Risks of Chlorpyrifos Use to Federally Threatened & Endangered California red-legged frog (*Rana aurora draytonii*), California tiger salamander *(Ambystoma californiense)*, San Francisco garter snake *(Thamnophis sirtalis tetrataenia)*, California clapper rail, *(Rallus longirostris obsoletus)*, Salt marsh harvest mouse *(Reithrodontomys raviventris)*, Bay checkerspot butterfly *(Euphydryas editha bayensis)*, Valley elderberry longhorn beetle *(Desmocerus californicus dimorphus)*, San Joaquin kit fox *(Vulpes macrotis mutica)*, California freshwater shrimp *(Syncaris pacifica)*, and Delta smelt *(Hypomesus transpacificus)*

Pesticide Effects Determinations

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1 Executive Summary

The purpose of this assessment is to evaluate potential direct and indirect effects on the California red-legged frog *(Rana aurora draytonii*), California tiger salamander *(Ambystoma californiense),* San Francisco garter snake *(Thamnophis sirtalis tetrataenia),* California clapper rail, *(Rallus longirostris obsoletus),* Salt marsh harvest mouse *(Reithrodontomys raviventris),* Bay checkerspot butterfly *(Euphydryas editha bayensis),* Valley elderberry longhorn beetle *(Desmocerus californicus dimorphus),* San Joaquin kit fox *(Vulpes macrotis mutica),* California freshwater shrimp *(Syncaris pacifica),* Delta smelt *(Hypomesus transpacificus)* arising from FIFRA regulatory actions regarding use of chlorpyrifos on agricultural and non-agricultural sites. Hereafter the non-California red legged frog (CRLF) species considered in this assessment will be referred to collectively as SFB species.

In addition, this assessment evaluates whether these actions can be expected to result in modification of designated critical habitat for the CRLF and SFB species. Critical habits have only been designated for the CRLF, BCB, VELB, CTS, and DS species. This assessment was completed in accordance with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998 and procedures outlined in the Agency's Overview Document (U.S. EPA, 2004). The CRLF was listed as a threatened species by USFWS in 1996. The species is endemic to California and Baja California (Mexico) and inhabits both coastal and interior mountain ranges.

Chlorpyrifos (CAS number 2921-88-2; PC Code 059101) [*O*,*O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate] is an insecticide belonging to the organophosphate class of pesticides. The pesticide acts through inhibition of acetylcholinesterase and is used to kill a broad range of insects and mites. Currently, labeled uses of chlorpyrifos include a wide variety of terrestrial food and feed crops, terrestrial non-food crops, greenhouse food/non-food, and domestic indoor and outdoor sites. There are currently 26 active registrants of chlorpyrifos with 99 active product labels, which include formulated products and technical grade chlorpyrifos.

The major route of dissipation of chlorpyrifos appears to be aerobic and anaerobic biodegradation. Abiotic hydrolysis under neutral and acidic conditions, photodegradation, and volatilization do not seem to play a significant role in the dissipation process. Based on available data, chlorpyrifos appears to degrade slowly in soil under both aerobic and anaerobic conditions: however, the persistence appears to variable. Information on leaching and adsorption/desorption indicate that parent chlorpyrifos is largely immobile.

The effects determinations for each listed species assessed is based on a weight-of-evidence method that relies heavily on an evaluation of risks to each taxon relevant to assess both direct and indirect effects to the listed species and the potential for modification of their designated critical habitat (*i.e*., a taxon-level approach). Since the assessed species exist within aquatic and terrestrial habitats, exposure of the listed species, their prey and their habitats to chlorpyrifos are assessed separately for the two habitats. Tier-II exposure models (PRZM/EXAMS) are used to estimate high-end exposures of chlorpyrifos in aquatic habitats resulting from runoff and spray drift from different uses. Peak model-estimated environmental concentrations (EEC) resulting from different chlorpyrifos uses range from <1 μg/L to 45 μg/L. The 45 μg/L is associated with ornamental use and is somewhat uncertain. The next highest EEC is 16 µg/L associated with use on cole crops. These estimates are supplemented with analysis of available California surface water monitoring data from U. S. Geological Survey's National Water Quality Assessment (NAWQA) program and the California Department of Pesticide Regulation and available open literature data. Chlorpyrifos has been widely detected in surface water samples in California from both the USGS NAWQA[1] and CDPR[2] data sets. Detection frequency in these data range from roughly 25% to 50%. Maximum concentrations detected in these data sets are as high as approximately 4 ppb though higher values have been reported in open literature. In addition, chlorpyrifos has been detected in sediment and air/rainfall samples. Overall, chlorpyrifos has been detected in runoff and eroded sediment and has been detected in air and rainfall samples far from the site of applications suggesting that chlorpyrifos is likely volatilized. Finally, chlorpyrifos oxon has been detected in surface water and air/rain samples suggesting similar transport processes as the parent.

To estimate chlorpyrifos exposures to terrestrial species resulting from uses involving chlorpyrifos applications, the T-REX model is used for both foliar and granular applications. AgDRIFT and AGDISP models are also used to estimate deposition of chlorpyrifos on terrestrial and aquatic habitats from spray drift. The T-HERPS model is used to allow for further characterization of dietary exposures of terrestrial-phase amphibians relative to birds.

KABAM ($\underline{K}_{OW}$ (based) Aquatic BioAccumulation Model) is used to estimate potential bioaccumulation of chlorpyrifos in freshwater aquatic food webs and subsequent risks to mammals and birds via consumption of contaminated aquatic prey. This bioaccumulation assessment predicts water and sediment concentrations from PRZM/EXAMS to estimate concentrations of chlorpyrifos in aquatic organisms. These estimated tissue concentrations are compared to toxicity values for various taxonomic groups that may eat aquatic organisms in order to evaluate potential risk. The model then uses chlorpyrifos tissue concentrations in aquatic animals to estimate dose- and dietary-based exposures and associated risks to mammals and birds consuming aquatic organisms, using an approach that is similar to the T-REX model (USEPA 2008).

The effects determination assessment endpoints for the listed species include direct toxic effects on the survival, reproduction, and growth of the listed species itself, as well as indirect effects, such as reduction of the prey base or modification of its habitat. If appropriate data are not available, toxicity data for birds are generally used as a surrogate for reptiles and terrestrial-phase amphibians and toxicity data from fish are used as a surrogate for aquatic-phase amphibians.

The major pathway of degradation begins with cleavage of the phosphorus ester bond to yield TCP. Cleavage degradates, such as TCP and analogs, were the only degradates identified in the submitted environmental fate studies. The degradates considered for inclusion in this assessment were 3,5,6-trichloro-2-pyridinol (TCP) and chlorpyrifos-oxon (though not detected in fates studies the oxon has been detected in monitoring data). Toxicity studies (both registrant submitted and from open literature) for the major chlorpyrifos degradation product, TCP, suggest

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[1] http://water.usgs.gov/nawqa/
[2] http://www.cdpr.ca.gov/docs/emon/surfwtr/surfdata.htm

that the degradate is significantly less toxic than the TGAI. For aquatic species TCP is 3 to 4 orders of magnitude less toxic than chlorpyrifos and for terrestrial species it is roughly 1 to 2 orders of magnitude less toxic; due to lower toxicity than the parent, TCP exposure was not evaluated in this assessment. Chlorpyrifos-oxon, a minor degradation product of chlorpyrifos, has been detected in environmental samples, including drinking water, surface water and precipitation. Toxicity data based on human health studies[3] indicate that chlorpyrifos oxon may be up to 10 times more toxic than parent chlorpyrifos. Additional open literature data provide further evidence for chlopyrifos oxon being more toxic to non-target organisms than parent chlorpyrifos.

Risk quotients (RQs) are derived as quantitative estimates of potential high-end risk. Acute and chronic RQs are compared to the Agency's levels of concern (LOCs) to identify instances where chlorpyrifos use within the action area has the potential to adversely affect the assessed species and designated critical habitat (if applicable) via direct toxicity or indirectly based on direct effects to its food supply or habitat. When RQs for each particular type of effect are below LOCs, the pesticide is determined to have "no effect" on the listed species being assessed. Where RQs exceed LOCs, a potential to cause adverse effects is identified, leading to a conclusion of "may affect." If a determination is made that use of chlorpyrifos use "may affect" the listed species being assessed and/or its designated critical habitat (if applicable), additional information is considered to refine the potential for exposure and effects. Best available information is used to distinguish those actions that "may affect, but are not likely to adversely affect" (NLAA) from those actions that are "likely to adversely affect" (LAA) for each listed species assessed. For designated critical habitat, distinctions are made for actions that are expected to have 'no effect' on a designated critical habitat from those actions that have a potential to result in 'habitat modification'.

Based on the best available information, the Agency makes a May Affect, and Likely to Adversely Affect determination for all species being assessed from the use of chlorpyrifos. These include the CRLF, California tiger salamander (CTS), San Francisco garter snake (SFGS), California clapper rail (CCR), Salt marsh harvest mouse (SMHM), Bay checkerspot butterfly (BCB), Valley elderberry longhorn beetle (VELB), San Joaquin kit fox (SJKF), California freshwater shrimp (CFS), and Delta smelt (DS).

Additionally, the Agency has determined that there is the potential for modification of designated critical habitat for the CRLF, BCB, VELB, CTS, and DS from the use of chlorpyrifos. A summary of the risk conclusions and effects determinations for each listed species assessed here and their designated critical habitat (if applicable) is presented in **Tables 1.1** and **1.2**. 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 listed species being assessed and potential modification of designated critical habitat for those species being assessed with designated critical habitat, a description of the baseline status and cumulative effects for the CRLF is provided in **Attachment 2** and the baseline status and cumulative effects for the SFB are provided in **Attachment 4**].

[3] U.S. Environmental Protection Agency. 2006. Organophosphate Cumulative Risk Assessment. http://www.epa.gov/oppsrrd1/cumulative/2006-op/index.htm

Table 1.1 Effects Determination Summary for Effects of Chlorpyrifos on the CRLF and SFB Species
- Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly

Species	Effects Determination [1]	Basis for Determination
California red-legged frog (*Rana aurora draytonii*)	**LAA[1]**	**Potential for Direct Effects**
		Aquatic-phase (Eggs, Larvae, and Adults): **Direct Effects Determination**: African clawed frog, Xenopus laevis NOAEC = <0.1 ug/L;LOC exceeded for 46/47 uses of chlorpyrifos.
		Terrestrial-phase (Juveniles and Adults): **Direct Effects Determination:** Avian RQs exceed LOCs for all uses of chlorpyrifos. **<u>Bioaccumulation from Aquatic Prey:</u>** - Based on consumption of aquatic prey that is predicted to bioaccumulate chlorpyrifos, chronic RQs were exceeded using the KABAM model.
		Potential for Indirect Effects
		Aquatic prey items, aquatic habitat, cover and/or primary productivity **Indirect Effects Determination:** Blackfly, *Simulium vittatum IS-7* LC50 = 0.06 ug/L; **LOC exceeded for ALL uses,** and Daphnid, *Daphnia magna* NOAEC = 0.04 ug/L; **LOC exceeded for ALL uses** **Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**.
		Terrestrial prey items, riparian habitat **Indirect Effects Determination:** Avian acute and chronic RQs exceed LOCs for all uses of chlorpyrifos. Acute and chronic mammalian RQs exceed LOCs for the majority of uses of chlorpyrifos. The terrestrial invertebrate RQs for both small and large insects significantly exceed the acute LOC for all chlorpyrifos uses. No acceptable terrestrial plant studies are available; based on incident data the potential for indirect effects is presumed.
San Francisco garter snake (*Thamnophis sirtalis tetrataenia)*	**LAA**	**Potential for Direct Effects**
		Terrestrial-phase (Juveniles and Adults): **Direct Effects Determination:** See description above (CRLF) for direct effects on birds as surrogate for terrestrial phase amphibians. **<u>Bioaccumulation from Aquatic Prey:</u>** - Based on consumption of aquatic prey that is predicted to bioaccumulate chlorpyrifos, chronic RQs were exceeded using the KABAM model.
		Potential for Indirect Effects
		Aquatic prey items, aquatic habitat, cover and/or primary productivity **Indirect Effects Determination:** Blackfly, *Simulium vittatum IS-7* LC50 = 0.06 ug/L; **LOC exceeded for ALL uses,** and Daphnid, *Daphnia magna* NOAEC = 0.04 ug/L; **LOC exceeded for ALL uses** **Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**.

