appendix D). Metabolic conversion of malathion into maloxon is called activation because it is the maloxon metabolite that is responsible for most of the insecticidal activity of malathion, as well as most of its toxicity to other nontarget animals. All other non-oxon degradation and metabolic products of malathion exhibit much lower toxicity than maloxon. Thus, maloxon is the primary degradation product/metabolite considered to be a significant concern for ecological risk. Although little or no maloxon production is observed in registrant submitted aquatic and terrestrial exposure studies, maloxon has been detected in surface waters, rain water, and fog (Schomburg *et al*., 1990). Maloxon is also expected to form in the bodies of prey animals through biotransformation processes.

Malathion impurities and degradates were evaluated for inclusion in the current risk assessment. The hydrolysis, metabolism, demethylation reactions that malathion undergoes under most use conditions are similar to the biological reactions used by most biological entities to breakdown and detoxify malathion. Therefore, the majority of malathion degradates are less toxic than the parent with the exception being maloxon.

Other stressors of potential concern are impurities (chemicals that are not intentionally included in the pesticide formulation). In general, impurity concentrations tend to decrease as pesticide formulation methods improve over time. Because malathion has a long history extending back to the 1950s, impurities have been reported in relatively high concentrations. However, EFED assumes modern malathion formulations contain much lower concentrations of impurities.

Historically, EFED has assessed maloxon based on study results showing a maximum maloxon concentration observed in a soil aerobic metabolism study (MRID 41721701) of 1.8% of applied malathion (USEPA 2006a, USEPA 2007a). However, this maloxon is present from the beginning of this study and therefore, likely indicates that this maloxon is an impurity in the specific batch of technical grade malathion rather than a degradate produced in this study.

A CDPR study (1981) found a 10% conversion of malathion to maloxon on dry surfaces in a study that was cut short due to wet weather. The observation of maloxon production on dry surfaces is a potential explanation of the high maloxon concentrations (up to 328 µg/L) observed in runoff water collected in conjunction with the Medfly Eradication Program in California. EPA has requested a dry surface maloxon production study as well as several environmental fate and effect studies from the registrant as part of the registration review process.

Due to uncertainty in the production of maloxon, EFED elected to consider maloxon qualitatively rather than quantitatively in this assessment. Based on the findings in the CRLF assessment, it is assumed that a quantitative assessment based on the parent chemical alone will be sufficient to trigger a “likely to adversely affect” determination for all uses for indirect effects as well as many of the uses for direct effects to the CTS and DS in the current assessment. In the risk characterization section (5.2), the qualitative assessment of additional potential effects to the CTS and DS of exposure to environmental sources of maloxon will be factored in to provide an assessment of both malathion and maloxon.

2.2.2. Evaluation of Mixtures

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

Malathion has registered products that contain multiple active ingredients. Analysis of the available acute oral mammalian LD_{50} data for multiple active ingredient products relative to the single active ingredient is provided in Appendix J. Data were only available on a few products and all measured values were nondefinitive (*e.g*., no effects were observed at the highest dose tested). Given that the formulated products for malathion do not have LD_{50} data available, it is not possible to undertake a quantitative or qualitative analysis for potential interactive effects. Therefore, this assessment was based on the toxicity of the malathion alone.

In addition, several studies were located in the open literature that evaluated the potential toxicological interactions of malathion and other pesticides. These studies are summarized in Table 2-2. According to the available data, other pesticides may combine with malathion to produce synergistic, additive, and/or antagonistic toxic effects. Greater than additive effects have been demonstrated in birds, fish, and invertebrates when exposure to malathion was paired with exposure to other pesticides, including atrazine, carbaryl, carbofuran, chlorpyrifos, coumaphos, diazinon, EPN, fenthion, parathion, and trichlorfon (Table 2-2). If chemicals that show such effects are present in the environment in combination with malathion, the toxicity of malathion may be increased, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they are also present in the mixture. The variety of chemical interactions presented in the available data set suggest that the toxic effect of malathion, in combination with other pesticides used in the environment, can be a function of many factors including but not necessarily limited to: (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of malathion and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (*e.g.*, organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data. However, a qualitative discussion of implications of the available pesticide mixture effects data involving malathion on the confidence of risk assessment conclusions is addressed as part of the uncertainty analysis for this effects determination.

Table 2-2. Summary of Available Data That Evaluated Interactive Effects on the Toxicity of Malathion

Chemicals Tested (malathion + chemical named)	Species Tested	Reported Effect	Endpoint Evaluated	Citation
Coumaphos (Co-Ral)	Japanese Quail and ring-necked pheasants	Additive	Mortality	Kreitzer and Spann, 1973
EPN	Japanese Quail and ring-necked pheasants	Greater than additive	Mortality	Kreitzer and Spann, 1973
Parathion	Japanese Quail and ring-necked pheasants	Additive	Mortality	Kreitzer and Spann, 1973
Trichlorfon	Japanese Quail and ring-necked pheasants	Greater than additive	Mortality	Kreitzer and Spann, 1973
Aroclor 1262	Japanese Quail and ring-necked pheasants	Additive	Mortality	Kreitzer and Spann, 1973
Parathion	Bluegill	Greater than additive	Mortality	Macek, 1975
Fenthion (Baytex)	Bluegill	Greater than additive	Mortality	Macek, 1975
Carbaryl (Sevin)	Bluegill	Greater than additive	Mortality	Macek, 1975
EPN	Bluegill	Greater than additive	Mortality	Macek, 1975
Ethylan (Perthane)	Bluegill	Greater than additive	Mortality	Macek, 1975
DDT	Bluegill	Additive	Mortality	Macek, 1975
Toxaphene	Bluegill	Additive	Mortality	Macek, 1975
Copper Sulfate	Rainbow trout	Less than additive	Mortality	Macek, 1975
Diazinon	Coho Salmon	Greater than additive	Acetylcholinesterase inhibition	Laetz et al., 2009
Chlorpyrifos	Coho Salmon	Greater than additive	Acetylcholinesterase inhibition	Laetz et al., 2009
Carbaryl	Coho Salmon	Greater than additive	Acetylcholinesterase inhibition	Laetz et al., 2009
Carbofuran	Coho Salmon	Greater than additive	Acetylcholinesterase inhibition	Laetz et al., 2009
Atrazine	Midge	Greater than additive	Mortality	Pape-Lindstrom and Lydy, 1997
Endrin	Flagfish	Additive	Growth	Hermanutz et al., 1985

2.3. Previous Assessments

There is a long history of assessments for malathion because malathion has been used as a pesticide since the 1950s. The following sections summarize the most recent assessments and those most salient to endangered species issues.

2.3.1. Malathion Registration Eligibility Decision, 2006

In 2006, the Agency completed a screening-level ecological risk assessment in support of the Reregistration Eligibility Decision (RED) for malathion (USEPA 2006a). The RED was finalized as part of the organophosphate cumulative assessment (USEPA 2006b). The RED assessment was based on data collected in the laboratory and in the field to characterize the fate and ecotoxicological effects of malathion. Data sources used in this assessment included: 1) registrant submissions in support of reregistration, 2) publicly available literature on ecological effects, 3) monitoring data for freshwater streams, lakes, reservoirs, and estuarine areas, 4) incident reports of adverse effects on aquatic and terrestrial organisms associated with the use of malathion.

The ecological risk assessment in the RED concluded that use of malathion poses a high risk of mortality to fish and aquatic invertebrates from acute toxicity. Almost all uses are expected to pose a high risk of adversely effecting aquatic invertebrate populations, especially in urban streams and wetlands. High acute risk is also expected to fish and amphibians for uses with higher application rates or repeated applications. Numerous incidents of fish kills confirm the acute risk to fish. Use of malathion is generally not expected to pose a high risk of mortality to terrestrial wildlife (birds, mammals, and reptiles, terrestrial stages of amphibians) although the acute level of concern (LOC) is exceeded for some uses with high application rates and repeated applications. Use of malathion poses a risk of impairing reproduction in birds, and may cause other sublethal effects in wildlife. Although no risk assessment was conducted for beneficial insects, the RED concluded that use of malathion poses a hazard to bees and other insect pollinators based on evidence from toxicity studies, field studies, and incidents. Bees may be harmed from direct exposure, exposure to foliar residues, and exposure to residues on pollen brought back to the hive.

The ecological risk assessment in the RED concluded that use of malathion could potentially harm all taxa of threatened and endangered animals. Risk quotients exceeded the level of concern for threatened and endangered species of fish, aquatic invertebrates, birds, and mammals.

2.3.2. Organophosphate Cumulative Assessment, and Malathion Reregistration Eligibility Decision, 2006

Because the Agency had determined that malathion shares a common mechanism of toxicity with the structurally-related organophosphates insecticides, a cumulative human health risk assessment for the organophosphate pesticides was necessary before the Agency could make a final determination of reregistration eligibility of malathion. This cumulative assessment was finalized in 2006 (USEPA 2006b). The results of the Agency's ecological assessments for malathion are discussed in the July 2006 final Reregistration Eligibility Decision (RED) (USEPA 2006a).

2.3.3. California Red-legged Frog Endangered Species Assessment

The Agency recently completed an endangered species risk assessment of the potential effects of malathion and maloxon on the threatened California red-legged frog (*Rana aurora draytonii*; CRLF) arising from uses of malathion (USEPA 2007a). Uses included in this 2007 assessment reflected some post-RED mitigations. This endangered species risk assessment was part of the *Center for Biological Diversity (CBD) vs. EPA et al*. (Case No. 02-1580-JSW(JL)) settlement entered in the Federal District Court for the Northern District of California on October 20, 2006.

The assessment resulted in a determination that the use of pesticide products containing malathion is likely to adversely affect the CRLF. This determination is based on the potential for malathion use to both directly and indirectly affect the species and result in modification to designated critical habitat.

Toxicity values used in this document are in some cases different than those used in the malathion RED and those used in the current assessment of risk to the DS and CTS. Although the RED was published in 2006, following completion of the organophosphate cumulative assessment, the ecological risk assessment was compiled in 1999, prior to the regular incorporation of open literature ecotoxicological (ECOTOX) data into EFED risk assessments. Review of the open literature data resulted in a number of lower toxicity endpoints used in the CRLF assessment. Risk conclusions are similar, in that listed species LOCs are exceeded, but the risk quotients (RQs) presented in the CRLF assessment are higher than corresponding RQs in the RED. In this current assessment for the DS and CTS, open literature data have been further evaluated and toxicity endpoints have been further revised. Some of the toxicity endpoints were revised higher relative to those used in the CRLF document, and thus some of the RQs have decreased in this current assessment relative what was reported in the CRLF assessment.

2.3.4. Pacific Anadromous Salmonids Endangered Species Assessment

The Agency completed an endangered species risk assessment of the potential effects of malathion on 26 listed Evolutionarily Significant Units (ESUs) of Pacific salmon and steelhead arising from FIFRA regulatory actions regarding use of malathion (USEPA 2004*a*). This risk assessment was part of the *Washington Toxics Coalition vs. EPA* (Case No. C01-132C) order entered in the Federal District Court for the Western District of Washington on July 2, 2002. The assessment concluded that malathion is toxic to fish as well as to organisms that serve as food for threatened and endangered Pacific salmon and steelhead. The final conclusion was that the uses (at that time) of malathion (and its degradate maloxon) may affect 24 of these ESUs.

On November 18, 2008, the National Oceanic Atmospheric Administration National Marine Fisheries Service (NMFS) issued a final biological opinion on the effect of pesticide products containing malathion, chlorpyrifos, or diazinon on 28 listed Pacific salmonids (National Marine Fisheries Service, 2008). This opinion concluded that the effects of registration of pesticide products that contain malathion or the two other active ingredients is likely to jeopardize the continued existence of 27 of the 28 species of Pacific salmonids. They concluded that these pesticides are not likely to jeopardize the continued existence of Ozette Lake Sockeye salmon, but may adversely affect that species. Furthermore, they concluded that registration of these products is likely to destroy or adversely modify 25 of the 26 critical habitats that have been designated for these Pacific salmonids. The only critical habitat that they concluded would not be adversely modified is that of the Ozette Lake Sockeye salmon. This Biological Opinion is available on the internet (http://www.nmfs.noaa.gov/pr/pdfs/pesticide_biop.pdf).

2.4. Environmental Fate Properties

Endangered species may be exposed to malathion and its degradates through contamination of food, water, and air (by suspended particles) which can result from off-target drift, runoff, and direct application. Increased toxicity may be brought about through oxidation (to maloxon). Limited data are available on toxic degradates and impurities, but the fate data provided to EFED for malathion and maloxon was found to be acceptable for performing risk assessment (USEPA 2006) and shows that malathion, typically, will have little persistence in the environment.

Based on registrant submitted data and open literature reports, EFED concludes the primary routes of dissipation of malathion in surface soils appear to be microbially-mediated soil metabolism (half-lives measured as <1 to 2.5 days) and hydrolysis (pH 5, 7, and 9 half-lives of 107 days, 6.21 days, and 12 hours, respectively). Malathion monoester, ethyl hydrogen fumarate, diethyl thiosuccinate, malathion mono- and dicarboxylic acids, demethyl mono- and di-carboxylic acids, and CO_2 are known degradates. Table 2-3 lists the physical-chemical properties of malathion and maloxon.

Table 2-3. Physical-chemical Properties of Malathion and Maloxon

Property	Malathion (Parent Compound)		Maloxon (Transformation Product)	
	Value and units	**MRID or Source**	**Value and units**	**MRID or Source**
Molecular Weight	330.3 g/mole	Product Chemistry	314.3 g/mole	MRID 46396601
Chemical Formula	$C_{10}H_{19}O_6PS_2$	Product Chemistry	$C_{10}H_{19}O_7PS$	MRID 46396601
Vapor Pressure	4×10^{-5} Torr @ 30°C	Product Chemistry	1.02×10^{-4} Torr	EPIWeb 4.0 (modified Grain method)
Henry's Law Constant	1.2×10^{-7} atm-m³/mole @ 25°C	Estimated [1]	1.2×10^{-8} atm-m³/mole @ 25°C	Estimated [1]
Water Solubility	145 mg/L @ 25°C	Product Chemistry	7500 mg/L 50-100 g/L @ 20°C	NIH NTP Reports web-site cited in EPIWeb 4.0 MRID 46396601
Octanol – water partition coefficient (K_{OW})	613 (Log K_{OW} = 2.79) 628 (Log K_{OW} = 2.80) 560 (Log K_{OW} = 2.748) 2000 (Log K_{OW} = 3.30) 195 (Log K_{OW} = 2.29)	40119201 158054 and 158062 40944103, 40944104, and 40944108 40966603 EPIWeb 4.0	3.31 (Log K_{OW} = 0.52)	EPIWeb 4.0
Dissociation Constant (pKa and/or pKb)	13.18/M-hr	EPIWeb 4.0	144.7/M-hr	EPIWeb 4.0
Air-water partition coefficient (K_{AW})	2×10^{-7}	EPIWeb 4.0	2.2×10^{-8}	EPIWeb 4.0
Octanol-air partition coefficient (K_{OA})	1.15×10^{9}	EPIWeb 4.0	1.5×10^{8}	EPIWeb 4.0

[1] Calculated according to USEPA 2002 by: (VP*MW)÷(760*solubility).

Table 2-4 lists the other environmental fate properties of malathion, along with the major and minor degradates detected in the submitted environmental fate and transport studies.

Table 2-4. Summary of Malathion Environmental Fate Properties

Study	Value and unit	Major and Minor Degradates	MRID # or Citation	Study Classification, Comment
Abiotic Hydrolysis @ 25^{o}C	Half-life[1] = 107 days, pH 5 6 days, pH 7 0.5 days, pH 9	MCA – major @ pH 7 & 9; minor @ pH 5 MEF – major @ pH 7 & 9; minor @ pH 5 DETS – major @ pH 7 & 9 DCA – minor @ pH 7 & 9	40941201	Acceptable
	Aqueous photolysis dark controls: 250 days, pH 4 (non-sensitized) 219 days, pH 4 (sensitized)	Not measured	41673001	Acceptable
Air Photolysis	Assumed Stable	NA	40969301	Unacceptable
Direct Aqueous Photolysis	Half-life[1] = 97.88 days, pH 4	MCA – not quantified Several other peaks – not quantified or confirmed	41673001	Acceptable
Soil Photolysis	Stable (173 days), sandy loam soil	3 degradates were not identified	41695501	Supplemental
Aerobic Soil Metabolism[3]	Half-life[1] = 16.3 days, loam	α-MCA – minor β-MCA – minor DCA – major	41721701	Supplemental
	Half-life[1] = 5.3 days, silty clay 5.1 days, silty loam 4.7 days, sand 4.5 days, silty loam	α-MCA – minor β-MCA – major (minor in sand only) DCA – major	46769501	Currently being evaluated
	Half-life[1] = 25 days, loamy sand	MCA – minor DCA – major	47834301	Currently being evaluated
Anaerobic Soil Metabolism	Half-life[1] < 30 days, loamy sand	Not quantified	47834301	Currently being evaluated
Aerobic Aquatic Metabolism	Half-life[1] = Pond in Macon Co., IL: 1.09 days in water[2] pH 8.5 1.09 days in sediment[2] Sand, pH 7.8 1.09 days in total system	MCA – major DCA – major dMCA – major dDCA – minor, but increasing at study termination (30 days)	42271601	Supplemental
Anaerobic Aquatic Metabolism	Half-life[1] = Pond in Macon Co., IL: 2.54 days in water[2] pH 8.7 2.54 days in sediment[2] Sandy loam, pH 7.8 2.54 days in total system	MCA – major DCA – major dMCA – major dDCA – major	42216301	Supplemental
Soil-water distribution coefficient (K_d)	K_d = 0.5 L/kg, sandy loam 0.82 L/kg, loam 0.87 L/kg, sand 14.2 L/kg, silty clay	MCA – major DCA – major	43868601	Acceptable

Study	Value and unit	Major and Minor Degradates	MRID # or Citation	Study Classification, Comment
Organic-carbon normalized distribution coefficient (K_{OC})	K_{OC} = 151 L/kg, sandy loam 267 L/kg, sandy loam 308 L/kg, sand 176 L/kg, loam 183 L/kg, silt loam	MCA – minor DCA – minor	41345201	Acceptable
Volatility from Soil (Laboratory)	≤5.1% volatilized by 16 days, silt loam	NA	42015201	Acceptable
Terrestrial Field Dissipation	Dissipation Half-life[1,2] = <2 day, Cotton, CA	DCA	41727701 43042402	Acceptable
	Dissipation Half-life[1,2] = To rapid to determine, Cotton, bare ground, GA	DCA	41748901 43042401	Acceptable
Aquatic Field Dissipation	rice paddy, CA	NA	42058401	Unacceptable
	rice paddy, MO	NA	42058402	Unacceptable
Bioconcentration Factor (BCF)- Species Name	Steady State BCF= 23 to 135 L/kg wet wt whole fish 4.2 to 18 L/kg wet wt edible tissue 37 to 204 L/kg wet wt nonedible tissue	MCA – major DCA – minor Maloxon – minor dMalathion – minor MEF – minor oxalacetic acid – minor	43106401 43106402 43340301	Acceptable

Abbreviations: DCA = malathion dicarboxylic acid; dDCA = malathion demethyl dicarboxylic acid; DETS = diethyl thiosuccinate; dMCA = malathion demethyl monocarboxylic acid (α and/or β forms); MCA = malathion monocarboxylic acid (α and/or β forms); MEF = monoethyl fumerate; OA = oxalacetic acid; wt = weight. Chemical structures appear in Appendix Table D1. Some studies reported α and β forms of malathion monocarboxylic acid or demethyl monocarboxylic acid as total rather than as each chemical separately.

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

[2] The value may reflect both dissipation and degradation processes.

[3] Aerobic soil metabolism half-lives are extremely biphasic with short initial half-lives of less than a day for the first ~48 hours; followed longer halflives of >10 days.

Hydrolysis: Hydrolysis rates of malathion vary dramatically with pH (107 days at pH 5 to 0.5 days at pH 9). Similarly, maloxon hydrolysis rates also vary dramatically with pH (32 days at pH 5 to 0.16 days at pH 9), but are in general somewhat faster than the analogous (same pH) hydrolysis rates for malathion.

Aerobic soil Metabolism: Aerobic soil metabolism is the only route of degradation that appears to result in a faster degradation rate than hydrolysis for malathion. Malathion persistence under aerobic soil conditions has been examined in several open literature studies which are reviewed in Table 2-5. Reported half-life values (from field and laboratory studies) vary from hours to 11 days. Persistence is decreased with microbial activity, moisture, and high pH.

Table 2-5. Open Literature Studies Reporting Aerobic Soil Metabolism Degradation Rates

Source	Degradation Rate Value	Comments
Miles and Takashima 1991	$t_{½}$ = 8.2 h (laboratory) $t_{½}$ = 2 h (field)	Malathion was mixed with Lihue soil and incubated at 22^{o}C in lab experiment. Sterilization decreased rate by 2-fold.
Walker and Stojanovic 1974	47-95% at 7 days	Malathion was incubated with various *Arthrobacter* species. Degradation in the presence of the 5 most efficient species was reported.
Walker and Stojanovic 1973	$t_{½}$ = ~ 2 days under non-sterile unfavorable degradation conditions.	In 3 Mississippi soils examined at 25-26^{o}C, soil microflora were important in degradation. Slowest degradation occurred in soils with low nitrogen, moisture, and carbon content and increased acidity.
CalEPA 1996	DT_{50} = 4.2-6.9 days on sand	Measured at 5 sites under the conditions of the medfly eradication program. Each site consisted of 10 aluminum trays containing 500g of playground sand. Between applications trays were covered.
CalEPA 1993	DT_{50} < 12 h on sand	Application was under controlled conditions, but temperature was not noted.
CalEPA 1993	soil: 38% remaining at 12 hours 15% remaining at 20 days	66% sand, 24% silt, 10% clay, 0.78% water, pH 6.3. Malathion was applied under controlled conditions. Degradation was biphasic.
Kearney *et al* 1969	75-100% degradation in 1 week	Field persistence
Lichtenstein and Schultz 1964	85% dissipation in 3 days	Conducted under field conditions
Howard 1991	Reported average literature $t_{½}$ = 6 d	In this review, persistence is stated to vary with moisture content and pH.
USDA	$t_{½}$ = 3 days used for modeling	This value was chosen for modeling malathion in the Boll Weevil Eradication Program based on a personal communication with a previous malathion registrant.

In the three aerobic soil metabolism registrant submitted studies, half-lives are biphasic with short initial half-lives of less than a day for the first ~48 hours; followed by longer half-lives of >10 days. The first study has been reviewed by the agency, while the last two studies were only recently submitted and are currently under-going review.

In the first registrant submitted study, [2,3-^{14}C]malathion initially degraded with a calculated half-life of ~0.2 days (based on the first 48 hours of study data) and subsequently degraded with a half-life of ~24 days (based on the study data from 48 hours to study termination at 92 days) using loam soil (pH 6.1) incubated in the dark at 22 ± 2^{o}C and 75% of field capacity. An ancillary experiment was conducted to determine the rate of degradation of malathion in sterile soil. At 4 days post-treatment, malathion comprised close to 100% of the applied radioactivity in sterile soil (97.84% of the extractable radioactivity). The difference between half lives of the sterile and non-sterile treatments indicates that microorganisms are important in the rapid degradation of malathion in soil under acidic aerobic conditions.

Numerous degradates or impurities were identified in the soil extracts and are identified as follows as a percent of applied radioactivity: dicarboxylic acid of malathion (18.7 - 36.7%), the β-monocarboxylic acid of malathion (2.8 - 7.3%), the α-monocarboxylic acid of malathion (1.9 - 2.5%), and maloxon (0.6 - 1.8%). However, the variation of maloxon concentrations with time appears to indicate that it occurs as an impurity (maloxon is present at the beginning of this study and declines over time) rather than a degradate (which would be expected to form over the course of the study) (MRIDs 41721701 and 43166301).

Two additional aerobic soil metabolism studies were recently submitted to the agency, and are currently under review.

Anaerobic Aquatic Metabolism: An open literature study (Bourquin 1977) and the registrant's study suggest that malathion persistence in anaerobic environments is short; however, due to the high pH in the registrant's study a quantitative assessment of the degradation and degradation products could not be performed.

In the registrant submitted anaerobic aquatic metabolism study, [2,3-^{14}C]- and technical grade-malathion added to a sandy loam soil degraded with a half-life of approximately 2.5 days in sediment (pH 7.8) and water (pH 8.7). This study provides useful information, but hydrolysis was probably the main route of degradation in the study since the pH of the system was in the basic range which favors hydrolysis. Although most of the residues remained in the water phase (less than 20% of the applied radioactivity was associated with the soil at any sampling interval), the degradation products were similar in both sediment and water phases. The degradation products at maximum concentrations in the water phase were the monocarboxylic acid of malathion (MCA, 28% at Day 4), demethyl monocarboxylic acid (21% at Day 7), dicarboxylic acid (21 % at Day 14) and the demethyl dicarboxylic acid metabolite (39% at Day 45). The degradation products at maximum concentrations in the sediment were the monocarboxylic acid of malathion (4.5% at 6 hours), demethyl monocarboxylic acid (8.1% at Day 45), and dicarboxylic acid (5.2% at Day 4). The EFED calculated half-life for malathion monocarboxylic acid was 11 days.

Aerobic Aquatic Metabolism: USGS monitoring studies (Kratzer 1998, Domagalski, 2000) show detections of malathion in large rural and urban streams. Many open literature studies have been conducted on the fate and persistence of malathion in the aquatic environment. Reported degradation rates vary and are likely to be significantly increased by biodegradation and pH. Eichelberger and Lichtenberg (1971) found 75% and 90% degradation in river water in one and two weeks, respectively. Guerrant *et al* (1970) found malathion half lives in pond, lake, river and other natural waters varied from 0.5 to 10 days and was dependent on pH. Other studies are summarized in Mulla *et al* (1981) and Howard (1991).

Registrant submitted studies were conducted under alkaline conditions which favor hydrolysis. Thus, degradation rate and products may not be representative of acidic aquatic conditions. In the registrant submitted aerobic aquatic metabolism study, a mixture of [2,3-^{14}C]- and technical grade-malathion added to a sandy loam soil rapidly degraded in the aerobic aquatic environment with half-lives of approximately 1.09 days in the water phase (pH 7.8) and 2.55 days in sediment (pH 8.5). As mentioned previously, hydrolysis was probably the main route of degradation in the study since the pH of the system was in the basic range and hydrolysis occurs most rapidly at pH 9. Major degradates in water and soil were similar: mono- and dicarboxylic acids of malathion, demethyl monoacid and demethyl diacid, while in sediment no demethyl diacid was detected. The EFED calculated half-life for malathion monocarboxylic acid was 3 days.

Terrestrial field dissipation: Data from open literature and registrant-submitted field dissipation studies indicate that malathion dissipates rapidly when applied in the field. Open literature studies provide varying rates of terrestrial dissipation. Mulla *et al* (1981) summarizes degradation results from several field studies including: no residues after 6 months (Roberts *et al* 1962), and 85% degradation in 3 days and 97% in 8 days (Lichtenstein and Schulz 1964). The fastest route of terrestrial field dissipation is generally accepted to be microbial degradation.

In a registrant submitted field dissipation study using a rate of 1.16 lb ai/A, malathion or maloxon residues were detected at ≤10 µg/kg in the 0-6" layer in cotton/bare ground sites in GA. Due to the sampling depth it is not possible to determine how much malathion remained at the soil surface relative to that which moved through the first six inches. Residues detected in the plots in the 6-12" layer after the 2nd, 3rd, 4th, and 5th treatments averaged 35, 37, 5.6, and 9.4 µg/kg, respectively. Malathion was detected in the 12-18 inch soil depth at 16 µg/kg in one replicate soil sample; however, the detection was attributed to contamination. The detection of malathion below six inches along with the low K_d values reported for malathion make it feasible that leaching below 12 inches may have occurred in the field dissipation studies. The terrestrial field dissipation half-life could not be determined due to the rapid dissipation of malathion, although it is probably <1 day (MRID 41748901, 43042401, 43166301).

In a field dissipation study located in California, malathion was applied at a maximum rate of 1.16 lb ai/A once a week for 6 weeks. The resulting dissipation half-life was <0.2 days. In certain instances, malathion was detected below the 12 inch soil depth. No degradates were detected (MRID 41727701, 43042402, 43166301).

Aquatic field dissipation:

In the registrant aquatic field dissipation study located in Missouri, malathion was applied at a maximum rate of 0.58 lb ai/A in three weekly applications to a flooded rice paddy (soil pH 6.1, water pH not stated). Malathion residues detected in water samples collected after the first and second application dissipated to below the detection limit (10 µg/L) in samples taken prior to the second and third applications. In water samples collected one day after the last application, malathion concentrations averaged 17 µg/L and had decreased to 10 µg/L by the second sampling day. Maloxon residues were <10 µg/L at all sampling dates.

The data indicate a very rapid dissipation of malathion in water, probably <1 day. An accurate half-life could not be determined because of the rapid dissipation (MRID 42058402, 43166301).

A second aquatic field dissipation study performed in California was considered invalid because it seems that only 1-2% of the intended amount of malathion was applied (MRID 42058401, 43166301).

Accumulation in Fish. Aquatic bioconcentration factors ranging from 7.36 (lake trout), 29.3 (coho salmon), 869 (white shrimp), to 959 (brown shrimp) are summarized in Howard (1991).

The registrant submitted study shows [^{14}C]malathion residues did not significantly accumulate in bluegill sunfish exposed to 0.99 µg/L [^{14}C]malathion in a flow-through system for 28 days. Average concentrations of malathion were 3.9 to 18 µg/kg in the edible portions of fish, 21 to 130 µg/kg for whole fish, and 34 to 200 µg/kg in the non-edible tissue. [^{14}C]malathion residue equivalents in the edible fish tissue during depuration ranged from 18 µg/kg at the start to 4.8 µg/kg by day 14. Whole fish concentrations decreased from 110 to 4.5 µg/kg and non-edible fish concentrations decreased from 150 to 5.8 µg/kg after day 14. Approximately 73, 96, and 96% of the radioactivity depurated by day 28 from the edible, whole, and non-edible portions of fish, respectively.

The only residue detected in fish tissue at >10% of total radioactive residues (TRR) was malathion monocarboxylic acid (MCA) in concentrations of 33.3-35.9% (44.8-61.2 µg/kg) of TRR. Up to 22 other components were present in levels of 0.1 to 5.7% (0.1 to 7.7 µg/kg) and included malathion dicarboxylic acid (DCA), maloxon, desmethyl malathion, monoethylfumarate, and oxalacetic acid. Maloxon was present in concentrations ≤2.7 µg/kg; while parent malathion was present in concentrations of 0.2 µg/kg at the end of the depuration period.

Maximum BCFs, as a function of total radioactive residues present, ranged from 4.2 to 18, 23 to 135, and 37 to 204 for edible, whole fish, and non-edible, respectively (MRID 43106401, 43106402, 43340301).

Table 2-6 lists the other environmental fate properties of maloxon, along with the major and minor degradates detected in the submitted environmental fate and transport studies. Maloxon only differs structurally from malathion in the substitution of oxygen for sulfur at the double bond with phosphorus. Because both chemicals are very similar in form, both degrade into similar chemicals with the exception of the oxygen/sulfur substitution.

Table 2-6. Summary of Maloxon Environmental Fate Properties

Study	Value and unit	Major and Minor Degradates	MRID # or Citation	Study Classification, Comment
Abiotic Hydrolysis @ 25^{o}C	Half-life[1] = 32 days, pH 5 9 days, pH 7 0.16 days, pH 9	DEMS – major @ pH 9 DEF – major @ pH 9; minor @ pH 5 & 7 DMM – major @ pH 5 & 7 MA – major @ pH 7 & 9 DSD – major @ pH 9; minor @ pH 5 & 7 Other – major @ pH 7 & 9; minor @ pH 5	46396601	Acceptable

[1] Half-lives were calculated using the single-first order equation.

DEMS = Diethyl mercaptosuccinate; DEF = Diethyl fumarate; DMM = Desmethyl maloxon; MA = α & β monoacids; DSD = Disulfide dimer; Other = regions of the chromatograms not associated with known compounds (no individual "other" peaks exceeded 7.9% of applied radioactivity).

The aerobic half-life of maloxon has been reported as three and seven days in basic and acidic soils, respectively (Paschal and Neville 1976). This longer half-life relative to malathion is proposed to be a result of maloxon's biocidal effect on soil microbes which contribute to malathion's degradation.

2.4.1. Environmental Transport Mechanisms

Potential transport mechanisms include pesticide runoff to surface water, spray drift, and secondary drift of volatilized or soil-bound residues leading to deposition onto nearby or more distant ecosystems (>1000 ft). Runoff and spray drift are expected to be the major routes of exposure for malathion.

Data suggest that important routes of dissipation of malathion from soil are leaching and surface runoff. Malathion and its degradates, in general, are soluble and do not adsorb strongly to soils.

Acceptable adsorption/desorption data on parent malathion indicate that it is mobile to moderately mobile in all soils tested (based on the FAO classification system, K_{OC}s range from 151-308 L/kg; FAO 2000). Acceptable terrestrial field dissipation data indicate rapid dissipation ($T_{1/2}$ = <2 days). One detection of malathion below 12 inches was found in a terrestrial field dissipation study, indicating leaching as a likely route of dissipation (MRID 41727701). Similarly, column leaching studies demonstrated that malathion and its degradates, malathion mono- and dicarboxylic acids are very mobile in soil (MRID 43868601). Data presented to the Agency and in the "Pesticides and Groundwater Database" (USEPA 1992) demonstrate that malathion has the potential to leach to ground water. Malathion has been detected in ground water in three states (California, Mississippi, and Virginia) at levels ranging from 0.03 to 6.17 µg/L. Based on these data and the low K_d values, it is clear that malathion has the potential to contaminate ground water.

Although little or no maloxon production is observed in registrant submitted aquatic studies, maloxon has been detected in surface waters and the potential for maloxon runoff may be heightened relative to malathion because it is expected to have higher solubility. EFED is not aware of reports of maloxon ground water contamination. However, malathion has contaminated ground water in several states and has the potential to contaminate surface water through runoff. The increased polarity of maloxon due to the substitution of oxygen for sulfur increases the expected potential of this chemical to be mobile in soil.

Under many circumstances malathion degrades rapidly to compounds of lower toxicity, usually through microbial metabolism and hydrolysis. However, in urban areas (*e.g.*, aerial and ground application for mosquito control), it is likely that malathion will contact dry, microbially inactive, and low organic content surfaces such as concrete, asphalt, dry soil, roofing material, and glass. It is expected that maloxon production will be increased on these surfaces as malathion is exposed to air for extended periods until it is washed away by rain. This is supported by maloxon monitoring data in urban streams after malathion treatments to urban areas showing similar or higher levels of maloxon than malathion in some instances (CaEPA, 1981). CaEPA has published two studies measuring maloxon production on dry soil (CaEPA 1993) and steel sheets (CaEPA 1996). Both of these studies showed higher maloxon production than registrant submitted studies, but maximal levels of maloxon production were not achieved. On the steel surface, a rainfall event removed most of the malathion after only 2 days. On the dry soil, maloxon production did not decrease by the time the study was terminated at 22 days.

CaEPA has published a study describing maloxon production on low organic content soil (0.6%) with a moisture content less than 1% (CaEPA 1993) showing higher maloxon production than registrant submitted studies using soils with higher organic (2-2.7%) and moisture (75% of water holding capacity, capacity not stated) content. Based on the CaEPA data, it appears that maloxon production is favored on dry soils and thus may represent a higher risk scenario for maloxon production and runoff.

Leaching/adsorption/desorption: The short soil persistence of malathion reduces the risk of leaching to ground water; however, it has been detected in ground water in three states (USEPA 1992). Demethyl and carboxylic acid degradates are expected to be highly mobile particularly in alkaline soils.

Based on batch equilibrium (adsorption/desorption) studies, unaged [^{14}C]malathion was determined to be very mobile in sandy loam, sand, loam, and silt loam soils, with Freundlich K_{ads} values of 0.83 - 2.47 L/kg and K_{oc} values from 151-308 L/kg. Adsorption was correlated with organic carbon content. Values for 1/n for K_{ads} were clustered in the range of 0.904 - 0.978 (MRID 41345201).

Maloxon was not detected in any leachate or soil extracts in concentrations ≥0.12% (≥6 µg/L) of applied radioactivity (MRID 43868601, 41345201, 43166301)

Laboratory volatility: Three different malathion formulations [Ready To Use (RTU), Ultra Low Volume (ULV), and Emulsifiable Concentrate (EC)] added to a silt loam soil did not undergo any appreciable volatilization, when measured under different soil moisture regimes or air flow rates. No more than 5.1% of the applied radioactivity volatilized during the 16 days of the study (MRID 42015201).

Spray Drift/Long-range Transport: No registrant-submitted spray drift studies were reviewed. A study conducted for the Boll Weevil Eradication Program at Pennsylvania State University (1993) examined malathion drift under conditions of boll weevil control (1 lb/A = 112 mg/m^2) with an ultra-low volume (ULV) formulation. Deposition up to 21.0, 11.5, 2.9, and 0.7% of that applied was observed at 100, 200, 500, and 1000 meters downwind, respectively. Due to the size of the particles generated, the ULV formulation is expected to produce the highest levels of drift.

A number of studies have documented atmospheric transport and re-deposition of pesticides from the Central Valley to the Sierra Nevada Mountains (Fellers *et al.*, 2004; LeNoir *et al.*, 1999; McConnell *et al.*, 1998; Sparling *et al.*, 2001). Prevailing winds blow across the Central Valley eastward to the Sierra Nevada Mountains, transporting airborne industrial and agricultural pollutants into the Sierra Nevada ecosystems, where they are deposited in rain and snow.

McConnell *et al.* (1998) detected malathion in rain and snow samples collected from the Sierra Navada Mountains at 500 m elevation near the entrance of the Sequoia National Park, at 1920 m in the Sequoia National Park, and at 2,200m at Ward Creek, west of Lake Tahoe. Measured concentrations ranged from <0.046 to 24 ng/L. No malathion was detected in the surface water samples taken in this study. LeNoir et al. (1999) detected malathion in three air samples taken at 200 m and 533 m in Sequoia National Park. Concentrations in these samples ranged from 0.15 to 0.29 ng/m^3. They also detected malathion in water samples taken from a transect that ran from 200 m to 2,040 m at concentrations ranging from 66 to 83 ng/L. These results indicate that prevailing winds blowing from the Central Valley may transport and re-deposit malathion in higher elevations of the Sierra Nevada Mountains. This atmospheric transport may result in exposure to critical habitat segments of the California tiger salamander that are located east of the Central Valley. However, the California tiger salamander occurs in the foothills that lie between the Central Valley and the Sierra Nevada Mountains, not in the Sierra Nevada Mountains themselves. Therefore, the amount of atmospheric deposition that occurs in these foothill regions west of the high elevation mountain regions where studies were conducted is uncertain. It should be noted that besides atmospheric transport and re-deposition, exposure to these critical habitat could also occur from spray drift from nearby agricultural uses, as well as from residential and mosquito abatement uses occurring within the critical habitat.

Other studies have detected malathion in rainwater and air in urban areas within the Central Valley. Majewski *et al.* (2005) monitored pesticides in rainwater collected near Modesto, California between 2001 and 2004. They report a mean and maximum concentration of malathion of 0.031 and 0.383 µg/L, respectively, with a detection frequency of 43%. Majewski and Baston (2002) report on pesticides in air samples taken near Sacramento, California in 1996 and 1997. They detected malathion but at relatively low frequency (0.0 – 10.8%). Mean air concentrations were 1.13-2.89 ng/m^3 and maximum concentrations were 1.13-3.77 ng/m^3.

The magnitude of transport via secondary drift depends on malathion'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. Therefore, physicochemical properties of malathion that describe its potential to enter the air from water or soil (*e.g.*, Henry's Law constant and vapor pressure), pesticide use data, modeled estimated concentrations in water and air, and available air monitoring data from the Central Valley and the Sierra Nevada were considered in evaluating the potential for atmospheric transport of malathion to locations where it could impact the California tiger salamander.

In general, deposition of drifting or volatilized pesticides is expected to be greatest close to the site of application. The computer model(s) of spray drift AgDRIFT and AGDISP were used to determine potential exposures to aquatic and terrestrial organisms via spray drift. It should be noted that these models do not predict deposition of volatilized fractions of applied pesticide and its long-range transport.

2.4.2. Mechanism of Action

Malathion's mode of action is through acetylcholinesterase (AChE) inhibition which disrupts nervous system function. AChE is an enzyme which cleaves the neurotransmitter acetylcholine that resides within nervous system junctions. Inhibiting this enzyme leads to accumulation of the neurotransmitter thus causing signals in the nervous system to persist longer than normal. Typical symptoms for exposure to pesticides which act in this manner are defecation, urination, lacrimation, muscular twitching and weakness, and halted respiration.

Malathion, along with other phosphorodithioate insecticides (those containing two sulfur atoms bonded to phosphorus) must be oxidized before they have inhibitory potency and toxicity. Oxidation occurs via cytochrome p450 and results in the conversion of the P=S group in malathion to P=O forming its oxon, maloxon (Murphy *et al* 1968). This alteration of the phosphate group enables the molecule to covalently bind AChE resulting in long lasting inhibition of the enzyme. Maloxon binds to AChE by mimicking the structure of enzyme's natural substrate, acetylcholine. The similarity between the size, shape, and properties of maloxon and the neurotransmitter allow it to "fit" in the acetylcholine binding site on the enzyme. Altering the structure of maloxon or malathion reduces the ability of the oxon to bind AChE resulting in detoxification of the molecule.

Detoxification reactions may be a result of enzyme or chemical action on the molecule. It occurs very rapidly in mammals given pure malathion resulting in a very less acute toxicity [LD_{50} in rats is 12,500 mg/kg (Fukuto 1983)]. Important detoxification steps occur through nonspecific esterase enzymes which are capable of cleaving malathion to less toxic degradates. Common detoxification reactions for malathion (and maloxon) are ester hydrolysis, demethylation, and phosphorothiolate ester hydrolysis. When one or more of these detoxification steps are blocked by another chemical the toxicity of malathion is increased and the added chemical is considered to synergize malathion toxicity. Chemicals which increase the rate of malathion's conversion to maloxon may also be synergists.

Because organophosphate insecticides are inhibitors of esterases (most specifically AChE) they possess the ability to block detoxification enzymes. Several organophosphate impurities that have historically been present in technical malathion are known to synergize malathion toxicity probably through blocking malathion detoxification. The toxicity of several malathion impurities alone is also very high (*e.g.,* the LD_{50} of O,O,S-trimethyl phosphorothioate in rats is 15 mg/kg, or 833 times more toxic than pure malathion) and cause delayed toxicity suggesting a mode of action other than AChE inhibition. Impurities can be produced through improper storage of malathion as evidenced by a 35% increase in the acute toxicity of technical malathion stored at $40^{o}C$ for 6 months (Fukuto 1983).

2.4.3. Use Characterization

Analysis of labeled use information is the critical first step in evaluating the federal action. The current labels for malathion (at the time this report was written) represented the FIFRA regulatory action; therefore, labeled use and application rates specified on the label formed the basis of this assessment. The assessment of use information was critical to the development of the action area and selection of appropriate modeling scenarios and inputs.

Malathion is one of the most widely used insecticides in the U. S. for residential as well as agricultural pest control. It is used throughout the state of California. Historically, the predominant agricultural use was cotton for the Boll Weevil Eradication Program, but it is currently applied to a large number of other agricultural commodities, including various vegetable, grain, fruit, and nut crops, as well as stored grains. It is also used extensively in non-agricultural settings for residential insect control and for adult mosquito control by municipal vector control programs. Most malathion products are formulated as an emulsifiable concentrate (EC) spray, an ultralow-volume (ULV) concentrate, or a dust. A few products are formulated as a powder or wetable powder.

Because of the large numbers of use sites for malathion (**Table 2-7**), the uses have been grouped by similar application characteristics (application rates, number of applications per year, minimum retreatment intervals, and aquatic exposure modeling scenario).

Table 2-7. Malathion Uses, Application Information, and Modeling Scenarios Used in Exposure Assessment[1]

Scenario Group. Label Crop/Site	**Maximum Application Rates[2] (Lbs. ai/A)**	**Applications per Crop Cycle (Minimum Days before Re-treatment)**	**PRZM Scenario and Meteorological Station**
Agricultural Uses (spray drift buffers of 25 ft for ground applications and 50 ft for air)			
1. Alfalfa, Clover, Lespedeza, Lupine, Trefoil, and Vetch	Air: 1.56 ULV: 0.61 Ground: 1.56	5 (14) 2 (14) 5 (14)	CAalfalfa_WirrigOPCentral valley, CA (W93193)
2. Macadamia Nut (Bushnut)	Ground: 0.94 Airblast: 0.94	6 (7) 6 (7)	CAalmond_WirrigSTD Central valley, CA ~ San Joaquin county (W23232)
3 and 4. Pecan, Walnut (English/Black), and Chestnut	Ground: 2.5 Airblast: 2.5	3 (7) 3 (7)	CAalmond_WirrigSTD Central valley, CA ~ San Joaquin county (W23232)
6. Date (dust)	Air: 4.25 Ground: 4.25	5 (7) 5 (7)	CAalmond_WirrigSTD Central valley, CA ~ San Joaquin county (W23232)
8. Avocado	Ground: 4.7	2 (30)	CAAvocadoRLF San Diego County (W23188)
9. Citrus, Citrus Hybrids other than Tangelo, Grapefruit, Kumquat, Lemon, Lime, Orange, Tangelo, and Tangerines	Air: 7.5 ULV: 0.175 Ground: 7.5 Airblast: 7.5	3 (30) 3 (7) 3 (30) 3 (30)	CAcitrus_WirrigSTD Central valley, CA ~ Fresno County (W23155)
10. Amaranth - Chinese, Broccoli (Unspecified, Chinese, and Raab), Cabbage (Unspecified and Chinese), Canola\Rape, Cauliflower, Collards, Corn Salad, Dock (Sorrel), Horseradish, Kale, Kohlrabi, Mustard, Mustard Cabbage (Gai Choy/Pak-Choi), and Purslane (Garden and Winter)	Air: 1.25 Ground: 1.25	6 (7) 6 (7)	CAColeCropRLF Santa Maria Valley Area, CA; (W23234)
11. Corn (Unspecified, Field, Pop, and Sweet)	Air: 1.0 ULV: 0.61 Ground: 1.0	2 (5) 2 (5) 2 (5)	CAcornOP Stanislaus/San Joaquin Counties (W23232)

Scenario Group. Label Crop/Site	Maximum Application Rates[2] (Lbs. ai/A)	Applications per Crop Cycle (Minimum Days before Re-treatment)	PRZM Scenario and Meteorological Station
12. Cotton	Air: 2.5 ULV: 1.22 Ground: 2.5	3 (7) 3 (7) 3 (7)	CAcotton_WirrigSTD Fresno County, CA (W93193)
13. Hops	Air: 0.63 Ground: 0.63 Airblast: 0.63	3 (7) 3 (7) 3 (7)	ORhopsSTD Marion Co., OR (W24232)
15. Apricot	Ground: 1.5 Airblast: 1.5	2 (7) 2 (7)	CAfruit_WirrigSTD Fresno County, CA (W93193)
16. Nectarine and Peach	Ground: 3 Airblast: 3	3 (7) 3 (7)	CAfruit_WirrigSTD Fresno County, CA (W93193)
17. Cherry	Air: 1.75 ULV: 1.22 Ground: 1.75 Airblast: 1.75	4 (3) 6 (7) 4 (3) 4 (3)	CAfruit_WirrigSTD Fresno County, CA (W93193)
18. Fig	Ground: 2 Airblast: 2	2 (5) 2 (5)	CAfruit_WirrigSTD Fresno County, CA (W93193)
19. Pear	Ground: 1.25 Airblast: 1.25	2 (7) 2 (7)	CAfruit_WirrigSTD Fresno County, CA (W93193)
20 and 21. Guava, Mango, and Papaya	Ground: 1.25 Airblast: 1.25	13 (3) 13 (3)	CAfruit_WirrigSTD Fresno County, CA (W93193)
22. Garlic and Leek	Air: 1.56 Ground: 2	3 (7) 3 (6)	CAGarlicRLF Fresno County, CA (W23188)
23. Grapes	Ground: 1.88 Airblast: 1.88	2 (14) 2 (14)	CAgrapes_WirrigSTD Fresno County, CA (W93193)
24. Mushrooms	Ground: 1.7	4 (3)	CAfruit_WirrigSTD Fresno County, CA (W93193). (See justification below.)
26. Brussel Sprouts and Dandelion	Air: 1.25 Ground: 1.25	2 (7) 2 (7)	CAlettuceSTD Monterey County; CA (W23273)
27. Swiss Chard, Chervil, Endive (Escarole), Lettuce, Head Lettuce, Leaf Lettuce (Black Seeded Simpson, Salad Bowl, Etc.), Orach (Mountain Spinach), Parsley, Roquette (Arrugula), Salsify, and Spinach	Air: 1.88 Ground: 1.88	2 (5) 2 (5)	CAlettuceSTD Monterey County; CA (W23273)
29. Eggplant	Air: 1.56 Ground: 1.56	5 (5) 5 (5)	CAtomato_WirrigSTD San Joaquin County, CA (W93193).
30. Pumpkin	Air: 1 Ground: 1	2 (7) 2 (7)	CAMelonsRLF Fresno, Kern, Kings, Madera, and Merced Counties, CA (W93193)

Scenario Group. Label Crop/Site	**Maximum Application Rates[2] (Lbs. ai/A)**	**Applications per Crop Cycle (Minimum Days before Re-treatment)**	**PRZM Scenario and Meteorological Station**
31. Cucumber, Cucurbit Vegetables, Melons - Unspecified, Cantaloupe, Honeydew, Musk, Water, and Winter (Casaba/Crenshaw/Honeydew/Persian), and Squash (All Or Unspecified)	Air: 1.75 Ground: 1.75	3 (7) 3 (7)	CAMelonsRLF Fresno, Kern, Kings, Madera, and Merced Counties, CA (W93193)
32. Onion (Unspecified and Green), Radish, and Shallot	Air: 1.56 Ground: 1.56	2 (7) 2 (7)	CAonion_WirrigSTD Kern County, CA (W23155)
33 and 36. White/Irish Potato and Sweet Potato	Air: 1.56 Ground: 1.56	2 (7) 2 (7)	CAPotatoRLF Kern County, CA (W23155)
34 and 35. Turnip, Parsnip, and Rutabaga	Air: 1.25 Ground: 1.25	3 (7) 3 (7)	CAPotatoRLF Kern County, CA (W23155)
37. Bluegrass, Canarygrass, Grass Forage/Fodder/Hay, Pastures, Peas (Including Vines), Rangeland, and Sudangrass	Air: 1.25 ULV: 0.92 Ground: 1.25	1 1 1	CArangelandhayRLF San Francisco Bay Area, CA (W23232)
40. Beets and Peas (Unspecified and Field)	Air: 1 Ground: 1.25	2 (7) 3 (7)	CARowCropRLF Santa Maria Valley Area, CA (W23234)
41. Carrot (Including Tops), Celtuce, Fennel, and Pepper	Air: 1.56 Ground: 1.56	2 (5) 2 (5)	CARowCropRLF Santa Maria Valley Area, CA (W23234)
42. Beans, Beans - Dried-Type, Beans - Succulent (Lima), and Beans - Succulent (Snap)	ULV: 0.61	2 (7)	CARowCropRLF Santa Maria Valley Area, CA (W23234)
43. Celery	Air: 1.5 Ground: 1.5	2 (7) 2 (7)	CARowCropRLF Santa Maria Valley Area, CA (W23234)
44. Asparagus	Air: 1.25 Ground: 1.25	2 (7) 2 (7)	CARowCropRLF Santa Maria Valley Area, CA (W23234)
46. Strawberry	Air: 2 Ground: 2	4 (7) 4 (7)	CAStrawberry-noplasticRLF Santa Maria Valley Area, CA (W23234)
48. Tomato	Air: 1.56 Ground: 1.56	4 (5) 4 (5)	CAtomato_WirrigSTD San Joaquin County, CA (W93193)
49. Okra	Air: 1.2 Ground: 1.2	5 (7) 5 (7)	CAtomato_WirrigSTD San Joaquin County, CA (W93193)
51. Sorghum	Air: 1 ULV: 0.61 Ground: 1	2 (7) 2 (7) 2 (7)	CAWheatRLF Kings County, CA (W93193)
52. Barley, Cereal Grains, Oats, Rye, and Wheat	Air: 1.25 ULV: 0.61 Ground: 1.25	2 (7) 2 (7) 2 (7)	CAWheatRLF Kings County, CA (W93193)

Scenario Group. Label Crop/Site	**Maximum Application Rates[2] (Lbs. ai/A)**	**Applications per Crop Cycle (Minimum Days before Re-treatment)**	**PRZM Scenario and Meteorological Station**
53, 54, 56. Gooseberry, Blackberry, Boysenberry, Dewberry, Loganberry, Raspberry (Black - Red), Caneberries, and Currant	Air: 1.25 Ground: 2 Airblast: 2	3 (7) 3 (7) 3 (7)	CAWineGrapesRLF Sonoma County, CA (W23234)
55. Blueberry	Ground: 1.25 ULV: 0.77	3 (5) 3 (10)	CAWineGrapesRLF Sonoma County, CA (W23234)
57. Passion Fruit (Granadilla)	Ground: 1	8 (7)	CAWineGrapesRLF Sonoma County, CA (W23234)
58. Mint and Spearmint	Air: 0.94 Ground: 0.94	3 (7) 3 (7)	ORmintSTD Marion County, OR (W24232)
59. Rice and Wild Rice	Air: 1.25 ULV: 0.61 Ground: 1.25	2 (7) 2 (7) 2 (7)	Rice Guidance[3]
61. Water Cress	Air: 1.25 Ground: 1.25	5 (3) 5 (3)	Rice Guidance[3]
Non-agricultural Uses			
Cull Piles and agricultural Structures and Equipment. Cull Piles, Agricultural/Farm Structures/Buildings and Equipment, Commercial/Institutional/Industrial Premises/Equipment (Outdoor), and Meat Processing Plant Premises (Nonfood Contact)	Drench: 298.7	1	CAcitrus_WirrigSTD Central valley, CA ~ Fresno County (W23155)
Fence rows/hedge rows.	Ground: 10.6	1	CArightofwayRLF Central/Coastal, CA (W23234).
Forestry. Christmas Tree Plantations, Pine (Seed Orchard), and Slash Pine (Forest)	Air: 3.2 ULV: 0.9375 Ground: 3.2 Airblast: 3.2	2 (7) 2 (7) 2 (7) 2 (7)	CAForestryRLF Shasta County, CA (W24283)
Nursery. Outdoor Nursery, Outdoor Premises, Ornamental and/or Shade Trees, Ornamental Herbaceous Plants, Ornamental Lawns and Turf, Ornamental Non-flowering Plants, Ornamental Woody Shrubs and Vines, and Urban Areas	Air: 2.5 Ground: 2.5	2 (10) 2 (10)	CAnurserySTD San Diego, CA (W23188)
Rights-of-way. Uncultivated agricultural areas, Nonagricultural Rights-of-way/Fencerows, and Nonagricultural Uncultivated Areas/Soils	Air: 1 ULV: 0.9281 Ground: 1 Airblast: 1	1 1 1 1	CArightofwayRLF CAImperviousRLF Central/Coastal, CA (W23234).
Public Health and Mosquito and Medfly Control. Nonagricultural Areas (Public Health Use), Urban Areas, Wide Area/General Outdoor Treatment (Public Health Use), Intermittently Flooded Areas/Water, Lakes/Ponds/Reservoirs (with Human or Wildlife Use), Lakes/Ponds/Reservoirs (without Human or Wildlife Use), Polluted Water, and Swamps/Marshes/Wetlands/Stagnant Water	Air: 0.5078 ULV: 0.23	1 1	CAImperviousRLF San Francisco Bay Area, CA (W23234)

Scenario Group. Label Crop/Site	**Maximum Application Rates**[2] **(Lbs. ai/A)**	**Applications per Crop Cycle (Minimum Days before Re-treatment)**	**PRZM Scenario and Meteorological Station**
Residential and Refuse/Solid Waste. Household/Domestic Dwellings (perimeter around dwelling), Refuse/Solid Waste Containers (Garbage Cans), and Refuse/Solid Waste Sites (Outdoor)	Ground: 10.6	1	CAresidentialRLF CAImperviousRLF San Francisco Bay Area, CA (W23234)
Turf. Golf Course Turf (Bermudagrass)	Air: 1.25 ULV: 0.92 Ground: 1.25	1 1 1	CATurfRLF San Francisco Bay Area, CA (W23234)

1 Uses assessed based on memorandum from Pesticide Re-evaluation Division (PRD) dated 1/25/2010.

[2] Air, ULV, Ground and Airblast refers to aerial, ultra-low volume, ground, and airblast application methods.