Table 1.1 Effects Determination Summary for Effects of Chlorpyrifos on the CRLF and SFB Species - Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly		
Species	**Effects Determination [1]**	**Basis for Determination**
		Terrestrial prey items, riparian habitat **Indirect Effects Determination:** Avian acute and chronic RQs exceed LOCs for all uses of chlorpyrifos. Acute and chronic mammalian RQs exceed LOCs for the majority of uses of chlorpyrifos. The terrestrial invertebrate RQs for both small and large insects significantly exceed the acute LOC for all chlorpyrifos uses. No acceptable terrestrial plant studies are available; based on incident data the potential for indirect effects is presumed.
California Clapper Rail (*Rallus longirostris obsoletus)*	**LAA**	**Potential for Direct Effects**
		Terrestrial-phase (Juveniles and Adults): **Direct Effects Determination:** Avian acute dose- and dietary-based RQs are exceeded for all uses of chlorpyrifos. **<u>Bioaccumulation from Aquatic Prey:</u>** - Based on consumption of aquatic prey that is predicted to bioaccumulate chlorpyrifos, chronic RQs were exceeded using the KABAM model.
		Potential for Indirect Effects
		Aquatic; prey items and primary productivity: **Indirect Effects Determination:** Blackfly, *Simulium vittatum IS-7* LC50 = 0.06 ug/L; **LOC exceeded for ALL uses,** and Daphnid, *Daphnia magna* NOAEC = 0.04 ug/L; **LOC exceeded for ALL uses** **Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**
		Terrestrial prey items, riparian habitat **Indirect Effects Determination:** Avian acute and chronic RQs exceed LOCs for all uses of chlorpyrifos. Acute and chronic mammalian RQs exceed LOCs for the majority of uses of chlorpyrifos. The terrestrial invertebrate RQs for both small and large insects significantly exceed the acute LOC for all chlorpyrifos uses. No acceptable terrestrial plant studies are available; based on incident data the potential for indirect effects is presumed.
Salt marsh harvest mouse (*<u>Reithrodontomys raviventris</u>*)	**LAA**	**Potential for Direct Effects**
		Terrestrial-phase (Juveniles and Adults): **Direct Effects Determination:** Acute and chronic mammalian RQs exceed LOCs for the majority of uses of chlorpyrifos.
		Potential for Indirect Effects
		Terrestrial prey items, riparian habitat **Indirect Effects Determination:** Avian acute and chronic RQs exceed LOCs for all uses of chlorpyrifos. Acute and chronic mammalian RQs exceed LOCs for the majority of uses of chlorpyrifos. The terrestrial invertebrate RQs for both small and large insects significantly exceed the acute LOC for all chlorpyrifos uses. No acceptable terrestrial plant studies are available; based on incident data the potential for indirect effects is presumed. **Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use..**
Bay checkerspot butterfly (BCB) (*<u>Euphydryas editha</u>*	**LAA**	**Potential for Direct Effects**
		Direct Effects Determination: The terrestrial invertebrate RQs for both small and large insects significantly exceed the acute LOC for all chlorpyrifos uses.

Table 1.1 Effects Determination Summary for Effects of Chlorpyrifos on the CRLF and SFB Species - Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly		
Species	**Effects Determination** [1]	**Basis for Determination**
bayensis)		**Potential for Indirect Effects** **Indirect Effects Determination:** No acceptable terrestrial plant studies are available; based on incident data the potential for indirect effects is presumed.
Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)	**LAA**	**Potential for Direct Effects** **Direct Effects Determination:** The terrestrial invertebrate RQs for both small and large insects significantly exceed the acute LOC for all chlorpyrifos uses. **Potential for Indirect Effects** **Indirect Effects Determination:** No acceptable terrestrial plant studies are available; based on incident data the potential for indirect effects is presumed.
San Joaquin kit fox (*Vulpes macrotis mutica*)	**LAA**	**Potential for Direct Effects** ***Terrestrial-phase (Juveniles and Adults)***: **Direct Effects Determination:** Acute and chronic mammalian RQs exceed LOCs for the majority of uses of chlorpyrifos. **Potential for Indirect Effects** ***Terrestrial prey items, riparian habitat*** **Indirect Effects Determination:** Avian acute and chronic RQs exceed LOCs for all uses of chlorpyrifos. Acute and chronic mammalian RQs exceed LOCs for the majority of uses of chlorpyrifos. The terrestrial invertebrate RQs for both small and large insects significantly exceed the acute LOC for all chlorpyrifos uses. No acceptable terrestrial plant studies are available; based on incident data the potential for indirect effects is presumed. **Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**.
California tiger salamander (*Ambystoma californiense*)	**LAA**	**Potential for Direct Effects** ***Aquatic-phase (Eggs, Larvae, and Adults)***: **Direct Effects Determination**: African clawed frog, Xenopus laevis NOAEC = <0.1 ug/L;LOC exceeded for 46/47 uses of chlorpyrifos. ***Terrestrial-phase (Juveniles and Adults)***: **Direct Effects Determination:** See description above (CRLF) for direct effects on birds as surrogate for terrestrial phase amphibians **Bioaccumulation in Aquatic Prey:** - Based on consumption of aquatic prey that is predicted to bioaccumulate chlorpyrifos, chronic RQs were exceeded using the KABAM model. **Potential for Indirect Effects** ***Aquatic prey items, aquatic habitat, cover and/or primary productivity*** **Indirect Effects Determination:** Blackfly, *Simulium vittatum IS-7* LC50 = 0.06 ug/L; **LOC exceeded for ALL uses,** and Daphnid, *Daphnia magna* NOAEC = 0.04 ug/L; **LOC exceeded for ALL uses** **Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**.

Table 1.1 Effects Determination Summary for Effects of Chlorpyrifos on the CRLF and SFB Species - Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly		
Species	**Effects Determination [1]**	**Basis for Determination**
		Terrestrial prey items, riparian habitat **Indirect Effects Determination:** Avian acute and chronic RQs exceed LOCs for all uses of chlorpyrifos. Acute and chronic mammalian RQs exceed LOCs for the majority of uses of chlorpyrifos. The terrestrial invertebrate RQs for both small and large insects significantly exceed the acute LOC for all chlorpyrifos uses. No acceptable terrestrial plant studies are available; based on incident data the potential for indirect effects is presumed.
Delta smelt (*Hypomesus transpacificus*)	**LAA**	**Direct Effects Determination: Freshwater Habitat:** Bluegill Sunfish, *Lepomis macrochirus* LC50 =1.8 ug/L; **LOC exceeded for 46/47 uses;** Fathead minnow, *Pimephales promelas* NOAEC = 0.57 ug/L, **LOC exceeded for 25/47 uses.** **Saltwater Habitat:** Tidewater silverside,*Menidia peninsulae* LC50 = 0.7 ug/L, **LOC exceeded for 45/47 uses; and** Atlantic silverside, *Menidia menidia* NOAEC = 0.28 ug/L, **LOC exceeded for 42/47 uses** Aquatic:, prey items and primary productivity. **Indirect Effects Determination:** Freshwater Food: Blackfly, *Simulium vittatum IS-7* LC50 = 0.06 ug/L; **LOC exceeded for ALL uses,** and Daphnid, *Daphnia magna* NOAEC = 0.04 ug/L; **LOC exceeded for ALL uses** Saltwater Food: Mysid shrimp, *Americamysis bahia*, LC50 = 0.035 ug/L, **LOC exceeded for ALL uses;** and NOAEC = 0.0046 ug/L, **LOC exceeded for ALL uses** **Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**.
California freshwater shrimp (*Syncaris pacifica*)	**LAA**	**Direct Effects:** Daphnid, *Ceriodaphnia dubia* LC50 = 0.07 ug/L; **LOC exceeded for ALL uses;** also Daphnid, *Daphnia magna* NOAEC = 0.04 ug/L; **LOC exceeded for ALL registered uses of chlorpyrifos.** **Indirect Effects/Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**.

[1] No effect (NE); May affect, but not likely to adversely affect (NLAA); May affect, likely to adversely affect (LAA)

Table 1.2 Effects Determination Summary for the Critical Habitat Impact AnalysisEffects Determination Summary for the Critical Habitat Impact Analysis		
Designated Critical Habitat for:	**Effects Determination [1]**	**Basis for Determination**
California red-legged frog (*Rana aurora draytonii*)	**HM[1]**	**Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**. This was the only plant data considered. EPA's determination of LAA is based on incident data linking chlorpyrifos to adverse effects on plant species.
Bay checkerspot butterfly (BCB) (*Euphydryas editha bayensis*)	**HM**	**Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**. This was the only plant data considered. EPA's determination of LAA is based on incident data linking chlorpyrifos to adverse effects on plant species.
Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)	**HM**	**Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**. This was the only plant data considered. EPA's determination of LAA is based on incident data linking chlorpyrifos to adverse effects on plant species.
California tiger salamander (*Ambystoma californiense*)	**HM**	**Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**. This was the only plant data considered. EPA's determination of LAA is based on incident data linking chlorpyrifos to adverse effects on plant species.
Delta smelt (*Hypomesus transpacificus*)	**HM**	**Primary Productivity Determination:** Alga, *Isochrysis galbana*, EC50 – 140 ug/L = **LOC not exceeded for any use.**. This was the only plant data considered. EPA's determination of LAA is based on incident data linking chlorpyrifos to adverse effects on plant species.

[1] Habitat Modification.

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 to seek concurrence with the LAA determinations for the CRLF and all SFB species covered by this assessment and to determine whether there are reasonable and prudent alternatives and/or measures to reduce and/or eliminate potential incidental take.

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 CRLF and SFB species 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* (U.S. EPA, 1998), the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS 1998) and is consistent with procedures and methodology outlined in the Overview Document (U.S. EPA, 2004) and reviewed by the U.S. Fish and Wildlife Service and National Marine Fisheries Service (USFWS/NMFS 2004).

2.1 Purpose

The purpose of this endangered species assessment is to evaluate potential direct and indirect effects on individuals of the federally threatened California red-legged frog *(Rana aurora draytonii*) (CRLF) and SFB species arising from FIFRA regulatory actions regarding use of chlorpyrifos on a larger variety of agricultural and non-agricultural uses. In addition, this assessment evaluates whether use on these use sites is expected to result in modification of designated critical habitat for the CRLF, BCB, VELB, CTS, and DS (only five of the species have designated critical habitat). This ecological risk assessment has been prepared consistent with the settlement agreements in two court cases. The first case referring to the CRLF is the *Center for Biological Diversity (CBD) vs. EPA et al*. (Case No. 02-1580-JSW(JL)) settlement entered in Federal District Court for the Northern District of California on October 20, 2006. The second case referring to the and SFB species is the *Center for Biological Diversity (CBD) vs. EPA et al*. (Case No. 07-2794-JCS).

In this assessment, direct and indirect effects to the CRLF and SFB species and potential modification to designated critical habitat for the CRLF, BCB, VELB, CTS, and DS are evaluated in accordance with the methods described in the Agency's Overview Document (U.S. EPA 2004). The effects determinations for each listed species assessed is based on a weight-of-evidence method that relies heavily on an evaluation of risks to each taxon relevant to assess both direct and indirect effects to the listed species and the potential for modification of their designated critical habitat (*i.e*., a taxon-level approach). Screening level methods include use of standard models such as PRZM-EXAMS, T-REX, TerrPlant, AgDRIFT, and AGDISP, all of which are described at length in the Overview Document. Use of such information is consistent with the methodology described in the Overview Document (USEPA, 2004), which specifies that "the assessment process may, on a case-by-case basis, incorporate additional methods, models, and lines of evidence that EPA finds technically appropriate for risk management objectives" (Section V, page 31 of USEPA, 2004).

In accordance with the Overview Document, provisions of the ESA, and the Services' *Endangered Species Consultation Handbook*, the assessment of effects associated with registrations of chlorpyrifos is based on an action area. The action area is the area directly or indirectly affected by the federal action, as indicated by the exceedence 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 chlorpyrifos may potentially involve numerous areas throughout the United States and its Territories. However, for the purposes of this assessment, attention will be focused on relevant sections of the action area including those geographic areas associated with locations of the CRLF and SFB species and their designated critical habitat within the state of California. As part of the "effects determination," one of the following three conclusions will be reached separately for each of the assessed species in the lawsuits regarding the potential use of chlorpyrifos in accordance with current labels:

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

Only the CRLF, BCB, VELB, CTS, and DS have designated critical habitats associated with them. Designated critical habitat identifies specific areas that have the physical and biological features, (known as primary constituent elements or PCEs) essential to the conservation of the listed species. The PCEs for CRLF are aquatic and upland areas where suitable breeding and non-breeding aquatic habitat is located, interspersed with upland foraging and dispersal habitat. A complete description of the PCEs for each species assessed may be found in Table 2.5.

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

If a determination is made that use of chlorpyrifos "may affect" a listed species or its designated critical habitat, additional information is considered to refine the potential for exposure and for effects to each species and other taxonomic groups upon which these species depend (*e.g.*, prey items). Additional information, including spatial analysis (to determine the geographical proximity of the assessed species' habitat and chlorpyrifos use sites) and further evaluation of the potential impact of chlorpyrifos on the PCEs is also used to determine whether modification of designated critical habitat may occur. Based on the refined information, the Agency uses the best available information to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that "may affect and are likely to adversely affect" the assessed listed species and/or result in "no effect" or potential modification to the PCEs of its designated critical habitat. This information is presented as part of the Risk Characterization in Section 5 of this document.

The Agency believes that the analysis of direct and indirect effects to listed species provides the basis for an analysis of potential effects on the designated critical habitat. Because chlorpyrifos is expected to directly impact living organisms within the action area (defined in Section 2.7), critical habitat analysis for chlorpyrifos is limited in a practical sense to those PCEs of critical habitat that are biological or that can be reasonably linked to biologically mediated processes (*i.e.*, the biological resource requirements for the listed species associated with the critical habitat or important physical aspects of the habitat that may be reasonably influenced through biological processes). Activities that may modify critical habitat are those that alter the PCEs and appreciably diminish the value of the habitat. Evaluation of actions related to use of chlorpyrifos that may alter the PCEs of the assessed species' critical habitat form the basis of the critical habitat impact analysis. Actions that may affect the assessed species' designated critical habitat have been identified by the Services and are discussed further in Section 2.6.

2.2 Scope

Chlorpyrifos is an organophosphate used as an insecticide on a wide variety of terrestrial food and feed crops, terrestrial non-food crops, greenhouse food/non-food, and domestic indoor and outdoor sites. There are currently 26 active registrants of chlorpyrifos with 99 active product labels, which include formulated products and technical grade chlorpyrifos. Chlorpyrifos may be applied as a spray or as a granular insecticide. While foliar applications may be used, chlorpyrifos is most often applied directly to soil and may be incorporated (many uses allow for applications to both soil surface and soil incorporated and these methods have been assessed separately where appropriate).

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 chlorpyrifos in accordance with the approved product labels for California is "the action" relevant to this ecological risk assessment.

Although current registrations of chlorpyrifos allow for use nationwide, this ecological risk assessment and effects determination addresses currently registered uses of chlorpyrifos in portions of the action area that are reasonably assumed to be biologically relevant to the CRLF and SFB species and their designated critical habitat. Further discussion of the action area for the CRLF and SFB species and their critical habitat is provided in Section 2.7.

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

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

2.3 Previous Assessments

The Agency has conducted previous ecological risk assessments on chlorpyrifos that serve as a basis for this problem formulation. Each of the previous risk assessments is briefly discussed below.

Chlorpyrifos Interim Registration Eligibility Decision, 2002

The Agency completed a screening-level ecological risk assessment (dated October 1999 and revised March and June 2000) in support of the Interim Reregistration Eligibility Decision (IRED) for chlorpyrifos (U.S. EPA, 2002). Completion of the organophosphate (OP) cumulative assessment (U.S. EPA, 2006b) resulted in finalization of the IRED as a Reregistration Eligibility Decision (RED) (U.S. EPA, 2006a), which is described below.

The IRED assessment was based on data collected in the laboratory and in the field to characterize the fate and ecotoxicological effects of chlorpyrifos. Data sources used in this assessment included: 1) registrant submissions in support of reregistration, 2) publicly available literature on ecological effects, 3) surface water monitoring data, and 4) incident reports of adverse effects on aquatic and terrestrial organisms associated with the use of chlorpyrifos.

Risk quotients (RQs) based on estimated environmental concentrations (EECs) derived from both monitoring data and exposure modeling and the available toxicity information indicated that a *single* application of chlorpyrifos posed high risks to small mammals, birds, fish and aquatic invertebrate species for nearly all registered outdoor uses. Multiple applications of chlorpyrifos resulted in higher estimated exposures and risks. Bioconcentration of chlorpyrifos in aquatic environments was purported to result in additional acute and chronic risks to aquatic birds and mammals feeding adjacent to treated areas.

The presumption of risk to non-target aquatic and terrestrial animals was supported by field studies and adverse ecological incidents. Three extensive terrestrial field studies on corn in Iowa, citrus in California, and golf courses in central Florida, report cholinesterase-inhibition effects and chlorpyrifos-related mortality in non-target organisms. Chlorpyrifos-related mortalities were reported in small mammals, birds, reptiles, and amphibians as determined by measurable chlorpyrifos residues in the carcasses. Measured chlorpyrifos levels on foliage samples and water samples reported in all three studies generally exceeded the model-predicted exposures. Aquatic field studies where chlorpyrifos has been applied directly to water for insect control have shown adverse effects on non-target species, including fish recruitment and growth and near elimination of some aquatic invertebrate populations.

Reports of incidents involving songbird kills and occasional fish kills mostly associated with termite applications, particularly perimeter treatments. Wildlife incidents associated with lawn care treatment with chlorpyrifos for soil insect control include the deaths of robins, starlings, sparrows, geese, goslings, a bluebird, a cat, and fish.

Ecotoxicity data for the principal degradate of chlorpyrifos, 3, 5, 6-trichloro-2-pyridinol (TCP), indicated that the degradate was no more toxic than the parent compound; thus, exposure estimates for non-target aquatic organisms were estimated only for the parent chlorpyrifos. Chlorpyrifos-oxon was not assessed quantitatively for either the ecological or the human health risk assessment in support of the IRED.

Also as part of the IRED an extensive review of available surface water and groundwater monitoring data was completed. Data sources included national scale assessment, state and local data, open literature studies, and registrant submitted studies.

To mitigate ecological risks the technical registrants agreed to label amendments that included the use of buffer zones to protect water quality, fish and wildlife, reductions in application rates, number of applications per season, seasonal maximum amounts applied, and increases in the minimum intervals for retreatment. In addition, the residential uses of chlorpyrifos were eliminated, the termiticide use was phased out, and the application rate on golf courses has been reduced from 4 to 1 lb/ai/A. Additionally, no-spray buffers around surface water bodies, as well as rate reductions for agricultural uses were implemented as a result of this IRED.

Organophosphate Cumulative Assessment, and Chlorpyrifos Reregistration Eligibility Decision, 2006

Because the Agency determined that chlorpyrifos shares a common mechanism of toxicity with the structurally-related organophosphates insecticides, a cumulative human health risk assessment for the organophosphate (OP) pesticides was necessary before the Agency could make a final determination of reregistration eligibility of chlorpyrifos. This cumulative assessment was finalized in 2006 (U.S. EPA, 2006b). The results of the Agency's ecological assessments for chlorpyrifos are discussed in the July 31, 2006, final Reregistration Eligibility Decision (RED) (U.S. EPA 2006a).

The OP cumulative relied on a combined assessment methodology of modeling and monitoring data for human health exposure via drinking water. Unlike other assessments, the cumulative approach focused on regions of high OP use. No ecological risks were evaluated in the OP cumulative process. Unlike the IRED, the cumulative assessment included a qualitative evaluation of the impact of oxon formation via drinking water treatment (*i.e.*, chlorination) effects. For chlorpyrifos, this included laboratory toxicity information which indicated that chlorpyrifos-oxon was more toxic than the parent (Chambers and Carr, 1993).

Aquatic Life Criteria

The Clean Water Act requires the EPA to publish water quality criteria that accurately reflect the latest scientific knowledge on the kind and extent of all identifiable effects on health and welfare which might be expected from the presence of pollutants in any body of water, including ground water. An Aquatic Life Ambient Water Quality Criteria document was published for chlorpyrifos in 1986 (U.S. EPA, 1986). The recommendation of the document in regards to freshwater aquatic life states the following: "Freshwater aquatic life should not be affected if the four-day average concentration of chlorpyrifos does not exceed 0.041 micrograms per liter (µg/L) more than once every three years on the average and if the one-hour average concentration of chlorpyrifos does not exceed 0.083 µg/L more than once every three years on the average." While these recommended criteria do not, in themselves, impose any requirements, states and authorized tribes can use them to develop water quality standards.

WTC Lawsuit Biological Evaluation (BE)

In 2002 the United States District Court, Western District of Washington at Seattle ordered the EPA to conduct effects determinations for 54 pesticides for listed salmonids in the states of California, Idaho, Oregon, and Washington (collectively the Pacific Northwest, PNW). On March 31, 2003 OPP completed an evaluation of the risk to Endangered and Threatened Salmon and Steelhead (EPA, 2003) from the registered use of chlorpyrifos in the PNW. In that assessment OPP determined that the use of chlorpyrifos may affect 19 of 27 evolutionarily significant units (ESU), had no effect on two ESU, and was not likely to adversely affect six ESU.

2.4 Stressor Source and Distribution

2.4.1 Environmental Fate Properties

The environmental fate database for parent chlorpyrifos is largely complete , however, there is limited fate data for TCP and no fate data for chlorpyrifos oxon. The major route of dissipation appears to be aerobic and anaerobic metabolism. Abiotic hydrolysis, photodegradation, and volatilization do not seem to play a significant role in the dissipation process. Based on available data, chlorpyrifos appears to degrade slowly in soil under both aerobic and anaerobic conditions. Information on leaching and adsorption/desorption indicate that parent chlorpyrifos is largely immobile. The environmental fate data for the major chlorpyrifos degradate, TCP, indicate that it is mobile in soils and persistent in soils when not exposed to light. Available field data indicate that chlorpyrifos has a half-life in the field of less than 60 days, with little or no leaching observed. Because of its low water solubility and high soil binding capacity, there is potential for chlorpyrifos sorbed to soil to runoff into surface water via erosion. Chlorpyrifos has the potential to bioaccumulate in fish and other aquatic organisms and enter the aquatic food web. Chlorpyrifos may oxidize in the environment to form chlorpyrifos-oxon (the oxon was not identified in any submitted fate studies but has been documented to occur in monitoring data). Studies have shown chlorprifos oxon can form up to nearly 100% of parent from drinking water treatment. Lesser amounts of oxon formation are expected in other media (soil, air, and surface water) however, insufficient data are currently available to quantify this amount.

The major pathway of degradation begins with cleavage of the phosphorus ester bond to yield TCP. Cleavage degradates, such as TCP and analogs were the only degradates identified in the submitted environmental fate studies. The degradate 3,5,6-trichloro-2-pyridinol is more persistent and mobile that chlorpyrifos and has been found to form up to 30% of the parent in aerobic soil metabolism studies suggesting it can form in the environment. This degradate is also a degradation product of triclopyr.

Chlorpyrifos-oxon, a minor degradation product of chlorpyrifos, has been detected in environmental samples, including drinking water, surface water and precipitation. Toxicity data based on human health studies[4] indicate that chlorpyrifos oxon is roughly 10 times more toxic than parent chlorpyrifos. Additional chlorpyrifos-oxon aquatic and terrestrial toxicity data are needed to reduce the uncertainty in the ecological risk assessment (see Section VII.G.2).

Results of field dissipation data indicate that chlorpyrifos is moderately persistent under field conditions. Calculated half-lives for chlorpyrifos were 33 to 56 days in three medium-textured soils planted to field corn in California, Illinois, and Michigan. In a field study conducted in an orange grove planted on sandy, low organic matter soil, the calculated half-lives were 1.3 to 4, 7.3 to <27, and 1.4 to <32 days following the first, second, and third applications, respectively. Chlorpyrifos declined to <0.1 ppm (detection limit) by day 27 following the second treatment, and by day 32 following the third treatment; chlorpyrifos was not detected below the 6-inch soil depth. Chlorpyrifos dissipated with initial phase (days 0 to 28) half-lives of 6.5 to 11.4 days and secondary phase (days 28 to 120) half-lives of 24 to 38.3 days when applied to fallow and turf-

[4] U.S. Environmental Protection Agency. 2006. Organophosphate Cumulative Risk Assessment. http://www.epa.gov/oppsrrd1/cumulative/2006-op/index.htm

covered soils in Florida and Indiana. Neither chlorpyrifos nor it's degradates were detected (<0.01 µg/g) below soil depths of 10 to 15 cm.

In both the IRED and OP cumulative risk assessments a large body of surface water monitoring data were available to assess the potential for exposure to humans via ingestion of drinking water and for direct and indirect effects to non-target aquatic organisms. Sources of data evaluated include national data sets (e.g. United States Geological Survey (USGS) National Water-Quality Assessment Program (NAWQA)), state and local data (e.g. California Department of Pesticide Regulation (CDPR)), open literature data, as well as registrant submitted studies. In all cases, the data suggest that chlorpyrifos is less frequently detected in surface waters than other widely used pesticides, and the detected concentrations are generally less than those predicted by modeling. These data along with more recently available data will be evaluated as part of the ecological and human health risk assessments. In addition, for human health risk assessment purposes, this evaluation will include a search for data on chlorpyrifos degradates of concern, such as TCP and chlorpyrifos-oxon.