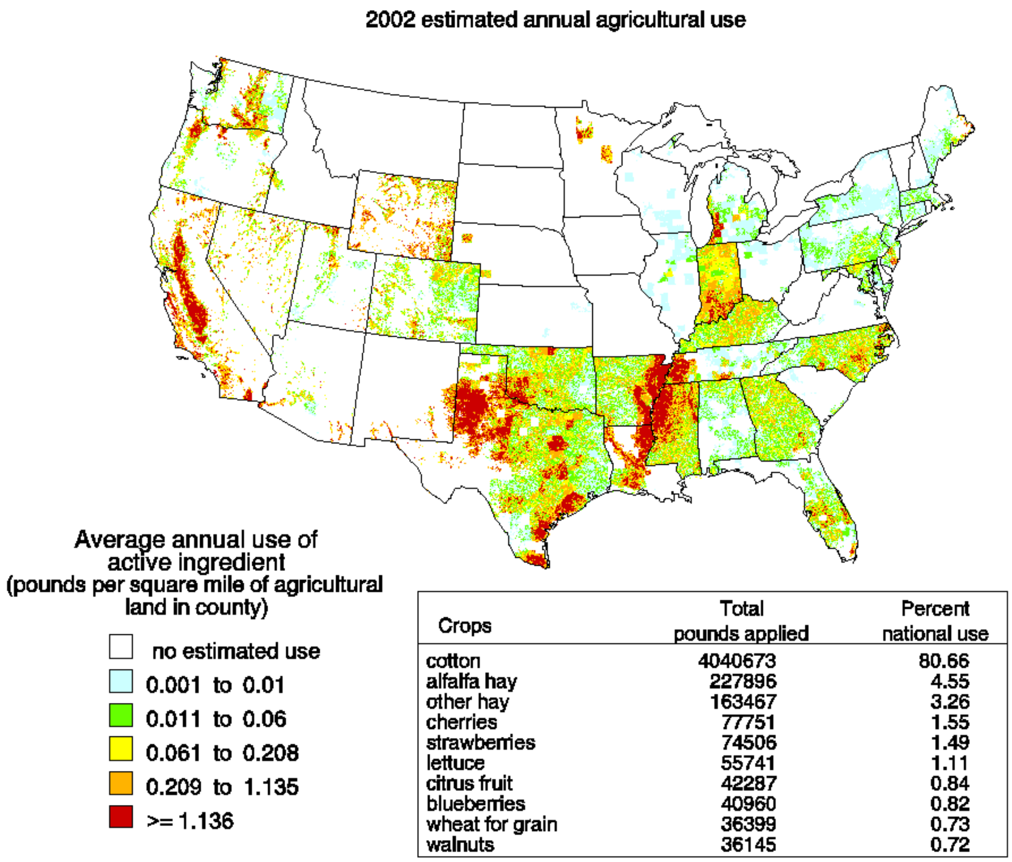
[3] http://www.epa.gov/oppefed1/models/water/rice_tier_i.htm

Uses that will no longer remain registered after implementation of the 2006 RED and are therefore not considered in this assessment are: almond; filbert (hazelnut); millet (foxtail) and sunflower; manure; apple and quince; plum and prune; peppermint; cowpea/blackeyed pea; peanuts; safflower; anise; and sugar beets (incl. tops).

In June 2009, the Product Registration Division (PRD, previously SRRD) required all malathion registrants to amend their product labels to reflect mitigation specified in the May 2009 revised malathion RED. Registrants have since submitted revised labels or voluntary cancellation requests for the majority of malathion product labels. The revised labels are currently being reviewed by the Registration Division. Revisions to malathion product labeling are expected to be substantially complete by December 2010. Because the existing labels are currently being revised according to a legally binding agreement between the registrant and U.S. EPA, the maximum per application rate, minimum re-application interval, and maximum number of applications for each use (use application characteristics) were taken from those listed in the final revision of the 2006 RED, as defined in Appendix Table D2, rather than from the current labels at the time this document was written. All future labels (after December of 2010 and once previously labeled stock has been sold) should conform to the specifications given in Appendix B. Appendix Table D2 presents the same use specifications as given in Appendix B with the exception that the uses have been grouped by similar application rates, number of applications, re-treatment interval, and aquatic modeling scenario.

Some malathion products specify application rates on a per crop cycle basis (not on a per year basis). Information from BEAD indicates that many crops can be grown more than one time/year in California (U.S. EPA 2007b). Since standard PRZM scenarios only consist of one crop per year, applications to only one crop per year were modeled. The crops that may be grown multiple times in a calendar year that can be treated by malathion include Alfalfa, Clover, Lespedeza, Trefoil, Vetch, and Turf. If malathion is applied for multiple cropping cycles within a year, EECs presented in this assessment may underpredict exposures. Because malathion displays little persistence in the environment (aerobic soil metabolism and terrestrial field dissipation half-lives from <1 to 2 days), any build up of malathion over succeeding crop cycles would be minimal. Any under-prediction of exposure is also likely to be minimal. For all other labeled uses, it was assumed that a maximum seasonal application specified was equivalent to a maximum annual application.

According to the United States Geological Survey's (USGS) national pesticide usage data (based on information from 1999 to 2004), an average of 5 million lbs of malathion is applied nationally to agricultural use sites in the U.S. (non-agricultural uses are not included) (Figure 2-1). Cotton has the greatest use of malathion nationally claiming over 80% of total annual usage.



Crops	Total pounds applied	Percent national use
cotton	4040673	80.66
alfalfa hay	227896	4.55
other hay	163467	3.26
cherries	77751	1.55
strawberries	74506	1.49
lettuce	55741	1.11
citrus fruit	42287	0.84
blueberries	40960	0.82
wheat for grain	36399	0.73
walnuts	36145	0.72

Figure 2-1. Malathion use in total pounds per county
(from http://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=02&map=m6033)[1]

The Agency's Biological and Economic Analysis Division (BEAD) provided an analysis of both national- and county-level usage information (USEPA 2009) using state-level usage data obtained from USDA-NASS[2], Doane (www.doane.com; the full dataset is not provided due to its

[1] The pesticide use maps available from this site show the average annual pesticide use intensity expressed as average weight (in pounds) of a pesticide applied to each square mile of agricultural land in a county. The area of each map is based on state-level estimates of pesticide use rates for individual crops that were compiled by the CropLife Foundation, Crop Protection Research Institute based on information collected during 1999 through 2004 and on 2002 Census of Agriculture county crop acreage. The maps do not represent a specific year, but rather show typical use patterns over the five year period 1999 through 2004.
[2] United States Depart of Agriculture (USDA), National Agricultural Statistics Service (NASS) Chemical Use Reports provide summary pesticide usage statistics for select agricultural use sites by chemical, crop and state. See http://www.pestmanagement.info/nass/app_usage.cfm.

proprietary nature) and the California's Department of Pesticide Regulation Pesticide Use Reporting (CDPR PUR) database[3]. CDPR PUR is considered a more comprehensive source of usage data than USDA-NASS or EPA proprietary databases, and thus the usage data reported for malathion by county in this California-specific assessment were generated using CDPR PUR data. Nine years (1999-2007) of usage data were included in this analysis. Data from CDPR PUR were obtained for every agricultural pesticide application made on every use site at the section level (approximately one square mile) of the public land survey system.[4] BEAD summarized these data to the county level by site, pesticide, and unit treated. Calculating county-level usage involved summarizing across all applications made within a section and then across all sections within a county for each use site and for each pesticide. The county level usage data that were calculated include: average annual pounds applied, average annual area treated, and average and maximum application rate across all nine years. The units of area treated are also provided where available.

A summary of malathion usage for all California use sites is provided below in **Table 2-8.**

Table 2-8. Summary of California Department of Pesticide Registration (CDPR) Pesticide Use Reporting (PUR) Data from 1999 to 2007 for Currently Registered Malathion Uses[1]

Site Name	Average Annual Pounds Applied	Average Application Rate (lbs a.i./A)	Maximum Application Rate (lbs a.i./A)
Alfalfa	130,616	1.21	17.23
Almond	410	2.07	11.92
Apple	72	2.17	49.06
Apricot	5	2.88	6.13
Arrugula	16	1.79	7.67
Asparagus	848	1.18	1.92
Avocado	1,310	0.25	19.74
Barley	985	1.11	1.71
Bean, Dried	2,991	1.28	2.62
Bean, Succulent	1,498	1.34	6.39
Bean, Unspecified	341	1.42	14.72
Beet	154	1.95	8.18
Bermudagrass	4,434	1.12	4.58
Blackberry	1,229	3.43	16.35
Blueberry	102	1.86	2.55
Bok Choy	602	1.87	11.52
Broccoli	6,651	1.85	8.03
Brussels Sprout	71	1.38	2.43
Cabbage	2,015	1.87	12.27
Canola (Rape)	432	2.03	2.90

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

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

Site Name	**Average Annual Pounds Applied**	**Average Application Rate (lbs a.i./A)**	**Maximum Application Rate (lbs a.i./A)**
Cantaloupe	401	7.36	87.47
Carrot	2,316	1.63	4.19
Cauliflower	776	1.60	2.60
Celery	14,744	1.44	15.06
Cherimoya	0.03	0.24	0.24
Cherry	498	5.13	37.01
Chervil	0.85	1.92	1.92
Chicory	0.39	2.06	2.06
Chinese Cabbage (Nappa)	2,304	1.99	30.99
Chinese Greens	69	1.69	2.47
Chive	1.59	1.09	1.53
Christmas Tree	90	1.71	15.33
Citrus	197	2.51	40.88
Clover	93	2.21	3.91
Cole Crop	0.43	1.44	1.44
Collard	93	1.88	5.12
Commodity Fumigation	4.43	39.91	39.91
Corn (Forage - Fodder)	318	1.05	2.79
Corn, Human Consumption	906	0.96	6.39
Cotton	3,779	1.26	11.27
Cucumber	458	2.12	28.81
Daikon	0.11	0.53	0.99
Dandelion Green	0.18	1.15	1.28
Date	8,241	2.88	37.50
Eggplant	43	1.65	32.80
Endive (Escarole)	487	1.65	2.86
Fennel	20	1.79	2.10
Fig	949	2.06	2.56
Forage Hay/Silage	2,467	1.30	3.07
Gai Choy	5.55	1.73	4.09
Gai Lon	363	1.86	5.33
Garlic	1,425	1.89	9.81
Grape	2,071	2.41	25.56
Grape, Wine	4,326	2.07	40.89
Grapefruit	264	0.76	76.82
Grass, Seed	8.22	1.23	1.50
Herb, Spice	0.06	1.68	1.68
Kale	950	1.88	11.52
Kiwi	0.08	0.34	0.34
Kohlrabi	12	1.30	11.24
Kumquat	33	3.14	63.60
Landscape Maintenance	1.21	1.38	2.47
Leek	44	1.75	3.84

Site Name	Average Annual Pounds Applied	Average Application Rate (lbs a.i./A)	Maximum Application Rate (lbs a.i./A)
Lemon	3,249	5.31	81.77
Lettuce, Head	32,919	1.69	17.03
Lettuce, Leaf	17,638	1.66	21.12
Lime	11	0.36	11.52
Livestock	7.69	0.55	0.63
Mango	0.91	0.27	0.36
Melon	37	2.25	19.88
Mint	123	0.99	9.00
Mizuna	10	2.16	2.40
Mushroom	0.36	2.08	2.08
Mustard	216	1.52	10.22
Nectarine	102	6.43	32.71
N-Outdr Flower	512	1.44	32.71
N-Outdr Plants In Containers	5,157	2.44	65.41
N-Outdr Transplants	539	1.68	50.08
Nuts	3.19	0.97	1.00
Oat	226	1.14	1.62
Oat (Forage - Fodder)	148	1.18	1.92
Okra	45	1.35	1.54
Olive	3.16	1.93	1.93
Onion, Dry	4,847	1.51	16.35
Onion, Green	1,600	1.73	16.35
Orange	22,106	2.58	83.08
Parsley	18	1.39	8.18
Parsnip	42	1.84	1.94
Pastureland	192	1.10	2.04
Peach	45	3.26	12.34
Pear	103	5.74	37.01
Peas	1,404	0.82	24.36
Pecan	26	5.89	9.69
Pepper, Fruiting	700	1.17	10.06
Pepper, Spice	53	2.97	38.41
Plum	12	7.14	37.01
Pomegranate	0.05	0.08	0.08
Potato	195	1.88	3.08
Prune	132	3.55	9.69
Pumpkin	1,325	1.38	2.50
Quince	1.33	0.75	0.75
Radish	104	1.46	16.10
Rangeland	30	1.86	14.97
Rappini	20	2.22	2.57
Raspberry	1,947	1.40	24.53
Regulatory Pest Control	3,421	12.46	95.39

Site Name	Average Annual Pounds Applied	Average Application Rate (lbs a.i./A)	Maximum Application Rate (lbs a.i./A)
Research Commodity	0.82	0.37	2.72
Rice	729	1.32	1.75
Rice, Wild	2,124	1.48	11.84
Rights Of Way	0.39	0.60	1.24
Rutabaga	2.27	2.04	2.04
Ryegrass	4.27	1.16	1.16
Safflower	585	0.91	1.44
Shallot	15	2.05	2.05
Sorghum (Forage - Fodder)	51	1.17	1.47
Sorghum/Milo	37	2.40	4.22
Spinach	1,079	1.54	12.78
Squash	490	1.49	11.97
Squash, Summer	473	2.05	96.29
Squash, Winter	82	2.12	8.01
Squash, Zucchini	35	1.62	2.04
Strawberry	76,046	1.86	68.75
Structural Pest Control	6.28	1.94	1.94
Sudangrass	19	1.35	1.92
Sugarbeet	3,298	1.51	28.48
Sunflower	2.99	0.67	2.40
Sweet Potato	218	2.42	14.31
Swiss Chard	206	1.65	4.09
Tangelo	224	3.30	13.63
Tangerine	4,326	4.29	27.23
Tomatillo	11	1.04	2.00
Tomato	640	1.51	9.79
Tomato, Processing	2,674	1.14	9.99
Tropical/Subtropical Fruit	5.31	0.28	2.47
Turf/Sod	0.12	0.15	0.15
Turnip	161	1.52	16.36
Turnip (Forage - Fodder)	0.31	1.24	1.24
Uncultivated Ag	41	1.42	10.04
Uncultivated Non-Ag	36	1.33	2.04
Vegetable	5.00	2.08	3.84
Vegetables, Leafy	6.54	1.58	1.92
Walnut	26,005	3.82	61.46
Watercress	362	1.03	13.63
Watermelon	427	2.90	29.16
Wheat	3,055	1.05	2.83
Wheat (Forage - Fodder)	389	1.06	1.25
Regulatory Pest Control	2,368	0.60	0.64
Commodity Fumigation	68		
Fumigation, Other	71		

Site Name	Average Annual Pounds Applied	Average Application Rate (lbs a.i./A)	Maximum Application Rate (lbs a.i./A)
Landscape Maintenance	18,156		
Public Health	14,433		
Regulatory Pest Control	30,308		
Rights Of Way	504		
Structural Pest Control	31,914		

1- Based on data supplied by BEAD (U.S. EPA 2009).

2.5. Assessed Species

Table 2-9 provides a summary of the current distribution, habitat requirements, and life history parameters for the listed species being assessed. More detailed life-history and distribution information can be found in Attachment 3.

The DS was listed as threatened on March 5, 1993 (58 FR 12854) by the USFWS (USFWS, 2007). The current range of the DS is shown in Figure 2-2. DS are mainly found in the Suisun Bay and the Sacramento-San Joaquin estuary near San Francisco Bay. During spawning DS migrate upstream into freshwater rivers, sloughs, and tributaries that drain into the estuary.

The CTS is listed as three Distinct Population Segments (DPSs): the Sonoma County DPS (CTS-SC), the Santa Barbara County DPS (CTS-SB), and the Central California DPS (CTS-CC). This assessment considers exposure from uses of malathion to each DPS separately as they occupy different geographic areas; however, the natural history and toxic response to malathion is assumed to be similar for individuals of each of the three DPSs. Thus, the main difference among the three DPS's in the assessment was in the spatial analysis of the co-occurrences of habitat of each DPS and uses of malathion. The CTS-SB and CTS-SC were downlisted from endangered to threatened in 2004 by the USFWS, however, the downlisting was vacated by the U.S. District Court. Therefore, CTS-SB and CTS-SC are currently listed as endangered while the CTS-CC is listed as threatened. CTS utilize vernal pools, semi-permanent ponds, and permanent ponds (including constructed stock ponds), and surrounding grassland and oak savannah communities in central California. They inhabit valley-foothill habitats up to approximately 3000 ft (California DFG, 2005). The aquatic environment is essential for breeding and reproduction and mammal burrows are also important habitat for estivation. The CTS-CC occurs in isolated segments of the Coastal Range and foothills of the Sierra Nevada mountains that surround the Central Valley of California (Fig 2-3). The CTS-SC and CTS-SB inhabit Coastal Range habitats that are located entirely within Sonoma County and Santa Barbara County, respectively (Fig 2-3).

Table 2-9. Summary of Current Distribution, Habitat Requirements, and Life History Information for the Assessed Listed Species[1]

Assessed Species	**Size**	**Current Range**	**Habitat Type**	**Designated Critical Habitat?**	**Reproductive Cycle**	**Diet**
California Tiger Salamander (CTS) (*Ambystoma californiense*)	50 g	CTS-SC are primarily found on the Santa Rosa Plain in Sonoma County. CTS-CC occupies the Bay Area (central and southern Alameda, Santa Clara, western Stanislaus, western Merced, and the majority of San Benito Counties), Central Valley (Yolo, Sacramento, Solano, eastern Contra Costa, northeast Alameda, San Joaquin, Stanislaus, Merced, and northwestern Madera Counties), southern San Joaquin Valley (portions of Madera, central Fresno, and northern Tulare and Kings Counties), and the Central Coast Range (southern Santa Cruz, Monterey, northern San Luis Obispo, and portions of western San Benito, Fresno, and Kern Counties). CTS-SB are found in Santa Barbara County.	Freshwater pools or ponds (natural or man-made, vernal pools, ranch stock ponds, other fishless ponds); Grassland or oak savannah communities, in low foothill regions; Small mammal burrows	Yes	Emerge from burrows and breed: fall and winter rains Eggs: laid in pond Dec. – Feb., hatch: after 10 to 14 days Larval stage: 3-6 months, until the ponds dry out, metamorphose late spring or early summer, migrate to small mammal burrows	Aquatic Phase: algae, snails, zooplankton, small crustaceans, and aquatic larvae and invertebrates, smaller tadpoles of Pacific tree frogs, CRLF, toads; Terrestrial Phase: terrestrial invertebrates, insects, frogs, and worms
Delta Smelt (DS) (*Hypomesus transpacificus*)	Up to 120 mm in length	Suisun Bay and the Sacramento-San Joaquin estuary (known as the Delta) near San Francisco Bay, CA	The species is adapted to living in fresh and brackish water. They typically occupy estuarine areas with salinities below 2 parts per thousand (although they have been found in areas up to 18ppt). They live along the	Yes	They spawn in fresh or slightly brackish water upstream of the mixing zone. Spawning season usually takes place from late March through mid-May, although it may occur from late winter	They primarily planktonic copepods, cladocerans, amphipods, and insect larvae. Larvae feed on phytoplankton; juveniles feed on zooplankton.

Assessed Species	Size	Current Range	Habitat Type	Designated Critical Habitat?	Reproductive Cycle	Diet
			freshwater edge of the mixing zone (saltwater-freshwater interface).		(Dec.) to early summer (July-August). Eggs hatch in 9 – 14 days.	

[1] For more detailed information on the distribution, habitat requirements, and life history information of the assessed listed species, see Attachment 2.
[2] Oviparous = eggs hatch within the female's body and young are born live.
[3] No data on juvenile CCR body weights are available at this time. As a surrogate for CCR juveniles, data on captive 21-day king rails were averaged for the juvenile body weight. King rails make an appropriate proxy for the CCR in the absence of information. The birds were once considered the same species by taxonomists, are members of the same genus (*Rallus*), and occasionally interbreed where habitats overlap.

Delta Smelt Habitat

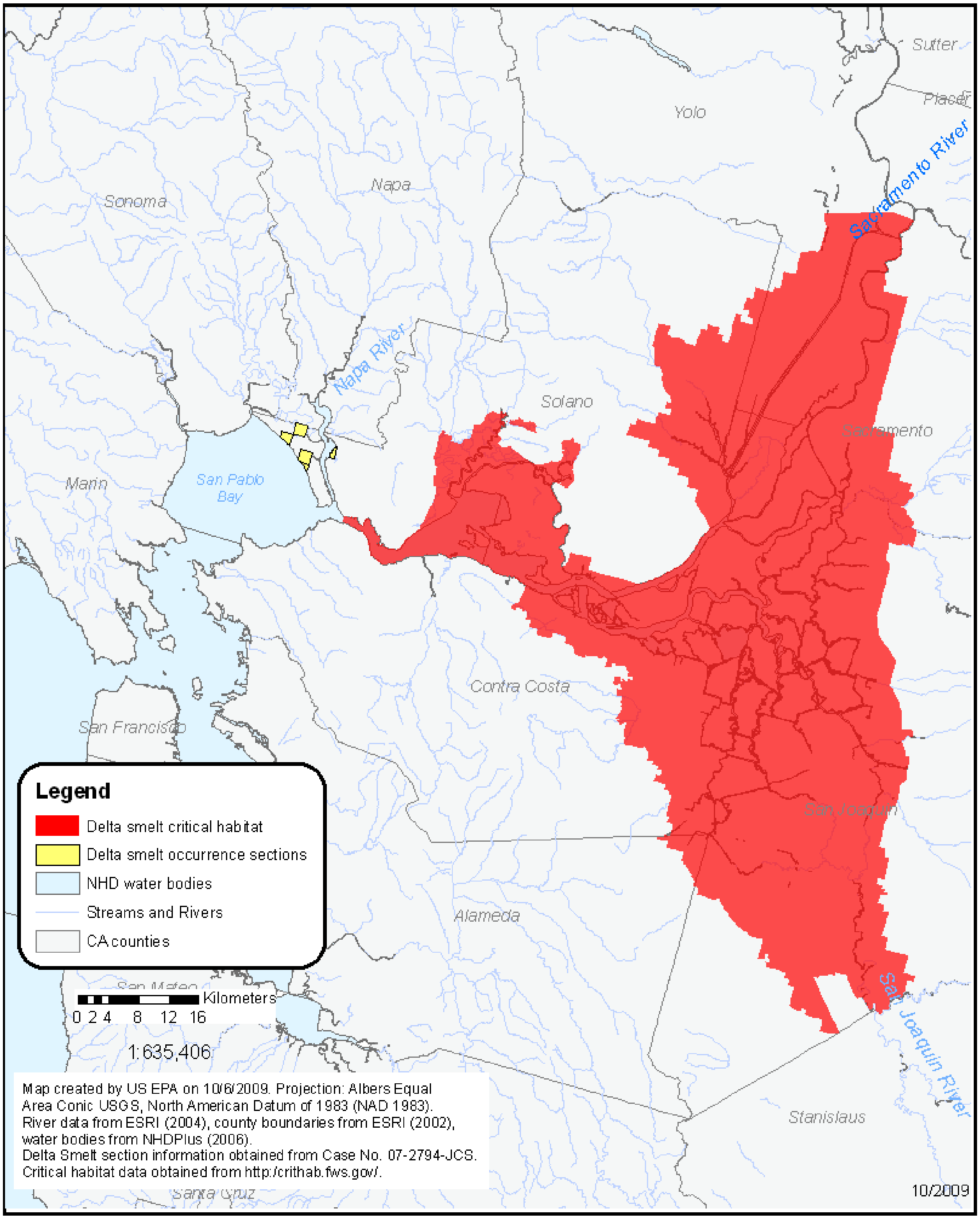


Figure 2-2. Critical habitat and occurrence sections of the delta smelt identified in Case No. 07-2794-JCS.

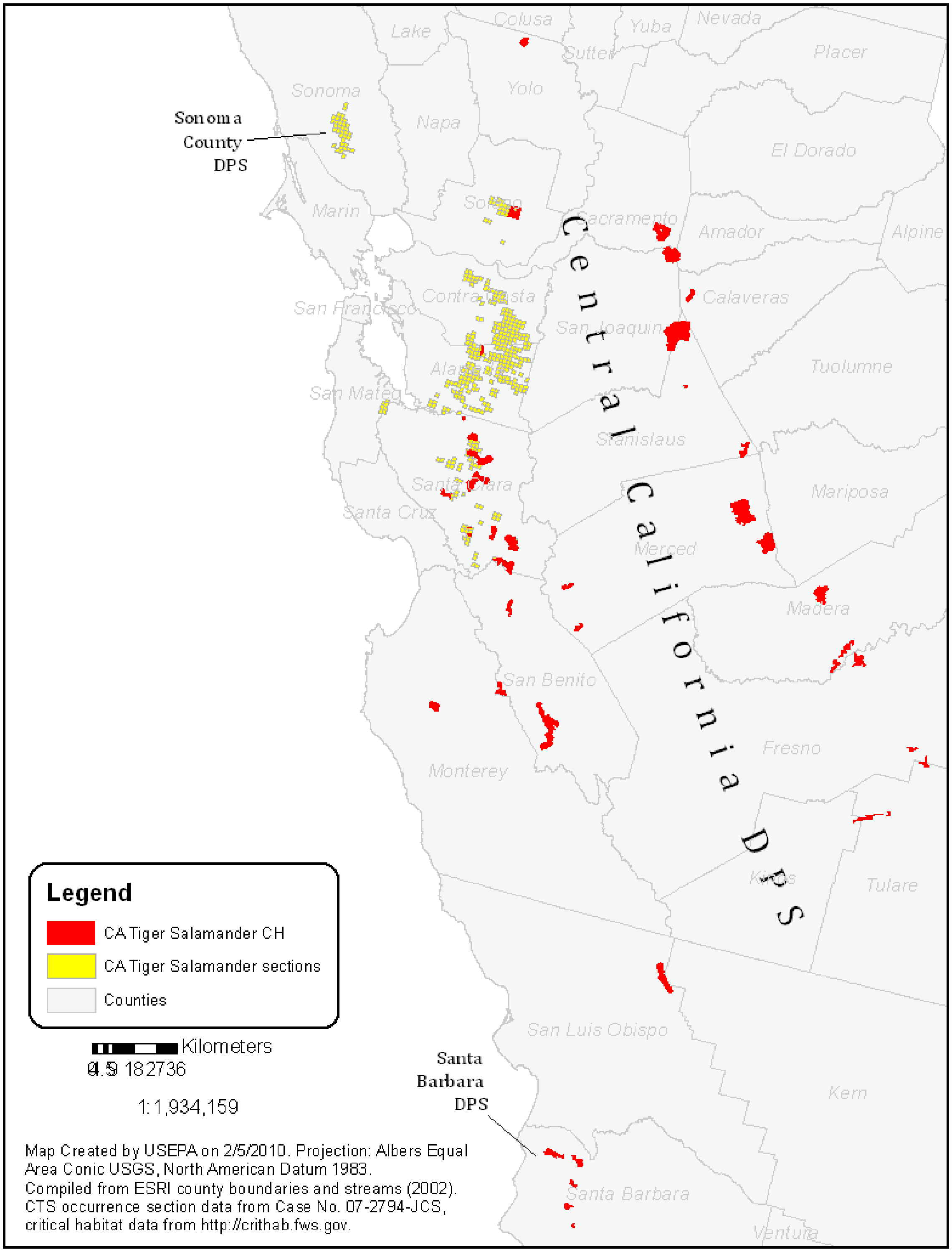


Figure 2-3. Critical Habitat and Occurrence Sections of the California Tiger Salamander (Central California DPS, Sonoma County DPS, and Santa Barbara DPS) identified in Case No. 07-2794-JCS. Habitat sections occurring in Sonoma County and Santa Barbara County comprise the Sonoma County DPS and Santa Barbara DPS, respectively. All other habitat and critical habitat segments shown are part of the Central California DPS.

2.6. Designated Critical Habitat

Critical habitat has been designated for the DS and CTS. Risk to critical habitat is evaluated separately from risk to effects on the species. 'Critical habitat' is defined in the ESA as the geographic area occupied by the species at the time of the listing where the physical and biological features necessary for the conservation of the species exist, and there is a need for special management to protect the listed species. It may also include areas outside the occupied area at the time of listing if such areas are 'essential to the conservation of the species. Critical habitat designations identify, to the extent known using the best scientific and commercial data available, habitat areas that provide essential life cycle needs of the species or areas that contain certain primary constituent elements (PCEs) (as defined in 50 CFR 414.12(b)). **Table 2-10** describes the PCEs for the critical habitats designated for the DS and CTS.

Table 2-10. Designated Critical Habitat PCEs for the DS and CTS[1]

Species	PCEs	Reference
California tiger salamander	Standing bodies of fresh water, including natural and man-made (*e.g.*, stock) ponds, vernal pools, and dune ponds, and other ephemeral or permanent water bodies that typically become inundated during winter rains and hold water for a sufficient length of time (*i.e.*, 12 weeks) necessary for the species to complete the aquatic (egg and larval) portion of its life cycle[2]	FR Vol. 69 No. 226 CTS, 68584, 2004
	Barrier-free uplands adjacent to breeding ponds that contain small mammal burrows. Small mammals are essential in creating the underground habitat that juvenile and adult California tiger salamanders depend upon for food, shelter, and protection from the elements and predation	
	Upland areas between breeding locations (PCE 1) and areas with small mammal burrows (PCE 2) that allow for dispersal among such sites	
Delta Smelt	Spawning Habitat—shallow, fresh or slightly brackish backwater sloughs and edgewaters to ensure egg hatching and larval viability. Spawning areas also must provide suitable water quality (*i.e.*, low "concentrations of pollutants) and substrates for egg attachment (*e.g.*, submerged tree roots and branches and emergent vegetation).	59 FR 65256 65279, 1994
	Larval and Juvenile Transport—Sacramento and San Joaquin Rivers and their tributary channels must be protected from physical disturbance and flow disruption. Adequate river flow is necessary to transport larvae from upstream spawning areas to rearing habitat in Suisun Bay. Suitable water quality must be provided so that maturation is not impaired by pollutant concentrations.	
	Rearing Habitat—Maintenance of the 2 ppt isohaline and suitable water quality (low concentrations of pollutants) within the Estuary is necessary to provide delta smelt larvae and juveniles a shallow protective, food-rich environment in which to mature to adulthood.	
	Adult Migration— Unrestricted access to suitable spawning habitat in a period that may extend from December to July. Adequate flow and suitable water quality may need to be maintained to attract migrating adults in the Sacramento and San Joaquin River channels and their associated tributaries. These areas also should be protected from physical disturbance and flow disruption during migratory periods.	

[1] These PCEs are in addition to more general requirements for habitat areas that provide essential life cycle needs of the species such as, space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing (or development) of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species.

[2] PCEs that are abiotic, including, physical-chemical water quality parameters such as salinity, pH, and hardness are not evaluated because these processes are not biologically mediated and, therefore, are not relevant to the endpoints included in this assessment.

More detail on the designated critical habitat applicable to this assessment can be found in Attachment 2. Activities that may destroy or adversely modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the species. Evaluation of actions related to use of malathion that may alter the PCEs of the designated critical habitat for the DS and CTS form the basis of the critical habitat impact analysis.

As previously noted in Section 2.1, the Agency believes that the analysis of direct and indirect effects to listed species provides the basis for an analysis of potential effects on the designated critical habitat. Because malathion is expected to directly impact living organisms within the action area, critical habitat analysis for malathion 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 and LAA Effects Determination Area

2.7.1. Action Area

The action area is used to identify areas that could be affected by the Federal action. The Federal action is the authorization or registration of pesticide use or uses as described on the label(s) of pesticide products containing a particular active ingredient. The action area is defined by the Endangered Species Act as, "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 CFR §402.2). Based on an analysis of the Federal action, the action area is defined by the actual and potential use of the pesticide and areas where that use could result in effects. Specific measures of ecological effect for the assessed species that define the action area include any direct and indirect toxic effect to the assessed species and any potential modification of its critical habitat, including reduction in survival, growth, and fecundity as well as the full suite of sublethal effects available in the effects literature.

It was recognized that the overall action area for the national registration of malathion was likely to encompass considerable portions of the United States based on the large array of agricultural and non-agricultural uses. However, the scope of this assessment limited consideration of the overall action area to those portions that may be applicable to the protection of the DS and CTS and their designated critical habitat within the state of California. For this assessment, the entire state of California was considered the action area. Because federal registrations of malathion include several residential uses for insect control, as well as forestry uses, the Agency believes that use of malathion could potentially occur in all areas of the state. The Agency therefore did not restrict the action area spatially based on co-occurrence with specific agricultural crops, as has been done for other pesticides. Defining the action area as the entire state ensures that the initial area of consideration encompasses all areas where the pesticide may be used now and in the future, including the potential for off-site transport via spray drift and downstream dilution that could influence the San Francisco Bay Species. Additionally, the concept of a state-wide action area takes into account the potential for direct and indirect effects and any potential modification to critical habitat based on ecological effect measures associated with reduction in survival, growth, and reproduction, as well as the full suite of sublethal effects available in the effects literature. The state-wide action area does not imply that direct and/or indirect effects and/or critical habitat modification are expected to or are likely to occur over the full extent of the action area, but rather to identify all areas that may potentially be affected by the action.

2.7.2. LAA Effects Determination Area

A stepwise approach was used to define the Likely to Adversely Affect (LAA) Effects Determination Area. An LAA effects determination applies to those areas where it is expected that the pesticide's use will directly or indirectly affect the species and/or modify its designated critical habitat using EFED's standard assessment procedures (see Attachment I) and effects endpoints related to survival, growth, and reproduction. This is the area where the "Potential Area of LAA Effects" (initial area of concern + drift distance or downstream dilution distance) overlaps with the range and/or designated critical habitat for the species being assessed. The first step in defining the LAA Effects Determination Area was to understand the federal action. The federal action was defined by the currently labeled uses for malathion. An analysis of labeled uses and review of available product labels was completed. Registrations like emergency exemptions which are restricted to states other than California were excluded from this assessment. In addition, a distinction was made between food use crops and those that are non-food/non-agricultural uses. For those uses relevant to the assessed species, the analysis indicated that, for malathion, there were a wide range of agricultural, residential, and forestry uses (summarized in Section 2.4.3. Following a determination of the assessed uses, an evaluation of the potential "footprint" of malathion use patterns (*i.e*., the area where pesticide application may occur) was determined. As discussed previously, the footprint for the use of malathion was considered to be the entire state of California.

Once the initial area of concern is defined, the next step typically is to define the potential boundaries of the Potential Area of LAA Effects by determining the extent of offsite transport via spray drift and runoff, and defining the additional areas beyond the footprint where exposure to the pesticide is predicted to exceed the listed species LOCs. The AgDRIFT model (Version 2.01 was used to define how far from the initial area of concern an effect to a given species may be expected via spray drift (*e.g*., the drift distance). The spray drift analysis for malathion uses the most sensitive endpoint of acute toxicity to terrestrial invertebrates. Further detail on the spray drift analysis is provided in Section 5.2.4.a.

In addition to the buffered area from the spray drift analysis, the Potential Area of LAA Effects area also typically considers the downstream extent of predicted pesticide concentrations that would exceed the LOC based on downstream dilution analysis. However, due to the widespread use of malathion across multiple land cover classes, this analysis was not performed.

2.8. Assessment Endpoints and Measures of Ecological Effect

2.8.1. Assessment Endpoints

A complete discussion of all the toxicity data available for this risk assessment, including resulting measures of ecological effect selected for each taxonomic group of concern, is included in Section 4 of this document. **Table 2-11** identifies the taxa used to assess the potential for direct and indirect effects from the uses of malathion for the two listed species assessed. The specific assessment endpoints used to assess the potential for direct and indirect effects to each listed species are provided in **Table 2-12**. For more information on the assessment endpoints, see Attachment 1.

Table 2-11. Taxa Used in the Analyses of Direct and Indirect Effects for the Assessed Listed Species

Listed Species	Birds	Mammals	Terr. Plants	Terr. Inverts.	FW Fish	FW Inverts.	Estuarine/ Marine Fish	Estuarine/ Marine Inverts.	Aquatic Plants
California tiger salamander (aquatic larval stages)	N/A	N/A	N/A	N/A	Direct[1]	Indirect (prey)	N/A	N/A	Indirect (food and habitat)
California tiger salamander (terrestrial adult stage)	Direct	Indirect (prey and habitat)	Indirect (habitat)	Indirect (prey)	Indirect (prey)	Indirect (prey)	N/A	N/A	N/A
Delta smelt	N/A	N/A	Indirect (habitat)	N/A	Direct[2]	Indirect (prey)	Direct[1]	Indirect (prey)	Indirect (food/ habitat)

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

[1] Toxicity data for frog tadpoles were also considered, but the assessment of direct effects was based on data for freshwater fish because they were more sensitive to malathion than the tadpoles.

[2] The most sensitive fish species was selected across freshwater and estuarine/marine test species because the delta smelt may be found in freshwater or brackish environments. In this case, the toxicity of a freshwater species (the rainbow trout) was used because it was the most sensitive.

Table 2-12. Taxa and Assessment Endpoints Used to Evaluate the Potential for Use of Malathion to Result in Direct and Indirect Effects to the Assessed Listed Species or Modification of Critical Habitat

Taxa Used	Assessed Listed Species	Assessment Endpoints	Measures of Ecological Effects
Freshwater Fish	Direct Effect – -Delta Smelt*	Survival, growth, and reproduction of individuals via direct effects	Freshwater fish 96-hr LC_{50} and chronic NOAEC
	Indirect Effect (prey) -California Tiger Salamander	Survival, growth, and reproduction of individuals via indirect effects on aquatic food supply (*i.e.*, fish and aquatic-phase amphibians)	
Aquatic-Phase Amphibians	Direct Effect – -California Tiger Salamander	Survival, growth, and reproduction of individuals via direct effects	Tadpole 48- or 96-hr LC_{50}
Freshwater Invertebrates	Indirect Effect (prey) - CA Tiger Salamander -Delta Smelt	Survival, growth, and reproduction of individuals via indirect effects on aquatic food supply	Freshwater crustacean 48- to 96-hr LC_{50} and chronic NOAEC
Estuarine/Marine Fish	Direct Effect – - Delta Smelt*	Survival, growth, and reproduction of individuals via direct effects	Estuarine/marine fish 96-hr LC_{50} and chronic NOAEC
Estuarine/Marine	Direct Effect	Survival, growth, and	Estuarine/marine crustacean or

Taxa Used	Assessed Listed Species	Assessment Endpoints	Measures of Ecological Effects
Invertebrates	-Delta Smelt (if more sensitive)	reproduction of individuals via indirect effects on aquatic food.	mollusk 48- to 96-hr LC_{50} and chronic NOAEC
Aquatic Plants (freshwater/marine)	Indirect Effect (food/habitat) -CA Tiger Salamander -Delta Smelt	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on habitat, cover, food supply, and/or primary productivity	Aquatic vascular plant (*Lemna*) IC_{50} (at least 14 days) and aquatic algal IC_{50} (at least 5 days)
Birds	Direct Effect -CA Tiger Salamander	Survival, growth, and reproduction of individuals via direct effects	Avian acute oral 14-D LD_{50}, subacute dietary LC_{50}, and avian reproduction chronic NOAEL
Mammals	Indirect Effect (prey/habitat from burrows/rearing sites) -CA Tiger Salamander	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on terrestrial prey and burrows/rearing sites	Laboratory rat acute LD_{50} chronic NOAEL
8. Terrestrial Invertebrates	Indirect Effect (prey) -CA Tiger Salamander	Survival, growth, and reproduction of individuals via indirect effects on terrestrial prey (terrestrial invertebrates)	Honey bee acute contact LD_{50}
9. Terrestrial Plants	Indirect Effect (food/habitat) (non-obligate relationship) -CA Tiger Salamander -Delta Smelt	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on food and habitat (*i.e.*, riparian and upland vegetation)	(No measurements are available on the toxicity of malathion to terrestrial plants.)

Abbreviations: SF=San Francisco
* The most sensitive fish species across freshwater and estuarine/marine environments is used to assess effects for these species because they may be found in freshwater or estuarine/marine environments.
** Birds are used as a surrogate for terrestrial-phase amphibians and reptiles.

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 malathion that may alter the PCEs of the assessed species' designated critical habitat. PCEs for the assessed species were previously described in Section 2.6. Actions that may modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the assessed species. Therefore, these actions are identified as assessment endpoints. It should be noted that evaluation of PCEs as assessment endpoints is limited to those of a biological nature (*i.e.*, the biological resource requirements for the listed species associated with the critical habitat) and those for which malathion effects data are available.

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

2.9. Conceptual Model

2.9.1. Risk Hypotheses

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

The labeled use of malathion within the action area may:

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

2.9.2. Diagram

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the malathion release mechanisms, biological receptor types, and effects endpoints of potential concern. The conceptual models for aquatic and terrestrial organisms are shown in Figure 2-4 and 2-5, respectively. The diagram for aquatic organisms is relevant to the DS and the aquatic phase of the CTS, whereas the diagram for terrestrial organisms is relevant to terrestrial stages of the CTS. Although the conceptual models for direct/indirect effects and modification of designated critical habitat PCEs are shown on the same diagrams, the potential for direct/indirect effects and modification of PCEs will be evaluated separately in this assessment.

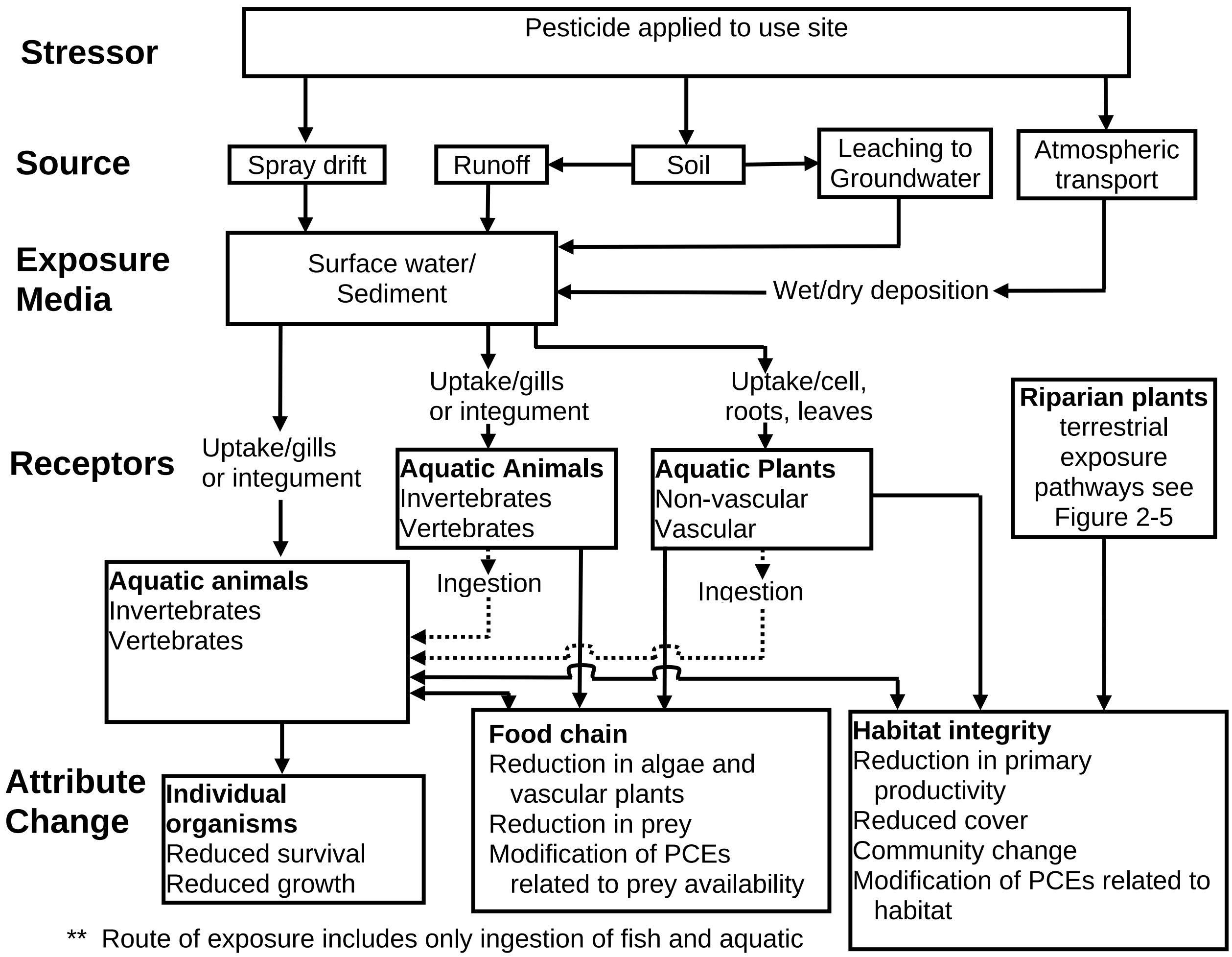


Figure 2-4. Conceptual model depicting stressors, exposure pathways, and potential effects to aquatic organisms from the use of malathion.
Dotted lines indicate exposure pathways that have a low likelihood of contributing to ecological risk.

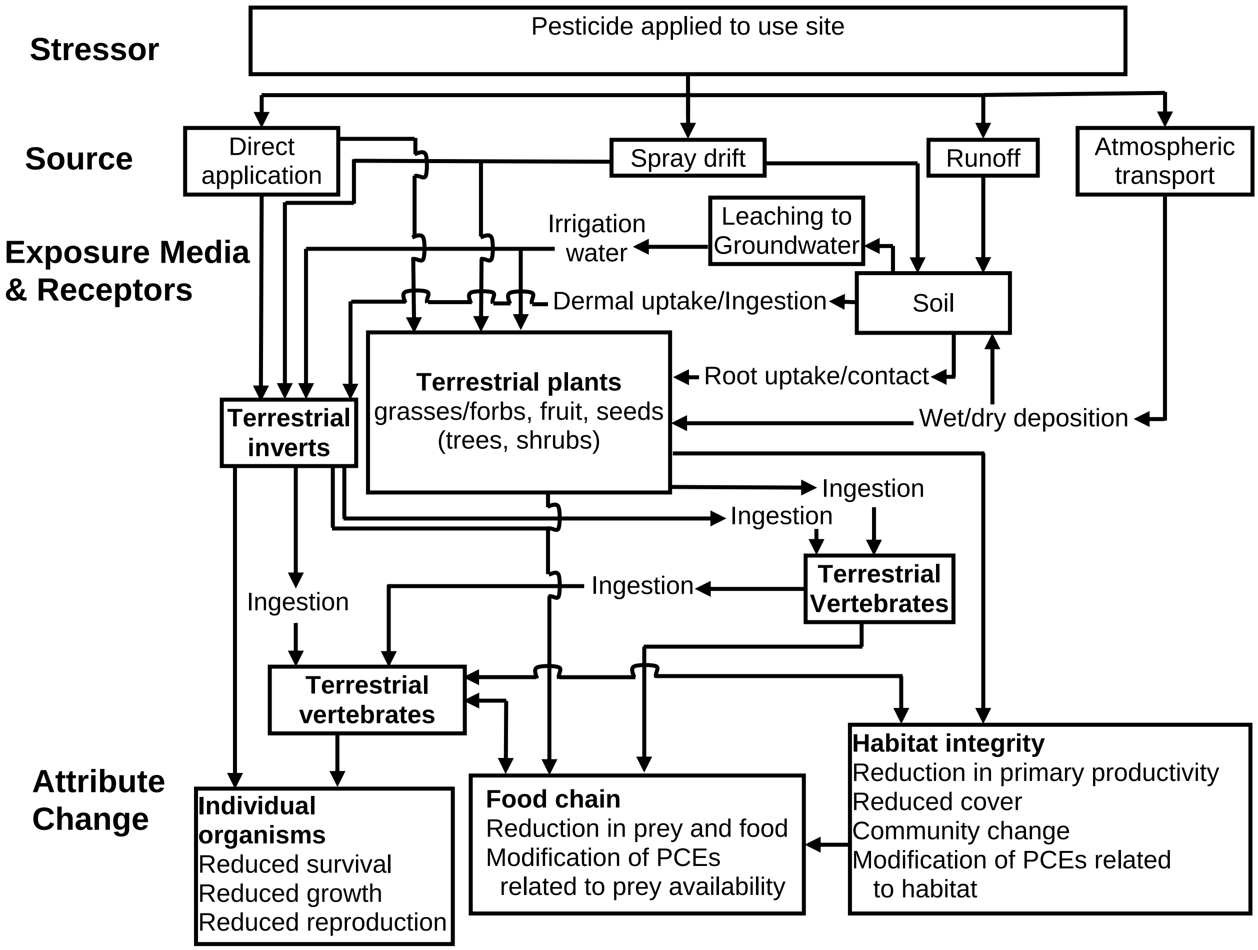


Figure 2-5. Conceptual model depicting stressors, exposure pathways, and potential effects to terrestrial organisms from the use of malathion.
Dotted lines indicate exposure pathways that have a low likelihood of contributing to ecological risk.

2.10. Analysis Plan

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

Descriptions of routine procedures for evaluating risk to the San Francisco Bay Species are provided in Attachment 1.

2.10.1. Measures of Exposure

The environmental fate properties of malathion along with available monitoring data indicated that runoff and spray drift are the principle transport mechanisms of malathion to the aquatic and terrestrial habitats. In this assessment, transport of malathion through runoff and spray drift were considered in deriving quantitative estimates of malathion exposure to the California tiger salamander and delta smelt, their prey, and habitats. Several studies have documented long range transport of pesticides from the Central Valley of California easterly into the Sierra Nevada Mountains (Fellers *et al.*, 2004; LeNoir *et al.*, 1999; McConnell *et al.*, 1998; Sparling *et al.*, 2001). These studies are discussed in Section 2.4.1. Long-range transport thus may be a significant mechanism of exposure for populations of the CTS-Central DPS which in mountainous areas east of the Central Valley. This exposure was not considered in the quantitative risk assessment, but was considered qualitatively in the characterization of risk for the CTS (see Section 5.2.2). Long range transport is not expected to be a significant route of exposure for the DS which is restricted to streams and rivers of the Central Valley and San Francisco Bay Estuary.

Measures of exposure were based on aquatic and terrestrial models that predict estimated environmental concentrations (EECs) of malathion using maximum labeled application rates and methods of application. The models used to predict aquatic EECs are the Pesticide Root Zone Model coupled with the Exposure Analysis Model System (PRZM/EXAMS) and EFED's tier 1 rice model (http://www.epa.gov/oppefed1/models/water/rice_tier_i.htm). Because spray drift buffers are required for agricultural applications of malathion, AgDrift was used to model the spray drift fraction contributed directly to the PRZM/EXAMS standard pond. The models used to predict terrestrial EECs on food items were Terrestrial Residue Exposure (T-REX) and Terrestrial Herpetofaunal Exposure Residue Program Simulation (T-HERPS). These models are parameterized using relevant reviewed registrant-submitted environmental fate data. More information on these models is available in Attachment 1.

2.10.2. Measures of Effect

Data identified in Section 2.8 are used as measures of effect for direct and indirect effects. Data were obtained from registrant submitted studies or from literature studies identified by ECOTOX. More information on the ECOTOXicology (ECOTOX) database and how toxicological data is used in assessments is available in Attachment 1.

2.10.2.a. Integration of Exposure and Effects

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

(USEPA, 2004) (see Appendix C). More information on standard assessment procedures is available in Attachment 1.

2.10.3. Data Gaps

The Agency has sufficient information for malathion and maloxon for the purposes of this assessment. However, lack of the following information and data results in uncertainties in this assessment: malathion aerobic aquatic metabolism under acidic conditions; maloxon production on dry, microbially-inactive surfaces; maloxon metabolism and leaching/adsorption/desorption; and maloxon effects on birds and aquatic animals.