Surface water monitoring data are available for chlorpyrifos from the USGS NAWQA. Because the sampling times and locations were not targeted for chlorpyrifos use areas and the sampling frequency was not designed to capture maximum concentrations, the reported concentrations of chlorpyrifos are not expected to be the most conservative exposure concentration. The reported peak concentration of chlorpyrifos in surface water is 0.57 µg/L (**Table 2.1**). Although the peak concentration of chlorpyrifos in ground water is reported as less than 0.5 µg/L, the maximum qualified detection of chlorpyrifos is 0.210 µg/L. Detection frequencies of chlorpyrifos ranged from 17.18 % in surface water to 0.48% in ground water. Although chlorpyrifos was detected at a maximum concentration of 0.034 µg/L in raw drinking water in the USGS-EPA Pilot reservoir monitoring program (Blomquist et al., 2001), there were no detections of chlorpyrifos or chlorpyrifos-oxon in finished drinking water. Additionally, there were no monitoring data for TCP.

Table 2.1 Distribution of chlorpyrifos concentrations from surface water and ground water monitoring data (USGS NAWQA, 2007)

Data	# of samples	% Detects	Percentile								
			Maximum	99.9	99	95	90	80	70	60	50
Surface Water	20749	17.18	0.57	0.5	0.067756	0.016	0.008	0.005	0.005	0.005	0.004
Ground Water	9626	0.48	< 0.50	0.5	0.005	0.005	0.005	0.005	0.005	0.004	0.004

Recent studies have demonstrated that chlorpyrifos and chlorpyrifos-oxon have been detected in surface waters far removed from the site of application (Sparling et al., 2001 as an example). As part of this assessment, available monitoring from the open literature will be evaluated to assess the potential impacts of atmospheric transport other than spray drift on human health and non-target organisms.

In water bodies, chlorpyrifos is expected to persist in the water column; it is also expected that chlorpyrifos will partition to and persist in sediment. Thus, acute and chronic risks may exist to organisms residing in the water column and in sediment. Bioconcentration factors (BCF) greater than 1,000 in rainbow trout exposed to 0.30 ppb chlorpyrifos in a 28-day flow-through study (1,280 for edible tissues, 2,727 for whole fish, and 3,903 for viscera) and in eastern oysters (2,500 for edible tissues, 3,900 for viscera, and 1,900 for whole body) indicate some potential for bioaccumulation especially for predatory animals and piscivorous birds.

The estimated log octanol-air partition coefficient (Log K_{OA}) of 8.882 (EPIsuite, v.3.20) suggests that bioaccumulation of chlorpyrifos in air breathing organisms is possible (Kelly et al., 2007). Potential bioaccumulation of chlorpyrifos in air breathing organisms was considered in this risk assessment using the KABAM model.

Table 2.2 lists the physical/chemical properties for chlorpyrifos and **Table 2.3** lists the environmental fate properties of chlorpyrifos, along with the major and minor degradates detected in the submitted environmental fate and transport studies.

TABLE 2.2 Physical/chemical properties of chlorpyrifos

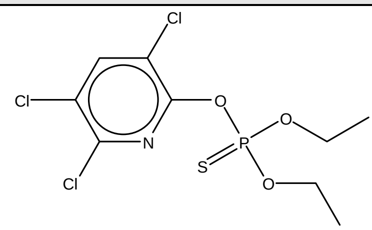
Property	Value	Source
Structure		
Synonyms	IUPAC name: *O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate	Tomlin 2004
Molecular formula	$C_9H_{11}Cl_3NO_3PS$	Tomlin 2004
Molecular weight	350.6	Tomlin 2004
SMILES notation	CCOP(=S)(OCC)Oc1nc(Cl)c(Cl)cc1Cl	
CAS number	2921-88-2	Tomlin 2004
Odor	mild mercaptan-like odor	
form	white granular crystals	
Melting point	approximately 42–43.5 °C	
Water solubility (mg/L)	1.4	Tomlin 2004
Log K_{ow}	4.7	Tomlin 2004
Vapor pressure (mm Hg) at 25 °C	2.02×10^{-5}	Tomlin 2004
Henry's Law constant (atm-m^3/mol)	4.2×10^{-6}	Tomlin 2004
Bioconcentration factor (BCF)	2727 (rainbow trout, whole body)	EPA IRED 2000

Table 2.3 Summary of Chlorpyrifos Environmental Fate Properties				
Study	**Value (units)**	**Major Degradates** ***Minor Degradates***	**MRID #**	**Study Status**
Hydrolysis	pH 5: 72 days pH 7: 72 days pH 9: 16 days	TCP *O-ethyl O-(3,5,6-trichloro-2-pyridinol) phosphorothioate,*	00155577	Acceptable
Direct Aqueous Photolysis	29.6 days @ pH 7	none	41747206	Acceptable
Soil Photolysis	Stable	none	42495403 43509201	Acceptable
Aerobic Soil Metabolism	11 to 180 days		00025619 42144911 42144912	Acceptable
Anaerobic Soil Metabolism	39 to 51 days (2 soils)	TCP *3,5,6-trichloro-2-methoxypyridine*	00025619	Acceptable
Anaerobic Aquatic Metabolism	No data			
Aerobic Aquatic Metabolism	No data			
$K_{d\text{-}ads}$ / $K_{d\text{-}des}$ (mL/g) $K_{oc\text{- }ads}$ / $K_{oc\text{-}des}$ (mL/g)	50 to 260 360 to 31000		00155636 00155637 40050401 41892801 41892802 42493901	Acceptable
Terrestrial Field Dissipation	33 to 56 days 1.3-4, 7.3-<27, and 1.4-<32 days 6.5-11.4 days and secondary phase (days 28-120) half-lives of 24-38.3 days	TCP and hydroxy-chlorpyrifos	40059001 40356608 40395201 42874703 42874704 42924801 42924802	Acceptable
Aquatic Field Dissipation	No data			

2.4.2 Environmental Transport Mechanisms

The major route of dissipation appears to be aerobic and anaerobic biodegradation. Abiotic hydrolysis under neutral and acidic conditions, photodegradation, and volatilization do not seem to play a significant role in the dissipation process. Under alkaline conditions (pH 9), hydrolysis of chlorpyrifos occurs more rapidly with a half-life of approximately 2 weeks. Based on available data, chlorpyrifos appears to degrade slowly in soil under both aerobic and anaerobic conditions. However, the half life appears to vary over about two orders of magnitude (from a few days to well over 100 days and typically greater than 200 days for termiticidal uses (though this use has been phased out) depending on soil type, environmental conditions, and possibly previous use history at the treatment site. Information on leaching and adsorption/desorption indicate that parent chlorpyrifos is largely immobile. The environmental fate of the major chlorpyrifos degradate, TCP, indicates that it is mobile in soils and persistent in soils when not exposed to light. Available field data indicate that chlorpyrifos has a half-life in the field of less than 60 days, with little or no leaching observed. Volatilization from soil and water surfaces is expected to occur slowly; however, chlorpyrifos has been detected in air samples several kilometers from its application site suggesting that some volatilization and atmospheric transport may occur. Because of its low water solubility and high soil binding capacity, there is potential for chlorpyrifos sorbed to soil to be transported into surface water via erosion. Chlorpyrifos has the potential to bioaccumulate in fish and other aquatic organisms and enter the aquatic food web. Chlorpyrifos residues in aquatic species may result in dietary exposure for aquatic birds and mammals feeding on aquatic organisms. Chlorpyrifos rapidly depurates from fish when aquatic exposures cease.

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

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, Sparling et al., 2001, LeNoir et al., 1999, and McConnell et al., 1998). Prevailing winds blow across the Central Valley eastward to the Sierra Nevada Mountains, transporting airborne industrial and agricultural pollutants into the Sierra Nevada ecosystems (Fellers et al., 2004, LeNoir et al., 1999, and McConnell et al., 1998). Several sections of the range and critical habitat for the CLRF and SFB species are located east of the Central Valley. The magnitude of transport via secondary drift depends on the chlorpyrifos'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 chlorpyrifos 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 are considered in evaluating the potential for atmospheric transport of chlorpyrifos to locations where it could impact the CRLF and SFB species.

In general, deposition of drifting or volatilized pesticides is expected to be greatest close to the site of application. Computer models of spray drift (AgDRIFT and/or AGDISP) are used to determine potential exposures to aquatic and terrestrial organisms via spray drift.

2.4.3 Mechanism of Action

Chlorpyrifos (CAS number 2921-88-2; PC Code 059101) [*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate] is an insecticide belonging to the organophosphate class of pesticides. The pesticide acts through inhibition of acetylcholinesterase and is used to kill a broad range of insects and mites. Organophosphate toxicity is based on the inhibition of the enzyme acetylcholinesterase which cleaves the neurotransmitter acetylcholine. Inhibition of acetylcholinesterase by organophosphate insecticides, such as chlorpyrifos, interferes with proper neurotransmission in cholinergic synapses and neuromuscular junctions (U.S. EPA 2000).

2.4.4 Use Characterization

Chlorpyrifos is used as an insecticide on a wide variety of terrestrial food and feed crops, terrestrial non-food crops, greenhouse food/non-food, and domestic indoor and outdoor sites. There are currently 26 active registrants of chlorpyrifos with 99 active product labels, which include formulated products and technical grade chlorpyrifos. Based on usage data provided by the Biological and Economic Analysis Division (BEAD), on average, roughly 8 million pounds of chlorpyrifos were applied to about 180 million acres of agricultural crops in the United States between 2000 and 2006. The largest terrestrial crop usage was for corn, with roughly 3 million pounds of active ingredient applied, representing greater than 40% of its total crop usage. Chlorpyrifos may be applied as a spray or as a granular insecticide. While foliar applications may be used, chlorpyrifos is most often applied directly to soil and incorporated (for some uses) to a depth ranging from 0.5 to 4 inches prior to planting. The application rates vary according to the intended use. Registered non-crop uses of chlorpyrifos include termiticide, turf, golf courses, cattle ear tags, turkey farms, ultra low volume (ULV) mosquito adulticide, ornamental sites, indoor pest control, and pet tick and flea products. In 2002, approximately 25% of the total volume of chlorpyrifos was used for control of subterranean termites. However, as of December 31, 2005, chlorpyrifos products were banned for use in pre-construction termite control (U.S. EPA 2006a). In addition, retail sale of chlorpyrifos products labeled for use in and around homes in the United States were discontinued December 31, 2001.

The EFED has previously grouped the various chlorpyrifos uses into ten categories based on similarities of crops grown, field conditions, and non-crop uses. These “groups” formed the basis for assessing risk to non-target species in the IRED. The current assessment relies on a more expansive set of modeling scenarios and thus the original “grouping” approach has been revised. The revised approach is discussed in more detail in Section VII. Chlorpyrifos may be applied as spray or as a granular insecticide. The application rates and aerial or ground application vary according to the intended use.

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

Chlorpyrifos is currently registered for a wide variety of agricultural and non-agricultural uses. As such, EFED in consultation with the Pesticide Re-evaluation Division (PRD) and the Biological and Economic Analysis Division (BEAD) have developed a current list of all registered uses. The attached summary was verified in a memorandum from PRD and BEAD dated August 6, 2009 and confirms that all mitigations implemented subsequent to the RED have been implemented and are reflected in the following labeled use summary. EFED has outlined a modeling approach for aquatic exposures that associates a PRZM/EXAMS modeling scenario (or scenarios where more than one exists for a particular use) for all uses. Where possible, EFED has attempted to "bin" uses in order to simplify the exposure assessment. Where multiple scenarios exist for a use or suite of uses, EFED has indicated in the following tables which scenario will be used initially for conducting the exposure assessment. Depending on the results of the initial screen, a decision will be made during the analysis phase of the risk assessment as to whether additional modeling of other scenarios is needed to provide a spatial context to risk. Chlorpyrifos currently has three distinct formulation types – liquid, granular, and flowable concentrate. Though the flowable concentrate seed treatment use is expected to yield significantly lower exposures than the liquid and granular formulations the uses have been assessed quantitatively to provide a lower bound on expected exposures. Chlorpyrifos uses are summarized in the following tables by formulation type including **Table 2.4 (Liquid Formulations), Table 2.5 (Granular Formulations),** and **Table 2.6 (Flowable Concentrate Formulations).**

Table 2.4 Liquid Chlorpyrifos Uses and Application Information								
Use Site		**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Maximum No. Apps.**	**Minimum App. Interval (days)**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Alfalfa (Clover)		broadcast foliar spray - aerial or ground; chemigation	1	4	10	4		
Asparagus		ground broadcast foliar - aerial or ground	1.5	3	10	3		1 preharvest 2 postharvest
Christmas Trees (Nurseries & Plantations)		foliar spray - ground	1	3	7	3		phytotoxicity 3 qt/gal for pales weevil
Citrus Fruits		concentrate or dilute spray	4	2	30	7.5	6 lbs/acre application rate only allowed in CA counties: Fresno, Tulare, Kern, Kings, Stanislaus, and Madera	In CA & AZ, do not use in combo with spray oil when temps < 95; do not apply in dec, jan, or feb
Citrus Orchard Floors (Fire Ants & Other Ant Species)		ground broadcast spray; chemigation	2	3	10	3		
Cole Crop (Brassica) Leafy Vegetables and Radish, Rutabaga and Turnip	General	aerial or ground foliar application; soil application	3	3	10	6		3 lbs max app rate for Lorsban-4E
	Cauliflower (Brassica)	soil application	1	1	N/A	1		
	Brussels Sprouts	foliar spray	1	3	10	3		

Table 2.4 Liquid Chlorpyrifos Uses and Application Information								
Use Site		**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Maximum No. Apps.**	**Minimum App. Interval (days)**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
	Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Turnip	soil application	2.25	1	N/A	2.25		
	Radish	soil application	2.75	1	N/A	2.75		
	Rutabaga	soil application	2.25	1	N/A	2.25		do not use rutabaga tops for food or feed purposes.
Corn (Field Corn and Sweet Corn)		broadcast spray - aerial or ground; chemigation	1	3	10	3		
Cotton		broadcast foliar spray - aerial or ground; chemigation	1	3	10	3		specific rates for AZ and CA
Cranberry		broadcast foliar spray; chemigation	1.5	2	10	3		
Fig		dormant application, broadcast spray - ground, incorporate	2	1	N/A	2	use in CA only	

Table 2.4 Liquid Chlorpyrifos Uses and Application Information							
Use Site	**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Maximum No. Apps.**	**Minimum App. Interval (days)**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Grape	soil surface application(application rate in lbs/100gal)	2.25	1	N/A	2.25		do not allow spray to contact fruit or foliage
	prebloom spray drench ground application	1	1	N/A	1		
Legume Vegetables (Succulent or Dried) (Except Soybean) (Includes: bean, blackeyed pea, chickpea, field bean, field pea, garden pea, lima bean, kidney bean, lentil, navy bean, pea, pinto bean)	preplant incorporated broadcast spray - ground; broadcast spray - ground	0.5	1	N/A	0.5		
Mint	broadcast spray - chemigation	2	3	N/A	6		1 preplant 1 growing season 1 postplant
Onion (Dry Bulb)	soil drench spray - at plant	1	1	N/A	1		
	soil drench spray - post plant	1	1	N/A	1		
Orchard Floors (Ant Control in Almond, Pecan and Walnut)	ground broadcast spray; chemigation	2	5	10	5		Some labels indicate ability to use 4 lbs ai/A once
Peanut	preplant broadcast spray, soil incorporation	2	2	NS	4		1 preplant 1 postplant
Pear	postharvest application ground spray	2	1	N/A	2		

Table 2.4 Liquid Chlorpyrifos Uses and Application Information							
Use Site	Application Method	Maximum App. Rate (lbs a.i./A)	Maximum No. Apps.	Minimum App. Interval (days)	Maximum Annual App. Rate (lbs a.i./A)	Geographic Restrictions	Other Restrictions
Sorghum - Grain Sorghum (Milo)	postemergence broadcast spray - aerial or ground; chemigation	1	3	10	1.5		
Soybean	soil - ground broadcast spray; foliar - broadcast spray - aerial or ground; chemigation - broadcast	1	3	14	3		
Strawberry	preplant incorporation - uniform soil coverage	2	1	10	2		
	foliar - broadcast; postharvest - directed spray	1	2	10	2		
Sugarbeet	soil - incorporated; postemergence - broadcast or banded foliar spray; broadcast - aerial or ground; chemigation; banded foliar - lightly incorporated	1	3	10	3		
Sunflower	preplant incorporation - broadcast ground spray	2	3	10	3		
	postemergence - broadcast spray - aerial or ground	1.5	3	10	3		
Sweet Potato	preplant broadcast spray - incorporate	2	1	N/A	2		
Tobacco	preplant broadcast spray	2	1	N/A	2		

Table 2.4 Liquid Chlorpyrifos Uses and Application Information								
Use Site		**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Maximum No. Apps.**	**Minimum App. Interval (days)**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Tree Fruit and Tree Nuts (Dormant/Delayed Dormant Sprays)	Almond, cherry, nectarine, peach, pear, plum, prune	dormant or delayed dormant spray	2	1	N/A	2	do not apply on almonds in these CA counties: Butte, Colusa, Glenn, Solano, Sutter, Tehama, Yolo, and Yuba	
	Apple	dormant/delayed dormant spray	2	2	10	4		post-bloom application prohibited
Tree Fruit and Tree Nuts (Foliar Sprays) (Includes: almond, sour cherry, filbert, pecan, walnut)		foliar spray - aerial (less effective) or ground	2	3	10	6		do not use foliar sprays on sweet cherries; sour cherries can be sprayed up to 8 times
Tree Nuts (Foliar Sprays) (Includes: almond, filbert, pecan, walnut)		foliar spray - aerial (less effective) or ground	2	3	10	4		only 2 applications on walnuts

Table 2.4 Liquid Chlorpyrifos Uses and Application Information							
Use Site	**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Maximum No. Apps.**	**Minimum App. Interval (days)**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Tree Fruit and Tree Nuts (Trunk Spray or Preplant Dip) (Includes: cherry, almond, peach, nectarine)	coarse, low pressure spray (application rate in lbs/100 gal)	1.5	3	10	4.5		only 1 application in peaches and nectarines, 14 day min app interval for Lorsban
Wheat[1]	foliar - aerial or ground spray; chemigation	0.5	2	NS	1		14 days for grazing
Other Uses							
Ant Mounds	sprinkle over mound	2	2	10	4		
General Pest Control (warehouses, ship holds, railroad boxcars, industrial plants, manufacturing plants, and food processing plants)	localized spray	1	NS	7	NS		
Lumber, Logs, and other Wood Products (Fence posts, utility poles, railroad ties, landscape timbers, lumber, logs, pallets, poles, posts, wooden containers, and processed wood products)	dip, spray, brush, pressure and in-place treatment	1	NS	NS	NS		
Ornamentals Grown in Nurseries	hand or power operated spray equipment	2	NS	NS	NS		possible phytotoxicity

Table 2.4 Liquid Chlorpyrifos Uses and Application Information

Use Site	Application Method	Maximum App. Rate (lbs a.i./A)	Maximum No. Apps.	Minimum App. Interval (days)	Maximum Annual App. Rate (lbs a.i./A)	Geographic Restrictions	Other Restrictions
Ornamentals (Pre-Plant Incorporation Treatment of Field Grown Nursery Stock)	broadcast spray, incorporate	4	NS	NS	NS		
Road Median	hydraulic, knapsack sprayer or other hand or power spray equipment	1	NS	NS	NS		
Turfgrass	spray	4	NS	7	NS		

1 – Labeled buffers for wheat are 300 ft for aerial and 30 ft for ground applications
2 - Source: Texas A&M Fire Ant Program and other sources have reported that there can be 200 or more mounds per acre (http://fireant.tamu.edu/ & http://www.safe2use.com/pests/fireants/fireants1.htm).

Table 2.5 Granular Chlorpyrifos Uses and Application Information								
Use Site		**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Minimum App. Interval (days)**	**Maximum No. Apps.**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Alfalfa (Clover)		in-furrow	1	N/A	1	1		
Asparagus		postharvest ground application	1	10	3	3		
Citrus Orchard Floors (Fire Ants & Other Ant Species)		ground broadcast spray; chemigation	1	10	3	3		
Cole Crop (Brassica) Leafy Vegetables and Radish, Rutabaga and Turnip	General	at-plant T-band, incorporated	2.25	N/A	1	2.25		10 days application interval if using other chlorpyrifos formulation; do not use rutabaga tops for food or feed purposes
	Radish	at-plant in-furrow	2.76	N/A	1	2.76		
Corn (Field Corn and Sweet Corn)		at-plant T-band, at-plant in-furrow, postplant, postplant broadcast	1	10	3	3		
Onion (Dry Bulb)		at-plant, in-furrow treatment - incorporated	1	N/A	1	1		

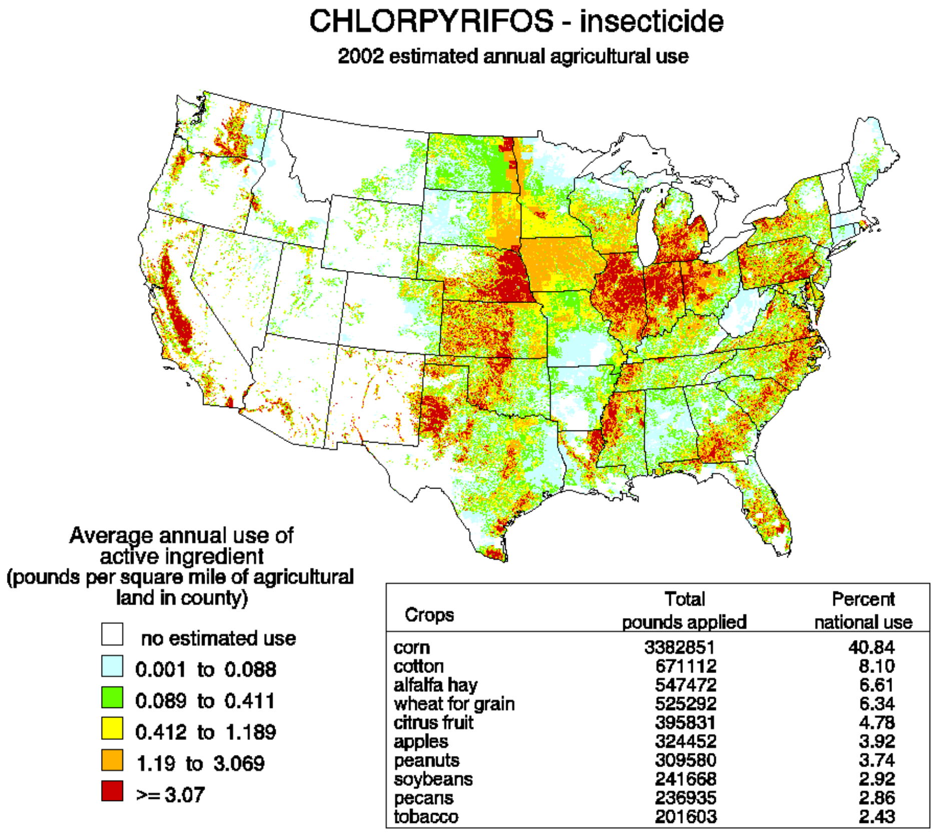
Table 2.5 Granular Chlorpyrifos Uses and Application Information							
Use Site	**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Minimum App. Interval (days)**	**Maximum No. Apps.**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Peanut	at-plant preventive, postplant preventive, band rescue - incorporated	2	10	2	4		aerial application prohibited
Sorghum - Grain Sorghum (Milo)	at-plant T-band, incorporated	1.5	N/A	1	1.5		10 days between granular and foliar application with Lorsban-4E
Soybean	at-plant T-band, incorporated	1.2	N/A	1	1.2		do not apply as in-furrow treatment; 10 days between granular and foliar application with Lorsban-4E
Sugarbeet	at-plant T-band - incorporated, postemergence band - incorporated	2	N/A	1	2		10 days between granular and foliar application with Lorsban-4E
Sunflower	at-plant T-band	1.3	N/A	1	1.3		10 days between granular and foliar application with Lorsban-4E
Sweet Potato	preplant broadcast - incorporated	2	N/A	1	2		
Tobacco	preplant broadcast - incorporated	2.025	N/A	1	2.025		
Other Uses							

Table 2.5 Granular Chlorpyrifos Uses and Application Information							
Use Site	**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Minimum App. Interval (days)**	**Maximum No. Apps.**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Ant Mounds	sprinkle over mound	1.6 oz/mound	NS	NS	NS		
Lumber, Logs, and other Wood Products (Fence posts, utility poles, railroad ties, landscape timbers, lumber, logs, pallets, poles, posts, wooden containers, and processed wood products)	dip, spray, brush, pressure and in-place treatment	1	NS	NS	NS		
Outdoor Nursery Uses	uniform distribution of granules	6	NS	NS	NS		only 6 lbs ai/acre for commercial approved use, all others 1 lb ai/acre
Processing Plants	spot or crack/crevice treatments	1	NS	NS	NS		
Road Median	hydraulic, knapsack sprayer or other hand or power spray equipment	1	NS	NS	NS		
Warehouses, Food Processing Sites, Industrial Plant Sites, Manufacturing Plant Sites	hand or power operated gravity or rotary type spreader	1	7	NS	NS		