3. Exposure Assessment

Most malathion products are formulated as a liquid, emulsifiable concentrate (EC), ultralow-volume (ULV) concentrate, or dust. A few products are formulated as a powder or wetable powder. Equipment used for application of malathion commonly includes low and high volume ground sprayers, airblast sprayers, sprayers mounted on fixed-winged aircraft and helicopters, chemigation equipment, mist blowers, ULV fog generators, and hand-held sprayers. Risks from ground, airblast, aerial and ultra-low volume (ULV) applications are considered in this assessment because they are expected to result in the highest off-target levels of malathion due to generally higher spray drift levels. ULV applications tend to use lower volumes applied in finer sprays than applications via ground boom, airblast, and non-ULV aerial applications and thus have a higher potential for off-target movement via spray drift.

3.1. Label Application Rates and Intervals

Malathion labels are currently being brought into compliance with the 2006 malathion RED. Appendix A of the 2006 RED specifies the maximum per application rates, minimum re-application intervals, and maximum number of applications that can be made to each use.

The RED stipulated usage characteristics are used rather than the current labels for two reasons. First as stated previously, all labels are currently being brought into compliance with the 2006 RED specifications. Second, the labels as they exist before being brought into compliance with the 2006 RED often did not specify the maximum number of applications or minimum re-treatment intervals.

Malathion is registered on many agricultural crops, including various grains, vegetables, fruits, and nuts, as well as cotton. It also has many nonagricultural uses, including residential uses and public health uses, such as mosquito control. Uses included in this assessment are listed in Section 2.4.3. Maximum label use rates and restrictions on the maximum number of application and minimum intervals between applications are provided for all uses in California in Appendix B.

3.2. Aquatic Exposure Assessment

3.2.1. Modeling Approach

The aquatic EECs (Estimated Environmental Concentrations) were calculated for all uses except rice, wild rice, water cress, and public health (adult mosquito control) using the EPA Tier II PRZM (Pesticide Root Zone Model) and EXAMS (Exposure Analysis Modeling System) with the EFED Standard Pond environment. PRZM was used to simulate pesticide transport as a result of runoff and erosion from an agricultural field, and EXAMS estimated environmental fate and transport of pesticides in surface water. The most recent PRZM/EXAMS linkage program (PE5, PE Version 5, dated Nov. 15, 2006) was used to pass data, parameter settings, and results between the two programs. Use-specific management practices for all of the assessed uses of malathion were used for modeling, including application rates, number of applications per year, application intervals, and the first application date for each use (**Table 2-7**).

PRZM/EXAMS EECs can vary greatly with application date(s). In California, EECs predicted in the standard pond will be almost exclusively due to spray drift if applications occur during the summer when little runoff occurs. Because malathion degrades and dissipates relatively quickly (terrestrial field dissipation half-lives can be less than 2 days), most of the applied malathion will gone by the time the rains become more substantial in the fall. In winter and other times of the year when rainfall is more common, EECs will be due to both spray drift and runoff.

In order to select the application dates that represent the maximum potential exposure from dates when malathion is likely to be applied, the multi-run function of the PE shell was used to calculate 90th percentile EECs for each potential application date (or set of application dates for uses that allow multiple applications). This distribution of EECs across application dates was compared to the distribution of dates when malathion was recorded in the PUR data to find the highest EECs that occur on a date when malathion is expected to be used in California.

Because the PUR data consists of the mass of active ingredient pesticide applied during each application, the PUR data is aggregated for each modeled use or modeled group of uses. For example, only aerial applications to date are summed for all malathion applications to date for each January first from the years 1990 to 2008 in the PUR data set as the first step in determining the distribution of malathion use on dates, while the aerial applications to alfalfa, clover, lespedeza, lupine, grain lupine, trefoil, and vetch use group is done similar to date with the exception that applications to any of the uses in this use group that occur on January first are summed across all years. These daily sums are divided by the number of years to estimate an average mass applied on that day of the year (data from February 29th can be omitted). A 15-day moving average (centered on the 8th day) is used to smooth interpolate the daily averages over the course of a year. It is this daily estimate for the 15-day moving average that is used to determine if malathion is used in California on that day (moving average > 0) or not (moving average = 0).

As an example, Figure 3-1 compares the variation of EECs across application dates for ground applications to pecan for the dates that malathion is applied as ground applications to pecan in California, according to the 1990-2008 PUR data set. The vast majority of ground malathion applications to pecans occurs in the dry summer months when EECs are relatively low because little runoff occurs. However, some applications do occur outside of the summer when EECs are higher because runoff is more frequent. Based on the method used in this document, the highest peak EEC that occurs when malathion is applied according to the PUR is 34.9 µg/L on January 7th, while the 21-day EEC of 12.1 µg/L and 60-day EEC of 4.6 µg/L both occur on January 5th (when only 1.5 lbs are applied per day). Similar graphs for all of the use groups modeled in this document are available in Appendix D Figure D1.

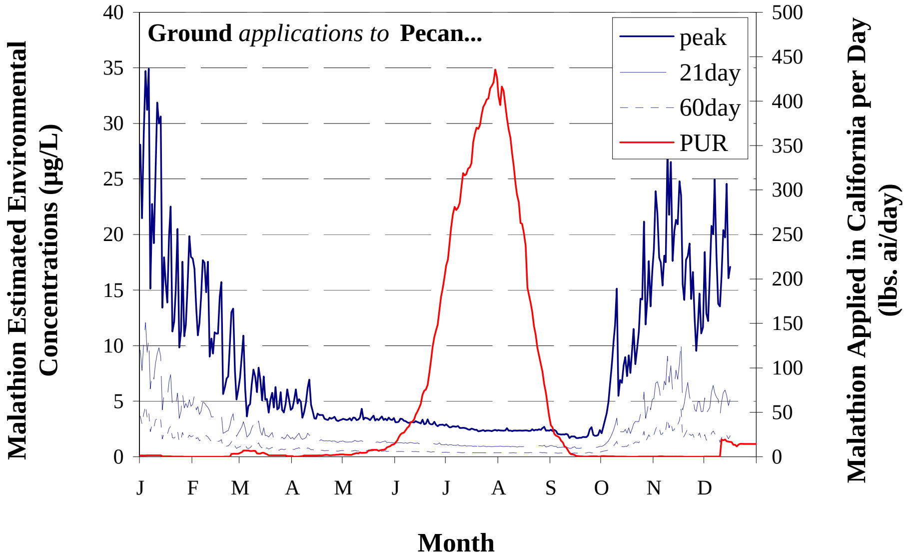


Figure 3-1. Variation in 90th percentile peak, 21-day average, and 60-day EECs across first application dates for ground application to pecan compared to a 15-day moving average of pounds of malathion applied per day. (Based on CDPR PUR data from years 1990 through 2008.)

Using the highest EECs from the time of the year when malathion is applied is a reasonable way to characterize the maximum potential aquatic exposure to malathion. However, there is the potential for the highest EEC to be atypical relative to the other times when malathion is applied to a use site. The question of how typical is it for malathion to be applied for each use at times when it is expected that EECs will exceed the levels of concern (LOCs) is addressed in the Section 6.1.1 of the document by calculating the percentage of the pounds of malathion applied in California on application dates that are expected to result in EECs exceeding the agencies LOCs versus the total pounds of malathion applied in California on all dates.

In two cases (macadamia nut and hops), no PUR data were available. Therefore, EECs used in the analysis were set to the highest EEC from anytime during the year (not just when malathion was applied). Similarly the percentage of malathion applications that exceeded the LOCs was based on the number of days when application of malathion would be expected to result in EECs that exceed the agencies LOCs versus the total number of days in a year (**Table 6-1**).

Mushrooms

Malathion is used to control various fly species that are attracted to mushrooms and the compost material in which mushrooms are grown (called "casing"). Typically, mushrooms are grown indoors in facilities where carbon dioxide and moisture levels can be controlled. Because the malathion is applied to the casing material inside of a structure, malathion applications to mushroom casing do not result in a direct exposure to environmental receptors. However, the mushroom casing material must be periodically replaced as it degrades over time and becomes less productive. The left-over casing material is typically applied to agricultural fields to increase soil fertility and water holding capacity of soils with limited water holding capacity (*e.g.*, sandy soils).

EFED does not have a standard scenario for assessing mushroom use. Because of the similarity in maximum single application rate to cherries (1.7 lbs/A for mushrooms and 1.75 lbs/A for cherries), number of uses (both 4) and retreatment intervals (both 3 days), ground applications to cherries could be used as a surrogate scenario for providing an upper bound of exposure for mushrooms. Ground applications to cherries assume a one percent spray drift exposure which may not be applicable to land application of mushroom casings. Also all of the applications of malathion to mushroom casings would have occurred some time before the casing material was land applied. Because mushroom casing material is wet, pH adjusted to near neutral, and likely has large populations of bacteria, it is likely that much of the malathion would be degraded due to hydrolysis and metabolism before it was land applied. Finally, mushroom casings are approximately 6 inches deep and, therefore, would likely be spread over a larger area assuming that the casing material would be spread to a depth considerably less than 6 inches. Therefore, assuming the malathion concentration is homogeneous throughout the casing material being spread, would result in a lower application rate than for cherries (*e.g.*, if it is spread on the land to a 2 inch depth, the malathion application rate would be 2 inches/6 inches or 1/3 of the application rate to the original casing material).

Additionally, it should be noted that Table 2-8 indicates that only 0.36 pounds of malathion are applied to mushrooms per year in California. Dividing by the average application of 2.08 lbs. ai/A (also in Table 2-8) indicates that approximately 0.17 acres of mushrooms are treated per year with malathion according to the CDPR PUR data.

Cull Piles and Agricultural Structures and Equipment

Three uses of malathion (Cull Piles, Grain/cereal/flour bins (empty), and Grain/cereal/flour elevators (empty)) are grouped together for assessment. Of the three uses, cull piles has the highest application rate by far. For cull piles, malathion is applied as a drench at a maximum single application rate of 298.7 lbs/A (6.857 lb/1000 ft^2). A scenario for cull piles was created that is expected to serve as surrogate scenario and provide conservative estimates of exposure for the other uses in this group of malathion uses. This scenario assumes the cull piles occur within the standard PRZM watershed, which drains to the standard EXAMS pond.

Because cull piles as well as the other uses in this group are likely to cover only a small portion of the watershed area, a method was devised which takes advantage of the linear relationship between application rate and EEC as well as an assumed linear relationship between the amount of watershed treated and EEC. Therefore for cull piles, a reference scenario based on a single application of 1 lbs/A over the entire 10 acre standard PRZM watershed was used to generate preliminary EECs (1 in 10 year peak EEC = 3.04 µg/L, 21-day average EEC = 0.72 µg/L, and 60-day average EEC = 0.26 µg/L) that then was adjusted to the actual application rate and an assumption of the area the cull pile occupies in the watershed. (The reason for creating the reference scenario was the concern that the EECs might be constrained by the solubility limit of malathion (145 mg/L) if the application rate was applied over the entire watershed.) The equations used to extrapolate the cull pile scenario EECs from the reference scenario appear below and are presented graphically in **Figure 3-2**.

$$EEC_{Peak} = \frac{\frac{3.04\ \mu\text{g/L}}{1\text{lb/A}} \times 298\text{lb/A} \times Area_{Cull\ Piles}\text{ft}^2}{43{,}560\text{ft}^2/\text{A} \times 10\text{A}} = 0.00208\,\frac{\mu\text{g/L}}{\text{ft}^2} \times Area_{Cull\ Piles}\text{ft}^2$$

$$EEC_{21-day} = \frac{\frac{0.72\ \mu\text{g/L}}{1\text{lb/A}} \times 298\text{lb/A} \times Area_{Cull\ Piles}\text{ft}^2}{43{,}560\text{ft}^2/\text{A} \times 10\text{A}} = 0.00049\,\frac{\mu\text{g/L}}{\text{ft}^2} \times Area_{Cull\ Piles}\text{ft}^2$$

$$EEC_{60-day} = \frac{\frac{0.26\ \mu\text{g/L}}{1\text{lb/A}} \times 298\text{lb/A} \times Area_{Cull\ Piles}\text{ft}^2}{43{,}560\text{ft}^2/\text{A} \times 10\text{A}} = 0.00018\,\frac{\mu\text{g/L}}{\text{ft}^2} \times Area_{Cull\ Piles}\text{ft}^2$$

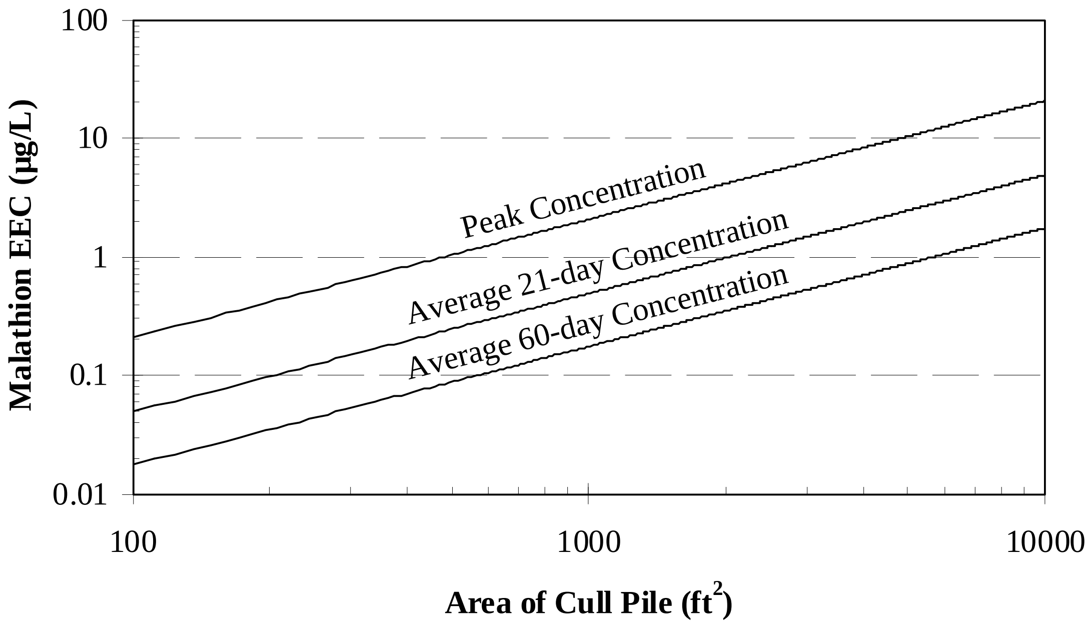


Figure 3-2. Variation in estimated environmental concentration (EEC) of malathion and area of cull piles in the standard PRZM watershed.

For the purpose of estimating risk quotients later in this report, it was assumed that there was one cull pile in each of the 10 acres of the PRZM watershed and each cull piles occupied 100 ft^2 (10 ft × 10 ft) or 1000 ft^2 over the entire watershed. Solving for 1000 ft^2 results in 1 in 10 year EECs of 2.08 µg/L (peak), 0.49 µg/L (average 21-day), and 0.18 µg/L (average 60-day).

Fence rows/hedge rows

For fence/hedge rows, malathion is applied as a ground application at a maximum single application rate of 10.62 lbs/A (0.24 Lb/1000 ft^2). Because fence/hedge rows would not cover the entire watershed area, a method was devised to take advantage of the linear relationship between application rate and EEC as well as an assumed linear relationship between the amount of watershed treated and EEC. Similar to cull piles, a reference scenario based on a single application of 1 lbs/A over the entire 10 acre standard PRZM watershed was used to generate preliminary EECs (1 in 10 year peak EEC = 32.3 µg/L, 21-day average EEC = 8.3 µg/L, and 60-day average EEC = 2.96 µg/L) that then was adjusted to the actual application rate and an assumption of the area the fence/hedge row occupies in the watershed. The equations used to extrapolate the fence/hedgerow scenario EECs from the reference scenario appear below and are presented graphically in **Figure 3-3**.

$$EEC_{Peak} = \frac{\frac{32.35\ \mu g/L}{1 lb/A} \times 10.62 lb/A \times Area_{FenceRow} ft^2}{43{,}560 ft^2/A \times 10A} = 0.00079 \frac{\mu g/L}{ft^2} \times Area_{FenceRow} ft^2$$

$$EEC_{21-day} = \frac{\frac{8.30\ \mu g/L}{1 lb/A} \times 10.62 lb/A \times Area_{FenceRow} ft^2}{43{,}560 ft^2/A \times 10A} = 0.000202 \frac{\mu g/L}{ft^2} \times Area_{FenceRow} ft^2$$

$$EEC_{60-day} = \frac{\frac{2.96\ \mu g/L}{1 lb/A} \times 10.62 lb/A \times Area_{FenceRow} ft^2}{43{,}560 ft^2/A \times 10A} = 0.0000722 \frac{\mu g/L}{ft^2} \times Area_{FenceRow} ft^2$$

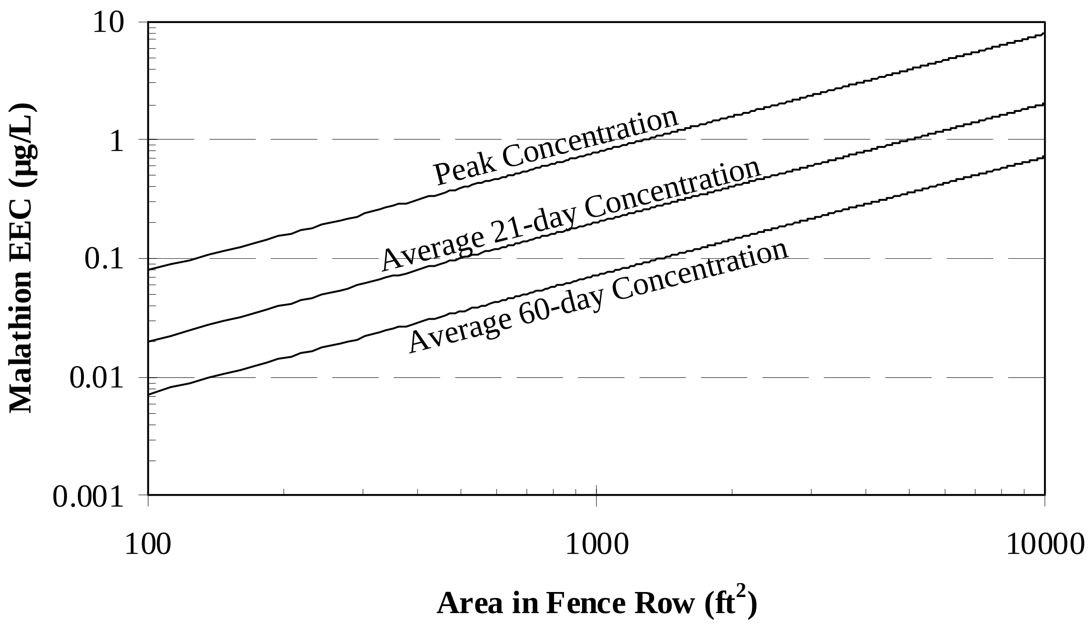


Figure 3-3. Variation in estimated environmental concentration (EEC) of malathion and area of fence row in the standard PRZM watershed.

For the purpose of estimating risk quotients later in this report, it was assumed that a fence row or hedge row is 10 ft wide and there is 100 ft of fence row or hedge in the 10-acre PRZM watershed. Therefore, 1000 ft^2 of the entire watershed was assumed to be covered by fence or hedge row. Solving for 1000 ft^2 results in 1 in 10 year EECs of 0.79 µg/L (peak), 0.20 µg/L (average 21-day), and 0.072 µg/L (average 60-day).

Rights-of-way

Three uses of malathion (Agricultural, uncultivated areas, Nonagricultural Rights-of-way/Fencerows, and Nonagricultural Uncultivated Areas/Soils) are grouped together for assessment under the category of “rights-of-way”. For additional information on this scenario, see Attachment IV (Supplemental Information on the California Right-of-Way Scenario) and the scenario description in **Table 2-7**.

Aquatic Agricultural Uses

For the aquatic agriculture uses of rice, wild rice, and water cress, aquatic EECs were estimated using the tier 1 rice model, which assumes direct application to water. This model assumes no degradation of malathion. The only pesticide removal process is partitioning to the sediment. This screening model is a single equation as presented below:

$$C_w = \frac{m_{ai}'}{0.00105 + 0.00013 K_d}$$

and, if appropriate:

$$K_d = 0.01K_{oc}$$

where:

C_w = water concentration [µg/L]
m_{ai}' = mass applied per unit area [kg/ha]
K_d = water-sediment partitioning coefficient [L/kg]
K_{oc} = organic carbon partitioning coefficient [L/kg]

Adult Mosquito Control Use

Aquatic EECs for public health use were estimated by using the AGDISP model to estimate the maximum deposition rate from aerial ULV applications. The predicted maximum deposition rate was assumed to occur on the EFED Standard Pond, and the residues were assumed to be distributed evenly throughout the volume of the pond. Aquatic exposure was modeled for residues of the parent compound, malathion, only. Residues of the toxic degradation product, maloxon, were not considered because the amount of formation of maloxon and many of the environmental fate characteristics of maloxon are unknown at this time.

Malathion is used to control adult mosquitoes in residential and recreational areas such as, but not limited to parks, campsites, woodlands, athletic fields, golf courses, garden playgrounds, recreational areas, *etc*. Some of these use sites could involve exposure to various types of water bodies. Mosquito adulticides are more efficacious if they come into contact with insects in flight. For that reason, mosquito abatement using malathion (as well as other mosquito adulticides) is typically applied via aerial or ground spray methods with very fine droplets or mists, to prevent immediate deposition of the pesticide. This type of application is called an ultra low volume application. The AGricultural DISPersal model (AGDISP v. 8.13) is used to calculate of spray drift and deposition from ULV applications. This model estimates the deposition of the pesticide from a treated area to water bodies using a sub-routine “Deposition Assessment” in the toolbox of AGDISP.

For aerial ULV spraying of malathion to control adult mosquitoes, most of the labels available for malathion have very few specifications on various parameters that may affect the exposure to adjacent bodies of water. The sample label selected for modeling was malathion ULV (EPA Reg. No. 19713-288). It contains 96.5% malathion and 3.5% other ingredients. The maximum application rate is 0.232 lb a.i./A. Only aerial mosquito adulticide use was modeled because the exposure value would be higher due to undiluted use of malathion as compared to diluted malathion used in ground application. According to the label, the spray equipment must be adjusted to produce $D_{V0.5}$ of 50 to 60 µm (half of the volume is contained in droplets smaller than 50 to 60 µm). The altitude or boom height is not specified in the label. Therefore, two heights (75 ft and 100 ft) above the ground were selected for modeling based on common practice of adulticide application. Since there is no specification for wind speed in the label, 10 and 15 mph were simulated for this assessment.

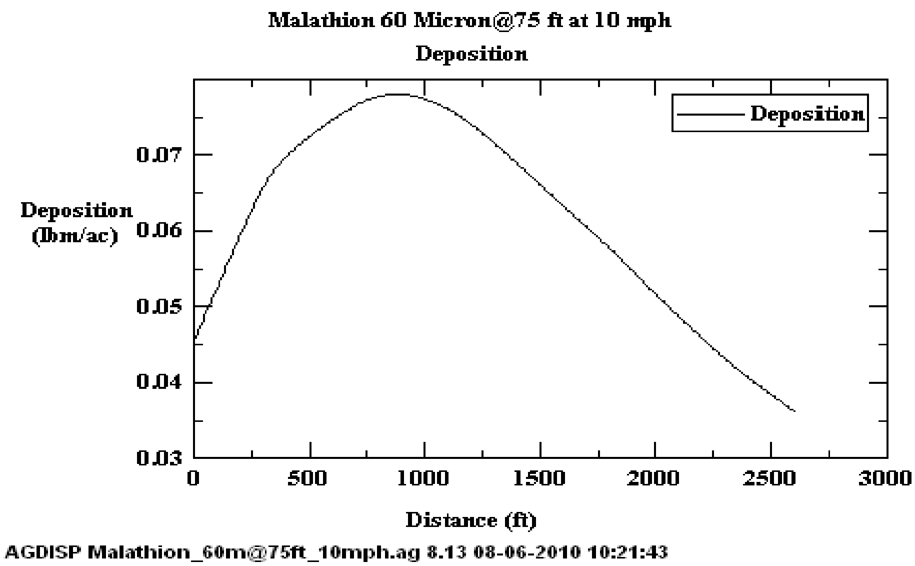


Figure 3-4. Deposition curve for a malathion application at a release height of 75 ft and a $D_{V0.5}$ of 60 µm and wind speed of 10 mph

The spray material is undiluted malathion with specific gravity of 1.23 kg/L and no evaporation rate was also assumed. The spray volume was 0.0234 gal/A (obtained from the label (3.0 oz/A). Generally, the remaining input parameters in AGDISP were kept at their default value (unless otherwise specified). The model assumes that the field of application is on a flat, treeless landscape, and, therefore, in most cases it will provide a conservative estimate. Also, the volume and droplet size used for the simulation are beyond the AGDISP's recommended values. Uncertainty associated with each of these individual components adds to the overall uncertainty of the modeled outputs. Labels do not specify a maximum number of applications per year. One application was simulated to provide acute exposure of malathion. This value was also used to calculate upper bound chronic risk. PRZM/EXAMS simulated exposures suggest that the chronic EEC values are always lower than the acute exposure EECs (Table 5.1). Therefore, chronic exposure values from adulticide applications are presumed to be lower than the estimated acute values, the acute exposure value is expected to be protective for assessing chronic risk. Various input parameters for AGDISP simulation are listed in Table 3-2. A sample deposition curve is depicted in Figure 3-2. In order to obtain maximum deposition of malathion in a water body (*i.e*. EPA pond) and terrestrial environment (point estimate), deposition assessment tool of AGDISP was used. Table 3-3 shows estimated acute concentrations in pond and the deposition rate in the terrestrial environment.

Table 3-2. Input Parameters Used in AGDISP Modeling for Adult Mosquito Control Use of Malathion

Parameter	**Value**
Aircraft type	Air tractor AT-401, fixed wing
Swath width	60 ft
Wing semispan	24.5 ft
Swath displacement	0 ft
Propeller rpm	2000, propeller rad. 4.5 ft
Fixed wing	1 engine

Parameter	Value
Flight lines	20
Flight speed	120 mph
Boom height	75 ft and 100 ft
Number of nozzles	42
Vortex decay rate	1.25 mph
Aircraft drag coefficient	0.1
Propeller efficiency	0.8
Ambient pressure	29.91 in Hg
Planform area	294 ft^2
Nozzle spacing (even)	0.78 ft
Wind speed	10 and 15 mph
Wind direction	90°, perpendicular to flight path
Surface roughness	0.0075 ft
Canopy roughness	0.07 ft (grass)
Stability	Overcast
Relative humidity	50%
Temperature	65°F
Droplet type	User defined
$D_{v0.1}$	24.5µm ($D_{v0.5}$ = 50 µm) and 33.6µm ($D_{v0.5}$ = 60 µm)
$D_{v0.5}$	50.1 µm ($D_{v0.5}$ = 50 µm) and 60.1µm ($D_{v0.5}$ = 60 µm)
$D_{v0.9}$	84.6 µm ($D_{v0.5}$ = 50 µm) and 94.5µm ($D_{v0.5}$ = 60 µm)
Relative span	1.2 ($D_{v0.5}$ = 50 µm) and 1.01 ($D_{v0.5}$ = 60 µm)
<141 µm	99.8 % ($D_{v0.5}$ = 50 µm) and 99.6 ($D_{v0.5}$ = 60 µm)
Spray material	Oil
Specific gravity	1.23
Active fraction	0.96
Nonvolatile fraction	1.00
Spray volume	0.0234 gal/A
Evaporation rate	Not applicable
Buffer zone	Not applicable
Aquatic Exposure Downwind water body width Average depth	 208.7 m 6.6 ft ~ 2 m
Terrestrial exposure	Point Estimate

Table 3-3. Deposition of Malathion in Water Body and Terrestrial Environment from Various Aerial Application Scenarios

Wind speed (mph)	Release Height (ft)	Maximum Deposition			
		Aquatic (pond) Conc. (µg/L)		Terrestrial (point) (lbs/A)	
		Dv0.5 = 50	Dv0.5 = 60	Dv0.5 = 50	Dv0.5 = 60
10	75	0.79	**1.06**[1]	0.058	**0.079**[1]
	100	0.52	0.65	0.038	0.055
15	75	0.44	0.63	0.032	0.046
	100	0.23	0.36	0.017	0.026
[1] = Bolded values were used in the risk assessment					

Residential and Refuse/Solid Waste

Three uses of malathion (Household/Domestic Dwellings (perimeter around dwelling), Refuse/Solid Waste Containers (Garbage Cans), and Refuse/Solid Waste Sites (Outdoor)) are grouped together for assessment. For all of these residential and refuse/solid waste uses, malathion is applied as a drench at a maximum single application rate of 10.62 lbs/A (0.24 Lb/1000 ft^2). A scenario for residential and refuse/solid waste uses was created that assumes the refuse/solid waste sites and containers (trash cans) occur within the standard PRZM watershed, which drains to the standard EXAMS pond.

Because trash cans as well as the other uses in this group are not likely to cover the entire watershed, a method was devised which takes advantage of the linear relationship between application rate and EEC as well as an assumed linear relationship between the amount of watershed treated and EEC. Similar to cull piles and fence/hedge rows, a reference scenario based on a single application of 1 lbs/A over the entire 10 acre standard PRZM watershed was used to generate preliminary EECs (1 in 10 year peak EEC = 140.6 µg/L, 21-day average EEC = 28.7 µg/L, and 60-day average EEC = 10.3 µg/L) that then was adjusted to the actual application rate and an assumption of the area the trash bins occupy in the watershed. The equations used to extrapolate the trash bin scenario EECs from the reference scenario appear below and are presented graphically in **Figure 3-5**.

$$EEC_{Peak} = \frac{\frac{140.6\ \mu\text{g/L}}{1\text{lb/A}} \times 10.62\text{lb/A} \times Area_{TrashBins}\text{ft}^2}{43{,}560\text{ft}^2/\text{A} \times 10\text{A}} = 0.00343\frac{\mu\text{g/l}}{\text{ft}^2} \times Area_{TrashBins}\text{ft}^2$$

$$EEC_{21-day} = \frac{\frac{28.7\ \mu\text{g/L}}{1\text{lb/A}} \times 10.62\text{lb/A} \times Area_{TrashBins}\text{ft}^2}{43{,}560\text{ft}^2/\text{A} \times 10\text{A}} = 0.000701\frac{\mu\text{g/l}}{\text{ft}^2} \times Area_{TrashBins}\text{ft}^2$$

$$EEC_{60-day} = \frac{\frac{10.3\ \mu\text{g/L}}{1\text{lb/A}} \times 10.62\text{lb/A} \times Area_{TrashBins}\text{ft}^2}{43{,}560\text{ft}^2/\text{A} \times 10\text{A}} = 0.00025\frac{\mu\text{g/l}}{\text{ft}^2} \times Area_{TrashBins}\text{ft}^2$$

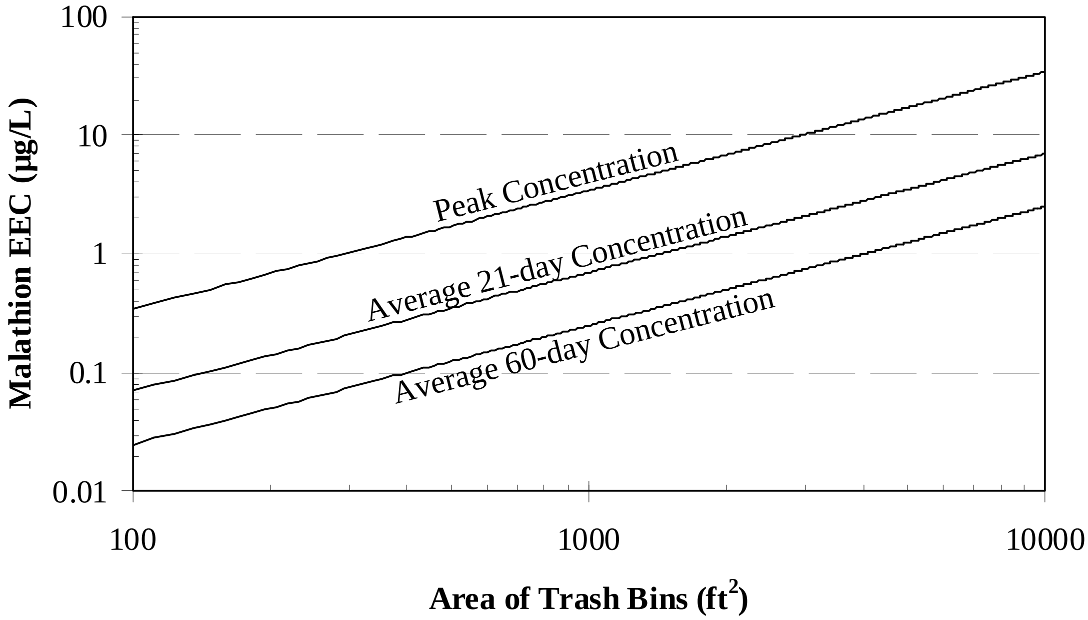


Figure 3-5. Variation in estimated environmental concentration (EEC) of malathion and area of trash bins in the standard PRZM watershed.

For the purpose of estimating risk quotients later in this report, it was assumed that there was one trash bin site that was treated with malathion in each of the 10 acres of the PRZM watershed and each trash bin site occupied 100 ft^2 (10 ft × 10 ft) or 1000 ft^2 over the entire watershed. Solving for 1000 ft^2 results in 1 in 10 year EECs of 3.43 µg/L (peak), 0.70 µg/L (average 21-day), and 0.25 µg/L (average 60-day).

3.2.2. Aquatic Exposure Modeling Results

The aquatic EECs for the various scenarios and application practices of malathion in California are listed in Table 3-4. The example output from PRZM-EXAMS is provided in Appendix D. In these scenarios, EECs varied were dependant on application method, application rate, number of application applied per year, the interval between applications, and the soil characteristics. Also, EECs were very dependant on the date of first application. Malathion degrades rapidly in soil. Therefore, aquatic exposure from runoff is much greater when a large rainfall event is predicted to occur soon after application. In California, rainfall occurs mainly during the winter months, whereas the summer months are very dry. Since the PRZM model uses historical meteorological data from the region to predict runoff, applications made during the winter months have much more runoff, and thus greater aquatic exposure, than applications made

during the summer. The EECs shown in Table 3-4 are the maximum of the set of EECs produced for all possible dates of the first day of application, with the restriction that the first day of application must fall within the period which malathion is typically used on the given crop. Thus, if all other factors were equal, crops for which malathion is typically applied during winter months have greater EECs than those for which malathion is only applied during the summer.

Appendix D presents graphs showing the relationship between malathion use, seasons, and rainfall for various uses.

Table 3-4. Aquatic EECs (µg/L) for Malathion Uses in California

Scenario	Appl. Method[1]	Maximum Application Rate (lbs/A)	Max. No. Apps. per Crop Cycle	Min. Retreatment Interval (days)	EECs (µg/L)		
					Peak EEC	21-day EEC	60-day EEC
1. Alfalfa, Clover, Lespedeza, Lupine, Grain Lupine, Trefoil, and Vetch	A	1.56	5	14	22.5	7.77	4.87
	ULV	0.61	2	14	8.17	2.85	1.11
	G	1.56	5	14	15.5	4.64	2.13
2. Macadamia Nut (Bushnut)	G	0.94	6	7	16.0	5.42	2.38
	AB	0.94	6	7	15.6	5.26	2.28
3. Pecan and Walnut (English/Black)	G	2.5	3	7	34.9	12.1	4.61
	AB	2.5	3	7	33.0	11.2	4.21
6. Date	A	4.25	5	7	62.2	25.1	13.3
	G	4.25	5	7	52.3	19.2	9.22
8. Avocado	G	4.7	2	30	59.3	12.6	4.77
9. Citrus Hybrids Other Than Tangelo, Grapefruit, Kumquat, Lemon, Lime, Orange, Tangelo, and Tangerines	A	7.5	3	30	50.1	13.1	8.35
	ULV	0.175	3	7	2.66	1.31	0.533
	G	7.5	3	30	23.1	5.44	2.37
	AB	7.5	3	30	22.1	5.11	2.15
10. Broccoli, Broccoli Raab, Cabbage, Chinese Amaranth, Chinese Broccoli, Chinese Cabbage, Canola\Rape, Cauliflower, Cole Crops, Collards, Corn Salad, Dock (Sorrel), Horseradish, Kale, Kohlrabi, Leafy Vegetables, Mustard, Mustard Cabbage (Gai Choy/ Pak-Choi), and Garden and Winter Purslane	A	1.25	6	7	37.6	14.9	7.62
	G	1.25	6	7	32.6	11.0	4.73
11. Corn (Silage and Unspecified), Field, Pop, and Sweet Corn, Millet (Foxtail), and Sunflower	A	1	2	5	33.7	10.4	3.78
	ULV	0.61	2	5	23.3	7.87	2.85
	G	1	2	5	22.3	6.46	2.37
12. Cotton (Unspecified)	A	2.5	3	7	37.3	14.5	5.76
	ULV	1.22	3	7	26.0	11.3	4.50
	G	2.5	3	7	23.8	7.26	2.68
13. Hops	A	0.63	3	7	14.6	5.46	2.20
	G	0.63	3	7	11.4	3.73	1.41
	AB	0.63	3	7	11.1	3.57	1.32
15. Apricot	G	1.5	2	7	10.7	3.2	1.17
	AB	1.5	2	7	10.1	2.9	1.04
16. Nectarine and Peach	G	3	3	7	25.3	7.71	2.92
	AB	3	3	7	24.0	6.69	2.56

Scenario	Appl. Method[1]	Maximum Application Rate (lbs/A)	Max. No. Apps. per Crop Cycle	Min. Retreatment Interval (days)	EECs (µg/L)		
					Peak EEC	21-day EEC	60-day EEC
17. Cherry	A	1.75	4	3	16.7	7.01	2.51
	ULV	1.22	6	7	15.4	7.35	4.74
	G	1.75	4	3	19.8	6.27	2.38
	AB	1.75	4	3	18.5	5.69	2.07
18. Fig	G	2	2	5	17.0	4.83	1.79
	AB	2	2	5	16.0	4.50	1.62
19. Pear	G	1.25	2	7	10.1	2.85	1.07
	AB	1.25	2	7	9.5	2.67	0.964
20. Guava, Mango, and Papaya	G	1.25	13	3	22.2	6.75	3.11
	AB	1.25	13	3	21.5	6.34	2.85
22. Garlic and Leek	A	1.56	3	7	34.2	10.8	4.08
	G	2	3	7	41.8	9.63	3.73
23. Grapes	G	1.88	2	14	12.8	3.68	1.39
	AB	1.88	2	14	11.8	3.31	1.24
26. Brussels Sprouts and Dandelion	A	1.25	2	7	52.0	15.4	5.73
	G	1.25	2	7	46.9	13.4	4.96
27. Chervil, Chrysanthemum - Garland, Endive (Escarole), Lettuce, Head and Leaf Lettuce, Orach (Mountain Spinach), Parsley, Roquette (Arrugula), Salsify, Spinach, and Swiss Chard	A	1.88	2	5	83.1	24.2	8.84
	G	1.88	2	5	74.4	21.2	7.68
29. Eggplant	A	1.56	5	5	25.6	11.6	4.95
	G	1.56	5	5	42.2	12.0	4.46
30. Pumpkin	A	1	2	7	8.30	2.42	0.869
	G	1	2	7	5.65	1.19	0.437
31. Cantaloupe, Honeydew, Musk, Water, and Winter Melons (Casaba/Crenshaw/Honeydew/Persian), Chayote, Cucumber, Melons, and Squash (All or Unspecified, Summer, and Winter (Hubbard))	A	1.75	3	7	49.7	17.7	6.74
	G	1.75	3	7	42.9	12.9	4.71
32. Onion, Onions (Green), Radish, and Shallot	A	1.56	2	7	15.9	5.23	1.94
	G	1.56	2	7	8.4	1.90	0.699
33. White/Irish Potato	A	1.56	2	7	12.7	4.35	1.60
	G	1.56	2	7	20.3	4.65	1.70
34. Turnip (Greens and Root)	A	1.25	3	7	23.2	7.30	2.81
	G	1.25	3	7	16.3	3.87	1.41
37. Bermudagrass, Bluegrass, Canarygrass, Grass	A	1.25	1	NA	16.6	4.57	1.64

Scenario	Appl. Method[1]	Maximum Application Rate (lbs/A)	Max. No. Apps. per Crop Cycle	Min. Retreatment Interval (days)	EECs (µg/L)		
					Peak EEC	21-day EEC	60-day EEC
Forage/Fodder/Hay, Pastures, Peas (Including Vines), Rangeland, Sudangrass, and Timothy	ULV	0.92	1	NA	17.1	4.60	1.65
	G	1.25	1	NA	19.2	5.94	2.14
40. Beets, Beets (Unspecified), Cowpea/Blackeyed Pea, Cowpeas, Field Peas, and Peas (Unspecified)	A	2.5	2	7	18.3	5.25	1.91
	G	2.5	3	7	20.1	4.64	1.72
41. Carrot (Including Tops), Celtuce, Fennel, Peanuts, Peanuts (Unspecified), and Pepper	A	2	2	5	32.4	8.61	3.12
	G	2	2	5	25.1	5.27	1.93
42. Beans and Dried-Type and Succulent (Lima and Snap) Beans	ULV	0.61	2	7	12.0	4.32	1.61
43. Celery	A	1.5	2	7	27.5	7.87	2.87
	G	1.5	2	7	22.2	4.58	1.66
44. Asparagus and Safflower (Unspecified)	A	1.25	2	7	22.9	6.56	2.39
	G	1.25	2	7	16.0	3.82	1.38
46. Strawberry	A	2	4	7	89.8	31.0	13.0
	G	2	4	7	84.6	26.1	10.2
48. Tomato	A	1.56	4	5	45.6	17.1	6.90
	G	1.56	4	5	37.1	11.9	4.52
49. Okra	A	1.2	5	7	12.6	4.15	2.27
	G	1.2	5	7	9.5	2.22	0.982
51. Sorghum and Sorghum Silage	A	1	2	7	9.3	2.53	0.930
	ULV	0.61	2	7	8.8	2.65	0.964
	G	1	2	7	11.6	3.91	1.44
52. Barley, Cereal Grains, Oats, Rye, and Wheat	A	1.25	2	7	33.4	10.4	3.88
	ULV	0.61	2	7	19.6	6.52	2.41
	G	1.25	2	7	28.2	8.29	3.01
53. Gooseberry	A	1.25	3	7	13.5	5.56	2.11
	G	2	3	7	35.7	10.3	3.83
	AB	2	3	7	35.0	9.86	3.60
55. Blueberry	ULV	0.77	3	10	8.87	3.63	1.80
	G	1.25	3	5	9.88	2.61	1.01
	AB	1.25	3	5	9.01	2.39	0.865
57. Passion Fruit (Granadilla)	G	1	8	7	0.827	0.401	0.363
	AB	1	8	7	0.614	0.284	0.257
58. Mint and Spearmint	A	0.94	3	7	8.30	3.60	1.36
	G	0.94	3	7	19.7	6.15	2.32

Scenario	Appl. Method[1]	Maximum Application Rate (lbs/A)	Max. No. Apps. per Crop Cycle	Min. Retreatment Interval (days)	EECs (µg/L)		
					Peak EEC	21-day EEC	60-day EEC
59. Rice and Wild Rice	A	1.25	2	7	1120	1120	1120
	ULV	0.61	2	7	548	548	548
	G	1.25	2	7	1120	1120	1120
61. Water Cress	A	1.25	5	3	1120	1120	1120
	G	1.25	5	3	1120	1120	1120
Non-Agricultural Uses							
Cull Piles and Agricultural Structures and Equipment. Cull Piles, Grain/cereal/flour bins (empty), and Grain/cereal/flour elevators (empty)	Drench	298.7	1	NA	2.08	0.491	0.176
Fence rows/hedge rows	Drench	10.6	1	NA	0.789	0.202	0.0722
Forestry. Christmas Tree Plantations, Pine (Seed Orchard), and Slash Pine (Forest)	A	3.2	2	7	60.0	19.8	7.18
	ULV	0.9375	2	7	19.9	7.12	2.60
	G	3.2	2	7	51.5	13.4	4.84
	AB	3.2	2	7	50.1	12.7	4.55
Nursery. Ornamental and/or Shade Trees, Ornamental Herbaceous Plants, Ornamental Non-flowering Plants, and Ornamental Woody Shrubs and Vines	A	2.5	2	10	59.2	16.7	6.05
	G	2.5	2	10	53.2	12.2	4.39
	AB	2.5	2	10	53.0	12.4	4.45
Public Health and Mosquito and Medfly Control. Wide Area/General Outdoor Treatment (Public Health Use), Intermittently Flooded Areas/Water, and Swamps/Marshes/Wetlands/Stagnant Water	ULV	0.23	1	NA	1.06	1.06	1.06
Residential and Refuse/Solid Waste. Household/Domestic Dwellings (perimeter around dwelling), Refuse/Solid Waste Containers (Garbage Cans), and Refuse/Solid Waste Sites (Outdoors)	Drench	10.6	1	NA	3.43	0.701	0.250
Rights-of-way. Agricultural, uncultivated areas, Nonagricultural Rights-of-way/Fencerows, and Nonagricultural Uncultivated Areas/Soils	A	1	1	NA	24.0	8.84	3.93
	ULV	0.9281	1	NA	7.31	2.76	1.07
	G	1	1	NA	5.436	2.08	0.777
	AB	1	1	NA	5.494	2.10	0.785
Turf. Golf Course Turf (Bermudagrass)	A	1.25	1	NA	10.3	2.87	1.02
	ULV	0.92	1	NA	12.2	3.22	1.15
	G	1.25	1	NA	5.69	1.53	0.547

[1] A = aerial spray, G = ground spray, AB = air blast, ULV = ultra-low volume.

3.2.3. Existing Monitoring Data

A critical step in the process of characterizing EECs is comparing the modeled estimates with available surface water monitoring data. Surface water monitoring data are presented from four monitoring programs. Two programs, California Department of Pesticide Regulation (CaDPR) and U.S. Geological Survey's National Water Quality Assessment (NAWQA), analyzed surface water samples for malathion in California, but were not targeted to malathion applications (non-targeted). Non-targeted monitoring programs are not designed to sample specifically in the vicinity of malathion applications and sampling is not timed to coincide specifically with malathion applications. These programs provide information about typical or average malathion concentrations and the general distribution of concentrations over the region, time period, and population of sites sampled. The PRZM/EXAMS EECs should, in general, be higher than non-targeted monitoring values with only the upper end of the distribution of non-targeted malathion concentration values approaching the PRZM/EXAMS EECs.

The other two USDA programs, the Boll Weevil Eradication Program (BWEP) and the Mediterranean fruit fly (medfly) control effort, are specifically designed to research the effects of malathion applications (targeted monitoring). Because targeted monitoring specifically samples water bodies expected to be most impacted by the malathion application being monitored, the after application samples should produce environmental concentrations that are much closer to corresponding PRZM/EXAMS EECs.

In the sections that follow, the ranges of the PRZM/EXAMS EECs are compared to non-targeted and targeted monitoring.

3.2.3.a. Non-targeted Monitoring

An evaluation of the surface water monitoring data was conducted to assess the occurrence of malathion and maloxon in California. Surface water data were obtained from the California Department of Pesticide Regulation (CaDPR) surface water database, (http://www.cdpr.ca.gov/docs/sw/surfdata.htm), U.S. Geological Survey's National Water Quality Assessment (NAWQA) data warehouse (http://water.usgs.gov/nawqa/data.html), and CaDPR and NAWQA publications. Maximum site concentrations from these data sets were compared with PRZM/EXAMS EECs. Because these surface water sampling programs are not targeted to malathion use areas and were not collected at sites similar to the standard EXAMS pond (which is designed to present a high EEC scenario), these sampling programs are not expected to produce concentrations as high as the PRZM/EXAMS EECs. However, any agreement or disagreement can aid in characterizing the uncertainty of the PRZM/EXAMS malathion EECs.

Frequency distributions of maximum site malathion concentrations are shown in Figure 3-3. At many sites, all samples collected were below the level of quantitation ("< LOQ" - gray left-most bars in each graph of Figure 3-3). The maximum reported concentration of malathion in the CaDPR data set is 6.00 µg/L from the Colusa Basin Drain #5 in Colusa County, CA, and 1.35 µg/L from Warm Creek Near San Bernardino (site 11060400) in San Bernardino, CA, for the USGS NAWQA data set. Note that these maximums were from locations that are slightly outside the range of the DS and CTS. The highest concentration found inside the range was 0.63 µg/L from Arcade Creek. However, the interpretation of these data sets is complicated because the LOQ varied between samples and over time. The maximum LOQs were 1 and 0.15 µg/L for the CaDPR and NAWQA data sets, respectively. Therefore, additional sites may have had actual concentrations approaching these LOQs in the samples that were collected that are listed as < LOQ. A total of 9 (CaDPR and NAWQA) sites had measured maximum concentrations in excess of 1 µg/L (the highest LOQ). Malathion concentrations specific to the habitat of the DS is further discussed in Section 5.2.1.a.

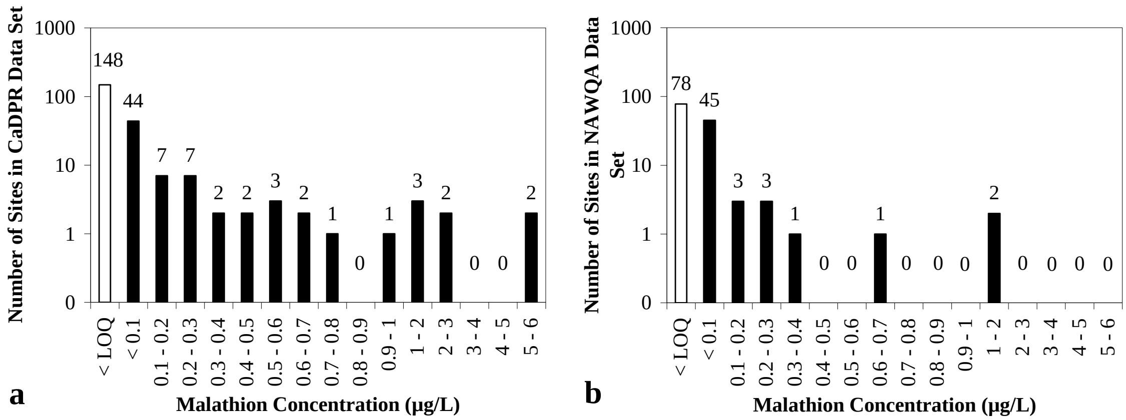


Figure 3-2. Frequency distributions of (a) maximum site malathion concentrations for California Department of Pesticide Regulation (CaDPR) and (b) U.S. Geological Survey's National Water Quality Assessment (NAWQA) data sets.

The only maloxon concentration measured above the detection limit in either the CaDPR or NAWQA data sets is 0.06 µg/L from the Alamo River at All American Canal in Imperial County, CA (from the CaDPR data set). The detection limits for maloxon varied from 0.05 to 0.2 µg/L for the CaDPR data set and from 0.008 to 0.09 µg/L for the NAWQA data set.

3.2.3.b. Targeted Monitoring

Boll Weevil Eradication Program: Malathion is water soluble and therefore has the potential to be dissolved in rain water and transported in runoff water from application sites. The Boll Weevil Eradication Program (BWEP) has monitored malathion in runoff, standing (ponded), and moving surface water.

Malathion in runoff: Levels of malathion in runoff water have been examined mostly using automatic runoff sampling equipment which consists of collection bottles with funnels recessed in the ground at sites where runoff is expected. The amount of malathion in runoff is expected to be affected by numerous variables including the soil type, half-life on the particular soil, the amount of time between application and precipitation, the amount of precipitation, and vegetation. Table 9 shows runoff monitoring data from five treated cotton fields in the Boll Weevil program close to bodies of water. Sampling was performed close to the field (10-25 feet) and farther from the field (40-135 feet from the field). In most cases, malathion concentrations were lower when the interval between application and rainfall was longer and/or distance from the field was farther. These observations are expected since increasing the time interval since application allows for more degradation to occur and longer runoff travel distances allow malathion to penetrate soil and adsorb to soil particles before reaching surface water.

Table 3-1. Field Monitored Runoff[1] from the Cotton Boll Weevil Control Program

Field Number	Time from Application to Rain (Days)	Field Runoff Malathion Concentration (µg/L)	
		Closer to Field (Distance in Feet)	Farther from Field (Distance in Feet)
1806-502	1	9.3 (20')	1.9 (110')
	3	7.5 (20')	3.5 (110')
	6	>0.3 (20')	>0.3 (110')
1806-504	1	70 (20')	33 (40')
	6	0.48 (20')	nd (40')
2025-187	2	0.42 (10')	0.53 (70')
2027-468	1	63 (15')	nd (135')
	5	nd (15')	-
2100-200	18	4.2 (25')	3.8 (50')
502	3	1.1 (20')	nd (110')
	7	0.5 (20')	nd (110')
504	1	10.9 (20')	nd (40')
	3	41.8 (20')	15.6 (40')
	7	146 (20')	93.5 (40')
7806	?	0.9 (0')	0.5 (45')
	6	1.7 (0')	1.1 (45')
	14	<0.3 (0')	0.3 (45')
325	2	8.54 (15')	0.82 (60')
	9	35.8 (15')	16.2 (60')

[1]Malathion levels were measured in runoff water from cotton fields after rain events. Two sets of measurements were made, one closer to the field and one farther from the field. Adapted from *Environmental Monitoring Report: 1997 Southeast Boll Weevil Eradication Program Sensitive Sites* (USDA 1997a) and *Environmental Monitoring Report: 1996 Southeast Boll Weevil Eradication Program* (USDA 1996)
nd = none detected.
- = not sampled.
? = not recorded.

Spray drift contributions to standing water bodies: In monitoring projects, the stability of malathion in still water has been examined. A half-acre pond surrounded by cotton fields with a 25 foot buffer was monitored for malathion (USDA 1993). Pesticide drift was determined to be the most important mechanism of contamination of the pond. Residue levels in the pond were lower before treatment (<0.1-0.44 µg/L) and higher immediately after malathion application (<0.33-91.4 µg/L). In most cases malathion in the pond degraded to <0.33 µg/L within 7 days. Runoff was only a minor contributor of residue to the pond but only two rainfalls occurred during the sampling period. The malathion in the runoff samples collected were 9.75 and 76.3 µg/L one day after the first and last treatments, respectively. Other natural bodies of water within treatment areas, but not intentionally receiving direct spray, showed no detectable levels of malathion 3-27 days after applications ceased (USDA 1995).