Table 2.5 Granular Chlorpyrifos Uses and Application Information							
Use Site	**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Minimum App. Interval (days)**	**Maximum No. Apps.**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Turfgrass	hand or power operated gravity or rotary type spreader	1	7	NS	NS		

Table 2.6 Flowable Concentrate Chlorpyrifos Uses, Scenarios, and Application Information							
Use	**Application Method**	**Maximum App. Rate (lbs a.i./A)**	**Maximum No. Apps.**	**Minimum App. Interval (days)**	**Maximum Annual App. Rate (lbs a.i./A)**	**Geographic Restrictions**	**Other Restrictions**
Legume Vegetables (Includes only: Field beans, green beans, kidney beans, lima beans, navy beans, snap beans, string beans, wax beans, black-eyed peas, field peas, garden peas)	liquid/slurry treatment	2.75 fl oz/100 lbs seed	NS	NS	NS		add dye to prevent accidental use as food for man or feed animals
Corn (Field and Sweet)	liquid/slurry treatment	2.75 fl oz/100 lbs seed	NS	NS	NS		add dye to prevent accidental use as food for man or feed animals
Cotton	liquid/slurry treatment	5.5 fl oz/100 lbs seed	NS	NS	NS		add dye to prevent accidental use as food for man or feed animals
Cucumbers	liquid/slurry treatment	2.75 fl oz/100 lbs seed	NS	NS	NS		add dye to prevent accidental use as food for man or feed animals
Pumpkins	liquid/slurry treatment	2.75 fl oz/100 lbs seed	NS	NS	NS		add dye to prevent accidental use as food for man or feed animals
Sorghum	liquid/slurry treatment	0.114 fl oz/100 lbs seed	NS	NS	NS		add dye to prevent accidental use as food for man or feed animals
Wheat	liquid/slurry treatment	0.114 fl oz/100 lbs seed	NS	NS	NS		add dye to prevent accidental use as food for man or feed animals
Outdoor Nursery Uses	Automatic release container	2	NS	3	NS		8% chlorpyrifos

A map **(Figure 2.1)** showing the estimated poundage of chlorpyrifos uses across the United States is provided below. The map was downloaded from a U.S. Geological Survey (USGS), National Water Quality Assessment Program (NAWQA) website.



Crops	Total pounds applied	Percent national use
corn	3382851	40.84
cotton	671112	8.10
alfalfa hay	547472	6.61
wheat for grain	525292	6.34
citrus fruit	395831	4.78
apples	324452	3.92
peanuts	309580	3.74
soybeans	241668	2.92
pecans	236935	2.86
tobacco	201603	2.43

Figure 2.1 Chlorpyrifos Use in Total Pounds per County

The Agency's Biological and Economic Analysis Division (BEAD) provides an analysis of both national- and county-level usage information (Kaul and Jones, 2006) using state-level usage data obtained from USDA-NASS[5], Doane (www.doane.com; the full dataset is not provided due to its proprietary nature) and the California's Department of Pesticide Regulation Pesticide Use Reporting (CDPR PUR) database[6]. 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 chlorpyrifos by county in this California-specific assessment were generated using CDPR PUR data. Seven years (1999-2006) of usage data were included in this analysis. Data from CDPR PUR were obtained for every pesticide application made on every use site at the section level (approximately one square mile) of the public land survey system. BEAD summarized these data to the

[5] 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.usda.gov/nass/pubs/estindx1.htm#agchem.

[6] 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.

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 seven years. The units of area treated are also provided where available.

Between 1999 and 2006 an average of approximately 1,600,000 lbs of chlorpyrifos have been applied across the state of California. Throughout this period total annual use has varied from a high of 2.2 million lbs (1999) to a low of 1.4 million lbs (2002). During this period across all uses chlorpyrifos has been applied with an average application rate of 1.3 lbs ai/acre and 2.6 lb ai/acre at the 95^{th}. A summary of chlorpyrifos usage for all California counties is provided below in **Table 2.7.** The top use site in California for chlorpyrifos is cotton with roughly 270,000 lbs applied annually followed by almonds, alfalfa, structural pest control, oranges, walnuts, broccoli, grapes, sugarbeets, and lemons. The top twenty uses for the period between 1999 and 2006 are summarized in **Table 2.8**.

Table 2.7 Summary of CDPR PUR Use by County

County	Average Annual Pounds Applied	Average Annual Area Treated	Average Application Rate (lbs ai/acre)	95 Percentile Application Rate (lbs ai/acre)	99 Percentile Application Rate (lbs ai/acre)
ALAMEDA	108.5	1,105.26	1.7	3.5	19.3
AMADOR	177.5	232.97	1.2	2.0	2.2
BUTTE	33,734.9	18,764.31	1.9	2.0	3.7
CALAVERAS	299.9	239.40	1.5	2.0	6.0
COLUSA	7,012.7	6,077.11	1.4	2.0	2.8
CONTRA COSTA	1,808.3	2,167.05	1.2	2.0	8.0
DEL NORTE	0.3	1.06	0.3	0.5	0.5
EL DORADO	36.3	18.44	1.9	2.5	2.5
FRESNO	319,333.5	266,587.76	1.6	3.0	6.0
GLENN	18,571.8	13,778.60	1.4	2.0	2.7
HUMBOLDT	18.5	49.72	0.5	0.5	11.3
IMPERIAL	80,522.7	143,460.78	0.6	1.0	1.2
KERN	201,610.2	173,195.18	1.3	5.9	6.0
KINGS	158,175.6	194,322.47	0.9	2.0	2.0
LAKE	2,162.4	1,578.56	1.5	2.1	16.6
LASSEN	664.0	984.93	0.8	2.0	2.0
LOS ANGELES	1,141.7	1,227.19	1.7	6.3	10.0
MADERA	44,284.4	30,528.82	1.6	4.0	6.0
MARIPOSA	0.1	1.25	0.1	0.1	0.1
MENDOCINO	1,844.4	1,301.03	1.7	2.0	3.0
MERCED	58,137.1	52,406.78	1.1	2.0	2.2

Table 2.7 Summary of CDPR PUR Use by County					
County	**Average Annual Pounds Applied**	**Average Annual Area Treated**	**Average Application Rate (lbs ai/acre)**	**95 Percentile Application Rate (lbs ai/acre)**	**99 Percentile Application Rate (lbs ai/acre)**
MODOC	1,272.3	1,475.25	0.9	1.8	3.3
MONTEREY	57,776.0	43,271.15	1.3	2.2	2.4
NAPA	1,266.9	699.98	1.7	2.5	4.2
NEVADA	0.0	0.13	0.0	0.0	0.0
ORANGE	1,869.3	2,713.49	3.9	15.7	37.7
PLACER	1,549.8	836.68	1.6	2.0	3.9
RIVERSIDE	23,058.9	41,475.02	0.8	2.5	6.0
SACRAMENTO	4,213.1	4,143.15	0.7	2.0	2.0
SAN BENITO	4,442.2	3,813.38	1.1	2.0	2.5
SAN BERNARDINO	1,924.0	3,018.22	0.9	2.0	4.9
SAN DIEGO	2,868.2	4,123.98	1.2	5.0	6.4
SAN JOAQUIN	65,750.9	61,751.39	1.3	2.0	3.6
SAN LUIS OBISPO	14,417.2	11,053.61	1.1	2.0	3.0
SAN MATEO	1,690.0	2,046.78	0.9	1.3	5.1
SANTA BARBARA	34,405.8	29,246.69	1.1	2.0	2.3
SANTA CLARA	1,855.6	1,638.97	1.0	2.0	7.5
SANTA CRUZ	6,869.2	5,860.41	1.1	2.0	3.0
SHASTA	1,762.6	1,017.69	1.6	2.0	5.0
SISKIYOU	1,635.1	2,302.25	0.7	1.0	1.5
SOLANO	10,085.3	8,930.21	1.3	2.0	3.0
SONOMA	3,332.2	2,281.48	1.4	2.1	4.2
STANISLAUS	81,132.6	55,055.67	1.7	2.1	4.8
SUTTER	21,220.4	13,094.35	1.8	2.0	4.0
TEHAMA	12,404.8	7,661.67	1.8	2.0	4.0
TULARE	239,287.3	162,889.89	2.0	6.0	6.1
TUOLUMNE	57.6	44.88	1.7	2.0	3.6
VENTURA	50,775.5	25,566.91	1.9	4.1	9.3
YOLO	17,628.5	21,405.77	0.9	2.0	2.0
YUBA	10,060.1	5,338.19	1.9	2.1	4.0

Table 2.8 Summary of CDPR PUR Use by Crop/Use Site	
Site Name	**Total Annual Pounds**
COTTON	270802
ALMOND	257313
ALFALFA	217819
ORANGE	194072
WALNUT	170838
BROCCOLI	62459
GRAPE	57746
SUGARBEET	57440
LEMON	55468
GRAPE, WINE	34912
CORN (FORAGE - FODDER)	29160
PEACH	28100
NECTARINE	24927
APPLE	20134
PLUM	18203
CAULIFLOWER	16715
CORN, HUMAN CONSUMPTION	10688
ASPARAGUS	7238

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.**

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 red-legged frog (*Rana aurora draytonii*)	Adult (85-138 cm in length), Females – 9-238 g, Males – 13-163 g; Juveniles (40-84 cm in length)	Northern CA coast, northern Transverse Ranges, foothills of Sierra Nevada, and in southern CA south of Santa Barbara	Freshwater perennial or near-perennial aquatic habitat with dense vegetation; artificial impoundments; riparian and upland areas	Yes	Breeding: Nov. to Apr. Tadpoles: Dec. to Mar. Young juveniles: Mar. to Sept.	Aquatic-phase[2]: algae, freshwater aquatic invertebrates Terrestrial-phase: aquatic and terrestrial invertebrates, small mammals, fish and frogs
San Francisco garter snake (*Thamnophis sirtalis tetrataenia*)	Adult (46-131 cm in length), Females – 227 g, Males – 113 g; Juveniles (18–20 cm in length)	San Mateo County	Densely vegetated freshwater ponds near open grassy hillsides; emergent vegetation; rodent burrows	No	Oviparous Reproduction[3] Breeding: Spring (Mar. and Apr.) and Fall (Sept. to Nov.) Ovulation and Pregnancy: Late spring and early summer Young: Born 3-4 months after mating	Juveniles: frogs (Pacific tree frog, CRLF, and bullfrogs depending on size) and insects Adults: primarily frogs (mainly CRLFs; also bullfrogs, toads); to a lesser extent newts; freshwater fish and invertebrates; insects and small mammals
California Clapper Rail (*Rallus longirostris obsoletus)*	250 - 350 g	Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma counties	Tidal marsh habitat	No	Breeding: Feb. - August Nesting: mid-March-Aug. Lay Eggs: March - July Incubation: 23 to 29 days; Leave nest: 35 to 42 days after hatch; Juveniles fledge at ten weeks and can breed during the spring after they hatch	Opportunistic feeders: freshwater and estuarine invertebrates, seeds, worms, mussels, snails, clams, crabs, insects, and spiders; occasionally consume small birds and mammals, dead fish, up

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**
						to 15% plant material
Salt marsh harvest mouse (*Reithrodontomys raviventris*)	Adult 8 – 14 g	Northern subspecies can be found in Marin, Sonoma, Napa, Solano, and northern Contra Costa counties. The southern subspecies occurs in San Mateo, Alameda, and Santa Clara counties with some isolation populations in Marin and Contra Costa counties.	Dense, perennial cover with preference for habitat in the middle and upper parts of the marsh dominated by pickleweed and peripheral halophytes as well as similar vegetation in diked wetlands adjacent to the Bay	No	Breeding: March – November Gestation period: 21 – 24 days	Leaves, seeds, and plant stems; may eat insects; prefers "fresh green grasses" in the winter and pickleweed and saltgrass during the rest of the year; drinks both salt and fresh water
Bay checkerspot butterfly (BCB) (*Euphydryas editha bayensis*)	Adult butterfly - 5 cm in length	Santa Clara and San Mateo Counties [Because the BCB distribution is considered a metapopulation, any site with appropriate habitat in the vicinity of its historic range (Alameda, Contra Costa, San Francisco, San Mateo, and Santa Clara counties) should be considered potentially occupied by the butterfly (USFWS 1998, p. II-177)].	1) Primary habitat – native grasslands on large serpentine outcrops; 2) Secondary habitat – 'islands' of smaller serpentine outcrops with native grassland; 3) Tertiary habitat – non-serpentine areas where larval food plants occur	Yes	Larvae hatch in March – May and grow to the 4th instar in about two weeks. The larvae enter into a period of dormancy (diapause) that lasts through the summer. The larvae resume activity with the start of the rainy season. Larvae pupate once they reach a weight of 300 - 500 milligrams. Adults emerge within 15 to 30 days depending on thermal conditions, feed on nectar, mate and lay eggs during a flight season that lasts 4 to 6 weeks from late February	Obligate with dwarf plantain. Primary diet is dwarf plantain plants (may also feed on purple owl's-clover or exserted paintbrush if the dwarf plantains senesce before the larvae pupate). Adults feed on the nectar of a variety of plants found in association with serpentine grasslands