Spray drift contributions to moving water bodies: The Boll Weevil Eradication Program also assessed spray drift contributions to moving water bodies (Tables 10, 11, and 12). Wide buffer strips (125-700 feet) with high vegetation appeared to reduce malathion drift to sensitive areas to levels below detection while narrower and lower buffer afforded less protection (Table 12). With aerial applications, 8 of 19 applications lead to higher aquatic malathion concentrations, whereas only 1 of 10 ground applications resulted in higher malathion levels. Aerial applications are more prone to drift than ground applications. Malathion levels in the streams, rivers, and canals increased after nearby treatments and then decreased rapidly. The lower concentrations measured over time are likely due to dilution and in-stream degradation.

Table 3-2. Southeast Boll Weevil Eradication Program Monitoring Data of Spray Drift to Adjacent Moving Water (USDA 1993)[a].

Site: Comments	**Application (Aerial / Ground)**	**Treatment Number (Days since Last Treatment)**	**Downstream Malathion Concentration**	
			µg/L (Minutes Before Treatment)	**µg/L (Minutes After Treatment)**
McCall's Creek: The creek was separated from the field (13.3 acre) by a continuous 600-700' buffer of 30-60' trees.	Aerial	1 (?)	nd	nd
	Aerial	2 (8)	nd	nd
	Aerial	3 (6)	nd	nd
	Aerial	4 (7)	nd	nd
	Aerial	5 (7)	16.1 (60)	nd
North River: The field (8.3 acre) is separated from the river by a continuous buffer of mature hardwoods and moderately dense understory approximately 125' deep.	Ground	1 (?)	-	nd
	Ground	2 (5)	nd	nd
	Ground	3 (7)	nd	nd
	Ground	4 (6)	<0.33 (45)	<0.33 (45)
	Ground	5 (6)	<0.33 (0)	<0.33 (0-120)
	Aerial	6 (10)	1.54 (45)	1.44 (60)
	Aerial	7 (6)	<0.33 (0)	<0.33 (0-120)
	Aerial	8 (7)	1.77 (60)	1.46 (0)
	Aerial	9 (10)	0.42 (45)	0.55 (45)
Pursley Creek: The field (95.3 acre) was separated from the creek by 100' of mature hardwoods with a dense understory.	Aerial	1 (?)	nd	3.54 (135)
	Aerial	2 (7)	nd	0.39 (120)
	Aerial	3 (7)	nd	1.03 (30)
	Aerial	4 (7)	nd	<0.33 (75-120)
	Aerial	5 (7)	6.63 (30)	3.80 (120)
	Aerial	6 (6)	nd	3.35 (150)
Stewart Creek: The field (19.2 acre) was separated from the creek by a 25' buffer of low -lying kudzu vegetation.	Ground	1 (?)	nd	nd
	Ground	2 (8)	<0.33 (60)	nd
	Aerial	3 (7)	nd	7.69 (60)
	Aerial	4 (5)	nd	3.16 (75)
	Ground	5 (7)	0.52	<0.33 (0-240)
	Ground	6 (4)	0.51	10.89 (15)
	Ground	7 (5)	<0.33	<0.33 (15, 105, 135-250)
	Aerial	8 (6)	1.01	4.52 (60)
	Aerial	9 (12)	<0.33	3.49 (105)

[a] Malathion levels in moving water adjacent to cotton fields were measured before and after treatment. Measurements were made downstream from the field every 15 minutes from one hour before until 2-3.25 hours after application. Application was made when wind was not blowing directly over the water.
? = not recorded.

Table 3-3. Texas Lower Rio Grande Valley Boll Weevil Eradication Program Monitoring Data of Spray Drift to Adjacent Moving Water (USDA 1995a)[a]

			Downstream Malathion Concentration	
Site/Comments	**Aerial/ Ground**	**Treat-ment #**	**µg/L (Minutes Before Treatment)**	**µg/L (Minutes After Treatment)**
#204060311/ Canal 200' from treated field.	?	1	0.324 (15)	0.297 (15)
	?	2	4.89 (15)	7.26 (30)
#2144070704 Canal 40' from treated field	?	1	6.38 (30)	11.4 (0)
	?	2	2.27 (45)	1.87 (0)
#212080704/ Canal 150' from treated field	?	1	4.81 (45)	4.15 (30,120)
	?	2	2.4 (30)	4.37 (120)
	?	3	5.92 (45)	4.21 (0)

[a] Malathion levels in moving water adjacent to cotton fields were measured before and after treatment. Measurements were made downstream from the field every 15 minutes from one hour before until 2-3.25 hours after application. Application was made when wind was not blowing directly over the water.
? = not recorded.

Table 3-4. Southern Rolling Plains Boll Weevil Eradication Program Monitoring Data of Spray Drift to Adjacent Moving Water (USDA 1994-5)[a]

			Peak Downstream Malathion Concentration	
Site/Comments	**Method of Application**	**Treat-ment #**	**µg/L (Minutes Before Treatment)**	**µg/L (Minutes After Treatment)**
Concho County Stream (10303-1408) Samples collected 0.25 miles downstream	Hi-Boy	1	0.849 (15)	6.95 (105)
	Mist blower	2	0.695 (45)	86.9 (225)
	Mist blower	3	0.273 (45)	0.503 (210)
Concho River (10708-2707) Samples collected 0.25 miles downstream	Mist blower	1	0.676 (15)	0.813 (0)
	Mist blower	2	0.871 (60)	0.589 (150)
	Mist blower	3	2.24 (60)	7.45 (15)

[a] Malathion levels in moving water adjacent to cotton fields were measured before and after treatment. Measurements were made downstream from the field every 15 minutes from one hour before until 2 - 3.25 hours after application. Application was made when wind was not blowing directly over the water.

Monitoring data suggests that urban malathion use poses the highest risk of contaminating surface water. However, use data are not available to correlate with monitoring data to determine which particular uses have the greatest impact. Total usage and use rates in specific cities are also unavailable. Targeted urban monitoring and preliminary fate experiments suggest that malathion contacting anthropogenic surfaces is likely to convert to the oxon and has a high runoff potential (CDPR 1981).

Mediterranean fruit fly (medfly) control effort: Malathion concentrations in water in and around urban medfly treatment areas in California and Florida have been measured. Although a risk assessment of malathion use for medfly control is not included in this document (these generally fall under section 18 local need uses), the monitoring studies associated with this use provide information on malathion fate and transport in residential settings. In urban areas not involved in medfly control measures, malathion can be found in runoff water at higher levels than agricultural areas. A monitoring report by United States Geological Survey showed that higher residues are found in urban areas. In this analysis of 11 urban streams (604 samples) and 37 agricultural streams (1530 samples) malathion concentrations were higher in the urban tributaries.

It is likely that proposed residential uses will result in aquatic contamination. Residential malathion uses include outdoor home and garden, public park, and commercial use as well as residential mosquito control. Home use formulations may be applied as a "... spray to lower foundation of house, patios and garbage cans ... along fences; to firewood piles; and other infested areas" (Ortho Malathion 50 Plus Insect Spray label). Malathion on the surfaces described on this label is likely to persist longer and be more available for runoff than malathion on soil. Fyfanon ULV formulation is applied at 0.2 - 0.23 lbs/A aerially at 150 mph over residential areas for mosquito control. In addition to covering anthropogenic surfaces it is likely that moderate sized bodies of water receive direct spray during normal aerial mosquito control use. In medfly treatments, malathion is mixed with a bait mixture and applied aerially at nearly the same rate as in mosquito control but with large buffers (up to 200 feet). Medfly applications in residential areas provide useful information on the fate and transport of malathion in these settings, but it is very likely that the smaller particles produced from the ULV formulation used in mosquito control results in more drift than the baited mixture for medfly. Thus, medfly monitoring data of drift will be expected to underestimate drift from ULV mosquito use.

In medfly control efforts larger bodies of water are "flagged" to avoid direct malathion treatment. Thus, contaminated water bodies presumably received insecticide residues by drift and runoff. On average, reservoirs in the treatment area which were flagged to avoid direct spray contained 0.16 µg/L before treatments and 2.59 µg/L immediately after treatment (Table 14). All waters in and around the treatment area, whether protected or not, showed increased malathion levels immediately after treatment. In general, applications were performed approximately weekly with no noted aggregate accumulation of malathion in water.

Rainwater runoff in California medfly treatment area contributed greatly to malathion levels in a stream passing through the treatment area. After precipitation, inflow into the treatment area contained less than 1 µg/L while downstream water contained up to 203 µg/L malathion. Maxima in 1990 and 1981 were 44.1 and 583 µg/L, respectively (CaEPA1996).

Table 3-5. Malathion Levels in Bodies of Water in Relation to Medfly Control Spraying[a]

Site	Treat-ment No.	Days since Last Spray	Malathion (µg/L)			Maloxon (µg/L)		
			No. of Samples	Before (Std. Err.)	After (Std. Err.)	No. of Samples	Before (Std. Err.)	After (Std. Err.)
Unprotected[1] natural waters	1	*	14	*	4.94 (2.71)	*	*	*
	2	9	6-16	0.20 (0.05)	18.66 (5.81)	1	*	18.0 (*)
	3	11	13-15	1.50 (1.17)	9.78 (2.47)	*	*	*
	4	7	14-15	.48 (.13)	95.4 (53.2)	1-2	0.64 (*)	1.9 (0.20)
	5	7	13-14	.66 (.12)	4.97 (1.05)	4-5	.19 (0.046)	.63 (.17)
	6	7	11-12	.57 (.20)	23.4 (11.6)	1-4	.90 (*)	.35 (.10)
Average	**-**	**8.2**	**-**	**.68 (.33)**	**26.19 (12.8)**	**-**	**-**	**-**
Protected[2] natural waters	1	*	20	.091 (.058)	.33 (.078)	*	*	*
	2	9	20	.12 (.07)	.56 (.10)	*	*	*
	3	11	19-20	.056 (.028)	.90 (.15)	*	*	*
	4	7	14-15	.12 (.07)	1.25 (.22)	*	*	*
	5	7	20-22	.040 (.019)	2.10 (.41)	1	*	.40 (*)

Site	Treat-ment No.	Days since Last Spray	Malathion (µg/L)			Maloxon (µg/L)		
			No. of Samples	Before (Std. Err.)	After (Std. Err.)	No. of Samples	Before (Std. Err.)	After (Std. Err.)
	6	7	15-19	.053 (.040)	.39 (.089)	2	*	.45 (.25)
Average	**-**	**8.2**	**-**	**.080 (.048)**	**.92 (.17)**	**-**	**-**	**-**
Flagged reservoirs	2	9	2	.18 (.03)	.75 (.65)	1	*	2.7 (*)
	3	11	2	*	.50 (.10)	*	*	*
	4	7	19-20	.033 (.024)	8.39 (3.81)	2	*	.92 (.29)
	5	7	10-12	.51 (.30)	1.90 (.94)	*	*	*
	6	7	8	.075 (.062)	1.42 (.41)	1	.1 (*)	.83 (*)
Average	**-**	**8.2**	**-**	**.16 (.083)**	**2.59 (1.18)**	**-**	**-**	**-**
Reservoirs outside treatment area	2	9	2	.05 (.05)	.34 (.07)	*	*	*
	3	11	2-4	.10 (.10)	1.0 (.55)	*	*	*
	4	7	10	.03 (.03)	.30 (.16)	*	*	*
	5	7	10	.036 (.024)	.14 (.058)	1	1.3 (*)	*
	6	7	8-10	.18 (.074)	.21 (.087)	*	*	*
Average	**-**	**8.2**	**-**	**.079 (.056)**	**.40 (.19)**	**-**	**-**	**-**

[a] Malathion was measured immediately before and after spraying a bait formulation at ~0.17 lbs ai/A from an altitude of 300 feet. This data was adapted from A Characterization of Sequential Aerial Malathion Applications in the Santa Clara Valley of California (CaEPA 1981).
[1] Unflagged and within the treatment area.
[2] Flagged to avoid treatment or outside the treatment area.
* No data.

Table 3-6. Malathion Level in 29 Ponds in Florida Exposed to Direct (Unprotected Aquatic Sites) or Indirect (Protected Aquatic Sites) Malathion Spray in Medfly Control[a]

site	Before Application			After Application		
	Number of Samples	Average (µg/L)	St. Dev. (µg/L)	Number of Samples	Average (µg/L)	St. Dev. (µg/L)
Unprotected Aquatic Sites						
Fairgrounds	8	0.06	0.07	9	1.20	1.54
Palm river	9	0.78	0.72	7	3.97	3.24
Ragen Park	6	14.12	14.17	7	35.75	27.50
University Square Mall	7	0.04	0.07	7	3.77	3.67
Pond Lake	6	4.11	4.35	10	9.25	11.78
Bloomingdale Area	9	0.81	0.71	9	6.12	7.22
Carrolwood	7	1.05	2.01	6	4.77	3.75
Town and Country	6	1.10	1.15	5	6.88	3.07
McDill Site	5	0.12	0.06	4	5.20	2.33
Brandon Town Center	5	3.50	1.86	8	65.71	149.18
Lowry Zoo	7	0.14	0.22	6	1.55	1.86
Sun 'n Fun	8	0.09	0.07	10	7.28	15.48
Hamilton Creek	6	0.61	0.41	7	10.74	19.51
Eagle Lake	7	1.60	2.29	7	13.99	10.39

site	Before Application			After Application		
	Number of Samples	Average (µg/L)	St. Dev. (µg/L)	Number of Samples	Average (µg/L)	St. Dev. (µg/L)
Protected Aquatic Sites						
Moore's lake	10	0.36	0.78	10	0.76	1.66
Lake Weeks	12	0.69	0.67	11	4.85	4.08
Lake Valrico	12	0.03	0.06	11	2.84	6.71
Lake Kathy	12	0.43	0.91	11	5.91	9.15
Lake Walden	6	0.21	0.14	6	2.21	2.37
Alafia River	6	0.13	0.17	6	1.93	4.06
Hillsborough River	8	0.35	0.39	8	5.02	9.13
Platt Lake	2	0.08	0.08	2	0.85	0.15
Lake Magdalene	2	0.08	0.08	2	0.80	0.20
Lake Carroll	2	0.31	0.16	2	1.65	0.55
Crystal Lake	9	0.02	0.05	9	0.46	0.74
Lake Horney	10	0.03	0.06	9	3.47	3.86
Banana Lake	7	0.21	0.33	7	2.48	3.97
Crews Lake	7	0.23	0.19	7	0.82	0.96

[a] Samples were collected within 18 hours of approximately weekly treatments of 0.15 lbs/A. Unprotected bodies of water were ~0.1 miles in length and may have received runoff from surrounding watersheds. Protected waters were rivers or larger lakes. Statistically, values below the detection limit (0.1 µg/L) were treated as 0 µg/L and values below limit of quantitation (0.3 µg/L) were treated as 0.15 µg/L. The data was adapted from the Environmental Monitoring Report: Cooperative Medfly Project Florida (USDA 1997b).

Residential settings are expected to be composed of numerous surfaces which may be physically and biologically impervious to malathion. The relative quantities and effects of adsorption and degradation on concrete, roofing, metal, and plastics is unknown in the residential settings where malathion may be sprayed for medfly and mosquito control. Monitoring results suggest that the residential surfaces increase availability of malathion for runoff, probably due to lack of microbial activity which decreases metabolism, less water content which decreases hydrolysis, and little adsorption. Although the application rate for mosquito control is low relative to agricultural use (0.20 - 0.6 lbs/A for aerial mosquito control versus 0.175 – 27.47 lbs/A for agricultural pest control), application over wide areas may be concentrated in storm drain systems along with malathion from home and garden and commercial site use.

The concentration factor appears to be greater in residential settings when comparing residential and agricultural runoff. This is consistent with the results of several USGS and USDA monitoring studies. Preliminary monitoring results for malathion in surface water (USGS 1997) show malathion was detected above 0.01 µg/L with a 2.61% frequency in agricultural streams while in urban streams the frequency was 20.86%. The USDA monitoring studies for boll weevil control show an average runoff concentration of 15.5 µg/L (Table 11) while average downstream creek concentrations in the urban Santa Clara Valley of central California were 177 µg/L during 1981 malathion spraying for medfly.

The highest levels of aquatic maloxon found in a search of available data were a result of medfly control efforts in California (CaDFG 1982). The following table is derived from the monitoring study during the malathion spraying in the Santa Clara Valley. Samples were taken 2 - 3.5 hours after the first rainfall six days after the last application. These runoff concentrations are much higher than agricultural runoff levels.

Table 3-7. Malathion and Maloxon Concentrations in Creeks after Malathion Applications in the Santa Clara Valley

Sampling Location		Average Concentration (Std. Dev.)	
		Malathion (µg/L)	Maloxon (µg/L)
Adobe Creek	50' Upstream	449 (17.7)	164 (33.2)
	Drain	583 (40.3)	328 (18.4)
	100' Downstream	361 (20.5)	169 (-)
Stevens Creek	50' Upstream	159 (-)	68.0 (-)
	Drain	434 (73.5)	147 (4.2)
	150' Downstream	156 (23.3)	68.0 (-)
Guadalupe Creek, Site 1	50' Upstream	1.9 (0.2)	0.8 (0.3)
	Drain	142 (-)	147 (4.2)
	150' Downstream	23.5 (2.1)	22.0 (-)
Guadalupe Creek, Site 2	50' Upstream	137 (25.4)	212 (9.2)
	Drain	188 (12.0)	250 (8.5)
	150' Downstream	169 (6.4)	231 (8.5)

Fate data for malathion clearly show that its major routes of degradation are through aerobic microbial metabolism and hydrolysis. Both of these routes are expected to be lower on inert, dry surfaces; thus malathion persistence would be expected to be increased. Malathion persistence on steel plates is extended relative to soil with only 15% lost in two days (CaEPA 1996) compared to several soils on which 50% can be degraded in 8 hours. Slowed malathion hydrolysis and metabolism is likely to result in increased maloxon levels via abiotic oxidation. On the steel plate study mentioned previously, maloxon accounted for 5% of the degradates, significantly higher than the maximum of 1.8% on soil reported by the registrant.

3.2.3.c. Atmospheric Monitoring Data

An evaluation of air monitoring data was conducted to assess the occurrence of malathion and maloxon. Air monitoring data were obtained from the California Department of Pesticide Regulation (Segawa, *et al*, 2003 and Kollman 2002). A review of the air monitoring data indicates that malathion was detected in trace quantities in an air monitoring study in Lompoc City, Santa Barbara County (Segawa, *et al*, 2003). Air concentrations of malathion were 7.6 ng/m^3 for the highest one day average, 1.01 ng/m^3 for the highest 3 day average, 0.54 ng/m^3 for the highest 18 day average concentration. Air concentrations of malathion were not reported in the California Pesticide Air Monitoring Results: 1986-2000 (Kollman 2002). Additionally, air monitoring data for the malathion degradation products was not found.

3.3. Terrestrial Animal Exposure Assessment

3.3.1. Exposure to Residues in Terrestrial Food Items

T-REX (version 1.4.1) was used to calculate dietary and dose-based exposure of malathion for birds (surrogate for terrestrial-phase amphibians and reptiles) and mammals. T-REX simulates exposure level for a 1-year period following one or multiple spray applications of malathion. T-HERPS (version 1.1) was then used to refine the EECs for amphibians and reptiles when risk quotients from T-REX exceeded the Agency’s LOCs. The EECs estimated by T-REX and T-

HERPS are applicable to all outdoor uses of malathion, including ground and aerial spraying and ULV applications. Terrestrial EECs were derived for 17 model scenarios to represent the range of uses of malathion. These scenarios were selected to assess risk for the most widespread uses and to reflect uses associated with extreme high- and low-end exposure. By including the high- and low-end scenarios, the scenarios are designed to reflect the full range of terrestrial exposure expected for all uses of malathion.

For aerial ULV spraying of malathion for control adult mosquitoes, AGDISP was used to predict deposition on the terrestrial surfaces. The deposition Assessment tool of AGDISP was used for malathion mass deposition based on point estimate rather than an area basis. The input and output were described in Section 3.2.2.b.

T-REX and T-HERPS estimate the peak residues that are expected to occur on wildlife food items following repeated applications of the pesticide. To calculate this, the models require an estimated half-life for the rate of dissipation of residues on the food item. This half-life was estimated based on the 37 foliar persistence half-lives published in Willis and McDowell (1987) for application of various malathion formulations on various agricultural crops. Half-life values ranged from 0.3 to 10.9 days. All but one of the half-life values were estimated based on total residues. One value based on dislodgable residues (6.1 days) was included in the analysis. The 90^{th} percentile on these 37 values (6.1 days) was used as the estimate in both models. Other use specific input values include number of applications and application rate. All input values used in T-Rex and T-HERPS are provided in **Table 3-8**. An example of output from T-REX and T-HERPS are available in Appendix E.

Table 3-8. Input Parameters for Foliar Applications Used to Derive Terrestrial EECs for Malathion with T-REX and T-HERPS

Use (Application method)	Application Rate (lbs a.i./A)	Number of Applications	Application Interval	Foliar Dissipation Half-Life
Agricultural Uses				
Citrus	7.5	1	n/a	6.1 days
Citrus (ULV)	0.175	3	30	6.1 days
Cotton, chestnut, and walnut	2.5	3	7	6.1 days
Pecan	2.5	2	7	6.1 days
Strawberry	2.0	4	7	6.1 days
Caneberry group	2.0	3	7	6.1 days
Mushroom	1.7	3	4	6.1 days
Papaya	1.25	8	3	6.1 days
Mango	0.9375	10	4	6.1 days
Rice, barley, broccoli, carrot, pear, et al.	1.25	2	7	6.1 days
Alfalfa	1.25	2	14	6.1 days
Field corn, wheat, oats, sorghum, melons, peas, et al.	1.0	2	7	6.1 days
Field corn, wheat, oats, sorghum, and beans (ULV)	0.61	2	7	6.1 days
Pastures (ULV)	0.92	1	n/a	6.1 days

Use (Application method)	Application Rate (lbs a.i./A)	Number of Applications	Application Interval	Foliar Dissipation Half-Life
Non-Agricultural Uses				
Cull Pile	299	1	n/a	6.1 days
Fence / hedge row, domestic dwelling (perimeter), and refuse/solid waste site	10.6	1	n/a	6.1 days
Adult mosquito control	0.23	0.079[a]	26	6.1 days

n/a = Not applicable

[a] Predicted maximum deposition rate from aerial ULV application at the maximum application rate of 0.23 lb ai/A

3.3.1.a. Dietary Exposure to Mammals, Birds, and Amphibians Derived Using T-REX

T-REX was used to assess direct and indirect effects on the terrestrial phase of the CTS based on dietary exposure to malathion. T-REX calculates EECs of malathion for various terrestrial food items, including grass, broadleaf plants, insects, and fruits/seeds. Predicted upper-bound EECs were derived (**Table 3-9**) and used to calculate risk quotients. As a first-tier screen for direct effects to the CTS, risk quotients were calculated for small birds (a surrogate for amphibians) consuming short grass. In addition, to assess indirect effects, risk quotients were calculated for small birds and mammals that feed on short grass. Small mammals are important because they are a prey item of the CTS, as well as because they create burrows which are an important habitat element for the CTS. Small birds were assessed as a surrogate for terrestrial amphibians, which are also prey of the CTS. The prey items were assumed to consume short grass because this is the dietary item predicted to have the highest residues of malathion.

Table 3-9. Upper-bound Kenaga Nomogram EECs for Dietary- and Dose-based Exposures of Birds and Mammals Derived Using T-REX for Malathion

Use Scenario	EECs for CTS and Other Amphibians (small birds consuming short grass)		EECs for Mammals (small mammals consuming short grass)	
	Dietary-based EEC (mg/kg-diet)	Dose-based EEC (mg/kg-bw)	Dietary-based EEC (mg/kg-diet)	Dose-based EEC (mg/kg-bw)
Agricultural Uses				
Citrus	1800	2050	1800	1720
Citrus (ULV)	43.4	93.5	43.4	41.4
Cotton, chestnut, and walnut	993	1130	993	947
Pecan	871	992	871	830
Strawberry	839	955	839	800
Caneberry group	697	793	697	664
Mushroom	831	947	831	763
Papaya	971	1110	971	925
Mango	410	467	410	391
Rice, barley, broccoli, carrots, pears, et al.	435	496	435	415
Alfalfa	361	411	361	344
Field corn, wheat, oats, sorghum, melons, peas, et al.	348	397	348	332

Use Scenario	EECs for CTS and Other Amphibians (small birds consuming short grass)		EECs for Mammals (small mammals consuming short grass)	
	Dietary-based EEC (mg/kg-diet)	Dose-based EEC (mg/kg-bw)	Dietary-based EEC (mg/kg-diet)	Dose-based EEC (mg/kg-bw)
Field corn, wheat, oats, sorghum, and beans (ULV)	212	242	212	203
Pastures (ULV)	221	251	221	211
Non-Agricultural Uses				
Cull Pile	71,700	81,600	71,700	68,300
Fence / hedge row, domestic dwelling (perimeter), and refuse/solid waste site	2,550	2,900	2,550	2,430
Adult mosquito control	23.8	27.1	23.8	22.7

3.3.2. Exposure to Terrestrial Invertebrates

T-REX was also used to calculate EECs for terrestrial invertebrates exposed to malathion. Available acute contact toxicity data for bees exposed to malathion (in units of µg a.i./bee), were converted to µg a.i./g (of bee) by multiplying by 1 bee/0.128 g. Dietary-based EECs calculated by T-REX for small and large insects (units of a.i./g) were used to bound an estimate of exposure to terrestrial invertebrates. **Table 3-10** provides EECs predicted for small insects. The EECs were then compared to the adjusted acute contact toxicity data for bees in order to derive RQs. An example output from T-REX v. 1.4.1 is available in Appendix E.

Table 3-10. Summary EECs for Terrestrial Insects (Surrogate for Terrestrial Arthropods) Derived Using T-REX ver. 1.4.1.

Use	Rate (mg ai/kg)	Number of Appl.	Appl. Interval (days)	Small insect EEC (mg/kg-bw)
Agricultural Uses				
Citrus	7.5	1	n/a	1012
Citrus (ULV)	0.175	3	30	24.4
Cotton, chestnut, and walnut	2.5	3	7	559
Pecan	2.5	2	7	490
Strawberry	2.0	4	7	472
Caneberry group	2.0	3	7	392
Mushroom	1.7	3	4	468
Papaya	1.25	8	3	546
Mango	0.9375	10	4	231
Rice, barley, broccoli, carrots, pears, et al.[1]	1.25	2	7	245
Alfalfa	1.25	2	14	203
Field corn, wheat, oats, sorghum, melons, peas, et al.	1.0	2	7	196
Field corn, wheat, oats, sorghum, and beans (ULV)	0.61	2	7	120
Pastures (ULV)	0.92	1	n/a	124
Non-Agricultural Uses				
Cull Pile	299	1	n/a	40,300
Fence / hedge row, domestic dwelling (perimeter), and refuse/solid waste site	10.6	1	n/a	1430
Adult mosquito control	0.23	23	7	13.4

[1] See Appendix B for a complete list of uses that fit this use scenario.

3.3.2.a. Dietary Exposure to Amphibians and Reptiles Derived Using T-HERPS

Birds were used as surrogate species for terrestrial-phase CTS. Terrestrial-phase amphibians and reptiles are poikilotherms indicating that their body temperature varies with environmental temperature. Birds are homeotherms indicating that their temperature is regulated, constant, and largely independent of environmental temperatures). As a consequence, the caloric requirements of terrestrial-phase amphibians and reptiles are markedly lower than birds. Therefore, on a daily dietary intake basis, birds consume more food than terrestrial-phase amphibians. This can be seen when comparing the caloric requirements for free living iguanid lizards (used in this case as a surrogate for terrestrial phase amphibians) to song birds (USEPA, 1993):

$$\text{iguanid FMR (kcal/day)} = 0.0535\ (\text{bw g})^{0.799}$$

$$\text{passerine FMR (kcal/day)} = 2.123\ (\text{bw g})^{0.749}$$

With relatively comparable slopes to the allometric functions, one can see that, given a comparable body weight, the free-living metabolic rate (FMR) of birds can be 40 times higher than reptiles, though the requirement differences narrow with high body weights.

Because the existing risk assessment process is driven by the dietary route of exposure, a finding of safety for birds, with their much higher feeding rates and, therefore, higher potential dietary exposure is reasoned to be protective of terrestrial-phase amphibians. For this not to be the case, terrestrial-phase amphibians would have to be 40 times more sensitive than birds for the differences in dietary uptake to be negated. However, existing dietary toxicity studies in terrestrial-phase amphibians for malathion are lacking. To quantify the potential differences in food intake between birds and terrestrial-phase CTS, food intake equations for the iguanid lizard were used to replace the food intake equation in T-REX for birds, and additional food items of the CTS were evaluated. These functions were encompassed in a model called T-HERPS. T-HERPS is available at: http://www.epa.gov/oppefed1/models/terrestrial/index.htm. EECs calculated using T-HERPS are shown in this Section and potential risk is further discussed in the risk characterization.

Table 3-11 show the EECs calculated using T-HERPS for the CTS and used in this risk assessment. Young CTS in the terrestrial phase consume predominantly arthropods, whereas larger adult CTS also consume frogs and small mammals. EECs generated by T-HERPS that are applicable to the CTS are thus small (2 g) amphibians consuming small and large insects, and medium (20 g) amphibians consuming small and large insects, small herbivorous and insectivorous mammals, and amphibians. For juvenile CTS, EECs used in this assessment were for consumption of small insects because the model assumes higher residues on small insects than on large insects. Likewise, for adult CTS, EECs used in this assessment were for consumption of herbivorous small mammals because that is the dietary item of adults that has the greatest predicted residues in this model. Results using these EECs thus would be protective of CTS which consume all other dietary items.

Table 3-11. Upper-bound Kenega Nomogram EECs for Dietary- and Dose-based Exposures of Amphibians and Reptiles Derived Using T-HERPS for Malathion

Use Scenario	EECs for Juvenile CTS Consuming Small Insects		EECs for Adult CTS Consuming Herbivorous Mammals	
	Dietary-based EEC (mg/kg-diet)	Dose-based EEC (mg/kg-bw)	Dietary-based EEC (mg/kg-diet)	Dose-based EEC (mg/kg-bw)
Agricultural Uses				
Citrus	1010	32.1	1810	1200
Citrus (ULV)	24.4	0.78	43.6	29.1
Cotton, chestnut, and walnut	559	17.7	997	664
Pecan	490	15.6	874	583
Strawberry	472	15.0	842	651
Caneberry group	447	14.2	797	532
Mushroom	468	14.8	834	556
Papaya	546	17.3	974	649
Mango	343	10.9	612	408
Rice, barley, broccoli, carrots, pears, et al.	245	7.77	437	291
Alfalfa	203	6.45	363	242
Field corn, wheat, oats, sorghum, melons, peas, et al.	196	6.22	350	233
Field corn, wheat, oats, sorghum, and beans (ULV)	120	3.79	213	142

Use Scenario	EECs for Juvenile CTS Consuming Small Insects		EECs for Adult CTS Consuming Herbivorous Mammals	
	Dietary-based EEC (mg/kg-diet)	Dose-based EEC (mg/kg-bw)	Dietary-based EEC (mg/kg-diet)	Dose-based EEC (mg/kg-bw)
Pastures (ULV)	124	3.94	221	148
Non-Agricultural Uses				
Cull Pile	40,400	1280	72,000	48,000
Fence/hedge row, domestic dwelling (perimeter), refuse/solid waste site	1430	45.4	2550	1700

3.4. Terrestrial Plant Exposure Assessment

No exposure assessment was conducted for terrestrial plants. No terrestrial plant toxicity data have been submitted to the Agency that can be used to compare to predicted exposure levels to conduct a quantitative risk assessment for terrestrial plants. Evidence from the open literature and the long history of use on a wide variety of plants indicate that malathion does not cause adverse effects on the plants (see Section 4.3.4). Therefore a quantitative risk assessment on terrestrial plants was not conducted.

4. Effects Assessment

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

This assessment evaluated the potential for malathion to directly or indirectly affect DS and CTS or modify their designated critical habitat. Assessment endpoints for the effects determination for each assessed species included direct toxic effects on the survival, reproduction, and growth, as well as indirect effects, such as reduction of the prey base or modification of its habitat. In addition, potential modification of critical habitat was assessed by evaluating effects to the PCEs, which are components of the critical habitat areas that provide essential life cycle needs of each assessed species. Direct effects to the DS and to the aquatic stages of the CTS were based on available toxicity data for fish. Available acute toxicity data for frog tadpoles were also considered for the assessment of aquatic stages of the CTS, but were not used in the quantitative risk calculations. Direct effects for the terrestrial stage of the CTS were based on avian toxicity data, given that birds are generally used as a surrogate for terrestrial-phase amphibians.

4.1. Ecotoxicity Study Data Sources

Toxicity endpoints were 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) (USEPA, 2004). Ecotoxicity data used in this risk assessment are summarized in Appendix I. Toxicity data on mammals were obtained from the data review conducted by the Health Effects Division and published in the Registration Eligibility Decision Document (RED) for Malathion. The chapter of this RED that presents these toxicity data are given in Appendix J. Open literature data presented in this assessment were obtained from a previous assessment for the California red-legged frog (USEPA, 2007a), a search of the ECOTOX database conducted in October 2008, as well as an update search conducted in February 2010. In order to be included in the ECOTOX database, papers must meet the following minimum criteria:

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

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

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

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

In addition to registrant-submitted and open literature toxicity information, ecological incident data were reviewed and used to refine the characterization of potential ecological effects associated with exposure to malathion. Available aquatic and terrestrial incident data associated with malathion are summarized in Section 4.5 and presented in detail in Appendix G.

4.2. Toxicity of Malathion to Aquatic Organisms

Table 4-1 summarizes the most sensitive aquatic toxicity endpoints, based on an evaluation of both the submitted studies and the open literature. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment for the DS and CTS is presented below. Additional information is provided in Sections 4.2.1 through 4.2.5. All endpoints are expressed in terms of the active ingredient (a.i.) unless otherwise specified.

Table 4-1. Aquatic Toxicity Profile for Malathion

Assessment Endpoint	Acute/ Chronic	Species	% AI	Toxicity Value (95 % Confidence Interval)	Citation MRID or ECOTOX[1]	Comment
Freshwater fish (surrogate for aquatic-phase amphibians)	Acute	Rainbow trout (*Oncorhynchus mykiss*)	95	96-hr LC_{50} = 33 (22 - 39) µg/L Slope = 4.45 (2.22 – 6.68)	Animal Biology Laboratory, 1968 MRID 48078003	This study was conducted at the Animal Biology Laboratory of the USDA. The Agency determined it was acceptable for quantitative risk assessment. The acute toxicity category is very highly toxic.
	Chronic	Flagfish (*Jordanella floridae*)	Tech.	LOAEC = 11 µg ai/L NOAEC = 8.6 µg/L	Eco ref. 000995 (Hermanutz, 1978)	Study was found to be acceptable for quantitative risk assessment.
Freshwater invertebrates	Acute	Water flea (*Simocephalus serrulatus*)		48-hr EC_{50} = 0.59 (0.46 – 0.77) µg/L Slope = 5.45 (2.78-8.12)	MRID 40098001 (Mayer and Ellersick, 1986)	Study was conducted by the Columbia national Fisheries Research Laboratories, US Fish and Wildlife Service. This study was found to be acceptable for quantitative risk assessment. The acute toxicity category is very highly toxic.
	Chronic	Water flea (*Simocephalus serrulatus*)		Estimated NOAEC = 0.035 µg/L		The chronic NOAEC for freshwater invertebrates was derived based on the

Assessment Endpoint	Acute/ Chronic	Species	% AI	Toxicity Value (95 % Confidence Interval)	Citation MRID or ECOTOX[1]	Comment
						ACR for daphnia (see Section 4.2.2.b.)
Estuarine/ marine fish	Acute	Sheepshead minnow (*Cyprinodon variegatus*)	94	96-hr LC_{50} = 33 (14 – 63) µg/L (Slope not determined)	MRID 41174301 (Bowman, 1989)	Study was found to be acceptable for quantitative risk assessment. The acute toxicity category is very highly toxic.
	Chronic	Bluehead wrasse (*Thalassoma bifasciatum*)		Estimated NOAEC = 17.3 µg/L		The chronic NOAEC for the estuarine/marine fish was derived based on the ACR for rainbow trout (see section 4.2.3.b)
Estuarine/ marine invertebrates	Acute	Mysid *(Americamysis bahia)*	94	96-hr EC_{50} = 2.2 (1.5 – 2.6) µg/L (Slope not determined)	MRID 41474501 (Forbis, 1990)	Data are from an acceptable study submitted by the registrant. The acute toxicity category is very highly toxic.
	Chronic	N/A		Estimated NOAEC = 0.013 µg/L		The chronic NOAEC for estuarine/marine invertebrates was derived based on the ACR for daphnia (see Section 4.2.4.b)
Aquatic plants	Non-Vascular	Green algae *Pseudokirchneriella subcapitata*	100	48-hr EC_{50} = 2400 (1500-3600) µg/L Slope = 3.58 NOAEC = 500 µg/L	Eco ref. 085816 (Yeh and Chen, 2006)	Study was found to be acceptable for quantitative risk assessment.
	Vascular	Duckmeat *Spirodela polyrhiza*	96.26	NOAEC= 9,630 µg/L	Eco ref. 054278 (Sinha *et al*., 1995)	Study was found to be not acceptable for qualitative use in risk assessment. However, it does provide adequate information to conclude that aquatic plants in the duckweed family are less sensitive to malathion than green algae. In the Registration Review Problem Formulation, this paper was incorrectly cited as Eco ref. 009184

1 Eco ref numbers refer to the reference numbers used in the ECOTOX database.

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

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

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

4.2.1. Toxicity to Freshwater Fish and Aquatic-Phase Amphibians

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

Table 4-3 summarizes acute toxicity data on the effects of malathion to freshwater fish and amphibians. Freshwater fish toxicity data for malathion were obtained from studies conducted at two federal government laboratories, the Columbia National Fisheries Research Laboratory (Mayer and Ellersieck, 1986) and from the former USEPA Animal Biology Laboratory. To date, no other freshwater fish toxicity data submitted by pesticide registrants on the toxicity of malathion has been found to be acceptable for use in this risk assessment. Two freshwater fish acute toxicity studies conducted in 2001 are currently being evaluated by the Agency. Preliminary results from these studies, shown in Table 4-3, indicate that neither provides the lowest acute toxicity endpoint for freshwater fish and, therefore, were not applicable for use in the screening-level risk assessment. Many studies from the open literature, identified through the ECOTOX literature search, also provided toxicity data on the acute effects of malathion to freshwater fish. None of the acute freshwater studies from the open literature are included in Table 4-3 because they did not provide the lowest toxicity endpoint for freshwater fish. Open literature data obtained in a 2007 ECOTOX literature search was previously described in the Agency's assessment for the California red-legged frog (USEPA, 2007a). For amphibians, acute toxicity data were obtained from studies conducted at the Columbia National Fisheries Research Laboratory (Mayer and Ellersieck, 1986) and from the open literature. All acute amphibian data obtained by the Agency are shown in Table 4-3.

In the CRLF assessment, the lowest acute toxicity 96-hr LC_{50} of 4.1 µg/L for the rainbow trout (*Oncorhynchus mykiss,* Soap Lake strain) (MRID 40098001, Mayer and Ellersieck, 1986) was used as the endpoint to evaluate direct and indirect effects to freshwater fish and aquatic-phase amphibians. Further review of this endpoint showed that it is inconsistent with other acute toxicity data for the rainbow trout, as well as with data for other salmonid species. Figure 4-1 shows a histogram of the 18 96-hr LC_{50} values obtained for trout. The value of 4.1 µg/L (converted to the log value of 0.61) clearly appears as an outlier among the other trout data which ranged from 34 to 280 µg/L. In addition, the 4.1 µg/L LC_{50} value is approximately five times lower than the chronic NOAEC values of 21 µg/L obtained from a fish early life-stage study with rainbow trout (MRID 41422401). Furthermore, in the Biological Opinion on the effect of pesticide products containing malathion, chlorpyrifos, or diazinon on 28 listed Pacific salmonids, the National Oceanic Atmospheric Administration National Marine Fisheries Service (NMFS) did not incorporate the value of 4.1 µg/L into their analysis, citing "experimental flaws" (National Marine Fisheries Service, 2008). Given the uncertainties associated with the 4.1 µg/L

LC_{50} value, this value was not chosen as the acute endpoint for use in the quantitative risk assessment freshwater fish and aquatic-phase amphibians.

Mayer and Ellersieck (1986) report the result for a study testing the toxicity of malathion to bluegill sunfish that yielded a 96-hr LC_{50} of 20 µg/L. However, this study was conducted with very warm water at 29.4° C (84.9° F). The test temperature was much greater than that recommended by the test guidelines (20-24° C, 68.0-75.2° C). The warm water would have resulted in reduced dissolved oxygen and may have stressed the test organisms. Another test reported in Mayer and Ellersieck (1986) that conducted with the same species, pH, and hardness but at a temperature of 24° C yielded a higher 96-hr LC_{50} of 40 µg/L. Therefore, the results from the test the very warm water temperature was not considered in this analysis.

The next two lowest reported 96-hr LC_{50} values among studies conducted at the Agency's recommended test temperature were 30 µg/L for the bluegill sunfish (MRID 40098001, Mayer and Ellersieck, 1986) and 32.8 µg/L reported for the rainbow trout (USEPA, 1968). Because the raw data could not obtained to validate the results of the bluegill sunfish study reported in Mayer and Ellersieck (1986), and because these two values were very similar and would yield essentially equivalent risk quotients, the Agency decided to use the more certain value of 32.8 µg/L from the acceptable rainbow trout study in the quantitative risk assessment. This rainbow trout 96-hr LC_{50} was lower than any of the reported 96-hr LC_{50} values for amphibians (tadpoles) in acceptable studies. Therefore, this value of 32.8 µg/L was selected as the acute endpoint for quantitative risk assessment of direct and indirect effects to the CTS. However, since this value was not less than the 96-hr LC_{50} for most sensitive marine/estuarine fish tests (bluehead wrasse, *Thalassoma bifaciatum*, LC_{50} = 27 µg/L), the lower value of 27 µg/L was selected for the DS, a species that inhabits both fresh and brackish water.

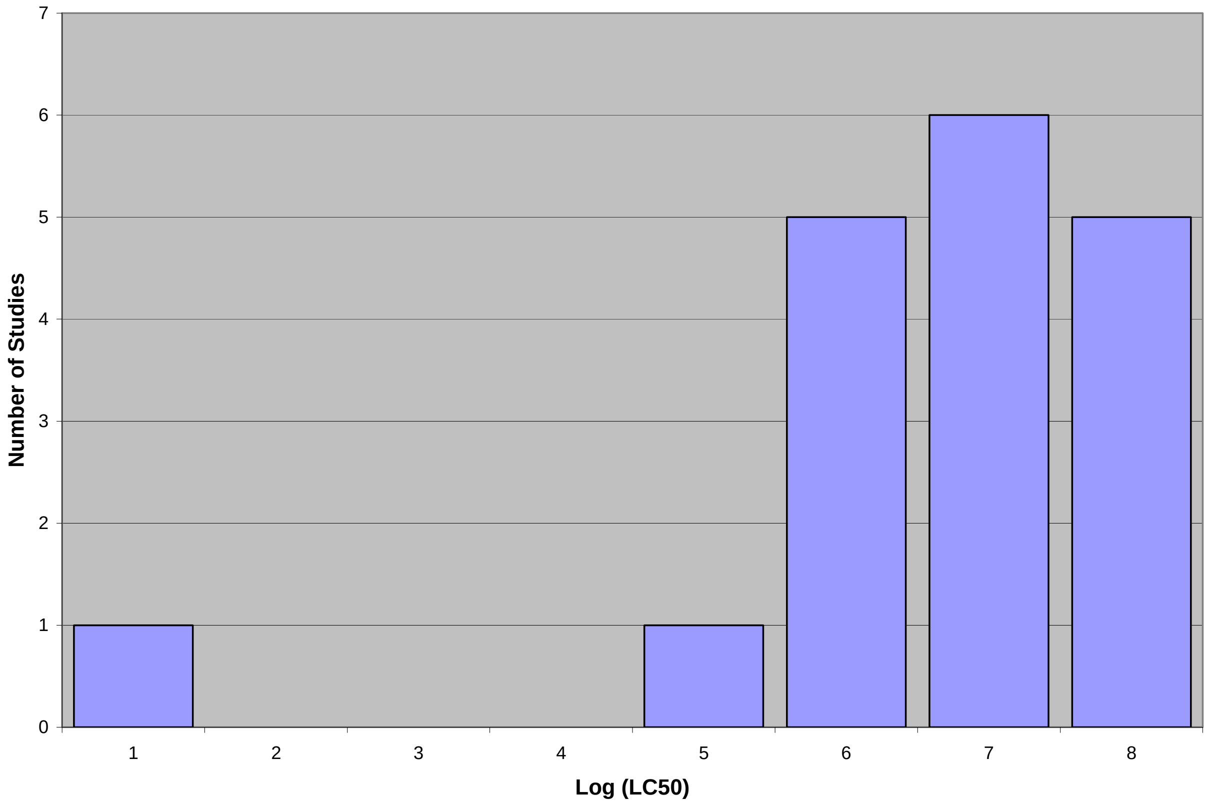


Figure 4.1. Distribution of values reported for the acute toxicity of malathion to trout. The bar on the far left represents a 96-hr LC_{50} value of 4.1 µg/L that was obtained in one of the 18 available 96-hr LC_{50} studies with trout. This value was considered and outlier and was not used for the lowest value in the quantitative risk assessment.

The lowest acute toxicity endpoint obtained for aquatic stages of amphibians was a 96-hr LC_{50} of 0.59 µg/L for the Indian frog *Rana hexadactyla* (Khangarot *et al*., 1985; Eco ref. 011521). However, the Agency found this study to be unacceptable for quantitative risk assessment because too little information was available on the testing methods and apparatus, exposure concentrations were not provided, and several deviations from the Agency's test guidelines were observed. The value was also inconsistently low compared to all other available acute toxicity data on amphibians. No other reported amphibian LC_{50} was lower than the lowest LC_{50} value for freshwater fish. Excluding this value, the range of endpoints for the aquatic-stage amphibians of 170 to 19,200 µg/L was well above the lowest acute endpoint for the freshwater fish; therefore, the lowest 96-hr LC_{50} value for freshwater fish (32.8 µg/L) was used to qualitatively assess direct effects to the aquatic-phase CTS.

Table 4-3. Freshwater Fish and Amphibian Acute Toxicity Studies OPP Data and ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species Tested	% ai	96-hr LC_{50} (Confidence Limits) in µg ai/L	Reference MRID or ECOTOX	Classification
		Freshwater fish		
Black bullhead catfish	95	11,700 (9,600-14,100)	40098001	Supplemental
Bluegill sunfish	95	20 (16-25)	40098001	Supplemental
Bluegill sunfish	95	30 (10-88)	40098001	Supplemental
Bluegill sunfish	95	40 (32-50)	40098001	Supplemental
Bluegill sunfish	95	55 (50-60)	40098001	Supplemental
Bluegill sunfish	95	103 (87-122)	40098001	Supplemental
Bluegill sunfish	96.9	48 (29-107)	47540304	Acceptable
Brown trout	95	101 (84-115)	40098001	Supplemental
Channel catfish	95	7620 (5820-9970)	40098001	Supplemental
Coho salmon	95	170 (160-180)	40098001	Supplemental
Common Carp	95	6,590 (4920-8820)	40098001	Supplemental
Cutthroat trout	95	174 (112-269)	40098001	Supplemental
Fathead minnow	95	8,650 (6450-11500)	40098001	Supplemental
Goldfish	95	10,700 (8,340-13,800)	40098001	Supplemental
Green sunfish	95	146 (90-234)	40098001	Supplemental
Lake trout	95	76 (47-123)	40098001	Supplemental
Largemouth bass	95	250 (229-310)	40098001	Supplemental
Rainbow trout	95	4.1 (2.2-7.4)	40098001	Supplemental
Rainbow trout	**95**	**32.8* (21.7-40.0)**	**Animal Biol Lab, 1968 48078003**	**Acceptable**
Rainbow trout	96.9	170 (90-460)	47540302	Supplemental
Red-ear sunfish	95	62 (58-67)	40098001	Supplemental
Tilapia	95	2000	40098001	Supplemental
Walleye	95	64 (59-70)	40098001	Supplemental
Yellow perch	95	263 (205-338)	40098001	Supplemental

Species Tested	% ai	96-hr LC_{50} (Confidence Limits) in µg ai/L	Reference MRID or ECOTOX	Classification
Amphibians				
African clawed frog *Xenopus laevis*	>90	9,810-10,900	Eco ref. 066506	Qualitative
Fowler's toad *Bufo woodhousei fowleri*	95	420 (90-980)	MRID 40098001 & 00084757 (Mayer and Ellersieck, 1986)	Supplemental
Rana hexadactyla	50	0.59 (0.43-0.78)	Khangarot et al., 1985 Eco ref. 011521	Qualitative
Striped northern chorus frog *Pseudacris triseriata*	95	200 (90-270)	40098001 (Mayer and Ellersieck, 1986)	Supplemental
Tiger frog, Indian bullfrog *Rana tigrina*	100	170	Eco ref. 061878 (Abbasi and Soni, 1991)	Qualitative
Western chorus frog *Pseudacris triseriata triseria*	Tech.	320 (180-680)	Eco ref. 002891 (Sanders, 1970)	Qualitative
Yellow-legged frog (*Rana boylii*)	--	2,140	Eco ref. 092498 (Sparling and Fellers, 2006)	Qualitative

* Endpoint used for quantitative assessment of risk.

In addition to the acute toxicity data presented in Table 4-3, Relyea (2004a, Eco ref 072798, and 2004b, Eco ref 086767) provides toxicity data on the effects of 16-day exposure of a formulated product of malathion (50.6 % AI) to larvae of several frog species. Data for the endpoint of mortality are presented in Table 4-4. Estimates of 16-day LC_{50} values which were provided in Relyea 2004a ranged from 633 µg/L for the wood frog to 2,990 µg/L for the American toad. These results were comparable to or higher than 96-hr LC_{50} values reported for other frog species (Table 4-3). None of these formulated product endpoints were lower than the lowest 96-hr LC_{50} obtained in other studies with amphibians, or lower than the lowest 96-hr LC_{50} value for freshwater fish.

Table 4-4. Sixteen-Day Mortality Data for Exposure of Frogs to Formulated Product of Malathion (50.6 % AI).

Species Tested	16 day LC_{50} µg ai/L	NOAEC µg ai/L	LOAEC µg ai/L	ECOTOX Reference	Classification
American toad (*Bufo americanus*)	2,990	506	2,530	Eco ref 072798	Qualitative
American toad (*Bufo americanus*)	--	1,000	2,000	Eco ref 086767	Qualitative
Bullfrog (*Rana catesbeiana*)	759	--	50.6	Eco ref 072798	Qualitative
Bullfrog (*Rana catesbeiana*)	--	1,000	2,000	Eco ref 086767	Qualitative
Gray tree frog (*Hyla versicolor*)	2,090[a] 1,010[b]	506	2,530	Eco ref 072798	Qualitative

Species Tested	16 day LC_{50} µg ai/L	NOAEC µg ai/L	LOAEC µg ai/L	ECOTOX Reference	Classification
Gray tree frog (*Hyla versicolor*)	--	2,000	--	Eco ref 086767	Qualitative
Green frog (*Rana clamitans*)	1,850	506	2,530	Eco ref 072798	Qualitative
Green frog (*Rana clamitans*)	--	2,000	--	Eco ref 086767	Qualitative
Leopard frog (*Rana pipiens*)	1,210	506	2,530	Eco ref 072798	Qualitative
Leopard frog (*Rana pipiens*)	--	2,000	--	Eco ref 086767	Qualitative
Wood frog (*Rana sylvatica*)	633	506	2,530	Eco ref 072798	Qualitative

a This value is for measurement of toxicity without stress from predatory cues.
b This value is for measurement of toxicity with stress from predatory cues.

Table 4-5 provides a summary of the available toxicity data of maloxon for fish and aquatic-phase amphibians obtained from the open literature. Based on this information, the acute malaxon endpoints for fish and amphibians range from 23 to 1600 µg/L. The amphibian data for the yellow-legged frog (*Rana boylii*) indicates that the oxon degredation product is approximately 89.9 times more toxic than parent malathion (Sparling and Fellers, 2007; Eco ref 092498). However, this relationship is uncertain because the toxicity tests with malathion conducted by Sparling and Fellers (2007) yielded poor data for estimation of the LC_{50}. Both the malathion and maloxon studies were conducted with only 4 test concentrations and the span of concentrations was not enough to produce a the full range of responses, as is needed for accurate estimation of the LC_{50}. In the malathion test, no concentration yielded less than 44% mortality, and in the maloxon test, no concentration yielded greater than 55% mortality. The other studies which provide data on the acute toxicity of maloxon were also judged to be inadequate for quantitative risk assessment. The tests with maloxon reported by both Tsuda *et al.* (1997) and Gantberg *et al.* (1989) were conducted with an exposure duration of only 48-hrs, whereas our test guidelines require 96-hr exposure duration. Furthermore, these papers did not report mortality data, thus the reported LC_{50} estimates could not be verified. As previously discussed, because of the lack of acceptable data on the toxicity and environmental fate of maloxon, the aquatic risks of exposure to maloxon was assessed only qualitatively.

Table 4-5. Aquatic Organism Maloxon Toxicity Studies (from ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species Tested	% a.i.	Duration Hours	LC_{50} µg/L	Reference MRID or ECOTOX	Classification
African clawed frog *Xenopus laevis.*	--	96	900	Snawder and Chamber, 1989 Eco ref. 066506	Qualitative
Yellow-legged frog *Rana boylii*	99	96	23.8	Sparling and Fellers, 2007 Eco ref. 092498	Qualitative
Medaka *Oryzias latipes*	>95	48	280	Tsuda et al. 1997 Eco ref. 018398	Qualitative
Carp *Cyprinus carpio*	95	48	1600	Gantberg et al., 1989 Eco ref. 000086	Qualitative
Perch *Perca fluviatilis*	95	48	150	Gantberg et al., 1989 Eco ref. 000086	Qualitative

Species Tested	% a.i.	Duration Hours	LC_{50} µg/L	Reference MRID or ECOTOX	Classification
Roach *Rutilus rulitus*	95	48	1100	Gantberg et al., 1989 Eco ref. 000086	Qualitative

Two studies with bluegill sunfish have been submitted that measures the toxicity to of two other degradation products of malathion, malathion monocarboxilic acid and malathion dicarboxylic acid (Table 4-6). Note that these results are reported in mg/L. Results from these studies indicate that both of these degradation products are over 1000× less toxic to freshwater fish than the parent compound, malathion.

Table 4-6. Studies Measuring the 96-hr Toxicity of Two Degradation Products of Malathion to Freshwater Fish

Test Material / Test Species	% AI	Duration (Hours)	LC_{50} in mg ai/L	Reference MRID or ECOTOX	Classification
Malathion dicarboxylic acid Bluegill sunfish (*Lepomis macrochirus*)	98.8	96	>87	47540306	Supplemental
Malathion monocarboxylic acid (α and β mixture) Bluegill sunfish (*Lepomis macrochirus*)	92.2	96	77 (51-151)	47540309	Acceptable

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

Table 4-7 summarizes the available toxicity data on the effects of chronic exposure of malathion to freshwater fish. Data on chronic fish toxicity were obtained from an acceptable study submitted by the registrant (MRID 41422401) and from the open literature. While the rainbow trout was the most sensitive freshwater fish tested based on acute data, the lowest chronic endpoint was obtained for the flagfish (*Jordanella floridae*). The chronic NOAEC obtained for this species was 8.6 µg/L (Hermanutz, 1978). For this species, the LOAEC was 10.9 µg/L based on decreased growth and 27.4 µg/L based on decreased survival of first-generation fish. This value was used in the quantitative risk assessment for direct and indirect chronic effects to freshwater fish. Because no chronic aquatic-phase amphibian data were available, and acute toxicity data indicated that freshwater fish are more sensitive to malathion than aquatic-phase amphibians, this chronic freshwater fish endpoint was also used to quantitatively risk assessment for direct and indirect chronic effects to aquatic-phase amphibians.

Table 4-7. Freshwater Fish Chronic Exposure Toxicity Data (Growth, Survival, and Reproduction Endpoints)

Species	% ai	Duration (Days)	LOAEC (µg/L)	NOAEC (µg/L)	Reference MRID or ECOTOX	Classification
Rainbow trout	94	97	44	21	MRID 41422401	Acceptable
Flagfish (*Jordanella floridae*)	**tech**	**110**	**11**	**8.6**	**Eco ref. 000995 (Hermanutz., 1978)**	**Quantitative**
Fathead minnow	tech	158	350	N.D.	D234663	Qualitative
Snakehead catfish	100	15	--	500	Eco ref. 014673	Qualitative
Medaka	99.8	14	798.4	199.6	Eco ref. 059285	Qualitative
Nile tilapia	100	168	500	--	Eco ref. 092183	Qualitative

4.2.1.c. Freshwater Fish: Sublethal Effects and Additional Open Literature Information

Appendix I presents available results of freshwater fish toxicity studies, including those which showed sublethal endpoints that cannot be directly related to the assessment endpoints of survival, growth, and reproduction. Sublethal effects observed in these studies include biochemical, behavioral, hematological, and immunological effects. In general, these additional sublethal endpoints were at concentrations higher than the endpoint which was used in the chronic risk assessment for fish and aquatic-phase amphibians (8.6 µg/L), which was based on growth effects. In only two cases were reported results for non-assessment endpoints lower concentrations. In the walking catfish (*Clarias batrachus*), 16-day exposure to malathion was reported to affect biochemical markers of thyroid function at concentrations as low as 3.5 µg/L (Sinha *et al*, 1992, Eco ref 089093). Drummond and Olson (1974) reported that a 10-day exposure to malathion affected the cough response In brook trout at concentrations as low as 6.9 µg/L (Eco ref 086858). These results cannot be quantitatively related to the growth, reproduction, or survival of fish, and thus were not used in the quantitative risk assessment.

4.2.2. Toxicity to Freshwater Invertebrates

4.2.2.a. Freshwater Invertebrates: Acute Exposure Studies

Table 4-8 provides available acute toxicity data of malathion to freshwater invertebrates. These data were obtained from studies submitted to the Agency by pesticide registrants, studies conducted at the Columbia National Fisheries Research Laboratory (Mayer and Ellersieck, 1986), and from studies published in the open literature sources which yielded a 48-hr or 96-hr EC_{50} value of 1.0 µg/L or less. Among the lowest acute toxicity endpoints reported for freshwater invertebrates are 0.098 µg/L (Rawash et al., 1975, Eco ref. 005539) and 0.67 µg/L (MRID 47540303), both from studies with the water flea (*Daphnia magna*). Rawash *et al.* (1975) was classified as “invalid” because the study lacked controls and replication, and the paper lacked adequate description of the experimental methods. MRID 47540303 was classified as “invalid” because contamination with an unknown substance was observed in the control. Therefore, data from both of these studies are unacceptable for quantitative or qualitative risk assessment. Mayer and Ellersieck (1986) reported a 96-hr EC_{50} value of 0.5 µg/L for the scud, but analytical results could not be verified because the raw data from this experiment were not available. Furthermore, no confidence intervals were reported for this value, adding to the uncertainty of this value. The next lowest EC_{50} value is the 48-hr EC_{50} of 0.59 µg/L for the water flea, *Simocephalus serrulatus* (MRID 40098001). This study was classified as supplemental because a non-preferred test species was used and the study was conducted at a temperature of 10°C, which is colder than that recommended by our test guidelines (20°C). Nevertheless, the Agency judged this study to be acceptable for use in quantitative risk assessment. This value was selected as a reasonable low-end value for use in the quantitative risk assessment for indirect effects (effects on food abundance) to the DS and CTS.

In a previous risk assessment conducted for effects of malathion to the California red-legged frog (USEPA, 2007a), the Agency based the acute risk assessment for aquatic invertebrates on an endpoint of 0.01 µg/L which was reported for a freshwater water flea (*Miona macrocopa*) by Wong *et al.* (1995, Eco ref 016371). However, further scrutiny of this study revealed that this result was actually for an effect of chronic exposure to malathion on survival, specifically a reduction in the median time to death. This result is therefore not appropriate to assess acute toxicity risk, which is based on the acute EC_{50}.

Table 4-8. Freshwater Invertebrate Acute Toxicity Studies from OPP Data and ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species Tested	% ai	Duration (Hours)	EC_{50} in µg/L (95% confidence interval)	Reference MRID or ECOTOX	Classification
Caddisfly, *Hydropsyche sp.*	95	48	5.0 (2.9-8.6)	40098001	Supplemental
Caddisfly, *Limnephalus sp.*	95	48	1.3 (0.77-2.0)	40098001	Supplemental
Crayfish,*Orconectes nais*	95	96	180 (140-230)	40098001	Supplemental
Damselfly, *Lestes congener*	95	48	10 (6.5-15.0)	40098001	Supplemental
Glass shrimp, *Palaemonetes kadiakensis*	95	96	12 (N.R.)	40098001	Supplemental
Scud, *Gammarus fasciatus*	95	96	0.5 (flow-through) (N.R.)	40098001	Supplemental
Scud, *Gammarus fasciatus*	95	96	0.76 (static) (0.63-0.92)	40098001	Supplemental
Scud, *Gammarus fasciatus*	95	96	0.90 (static) (0.64-1.26)	40098001	Supplemental
Scud, *Gammarus lacustris*	tech	48	1.8 (1.3-2.4)	05009242	Acceptable
Seed Shrimp, *Cypridopsis vidua*	95	48	47 (32-69)	40098001	Acceptable
Snipefly, *Atherix variegata*	95	48	385 (245-602)	40098001	Supplemental
Sowbug, *Asellus brevicaudus*	95	96	3000 (1500-8500)	40098001	Supplemental
Stonefly, *Claasenia sabulosa*	95	49	2.8 (1.4-4.3)	40098001	Supplemental
Stonefly, *Isoperla* sp.	95	48	0.70 (0.47-0.90)	40098001	Supplemental

Species Tested	% ai	Duration (Hours)	EC_{50} in µg/L (95% confidence interval)	Reference MRID or ECOTOX	Classification
Stonefly, *Pteronarcella badia*	95	48	1.1 (0.78-1.5)	40098001	Supplemental
Water flea, *Daphnia magna*	95	48	1.0 (0.7-1.4)	40098001	Acceptable
Water flea, *Daphnia magna*	57	48	2.2 (1.9-2.5)	41029701	Acceptable
Water flea, *Daphnia magna*	--	24	--	Rawash et al., 1975 Eco ref. 005539	Invalid
Water flea, *Daphnia magna*	96.9	48	--	47540303	Invalid
Water flea, *Daphnia pulex*	95	48	1.8 (1.4-2.4)	40098001	Acceptable
Water flea, *Simocephalus serrulatus*	**95**	**48**	**0.59* (0.46-0.77)**	**40098001**	**Supplemental**

*Endpoint used for quantitative assessment of risks.

No data are available on the oxon metabolite of malathion, maloxon, to freshwater invertebrates. Data on fish and amphibians indicate that maloxon is more toxic to than malathion (see section 4.2.1.a). A similar relationship in toxicity is expected for aquatic invertebrates. Two studies with the water flea (*Daphnia magna*) have been submitted that measures the toxicity of two other degradation products of malathion, malathion monocarboxilic acid and malathion dicarboxylic acid (Table 4-9). Both of these tests were classified as supplemental because the test was conducted with only one replicate chamber per test level, and the report lacked details about the health of the brood culture and did not provide required measurements of some water quality parameters. The studies nevertheless provide an approximate estimation of toxicity of these degredation products. Note that the results presented in Table 4-9 are expressed as mg/L, rather than µg/L as in other tables. These results indicate that both of these degradation products are over 1000× less toxic to freshwater invertebrates than the parent compound, malathion. No acute freshwater invertebrate data were available on the toxicity of formulated products of malathion.

Table 4-9. Studies with the Water Flea (*Daphnia magna*) Measuring the 48-hr Toxicity of Degradation Products of Malathion to Freshwater Invertebrates

Test Material	% ai	Duration (Hours)	EC_{50} in mg/L	Reference MRID or ECOTOX	Classification
Malathion dicarboxylic acid	98.8	48	66.9 (48.1 - 93.0)	47540305	Supplemental
Malathion monocarboxylic acid (α and β mixture)	92.2	48	3.1 (1.7 - 7.0)	47540310	Supplemental

4.2.2.b. Freshwater Invertebrates: Chronic Exposure Studies

Table 4-10 presents available chronic exposure effects endpoints for freshwater invertebrates. There are limited chronic effects studies for malathion. A life-cycle study with *Daphnia magna* yielded chronic NOAEC and LOAEC values of 0.060 µg/L and 0.10 µg/L, respectively (MRID 41718401). These chronic endpoints were based on a 16.5% reduction in number of young produced per day observed at the 0.10 µg/L exposure level. Because acute toxicity data indicates that the water flea *Simocephalus serrulatus* is more sensitive than *Daphnia magna*, a chronic endpoint was estimated for that species using the acute-to-chronic ratio (ACR) method. The ACR calculated based on data for *Daphnia magna* is 1.0/0.06 or 16.7. The estimated chronic NOAEC for *Simocephalus serrulatus* is therefore 0.59/16.7 or 0.035 µg/L. This value was used as the endpoint for quantitative assessing the chronic risk of malathion to aquatic invertebrates.

Table 4-10. Freshwater Invertebrate Chronic Exposure Toxicity Studies from OPP Data and ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species Tested	% ai	Duration (Days)	NOAEC (µg/L)	LOAEC (µg/L)	Reference MRID or ECOTOX	Classification
Water flea, *Daphnia magna*	**94**	**21**	**0.06**	**0.1**	**41718401**	**Acceptable**
Water flea, *Daphnia magna*	--	21	0.15	not reported	ECOTOX ref. 006449	Supplemental

*Endpoint used for quantitative assessment of risks.

4.2.3. Toxicity to Estuarine/Marine Fish

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

Table 4-11 summarizes acute toxicity data on the effects of malathion to estuarine and marine fish obtained from studies submitted by pesticide registrants and studies conducted at the USEPA Environmental Research Laboratory (Mayer, 1986, MRID 40228401). Also included in this table are results from one additional study on acute toxicity to estuarine/marine fish from the open literature which yielded a lower endpoint than any of the USEPA data. The lowest 96-hr LC_{50} value reported was 27 µg/L for the bluehead wrasse (*Thalassoma bifasciatum*). Given that the DS can occur in both freshwater and brackish, this endpoint, which is less than the freshwater fish acute endpoint, was used in the quantitative risk assessment for direct effects to the DS.

Table 4-11. Studies Measuring the 96-hr Toxicity of Two Degradation Products and One Formulated Product of Malathion to Freshwater Fish

Test Species	% ai	Duration (Hours)	LC_{50} in µg ai/L	Reference MRID or ECOTOX	Classification
Bluehead wrasse *Thalassoma bifasciatum*		96 hr	**27***	**Eco ref 000628 (Eisler, 1970)**	Quantitative
Longnose killifish	95	48 hr	150 (N.R.)	MRID 40228401	Supplemental
Sheepshead minnow (*Cyprinodon variegatus*)	95	96 hr	33.0 (14-63)	MRID 41174301	Acceptable
Sheepshead minnow (*Cyprinodon variegatus*)	57	96 hr	53 (46-67)	MRID 41252101	Acceptable
Spot	95	48 hr	320 (N.R.)	MRID 40228401	Supplemental
Striped bass	95	96 hr	60 (N.R.)	MRID 00156311	Supplemental
Striped mullet (*Mugil cephalus*)	95	48 hr	330 (N.R.)	MRID 40228401	Supplemental

*Endpoint used for quantitative assessment of risks.

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

No submitted data on the chronic toxicity of malathion to estuarine/marine fish are available. A search of the ECOTOX database yielded only one study that provided information on the chronic toxicity of malathion to a marine/estuarine fish and used experimental methods comparable to the EPA test guideline. This study was an unpublished Ph.D. dissertation that reported acute and chronic toxicity of malathion to red drum (*Sciaenops ocellatus*) larvae (ECOTOX Ref. No. 081672, Alvarez, 2005). According to this report, malathion did not cause any significant effects on the growth rate, behavior, or respiration rates in either of the two test concentrations (1.0 and 10 µg/L, nominal). The measured day-0 concentration of the higher test concentration was 7.4 µg/L. The study therefore established a NOAEC value for the Red drum at 7.4 µg/L, but a LOAEC value was not determined.

Given that a chronic LOAEC has not been established for marine/estuarine fish, and it is unclear whether the red drum is sensitive to malathion, a chronic effect NOAEC value endpoint was estimated for the bluehead wrasse based on acute and chronic toxicity data for freshwater fish. The NOAEC was estimated for the bluehead wrasse, the most sensitive marine/estuarine fish based on acute toxicity data, using the acute-to-chronic ratio (ACR) calculated based on rainbow trout data. For the rainbow trout, the LC_{50} obtained in a study that was found to be acceptable for quantitative risk assessment was 32.8 µg/L (Animal Biology Laboratory, 1968). The chronic NOAEC was for the rainbow trout was 21 µg/L (41422401). The ACR was thus 1.56. The bluehead wrasse 96-hr LC_{50} value (27 µg/L, Eco ref 000628) was divided by this ratio to yield an estimated marine/estuarine fish NOAEC value of 17.3 µg/L. This estimated NOAEC was used for the quantitative risk assessment to evaluate direct and indirect chronic effects to the DS. Characterization of the predicted ACR and resulting NOAEC based on consideration of the full range of acute rainbow trout data is provided as part of the Risk Description.

4.2.4. Toxicity to Estuarine/Marine Invertebrates

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

Table 4-12 gives results of studies of the acute toxicity of malathion to estuarine and marine invertebrates which were submitted by pesticide registrants or obtained from studies conducted at the EPA's Environmental Research Laboratory (MRID 40228401, Mayer, 1986). Table 4-12 also reports results from one study published in the open literature that reported acute toxicity of malathion to a saltwater amphipod, *Gammarus palustris* (Leight and Van Dolah, 1999, Eco ref. 051439). Results of this study are presented because they are essentially equivalent to the lowest acute endpoint obtained from EPA laboratory or registrant submitted studies. Another study in the open literature reported a lower LC_{50} of 1.2 µg/L for the Dungeness crab, *Cancer magister* (Caldwell, 1977, Eco ref. 006793). However, this study is classified as invalid, meaning the results are not suitable for quantitative or qualitative assessment of risk. This conclusion was based on a lack of negative controls, the reporting of nominal concentrations without indication if they were corrected for percent active ingredient, and the lack of availability of raw data. All other results from other published studies on acute toxicity to marine/estuarine invertebrates were higher (indicating less toxicity) and therefore are not reported here, but are presented in Appendix I. No additional information on the toxicity of maloxon or formulations of malathion to estuarine/marine invertebrates was available.

The lowest acute toxicity endpoint obtained for estuarine/marine invertebrates is the 96-hr LC_{50} value of 2.2 µg/L for the mysid (*Mysidopsis bahia*) (MRID 41474501). This toxicity value was used in the quantitative risk assessment for indirect effects (effects on food abundance) to the DS.

Table 4-12. Studies Measuring the 96-hr Toxicity of Malathion to Marine and Estuarine Invertebrates

Test Species	% ai	Duration (Hours)	EC_{50} or LC_{50} in µg ai/L	Reference MRID or ECOTOX	Classification
Blue Crab, *Callinectes sapidus*	95	48 hr	LC_{50} > 1000	MRID 40228401	Supplemental
Eastern oyster, *Crassostrea virginica*	95	96 hr	LC_{50} > 1000	MRID 40228401	Supplemental
Eastern oyster, *Crassostrea virginica*	57	96 hr	EC_{50} = 2960 (N.R.)	MRID 42249901	Acceptable
Gammarid amphipod *Gammarus palustris*	Tech.	96 hr	LC_{50} = 2.29 (1.74-3.03)	Eco ref 051439	Quantitative
Mysid, *Mysidopsis bahia*	**94**	**96 hr**	**LC_{50} = 2.2* (1.5-2.6)**	**MRID 41474501**	**Acceptable**
Pink shrimp, *Penaeus duorarum*	95	48 hr	LC_{50} = 280 (N.R.)	MRID 40228401	Supplemental

*Endpoint used for quantitative assessment of risks.

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

No submitted or open literature data on the chronic toxicity of malathion to estuarine/marine invertebrates were available. Therefore, a chronic NOAEC value was estimated using the ACR method based available acute and chronic toxicity data for the water flea (*Daphnia magna*). The water flea 48-hr EC_{50} value (0.59 µg/L) and NOAEC value (0.060 µg/L) yielded an ACR of 16.7. The mysid 96-hr LC_{50} value of 2.2 µg/L was divided by this ratio to yield an estimated estuarine/marine invertebrate NOAEC of 0.13 µg/L.

This estimated NOAEC was used for the quantitative risk assessment to evaluate direct and indirect chronic effects to the DS. Characterization of the predicted ACR and resulting NOAEC based on consideration of the full range of acute water flea data is provided as part of the Risk Description.

4.2.5. Toxicity to Aquatic Plants

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

Pesticide registrants have submitted no data to the Agency on the toxicity of malathion to aquatic plants. Table 4-13 summarizes available aquatic plant effects data obtained from the open literature. For unicellular aquatic plants, the lowest EC_{50} and NOAEC obtained were 2.32 mg/L and 0.50 mg/L, respectively. For vascular plants, there is no established EC_{50}; however, the NOAEC value was established at 24.1 mg/L based on no significant difference in biomass and fond number when compared to the control. The results from the study with green algae (Eco. ref 085816) were used quantitatively in the risk assessment, whereas the NOAEC reported for duckmeat (Eco ref. 054278) was used qualitatively as an indication that aquatic vascular plants are likely less sensitive to malathion than algae.

Table 4-3-13. Aquatic Plant Toxicity Studies from OPP Data and ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species Tested	% ai	Duration (Days)	EC_{50} (mg ai/L)	NOEAC (mg ai/L)	Reference MRID or ECOTOX	Classification
Blue-green algae *Anabaena flosaquae*	57	6	73.6	--	Eco ref. 061937 (Piri and Ordog, 1999)	Qualitative
Green algae *Scenedesmus obstusiusculus*	57	6	31.6	--	Eco ref. 061937 (Piri and Ordog, 1999)	Qualitative
Green algae *Dunaliella tertiolecta*	--	1	17.9	--	Eco ref.066270 (McFetters et al, 1983)	Qualitative
Green algae *Pseudokirchneriella subcapitata*	**100**	**2**	**2.4* (1.5-3.6)**	**1.2***	**Eco ref. 085816 (Yeh and Chen, 2006)**	**Quantitative**
Duckmeat *Spirodela polyrhiza*	96.26	7	--	24.1	Eco ref. 054278 (Sinha, Rai, and Chandra, 1995)	Qualitative

*Endpoint used for quantitative assessment of risks.

4.3. Toxicity of Malathion to Terrestrial Organisms

Table 4-14 summarizes the most sensitive terrestrial toxicity endpoints, based on an evaluation of both the submitted studies and the open literature. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment for the DS and CTS is presented below. Additional information is provided in Appendix **G**I. All endpoints are expressed in terms of the active ingredient (a.i.) unless otherwise specified

Table 4-14. Terrestrial Toxicity Profile for Malathion

Assessment Endpoint	Acute/ Chronic	Species	Toxicity Value Used in Risk Assessment (95% confidence interval)	Citation MRID/ ECOTOX reference No.	Comment
Birds (surrogate for terrestrial-phase amphibians and reptiles)	Acute Oral	Ring-necked pheasant (*Phasianus colchicus*)	14-day LD_{50} = 167 (120-231) mg/kg-bw Slope NA	MRID 00160000 (Hudson et al. 1984)	Data was generated by the US Fish and Wildlife Service and considered acceptable for quantitative risk assessment.
	Acute Dietary	Japanese quail *Coturnix japonica*	8-day LC_{50} = 2128 (1780-2546) mg/kg-	MRID 00062189, Eco ref. 035214,	This study was classified as supplemental.

Assessment Endpoint	Acute/ Chronic	Species	Toxicity Value Used in Risk Assessment (95% confidence interval)	Citation MRID/ ECOTOX reference No.	Comment
			diet Slope 3.62	Heath et al., 1972	
	Chronic	Northern bobwhite *Colinus virginianaus*	NOAEC = 110 mg/kg-diet LOAEL = 350 mg/kg-diet	MRID 43501501	The results are based on observation of regressed ovaries at the 350 mg/kg level. Data are from an acceptable study submitted by the registrant.
Mammals	Acute	Laboratory rat (*Rattus norvegicus*)	LD_{50} = 852 (607-1196) mg ai/kg-bw	MRID 42045401	This study was classified as *guideline*. The test was with Clean Crop 8E, 79.5% AI.
	Chronic	Laboratory rat (*Rattus norvegicus*)	NOAEL = 1700 mg/kg-diet LOAEL = 5000 mg/kg-diet	MRID 41583401	The results are based on a reduction of body weight of F1 and F2 pups. This study was found to be acceptable for quantitative risk assessment.
Terrestrial invertebrates	Acute Contact	Honey bee (*Apis melliferra*)	LD_{50} = 0.20 µg/bee	MRID 05001991 (Stevenson, 1978)	This study was found to be acceptable for quantitative risk assessment.
Terrestrial plants	NA	NA	NA	NA	No data are available for quantitative risk assessment of terrestrial plants.

NA: not applicable; ND = not determined; bw = body weight

Acute toxicity to terrestrial animals is categorized using the classification system shown in Table 4-15 (USEPA, 2004). Toxicity categories for terrestrial plants have not been defined.

Table 4-15. Categories of Acute Toxicity for Avian and Mammalian Studies

Toxicity Category	Oral LD_{50}	Dietary LC_{50}
Very highly toxic	< 10 mg/kg	< 50 mg/kg-diet
Highly toxic	10 - 50 mg/kg	50 - 500 mg/kg-diet
Moderately toxic	51 - 500 mg/kg	501 - 1000 mg/kg-diet
Slightly toxic	501 - 2000 mg/kg	1001 - 5000 mg/kg-diet
Practically non-toxic	> 2000 mg/kg	> 5000 mg/kg-diet

4.3.1. Toxicity to Birds, Reptiles, and Terrestrial-Phase Amphibians

A summary of acute and chronic bird and terrestrial-phase amphibian data, including data published in the open literature, is provided below in Sections 4.3.1.a and 4.3.1.b. As specified in the Overview Document, the Agency uses birds as a surrogate for terrestrial-phase amphibians when toxicity data for that taxon are not available (USEPA, 2004).

4.3.1.a. Birds: Acute Exposure (Mortality) Studies

Data on the acute toxicity of malathion to birds were obtained from Hudson *et al.* (1984), Hill *et al*, 1975, and other open literature papers. Results of avian oral acute tests with malathion are tabulated in Table 4-17. The most sensitive species tested was the ring-necked pheasant (*Phasianus colchicus*). The LD_{50} obtained for this species, 167 mg/kg-bw, was used in this assessment for quantitative risk estimations to terrestrial-phase amphibians including the CTS.

Table 4-17. Avian Acute Oral Toxicity Studies from OPP Data and ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species	% AI	LD_{50} (mg/kg-bw) (95% confidence interval)	MRID or ECOTOX	Classification
Mallard duck (*Anas platyrhynchos*)	95	14-day LD_{50} = 1485 (1020-2150)	MRID 00160000 (Hudson et al. 1984)	Acceptable
Ring-necked pheasant (*Phasianus colchicus*)	**95**	**14-day LD_{50} = 167* (120-231)**	**MRID 00160000** (Hudson et al. 1984)	**Acceptable**
Horned lark (*Eremophila alpestris*)	95	14-day LD_{50} = 403 (247-658)	MRID 00160000 (Hudson et al. 1984)	Supplemental
Sharp-tailed grouse (*Tympanuchus phasianellus*)	tech	LD_{50} = 220 (171-240)	Crabtree, D.G., 1965, Denver Wildlife Res. Center, USFWS as cited in RED	Supplemental
Bantam chicken	97.7	LD_{50} = 524.8	ECOTOX ref. 036916	Supplemental

*Endpoint used for quantitative assessment of risks.

Data from subacute avian studies with dietary exposure were also used to assess the risk of malathion to terrestrial-phase amphibians. Subacute dietary toxicity data were obtained from studies conducted at the US Fish and Wildlife Service (Heath *et al*., 1972; Hill *et al*., 1975; Hill and Camardese, 1986). These data are tabulated in Table 4-18. The lowest subacute dietary LC_{50} reported is 2128 mg/kg-diet. This value was used in the quantitative risk assessment for acute risk to terrestrial-phase amphibians.

Table 4-18. Avian Subacute Dietary Toxicity Studies from OPP data and ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species	% ai	LC_{50} (mg/kg-diet) (CL's, when available)	Reference MRID or ECOTOX	Classification
Ring-necked pheasant *Phasianus colchicus*	95	8-day LC_{50} = 2639 (2220-3098)	MRID 00022923 Hill et al., 1975	Acceptable
Northern bobwhite *Colinus virginianaus*	95	8-day LC_{50} = 3497 (2959-4011)	MRID 00022923 Hill et al., 1975	Acceptable
Japanese quail	95	8-day LC_{50} = 2962	MRID 00022923	Supplemental

Species	% ai	LC_{50} (mg/kg-diet) (CL's, when available)	Reference MRID or ECOTOX	Classification
Coturnix japonica		(2453-3656)	Hill et al., 1975	
Japanese quail ***Coturnix japonica***	**100**	**8-day LC_{50} = 2128*** **(1780-2546)**	**MRID 00062189** **Eco ref. 035214** **Heath et al., 1972**	**Supplemental**
Japanese quail *Coturnix japonica*	95	8-day LC_{50} = 2968 (2240-3932)	MRID 40910905 Eco ref. 050181 Hill and Camardese, 1986	Supplemental
Mallard *Anus plytyrhynchos*	95	8-day LC_{50} > 5000	MRID 00022923 Hill et al., 1975	Acceptable

*Endpoint used for quantitative assessment of risks.

Avian toxicity data on maloxon and formulations of malathion are not available.

4.3.1.b. Birds: Chronic Exposure (Growth, Reproduction) Studies

Available avian reproduction laboratory study results are tabulated in Table 4-19. At food exposure concentrations of 350 mg/kg-diet, 4 of 15 female bobwhite quail exposed to malathion for 21 weeks displayed regressed ovaries and abnormally enlarged/flaccid gizzards. A reduction in the proportion of eggs hatched per eggs set also was observed at 350 mg/kg-diet. The NOAEC established in this study was 110 mg/kg-diet. This was the NOAEC reported from a fully acceptable study for chronic effects to birds, and was the value used in the quantitative risk assessment for chronic effects to birds and reptiles.

Table 4-19. Avian Reproduction Studies from OPP Data and ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species	% ai	LOAEC mg/kg-diet Effected Parameters	NOAEC mg/kg-diet	MRID	Classification
Northern bobwhite ***Colinus virginianaus***	**96.4**	**21-wk LOAEC = 350 -- regressed ovaries and enlarged/flaccid gizzards,** 21-wk LOAEC = 1200 – reduction in proportion of eggs hatches per eggs set.	**110***	**MRID 43501501**	**Acceptable**
Mallard	94.0	20-wk LOAEC =2400 Growth and viability	1200	MRID 42782101	Acceptable
Bantam	100	56-day LOAEC not determined for growth, weight, or egg production	>100[a]	Eco ref. 038417	Qualitative

*Endpoint used for quantitative assessment of risks.
a. No adverse effects were observed in any of the concentrations tested.

Available supplemental data obtained from the ECOTOX database provided information on the reproductive effects of malathion to the bantam chicken (a domesticated chicken). The Agency categorized these data as “qualitative” for ecological risk assessment because they were for effects to a domesticated species. The lowest NOAEC for reproduction effects and chick growth in one study is 100 mg/kg-diet, the highest exposure level tested. An additional study with the same species and malathion at similar purity provided both a NOAEC and LOAEC for growth (475 mg/kg-diet and 237.5 mg/kg-diet) and a NOAEC for egg production (475 mg/kg-diet).

When taken together, these studies suggest that effects on growth and egg production for this species are not expected until exposure levels reach or exceed 475 mg/kg-diet in the bantam chicken. Therefore, the 100 mg/kg-diet NOAEC value is considered to be an artifact of dose selection rather than a true threshold for effects in the species.

4.3.2. Toxicity to Mammals

A summary of acute and chronic mammalian data, including data published in the open literature, is provided below in Sections 4.3.2.a and 4.3.2.b. A more complete analysis of toxicity data to mammals is available in Appendix J, which is a copy of the Health Effects Division (HED) chapter prepared in support of the reregistration eligibility decision completed in 2002, the most recently completed HED chapter for malathion.

4.3.2.a. Mammals: Acute Exposure (Mortality) Studies

Table 4-20 presents the available acute mammalian toxicity endpoints obtained from the Office of Pesticide Program's Health Effects Division (HED) and the open literature. The rat LD_{50} of 1036 mg/kg-bw reported by Boyd and Tanikella (1969) was the lowest acute endpoint; however, the Agency determined that the results from this study are not acceptable for quantitative use in risk assessment because the experimental design was not adequately described, the mortality data were not provided, and the statistical calculations were uncertain and incomplete. The next lowest LD_{50} value in an acceptable mammal acute toxicity study was 1072 mg/kg-bw, or 852 mg ai/kg-bw, from an acceptable study submitted by the registrant (MRID 42045401). This study was conducted with the product Clean Crop Malathion 8E ® (Registration Number 34704-00452). This value will be used was used in the risk assessment to evaluate indirect effects to the CTS related to acute toxic effects of malathion to mammals.

Table 4-20. Summary of Acute Toxicity Data of Malathion to Mammals

Species	Test Material (Reg. Number)	% AI	LD_{50} (mg ai/kg-bw)	MRID, Citation	Classification
Norway Rat (*Rattus norvegicus*)	TGAI	97.4	5400 (M) 5700 (F)	MRID 00159876	Acceptable
Norway Rat (*Rattus norvegicus*)	TGAI	80	1310 (M) 1550 (F)	MRID 00144490	Guideline
Norway Rat (*Rattus norvegicus*)	TGAI	95	1036	Eco ref. 108637 (Boyd and Tanikella, 1969)	Qualitative
Norway Rat (*Rattus norvegicus*)	TGAI	NR	2880 (M) (2660-3110)	Dauterman and Main, 1966	Qualitative
Norway Rat (*Rattus norvegicus*)	Fyfanon 57 (04878-0005)	96.5	3281 (2606-3957)	MRID 40247202	Guideline
Norway Rat (*Rattus norvegicus*)	**Clean Crop 8E (34704-00452)**	**79.5**	**852 (607-1196)**	**MRID 42045401**	**Guideline**
Norway Rat (*Rattus norvegicus*)	Malathion 8 EC (66330-00248)	80.75	2870 (M) 1360 (F)	MRID 43072404	Acceptable

*Endpoint used for quantitative assessment of risks.

Two studies submitted to the Agency indicate that malathion has relatively low acute toxicity to mammals when exposed through dermal and inhalation routes. The acute dermal LD_{50} for malathion was found to be greater than 2000 mg/kg (MRID 00159877). The acute inhalation LC_{50} was determined to be greater than 5.2 mg/L (MRID 00159878).

Malathion degrades and is metabolically transformed into the oxon derivative, maloxon, which is more toxic than the parent compound. No data on the acute toxicity of maloxon have been submitted by the registrant. Two studies in the open literature provide acute oral LD_{50} estimates for maloxon (Table 4-20). However, the Agency's review of these studies determined that they should not be used qualitatively in this risk assessment because of uncertainty of the purity of the test compounds and lack of information provided on the test methods. Both of these determined the acute oral LD_{50} of malathion as well. The reported malathion LD_{50} was 2880 mg/kg-bw in Dauterman and Main (1966), and 1942 mg/kg-bw in Chiu et al. (1968). These resulting estimated ratio of the malathion LD_{50} divided by the maloxon LD_{50} (*i.e.*, the number of times more toxic maloxon is to rats relative to malathion) is 18.2 based on data from Dauterman and Main (1966), and 7.99 based on data from Chiu *et al.* (1968).

Table 4-21. Reported Acute Oral Toxicity of Maloxon to Mammals

Species	Test Material[1]	LD_{50} (mg/kg-bw)	MRID, Citation	Classification
Norway Rat (*Rattus norvegicus*)	Carbethoxy malaoxon	158 (142 – 175)	Dauterman and Main, 1966	Qualitative
Norway Rat (*Rattus norvegicus*)	Succinate malaoxon	243 (218-280)	Chiu et al., 1968	Qualitative

[1] The exact descriptions of the test material as presented in the paper are provided. The Agency believes both of these test materials are equivalent to the form of maloxon that would form in the environment.

4.3.2.b. Mammals: Chronic Exposure (Growth, Reproduction) Studies

Table 4-21 presents the available chronic mammalian toxicity endpoints obtained from HED and the open literature that relates exposure to malathion to adverse growth and reproductive effects. The rat NOAEC of 1700 mg/kg-diet was the lowest chronic endpoint reported (MRID 41583401). This value was used in the risk assessment to evaluate indirect effects to the CTS related to chronic toxic effects of malathion to mammals.

Table 4-21. Malathion Chronic Mammalian Toxicity Data

Species	% AI	NOAEC (mg/kg-diet)	LOAEC (mg/kg-diet) Effected Parameters	Reference MRID or ECOTOX	Classification
Rat	Tech	Not determined	4000 reduced pup survival and 9-week body weight	Eco ref. 104601 (Kalow and Marton, 1961)	Qualitative
Rat	**94.0**	**1700***	**5000** **Reduced pup body weight**	**MRID 41583401**	**Acceptable**

*Endpoint used for quantitative assessment of risks.

4.3.3. Toxicity to Terrestrial Invertebrates

4.3.3.a. Terrestrial Invertebrates: Acute Exposure (Mortality) Studies

Table 4-22 tabulates available data on the effects of malathion on nontarget terrestrial invertebrates. Data were obtained from registrant submitted bee toxicity studies and from studies in the ECOTOX open literature query. Many of the studies listed in ECOTOX did not provide a quantitative estimate of the level of effect beyond a listing of near zero or near 100 percent. These studies have not been included in the following list as they do not provide endpoints useful for quantitative risk assessment. The most sensitive acute contact LD_{50} value obtained from a reliable source is 0.20 µg/bee for the honey bee (*Apis mellifera*) (MRID 05004151, Stevenson, 1968). This value will be used in the quantitative assessment of acute effects of malathion to nontarget insects.

Table 4-22. Non-Target Insect Acute Contact Toxicity Studies from OPP data and ECOTOX Studies Meeting Minimum Quality for Database and OPP

Species	% AI	LD_{50} (µg ai/animal)	Reference MRID or ECOTOX	Classification
Honey bee ***Apis mellifera***	**Tech**	**48 HR LD_{50} = 0.20***	**MRID 05001991 (Stevenson, 1978)**	**Acceptable**
Honey bee *Apis mellifera*	Tech	96 HR LD_{50} = 0.709 Slope = 8.04	MRID 0001999	Acceptable
Honey bee *Apis mellifera*	Tech	LD_{50} = 0.24[a] Slope = 8.3[a]	MRID 05004151 (Stevenson 1968)	Acceptable
Honey bee *Apis mellifera*	100	72 hr LD_{50} = 0.46	MRID 05008990 (Johansen et al., 1963)	Acceptable
Alfalfa leafcutter bee *Megachile rotundata*	100	72-hr LD_{50} =0.23	MRID 05008990 (Johansen et al., 1963)	Acceptable

*Endpoint used for quantitative assessment of risks.
[a] Results are weighted means of mean values reported for two tests conducted in 196 4 and 3 tests conducted in 1965. The duration of observation was not reported.

Johansen, C., Jaycox, E. R., and Hutt, R. (1963) determined the acute oral toxicity of technical grade malathion to the honey bee. The acute oral LD_{50} was found to be 0.38 µg/bee (MRID 05004151) and 0.76 µg/bee (MRID 05001991).

Aikins and Wright (1985) studied the acute toxicity of malathion to various larval stages of the cabbage moth (*Mamestra brassicae*). Twenty-four hour LD_{50} values, expressed in terms of µg per g of insect, ranged from 3.7 to 12.7 µg/g for topical application, 3.3 to 5.9 µg/g for application by injection, and 102 to 245 µg/g for application in food (Table 4-23). Note that these values are not directly comparable to those in Table 4-22 because the units are different.

Table 4.23. Acute 24-hr LD_{50} Values for the Instars of the Cabbage Moth (*Mamestra brassicae*) Exposed to Malathion by Three Types of Applications (from Aikins and Wright, 1985)

Larvae Instar	**24-hr LD_{50} (µg/g insect)**	**95% C.I.**	**Slope (±s.e.)**
Topical Application			
Second	3.7	0.9-9.5	0.8 (±0.1)
Third	7.3	2.6-16.9	1.0 (±0.1)
Fourth	11.3	2.4-38.3	1.1 (±0.2)
Fifth	10.2	2.3-29.2	1.0 (±0.2)
Sixth	12.7	3.7-39.1	0.7 (±0.1)
Application by Injection			
Fourth	3.3	1.2-7.4	0.7 (±0.1)
Fifth	5.0	0.9-18.6	0.7 (±0.2)
Sixth	5.9	2.1-14.7	0.8 (±0.1)
Application by Diet			
Fifth	102	89-135	2.0 (±0.4)
Sixth	245	214-387	0.9 (±0.2)

In 1989, the Malathion Registration Task Force submitted data on the toxicity of Cythion 57% EC to the honey bee (MRID 41208001). Cythion 57% EC is a formulated product containing 57% malathion, 30% xylene, and 13% inactive ingredients. (This formulation is no longer registered for use in the United States.) The formulated product was applied to alfalfa at a rate of 40 gal/acre, or 1.6 lb ai/acre. The alfalfa was aged and weathered in the field for selected periods under ambient outdoor conditions. The alfalfa was then chopped and placed in bee test chambers. Approximately 450 bees were introduced to the test chambers and monitored for mortality for 24 hours. This study found that residues on alfalfa caused mortality to honey bees when the alfalfa had been aged for 8 hours, but did not cause significant mortality when residues had been aged for 24 hours. The study concluded that application of this formulated product on alfalfa is highly toxic to honey bees for between 8 and 24 hours after application.

Martinez and Phenkowski (ECOTOX ref. 37837) reported immersion contact LC_{50} values (2 second immersion, 24 hour post exposure observation) for three insect species. The LC_{50} values for the potato leafhopper (*Empoasca fabae*), tarnished plant bug (*Lygus lineolaris*), and the predatory nabid (*Reduviolus americoferus*) were reported to be 41.32, 68.08, and 273.13 mg/l, respectively.

Panda and Sahu (ECOTOX ref. 52962) reported 96 hour LC_{50} values for the field earthworm (*Drawida willsi*) ranging from 15.1 to 18.8 mg/kg-soil. The same authors (ECOTOX ref. 89517) reported a reduction in the population of the same earthworm species relative to controls (measures at 60 days post application in laboratory colonies) at a malathion soil concentration of 2.2 mg/kg.

4.3.4. Toxicity to Terrestrial Plants

The risk assessment process relies predominantly on effects endpoints associated with seedling emergence, growth, and plant viability. There are no submitted registrant data for malathion and terrestrial plants. However, Brown *et al.* (1987) provides data on the phytotoxic effects of malathion to terrestrial plants that is comparable to the Agency's vegetative vigor tier-1 test guideline (850.4150). This study evaluated the use of malathion in "chemical exclusion" studies, that is ecological experiments in which a chemical is applied to exclude insect herbivores from experimental plots of natural vegetation. Five native herbaceous plant species (*Capsella bursa-pastoris*, *Chenopodium album*, *Raphanus raphanistrum*, *Lotus corniculatus*, and *Plantago lanceolata*) were grown from seeds in a greenhouse and then tested. Fifteen seedlings in individual pots were sprayed with Malathion-60 (60% malathion w/v) at a rate of 0.126 g ai/m^2 (1.41 lb ai.A), and fifteen control seedlings were treated with an equal volume of water. To compare plant growth, plant height and number of leaves were measured in all species. Biomass of plants harvested at the end of the growing season was also measured. The study found no significant difference between treated and control plants in any of these endpoints. The study authors concluded that the application of malathion showed no significant effects on the vegetation.

Efficacy tests, which evaluate the performance of malathion on protecting crops from insect damage, in some cases also provide data on effects of yield. This yield data provides information on the effects of malathion treatment to plants. Efficacy studies that tested application of malathion on wheat (rate 1.25 lb ai/A), field peas (rate 1.00 lb ai/A), and birdsfoot trefoil (rate 1.25 lb ai/A) found no significant difference between the plant yield in treated plots compared to untreated control plots (Beauerfeind and Wilde, 1993; Thompson and Sanderson, 1977; Peterson et al. 1992). Other efficacy tests on small grain (rate 1.0 lb ai/A) and cabbage (rate 0.89 lb ai/A) found significantly increased yields of plants in treated plots compared to control plots, presumably because of reduction of herbivorous insect pests (Noetzel, 1994, Azad Thukur and Deka, 1997,). These results indicate that exposure of malathion at rates between 0.89 and 1.25 lb ai/A do not cause toxic effects to terrestrial plants.

Finally, Allen and Snipes (1995) studied the interaction of foliar insecticides and the herbicide pyrithiobac when applied to greenhouse-grown cotton. As a control, the study included an evaluation of the effects of malathion applied alone. Endpoints measured were 14-day shoot wet weight and 14-day visually estimated plant injury. This test found that a foliar application malathion of 1.16 lb ai/A had no significant effect on treated cotton plants when compared to untreated control plants.

These studies provide evidence that malathion does not cause significant phytotoxic affects to both monocot and dicot terrestrial plants. This conclusion is further supported by the fact that malathion has been used for many years on a very wide variety of herbaceous and woody plants for protection from pests. The popularity of its use indicates that it is either nontoxic to plants at the use rates, or that any toxicity is minor and less than beneficial effects provided by protection from herbivorous insects. Exposure to natural vegetation off the treatment site, resulting from spray drift and runoff, would be only a fraction of the rate of the target plants that are treated directly. Since malathion has little or no adverse effects on the target plants, it is not predicted to have significant adverse effects to vegetation in the habitat of the DS or the CTS.

Finally, Lichtenstein *et al.* (1962) reports statistically significant ($P<0.01$) reductions in corn root length in seedlings grown for 21-days in a pure quartz sand matrix treated with 30 mg/kg malathion. However, this root length reduction did not translate into any adverse effect in above ground growth of the plants or reduction in root or shoot dry weight. Given the extreme growing conditions in pure quartz sand and the lack of frank effects on plant growth this study was judged not to demonstrate biologically relevant effects of malathion to monocot plants that would be manifested under field conditions.

4.4. Toxicity of Chemical Mixtures

As previously discussed, the results of available toxicity data for mixtures of malathion with other pesticides are presented in Appendix A. According to the available data, studies that tested the combined effects of malathion together with other pesticides have produced various results. When chemicals are present in the environment in combination with malathion, the toxicity of malathion may be increased, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they are also present in the mixture. The variety of chemical interactions presented in the available data set suggest that the toxic effect of malathion, in combination with other pesticides used in the environment, can be a function of many factors including but not necessarily limited to: (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of malathion and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (e.g. organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data. Studies that have evaluated the toxicity of the combination of malathion and other pesticides are summarized in Table 2-1 of Section 2.2.2. Appendix H also lists studies in the open literature that evaluated the toxicity of chemical mixtures of malathion.

4.5. Incident Database Review

A review of the Ecological Incident Information System (EIIS, version 2.1), the 'Aggregate Incident Reports' (v. 1.0) database, and the Avian Monitoring Information System (AIMS) for ecological incidents involving malathion was completed on February 22, 2010. The EIIS database contains data on pesticide-related incidents occurring through August 2009. The AIMS database contains data on pesticide-related avian incidents occurring through approximately August 2005. The results of this review for terrestrial, plant, and aquatic incidents are discussed below in Sections 4.5.1 through 4.5.3. A complete list of the incidents involving malathion is included as Appendix G.

Incidents recorded in these three databases include only reports which have been investigated, linked to one or more pesticide active ingredient, and reported to the Office of Pesticide Programs. We believe that these incidents represent only a fraction of the total number of incidents that have occurred. Incidents in this system are categorized by certainty, which indicates the Agency's judgment on the probability that malathion was the cause of the observed effects.

4.5.1. Aquatic Animal Incidents

Table 4-23 summarizes incidents reported in the EIIS database in which adverse effects to aquatic organisms were linked to use of malathion. The certainty level, which the Agency assigns to each incident, describes the level of certainty that malathion was the cause of the observed effects. Excluding incidents associated with misuses and those with a certainty level less than "possible," there were 23 incidents in which aquatic animals were killed. All of these incidents involved mortality of fish. One incident also involved death of blue crabs and one incident involved the death of an alligator. Aquatic incidents occurred in both freshwater and saltwater habitats. Incidents were associated with both agricultural uses and mosquito control uses of malathion. For both of these use types, there were numerous incidents with a high certainty level ("probable" or "highly probable"), providing strong evidence that both agricultural and mosquito control uses of malathion can sometimes result in mortality of fish and other aquatic organisms. There were 6 additional aquatic incidents with a certainty level of at least "possible" that were associated with known misuses of malathion.

Table 4-23. Summary of Aquatic Animal Incidents Associated with Malathion Use, by Certainty

Incident Type	Use Type	Certainty				
		All (excluding unlikely)	Unlikely	Possible	Probable	Highly Probable
Aquatic (excluding misuse)	Agricultural sites	10 (9)	1	4	4	1
	Mosquito control	7	0	1	4	2
	Unknown	7	0	4	2	1
	All	24 (23)	1	9	10	4
Aquatic (misuse only)	Agricultural sites	3 (2)	1	0	1	1
	Mosquito control	1	0	1	0	0
	Unknown/other	3	0	3	0	0
	All	7 (6)	1	3	1	1

In 1999, the population of the American lobster (*Homarus americanus*) in Long Island Sound suffered a severe mortality event, causing devastating economic damage to the regional lobster fishery. This die-off occurred following extensive aerial spraying of pesticides for vector control in the summer of 1999, which was undertaken in response to a widespread outbreak of West Nile Virus that was occurring at that time in the Northeast. Malathion had been applied in New York. Two pyrethroids (resmethrin and sumithrin) and methoprene were applied in both New York and Connecticut. Extensive research was undertaken after this event to identify the cause and to determine the role of exposure to these pesticides, if any, in the mortality event. The research ultimately concluded that an outbreak of a parasitic amoebae, *Neoparamoeba pemaquidensis*, was the proximal cause of the lobster mortality, but that multiple other stressors, including pesticide exposure, may have contributed to the die-off by physiologically weakening the lobsters, making their immune response too weak to fend off the disease (Pearce and Balcom, 2005). The findings of the numerous research projects on this topic and the potential contribution of malathion in the causation of this event is currently being investigated.

The query of the Aggregate Incident Reports database identified an additional four incidents linked to malathion use. According to the reporting rule for FIFRA Section 6(a)2, these incidents were reported to the Agency by pesticide registrants as aggregated counts of minor fish/wildlife incidents (W-B). Because details about these incidents were not reported, no information was available on the use site, the certainty level, or on the types of organisms that were involved. The Agency does not know if these minor incidents involved effects to fish or terrestrial wildlife; however, based on other reported incidents, they are more likely to involve aquatic organisms than terrestrial wildlife.

4.5.2. Terrestrial Animal Incidents

Table 4-13 summarizes incidents reported in the EIIS database in which adverse effects to terrestrial animals were linked to use of malathion. Eight incidents of bee kills were associated with malathion use. For three incidents, the Agency assigned certainty level of “probable” or “highly probable.” The bee incidents were associated with use of malathion on cherries (3 incidents), alfalfa (1 incident), cotton (1 incident), and unknown use sites (2 incidents). These incidents provide evidence that agricultural use of malathion can harm nontarget insects. No bee kill incidents were associated with mosquito control use.

Table 4-13. Summary of Terrestrial Animal Incidents Associated with Malathion Use, by Certainty

Incident Type	Use Type	Certainty				
		All	Unlikely	Possible	Probable	Highly Probable
Bees	Agricultural sites	6	0	3	1	2
	Unknown	2	0	2	0	0
	All	8	0	5	1	2
Wildlife	Mosquito control	1	0	1	0	0
	Unknown	1	0	1	0	0
	All	2	0	2	0	0

Only two incidents associated with malathion use involved mortality of wildlife. For both these incidents, the certainty level was “possible.” In both cases, wildlife was exposed to one or more pesticide, other than malathion, which is highly toxic to wildlife. In one incident involving mortality of 10 fox squirrels, the squirrels also were exposed to zinc phosphide, a rodenticide which frequently causes mortality of nontarget mammals. In the other terrestrial wildlife incident in which 17 western sandpipers were killed, the birds also were exposed to temephos, an insecticide that is much more toxic to birds than does malathion. It is uncertain how much exposure to malathion contributed to these mortalities.

A query of the AIMS database identified two additional bird kill incidents that were linked to exposure to malathion; however, in both cases the probable cause of death was diazinon exposure. The AIMS Event IDs for these two additional incidents are 190 and 254. These incidents were entered in EIIS as B0000-400-51 and B0000-400-82, respectively, but malathion was not recorded in the EIIS as a possible cause of death. In both cases, residue analysis of the carcass revealed very large amounts of diazinon and only trace amounts of malathion. Considering this, and the fact that diazinon is much more toxic to birds than is malathion, the malathion exposure likely had little if any role in causing the bird mortality in both incidents.

4.5.3. Plant Incidents

Table 4-14 summarizes incidents reported in the EIIS database in which adverse effects to plants were linked to use of malathion. Four incidents of plant damage have been associated with the use of malathion. One of these was assigned a certainty of "unlikely" and the other three were assigned a certainty of "possible." Of the three incidents with a certainty of "possible," two involved exposure to other pesticides, making the determination of cause uncertain. The third "possible" incident was a complaint from a homeowner that use of a product containing malathion damaged ornamental roses; however, this allegation was not verified.

Table 4-14. Summary of Plant Incidents Associated with Malathion Use, by Certainty

Incident Type	**Use Type**	**Certainty**				
		All (excluding unlikely)	**Unlikely**	**Possible**	**Probable**	**Highly Probable**
Plants	Agricultural use	2 (1)	1	1	0	0
	Homeowner use	1	0	1	0	0
	Unknown	1	0	1	0	0
	All	4 (3)	1	3	0	0

The query of the Aggregate Incident Reports database identified an additional 216 minor plant damage incidents linked to malathion use. According to the reporting rule for FIFRA Section 6(a)2, these incidents were classified as minor plant damage incidents (P-B) and were reported only as aggregated counts. Because details about these incidents were not reported, no information was available to determine the certainty level. Most of the incidents were associated with use of malathion products sold for residential uses. Homeowners frequently issue complaints to pesticide registrants that pesticide products caused damage to ornamental plants, but these complaints are usually not investigated and thus the cause of the reported plant damage is seldom determined.

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

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

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

5. Risk Characterization

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

5.1. Risk Estimation

Risk is estimated by calculating the ratio of exposure to toxicity. This ratio is the risk quotient (RQ), which is then compared to pre-established acute and chronic levels of concern (LOCs) for each category evaluated (Appendix C). For acute exposures to the aquatic animals, as well as terrestrial invertebrates, the LOC is 0.05. For acute exposures to the birds, mammals, reptiles, and terrestrial-phase amphibians the LOC is 0.1. The LOC for chronic exposures to animals, as well as acute exposures to plants is 1.0.

Acute and chronic risks to aquatic organisms are estimated by calculating the ratio of exposure to toxicity. Exposure values were 1-in-10 year aquatic EECs (Table 3-) based on the label-recommended malathion use scenarios summarized in Appendix D. Toxicity values were appropriate aquatic toxicity endpoint from Table 4-1. Acute and chronic risks to terrestrial animals are based on estimated residues on terrestrial food items predicted for malathion uses (Table 3-6 through 3-8) and the appropriate toxicity endpoint from Table 4-14.

5.1.1. Exposures in the Aquatic Habitat

5.1.1.a. Freshwater Fish and Aquatic-phase Amphibians

Acute risk to fish and aquatic-phase amphibians is based on 1 in 10 year peak EECs in the standard pond and the lowest acute toxicity value for freshwater fish. Chronic risk is based on the 1 in 10 year 60-day EECs and the lowest chronic toxicity value for freshwater fish. Risk quotients for freshwater fish are shown in Table 5-1. Acute RQs ranged from 0.02 to 2.72 for non-aquatic agricultural uses, 16.6 to 34.0 for aquatic agricultural uses (rice, wild rice, and water cress), and 0.02 to 1.82 for nonagricultural uses. The acute RQ exceeded the LOC for acute risk for all use sites except passion fruit and ULV application citrus, ULV wide area application (e.g. adult mosquito control), cull piles, and fence rows. Due to the rapid degradation of malathion, chronic RQs generally were lower than acute RQs. They ranged from 0.02 to 1.52 for non-aquatic agricultural uses, 63.7 to 130 for aquatic agricultural uses, and 0.01 to 0.83 for nonagricultural uses.