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**
					to early May	
Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)	Males: 1.25–2.5 cm length Females: 1.9–2.5 cm length	Central Valley of California (from Shasta County to Fresno County in the San Joaquin Valley)	Completely dependent on its host plant, elderberry (*Sambucus species*), which is a common component of the remaining riparian forests and adjacent upland habitats of California's Central Valley	Yes	The larval stage may last 2 years living within the stems of an elderberry plant. Then larvae enter the pupal stage and transform into adults. Adults emerge and are active from March to June feeding and mating, when the elderberry produces flowers.	Obligates with elderberry trees (*Sambucus* sp). Adults eat the elderberry foliage until about June when they mate. Upon hatching the larvae tunnel into the tree where they will spend 1-2 years eating the interior wood which is their sole food source.
San Joaquin kit fox (*Vulpes macrotis mutica*)	Adult ~2 kg	Alameda, Contra Costa, Fresno, Kern, Kings, Madera, Merced, Monterey, San Benito, San Joaquin, San Luis Obispo, Santa Barbara, Santa Clara, Stanislaus, Tulare and Ventura counties	A variety of habitats, including grasslands, scrublands (*e.g.*, chenopod scrub and sub-shrub scrub), vernal pool areas, oak woodland, alkali meadows and playas, and an agricultural matrix of row crops, irrigated pastures, orchards, vineyards, and grazed annual grasslands. Kit foxes dig their own dens, modify and use those already constructed by other animals (ground squirrels,	No, but has designated core areas	Mating and conception: late December - March. Gestation period: 48 to 52 days. Litters born: February - late March Pups emerge from their dens at about 1-month of age and may begin to disperse after 4 – 5 months usually in Aug. or Sept.	Small animals including blacktailed hares, desert cottontails, mice, kangaroo rats, squirrels, birds, lizards, insects and grass. It satisfies its moisture requirements from prey and does not depend on freshwater sources.

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**
			badgers, and coyotes), or use human-made structures .(culverts, abandoned pipelines, or banks in sumps or roadbeds). They move to new dens within their home range often (likely to avoid predation by coyotes)			
California tiger salamander (*Ambystoma californiense*)	50 g	There are two distinct population segments; one in Santa Barbara County and the other in Sonoma 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 (*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	Yes	They spawn in fresh or slightly brackish water upstream of the mixing zone. Spawning season usually takes place from late March through mid-May, although it may occur from late winter (Dec.) to early summer	They primarily planktonic copepods, cladocerans, amphipods, and insect larvae. Larvae feed on phytoplankton; juveniles feed on zooplankton.

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**
			in areas up to 18ppt). They live along the freshwater edge of the mixing zone (saltwater-freshwater interface).		(July-August). Eggs hatch in 9 – 14 days.	
California freshwater shrimp (*Syncaris pacifica*)	Up to 50 mm postorbital length (from the eye orbit to tip of tail)	Marin, Napa, and Sonoma Counties, CA	Freshwater, perennial streams; they prefer quiet portions of tree-lined streams with underwater vegetation and exposed tree roots	No	Breed once a year, typically in Sept. Eggs adhere to the pleopods and are cared for 8 – 9 months; embryos emerge during May or early June.	Feed on detritus (algae, aquatic macrophyte fragments, zooplankton, and aufwuchs)

[1] For more detailed information on the distribution, habitat requirements, and life history information of the assessed listed species, see Attachment 3

[2] For the purposes of this assessment, tadpoles and submerged adult frogs are considered "aquatic" because exposure pathways in the water are considerably different than those that occur on land.

[3] Oviparous = eggs hatch within the female's body and young are born live.

2.6 Designated Critical Habitat

Critical habitats have only been designated for the CRLF, BCB, VELB, CTS, and DS. ‘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 receives protection under Section 7 of the ESA through prohibition against destruction or adverse modification with regard to actions carried out, funded, or authorized by a federal Agency. Section 7 requires consultation on federal actions that are likely to result in the destruction or adverse modification of critical habitat.

To be included in a critical habitat designation, the habitat must be ‘essential to the conservation of the species.’ Critical habitat designations identify, to the extent known using the best scientific and commercial data available, habitat areas that provide essential life cycle needs of the species or areas that contain certain primary constituent elements (PCEs) (as defined in 50 CFR 414.12(b)). PCEs include, but are not limited to, space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing (or development) of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species. **Table 2.10** describes the PCEs for the critical habitats designated for the CRLF, BCB, VELB, CTS, and DS.

Table 2.10 Designated Critical Habitat PCEs for the CRLF, BCB, VELB, CTS, and DS.

Species	PCEs[1]	Reference
CRLF	Alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond.	50 CFR 414.12(b), 2006
	Alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food source.	
	Alteration of other chemical characteristics necessary for normal growth and viability of CRLFs and their food source.	
	Reduction and/or modification of aquatic-based food sources for pre-metamorphs (*e.g.*, algae)	
	Elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs: Upland areas within 200 ft of the edge of the riparian vegetation or dripline surrounding aquatic and riparian habitat that are comprised of grasslands, woodlands, and/or wetland/riparian plant species that provides the CRLF shelter, forage, and predator avoidance	
	Elimination and/or disturbance of dispersal habitat: Upland or riparian dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal	
	Reduction and/or modification of food sources for terrestrial phase juveniles and adults	
	Alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs and their food source.	
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	
Valley Elderberry Longhorn Beetle	Areas that contain the host plant of this species [*i.e*., elderberry trees (*Sambucus* sp.)] (a dicot)	43 FR 35636 35643, 1978
Bay Checkerspot Butterfly	The presence of annual or perennial grasslands with little to no overstory that provide north/south and east/west slopes with a tilt of more than 7 degrees for larval host plant survival during periods of atypical weather (e.g., drought).	66 FR 21449 21489, 2001
	The presence of the primary larval host plant, dwarf plantain (*Plantago erecta*) (a dicot) and at least one of the secondary host plants, purple owl's-clover or exserted paintbrush, are required for reproduction, feeding, and larval development.	
	The presence of adult nectar sources for feeding.	

Table 2.10 Designated Critical Habitat PCEs for the CRLF, BCB, VELB, CTS, and DS.		
Species	**PCEs[1]**	**Reference**
	Aquatic features such as wetlands, springs, seeps, streams, lakes, and ponds and their associated banks, that provide moisture during periods of spring drought; these features can be ephemeral, seasonal, or permanent.	
	Soils derived from serpentinite ultramafic rock (Montara, Climara, Henneke, Hentine, and Obispo soil series) or similar soils (Inks, Candlestick, Los Gatos, Fagan, and Barnabe soil series) that provide areas with fewer aggressive, nonnative plant species for larval host plant and adult nectar plant survival and reproduction.[2]	
	The presence of stable holes and cracks in the soil, and surface rock outcrops that provide shelter for the larval stage of the bay checkerspot butterfly during summer diapause.[2]	
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, physico-chemical water quality parameters such as salinity, pH, and hardness are not evaluated because these processes are not biologically mediated and, therefore, are not relevant to the endpoints included in this assessment.

More detail on the designated critical habitat applicable to this assessment can be found in **Attachment 1** (for the CRLF) and **Attachment 3** for the SFB species. 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 chlorpyrifos that may alter the PCEs of the existing designated critical habitats for the CRLF, BCB, VELB, CTS, and DS form the basis of the critical habitat impact analysis.

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

2.7 Action Area

For listed species assessment purposes, the action area is considered to be the area affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). It is recognized that the overall action area for the national registration of chlorpyrifos is likely to encompass considerable portions of the United States based on the large array of agricultural and/or non-agricultural uses. However, the scope of this assessment limits consideration of the overall action area to those portions that may be applicable to the protection of the CRLF and SFB species and their designated critical habitat within the state of California. Although the watershed for the San Francisco Bay extends northward into the very southwestern portion of Lake County, Oregon, and westward into the western edge of Washoe County, Nevada, the non-California portions of the watershed are small and very rural with little, if any, agriculture. Therefore, no use of chlorpyrifos is expected in these areas..

The definition of action area requires a stepwise approach that begins with an understanding of the federal action. The federal action is defined by the currently labeled uses for chlorpyrifos. An analysis of labeled uses and review of available product labels was completed. Several of the currently labeled uses are special local needs (SLN) uses or are restricted to specific states and are excluded from this assessment. In addition, a distinction has been made between food use crops and those that are non-food/non-agricultural uses. For those uses relevant to the assessed species, the analysis indicates that, for chlorpyrifos, the following agricultural uses are considered as part of the federal action evaluated in this assessment:

Following a determination of the assessed uses, an evaluation of the potential "footprint" of chlorpyrifos use patterns (*i.e*., the area where pesticide application occurs) is determined. This "footprint" represents the initial area of concern, based on an analysis of available land cover data for the state of California. The initial area of concern is defined as all land cover types and the stream reaches within the land cover areas that represent the labeled uses described above. Because of the diverse nature of the registered chlorpyrifos uses being covered in this assessment an initial area of concern map has not been created.

Once the initial area of concern is defined, the next step is to define the potential boundaries of the action area by determining the extent of offsite transport via spray drift and runoff where exposure of one or more taxonomic groups to the pesticide exceeds the listed species LOCs.

The Agency's approach to defining the action area under the provisions of the Overview Document (U.S. EPA, 2004) considers the results of the risk assessment process to establish boundaries for that action area with the understanding that exposures below the Agency's defined Levels of Concern (LOCs) constitute a no-effect threshold. Deriving the geographical extent of this portion of the action area is based on consideration of the types of effects that chlorpyrifos may be expected to have on the environment, the exposure levels to chlorpyrifos that are associated with those effects, and the best available information concerning the use of chlorpyrifos and its fate and transport within the state of California. 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. Therefore, the action area extends to a point where environmental exposures are below any measured lethal or sublethal effect threshold for any biological entity at the whole organism, organ, tissue, and cellular level of organization. In situations where it is not possible to determine the threshold for an observed effect, the action area is not spatially limited and is assumed to be the entire state of California.

Due to the lack of a defined no effect concentration for the most sensitive reported effect and/or a positive result in a mutagenicity test, the spatial extent of the action area (*i.e.*, the boundary where exposures and potential effects are less than the Agency's LOC) for chlorpyrifos cannot be determined. Therefore, it is assumed that the action area encompasses the entire state of California, regardless of the spatial extent (*i.e.*, initial area of concern or footprint) of the pesticide use(s).

This determination is also supported by the fact that chlorpyrifos and it's oxon degradate have been shown to transport long distances from the site of application and at concentrations that would approach effects levels. In addition, chlorpyrifos has several studies without a NOEC/NOEAL (e.g., De Silva & Samayawardhena, 2002; Richards & Kendall, 2003) and is a potential mutagen. Both of these factors together support the establishment of the entire state of California as the action area for this assessment.

2.8 Assessment Endpoints and Measures of Ecological Effect

Assessment endpoints are defined as "explicit expressions of the actual environmental value that is to be protected."[7] Selection of the assessment endpoints is based on valued entities (*e.g.,* CRLF), organisms important in the life cycle of the assessed species, and the PCEs of its designated critical habitat), the ecosystems potentially at risk (*e.g.,* waterbodies, riparian vegetation, and upland and dispersal habitats), the migration pathways of chlorpyrifos (*e.g.,* runoff, spray drift, *etc*.), and the routes by which ecological receptors are exposed to chlorpyrifos *(e.g.,* direct contact, *etc.).*

[7] From U.S. EPA (1992). *Framework for Ecological Risk Assessment.* EPA/630/R-92/001.

2.8.1 Assessment Endpoints

Assessment endpoints for the CRLF and SFB species include direct toxic effects on the survival, reproduction, and growth of individuals, as well as indirect effects, such as reduction of the prey base or modification of its habitat. In addition, potential modification of critical habitat is assessed by evaluating potential effects to PCEs, which are components of the habitat areas that provide essential life cycle needs of the assessed species. Each assessment endpoint requires one or more "measures of ecological effect," defined as changes in the attributes of an assessment endpoint or changes in a surrogate entity or attribute in response to exposure to a pesticide. Specific measures of ecological effect are generally evaluated based on acute and chronic toxicity information from registrant-submitted guideline tests that are performed on a limited number of organisms. Additional ecological effects data from the open literature are also considered. It should be noted that assessment endpoints are limited to direct and indirect effects associated with survival, growth, and fecundity, and do not include the full suite of sublethal effects used to define the action area. According the Overview Document (U.S. EPA, 2004), the Agency relies on acute and chronic effects endpoints that are either direct measures of impairment of survival, growth, or fecundity or endpoints for which there is a scientifically robust, peer reviewed relationship that can quantify the impact of the measured effect endpoint on the assessment endpoints of survival, growth, and fecundity.