Table 5-1. Acute and Chronic RQs for Freshwater Fish. Risk quotients that exceed the LOC are shown in bold. The acute LOC is 0.5 for the acute effects and 1.0 for chronic effects.

Scenario	Application Method	EECs		Risk Quotient	
		Peak EEC	60-day EEC	Acute	Chronic
1. Alfalfa, Clover, Lespedeza, Lupine, Grain Lupine, Trefoil, and Vetch	A	22.5	4.9	**0.68**	0.57
	ULV	8.2	1.1	**0.25**	0.13
	G	15.5	2.1	**0.47**	0.25
2. Macadamia Nut (Bushnut)	G	16.0	2.4	**0.48**	0.28
	AB	15.6	2.3	**0.47**	0.26
3. Pecan and Walnut (English/Black)	G	34.9	4.6	**1.06**	0.54
	AB	33.0	4.2	**1.00**	0.49
6. Date	A	62.2	13.3	**1.88**	**1.54**
	G	52.3	9.2	**1.59**	**1.07**
8. Avocado	G	59.3	4.8	**1.80**	0.55
9. Citrus Hybrids Other Than Tangelo, Grapefruit, Kumquat, Lemon, Lime, Orange, Tangelo, and Tangerines	A	50.1	8.3	**1.52**	0.97
	ULV	2.7	0.5	**0.08**	0.06
	G	23.1	2.4	**0.70**	0.28
	AB	22.1	2.1	**0.67**	0.25
10. Broccoli, Broccoli Raab, Cabbage, Chinese Amaranth, Chinese Broccoli, Chinese Cabbage, Canola\Rape, Cauliflower, Cole Crops, Collards, Corn Salad, Dock (Sorrel), Horseradish, Kale, Kohlrabi, Leafy Vegetables, Mustard, Mustard Cabbage (Gai Choy/ Pak-Choi), and Garden and Winter Purslane	A	37.6	7.6	**1.14**	0.89
	G	32.6	4.7	**0.99**	0.55
11. Corn (Silage and Unspecified), Field, Pop, and Sweet Corn, Millet (Foxtail), and Sunflower	A	33.7	3.8	**1.02**	0.44
	ULV	23.3	2.9	**0.71**	0.33
	G	22.3	2.4	**0.67**	0.28
12. Cotton (Unspecified)	A	37.3	5.8	**1.13**	0.67
	ULV	26.0	4.5	**0.79**	0.52
	G	23.8	2.7	**0.72**	0.31
13. Hops	A	14.6	2.2	**0.44**	0.26
	G	11.4	1.4	**0.35**	0.16
	AB	11.1	1.3	**0.34**	0.15
15. Apricot	G	10.7	1.2	**0.32**	0.14
	AB	10.1	1.0	**0.31**	0.12

Scenario	Application Method	EECs		Risk Quotient	
		Peak EEC	60-day EEC	Acute	Chronic
16. Nectarine and Peach	G	25.3	2.9	**0.77**	0.34
	AB	24.0	2.6	**0.73**	0.30
17. Cherry	A	16.7	2.5	**0.50**	0.29
	ULV	15.4	4.7	**0.47**	0.55
	G	19.8	2.4	**0.60**	0.28
	AB	18.5	2.1	**0.56**	0.24
18. Fig	G	17.0	1.8	**0.52**	0.21
	AB	16.0	1.6	**0.48**	0.19
19. Pear	G	10.1	1.1	**0.31**	0.12
	AB	9.5	1.0	**0.29**	0.11
20. Guava, Mango, and Papaya	G	22.2	3.1	**0.67**	0.36
	AB	21.5	2.8	**0.65**	0.33
22. Garlic and Leek	A	34.2	4.1	**1.04**	0.47
	G	41.8	3.7	**1.27**	0.43
23. Grapes	G	12.8	1.4	**0.39**	0.16
	AB	11.8	1.2	**0.36**	0.14
26. Brussels Sprouts and Dandelion	A	52.0	5.7	**1.58**	0.67
	G	46.9	5.0	**1.42**	0.58
27. Chervil, Chrysanthemum - Garland, Endive (Escarole), Lettuce, Head and Leaf Lettuce, Orach (Mountain Spinach), Parsley, Roquette (Arrugula), Salsify, Spinach, and Swiss Chard	A	83.1	8.8	**2.52**	1.03
	G	74.4	7.7	**2.25**	0.89
29. Eggplant	A	25.6	5.0	**0.78**	0.58
	G	42.2	4.5	**1.28**	0.52
30. Pumpkin	A	8.3	0.9	**0.25**	0.10
	G	5.7	0.4	**0.17**	0.05
31. Cantaloupe, Honeydew, Musk, Water, and Winter Melons (Casaba/Crenshaw/Honeydew/Persian), Chayote, Cucumber, Melons, and Squash (All or Unspecified, Summer, and Winter (Hubbard))	A	49.7	6.7	**1.50**	0.78
	G	42.9	4.7	**1.30**	0.55
32. Onion, Onions (Green), Radish, and Shallot	A	15.9	1.9	**0.48**	0.23
	G	8.4	0.7	**0.25**	0.08
33. White/Irish Potato	A	12.7	1.6	**0.38**	0.19
	G	20.3	1.7	**0.62**	0.20
34. Turnip (Greens and Root)	A	23.2	2.8	**0.70**	0.33
	G	16.3	1.4	**0.49**	0.16
37. Bermudagrass, Bluegrass, Canarygrass, Grass Forage/Fodder/Hay, Pastures, Peas (Including Vines), Rangeland, Sudangrass, and Timothy	A	16.6	1.6	**0.50**	0.19
	ULV	17.1	1.6	**0.52**	0.19
	G	19.2	2.1	**0.58**	0.25
40. Beets, Beets (Unspecified), Cowpea/Blackeyed Pea, Cowpeas, Field Peas, and Peas (Unspecified)	A	18.3	1.9	**0.56**	0.22
	G	20.1	1.7	**0.61**	0.20
41. Carrot (Including Tops), Celtuce, Fennel, Peanuts, Peanuts (Unspecified), and Pepper	A	32.4	3.1	**0.98**	0.36
	G	25.1	1.9	**0.76**	0.22
42. Beans and Dried-Type and Succulent (Lima and Snap) Beans	ULV	12.0	1.6	**0.37**	0.19
43. Celery	A	27.5	2.9	**0.83**	0.33
	G	22.2	1.7	**0.67**	0.19

Scenario	Application Method	EECs		Risk Quotient	
		Peak EEC	60-day EEC	Acute	Chronic
44. Asparagus and Safflower (Unspecified)	A	22.9	2.4	**0.69**	0.28
	G	16.0	1.4	**0.49**	0.16
46. Strawberry	A	89.8	13.0	**2.72**	1.52
	G	84.6	10.2	**2.56**	1.18
48. Tomato	A	45.6	6.9	**1.38**	0.80
	G	37.1	4.5	**1.12**	0.53
49. Okra	A	12.6	2.3	**0.38**	0.26
	G	9.5	1.0	**0.29**	0.11
51. Sorghum and Sorghum Silage	A	9.3	0.9	**0.28**	0.11
	ULV	8.8	1.0	**0.27**	0.11
	G	11.6	1.4	**0.35**	0.17
52. Barley, Cereal Grains, Oats, Rye, and Wheat	A	33.4	3.9	**1.01**	0.45
	ULV	19.6	2.4	**0.59**	0.28
	G	28.2	3.0	**0.86**	0.35
53. Gooseberry	A	13.5	2.1	**0.41**	0.25
	G	35.7	3.8	**1.08**	0.45
	AB	35.0	3.6	**1.06**	0.42
55. Blueberry	ULV	8.9	1.8	**0.27**	0.21
	G	9.9	1.0	**0.30**	0.12
	AB	9.0	0.9	**0.27**	0.10
57. Passion Fruit (Granadilla)	G	0.8	0.4	0.03	0.04
	AB	0.6	0.3	0.02	0.03
58. Mint and Spearmint	A	8.3	1.4	**0.25**	0.16
	G	19.7	2.3	**0.60**	0.27
59. Rice and Wild Rice	A	1123.3	1123.3	**34.04**	**130.62**
	ULV	548.2	548.2	**16.61**	**63.74**
	G	1123.3	1123.3	**34.04**	**130.62**
61. Water Cress	A	1123.3	1123.3	**34.04**	**130.62**
	G	1123.3	1123.3	**34.04**	**130.62**
Cull Piles, Agricultural/Farm Structures/Buildings and Equipment, Commercial/Institutional/Industrial Premises/Equipment (Outdoor), Meat Processing Plant Premises (Nonfood Contact), and Nonagricultural Outdoor Buildings/Structures	Drench	2.1	0.2	**0.06**	0.02
Fence Rows	Drench	0.8	0.1	0.02	0.01
Forestry. Christmas Tree Plantations, Pine (Seed Orchard), and Slash Pine (Forest)	A	60.0	7.2	**1.82**	0.83
	ULV	19.9	2.6	**0.60**	0.30
	G	51.5	4.8	**1.56**	0.56
	AB	50.1	4.5	**1.52**	0.53
Nursery. Nursery Stock	A	59.2	6.0	**1.79**	0.70
	G	53.2	4.4	**1.61**	0.51
	AB	53.0	4.4	**1.61**	0.52
Public Health (Adult Mosquito Control) and Medfly Control. Nonagricultural Areas (Public Health Use), Urban Areas, and Wide Area/General Outdoor Treatment	ULV	1.06	1.06[a]	0.03	0.12
Residential	Drench	3.43	0.25	**0.10**	0.03

Scenario	Application Method	EECs		Risk Quotient	
		Peak EEC	60-day EEC	Acute	Chronic
Rights-of-Way. Fencerows/Hedgerows, Nonagricultural Rights-of-Way/Fencerows/Hedgerows, and Nonagricultural Uncultivated Areas/Soils	A	24.0	3.9	**0.73**	0.46
	ULV	7.3	1.1	**0.22**	0.12
	G	5.4	0.8	**0.16**	0.09
	AB	5.5	0.8	**0.17**	0.09
Turf. Golf Course Turf (Bermudagrass)	A	10.3	1.0	**0.31**	0.12
	ULV	12.2	1.1	**0.37**	0.13
	G	5.7	0.5	**0.17**	0.06

a. A prediction of the chronic aquatic EEC for wide area aerial ULV applications was not possible. The acute EEC was used as a protective estimate of the chronic EEC because the chronic EEC is expected to be smaller.

Based on these results, use of malathion has the potential to directly affect the DS and CTS. Additionally, since the acute RQs exceed the LOC for most uses, malathion use has the potential to indirectly affect the DS and CTS because it may affect fish and amphibian prey used by these species.

5.1.1.b. Freshwater Invertebrates

Acute risk to freshwater invertebrates is based on 1 in 10 year peak EECs in the standard pond and the lowest acute toxicity value for freshwater invertebrates. Chronic risk is based on 1 in 10 year 21-day EECs and the lowest chronic toxicity value for freshwater invertebrates. Risk quotients for freshwater fish are shown in Table 5-2. Acute RQs ranged from 1.04 to 152 for non-aquatic agricultural uses, 929 to 1900 for aquatic agricultural uses (rice, wild rice, and water cress), and 1.34 to 102 for nonagricultural uses. Chronic RQs ranged from 8.11 to 866 for non-aquatic agricultural uses, 15,600 to 32,100 for aquatic agricultural uses, and 5.78 to 564 for nonagricultural uses. Both acute and chronic RQs exceeded the LOC for all uses.

Table 5-2. Summary of Acute and Chronic RQs for Aquatic Invertebrates. Risk quotients that exceed the LOC are shown in bold. The acute LOC is 0.1 for the acute effects and 1.0 for chronic effects.

Scenario	Application Method	EECs		Freshwater invertebrates	
		Peak EEC	21-day EEC	Acute	Chronic
1. Alfalfa, Clover, Lespedeza, Lupine, Grain Lupine, Trefoil, and Vetch	A	22.5	7.8	**38.2**	**222.0**
	ULV	8.2	2.8	**13.9**	**81.3**
	G	15.5	4.6	**26.3**	**132.5**
2. Macadamia Nut (Bushnut)	G	16.0	5.4	**27.0**	**154.9**
	AB	15.6	5.3	**26.4**	**150.4**
3. Pecan and Walnut (English/Black)	G	34.9	12.1	**59.2**	**345.1**
	AB	33.0	11.2	**55.9**	**321.2**
6. Date	A	62.2	25.1	**105.4**	**717.7**
	G	52.3	19.2	**88.7**	**548.3**
8. Avocado	G	59.3	12.6	**100.4**	**359.6**
9. Citrus Hybrids Other Than Tangelo, Grapefruit, Kumquat, Lemon, Lime, Orange,	A	50.1	13.1	**84.9**	**372.9**
	ULV	2.7	1.3	**4.5**	**37.4**

Scenario	Application Method	EECs		Freshwater invertebrates	
		Peak EEC	21-day EEC	Acute	Chronic
Tangelo, and Tangerines	G	23.1	5.4	**39.1**	**155.3**
	AB	22.1	5.1	**37.5**	**146.0**
10. Broccoli, Broccoli Raab, Cabbage, Chinese Amaranth, Chinese Broccoli, Chinese Cabbage, Canola\Rape, Cauliflower, Cole Crops, Collards, Corn Salad, Dock (Sorrel), Horseradish, Kale, Kohlrabi, Leafy Vegetables, Mustard, Mustard Cabbage (Gai Choy/ Pak-Choi), and Garden and Winter Purslane	A	37.6	14.9	**63.7**	**425.3**
	G	32.6	11.0	**55.2**	**313.4**
11. Corn (Silage and Unspecified), Field, Pop, and Sweet Corn, Millet (Foxtail), and Sunflower	A	33.7	10.4	**57.1**	**296.4**
	ULV	23.3	7.9	**39.5**	**224.8**
	G	22.3	6.5	**37.7**	**184.7**
12. Cotton (Unspecified)	A	37.3	14.5	**63.3**	**413.9**
	ULV	26.0	11.3	**44.1**	**321.7**
	G	23.8	7.3	**40.4**	**207.3**
13. Hops	A	14.6	5.5	**24.8**	**156.1**
	G	11.4	3.7	**19.4**	**106.6**
	AB	11.1	3.6	**18.9**	**101.9**
15. Apricot	G	10.7	3.2	**18.1**	**92.5**
	AB	10.1	2.9	**17.2**	**82.9**
16. Nectarine and Peach	G	25.3	7.7	**42.9**	**220.4**
	AB	24.0	6.8	**40.7**	**194.0**
17. Cherry	A	16.7	7.0	**28.2**	**200.2**
	ULV	15.4	7.3	**26.0**	**210.0**
	G	19.8	6.3	**33.5**	**179.3**
	AB	18.5	5.7	**31.4**	**162.5**
18. Fig	G	17.0	4.8	**28.9**	**138.1**
	AB	16.0	4.5	**27.1**	**128.5**
19. Pear	G	10.1	2.9	**17.1**	**81.6**
	AB	9.5	2.7	**16.1**	**76.3**
20. Guava, Mango, and Papaya	G	22.2	6.7	**37.6**	**192.8**
	AB	21.5	6.3	**36.5**	**181.1**
22. Garlic and Leek	A	34.2	10.8	**58.0**	**309.9**
	G	41.8	9.6	**70.9**	**275.3**
23. Grapes	G	12.8	3.7	**21.6**	**105.1**
	AB	11.8	3.3	**20.1**	**94.7**
26. Brussels Sprouts and Dandelion	A	52.0	15.4	**88.1**	**440.9**
	G	46.9	13.4	**79.5**	**382.4**
27. Chervil, Chrysanthemum - Garland, Endive (Escarole), Lettuce, Head and Leaf Lettuce, Orach (Mountain Spinach), Parsley, Roquette (Arrugula), Salsify, Spinach, and Swiss Chard	A	83.1	24.2	**140.8**	**691.2**
	G	74.4	21.2	**126.0**	**605.2**
29. Eggplant	A	25.6	11.6	**43.4**	**331.1**
	G	42.2	12.0	**71.4**	**341.5**
30. Pumpkin	A	8.3	2.4	**14.1**	**69.1**
	G	5.7	1.2	**9.58**	**34.0**

Scenario	Application Method	EECs		Freshwater invertebrates	
		Peak EEC	21-day EEC	Acute	Chronic
31. Cantaloupe, Honeydew, Musk, Water, and Winter Melons (Casaba/Crenshaw/Honeydew/Persian), Chayote, Cucumber, Melons, and Squash (All or Unspecified, Summer, and Winter (Hubbard))	A	49.7	17.7	**84.2**	**505.9**
	G	42.9	12.9	**72.7**	**368.4**
32. Onion, Onions (Green), Radish, and Shallot	A	15.9	5.2	**27.0**	**149.4**
	G	8.4	1.9	**14.3**	**54.4**
33. White/Irish Potato	A	12.7	4.4	**21.5**	**124.3**
	G	20.3	4.6	**34.5**	**132.8**
34. Turnip (Greens and Root)	A	23.2	7.3	**39.3**	**208.5**
	G	16.3	3.9	**27.6**	**110.5**
37. Bermudagrass, Bluegrass, Canarygrass, Grass Forage/Fodder/Hay, Pastures, Peas (Including Vines), Rangeland, Sudangrass, and Timothy	A	16.6	4.6	**28.1**	**130.6**
	ULV	17.1	4.6	**28.9**	**131.4**
	G	19.2	5.9	**32.5**	**169.8**
40. Beets, Beets (Unspecified), Cowpea/Blackeyed Pea, Cowpeas, Field Peas, and Peas (Unspecified)	A	18.3	5.2	**31.0**	**149.9**
	G	20.1	4.6	**34.0**	**132.5**
41. Carrot (Including Tops), Celtuce, Fennel, Peanuts, Peanuts (Unspecified), and Pepper	A	32.4	8.6	**54.9**	**245.9**
	G	25.1	5.3	**42.6**	**150.5**
42. Beans and Dried-Type and Succulent (Lima and Snap) Beans	ULV	12.0	4.3	**20.4**	**123.5**
43. Celery	A	27.5	7.9	**46.6**	**224.9**
	G	22.2	4.6	**37.6**	**131.0**
44. Asparagus and Safflower (Unspecified)	A	22.9	6.6	**38.8**	**187.4**
	G	16.0	3.8	**27.2**	**109.2**
46. Strawberry	A	89.8	31.0	**152.2**	**886.0**
	G	84.6	26.1	**143.3**	**746.1**
48. Tomato	A	45.6	17.1	**77.3**	**487.8**
	G	37.1	11.9	**62.9**	**340.2**
49. Okra	A	12.6	4.1	**21.4**	**118.5**
	G	9.5	2.2	**16.1**	**63.3**
51. Sorghum and Sorghum Silage	A	9.3	2.5	**15.8**	**72.4**
	ULV	8.8	2.7	**14.9**	**75.8**
	G	11.6	3.9	**19.7**	**111.8**
52. Barley, Cereal Grains, Oats, Rye, and Wheat	A	33.4	10.4	**56.6**	**298.0**
	ULV	19.6	6.5	**33.3**	**186.2**
	G	28.2	8.3	**47.8**	**236.8**
53. Gooseberry	A	13.5	5.5	**22.9**	**156.1**
	G	35.7	10.3	**60.6**	**294.1**
	AB	35.0	9.9	**59.3**	**281.7**
55. Blueberry	ULV	8.9	3.6	**15.0**	**103.7**
	G	9.9	2.6	**16.8**	**74.7**
	AB	9.0	2.4	**15.3**	**68.4**
57. Passion Fruit (Granadilla)	G	0.8	0.4	**1.40**	**11.5**
	AB	0.6	0.3	**1.04**	**8.11**
58. Mint and Spearmint	A	8.3	3.6	**14.1**	**102.9**

Scenario	Application Method	EECs		Freshwater invertebrates	
		Peak EEC	21-day EEC	Acute	Chronic
	G	19.7	6.1	**33.4**	**175.7**
59. Rice and Wild Rice	A	1123.3	1123.3	**1903.9**	**32095.0**
	ULV	548.2	548.2	**929.1**	**15662.4**
	G	1123.3	1123.3	**1903.9**	**32095.0**
61. Water Cress	A	1123.3	1123.3	**1903.9**	**32095.0**
	G	1123.3	1123.3	**1903.9**	**32095.0**
Cull Piles, Agricultural/Farm Structures/Buildings and Equipment, Commercial/Institutional/Industrial Premises/Equipment (Outdoor), Meat Processing Plant Premises (Nonfood Contact), and Nonagricultural Outdoor Buildings/Structures	Drench	2.1	0.5	**3.53**	**14.0**
Fence Rows	Drench	0.8	0.2	**1.34**	**5.78**
Forestry. Christmas Tree Plantations, Pine (Seed Orchard), and Slash Pine (Forest)	A	60.0	19.8	**101.6**	**564.3**
	ULV	19.9	7.1	**33.7**	**203.5**
	G	51.5	13.4	**87.2**	**382.5**
	AB	50.1	12.7	**84.9**	**362.3**
Nursery. Nursery Stock	A	59.2	16.7	**100.3**	**476.1**
	G	53.2	12.2	**90.1**	**348.9**
	AB	53.0	12.4	**89.8**	**353.1**
Public Health (Adult Mosquito Control) and Medfly Control. Nonagricultural Areas (Public Health Use), Urban Areas, and Wide Area/General Outdoor Treatment	ULV	1.06	1.06	**1.80**	**30.3**
Residential	Drench	3.43	0.701	**5.81**	**20.0**
Rights-of-Way. Fencerows/Hedgerows, Nonagricultural Rights-of-Way/Fencerows/Hedgerows, and Nonagricultural Uncultivated Areas/Soils	A	24.0	8.8	**40.6**	**252.5**
	ULV	7.3	2.8	**12.4**	**78.9**
	G	5.4	2.1	**9.21**	**59.3**
	AB	5.5	2.1	**9.31**	**59.9**
Turf. Golf Course Turf (Bermudagrass)	A	10.3	2.9	**17.4**	**81.9**
	ULV	12.2	3.2	**20.7**	**92.0**
	G	5.7	1.5	**9.64**	**43.7**

a. A prediction of the chronic aquatic EEC for wide area aerial ULV applications was not possible. The acute EEC was used as a protective estimate of the chronic EEC because the chronic EEC is expected to be smaller.

Based on these results, use of malathion use has the potential to indirectly affect the DS and CTS because it may affect freshwater invertebrate prey used by these species.

5.1.1.c. Estuarine/Marine Fish

Acute risk to fish is based on 1 in 10 year peak EECs in the standard pond and the lowest acute toxicity value for freshwater fish. Chronic risk is based on the 1 in 10 year 60-day EECs and the lowest chronic toxicity value for freshwater fish. Risk quotients for freshwater fish are shown in Table 5-3. Acute RQs ranged from 0.02 to 2.72 for non-aquatic agricultural uses, 16.6 to 34.0 for aquatic agricultural uses (rice, wild rice, and water cress), and 0.02 to 1.82 for nonagricultural uses. The acute RQ exceeded the LOC for acute risk for all use sites except passion fruit and ULV application citrus, cull piles, and fence rows. Due to the rapid degradation of malathion, chronic RQs generally were lower than acute RQs. They ranged from 0.01 to 0.77 for non-aquatic agricultural uses, 31.7 to 64.9 for aquatic agricultural uses, and <0.01 to 0.41 for nonagricultural uses.

Table 5-3. Summary of RQs for Estuarine/Marine Fish. Risk quotients that exceed the LOC are shown in bold. The acute LOC is 0.05 for the acute effects and 1.0 for chronic effects.

Scenario	Application Method	EECs		Estuarine/ marine fish	
		Peak EEC	60-day EEC	Acute	Chronic
1. Alfalfa, Clover, Lespedeza, Lupine, Grain Lupine, Trefoil, and Vetch	A	22.5	4.9	**0.68**	0.28
	ULV	8.2	1.1	**0.25**	0.06
	G	15.5	2.1	**0.47**	0.12
2. Macadamia Nut (Bushnut)	G	16.0	2.4	**0.48**	0.14
	AB	15.6	2.3	**0.47**	0.13
3. Pecan and Walnut (English/Black)	G	34.9	4.6	**1.06**	0.27
	AB	33.0	4.2	**1.00**	0.24
6. Date	A	62.2	13.3	**1.88**	0.77
	G	52.3	9.2	**1.59**	0.53
8. Avocado	G	59.3	4.8	**1.80**	0.28
9. Citrus Hybrids Other Than Tangelo, Grapefruit, Kumquat, Lemon, Lime, Orange, Tangelo, and Tangerines	A	50.1	8.3	**1.52**	0.48
	ULV	2.7	0.5	**0.08**	0.03
	G	23.1	2.4	**0.70**	0.14
	AB	22.1	2.1	**0.67**	0.12
10. Broccoli, Broccoli Raab, Cabbage, Chinese Amaranth, Chinese Broccoli, Chinese Cabbage, Canola\Rape, Cauliflower, Cole Crops, Collards, Corn Salad, Dock (Sorrel), Horseradish, Kale, Kohlrabi, Leafy Vegetables, Mustard, Mustard Cabbage (Gai Choy/ Pak-Choi), and Garden and Winter Purslane	A	37.6	7.6	**1.14**	0.44
	G	32.6	4.7	**0.99**	0.27
11. Corn (Silage and Unspecified), Field, Pop, and Sweet Corn, Millet (Foxtail), and Sunflower	A	33.7	3.8	**1.02**	0.22
	ULV	23.3	2.9	**0.71**	0.16
	G	22.3	2.4	**0.67**	0.14
12. Cotton (Unspecified)	A	37.3	5.8	**1.13**	0.33
	ULV	26.0	4.5	**0.79**	0.26
	G	23.8	2.7	**0.72**	0.15
13. Hops	A	14.6	2.2	**0.44**	0.13
	G	11.4	1.4	**0.35**	0.08
	AB	11.1	1.3	**0.34**	0.08
15. Apricot	G	10.7	1.2	**0.32**	0.07
	AB	10.1	1.0	**0.31**	0.06
16. Nectarine and Peach	G	25.3	2.9	**0.77**	0.17
	AB	24.0	2.6	**0.73**	0.15
17. Cherry	A	16.7	2.5	**0.50**	0.14
	ULV	15.4	4.7	**0.47**	0.27
	G	19.8	2.4	**0.60**	0.14
	AB	18.5	2.1	**0.56**	0.12
18. Fig	G	17.0	1.8	**0.52**	0.10

	AB	16.0	1.6	**0.48**	0.09
19. Pear	G	10.1	1.1	**0.31**	0.06
	AB	9.5	1.0	**0.29**	0.06
20. Guava, Mango, and Papaya	G	22.2	3.1	**0.67**	0.18
	AB	21.5	2.8	**0.65**	0.16
22. Garlic and Leek	A	34.2	4.1	**1.04**	0.24
	G	41.8	3.7	**1.27**	0.22
23. Grapes	G	12.8	1.4	**0.39**	0.08
	AB	11.8	1.2	**0.36**	0.07
26. Brussels Sprouts and Dandelion	A	52.0	5.7	**1.58**	0.33
	G	46.9	5.0	**1.42**	0.29
27. Chervil, Chrysanthemum - Garland, Endive (Escarole), Lettuce, Head and Leaf Lettuce, Orach (Mountain Spinach), Parsley, Roquette (Arrugula), Salsify, Spinach, and Swiss Chard	A	83.1	8.8	**2.52**	0.51
	G	74.4	7.7	**2.25**	0.44
29. Eggplant	A	25.6	5.0	**0.78**	0.29
	G	42.2	4.5	**1.28**	0.26
30. Pumpkin	A	8.3	0.9	**0.25**	0.05
	G	5.7	0.4	**0.17**	0.03
31. Cantaloupe, Honeydew, Musk, Water, and Winter Melons (Casaba/Crenshaw/Honeydew/Persian), Chayote, Cucumber, Melons, and Squash (All or Unspecified, Summer, and Winter (Hubbard))	A	49.7	6.7	**1.50**	0.39
	G	42.9	4.7	**1.30**	0.27
32. Onion, Onions (Green), Radish, and Shallot	A	15.9	1.9	**0.48**	0.11
	G	8.4	0.7	**0.25**	0.04
33. White/Irish Potato	A	12.7	1.6	**0.38**	0.09
	G	20.3	1.7	**0.62**	0.10
34. Turnip (Greens and Root)	A	23.2	2.8	**0.70**	0.16
	G	16.3	1.4	**0.49**	0.08
37. Bermudagrass, Bluegrass, Canarygrass, Grass Forage/Fodder/Hay, Pastures, Peas (Including Vines), Rangeland, Sudangrass, and Timothy	A	16.6	1.6	**0.50**	0.09
	ULV	17.1	1.6	**0.52**	0.10
	G	19.2	2.1	**0.58**	0.12
40. Beets, Beets (Unspecified), Cowpea/Blackeyed Pea, Cowpeas, Field Peas, and Peas (Unspecified)	A	18.3	1.9	**0.56**	0.11
	G	20.1	1.7	**0.61**	0.10
41. Carrot (Including Tops), Celtuce, Fennel, Peanuts, Peanuts (Unspecified), and Pepper	A	32.4	3.1	**0.98**	0.18
	G	25.1	1.9	**0.76**	0.11
42. Beans and Dried-Type and Succulent (Lima and Snap) Beans	ULV	12.0	1.6	**0.37**	0.09
43. Celery	A	27.5	2.9	**0.83**	0.17
	G	22.2	1.7	**0.67**	0.10
44. Asparagus and Safflower (Unspecified)	A	22.9	2.4	**0.69**	0.14
	G	16.0	1.4	**0.49**	0.08
46. Strawberry	A	89.8	13.0	**2.72**	0.75
	G	84.6	10.2	**2.56**	0.59
48. Tomato	A	45.6	6.9	**1.38**	0.40
	G	37.1	4.5	**1.12**	0.26
49. Okra	A	12.6	2.3	**0.38**	0.13
	G	9.5	1.0	**0.29**	0.06

51. Sorghum and Sorghum Silage	A	9.3	0.9	**0.28**	0.05
	ULV	8.8	1.0	**0.27**	0.06
	G	11.6	1.4	**0.35**	0.08
52. Barley, Cereal Grains, Oats, Rye, and Wheat	A	33.4	3.9	**1.01**	0.22
	ULV	19.6	2.4	**0.59**	0.14
	G	28.2	3.0	**0.86**	0.17
53. Gooseberry	A	13.5	2.1	**0.41**	0.12
	G	35.7	3.8	**1.08**	0.22
	AB	35.0	3.6	**1.06**	0.21
55. Blueberry	ULV	8.9	1.8	**0.27**	0.10
	G	9.9	1.0	**0.30**	0.06
	AB	9.0	0.9	**0.27**	0.05
57. Passion Fruit (Granadilla)	G	0.8	0.4	0.03	0.02
	AB	0.6	0.3	0.02	0.01
58. Mint and Spearmint	A	8.3	1.4	**0.25**	0.08
	G	19.7	2.3	**0.60**	0.13
59. Rice and Wild Rice	A	1123.3	1123.3	**34.04**	**64.93**
	ULV	548.2	548.2	**16.61**	**31.69**
	G	1123.3	1123.3	**34.04**	**64.93**
61. Water Cress	A	1123.3	1123.3	**34.04**	**64.93**
	G	1123.3	1123.3	**34.04**	**64.93**
Cull Piles, Agricultural/Farm Structures/Buildings and Equipment, Commercial/Institutional/Industrial Premises/Equipment (Outdoor), Meat Processing Plant Premises (Nonfood Contact), and Nonagricultural Outdoor Buildings/Structures	Drench	2.1	0.2	**0.06**	0.01
Fence Rows	Drench	0.8	0.1	0.02	<0.01
Forestry. Christmas Tree Plantations, Pine (Seed Orchard), and Slash Pine (Forest)	A	60.0	7.2	**1.82**	0.41
	ULV	19.9	2.6	**0.60**	0.15
	G	51.5	4.8	**1.56**	0.28
	AB	50.1	4.5	**1.52**	0.26
Nursery. Nursery Stock	A	59.2	6.0	**1.79**	0.35
	G	53.2	4.4	**1.61**	0.25
	AB	53.0	4.4	**1.61**	0.26
Public Health (Adult Mosquito Control) and Medfly Control. Nonagricultural Areas (Public Health Use), Urban Areas, and Wide Area/General Outdoor Treatment	ULV	1.06	1.06[a]	0.03	0.06
Residential	Drench	3.43	0.25	**0.10**	0.01
Rights-of-Way. Fencerows/Hedgerows, Nonagricultural Rights-of-Way/Fencerows/Hedgerows, and Nonagricultural Uncultivated Areas/Soils	A	24.0	3.9	**0.73**	0.23
	ULV	7.3	1.1	**0.22**	0.06
	G	5.4	0.8	**0.16**	0.04
	AB	5.5	0.8	**0.17**	0.05
Turf. Golf Course Turf (Bermudagrass)	A	10.3	1.0	**0.31**	0.06
	ULV	12.2	1.1	**0.37**	0.07
	G	5.7	0.5	**0.17**	0.03

a. A prediction of the chronic aquatic EEC for wide area aerial ULV applications was not possible. The acute EEC was used as a protective estimate of the chronic EEC because the chronic EEC is expected to be smaller.

Based on these results, use of malathion has the potential to directly affect the DS. Additionally, since the acute RQs exceed the LOC for most uses, malathion use has the potential to indirectly affect DS because it may affect estuarine fish prey used by this species.

5.1.1.d. Estuarine/Marine Invertebrates

Acute risk to freshwater invertebrates is based on 1 in 10 year peak EECs in the standard pond and the lowest acute toxicity value for freshwater invertebrates. Chronic risk is based on 1 in 10 year 21-day EECs and the lowest chronic toxicity value for freshwater invertebrates. Risk quotients for freshwater fish are shown in Table 5-4. Acute RQs ranged from 0.28 to 40.8 for non-aquatic agricultural uses, 249 to 510 for aquatic agricultural uses (rice, wild rice, and water cress), and 0.36 to 27.3 for nonagricultural uses. Chronic RQs ranged from 21.8 to 2390 for non-aquatic agricultural uses, 42,200 to 86,400 for aquatic agricultural uses, and 15.6 to 1520 for nonagricultural uses. Both acute and chronic RQs exceeded the LOC for all uses.

Table 5-4. Summary of Acute and Chronic RQs for Estuarine/Marine Invertebrates. Risk quotients that exceed the LOC are shown in bold. The acute LOC is 0.1 for the acute effects and 1.0 for chronic effects.

Scenario	**Application Method**	**EECs**		**Estuarine/ marine invertebrates**	
		Peak EEC	**21-day EEC**	**Acute**	**Chronic**
1. Alfalfa, Clover, Lespedeza, Lupine, Grain Lupine, Trefoil, and Vetch	A	22.5	7.8	**10.2**	**597.8**
	ULV	8.2	2.8	**3.72**	**218.9**
	G	15.5	4.6	**7.05**	**356.7**
2. Macadamia Nut (Bushnut)	G	16.0	5.4	**7.25**	**416.9**
	AB	15.6	5.3	**7.09**	**404.8**
3. Pecan and Walnut (English/Black)	G	34.9	12.1	**15.8**	**929.0**
	AB	33.0	11.2	**15.0**	**864.8**
6. Date	A	62.2	25.1	**28.3**	**1932.2**
	G	52.3	19.2	**23.8**	**1476.2**
8. Avocado	G	59.3	12.6	**26.9**	**968.1**
9. Citrus Hybrids Other Than Tangelo, Grapefruit, Kumquat, Lemon, Lime, Orange, Tangelo, and Tangerines	A	50.1	13.1	**22.8**	**1003.8**
	ULV	2.7	1.3	**1.21**	**100.6**
	G	23.1	5.4	**10.5**	**418.2**
	AB	22.1	5.1	**10.1**	**393.2**
10. Broccoli, Broccoli Raab, Cabbage, Chinese Amaranth, Chinese Broccoli, Chinese Cabbage, Canola\Rape, Cauliflower, Cole Crops, Collards, Corn Salad, Dock (Sorrel), Horseradish, Kale, Kohlrabi, Leafy Vegetables, Mustard, Mustard Cabbage (Gai Choy/ Pak-Choi), and Garden and Winter Purslane	A	37.6	14.9	**17.1**	**1144.9**
	G	32.6	11.0	**14.8**	**843.8**
11. Corn (Silage and Unspecified), Field, Pop, and Sweet Corn, Millet (Foxtail), and Sunflower	A	33.7	10.4	**15.3**	**798.0**
	ULV	23.3	7.9	**10.6**	**605.1**
	G	22.3	6.5	**10.1**	**497.2**
12. Cotton (Unspecified)	A	37.3	14.5	**17.0**	**1114.2**
	ULV	26.0	11.3	**11.8**	**866.2**
	G	23.8	7.3	**10.8**	**558.2**

Scenario	Application Method	EECs		Estuarine/ marine invertebrates	
		Peak EEC	21-day EEC	Acute	Chronic
13. Hops	A	14.6	5.5	**6.66**	**420.2**
	G	11.4	3.7	**5.20**	**287.0**
	AB	11.1	3.6	**5.06**	**274.3**
15. Apricot	G	10.7	3.2	**4.86**	**249.0**
	AB	10.1	2.9	**4.61**	**223.3**
16. Nectarine and Peach	G	25.3	7.7	**11.5**	**593.4**
	AB	24.0	6.8	**10.9**	**522.2**
17. Cherry	A	16.7	7.0	**7.57**	**539.1**
	ULV	15.4	7.3	**6.98**	**565.3**
	G	19.8	6.3	**8.98**	**482.6**
	AB	18.5	5.7	**8.42**	**437.5**
18. Fig	G	17.0	4.8	**7.75**	**371.9**
	AB	16.0	4.5	**7.27**	**346.1**
19. Pear	G	10.1	2.9	**4.58**	**219.6**
	AB	9.5	2.7	**4.31**	**205.5**
20. Guava, Mango, and Papaya	G	22.2	6.7	**10.1**	**519.0**
	AB	21.5	6.3	**9.78**	**487.7**
22. Garlic and Leek	A	34.2	10.8	**15.6**	**834.2**
	G	41.8	9.6	**19.0**	**741.1**
23. Grapes	G	12.8	3.7	**5.80**	**282.9**
	AB	11.8	3.3	**5.38**	**255.0**
26. Brussels Sprouts and Dandelion	A	52.0	15.4	**23.6**	**1187.1**
	G	46.9	13.4	**21.3**	**1029.4**
27. Chervil, Chrysanthemum - Garland, Endive (Escarole), Lettuce, Head and Leaf Lettuce, Orach (Mountain Spinach), Parsley, Roquette (Arrugula), Salsify, Spinach, and Swiss Chard	A	83.1	24.2	**37.8**	**1861.0**
	G	74.4	21.2	**33.8**	**1629.5**
29. Eggplant	A	25.6	11.6	**11.6**	**891.5**
	G	42.2	12.0	**19.2**	**919.3**
30. Pumpkin	A	8.3	2.4	**3.77**	**186.0**
	G	5.7	1.2	**2.57**	**91.4**
31. Cantaloupe, Honeydew, Musk, Water, and Winter Melons (Casaba/Crenshaw/Honeydew/Persian), Chayote, Cucumber, Melons, and Squash (All or Unspecified, Summer, and Winter (Hubbard))	A	49.7	17.7	**22.6**	**1362.1**
	G	42.9	12.9	**19.5**	**991.8**
32. Onion, Onions (Green), Radish, and Shallot	A	15.9	5.2	**7.24**	**402.3**
	G	8.4	1.9	**3.82**	**146.5**
33. White/Irish Potato	A	12.7	4.4	**5.76**	**334.7**
	G	20.3	4.6	**9.24**	**357.5**
34. Turnip (Greens and Root)	A	23.2	7.3	**10.5**	**561.3**
	G	16.3	3.9	**7.40**	**297.4**
37. Bermudagrass, Bluegrass, Canarygrass, Grass Forage/Fodder/Hay, Pastures, Peas (Including Vines), Rangeland, Sudangrass, and Timothy	A	16.6	4.6	**7.53**	**351.7**
	ULV	17.1	4.6	**7.75**	**353.7**
	G	19.2	5.9	**8.72**	**457.2**

Scenario	Application Method	EECs		Estuarine/ marine invertebrates	
		Peak EEC	21-day EEC	Acute	Chronic
40. Beets, Beets (Unspecified), Cowpea/Blackeyed Pea, Cowpeas, Field Peas, and Peas (Unspecified)	A	18.3	5.2	**8.33**	**403.7**
	G	20.1	4.6	**9.12**	**356.6**
41. Carrot (Including Tops), Celtuce, Fennel, Peanuts, Peanuts (Unspecified), and Pepper	A	32.4	8.6	**14.7**	**662.0**
	G	25.1	5.3	**11.4**	**405.3**
42. Beans and Dried-Type and Succulent (Lima and Snap) Beans	ULV	12.0	4.3	**5.48**	**332.5**
43. Celery	A	27.5	7.9	**12.5**	**605.5**
	G	22.2	4.6	**10.1**	**352.7**
44. Asparagus and Safflower (Unspecified)	A	22.9	6.6	**10.4**	**504.6**
	G	16.0	3.8	**7.29**	**293.9**
46. Strawberry	A	89.8	31.0	**40.8**	**2385.5**
	G	84.6	26.1	**38.4**	**2008.8**
48. Tomato	A	45.6	17.1	**20.7**	**1313.3**
	G	37.1	11.9	**16.9**	**915.8**
49. Okra	A	12.6	4.1	**5.73**	**319.0**
	G	9.5	2.2	**4.32**	**170.4**
51. Sorghum and Sorghum Silage	A	9.3	2.5	**4.23**	**194.9**
	ULV	8.8	2.7	**4.00**	**204.1**
	G	11.6	3.9	**5.28**	**301.1**
52. Barley, Cereal Grains, Oats, Rye, and Wheat	A	33.4	10.4	**15.2**	**802.3**
	ULV	19.6	6.5	**8.92**	**501.3**
	G	28.2	8.3	**12.8**	**637.6**
53. Gooseberry	A	13.5	5.5	**6.15**	**420.3**
	G	35.7	10.3	**16.2**	**791.9**
	AB	35.0	9.9	**15.9**	**758.5**
55. Blueberry	ULV	8.9	3.6	**4.03**	**279.1**
	G	9.9	2.6	**4.49**	**201.1**
	AB	9.0	2.4	**4.09**	**184.0**
57. Passion Fruit (Granadilla)	G	0.8	0.4	**0.38**	**30.8**
	AB	0.6	0.3	**0.28**	**21.8**
58. Mint and Spearmint	A	8.3	3.6	**3.77**	**276.9**
	G	19.7	6.1	**8.97**	**473.0**
59. Rice and Wild Rice	A	1123.3	1123.3	**510.6**	**86409.6**
	ULV	548.2	548.2	**249.2**	**42167.9**
	G	1123.3	1123.3	**510.6**	**86409.6**
61. Water Cress	A	1123.3	1123.3	**510.6**	**86409.6**
	G	1123.3	1123.3	**510.6**	**86409.6**
Cull Piles, Agricultural/Farm Structures/Buildings and Equipment, Commercial/Institutional/Industrial Premises/Equipment (Outdoor), Meat Processing Plant Premises (Nonfood Contact), and Nonagricultural Outdoor Buildings/Structures	Drench	2.1	0.5	**0.95**	**37.8**
Fence Rows	Drench	0.8	0.2	**0.36**	**15.6**
Forestry. Christmas Tree Plantations, Pine (Seed Orchard), and Slash Pine (Forest)	A	60.0	19.8	**27.3**	**1519.3**
	ULV	19.9	7.1	**9.03**	**547.9**

Scenario	Application Method	EECs		Estuarine/ marine invertebrates	
		Peak EEC	21-day EEC	Acute	Chronic
	G	51.5	13.4	**23.4**	**1029.8**
	AB	50.1	12.7	**22.8**	**975.5**
Nursery. Nursery Stock	A	59.2	16.7	**26.9**	**1281.8**
	G	53.2	12.2	**24.2**	**939.5**
	AB	53.0	12.4	**24.1**	**950.7**
Public Health and Medfly Control. Nonagricultural Areas (Public Health Use), Urban Areas, and Wide Area/General Outdoor Treatment (Public Health Use)	ULV	1.06	1.06[a]	**0.48**	**81.5**
Residential	Drench	3.43	0.70	**1.56**	**53.9**
Rights-of-Way. Fencerows/Hedgerows, Nonagricultural Rights-of-Way/Fencerows/Hedgerows, and Nonagricultural Uncultivated Areas/Soils	A	24.0	8.8	**10.9**	**679.7**
	ULV	7.3	2.8	**3.32**	**212.4**
	G	5.4	2.1	**2.47**	**159.7**
	AB	5.5	2.1	**2.50**	**161.4**
Turf. Golf Course Turf (Bermudagrass)	A	10.3	2.9	**4.67**	**220.6**
	ULV	12.2	3.2	**5.54**	**247.6**
	G	5.7	1.5	**2.59**	**117.7**

a. A prediction of the chronic aquatic EEC for wide area aerial ULV applications was not possible. The acute EEC was used as a protective estimate of the chronic EEC because the chronic EEC is expected to be smaller.

Based on these results, use of malathion use has the potential to indirectly affect the DS because it may affect estuarine invertebrate prey used by these species.

5.1.1.e. Aquatic Plants

Risk to aquatic plants is based on 1 in 10 year peak EECs in the standard pond and the lowest acute toxicity value. Risk quotients are shown in Table 5-3. Aquatic plant RQs were calculated based on toxicity data for non-vascular aquatic plants because no acceptable data were available for vascular aquatic plants. However, supplemental data did show that vascular aquatic plants are less sensitive to malathion than nonvascular aquatic plants. Therefore, these RQs are assumed to be protective for all aquatic plants, including vascular ones. Aquatic plants RQs ranged from <0.01 to 0.04 for non-aquatic agricultural uses, 0.23 to 0.47 for aquatic agricultural uses (rice, wild rice, and water cress), and <0.01 to 0.02 for nonagricultural uses. None of the RQs exceeded the LOC for any of the uses of malathion.

Table 5-3. Summary of Acute RQs for Aquatic Plants

Scenario	Application Method	Peak EEC	Risk Quotient
1. Alfalfa, Clover, Lespedeza, Lupine, Grain Lupine, Trefoil, and Vetch	A	22.5	0.01
	ULV	8.2	<0.01
	G	15.5	0.01
2. Macadamia Nut (Bushnut)	G	16.0	0.01
	AB	15.6	0.01
3. Pecan and Walnut (English/Black)	G	34.9	0.01

	AB	33.0	0.01
6. Date	A	62.2	0.03
	G	52.3	0.02
8. Avocado	G	59.3	0.02
9. Citrus Hybrids Other Than Tangelo, Grapefruit, Kumquat, Lemon, Lime, Orange, Tangelo, and Tangerines	A	50.1	0.02
	ULV	2.7	<0.01
	G	23.1	0.01
	AB	22.1	0.01
10. Broccoli, Broccoli Raab, Cabbage, Chinese Amaranth, Chinese Broccoli, Chinese Cabbage, Canola\Rape, Cauliflower, Cole Crops, Collards, Corn Salad, Dock (Sorrel), Horseradish, Kale, Kohlrabi, Leafy Vegetables, Mustard, Mustard Cabbage (Gai Choy/ Pak-Choi), and Garden and Winter Purslane	A	37.6	0.02
	G	32.6	0.01
11. Corn (Silage and Unspecified), Field, Pop, and Sweet Corn, Millet (Foxtail), and Sunflower	A	33.7	0.01
	ULV	23.3	0.01
	G	22.3	0.01
12. Cotton (Unspecified)	A	37.3	0.02
	ULV	26.0	0.01
	G	23.8	0.01
13. Hops	A	14.6	0.01
	G	11.4	<0.01
	AB	11.1	<0.01
15. Apricot	G	10.7	<0.01
	AB	10.1	<0.01
16. Nectarine and Peach	G	25.3	0.01
	AB	24.0	0.01
17. Cherry	A	16.7	0.01
	ULV	15.4	0.01
	G	19.8	0.01
	AB	18.5	0.01
18. Fig	G	17.0	0.01
	AB	16.0	0.01
19. Pear	G	10.1	<0.01
	AB	9.5	<0.01
20. Guava, Mango, and Papaya	G	22.2	0.01
	AB	21.5	0.01
22. Garlic and Leek	A	34.2	0.01
	G	41.8	0.02
23. Grapes	G	12.8	0.01
	AB	11.8	<0.01
26. Brussels Sprouts and Dandelion	A	52.0	0.02
	G	46.9	0.02
27. Chervil, Chrysanthemum - Garland, Endive (Escarole), Lettuce, Head and Leaf Lettuce, Orach (Mountain Spinach), Parsley, Roquette (Arrugula), Salsify, Spinach, and Swiss Chard	A	83.1	0.03
	G	74.4	0.03

29. Eggplant	A	25.6	0.01
	G	42.2	0.02
30. Pumpkin	A	8.3	<0.01
	G	5.7	<0.01
31. Cantaloupe, Honeydew, Musk, Water, and Winter Melons (Casaba/Crenshaw/Honeydew/Persian), Chayote, Cucumber, Melons, and Squash (All or Unspecified, Summer, and Winter (Hubbard))	A	49.7	0.02
	G	42.9	0.02
32. Onion, Onions (Green), Radish, and Shallot	A	15.9	0.01
	G	8.4	<0.01
33. White/Irish Potato	A	12.7	0.01
	G	20.3	0.01
34. Turnip (Greens and Root)	A	23.2	0.01
	G	16.3	0.01
37. Bermudagrass, Bluegrass, Canarygrass, Grass Forage/Fodder/Hay, Pastures, Peas (Including Vines), Rangeland, Sudangrass, and Timothy	A	16.6	0.01
	ULV	17.1	0.01
	G	19.2	0.01
40. Beets, Beets (Unspecified), Cowpea/Blackeyed Pea, Cowpeas, Field Peas, and Peas (Unspecified)	A	18.3	0.01
	G	20.1	0.01
41. Carrot (Including Tops), Celtuce, Fennel, Peanuts, Peanuts (Unspecified), and Pepper	A	32.4	0.01
	G	25.1	0.01
42. Beans and Dried-Type and Succulent (Lima and Snap) Beans	ULV	12.0	0.01
43. Celery	A	27.5	0.01
	G	22.2	0.01
44. Asparagus and Safflower (Unspecified)	A	22.9	0.01
	G	16.0	0.01
46. Strawberry	A	89.8	0.04
	G	84.6	0.04
48. Tomato	A	45.6	0.02
	G	37.1	0.02
49. Okra	A	12.6	0.01
	G	9.5	<0.01
51. Sorghum and Sorghum Silage	A	9.3	<0.01
	ULV	8.8	<0.01
	G	11.6	<0.01
52. Barley, Cereal Grains, Oats, Rye, and Wheat	A	33.4	0.01
	ULV	19.6	0.01
	G	28.2	0.01
53. Gooseberry	A	13.5	0.01
	G	35.7	0.01
	AB	35.0	0.01
55. Blueberry	ULV	8.9	<0.01
	G	9.9	<0.01
	AB	9.0	<0.01
57. Passion Fruit (Granadilla)	G	0.8	<0.01

	AB	0.6	<0.01
58. Mint and Spearmint	A	8.3	<0.01
	G	19.7	0.01
59. Rice and Wild Rice	A	1123.3	0.47
	ULV	548.2	0.23
	G	1123.3	0.47
61. Water Cress	A	1123.3	0.47
	G	1123.3	0.47
Cull Piles, Agricultural/Farm Structures/Buildings and Equipment, Commercial/Institutional/Industrial Premises/Equipment (Outdoor), Meat Processing Plant Premises (Nonfood Contact), and Nonagricultural Outdoor Buildings/Structures	Drench	2.1	<0.01
Fence Rows	Drench	0.8	<0.01
Forestry. Christmas Tree Plantations, Pine (Seed Orchard), and Slash Pine (Forest)	A	60.0	0.02
	ULV	19.9	0.01
	G	51.5	0.02
	AB	50.1	0.02
Nursery. Nursery Stock	A	59.2	0.02
	G	53.2	0.02
	AB	53.0	0.02
Public Health (Adult Mosquito Control) and Medfly Control. Nonagricultural Areas (Public Health Use), Urban Areas, and Wide Area/General Outdoor Treatment	ULV	1.06	<0.01
Residential	Drench	3.43	<0.01
Rights-of-Way. Fencerows/Hedgerows, Nonagricultural Rights-of-Way/Fencerows/Hedgerows, and Nonagricultural Uncultivated Areas/Soils	A	24.0	0.01
	ULV	7.3	<0.01
	G	5.4	<0.01
	AB	5.5	<0.01
Turf. Golf Course Turf (Bermudagrass)	A	10.3	<0.01
	ULV	12.2	0.01
	G	5.7	<0.01

Based on these results, use of malathion as described does not have the potential to indirectly affect the DS and CTS through adverse effects on aquatic plants which are used as food by these species.

5.1.2. Exposures in the Terrestrial Habitat

5.1.2.a. Birds (surrogates for Terrestrial-phase Amphibians) and Mammals

As previously discussed in Section 3.3, potential direct effects to terrestrial species were based on foliar and ULV applications of malathion. We used the T-REX model to calculate acute and chronic risk quotients (RQs) for birds, which serve as surrogates for terrestrial-phase amphibians, and separate RQs for mammals. Acute and chronic RQs were calculated based on acute and chronic toxicity data for the most sensitive bird and mammal species for which data were available. For terrestrial-phase amphibians, T-REX was used as a screening tool to determine if a refined assessment with T-HERPS was necessary. For this screen, the most protective RQs were calculated by assuming a small bird (surrogate for amphibians) consuming short grass. This serves as a screen for both direct and indirect effects to the CTS. For mammals, RQs were calculated for small (15 g) herbivorous mammal feeding on short grass. This represents the most sensitive mammal species that, if impacted, could cause indirect effects to the CTS.

Acute and chronic RQs derived using T-REX for the CTS, other amphibians, and mammals are shown in Table 5-4. For all uses assessed, the acute RQ exceed the LOC for direct effects to amphibians. In addition, the chronic RQ exceeded the LOC for amphibians for all uses except ULV applications on citrus and ULV application for adult mosquito control. Because all uses fail to pass this risk screen, refined RQs were derived for amphibians using T-HERPS (see below).

For mammals, the chronic dose-based RQs exceeded the LOC for all uses except for ULV applications on citrus and ULV use for adult mosquito control. Therefore, all uses except the citrus ULV use are predicted to potentially affect the CTS indirectly through effects on small mammals. The citrus ULV use of malathion had the lowest maximum application rate of all uses, 0.175 lb ai/A. Adult mosquito control also had low exposure to terrestrial animals because only a small fraction of the applied material is predicted to deposit on the surface. We predict that the terrestrial exposure for these two uses is small enough to not result in adverse effects to small mammals. Uses with the highest use rates, including use on cotton, nuts, and citrus (non ULV) also had acute RQs that exceeded the LOC for acute risk, thereby predicting potentially acute toxic effects as well as chronic effects for these uses.

Table 5-4. Acute and Chronic RQs Derived Using T-REX for Malathion and Birds and Amphibians. Risk quotients that exceed the LOC are shown in bold. The acute LOC is 0.1 for the CTS (direct effect) and 0.5 for other amphibians and mammals; the chronic LOC is 1.0 for all species.

Use, Formulation, Type of Application	**RQs for CTS and other Amphibians (Direct and Indirect Effects)** Acute (Dose-Based)[1]	**RQs for CTS and other Amphibians (Direct and Indirect Effects)** Chronic (Dietary Based)[2]	**RQs for Small Mammals (Indirect Effects)** Acute (Dose-Based)[3]	**RQs for Small Mammals (Indirect Effects)** Chronic (Dietary Based)[4]	**RQs for Small Mammals (Indirect Effects)** Chronic (Dose Based)[5]
Agricultural Uses					
Citrus	**21.92**	**16.36**	**0.92**	**1.06**	**9.19**
Citrus (ULV)	**0.53**	0.39	0.02	0.03	0.22
Cotton, chestnut, and walnut	**12.09**	**9.03**	**0.51**	0.58	**5.07**
Pecan	**10.60**	**7.92**	0.44	0.51	**4.44**
Strawberry	**10.21**	**7.62**	0.43	0.49	**4.28**
Caneberry group	**8.48**	**6.33**	0.35	0.41	**3.56**
Mushroom	**10.12**	**7.56**	0.42	0.49	**4.24**
Papaya	**11.82**	**8.82**	0.49	0.57	**4.95**
Mango	**4.99**	**3.73**	0.21	0.24	**2.09**
Rice, barley, broccoli, carrots, pears, et al.	**5.30**	**3.96**	0.22	0.26	**2.22**
Alfalfa	**4.40**	**3.28**	0.18	0.21	**1.84**

Use, Formulation, Type of Application	RQs for CTS and other Amphibians (Direct and Indirect Effects)		RQs for Small Mammals (Indirect Effects)		
	Acute (Dose-Based)[1]	Chronic (Dietary Based)[2]	Acute (Dose-Based)[3]	Chronic (Dietary Based)[4]	Chronic (Dose Based)[5]
Field corn, wheat, oats, sorghum, melons, peas, et al.	**4.24**	**3.17**	0.18	0.20	**1.78**
Field corn, wheat, oats, sorghum, and beans (ULV)	**2.59**	**1.93**	0.11	0.12	**1.08**
Pastures (ULV)	**2.69**	**2.01**	0.11	0.13	**1.13**
Non-Agricultural Uses					
Cull piles	**872.79**	**651.69**	**36.50**	**42.17**	**365.85**
Fence/hedge row, domestic dwelling (perimeter), and refuse/solid waste site	**31.04**	**23.18**	**1.30**	**1.50**	**13.01**
Adult mosquito control	**0.29**	0.22	0.01	0.01	0.12

[1]Based on dose-based EEC and ring-necked pheasant acute oral LD_{50} of 167 mg/kg-bw.
[2]Based on dietary-based EEC and northern bobwhite quail chronic NOAEC of 110 mg/kg-diet.
[3]Based on dose-based EEC and rat acute oral LD_{50} of 852 mg/kg-bw.
[4]Based on dietary-based EEC and rat chronic NOAEL of 1700 mg/kg-diet.
[5]Based on dose-based EEC and rat chronic NOAEL of 1700 mg/kg-diet.

T-HERPS was used to derive refined RQs for amphibians. These RQs were used to assess both direct and indirect effects to the CTS. Effects on amphibians could indirectly affect the CTS because small frogs are a prey item of this species. RQs were derived for both juvenile and adult salamanders. Juvenile (but post-metamorphosis) salamanders were assumed to be 2 g and to feed on small insects. Small insects are predicted to have greater pesticide residues than large insects. RQs derived with this same scenario were also used to assess the risk of effects on small frogs, a prey item of adult CTS. For direct effects to the CTS, salamanders were assumed to be 20 g and feeding on herbivorous small mammals. Herbivorous small mammals were chosen because this is the food type that is predicted to have the greatest pesticide residues.

RQs derived for the CTS using T-HERPS are given in Table 5-7. All uses of malathion yielded at least one RQ that exceed the LOC. For ULV use on citrus and ULV use for adult mosquito control, only the acute dose-based RQ exceeded the LOC (0.1). For all other uses, RQs met or exceeded the LOC for both acute and chronic risk to adult salamanders, as well as chronic risk to juvenile salamanders. Uses with higher application rates (>1.0 lb ai/A) also yielded an acute RQ that exceeded the LOC for juvenile salamanders consuming small insects. Thus, all uses of malathion are predicted to potentially cause adverse direct and indirect effects to the CTS through toxicity to amphibians. This risk conclusion is less certain for citrus ULV use than for other uses.

Table 5-5. Acute and Chronic RQs for Amphibians Derived Using T-HERPS. Risk quotients that exceed the LOC are shown in bold. The acute LOC is 0.1 and the chronic LOC is 1.0.

Use, Formulation, Type of Application	RQs for Juvenile CTS and Small Frogs Consuming Small Insects			RQs for Adult CTS Consuming Herbivorous Mammals		
	Acute (Dose-Based)[1]	Acute (Dietary-based)[2]	Chronic (Dietary Based)[3]	Acute (Dose-Based)[1]	Acute (Dietary-Based)[2]	Chronic (Dietary Based)[3]
Agricultural Uses						

Use, Formulation, Type of Application	RQs for Juvenile CTS and Small Frogs Consuming Small Insects			RQs for Adult CTS Consuming Herbivorous Mammals		
	Acute (Dose-Based)[1]	Acute (Dietary-based)[2]	Chronic (Dietary Based)[3]	Acute (Dose-Based)[1]	Acute (Dietary-Based)[2]	Chronic (Dietary Based)[3]
Citrus	**0.23**	**0.48**	**9.20**	**8.2**	**0.85**	**16.42**
Citrus (ULV)	0.01	0.01	0.22	**0.20**	0.02	0.40
Cotton, chestnut, and walnut	**0.13**	**0.26**	**5.08**	**4.51**	**0.47**	**9.06**
Pecan	**0.11**	**0.23**	**4.45**	**3.95**	**0.41**	**7.95**
Strawberry	**0.11**	**0.22**	**4.29**	**3.81**	**0.40**	**7.65**
Caneberry group	**0.10**	**0.21**	**4.06**	**3.61**	**0.37**	**7.25**
Mushroom	**0.11**	**0.22**	**4.25**	**3.77**	**0.39**	**7.59**
Papaya	**0.13**	**0.26**	**4.96**	**4.41**	**0.46**	**8.86**
Mango	0.08	**0.16**	**3.12**	**2.77**	**0.29**	**5.56**
Rice, barley, broccoli, carrots, pears, et al.	0.06	**0.12**	**2.23**	**1.98**	**0.21**	**3.97**
Alfalfa	0.05	**0.10**	**1.85**	**1.64**	**0.17**	**3.30**
Field corn, wheat, oats, sorghum, melons, peas, et al.	0.05	0.09	**1.78**	**1.58**	**0.16**	**3.18**
Field corn, wheat, oats, sorghum, and beans (ULV)	0.03	0.06	**1.09**	**0.96**	**0.10**	**1.94**
Pastures (ULV)	0.03	0.06	**1.1**	**1.0**	**0.10**	**2.0**
Non-Agricultural Uses						
Cull piles	**9.36**	**19.0**	**367**	**325**	**33.9**	**655**
Fence/hedge row, domestic dwelling (perimeter), and refuse/solid waste site	**0.33**	**0.67**	**13.0**	**11.5**	**1.20**	**23.2**
Adult mosquito control	<0.01	0.01	0.12	**0.11**	0.01	0.22

[1]Based on dose-based EEC and ring-necked pheasant acute oral LD_{50} of 167 mg/kg-bw.
[2]Based on dietary-based EEC and Japanese quail subacute LC_{50} of 2128 mg/kg-diet.
[3]Based on dietary-based EEC and northern bobwhite quail chronic NOAEC of 110 mg/kg-diet.

5.1.2.b. Terrestrial Invertebrates

Because insects are a prey item of the CTS, adverse effects on insects may indirectly affect the CTS. Risk of malathion to terrestrial invertebrates was assessed using data for acute contact toxicity to the honey bee. The lowest measured acute contact LD_{50} from an acceptable study, which was 0.20 µg a.i./bee, was used to calculate risk quotients (MRID 05001991). After multiplying this value by the conversion factor of 1 bee/0.000128 g, this endpoint becomes 1560 µg ai/kg, or 1.56 mg ai/kg. RQs were then calculated by dividing the EECs calculated by T-REX for small insects by this LD_{50} endpoint. Small insects were chosen because they are predicted to have greater residues on a per bodyweight basis than large insects.

Table 5-6. Summary of RQs for Terrestrial Invertebrates. Risk quotients that exceed the LOC of 0.1 are shown in bold.

Use	Small insect EEC (mg/kg-bw)	Small Insect RQ*
Agricultural Uses		
Citrus	1012	**649**
Citrus (ULV)	24.4	**15.6**
Cotton, chestnut, and walnut	559	**358**
Pecan	490	**314**
Strawberry	472	**302**
Caneberry group	392	**251**
Mushroom	468	**300**
Papaya	546	**350**
Mango	231	**148**
Rice, barley, broccoli, carrots, pears, et al.	245	**157**
Alfalfa	203	**130**
Field corn, wheat, oats, sorghum, melons, peas, et al.	196	**126**
Field corn, wheat, oats, sorghum, and beans (ULV)	120	**76.9**
Pastures (ULV)	124	**79.5**
Non-Agricultural Uses		
Cull Piles	40,300	**25,800**
Fence / hedge row, domestic dwelling (perimeter), and refuse/solid waste site	1430	**917**
Adult mosquito control	13.4	**8.59**

LOC exceedances (RQ $\geq$ 0.05) are bolded.

All uses of malathion are predicted to potentially cause indirect effect the CTS by adversely affecting the insects on which it relies for food. Since the RQs are much greater than 1 for all uses, the certainty of this conclusion is high.

5.1.2.c. Terrestrial Plants

Adverse effects on terrestrial plants may have indirect effects on the DS and CTS by way of habitat degradation. Generally, for indirect effects, potential effects on terrestrial vegetation are assessed using RQs from terrestrial plant seedling emergence and vegetative vigor EC_{25} data as a screen. In the case of malathion, toxicity data not are available from which one can derive EC_{25} or NOAEC values for assessment endpoints related to growth and reproduction. Therefore, no quantitative risk assessment for terrestrial plants was conducted in this assessment. As described in Section 4.3.4, however, several studies are available from open literature studies which evaluate effects of direct application of malathion at typical application rates (0.89 – 1.41 lb ai/A) to various plant species. In all of these studies, the direct application of malathion either resulted in no observable adverse effects, or in some cases, result in enhanced biomass relative to control plants, presumable because of the protection it provides from herbivorous insects. Nontarget plants outside of the treated area of course would receive much less exposure that plants which are directly treated. These results indicate that malathion has little phytotoxicity and is unlikely to result in significant adverse effects to terrestrial plants at environmentally relevant exposure levels.

5.1.3. Primary Constituent Elements of Designated Critical Habitat

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

5.2. Risk Description

The risk description synthesizes overall conclusions regarding the likelihood of adverse impacts leading to an effects determination (*i.e.*, “no effect,” “may affect, but not likely to adversely affect,” or “likely to adversely affect”) for the assessed species and the potential for modification of their designated critical habitat. If the RQs presented in the Risk Estimation (Section 5.1) show no direct or indirect effects for the assessed species, and no modification to PCEs of the designated critical habitat, a “no effect” determination is made, based on malathion’s use within the action area. However, if LOCs for direct or indirect effect are exceeded or effects may modify the PCEs of the critical habitat, the Agency concludes a preliminary “may affect” determination for the FIFRA regulatory action regarding malathion.

A summary of the risk estimation results are provided in Table 5-7 for direct and indirect effects to the listed species assessed here and in Table 5-8 for the PCEs of their designated critical habitat. For the DS, a preliminary “may effect” determination is concluded based on predicted potential direct effects of malathion uses as well as potential indirect effects manifested by way of adverse effects to freshwater and estuarine fish, freshwater and estuarine invertebrates, and terrestrial invertebrates (which may have aquatic life-stages). For the CTS, a preliminary “may effect” determination is concluded based on predicted potential direct effects of malathion uses as well as potential indirect effects manifested by way of adverse effects to freshwater fish, freshwater invertebrates, terrestrial invertebrates, terrestrial-phase amphibians, small mammals.

Table 5-7. Risk Estimation Summary for Malathion - Direct and Indirect Effects

Taxa	LOC Exceeded	Description of Results of Risk Estimation	Assessed Species Potentially Affected
Freshwater Fish and Aquatic-phase Amphibians	Yes	RQ for acute toxicity exceeds the LOC for all uses except passion fruit and ULV application on citrus and kumquat. RQ for chronic toxicity also exceeds the LOC for some uses	Direct Effects: DS, CTS Indirect Effects: DS, CTS
Freshwater Invertebrates	Yes	Both acute and chronic RQs exceed the LOCs for all uses.	Indirect Effects: DS, CTS
Estuarine/Marine Fish	Yes	RQ for acute toxicity exceeds the LOC for all uses except passion fruit and ULV application on citrus and kumquat. RQ for chronic toxicity also exceeds the LOC for rice, wild rice, water cress, mosquito control, and several nonagricultural uses.	Direct Effects: DS Indirect Effects: DS
Estuarine/Marine Invertebrates	Yes	Both acute and chronic RQs exceed the LOCs for all uses.	Indirect Effects: DS
Vascular Aquatic Plants	No	Acute and chronic RQs are below the LOC for all uses.	Indirect Effects: none
Non-Vascular Aquatic Plants	No	Acute and chronic RQs are below the LOC for all uses.	Direct Effects: none
Terrestrial-Phase Amphibians	Yes	RQ for acute toxicity exceeds the LOC for all uses and RQ for chronic toxicity exceeds the LOC for all uses except ULV application on citrus and kumquat	Direct Effects: CTS Indirect Effects: CTS
Mammals	Yes	Both acute and chronic RQs exceed the LOCs for all uses except ULV application on citrus and kumquat.	Indirect Effects: CTS
Terrestrial Invertebrates	Yes	Acute toxicity (all uses)	Direct/Indirect Effects: DS and CTS
Terrestrial Plants - Monocots	No	--	--
Terrestrial Plants - Dicots	No	--	--

Table 5-8. Risk Estimation Summary for Malathion – Effects to Designated Critical Habitat (PCEs)

Taxa	LOC Exceeded	Description of Results of Risk Estimation	Species Associated with a Designated Critical Habitat that May Be Modified by the Assessed Action
Freshwater Fish	Yes	Risk to water quality.	DS
Freshwater Invertebrates	Yes	Risk to water quality.	DS
Estuarine/Marine Fish	Yes	Risk to water quality.	DS

Taxa	LOC Exceeded	Description of Results of Risk Estimation	Species Associated with a Designated Critical Habitat that May Be Modified by the Assessed Action
Estuarine/Marine Invertebrates	Yes	Risk to water quality.	DS
Vascular Aquatic Plants	No	--	--
Non-Vascular Aquatic Plants	No	--	--
Mammals	Yes	Both acute and chronic RQs exceed the LOCs for all uses except ULV application on citrus and kumquat.	CTS
Terrestrial Plants - Monocots	No	--	--
Terrestrial Plants - Dicots	No	--	--

Following a "may affect" determination, additional information was considered to refine the potential for exposure at the predicted levels based on the life history characteristics (*i.e.*, habitat range, feeding preferences, *etc*.) of the assessed species. Based on the best available information, the Agency used 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 DT and CTS and their designated critical habitat.

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

- Significance of Effect: Insignificant effects are those that cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where "take" occurs for even a single individual. "Take" in this context means to harass or harm, defined as the following:
    - Harm includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering.
    - Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering.
- Likelihood of the Effect Occurring: Discountable effects are those that are extremely unlikely to occur.
- Adverse Nature of Effect: Effects that are wholly beneficial without any adverse effects are not considered adverse.

A description of the risk and effects determination for each of the established assessment endpoints for the assessed species and their designated critical habitat is provided in Section 5.2.1 for the DS and in Section 5.2.2 for the CTS. The discussion of effects determination follows a similar pattern for both species. Each starts with a discussion of the potential for direct effects, followed by a discussion of the potential for indirect effects. Since both species have designated critical habitat, the section will end with a discussion on the potential for modification to the critical habitat from the use of malathion. Finally, a discussion of any potential overlap between areas of concern and the species (including any designated critical habitat) is presented in the spatial analysis section.

5.2.1. Delta Smelt

5.2.1.a. Direct Effects

Risk quotient analysis indicate that all uses of malathion except for passion fruit, fence rows/hedge rows, and ULV application for adult mosquito control potentially could adversely effect freshwater and saltwater fish, and thus could have direct adverse effects on the DS (Table 5.1 and 5-3). Since this risk assessment was based on predicted exposure of malathion to a 1-acre farm pond, considerable uncertainty exists in applying these results to predict risk in the large rivers and Suisun Bay where the fish lives outside of spawning periods. In these habitats, it is possible that dilution would result in much lower malathion concentrations, and thus lower risk to the DS. This has been corroborated by surface water monitoring (see discussion below). During spawning, however, DS migrate up into shallow freshwater tributaries, soughs, and drains to reproduce and lay eggs. The aquatic exposure predictions based on the farm pond scenarios would be much more appropriate for these aquatic habitats. Furthermore, the eggs and larval stages of the DS would be present in the low-volume habitats with greatest concentration, and these are generally the life stages with the greatest sensitivity to pesticides. Thus, we conclude that many uses of malathion could potentially adversely affect adult DS during periods of spawning, as well as the egg and larval stages.

This conclusion is supported by evidence from ecological incident data. Twenty-three incidents of mortality of fish and aquatic organisms have been linked to exposure of malathion. Several of these incidents have been linked to agricultural use of malathion, and several other have been linked to adult mosquito control use. For both agricultural uses and mosquito control uses, many of the incidents were given a certainty of probably or highly-probable for malathion being the cause of the mortality. Numerous incidents of fish kills have been reported for both agricultural and nonagricultural uses of malathion, many of which were conclusively linked to exposure to malathion (Table 4-23). Thus, incident data support that both agricultural and urban uses of malathion have the potential to cause direct adverse effects to the DS.

Findings of recent surface water monitoring programs provide additional information on the potential of malathion to cause direct effects to the DS. Table 5-12 summarizes detections of malathion from surface water monitoring in the basins of the Sacramento River and San Joaquin River in and near the DS habitat. Monitoring data show that malathion was seldom detected in the main channels of these rivers, as well as the large tributaries of the Merced River and Tuolumne River, and was never detected above 0.025 µg/L. In the Yolo Bypass, which receives overflow water from the Sacramento River during times of high flow, malathion detections were more frequent (25%), but measured concentrations did not exceed 0.015 µg/L. In contrast, detections of malathion were frequent and maximum concentrations were much higher in the smaller tributaries, sloughs, and agricultural drains. The highest malathion detection frequencies and concentrations were observed in Arcade Creek near Knights Landing, California, where the malathion detection frequency was 53.3% and the maximum concentration was 0.63 µg/L (Domagalski, 2000). This small stream mainly drains areas with predominantly urban land use (Domagalski, 2000). Contamination was only slightly lower in Salt Slough in 1993, when the malathion detection frequency was 23% and the maximum concentration was 0.39 µg/L (Panshin et al. 1998). Salt Slough drains mainly agricultural lands, and receives both sub-surface drainage and surface irrigation return flows (Panshin et al., 1998). A peak concentration of 0.11 µg/L was observed in the Orestimba River in the 2002 (Starner et al., 2005). During the time of the sampling (July – September), this stream would contain predominantly irrigation return flow from agricultural lands (Panshin et al., 1998). These data indicate that both urban and agricultural uses of malathion contribute to contamination of surface water, and that concentrations of malathion are greatest in small streams, sloughs, and agricultural drains.

Higher concentrations of malathion were detected outside range of the DS. Sampling in the Colusa Basin Drain, conducted by the California Department of Pesticide Regulations in 1996, detected malathion concentrations as high as 6.0 µg/L (Gorder *et al*., 1996). The sampling site with the highest malathion detections was near the city of Colusa in Colusa County, approximately 50 miles north of the northernmost reaches of the designated critical habitat of the DS. The Colusa Basin Drain receives water largely from intensive rice production in the area, and the malathion peak concentration occurred just after discharge of water from a rice field that was treated with malathion just one day prior. This observation represents a high-end exposure level for malathion that may occur in a drain receiving water from rice production. How representative this drain is to ones inhabited by the DS, however, is uncertain.

Pulses of elevated insecticide concentrations flow down the Sacramento River and San Joaquin River into the Suisun Bay following large rainfall events that occur in the region during the winter. In winter, the primary source of these residues is believed to be spraying of insecticides, including malathion, on dormant fruit and nut trees (Kuivila and Foe, 1995; Kuivila and Hladik, 2008). Kuivila and Hladik (2008) attributed the detection of malathion in creeks and streams in the spring largely to malathion applications on alfalfa, and detections in the summer largely to applications on almonds and walnuts. In contrast, contamination of malathion in streams that drain predominantly urban areas occurs year-round and is attributed to various residential and commercial uses of malathion.

In small freshwater tributaries and sloughs within the range of the DS, monitoring studies found malathion concentrations up to approximately 0.63µg/L (Table 5-12). The toxicity assessment endpoint for acute toxicity of malathion was 33 µg/L for both freshwater and saltwater fish (Table 4-1.) The margin of safety between the maximum measured concentrations and median lethal level for fish is 52.3. A peak concentration of 6.00 µg/L was measured in the Colusa Basin Drain (Gorder et al. 1996), which is approximately 50 miles to the north of the northern reaches of the DS. Then the acute toxicity endpoint is compared to this value, the margin of safety is only 5.5. While these results do not indicate that malathion exposure would likely to cause mortality to DS, they do not dismiss the risk conclusion based on the RQ analysis. The assessment endpoint of malathion for chronic effects, including reproductive effects, is 8.6 to freshwater fish (Table 4-1). The margin of safety between maximum measured concentration and the chronic NOAEC is 21.5 when compared to the peak concentration in the range of the DS, or only 1.4 when compared to the peak concentration measured in the Colusa Basin Drain.

Thus, monitoring data do not confirm that exposure to malathion would cause direct acute or chronic effects to the DS; however, the margin of safety is not great enough to discount the possibility of direct effects. All of the available surface water monitoring data are from general monitoring programs that did not target malathion. Thus, sampling times were not timed to target periods when malathion concentrations were expected to peak. Furthermore, the duration of peak concentrations may be very short compared to the sampling interval of these studies. Therefore, these monitoring studies could have easily missed the peak malathion concentrations. The RQ analyses, on the other hand, were based on modeled concentrations designed to represent a reasonable upper bound of malathion concentrations that would be predicted in these habitats.

Monitoring data indicate that portions of the DS habitat would be contaminated quite frequently with malathion concentrations that are non-negligible but below acute and chronic thresholds. Malathion is an organophosphate insecticide whose mode of action in fish is disruption of nerve function through inhibition of acetylcholinesterase. Numerous other organophosphorous and carbamate insecticides with this same mode of action were also detected in these waters, including chlorpyrifos, diazinon, and methidathion, and carbofuran (see review in Kuivila and Hladik, 2008). The effects of the malathion on inhibition of acetylchonesterase would likely be at least additive, and in some cases may be synergistic, to the effects of these other insecticides present in the water (see Section 2.2.2). Bioassays with whole water samples have shown that the combination of these insecticides occasionally reach levels that are toxic to the water flea, *Ceriodaphnia dubia* (Werner et al. 2000) Thus, even at subtoxic levels, malathion contamination would contribute to the overall degradation of water quality in the habitat of the DS.

The potential for DS to be exposed to the oxon derivative of malathion, maloxon, as well as the parent compound, adds uncertainty to the assessment of potential direct effects to the DS. Current information on maloxon formation is very limited, but there appears to be a potential for low levels of maloxon to be present in surface water. Information on the toxicity of maloxon is also uncertain, but current data suggest that it may be between 4.1 and 90 times more acutely toxic to aquatic vertebrates than malathion. Thus, any presence of maloxan would elevate toxicity above that predicted in this assessment, thereby increasing the likelihood of direct effects to the DS. See Section 6.1.4 for more information on this uncertainty.

Table 5-12. Summary of Surface Water Monitoring in the Sacramento River and San Joaquin River Basins in and near the Habitat of the DS

Sampling Site	**Years**	**Max. Conc. (µg/l)**	**Min. Conc. (µg/l)**[1]	**Median Conc. (µg/l)**	**Detection Frequency**	**LOD or LOR**	**Reference**
Colusa Basin Drain at Rd. 99E near Knights Landing	1996-1998	0.054	0.0055	ld	33.3%	0.005 (LOR)	Domagalski 2000
Arcade Creek near Del Paso Heights	1996-1998	0.63	0.012	0.013	53.3%	0.005 (LOR)	Domagalski 2000
Sacramento River at Sacramento	1991-1992	ld	ld	ld	0%	0.019 (LOD)	MacCoy et al., 1995
	1992-1994	ld	ld	ld	0%	0.035 (LOD)	MacCoy et al., 1995
Sacramento River at Freeport	1996-1998	e0.004	e0.004	ld	5.3%	0.005 (LOR)	Domagalski 2000
Yolo Bypass at Interstate 80	1996-1998	0.015	0.015	ld	25%	0.005 (LOR)	Domagalski 2000
San Joaquin River near Vernalis	1991-1992	ld	ld	ld	0%	0.031 (LOD)	MacCoy et al., 1995
	1992-1994	ld	ld	ld	0%	0.044 (LOD)	MacCoy et al., 1995
	2002	ld	ld	ld	0%	0.012 (LOD) 0.05 (LOR)	Starner et al. 2005
San Joaquin River near Vernalis	1993	0.025	nr	ld	14%	0.005 (LOD)	Panshin et al. 1998
Tuolumne River at Shiloh	2002	ld	ld	ld	0%	0.012 (LOD) 0.05 (LOR)	Starner et al. 2005
Orestimba Creek at River Road near Crows Landing	1993	0.006	nr	ld	2.1%	0.005 (LOD)	Panshin et al. 1998
	2002	0.111	nr	ld	7.1%	0.012 (LOD) 0.05 (LOR)	Starner et al. 2005
Merced River at River Road near Newman	1993	0.009	nr	ld	2.5%	0.005 (LOD)	Panshin et al. 1998
Salt Slough at Highway 165 near Stevinson	1993	0.39	nr	ld	23%	0.005 (LOD)	Panshin et al. 1998
	2002	ld	ld	ld	0%	0.012 (LOD) 0.05 (LOR)	Starner et al. 2005

[1] *ld* signifies less than reporting limit; *nr* signifies data were not reported.

5.2.1.b. Indirect Effects

i. Potential Loss of Prey

The DS feeds on small fish and aquatic invertebrates. Thus, toxic effect on either fish or invertebrates could reduce the availability of prey and result in indirect effects on the DS. As discussed in the previous section, RQ analysis showed that most uses of malathion are predicted to potentially cause adverse acute effects on fish (Table 5-1 and 5-3). This conclusion is supported by the numerous incidents of fish kills that have been linked to both agricultural and nonagricultural uses of malathion (Table 4-23). For indirect effects mediated through effects on invertebrate prey, the risk quotient analysis indicates that all uses of malathion have the potential to cause both acute and chronic toxic effect to both freshwater and saltwater invertebrates (Table 5-2 and 5-4). Risk of sublethal effects from chronic exposure appears to be especially high, for which risk was indicated for all uses, most RQ for most uses exceeding 100 and for some uses exceeding 1000. Thus, we conclude that the use of malathion has a high potential to cause indirect effects on the DS through reduction of fish and invertebrate prey. As with direct effects, indirect risks are expected to be greatest in the shallow freshwater habitats that the DS use for spawning and reproduction.

Direct and indirect risks to the DS can also be evaluated by comparing monitoring data for malathion with acute and chronic toxicity values. Table 5-12 summarizes detections of malathion from recent surface water monitoring in the basins of the Sacramento River and San Joaquin River in and near the DS habitat. As was discussed in the previous section, surface water sampling in the basins has found that malathion concentrations are highest in small streams, sloughs, and drains where the predominant land use of the watershed is either urban or agricultural (Domagalski 2000, Panshin et al. 1998, and Starner et al. 2005). The highest measure concentration of malathion within the range of the DS was 0.63 µg/L, which was measured in Arcade Creek, a small urban stream (Domagalski 2000). In small streams and sloughs that drain predominantly agricultural lands, peak concentrations were 0.39 µg/L in Salt Slough, a tributary of the San Joaquin River (Panshin et al. 1998) and 0.11 µg/L in Orestimba Creek (Starner et al. 2005). The assessment endpoint for the threshold of acute toxicity to freshwater invertebrates is 0.59 µg/L. Thus, monitoring results indicate that malathion concentrations occasionally approach or exceed the levels toxic to freshwater invertebrates. Considering that the monitoring programs were not targeted to capture peak malathion concentrations, and the water sampling associated with these studies were spatially and temporally limited, it is likely that peak malathion concentrations occasionally reach levels higher than observed in these studies. Sampling from the Colusa Basin Drain in Colusa County, approximately 50 miles north of the northernmost reaches of the designated critical habitat of the DS, detected malathion concentrations as high as 6.0 µg/L (Gorder *et al.*, 1996). Thus, it is likely that malathion concentrations in both primarily agricultural and primarily urban water bodies will occasionally exceed acute toxicity threshold of aquatic invertebrates.

Concerning chronic effects, measured peak concentrations of malathion were well above the predicted NOAEC that was derived for freshwater invertebrates using the acute-to-chronic ratio method. Measured peak concentrations also exceed both the NOAEC (0.06 µg/L) and the LOAEC (0.10 µg/L) for reproductive effects measured in a life-cycle study with the water flea, *Daphnia magna* (MRID 41718401). Uncertainty exists in this comparison because the duration of exposure to malathion at or above toxic levels in the streams may not be comparable to the duration of exposure in the laboratory study. Nevertheless, these findings support the quotient-based risk assessment that agricultural and urban uses of malathion may cause chronic as well as acute toxic effects on the invertebrate prey of the DS.

Monitoring data found that detections of malathion were much less frequent, and peak concentrations were much lower, in the main channel of the Sacramento River and San Joaquin Rivers (Domagalski 2000, MacCoy et al. 1995, Panshin et al. 1998). The highest peak malathion concentration observed was 0.025 µg/L in the San Joaquin River (Panshin et al. 1998) and approximately 0.004 µg/L in the Sacramento River (Domagalski 2000). These peaks concentrations are over one order of magnitude less than the acute toxicity assessment endpoint for freshwater invertebrates (0.59 µg/L). They are also less than the NOAEC measured for *Daphnia magna* (0.06 µg/L), although the peak concentration observed in the San Joaquin River exceeds the chronic NOAEC predicted for freshwater invertebrates using the acute-to-chronic ratio method (0.035 µg/L). Detection frequencies of malathion were 0-5.3 % in monitoring studies in the lower Sacramento River (MacCoy et al. 1995, Domagalski 2000) and 14% in the lower San Joaquin (Panshin et al. 1998), compared to up to 53.3% and 33.3% in small urban and agricultural streams, respectively. In all, the monitoring data suggest that malathion concentrations are likely to be relatively low in the main channel of the lower Sacramento and San Joaquin Rivers, as well as in the Suisan Bay. Therefore, malathion would be less likely to adversely affect invertebrate prey in these areas which comprise the main range of DS outside of spawning. However, as noted previously, several other organophosphate and carbamate insecticides were detected in the lower reaches of these rivers, and while malathion may not frequently reach toxic levels on its own, it may contribute to a combined accumulative toxicity that could have significant toxic effects on invertebrate prey.

Kuivila and Foe (1995) conducted bioassays with the water flea (*Ceriodaphnia dubia*) using water sampled from the lower Sacramento River and San Joaquin River, and found that the river water caused 100% mortality during peaks of insecticide concentrations associated with the pulses of insecticides moving past the sampling sites. However, they did not detect any malathion in any of the samples they collected from either river, and thus did not attribute the toxicity to the water flea to malathion. They determined that the elevated diazinon concentrations in the water were sufficient to explain most of the toxicity. Other dormant spray insecticides, including methidathion and chlorpyrifos, were also present in elevated concentrations and likely also significantly contributed to the toxicity of the water. They attributed the lack of malathion in detectable concentrations to the lower use compared to other insecticides and the rapid degradation it undergoes in soil. Thus, these studies show that insecticides concentrations sometimes reach levels that are toxic to the invertebrate prey of the DS in waters of the Suisun Bay and large rivers that make up non-breeding habitat of the DS; however, little of the toxicity in these areas can be attributed to malathion.

Werner et al. (2000) sampled water from numerous sites in the Sacramento/San Joaquin River Delta between 1993 and 1995, conducted water monitoring for pesticides, and evaluated water samples for toxicity to the water flea (*Ceriodaphnia dubia*). Toxicity testing with the water flea included evaluation of both mortality and reproduction impairment. Unlike the studies discussed above, this study included many monitoring sites at back soughs and small upland streams where monitoring indicates pesticide concentrations are greatest. They found that a sizable percent (16.6%) of the samples taken from back sloughs were toxic to *C. dubia*, whereas toxicity occurred less frequently in main-stem rivers (6.9%) and rarely in the main channel of the Sacramento River and San Joaquin River. Toxicity identification evaluations conducted on some of the toxic water samples identified chlorpyrifos and diazinon as the primary toxicants at most of the sampling sites. Malathion was identified as a significant contributor to total toxicity in water from only two sites, Ulatis Creek and French Camp Slough. Both of these sites were back sloughs or small upland drainages that receive drainage from agricultural areas. Ulatis Creek also receives drainage from urban areas. Water samples from Ulatis Creek caused over 50% mortality to *C. dubia* in March, May, July, and September, November, and December; and samples from French Camp Slough caused mortality of 50% or more in March and September. Water samples from these sites also caused significant reproductive impairment to *C. dubia*.

This paper concluded that malathion was identified as a significant but relatively minor contributor to toxicity in the tributaries of the Sacramento/San Joaquin River Delta. The highest malathion concentration measured was 0.061 µg/L. This level is considerably less than the acute and chronic assessment endpoint for freshwater fish (33 µg/L and 8.6 µg/L, respectively). It is approximately 10-fold less than the acute assessment endpoint for freshwater invertebrates (0.70 µg/L). However, it exceeds the chronic NOAEC estimated for sensitive freshwater invertebrates using the acute-to-chronic method (0.035 µg/L). Compared to the chronic toxicity endpoints measured for the water flea (*Daphnia magna*, MRID 41718401), it is approximately equal to the NOAEC (0.06 µg/L) and less than the LOAEC (0.1 µg/L) by a factor of 0.61.

Considered together, both agricultural uses and urban uses appear to contribute to occasional poor water quality that occasionally may result in loss of aquatic invertebrate prey in the habitat of the DS, primarily in the small streams, sloughs, and drains that the fish inhabits during spawning. The monitoring data show that malathion concentrations in these areas approach or exceed toxic levels only for short periods during short-term peaks, while remaining well below toxic levels at other times (Domagalski 2000, Starner et al. 2005). This observation agrees with the known environmental fate properties of malathion which suggest that it will not be persistent in soil or water. Thus high levels of water contamination would likely be limited to rainfall events that occur shortly after application of malathion, and cause runoff before the soil residues have time to degrade significantly. Nevertheless, these findings indicate that malathion concentrations alone may occasionally be toxic to invertebrate prey of the DS in parts of its range, as well as significantly contribute to the overall toxicity of mixtures of organophosphate and carbamate insecticides that known to contaminate these waters

ii. Potential Modification of Habitat

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

Toxicity testing has found that malathion has low toxicity to aquatic plants. Risk quotients for all uses of malathion were well below 1. For nonaquatic agricultural uses and nonagricultural uses, RQs were never greater than 0.04. For aquatic agricultural uses, RQs were as high as 0.47, but the exposure estimates for these uses are for peak concentrations on the flooded field and are likely to be much greater than what would occur in off-site aquatic habitats. Peak concentrations in offsite receiving waters would be much less because of the rapid degradation that malathion would undergo while the water is held on the field, and because of the dilution that would occur when the released water mixes with uncontaminated water. We therefore consider the risk of indirect effects to the DS from malathion causing adverse effects on aquatic plants to be insignificant and discountable.

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

Despite widespread use, malathion has not been observed to be phytotoxic to the wide variety of crop and ornamental plants to which it is directly applied. As discussed in Section 4.3.4, plant field tests have found that application of malathion at typical use rates either do not have significant effects on the growth of plants, or have significant beneficial effects due to control of plant pests. Vegetation in the habitat of the DS would be exposed from drift and runoff from treated sites. This exposure would be at rates much less than the target plants that are directly treated. Therefore, exposure of plants to malathion in the DS habitat is not expected to result in any significant damage to vegetation.

5.2.1.c. Modification of Designated Critical Habitat

The PCEs for the DS state that suitable water quality must be maintained in the habitat used by all life-stages of the smelt. This includes the Sacramento River and San Joaquin River channels and their tributary channels that the DS inhabits as larvae and juveniles (PCE 2) and migrates into as adults during spawning periods (PCE 4). It also includes the bays of the Sacramento and San Joaquin Estuary where the adult smelt occurs outside of spawning (PCE 3). As described in Section 5.2.1.a, urban and agricultural uses of malathion are predicted to cause occasional contamination of the tributaries of the Sacramento River and San Joaquin River that could potentially be toxic to the larvae and juvenile traveling down the channels, as well as the adult fish migrating up the channels during spawning. Thus, malathion use may significantly degrade the water quality in these sections of the critical habitat. Due to dilution with less contaminated water, malathion levels are expected to generally remain below levels that would be directly toxic to the DS in the main channels of the lower Sacramento River and San Joaquin River, as well as the Suisan Bay. However, even in these areas, some malathion contamination will occur, and their toxicity would add to that of the other organophosphate and carbamate insecticides that are known to be present in these waters, including chlorpyrifos, diazinon, and carbofuran. Thus, malathion residues may significantly contribute to deterioration of water quality in these areas even though may not reach toxic levels by themselves.

Availability of fish and aquatic invertebrates is also an important requirement of the habitat of the DS because the species depends on these taxa for food. As discussed in Section 5.2.1.b.i, all uses of malathion are predicted to potential cause mortality to aquatic invertebrates, and most uses are also predicted to potential cause mortality to fish, especially in the shallow freshwater habitats used during spawning. Therefore, use of malathion may degrade the critical habitat of the DS by reducing prey abundance.

5.2.1.d. Spatial Extent of Potential Effects

When LOCs are exceeded, the Agency typically does analysis to determine the spatial extent of potential "likely to adverse affect" (LAA) where effects may occur in relation to the treated site. In this assessment, however, the use "footprint" of the use of malathion was considered to be the entire state of California. All uses of malathion result in an LAA determination because of the potential for direct and/or chronic effects. Uses include a very wide range of agricultural crops, fruit and nut trees, forestry, commercial, and residential uses. Since uses are expected in all land use categories (agricultural crops, orchards, forests, rangeland, and urban areas), the spatial extent of effects is not limited by the location of uses. Any place where the DS occurs, or that is part of its critical habitat, is considered to be part of the LAA area.

5.2.1.e. Spray Drift

In order to determine aquatic habitats of concern due to malathion exposures through spray drift, it is necessary to estimate the distance that spray applications can drift from the treated area and still be present at concentrations that exceed levels of concern. While we assume that malathion can potentially be applied anywhere in the state, these calculations may be useful to determine necessary buffers from local use sites that would be needed to protect aquatic habitats from spray drift.

For the flowable uses, a quantitative analysis of spray drift distances was completed using AgDRIFT (v. 2.01) using default inputs for ground applications (*i.e.*, high boom, ASAE droplet size distribution = Very Fine to Fine, 90^{th} data percentile) and aerial applications (*i.e.*, ASAE Very Fine to Fine). Winds speed was set at 10 mph. EECs for loading by drift only were calculated assuming 5% spray drift for aerial applications and 1% spray drift for ground applications. Drift was assumed to deposit and uniformly dilute into a water body 3-meter deep. Indirect risk to the DS was assessed based on the acute toxicity endpoint for freshwater invertebrates (EC_{50} = 0.59 µg/L). Results of this analysis are shown in Table 5-13. The distance a water body must be from the treated site for spray drift to not result in risk that exceeds the LOC ranges from 0 ft (adjacent) to >1000 feet, depending on the method of application and the application rate. This analysis assumes that loading occurs from a single application to a single use site, with no contributions occurring from other potential use sites.

Table 5-13. Maximum Distance from Edge of Field at which the Spray Drift Deposition from Malathion Applications are Predicted to Result in an Aquatic Risk Quotient that Exceeds the LOC

Use	Use Rate	Application Method[1]	Freshwater Invert. RQ	Distance for Exceed LOC (Feet)
Agricultural Uses				
Citrus	7.5	A	5.835	>1000
		AB	1.169	Adjacent
Pecan, chestnut, and walnut	2.5	A	1.945	>1000
		AB	0.390	Adjacent
Cotton	2.5	A	1.945	>1000
		G	0.390	Adjacent
Strawberry, caneberry group	2.0	A	1.556	>1000
		G	0.312	Adjacent
Pears, papaya, and guava.	1.25	A	0.972	623
		AB	0.195	Adjacent
Alfalfa, rice, barley, broccoli, carrots, et al.	1.25	A	0.972	623
		G	0.195	Adjacent
Field corn, wheat, oats, sorghum, melons, peas, et al.	1.0	A	0.778	436
		G	0.156	Adjacent
Mango	0.9375	A	0.729	387
		AB	0.146	Adjacent
Non-Agricultural Uses				
Fence / hedge row, domestic dwelling (perimeter), and refuse/solid waste site	10.6	G	1.653	20

[1] "A" signifies Aerial, "AB" signifies airblast, "G" signifies ground spray.

5.2.1 f. Downstream Dilution Analysis

Typically, the downstream dilution model is used to determine the extent of exposure in streams and rivers where the EEC could potentially be above levels that would exceed the most sensitive LOC. For this assessment, however, the use of malathion is not limited to certain land use classes, but may be used throughout the state. The entire range of the DS is considered to be within the potential area of use of malathion. Therefore, analysis of downstream dilution was not necessary for defining the overlap of the potential area of LAA with the habitat and occurrence of the DS.

5.2.1.g. Overlap of Potential Areas of LAA Effect and Habitat and Occurrence of the Delta Smelt

As stated above, the LAA determinations for the DS is defined as the entire area of the occurrence of the DS and its critical habitat, as depicted in Fig. 2-2. Malathion may be used throughout the entire state of California, and therefore the use area does not spatially limit the extent of the potential adverse effects to the DS.

5.2.2. California Tiger Salamander

5.2.2.a. Direct Effects

Both aquatic and terrestrial RQs were evaluated to assess direct effects to the CTS. Aquatic RQs were based on toxicity assessment endpoints for freshwater fish (surrogate for aquatic stages of amphibians) and predicted water concentrations in a modeled farm pond. They were used to predict possible effects on the eggs and aquatic larval stages of the CTS, as well for terrestrial juvenile and adult stages for times when individuals in these stages are submerged in water. Terrestrial RQs were based on toxicity assessment endpoints for birds (surrogate for terrestrial stages of amphibians) and exposure to malathion predicted from dietary exposure.

Aquatic-Phase

Eggs and aquatic larvae stages of the CTS occur primarily in shallow vernal pools. These small water bodies may receive a large percentage of their water runoff and drainage from surrounding agricultural and urban areas with malathion use, with little dilution from untreated areas. Also, the impact of spray drift deposition to these shallow stagnant water bodies would be relatively high compared to deeper water bodies. Thus, the relatively high (protective) aquatic EECs predicted by the PRISM and EXAMS models, which predict concentrations for a 1-acre farm pond, are expected to be more appropriate for assessing aquatic exposure to the CTS than concentrations measured in streams and rivers from monitoring studies.

Toxicity data for freshwater fish was used to assess risk to aquatic stages of the CTS. Freshwater fish RQs are shown in Table 5-1. The RQ for acute toxicity exceeded the endangered species LOC (0.05) for all uses of malathion except passion fruit and aerial ULV applications for public health use (e.g., adult mosquito control). For approximately half the uses of malathion, the acute RQ also exceeded the LOC for nonendangered species (0.5). For 32 agricultural uses and 9 nonagricultural uses, the RQ exceeds 1.0, indicating that the predicted peak concentration exceeds the median lethal dose for sensitive species. Thus, assuming the acute toxicity levels measured for fish are representative of larvae of the CTS, there is a high likelihood that at least some of the uses of malathion could cause direct adverse effects to this species by way of acute toxicity.

Chronic RQs exceeded the LOC (1.0) less frequently. This is likely because malathion residues are not persistent in water and thus chronic EECs were considerably less than peak EECs. Chronic RQs exceeded the LOC for 10 agricultural uses and 1 nonagricultural use.

Data are not available on the toxicity of malathion to any species of salamander larvae. However, limited data are available on the acute toxicity of malathion to larvae stages of frogs (i.e., tadpoles). Reported acute toxicity data for frog tadpoles range widely from 0.59 µg/L for the Indian frog (*Rana hexadactyla*) to 19,200 µg/L for the yellow-legged frog (*Rana boylii*).

Thus, it is uncertain how the toxicity of malathion to frog tadpoles relate to the toxicity to young rainbow trout, the species of the assessment endpoint used to calculate the acute RQs. The lowest acute toxicity endpoint obtained, 0.59 µg/L for the Indian frog *Rana hexadactyla* (Khangarot et al., 1985; Eco ref. 011521), was judged to be unacceptable for quantitative risk assessment because too little information was available on the testing methods and apparatus, exposure concentrations were not provided, and several deviations from the Agency's test guidelines were observed. Excluding this value, the range of endpoints for the aquatic-stage amphibians is 170 to 19,200 µg/L, indicating that the toxicity to frog tadpoles is less than that to the rainbow trout. All of these studies, however, had deficiencies and were not judged to be acceptable for quantitative risk assessment. Peak EECs (Table 3-2) were greater than the lowest frog toxicity endpoint estimate of 0.59 µg/L for all uses, but were greater than the other frog toxicity estimates for all uses except for aquatic agriculture. In conclusion, the toxicity data for amphibian species is too variable and uncertain to draw conclusions of the effects of malathion to aquatic stages of the CTS.

Sparling and Fellers (2007) found that the oxon of malathion, maloxon, is approximately 90 times more toxic to tadpoles of the yellow-legged frog (*Rana boylii*) than is malathion. Maloxon may form on the dry surface of plants and then could be washed into ponds by rainfall. In addition, maloxon has been found to occur in significant quantities in rainwater (Vogel et al., 2008) and fog (Schomburg et al., 1991) in California. Thus, malathion may be deposited into ponds by precipitation. Any exposure to maloxon would likely increase the toxicity to eggs and larvae of the CTS above that which we predicted for exposure to malathion alone. This increases the certainty in our conclusion that use of malathion may cause direct adverse effects to aquatic stages of the CTS. See Section 6.1.4 for more information about the uncertainties concerning maloxon fate and toxicity.

Terrestrial-Phase

RQs were calculated for terrestrial amphibians (using birds as a surrogate) to assess the risk of malathion exposure to terrestrial stages of the CTS. Screening-level RQs were first calculated using the T-Rex model. The acute RQs derived with T-REX exceeded the acute LOC for all uses (Table 5-7). For most uses, the chronic RQ exceeded the chronic LOC as well. Therefore, the T-HERPS model was used to derive more refined RQs for the CTS. For juveniles, refined RQs were calculated for salamanders consuming small insects. For adults, refined RQs were calculated for salamanders consuming herbivorous small mammals. A diet of small mammals was selected because this food item is predicted to contain the greatest residues of malathion. Refined RQs from T-HERPS are presented in Table 5-8.

Greater risk was predicted for adult salamanders feeding on herbivorous small mammals than for the juvenile salamanders feeding on insects. For adults, acute RQs derived from dose-based calculations exceeded the LOC for listed species (0.1) for all uses. Use of malathion ultra-low volume (ULV) products had lower RQs than other agricultural uses because of the lower application rates used for ULV applications. The RQ for adult mosquito control was also lower because only a small fraction of the aerial ULV application was predicted to deposit on the surface and expose terrestrial organisms. For ULV applications on citrus and kumquats, and for adult mosquito control, the acute RQ exceeded the LOC for listed species (0.1) but not the LOC for non-listed species (0.5). Acute RQs derived from dietary-based calculations exceeded the listed species LOC for listed species (0.1) for all uses except ULV application on citrus and kumquats, and ULV application for adult mosquito control. The only use with a dietary-based RQ that exceeded 0.5 was non-ULV use on citrus and kumquats, for which the RQ was 0.85. For chronic risk, dietary-based RQs exceeded the LOC of 1.0 for all uses except ULV use on citrus and kumquats, for which the chronic RQ was 0.40, and ULV application for adult mosquito control, for which the chronic RQ was 0.22.

The terrestrial exposure modeling was less conservative for juvenile salamanders consuming small insects, and thus yielded lower RQs. Acute RQs exceeded 0.1, the LOC for listed species, for uses with higher use rates (e.g., non-ULV citrus, cotton, nuts, and berries), but not for uses with lower use rates (e.g., grains, melons, beans, and pastures). None of the acute RQs for juveniles exceeded 0.5, the LOC for nonendangered species. Chronic RQs were also lower in the assessment for juveniles, but all still exceeded the LOC of 1.0 except for ULV application on citrus and kumquats, which had a chronic RQ of 0.22, and for ULV application for adult mosquito control, which had a chronic RQ of 0.12.

Taken together, the RQ analysis for adult CTS indicate that all uses of malathion in California have the potential to cause direct adverse effects to terrestrial-phase CTS, although this conclusion is less certain for ULV applications to citrus and kumquats, and ULV application for adult mosquito control. It should be noted however, that use of non-ULV malathion products on citrus and kumquats yielded the highest RQs of any use. It should also be noted that even the ULV use on citrus and kumquats and the ULV use for adult mosquito control had aquatic risk quotients that indicate potential adverse effects on aquatic stages of the CTS.

Incident data confirm that malathion may cause direct effects to aquatic stages of the CTS. Twenty-three incidents of mortality of fish and aquatic organisms have been linked to exposure of malathion. Several of these incidents have been linked to agricultural use of malathion, and several other have been linked to adult mosquito control use. For both agricultural uses and mosquito control uses, many of the incidents were given a certainty of probably or highly-probable for malathion being the cause of the mortality. Thus, incident data supports the conclusion of risk to aquatic stages of the CTS from both agricultural uses and the mosquito-control use. In contrast, incident data do not confirm that use of malathion poses a risk to terrestrial adult stages of the CTS. Only four incidents of adverse effects to terrestrial vertebrates have been linked with exposure to malathion. In all four cases, simultaneous exposure to another more toxic pesticide occurred which was more likely the cause of the observed effects.

Several studies have shown that long range transport of pesticides used from intensive agricultural areas of the Central Valley of California contaminate aquatic habitats of amphibians living in the Sierra Nevada Mountains that lie to the east of the use areas (e.g., McConnell et al. 1998, LeNoir et al. 1999, Fellers et al. 2004). The range of the CTS does not extend into high mountain regions of the Sierra Nevada, but portions of the central DPS does include areas in the Sierra Nevada foothills with elevations up to approximately 610 meters (USFWS 2009). In the summer of 1997, LeNoir et al. (1999) detected malathion in air sampled at 200 m and 533 m, and detected malathion in surface water at sites ranging from 118 to 2042 m. Surface water concentrations of malathion sampled at elevations within the range used by the CTS (118-488 m) ranged from 64.97 to 83 ng/L. In 1996, McConnell et al. (1998) measured malathion in rain and snow from Ash Mountain (elevation 500 m) at concentrations as high as 24 ng/L. malathion concentration measured in both of these studies were less than the assessment endpoint for direct effects to the CTS for acute toxicity (LC_{50} = 33 µg/L) and chronic toxicity (NOAEC = 8.6 µg/L). Thus, while malathion concentrations may reach levels that are toxic by themselves, they add to the toxicity of other organophosphate insecticides that were also detected in these waters, such as chlorpyrifos and diazinon (McConnell et al. 1998, LeNoir et al. 1999, Fellers et al. 2004), and could significantly contribute to poor water quality conditions for this species.

The Sonoma County DPS and Santa Barbara County DPS do not occur in the Sierra Nevada mountains or foothills, but do occur in the Coastal Range that lies between the Central Valley and the Pacific Ocean. Some segments of the Central DPS also occur in the Coastal Range. CTS in these areas occur at elevations up to 1067 m (USFWS 2009). Since the prevailing winds which cause most of the precipitation on mountains areas are from the east, precipitation in the Coastal Range would not be subject to long range transport of pesticides used in the Central Valley, but would be subject to long range transport from agricultural areas lying between the Coastal Range and the Pacific Ocean.

5.2.2.b. Indirect Effects

i. Potential Loss of Prey

The CTS consumes a wide variety of dietary items throughout its life cycle, including terrestrial and aquatic invertebrates, fish, worms, terrestrial arthropods, amphibians, small mammals, and algae. Thus, to assess indirect effects through potential loss of food items, RQs were calculated for freshwater invertebrates, freshwater fish, aquatic plants (algae), terrestrial invertebrates, amphibians, and small mammals.

RQs for aquatic invertebrates, shown in Table 5-2, can be used to evaluate the potential for malathion use to cause adverse effects on the abundance of zooplankton and aquatic arthropods and mollusks that larval stages of the CTS depend on for food. For all uses, the acute RQ exceeded the LOC for both listed species (0.05) and for nonlisted species (0.5). The RQs for all uses except passion fruit also exceeded 1.0, indicating that peak concentrations are expected to exceed the median lethal dose of aquatic invertebrates. RQs for chronic risks were even greater than those for acute risk, with RQs for most uses exceeding 100, and for some uses exceeding 1000. This fact indicates that the extreme sensitivity of aquatic invertebrates to sublethal toxicity by malathion outweighed the relatively low persistence of the chemical in water. All chronic RQs exceeded the LOC (1.0), and the RQ for many uses, both agricultural and nonagricultural, exceeded 100. Therefore, the use of malathion is likely to cause adverse effects to the aquatic prey of the CTS.

As discussed above, several studies have shown that long range transport of pesticides used from intensive agricultural areas of the Central Valley of California contaminate aquatic habitats of amphibians in the Sierra Nevada Mountains (e.g., McConnell et al. 1998, LeNoir et al. 1999, Fellers et al. 2004). LeNoir et al (1999) detected malathion in air sampled at 200 m and 533 m, and detected malathion in surface water at sites ranging from 118 to 2042 m. Surface water concentrations of malathion sampled at elevations within the range used by the CTS (118-488 m) ranged from 64.97 to 83 ng/L. In 1996, McConnell et al. (1998) measured malathion in rain and snow from Ash Mountain (elevation 500 m) at concentrations as high as 24 ng/L. Malathion concentration measured in both of these studies were less than the acute toxicity assessment for freshwater invertebrates (LC_{50} = 700 ng/L) by only a factor of 10 and exceeded the assessment endpoint for chronic toxicity (NOAEC = 35 ng/L). Thus, it appears that long-range transport of malathion, with deposition into aquatic habitats from precipitation potentially may cause reduction in the abundance of invertebrate prey in portions of the CTS habitat located in the foothills of the Sierra Nevada. While not investigated in these studies, it is also possible that areas of the CTS range in the Coastal Range could likewise be affected from long range transport and deposition of malathion from agricultural areas lying between the Coastal Range and Pacific Ocean. Toxic effects of malathion on aquatic amphibians would be additive with those of other organophosphate insecticides known to be deposited by rainwater, including chlorpyrifos and diazinon (McConnell et al. 1998, LeNoir et al. 1999, Fellers et al. 2004), thereby creating even greater combined toxicity to aquatic invertebrates.

Being that malathion is an insecticide, it would be expected to also cause adverse effects on terrestrial invertebrate prey of the CTS. RQs calculated for terrestrial invertebrates (Table 5-9) did indeed show this to be the case. For various uses of malathion, terrestrial invertebrate RQs ranged from 76.5 to 648. Thus, all uses of malathion are predicted to have the potential to adversely affect the abundance of invertebrate prey of the CTS.

Adult CTS may also feed on small mammals and other amphibians. RQs for these prey items are shown in Table 5-7. For amphibians, RQs for acute toxicity exceeded the LOC for nonlisted species (0.50) for all uses of malathion. RQs for chronic toxicity also exceeded the LOC (1.0) for all uses except for ULV application on citrus and kumquats. As discussed above, all uses of malathion are predicted to potentially cause adverse effects on aquatic stages of amphibians, which of course could also lead to impacts on the abundance of the adult terrestrial stages. For mammal prey, acute RQs were lower and exceeded the nonendangered LOC only for crops with higher use rates (e.g. citrus, cotton, and walnuts). However, the dosed-based chronic RQs exceeded the chronic LOC (1.0) for all uses except ULV application on citrus and kumquats.

In summary, risk assessments based on RQs indicate that all uses of malathion have the potential to adversely affect prey items of the CTS, including aquatic invertebrates, terrestrial invertebrates, fish, and amphibians. All uses except ULV use on citrus and kumquats are also predicted to cause potential adverse effects on small mammal prey.

ii. Potential Modification of Habitat

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

Toxicity testing has found that malathion has low toxicity to aquatic plants. Risk quotients for all uses of malathion were well below 1. For nonaquatic agricultural uses and nonagricultural uses, RQs were never greater than 0.04. For aquatic agricultural uses, RQs were as high as 0.47, but the exposure estimates for these uses are for peak concentrations on the flooded field and are likely to be much greater than what would occur in off-site aquatic habitats. Peak concentrations in offsite receiving waters would be much less because of the rapid degradation that malathion would undergo while the water is held on the field, and because of the dilution that would occur when the released water mixes with uncontaminated water. We therefore consider the risk of indirect effects to the CTS from malathion causing adverse effects on aquatic plants to be insignificant and discountable.

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

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Small mammals play an important roll in the survival of the CTS. CTS depend on the burrows of small mammals for underground refugia. CTS use the borrows for shelter, protection from predators, and feeding habitat. Thus, in reduction in the abundance of small mammals would potentially adversely affect the habitat of the CTS by reducing the availability of burrows.

Despite widespread use, malathion has not been observed to be phytotoxic to the wide variety of crop and ornamental plants to which it is directly applied. As discussed in Section 4.3.4, efficacy studies have found that application of malathion at typical use rates either do not have significant effects on the growth of plants, or have significant beneficial effects due to control of plant pests. Vegetation in the habitat of the CTS would be exposed from drift and runoff from treated sites. This exposure would be at rates much less than the target plants that are directly treated. Therefore, exposure of plants to malathion in the CTS habitat is not expected to result in any significant damage to vegetation.

5.2.3. Modification of Designated Critical Habitat

Primary constituent element (PCE) 2 states that there must be “barrier-free uplands adjacent to breeding ponds that contain small mammals” because “small mammals are essential in creating the underground habitat that juvenile and adult CTS depend upon for protection from the elements and predation.” RQs for small mammals, shown in Table 5-4, indicate that all uses of malathion in California have the potential to cause adverse effects to small mammals. Acute RQ calculated based on oral dose exceeded the listed species LOC (0.1) for all uses. Acute RQs calculated based on dietary dose also exceeded the LOC for all uses except ULV applications on citrus and kumquats, and ULV application for adult mosquito control. For chronic risk, RQs exceeded the LOC for all uses except ULV applications on citrus and kumquats, and ULV application for adult mosquito control. In conclusion, the RQ analysis indicates that all uses have the potential to cause adverse effects to critical habitat of the CTS by causing acute and chronic effects to small mammals that the species depends upon for creation of underground refugia. As for direct effects to the CTS, risk to mammals is lower for ULV use on citrus and kumquats, and ULV use for adult mosquito control, making the conclusion of potential effects to mammals less certain for these uses than for the other uses.

Availability of terrestrial and aquatic invertebrates, amphibians, and small mammals is also an important requirement of the habitat of the CTS because the species depends on these taxa for food. As discussed in Section 5.2.2.b.i, all uses of malathion are predicted to potential cause mortality to aquatic and terrestrial invertebrates, as well as small terrestrial vertebrate prey (e.g. small mammals and frogs). Therefore, use of malathion may degrade the critical habitat of the CTS by reducing prey abundance.

5.2.4. Spatial Extent of Potential Effects

When LOCs are exceeded, the Agency typically does analysis to determine the spatial extent of potential “likely to adverse affect” (LAA) where effects may occur in relation to the treated site. In this assessment, however, the use “footprint” of the use of malathion was considered to be the entire state of California. All uses of malathion result in an LAA determination because of the potential for direct and/or chronic effects. Uses include a very wide range of agricultural crops, fruit and nut trees, forestry, commercial, and residential uses. Since uses are expected in all land use categories (agricultural crops, orchards, forests, rangeland, and urban areas), the spatial extent of effects is not limited by the location of uses. Any place where the CTS occurs, or that is part of its critical habitat, is considered to be part of the LAA area.

5.2.4.a. Spray Drift

To further characterize the terrestrial risk the use of malathion, the Agency has estimated the maximum distance from the edge of the treatment area at which spray drift from malathion uses would result in terrestrial deposition at a rate that would still exceed levels of concern (LOC). Analysis was conducted using both the LOC for acute risk to terrestrial organisms (0.5) and the LOC for potential adverse effects to endangered species (0.1). For the flowable uses, a quantitative analysis of spray drift distances was completed using AgDRIFT (v. 2.01) using default inputs for ground applications (*i.e.*, high boom, ASAE droplet size distribution = Very Fine to Fine, 90th data percentile) and aerial applications (*i.e.*, ASAE Very Fine to Fine).

Calculations were based on toxicity to for terrestrial invertebrates, as measured by the honeybee acute contact tests, because this was the most sensitive taxa to malathion. Analysis of all uses was based on a single application. Analysis was only conducted for non-ULV applications.

For aerial applications, the distance at which spray drift deposition would exceed both LOCs for the CTS exceeded 1000 ft, the maximum distance predicted by the AgDrift model, for all agricultural uses for which aerial application is permitted. Distances for uses with ground and air blast applications are shown in Table 5-14. For ground applications, the distance for exceeding the endangered species LOC exceeds 1000 ft for all agricultural and nonagricultural uses. The distance for exceeding the LOC for acute risk also exceeded 1000 ft for the nonagricultural uses assessed, and range from 374 ft to 725 ft for agricultural uses. The distances were much shorter for uses with air blast application. For these uses, distances ranged from 52 ft (mango) to 348 ft (citrus) for exceeding the endangered species LOC, and from 7 ft to 82 ft for exceeding the acute risk LOC.

Table 5-14. Maximum Distance from Edge of Field at which the Spray Drift Deposition from Ground Applications Are Predicted to Result in a Risk Quotient for the CTS that Exceeds the LOC

Use	Use Rate	Application Method[1]	Small Insect RQ	Distance for Exceed LOC (Feet)	
				Acute Risk LOC (0.5)	Endangered Species LOC (0.1)
Agricultural Uses					
Citrus	7.5	AB	649	82	348
Pecan, chestnut, and walnut	2.5	AB	216	26	135
Cotton	2.5	G	216	725	> 1000
Strawberry, caneberry group	2.0	G	173	623	> 1000
Pears, papaya, and guava.	1.25	AB	108	10	69
Alfalfa, rice, barley, broccoli, carrots, et al.	1.25	G	108	443	> 1000
Field corn, wheat, oats, sorghum, melons, peas, et al.	1.0	G	86.5	374	> 1000
Mango	0.9375	AB	81.1	7	52
Non-Agricultural Uses					
Fence / hedge row, domestic dwelling (perimeter), and refuse/solid waste site	10.6	G	917	> 1000	> 1000

[1] "AB" signifies airblast, "G" signifies ground spray.

For the aquatic stages of the CTS, the spray drift distances would be identical to those calculated for the DS. These distances are provided in Table 5-13.

5.2.4.b. Downstream Dilution Analysis

Typically, the downstream dilution model is used to determine the extent of exposure in streams and rivers where the EEC could potentially be above levels that would exceed the most sensitive LOC. For this assessment, however, the use of malathion is not limited to certain land use classes, but may be used throughout the state. The entire range of the CTS is considered to be within the potential area of use of malathion. Therefore, analysis of downstream dilution was not necessary for defining the overlap of the potential area of LAA with the habitat and occurrence of the CTS

5.2.4.c. Overlap of Potential Areas of LAA Effect and Habitat and Occurrence of the DS and CTS

As stated above, the Limit of Area Affect (LAA) for effects on survival, growth, and reproduction for the DS is defined as the entire habitat of the DS and its critical habitat, as depicted in Fig. 2-3. Because malathion is used in areas of all land uses throughout the entire state, no spatial restrictions were imposed based on use.

5.3. Effects Determinations

5.3.1. Assessed Species

This risk assessment clearly indicates that even with the mitigation measures imposed by the Malathion RED (USEPA 2006), use of malathion in California has a potential to cause adverse effects to both the DS and the CTS. Adverse effects may be manifested by both direct acute and chronic toxicity to the species themselves, as well as indirect effects on prey items and habitat requirements.

The DS is subject to contamination of malathion because it inhabits water that drains areas of intensive agricultural and urban land uses. Intensive agricultural areas of the Central Valley are drained by tributaries which flow into the Sacramento River, San Joaquin River, and the San Francisco Estuary. Malathion is used on many crops in this area, including cotton, grains, alfalfa, vegetables, fruits, and nuts. Malathion is also used extensively by homeowners, property owners, and public health agencies in urban areas near the DS habitat, including Sacramento, Stockton, and Modesto. Surface water monitoring data have found that potentially harmful concentrations of malathion occasionally occur in back tributaries that drain agricultural and/or urban areas. This contamination may cause direct toxic effects to the eggs and larvae that migrate down these tributaries, as well as the adults that migrate into these tributaries during spawning. The predicted risk of direct toxic effects to the DS is supported by numerous fish kills that have been linked with high certainty to exposure to malathion. The DS potentially could also be adversely impacted by indirect effects of malathion on prey abundance. Malathion is predicted to reach levels which may be toxic to prey of the DS, especially to aquatic arthropods which have been shown to be very sensitive to malathion. Toxicity to malathion could be exasperated by exposure to the oxon degradation product maloxon, which has been shown to be up to 90 times more toxic than the parent compound. The amount of exposure to maloxon in water inhabited by the DS is currently largely unknown, but any exposure would increase the risk beyond what was predicted in this assessment based on exposure to malathion alone. Residues of malathion and potentially maloxon that enter the San Francisco Estuary by flowing down the Sacramento River and San Joaquin River, and by deposition of spray drift by aerial applications, would add to the toxicity of the numerous other organophosphate and carbamate insecticides that are known to occur in these water, and would thereby contribute to the overall water quality degradation caused by pesticides in the waters inhabited by the DS.

The listing of the CTS is comprised of three DPS, the Central California DPS, the Sonoma County DPS, and the Santa Barbara DPS. The use of malathion in California is so widespread that it could not be restricted spatially. Since the potential area of effects comprise all areas of California, all of the three DPSs are entirely within the potential area of effects, and all three were assessed together. Thus, the following discussion of the CTS applies to all three DPSs.

Considering the numerous widespread agricultural and residential uses of malathion, all segments of the CTS population could be potentially subjected to exposure to malathion. The vernal ponds and pools where the species lays its eggs and where the aquatic larval stages live could be contaminated by spray drift, from runoff from agricultural and urban areas, and from deposition in rainwater. Contamination levels could be relatively high in these small shallow water bodies where there would be little dilution of contaminated inflows and spray drift deposition. The quantitative risk assessment found that almost all uses of malathion could potentially cause direct adverse effect to the eggs and larvae of the CTS living in these habitats. In addition, the residue levels of malathion in these habitats are predicted to potentially exceed the toxicity level of many of the invertebrate prey species of the CTS. Malathion exposure could cause reduction in the abundance of zooplankton and aquatic arthropods in these ponds, thereby limiting the food supply of the larvae. The direct and indirect effects on the eggs and larvae of the CTS could result in reduced recruitment of breeding adult.

The terrestrial stages of the CTS may also be adversely affected by use of malathion. The quantitative risk assessment found that all uses of malathion could potentially contaminate food items of the CTS enough to cause direct acute and/or chronic effects to the juvenile and adult salamanders. The risk assessment did not take into account exposure through dermal absorption or drinking water, but additional exposure through these sources of exposure potentially could increase risk above that predicted by the risk assessment. In addition to direct effects, all uses of malathion are predicted to potentially adversely affect terrestrial invertebrates that comprise a large portion of the diet of terrestrial-phase CTS. Many uses are also predicted to potentially cause acute or chronic effects on small terrestrial vertebrates that are also consumed by the CTS. This could potentially reduce the abundance of food for the terrestrial-phase salamanders. Finally, many uses of malathion could potential affect small mammals. This could adversely impact the critical habitat of this species because the terrestrial-phase CTS depend on burrows created by small mammals for food, shelter and protection from predators.

In conclusion, the Agency makes a "may affect" and "likely to adversely affect" determination for the DS and for all DPSs of the CTS, as well as a habitat modification determination for their designated critical habitat of these species, based on the potential for direct and indirect effects and effects to the PCEs of critical habitat.

5.3.2. Addressing the Risk Hypotheses

In order to conclude this risk assessment, it is necessary to evaluate the risk hypotheses defined in Section 2.9.1. Based on the conclusions of this assessment, several of the risk hypotheses cannot be rejected. For direct effects of malathion to the DS and CTS, none of the risk hypothesis could be rejected. For indirect effects and/or modification of critical habitat, only the hypotheses related to alterations of aquatic and terrestrial plant communities could be rejected. Hypotheses related to other indirect effects and/or modification of critical habitat (i.e., adverse effects on water quality, prey availability, and availability of small mammal burrows) could not be rejected. Considered in total, the failures to reject stated hypotheses represent concerns in terms of direct and indirect effects of malathion on the DS and CTS, as well as potential modification of critical habitat.

Specifically, the assessment failed to reject that the labeled use of malathion within the action area may:

- directly affect DS and CTS by causing mortality or by adversely affecting growth or fecundity;
- indirectly affect DS and CTS and/or modify their designated critical habitat by reducing or changing the composition of food supply;
- indirectly affect DS and CTS and/or modify their designated critical habitat by reducing or changing aquatic habitat in their current range (via modification of water quality parameters, habitat morphology, and/or sedimentation);
- indirectly affect CTS and/or modify their designated critical habitat by reducing or changing terrestrial habitat in their current range (via reduction in small burrowing mammals leading to reduction in underground refugia/cover).

However, the assessment did reject the hypotheses that labeled use of malathion within the action area may:

- indirectly affect DS and CTS and/or modify their designated critical habitat by reducing or changing the composition of the aquatic plant community in the species' current range, thus affecting primary productivity and/or cover;
- indirectly affect DS and CTS and/or modify their designated critical habitat by reducing or changing the composition of the terrestrial plant community in the species' current range.

6. Uncertainties

Uncertainties that apply to most assessments completed for the San Francisco Bay Species Litigation are discussed in Attachment 1. This section describes additional uncertainties specific to this assessment.

6.1. Exposure Assessment Uncertainties

6.1.1. Aquatic Exposure Modeling of Malathion

Because malathion degrades rapidly in the pH-neutral conditions modeled in the aquatic exposure assessment, the amount of malathion that is transported from treated fields to aquatic environments via runoff will depend strongly on how soon after application a major rainfall event occurs. In central and southern California, rainfall is highly seasonal, with almost all of the annual rainfall occurring during the winter months. Together, these factors make model predictions of malathion concentrations highly dependant on the dates chosen for the applications, which in turn depend on the date chosen for the first application. Because of the greater rainfall, setting the date of first application during the fall or winter would generate much higher EECs than setting it in the spring or summer. Analysis of the CDPR-PUR data indicated that many of the uses of malathion occur primarily in the summer, but some lower level of use occurred in winter also (see Appendix D). To account for the high variability related to date of first application, the multi-run function of the PE shell was used to calculate 90th percentile EECs for each potential application date (or set of application dates for uses that allow multiple applications). This distribution of EECs across application dates was compared to the distribution of dates when malathion use was recorded in the PUR data. The data were limited to application dates that were within the period when the CDPR-PUR data showed it was used in California. The scenario with the application date that predicted the highest EEC was then used in the assessment.

Using the highest EECs from the time of the year when malathion is applied is a reasonable way to characterize the maximum potential aquatic exposure to malathion. However there is the potential for the highest EEC to be atypical relative to the other times when malathion is applied to a use site. The question of how typical is it for malathion to be applied for each use at times when it is expected that EECs will exceed the agencies levels of concern (LOCs) is addressed by summing the pounds of malathion applied in California on application dates that are expected to result in EECs that exceed the agencies LOCs divided by the total pounds of malathion applied in California times 100 (Table 6-1).

Table 6-1. Percentage of Pesticide Expected to be Applied on Application Dates when EECs Are Expected to Exceed Agency Levels of Concern (LOCs) for the Aquatic Impacts of Legal Uses of Malathion in California

Scenario Group. **Label Crop/Site**	Maximum Application Rates[1] (Lbs. ai/A)	Expected Percentage of Pesticide Mass Applied (%) in California								
		Freshwater fish		Freshwater invertebrates		Estuarine/Marine fish		Estuarine/Marine invertebrates		Aquatic plants
		Acute 33 µg/L	Chronic 8.6 µg/L	Acute 0.59 µg/L	Chronic .035µg/L	Acute 33 µg/L	Chronic 17.3 µg/L	Acute 2.2 µg/L	Chronic .013 µg/L	2400 µg/L
Agricultural Uses (spray drift buffers of 25 ft for ground applications and 50 ft for air)										
1. **Alfalfa, Clover, Lespedeza, Lupine, Trefoil, and Vetch**	**Air: 1.56**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	ULV: 0.61	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	Ground: 1.56	**98**	**0**	**100**	**100**	**98**	**100**	**100**	**100**	**0**
2. **Macadamia Nut (Bushnut)**	**Ground: 0.94**	**56**	**0**	**100**	**100**	**56**	**0**	**100**	**100**	**0**
	Airblast: 0.94	**54**	**0**	**100**	**100**	**54**	**0**	**100**	**100**	**0**
3 and 4. **Pecan, Walnut (English/Black), and Chestnut**	**Ground: 2.5**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	Airblast: 2.5	**10**	**0**	**100**	**100**	**10**	**100**	**100**	**100**	**0**
6. **Date (dust)**	**Air: 4.25**	**100**	**14**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	Ground: 4.25	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
8. **Avocado**	**Ground: 4.7**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
9. **Citrus, Citrus Hybrids other than Tangelo, Grapefruit, Kumquat, Lemon, Lime, Orange, Tangelo, and Tangerines**	**Air: 7.5**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	ULV: 0.175	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	Ground: 7.5	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	Airblast: 7.5	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
10. **Amaranth - Chinese, Broccoli (Unspecified, Chinese, and Raab), Cabbage (Unspecified and Chinese), Canola\Rape, Cauliflower, Collards, Corn Salad, Dock (Sorrel), Horseradish, Kale, Kohlrabi, Mustard, Mustard Cabbage (Gai Choy/Pak-Choi), and Purslane (Garden and Winter)**	**Air: 1.25**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	Ground: 1.25	**59**	**0**	**100**	**100**	**59**	**100**	**100**	**100**	**0**
11. **Corn (Unspecified, Field, Pop, and Sweet)**	**Air: 1.0**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	ULV: 0.61	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	Ground: 1.0	**56**	**0**	**100**	**100**	**56**	**100**	**100**	**100**	**0**
12. **Cotton**	**Air: 2.5**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	ULV: 1.22	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
	Ground: 2.5	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
13. **Hops**	**Air: 0.63**	**100**	**0**	**100**	**100**	**100**	**0**	**100**	**100**	**0**
	Ground: 0.63	**55**	**0**	**100**	**100**	**55**	**0**	**100**	**100**	**0**
	Airblast: 0.63	**53**	**0**	**100**	**91**	**53**	**0**	**92**	**93**	**0**

Scenario Group. **Label Crop/Site**	Maximum Application Rates[1] (Lbs. ai/A)	Expected Percentage of Pesticide Mass Applied (%) in California								
		Freshwater fish		Freshwater invertebrates		Estuarine/Marine fish		Estuarine/Marine invertebrates		Aquatic plants
		Acute 33 µg/L	Chronic 8.6 µg/L	Acute 0.59 µg/L	Chronic .035µg/L	Acute 33 µg/L	Chronic 17.3 µg/L	Acute 2.2 µg/L	Chronic .013 µg/L	2400 µg/L
15. **Apricot**	**Ground: 1.5** **Airblast: 1.5**	**11** **10**	**0** **0**	**100** **100**	**100** **78**	**11** **10**	**100** **45**	**100** **79**	**100** **76**	**0** **0**
16. **Nectarine and Peach**	**Ground: 3** **Airblast: 3**	**100** **29**	**0** **0**	**100** **100**	**100** **100**	**100** **29**	**100** **52**	**100** **100**	**100** **100**	**0** **0**
17. **Cherry**	**Air: 1.75** **ULV: 1.22** **Ground: 1.75** **Airblast: 1.75**	**100** **100** **83** **63**	**0** **0** **0** **0**	**100** **100** **100** **100**	**100** **100** **100** **100**	**100** **100** **83** **63**	**100** **100** **100** **71**	**100** **100** **100** **100**	**100** **100** **100** **100**	**0** **0** **0** **0**
18. **Fig**	**Ground: 2** **Airblast: 2**	**1** **0**	**0** **0**	**100** **100**	**100** **61**	**1** **0**	**100** **2**	**100** **100**	**100** **38**	**0** **0**
19. **Pear**	**Ground: 1.25** **Airblast: 1.25**	**94** **91**	**0** **0**	**100** **100**	**100** **96**	**94** **91**	**100** **95**	**100** **97**	**100** **96**	**0** **0**
20 and 21. **Guava, Mango, and Papaya**	**Ground: 1.25** **Airblast: 1.25**	**41** **38**	**0** **0**	**100** **100**	**100** **100**	**41** **38**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
22. **Garlic and Leek**	**Air: 1.56** **Ground: 2**	**100** **95**	**0** **0**	**100** **100**	**100** **100**	**100** **95**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
23. **Grapes**	**Ground: 1.88** **Airblast: 1.88**	**9** **6**	**0** **0**	**100** **100**	**100** **100**	**9** **6**	**100** **19**	**100** **100**	**100** **100**	**0** **0**
26. **Brussel Sprouts and Dandelion**	**Air: 1.25** **Ground: 1.25**	**100** **33**	**0** **0**	**100** **100**	**100** **100**	**100** **33**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
27. **Swiss Chard, Chervil, Endive (Escarole), Lettuce, Head Lettuce, Leaf Lettuce (Black Seeded Simpson, Salad Bowl, Etc.), Orach (Mountain Spinach), Parsley, Roquette (Arrugula), Salsify, and Spinach**	**Air: 1.88** **Ground: 1.88**	**100** **36**	**0** **0**	**100** **100**	**100** **100**	**100** **36**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
29. **Eggplant**	**Air: 1.56** **Ground: 1.56**	**100** **37**	**0** **0**	**100** **100**	**100** **100**	**100** **37**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
30. **Pumpkin**	**Air: 1** **Ground: 1**	**100** **4**	**0** **0**	**100** **100**	**100** **100**	**100** **4**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
31. **Cucumber, Cucurbit Vegetables, Melons - Unspecified, Cantaloupe, Honeydew, Musk, Water, and Winter (Casaba/Crenshaw/Honeydew/Persian), and Squash (All Or Unspecified)**	**Air: 1.75** **Ground: 1.75**	**100** **46**	**0** **0**	**100** **100**	**100** **100**	**100** **46**	**100** **100**	**100** **100**	**100** **100**	**0** **0**

Scenario Group. **Label Crop/Site**	Maximum Application Rates[1] (Lbs. ai/A)	Expected Percentage of Pesticide Mass Applied (%) in California								
		Freshwater fish		Freshwater invertebrates		Estuarine/Marine fish		Estuarine/Marine invertebrates		Aquatic plants
		Acute 33 µg/L	Chronic 8.6 µg/L	Acute 0.59 µg/L	Chronic .035µg/L	Acute 33 µg/L	Chronic 17.3 µg/L	Acute 2.2 µg/L	Chronic .013 µg/L	2400 µg/L
32**. Onion (Unspecified and Green), Radish, and Shallot**	**Air: 1.56** **Ground: 1.56**	**100** **38**	**0** **0**	**100** **100**	**100** **100**	**100** **38**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
33 and 36**. White/Irish Potato and Sweet Potato**	**Air: 1.56** **Ground: 1.56**	**100** **15**	**0** **0**	**100** **100**	**100** **100**	**100** **15**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
34 and 35**. Turnip, Parsnip, and Rutabaga**	**Air: 1.25** **Ground: 1.25**	**100** **57**	**0** **0**	**100** **100**	**100** **100**	**100** **57**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
37**. Bluegrass, Canarygrass, Grass Forage/Fodder/Hay, Pastures, Peas (Including Vines), Rangeland, and Sudangrass**	**Air: 1.25** **ULV: 0.92** **Ground: 1.25**	**100** **100** **8**	**0** **0** **0**	**100** **100** **100**	**100** **100** **100**	**100** **100** **8**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**0** **0** **0**
40**. Beets and Peas (Unspecified and Field)**	**Air: 1** **Ground: 1.25**	**100** **32**	**0** **0**	**100** **100**	**100** **100**	**100** **32**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
41**. Carrot (Including Tops), Celtuce, Fennel, and Pepper**	**Air: 1.56** **Ground: 1.56**	**100** **39**	**0** **0**	**100** **100**	**100** **100**	**100** **39**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
42**. Beans, Beans - Dried-Type, Beans - Succulent (Lima), and Beans - Succulent (Snap)**	**ULV: 0.61**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**0**
43**. Celery**	**Air: 1.5** **Ground: 1.5**	**100** **41**	**0** **0**	**100** **100**	**100** **100**	**100** **41**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
44**. Asparagus**	**Air: 1.25** **Ground: 1.25**	**100** **45**	**0** **0**	**100** **100**	**100** **100**	**100** **45**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
46**. Strawberry**	**Air: 2** **Ground: 2**	**100** **58**	**6** **0**	**100** **100**	**100** **100**	**100** **58**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
48**. Tomato**	**Air: 1.56** **Ground: 1.56**	**100** **42**	**0** **0**	**100** **100**	**100** **100**	**100** **42**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
49**. Okra**	**Air: 1.2** **Ground: 1.2**	**100** **17**	**0** **0**	**100** **100**	**100** **100**	**100** **17**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
51**. Sorghum**	**Air: 1** **ULV: 0.61** **Ground: 1**	**100** **100** **81**	**0** **0** **0**	**100** **100** **100**	**100** **100** **100**	**100** **100** **81**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**0** **0** **0**
52**. Barley, Cereal Grains, Oats, Rye, and Wheat**	**Air: 1.25** **ULV: 0.61** **Ground: 1.25**	**100** **100** **92**	**0** **0** **0**	**100** **100** **100**	**100** **100** **100**	**100** **100** **92**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**0** **0** **0**
53, 54, 56**. Gooseberry, Blackberry, Boysenberry, Dewberry, Loganberry, Raspberry (Black - Red), Caneberries, and Currant**	**Air: 1.25** **Ground: 2** **Airblast: 2**	**100** **25** **20**	**0** **0** **0**	**100** **100** **100**	**100** **100** **100**	**100** **25** **20**	**100** **100** **65**	**100** **100** **100**	**100** **100** **100**	**0** **0** **0**

Scenario Group. **Label Crop/Site**	Maximum Application Rates[1] (Lbs. ai/A)	Expected Percentage of Pesticide Mass Applied (%) in California								
		Freshwater fish		Freshwater invertebrates		Estuarine/Marine fish		Estuarine/Marine invertebrates		Aquatic plants
		Acute 33 µg/L	Chronic 8.6 µg/L	Acute 0.59 µg/L	Chronic .035µg/L	Acute 33 µg/L	Chronic 17.3 µg/L	Acute 2.2 µg/L	Chronic .013 µg/L	2400 µg/L
55. **Blueberry**	**ULV: 0.77** **Ground: 1.25** **Airblast: 1.25**	**100** **2** **2**	**0** **0** **0**	**100** **100** **100**	**100** **100** **100**	**100** **2** **2**	**100** **100** **3**	**100** **100** **11**	**100** **100** **100**	**0** **0** **0**
57. **Passion Fruit (Granadilla)**	**Ground: 1** **Airblast: 1**	**24** **22**	**0** **0**	**100** **100**	**100** **100**	**24** **22**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
58. **Mint and Spearmint**	**Air: 0.94** **Ground: 0.94**	**100** **31**	**0** **0**	**100** **100**	**100** **100**	**100** **31**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
59. **Rice and Wild Rice**	**Air: 1.25** **ULV: 0.61** **Ground: 1.25**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**0** **0** **0**
61. **Water Cress**	**Air: 1.25** **Ground: 1.25**	**100** **100**	**100** **100**	**100** **100**	**100** **100**	**100** **100**	**100** **100**	**100** **100**	**100** **100**	**0** **0**
Non-agricultural Uses										
Cull Piles and agricultural Structures and Equipment**. Cull Piles, Agricultural/Farm Structures/Buildings and Equipment, Commercial/Institutional/Industrial Premises/Equipment (Outdoor), and Meat Processing Plant Premises (Nonfood Contact)**	**Drench: 298.7**	**1**	**0**	**100**	**100**	**1**	**0**	**100**	**100**	**0**
Fence rows/hedge rows**.**	**Ground: 10.6**	**1**	**0**	**100**	**45**	**1**	**0**	**100**	**44**	**0**
Forestry**. Christmas Tree Plantations, Pine (Seed Orchard), and Slash Pine (Forest)**	**Air: 3.2** **ULV: 0.9375** **Ground: 3.2** **Airblast: 3.2**	**100** **100** **100** **100**	**0** **0** **0** **0**	**100** **100** **100** **100**	**100** **100** **100** **100**	**100** **100** **100** **100**	**100** **100** **100** **100**	**100** **100** **100** **100**	**100** **100** **100** **100**	**0** **0** **0** **0**
Nursery**. Outdoor Nursery, Outdoor Premises, Ornamental and/or Shade Trees, Ornamental Herbaceous Plants, Ornamental Lawns and Turf, Ornamental Non-flowering Plants, Ornamental Woody Shrubs and Vines, and Urban Areas**	**Air: 2.5** **Ground: 2.5** **Airblast: 2.5**	**100** **55** **100**	**0** **0** **0**	**100** **100** **100**	**100** **100** **100**	**100** **55** **100**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**0** **0** **0**
Rights-of-way**. Uncultivated agricultural areas, Nonagricultural Rights-of-way/Fencerows, and Nonagricultural Uncultivated Areas/Soils**	**Air: 1** **ULV: 0.9281** **Ground: 1** **Airblast: 1**	**NA (Scenario can not be run across a distribution of dates.)**								

Scenario Group. **Label Crop/Site**	Maximum Application Rates[1] (Lbs. ai/A)	Expected Percentage of Pesticide Mass Applied (%) in California								
		Freshwater fish		Freshwater invertebrates		Estuarine/Marine fish		Estuarine/Marine invertebrates		Aquatic plants
		Acute 33 µg/L	Chronic 8.6 µg/L	Acute 0.59 µg/L	Chronic .035µg/L	Acute 33 µg/L	Chronic 17.3 µg/L	Acute 2.2 µg/L	Chronic .013 µg/L	2400 µg/L
Public Health and Mosquito and Medfly Control. **Nonagricultural Areas (Public Health Use), Urban Areas, Wide Area/General Outdoor Treatment (Public Health Use), Intermittently Flooded Areas/Water, Lakes/Ponds/Reservoirs (with Human or Wildlife Use), Lakes/Ponds/Reservoirs (without Human or Wildlife Use), Polluted Water, and Swamps/Marshes/Wetlands/Stagnant Water**	**ULV: 0.23**	**0**	**0**	**100**	**100**	**0**	**0**	**100**	**100**	**0**
Residential and Refuse/Solid Waste. **Household/Domestic Dwellings (perimeter around dwelling), Refuse/Solid Waste Containers (Garbage Cans), and Refuse/Solid Waste Sites (Outdoor)**	**Ground: 10.6**	**13**	**0**	**77**	**65**	**13**	**0**	**68**	**65**	**0**
Turf. **Golf Course Turf (Bermudagrass)**	**Air: 1.25** **ULV: 0.92** **Ground: 1.25**	**100** **100** **23**	**0** **0** **0**	**100** **100** **100**	**100** **100** **100**	**100** **100** **23**	**100** **100** **100**	**100** **100** **100**	**100** **100** **100**	**0** **0** **0**

[1] Air, ULV, Ground, and Airblast refer to aerial, ultra-low volume, ground, and airblast application methods, respectively.

In two cases (macademia nut and hops), no PUR data were available. Therefore the highest EEC from anytime during the year was used as the highest EECs (not just when malathion was applied). Similarly the percentage of malathion applications that exceeded agency LOCs was estimated by counting the days when application of malathion would be expected to result in EECs that exceed the agencies LOCs divided by the total number of days in a year times 100.

The PRZM model only accounts for runoff that occurs from rainfall events. Even those scenarios in which surface irrigation is considered, irrigation is not assumed to generate any additional runoff. However, in central and southern California, many crops are watered by surface irrigation. Excess irrigation may drain into aquatic habitat of the CTS and DS, resulting in contamination even when there is not rainfall. In addition, malathion transported via groundwater may also enter surface water habitats following irrigation. The model predictions do not include contribution of aquatic residues from these sources.

The PRZM and EXAMS models account for transport of pesticide residues from treated areas to aquatic habitats occurring by way of runoff and spray drift, but does not account for additional contributions from long range transport of the volatilized fraction of malathion in the air. Several studies have shown that prevailing easterly winds transport pesticides applied in the Central Valley to the Sierra Nevada Mountains to the east, where the residues are deposited via dry and wet deposition McConnell et al. 1998, LeNoir et al. 1999). Malathion has been measured from a few sites in the Sierra Nevada Mountains, but the degree that measurements from these sites represent concentrations in aquatic habitats used by the CTS is unknown. Some segments of the CTS lie in the foothills of the Sierra Nevada Mountains, but in areas that are west of the sampling sites of these studies. In addition, no information is available about the amount of pesticide deposition or malathion concentrations in aquatic habitats of the Coastal Range where other segments of the CTS range occur. Because the aquatic exposure modeling did not account for contribution to aquatic habitats of the CTS from long-range atmospheric transport of malathion, the RQ that were generated based on model predictions may underestimate exposure to aquatic phase of the CTS.

The Agency is uncertain how much of the oxon of malathion, maloxon, will be present in aquatic habitats. Maloxon appears to either not form or degrade very rapidly in moist soil and in water. Field dissipation studies did not detect any maloxon in water or soil (MRIDs 41748901, 43042402, 41748901, and 43042401). On the other hand, maloxon appears to form on dry surfaces (CDPR 1981). Therefore, maloxon theoretically could form on leaves (if they remain sufficiently dry) and rain could wash off the residues and cause them to be transported to aquatic habitats via runoff. The Agency does not currently have sufficient information on the environmental fate of maloxon to model this process. Maloxon also has been detected in California in rainwater (Vogel et al. 2008) and fog (Schomburg et al. 1991), which indicates some maloxon residues are likely deposited into water bodies from precipitation. The amount of deposition from precipitation is currently uncertain. Because of these uncertainties, predictions of maloxon concentrations in aquatic habitats were not attempted.

Not accounting for added toxicity from exposure to maloxon and, for the CTS, additional exposure to malathion and maloxon from long -range atmospheric transport, could have made the RQs calculated in this assessment underprotective for predicting the potential for adverse effects. However, even without these additional risk factors being considered, all uses of malathion were determined to cause potential adverse effects to both the DS and CTS. Accounting for these additional risk factors could only make these determinations more certain. The only potential effect on the risk determination from including these factors would be that the few uses for which no direct effects were determined (passion fruit and ULV applications on citrus, and ULV applications for adult mosquito control) may also result in direct adverse effect to this species. It is noted however, that a LAA determination for the DS was made even for these uses based on indirect effects and impact on critical habitat. All uses already have been determined to have the potential to cause direct as well as indirect effects to the CTS.

Three of the uses (cull piles, hedge/fence rows, and residential and refuse/solid waste) would not be expected to result in treatment of the entire upstream watershed which PRZM models. These uses were modeled by adjusting the EECs generated from a reference scenario to account for differences in application rate and spatial extent of treatment. Essentially, this results in a spatially homogeneous application scenario being used to model a spatially variable application. For cull piles, an important source of uncertainty is the location of the cull piles within the watershed. The cull piles will likely produce higher EECs in runoff if the cull piles are located in drainage ways rather than ridge tops. Similarly, fence/hedge rows will likely produce higher EECs in runoff if the fence/hedge rows cross or are located along drainage ways; and lower EECs the further the fence/hedge row is away from the drainage way. For trash bins, a site may be located just upstream of a storm drain that leads directly to a pond occupied by the CTS or stream with DS. Therefore, there is the potential for malathion to runoff the application site with little or no rain occurring and the diluting effects that that rain might provide. However, PRZM/EXAMS modeling does not account for such within watershed spatial variation.

6.1.2. Exposure in Estuarine/marine Environments

Uncertainties regarding dilution and chemical transformations in estuaries

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

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

6.1.3. Modeled Versus Monitoring Concentrations

In order to account for uncertainties associated with modeling, available monitoring data were compared to PRZM/EXAMS estimates of peak EECs for the different uses. As discussed in Section 5.2.1, several data values were available from the USGS NAWQA program the California Department of Pesticide Regulation (CDPR) for malathion concentrations measured in surface waters receiving runoff from agricultural and urban areas near the San Francisco Estuary. 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 malathion use areas. The maximum malathion concentration detected in surface water monitoring was 6 µg/L (see Section 3.2.4.a). The maximum peak EEC predicted by PRZM/EXAMS was 89.8 µg/L for non-aquatic agricultural uses, 1120 µg/L for aquatic agricultural uses, and 60.0 for non-agricultural uses. Part of the reason for the difference is that all of the surface water was done in lotic ecosystems (streams and rivers) whereas the modeling was done for a static pond. In lotic ecosystems, runoff from contaminated sources is generally diluted with considerable quantity of water from uncontaminated sources. In the standard pond, however, 100% of the water in the pond was assumed to have drained from land treated with malathion. The use in the quantitative risk assessment of EECs modeled for a static pond probably make the results protective of all or most aquatic habitats, but probably overestimate exposure to organisms living in lotic ecosystems. The DS lives in streams and rivers, and in inland bays that receive water from streams and rivers. Therefore, the EECs modeled for a static pond probably overestimates exposure for this species. That is why in Section 5.2.2, the quantitative risk assessment was supplemented with comparisons of toxicity levels of various species with measured concentrations from water monitoring programs. The aquatic stages of the CTS, on the other hand, live in small vernal ponds and pools. These habitats are likely to be represented much better by the static pond scenario used in the PRZM/EXAMS models. In fact, malathion concentrations in these habitats may be even greater than predicted by the EECs because the ponds and pools may be shallower than the 1 acre, 2 m deep pond used for our modeling scenarios. Shallower water bodies would have greater surface area relative to the volume, and therefore would receive greater input from spray drift per unit volume compared to deeper water bodies. Unfortunately, no monitoring data in small ponds or pools were available to compare with the modeled EECs.

6.1.4. Maloxon formation, environmental fate, and toxicity

Malathion can convert to the oxon derivative, maloxon, through environmental degradation processes as well as by metabolic processes by animals and microbes. As has been found with other oxons of organophosphorous pesticides, maloxon has been shown to be more toxic to terrestrial and aquatic animals than the parent product. Based on data available on acute toxicity of malathion and maloxon for the same species, estimated maloxon to malathion ratio of 96-hr LC_{50} values for aquatic vertebrates has been range from 4.1 and 89.9 (**Table 6-2**). In order to be protective, the maximum ratio of 92.9 was assumed in this risk assessment.

Table 6-2. Within Species Comparisons of Malathion and Maloxon Acute Toxicity

Species Tested	Malathion LC_{50} µg/L (Reference)	Maloxon LC_{50} µg/L (Reference)	Ratio of Malathion to Maloxon Toxicity
Carp *Cyprinus carpio*	6590 – 23180 (MRID 40098001, Eco ref. 089874 and 014861)	1600 (Eco ref 000086)	4.1 – 14.5
Medaka *Oryzias latipes*	1800 (Eco ref 018398)	280 (Eco ref 018398)	48.5
Yellow-legged frog *Rana boylii*	2140 (Eco ref 092498)	23.8 (Eco ref 092498)	89.9

The quantitative risk assessments of direct and indirect effects to the DS and CTS were based on the parent compound, but the potential additional toxicity resulting from maloxon exposure, assuming additive toxicity of malathion and maloxon, was evaluated qualitatively in the risk characterization. This assessment was based on estimated maloxon toxicity of the most sensitive test species, which was calculated by dividing the acute LC_{50} for malathion by the malathion-to-maloxon ratio of 89.9.

The same approach was used to estimate the toxicity of maloxon to terrestrial animals. Maloxon toxicity data were not available for birds, but data on acute toxicity of maloxon to the laboratory rat was provided by a study published in the open literature. The acute oral LD_{50} of malathion and maloxon to the laboratory rat was determined to be 2880 and 158 mg/kg-bw, respectively (Dauterman and Main, 1966). The malathion-to-maloxon ratio for terrestrial organisms was therefore 18.2. This ratio was used to estimate the acute oral maloxon LD_{50} for the most sensitive bird test species, which was then used in a qualitative assessment of the potential risk additional risk of maloxon exposure to the CTS, assuming additive toxicity of malathion and maloxon.

In terrestrial ecosystems, the formation of maloxon is likely to depend strongly on moisture levels on treated surfaces, which in turn would be dependent on irrigation method used. Irrigation techniques in Central California includes surface irrigation, micro-irrigation (drip, bubbler, microspray, etc.), and traditional above ground sprinkler. When surface or micro-irrigation techniques are used, the vegetation would not be wetted. In addition, vegetation would not be wetted by rainfall very often because of the dry climate of the region. Malathion would likely be more persistent under such conditions because of the lack of hydrolysis and the lack of wash-off. Therefore, the half-life of terrestrial residues may be somewhat longer than in the published literature studies that yielded data estimating foliar persistence (Wellis and McDowell, 1987). Those studies were all conducted in eastern and southern states where rainfall is greater. Thus, on sites where surface or micro-irrigation techniques are used, terrestrial residues may be more persistent than assumed in the T-REX and T-HERPS models, resulting in greater peak concentrations after repeated applications, and higher risk than predicted.

6.2. Effects Assessment Uncertainties

6.2.1. Data Gaps and Uncertainties

Data are not available to adequately assess the toxicity of malathion to plants. The Agency is aware of no data that indicates malathion will significantly effect the growth and reproduction of plants at environmentally relevant exposure levels. In addition, acceptable data for aquatic plants were only available for nonvascular plants. One study was available on the toxicity or malathion to a vascular aquatic plant (Sinha, Rai, and Chandra, 1995), but upon review by the Agency the study was found to be unacceptable for use in quantitative risk assessment.

6.2.2. Use of Surrogate Species Effects Data

Guideline toxicity tests and open literature data on malathion are limited for aquatic-phase amphibian. Available data were only for acute toxicity to frogs, which may be more or less sensitive than salamanders. Furthermore, all available acute toxicity data for frogs were classified as supplemental or as appropriate for only qualitative use. In addition, no data are available on the chronic effects of malathion to aquatic-phase amphibians. Therefore, freshwater fish are used as surrogate species for aquatic-phase amphibians and the CTS. Data available from the open literature on malathion toxicity to aquatic-phase amphibians yielded highly variable results (Table 4-3). The majority of the results indicated that amphibians were considerably less sensitive than the rainbow trout. Six out of seven studies estimated 96-hr LC_{50} studies that were greater than that estimated for the rainbow trout and used in this assessment (33 μg/L). These studies indicated that that acute toxicity is endpoints for aquatic-phase amphibians are 5.2 to 330 times less sensitive than freshwater fish. One study, however, estimated an LC_{50} of 0.50 μg/L (Khangarot et al., 1985), which was indicates toxicity 56 times greater than the rainbow trout. We did not have enough confidence with this result to use it in our assessment because too little information was available on the testing methods and apparatus used, exposure concentrations were not provided, and several deviations from the Agency's test guidelines were observed. On the whole, the data for amphibians suggest that the endpoint we used based on freshwater fish toxicity are likely to be protective of potential direct effects to aquatic-phase amphibians including the CTS. The Agency's LOCs for listed species are intentionally set low in part to account for possible differences in sensitivity between surrogate species and the species being protected. Conservative estimates made in the screening level risk assessment would also compensate for these uncertainties.

6.2.3. Sublethal Effects

In this risk assessment, risk from acute exposure was based on mortality as the assessment endpoint. Organisms may also suffer adverse sublethal effects from acute exposure levels less than those which produce mortality. For chronic exposure, risk was assessed based sublethal effects, but limited to those effects that could be directly related to the assessment endpoints of survival, growth, and reproduction of organisms. Chronic exposure may produce some sublethal effects which were not considered in this assessment because they could not be readily extrapolated to effects on the assessment endpoints. To the extent to which sublethal effects are not considered in this assessment, the potential direct and indirect effects of malathion on listed species may be underestimated.

7. Risk Conclusions

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

Based on the best available information, the Agency makes a Likely to Adversely Affect (LAA) determination for the DS and for all three DPSs of the CTS (CTS-CC, CTS-SB, and CTS-SC). Additionally, the Agency has determined that there is potential for modification of the designated critical habitat for the DS and CTS from the use of the chemical. Given the LAA determination and the potential modification of designated critical habitat for the DS and CTS, a description of the baseline status and cumulative effects is provided in Attachment 3.

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

Table 7-1. Effects Determination Summary for Effects of Malathion on the DS and CTS

Species	Effects Determination	Basis for Determination
		Potential for Direct Effects

Species	Effects Determination	Basis for Determination
Delta Smelt (*Hypomesus transpacificus*)	Likely to Adversely Affect (LAA)	***Aquatic-phase (Eggs, Larvae, and Adults):*** Exposure from uses of malathion is expected to occur throughout the entire range of the DS. Risk quotients exceed the Agency LOCs for listed species. Mortality was observed in the rainbow trout (a freshwater fish) and the sheepshead minnow (an estuarine/marine fish) with acute exposure to malathion at concentrations less than one-twentieth the malathion EEC, and reproductive impairment was observed in the flagfish (a freshwater fish) and the bullhead (an estuarine/marine fish) with chronic exposure to malathion at concentrations less than the chronic EEC. In addition, numerous fish kills have been linked to malathion use.
		Potential for Indirect Effects
		Aquatic prey items, aquatic habitat, cover and/or primary productivity Exposure from uses of malathion is expected to occur throughout the entire range of the DS. Risk quotients exceed the Agency LOCs for taxa that comprise the prey of the DS. Toxicological data indicate that use of malathion is likely to reduce abundance of prey of the DS. Mortality was observed in the water flea (a freshwater crustacean) and the mysid (an estuarine/marine crustacean) with acute exposure to malathion at concentrations much less than less than one-tenth the malathion EEC, and reproductive impairment was predicted in the water flea (a freshwater crustacean) and the mysid (an estuarine/marine crustacean) with chronic exposure to malathion at concentrations much less than the chronic EEC, as well as less than some malathion concentrations from surface water samples taken within the range of the DS.
California Tiger Salamander (*Ambystoma californiense*), including Central, Santa Barbara, and Sonoma County distinct population segments	Likely to adversely affect (LAA)	**Potential for Direct Effects**
		Aquatic-phase (Eggs, Larvae, and Adults): Aquatic exposure from uses of malathion is expected to occur throughout the entire range of the CTS, including all DPSs. Risk quotients exceed the Agency LOCs for listed species. Mortality was observed in the rainbow trout (a freshwater fish, surrogate for freshwater amphibians) with acute exposure to malathion at concentrations less than less than one-twentieth the malathion EEC, and reproductive impairment was observed in the flagfish (a freshwater fish, surrogate for freshwater amphibians) with acute exposure to malathion at concentrations less than less than the chronic malathion EEC.
		Terrestrial-phase (Juveniles and Adults): Terrestrial exposure from uses of malathion is expected to occur throughout the entire range of the CTS, including all DPSs. Risk quotients exceed the Agency LOCs for listed species. Mortality was predicted for CTS (based on acute toxicity data for the ring-neck pheasant and Japanese quail, surrogates for the CTS) at dietary concentrations less than one-tenth the acute EEC, and reproduction impairment was predicted for CTS (based on reproduction toxicity data for the northern bobwhite) at dietary concentrations less than the chronic EEC.
		Potential for Indirect
		Aquatic prey items, aquatic habitat, cover and/or primary productivity Aquatic exposure from uses of malathion is expected to occur throughout the entire range of the CTS, including all DPSs. Risk quotients exceed the

Species	Effects Determination	Basis for Determination
		Agency LOCs for taxa that comprise the prey of the CTS. Toxicological data indicate that use of malathion is likely to reduce abundance of prey of the CTS. Mortality was observed in the water flea (a freshwater crustacean) with acute exposure to malathion at concentrations much less than less than one-tenth the malathion EEC, and reproductive impairment was predicted in the water flea (a freshwater crustacean) with chronic exposure to malathion at concentrations much less than the chronic EEC.
		Terrestrial prey items, riparian habitat Terrestrial exposure from uses of malathion is expected to occur throughout the entire range of the CTS, including all DPSs. Risk quotients exceed the Agency LOCs for taxa that comprise the prey of the CTS. Mortality was observed in the honey bee and the rat (surrogates for terrestrial prey of the CTS) at concentrations less than one-tenth the acute EEC, and reproduction impairment was observed in the rat at concentrations less than the chronic EEC.

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

Designated Critical Habitat for:	Effects Determination	Basis for Determination
Delta Smelt (*Hypomesus transpacificus*)	Habitat Modification	Use of malathion has the potential to cause degradation of water quality in the estuarine and freshwater habitats used by the DS.
California Tiger Salamander (*Ambystoma californiense*), including Central, Santa Barbara, and Sonoma County distinct population segments	Habitat Modification	Use of malathion has the potential to cause acute and chronic effects to small mammals, thereby potentially reducing the availability of burrows on which the CTS depends for underground refugia.

Table 7-3. Malathion Use-Specific Risk Summary for Delta Smelt and California Tiger Salamander

Use(s)	Species Effects Determination	Critical Habitat Modification	Potential for Effects	
			Direct	Indirect
Delta Smelt				
All uses except passion fruit, ULV application on citrus, and ULV application for adult mosquito control	LAA	Yes	Acute toxicity (all uses) and chronic toxicity (some uses)	Acute and chronic toxicity, reduced prey abundance, and degradation of water quality
Passion fruit, ULV application on citrus, and ULV application for adult mosquito control	LAA	Yes	None	Acute and chronic toxicity, reduced prey abundance, and degradation of water quality
California Tiger Salamander				
All uses except ULV application on citrus, and ULV application for adult mosquito control	LAA	Yes	Acute toxicity and chronic toxicity	Acute toxicity to insects, chronic toxicity to mammals, acute toxicity to mammals (some uses), reduced prey abundance, and reduction of mammal burrows
ULV application on citrus, and ULV application for adult mosquito control	LAA	Yes	Acute toxicity	Acute toxicity to insects and reduced prey abundance

Abbreviations: n/A= Not applicable; NE = No effect; NLAA = May affect, but not likely to adversely affect; LAA = Likely to adversely affect

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

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

- Enhanced information on the density and distribution of DS and CTS life stages within the action area and/or applicable designated critical habitat. This information would allow for quantitative extrapolation of the present risk assessment's predictions of individual effects to the proportion of the population extant within geographical areas where those effects are predicted. Furthermore, such population information would allow for a more comprehensive evaluation of the significance of potential resource impairment to individuals of the assessed species.

- Quantitative information on prey base requirements for the assessed species. While existing information provides a preliminary picture of the types of food sources utilized by the assessed species, it does not establish minimal requirements to sustain healthy individuals at varying life stages. Such information could be used to establish biologically relevant thresholds of effects on the prey base, and ultimately establish geographical limits to those effects. This information could be used together with the density data discussed above to characterize the likelihood of adverse effects to individuals.

- Information on population responses of prey base organisms to the pesticide. Currently, methodologies are limited to predicting exposures and likely levels of direct mortality, growth or reproductive impairment immediately following exposure to the pesticide. The degree to which repeated exposure events and the inherent demographic characteristics of the prey population play into the extent to which prey resources may recover is not predictable. An enhanced understanding of long-term prey responses to pesticide exposure would allow for a more refined determination of the magnitude and duration of resource impairment, and together with the information described above, a more complete prediction of effects to individual species and potential modification to critical habitat.

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