A complete discussion of all the toxicity data available for this risk assessment, including resulting measures of ecological effect selected for each taxonomic group of concern, is included in Section 4 of this document. A summary of the assessment endpoints and measures of ecological effect selected to characterize potential assessed direct and indirect risks for each of the assessed species associated with exposure to chlorpyrifos is provided in Section 2.5 and **Table 2.11**.

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

Table 2.11 identifies the taxa used to assess the potential for direct and indirect effects from the uses of chlorpyrifos for each listed species assessed here. The specific assessment endpoints used to assess the potential for direct and indirect effects to each listed species are provided in **Table 2.12**.

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 red-legged frog	Direct Indirect (prey)	Indirect (prey)	Indirect (habitat)	Indirect (prey)	Direct Indirect (prey)	Indirect (prey)	N/A	N/A	Indirect (food/ habitat)
San Francisco garter snake	Direct Indirect (prey)	Indirect (prey)	Indirect (habitat)	Indirect (prey)	Indirect (prey)	Indirect (prey)	N/A	N/A	Indirect (habitat)
California clapper rail	Direct Indirect (prey)	Indirect (prey)	Indirect (habitat)	Indirect (prey)	Indirect (prey)	Indirect (prey)	Indirect (prey)	Indirect (prey)	Indirect (habitat)
Salt marsh harvest mouse	Indirect (rearing sites)	Direct Indirect (rearing sites)	Indirect (food, habitat)	Indirect (prey)	N/A	N/A	N/A	N/A	Indirect (habitat)
Bay checkerspot butterfly	N/A	N/A	Indirect (food/ habitat) *	Direct	N/A	N/A	N/A	N/A	N/A
Valley elderberry longhorn beetle	N/A	N/A	Indirect (food/ habitat) *	Direct	N/A	N/A	N/A	N/A	N/A
San Joaquin kit fox	Indirect (prey)	Direct Indirect (prey)	Indirect (food/ habitat)	Indirect (prey)	N/A	N/A	N/A	N/A	N/A
California tiger salamander	Direct	N/A	Indirect (habitat)	Indirect (prey)	Direct Indirect (prey)	Indirect (prey)	N/A	N/A	Indirect (food/ habitat)
Delta smelt (USE THE MOST SENTITIVE OF THE FRESHWATER AND E/M FISH FOR DIRECT EFFECTS)	N/A	N/A	Indirect (habitat)	N/A	Direct (IF MORE SENSITIVE THAN E/M FISH)	Indirect (prey)	Direct (IF MORE SENSITIVE THAN F FISH)	Indirect (prey)	Indirect (food/ habitat)
California freshwater shrimp	N/A	N/A	Indirect (food/ habitat)	Indirect (prey)	N/A	Direct Indirect (prey)	N/A	N/A	Indirect (food/ habitat)

N/A = Not applicable
Terr. = Terrestrial
Invert. = Invertebrate

FW = Freshwater
* = obligate relationship

Table 2.12 Taxa and Assessment Endpoints Used to Evaluate the Potential for the Use of Chlorpyrifos to Result in Direct and Indirect Effects to the Assessed Listed Species - CRLF, Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly.			
Taxa Used to Assess Direct and/or Indirect Effects to Assessed Species	**Assessed Listed Species**	**Assessment Endpoints**	**Measures of Ecological Effects**
1. Freshwater Fish and Aquatic-phase Amphibians	Direct Effect – -Aquatic-phase CRLF -Aquatic-phase CTS -Delta Smelt	Survival, growth, and reproduction of individuals via direct effects	1a. Amphibian acute LC_{50} (ECOTOX) or most sensitive fish acute LC_{50} (guideline or ECOTOX) if no suitable amphibian data are available 1b. Amphibian chronic NOAEC (ECOTOX) or most sensitive fish chronic NOAEC (guideline or ECOTOX) 1c. Amphibian early-life stage data (ECOTOX) or most sensitive fish early-life stage NOAEC (guideline or ECOTOX) *(if sufficient data are available, split the evaluation for eggs and larvae out, and use the ELS endpoint*
	Indirect Effect (prey) -Aquatic-phase and Terrestrial-phase CRLF -S. F. Garter Snake -Clapper Rail	Survival, growth, and reproduction of individuals via indirect effects on aquatic prey food supply (*i.e.*, fish and aquatic-phase amphibians)	
2. Freshwater Invertebrates	Direct Effect – -California Freshwater Shrimp Indirect Effect (prey) -Aquatic-phase and Terrestrial-phase CRLF -S. F. Garter Snake -Clapper Rail	Survival, growth, and reproduction of individuals via indirect effects on aquatic prey food supply (*i.e.*, freshwater invertebrates)	2a. Most sensitive freshwater invertebrate EC_{50} (guideline or ECOTOX) 2b. Most sensitive freshwater invertebrate chronic NOAEC (guideline or ECOTOX)
3. Estuarine/Marine Fish	Direct Effect – -Delta Smelt Indirect Effect (prey) -Clapper Rail	Survival, growth, and reproduction of individuals via indirect effects on aquatic prey food supply (*i.e.*, estuarine/marine fish)	3a. Most sensitive estuarine/marine fish EC_{50} (guideline or ECOTOX) 3b. Most sensitive estuarine/marine fish chronic NOAEC (guideline or ECOTOX)
4. Estuarine/Marine Invertebrates	Indirect Effect (prey) -Clapper Rail -Delta Smelt	Survival, growth, and reproduction of individuals via indirect effects on aquatic prey food supply (*i.e.*, estuarine/marine invertebrates)	4a. Most sensitive estuarine/marine invertebrate EC_{50} (guideline or ECOTOX) 4b. Most sensitive estuarine/marine invertebrate chronic NOAEC (guideline or ECOTOX)
5. Aquatic Plants (freshwater/marine)	Indirect Effect (food/habitat) -Aquatic-phase CRLF -Aquatic-phase CTS -Clapper Rail -Salt Marsh Harvest Mouse -S. F. Garter Snake -Delta Smelt California Freshwater Shrimp	Survival, growth, and reproduction of individuals via indirect effects on habitat, cover, food supply, and/or primary productivity (*i.e.*, aquatic plant community)	5a. Vascular plant acute EC_{50} (duckweed guideline test or ECOTOX vascular plant) 5b. Non-vascular plant acute EC_{50} (freshwater algae or diatom, or ECOTOX non-vascular)

Table 2.12 Taxa and Assessment Endpoints Used to Evaluate the Potential for the Use of Chlorpyrifos to Result in Direct and Indirect Effects to the Assessed Listed Species - CRLF, Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly.

Taxa Used to Assess Direct and/or Indirect Effects to Assessed Species	Assessed Listed Species	Assessment Endpoints	Measures of Ecological Effects
6. Birds	<u>Direct Effect</u> -Terrestrial-phase CRLF -S. F. Garter Snake -Clapper Rail	Survival, growth, and reproduction of individuals via direct effects	6a. Most sensitive bird[b] or terrestrial-phase amphibian acute LC_{50} or LD_{50} (guideline or ECOTOX) 6b. Most sensitive bird[b] or terrestrial-phase amphibian chronic NOAEC (guideline or ECOTOX)
	<u>Indirect Effect (prey)</u> -Clapper Rail -San Joaquin Kit Fox	Survival, growth, and reproduction of individuals via indirect effects on terrestrial prey (birds)	
7. Mammals	<u>Direct Effect</u> -Salt Marsh Harvest Mouse -San Joaquin Kit Fox	Survival, growth, and reproduction of individuals via direct effects	7a. Most sensitive laboratory rat acute LC_{50} or LD_{50} (guideline or ECOTOX) 7b. Most sensitive laboratory rat chronic NOAEC (guideline or ECOTOX)
	<u>Indirect Effect (prey/habitat from burrows)</u> -Terrestrial-phase CRLF -San Joaquin Kit Fox	Survival, growth, and reproduction of individuals via indirect effects on terrestrial prey (mammals)	
8. Terrestrial Invertebrates	<u>Direct Effect</u> -Bay Checkerspot Butterfly -Valley elderberry longhorn beetle	Survival, growth, and reproduction of individuals via direct effects	8a. Most sensitive terrestrial invertebrate acute EC_{50} or LC_{50} (guideline or ECOTOX)[c] 8b. Most sensitive terrestrial invertebrate chronic NOAEC (guideline or ECOTOX)
	<u>Indirect Effect (prey)</u> -Terrestrial-phase CRLF -Clapper Rail -Salt Marsh Harvest Mouse -S. F. Garter Snake -San Joaquin Kit Fox	Survival, growth, and reproduction of individuals via indirect effects on terrestrial prey (terrestrial invertebrates)	
9. Terrestrial Plants	<u>Indirect Effect (food/habitat) (non-obligate relationship)</u> -Terrestrial-phase CRLF -Clapper Rail -Salt Marsh Harvest Mouse -S. F. Garter Snake -San Joaquin Kit Fox	Survival, growth, and reproduction of individuals via indirect effects on food and habitat (*i.e.*, riparian and upland vegetation)	9a. Distribution of EC_{25} for monocots (seedling emergence, vegetative vigor, or ECOTOX 9b. Distribution of EC_{25} (EC_{05} or NOAEC for the Bay checkerspot butterfly and the valley elderberry longhorn beetle) for dicots (seedling emergence, vegetative vigor, or ECOTOX)

Table 2.12 Taxa and Assessment Endpoints Used to Evaluate the Potential for the Use of Chlorpyrifos to Result in Direct and Indirect Effects to the Assessed Listed Species - CRLF, Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly.			
Taxa Used to Assess Direct and/or Indirect Effects to Assessed Species	**Assessed Listed Species**	**Assessment Endpoints**	**Measures of Ecological Effects**
	Indirect Effect (food/habitat) (obligate relationship) -Bay Checkerspot Butterfly -Valley Elderberry Longhorn Beetle		

2.8.2 Assessment Endpoints for Designated Critical Habitat

As previously discussed, designated critical habitats are assessed to evaluate actions related to the use of chlorpyrifos 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 chlorpyrifos effects data are available.

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. Measures of ecological effect used to assess the potential for adverse modification to the critical habitat of the CRLF and SFB species are described in **Table 2.13**.

Table 2.13 Summary of Assessment Endpoints and Measures of Ecological Effect for Primary Constituent Elements of Designated Critical Habitat for CRLF and SFB Species (Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly**).**			
Taxon Used to Assess Modification of PCE	**Assessed Listed Species Associated with the PCE**	**Assessment Endpoints**	**Measures of Ecological Effects**
1. Aquatic Plants (freshwater/marine)	Indirect Effect (food/habitat) -Aquatic-phase CRLF -Aquatic-phase CTS -Delta Smelt	Modification of critical habitat via change in habitat, cover, food supply, and/or primary productivity (*i.e.*, aquatic plant community)	1a. Vascular plant acute EC_{50} (duckweed guideline test or ECOTOX vascular plant) 1b. Non-vascular plant acute EC_{50} (freshwater algae or diatom, or ECOTOX non-vascular)
2. Terrestrial Invertebrates	Direct Effect -Bay Checkerspot Butterfly -Valley elderberry longhorn beetle	Survival, growth, and reproduction of individuals via direct effects	2a. Most sensitive terrestrial invertebrate acute EC_{50} or LC_{50} (guideline or ECOTOX)[c] 2b. Most sensitive terrestrial invertebrate chronic NOAEC (guideline or ECOTOX)
	Indirect Effect (prey) -Terrestrial-phase CRLF	Modification of critical habitat via change in terrestrial prey (terrestrial invertebrates)	
3. Terrestrial Plants	Indirect Effect (food/habitat) (non-obligate relationship) -Terrestrial-phase CRLF	Modification of critical habitat via change in food and habitat (*i.e.*, riparian and upland vegetation)	3a. Distribution of EC_{25} for monocots (seedling emergence, vegetative vigor, or ECOTOX 3b. Distribution of EC_{25} (EC_{05} or NOAEC for the Bay checkerspot butterfly and the valley elderberry longhorn beetle) for dicots (seedling emergence, vegetative vigor, or ECOTOX)
	Indirect Effect (food/habitat) (obligate relationship) -Bay Checkerspot Butterfly -Valley Elderberry Longhorn Beetle		

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 (U.S. EPA, 1998). For this assessment, the risk is stressor-linked, where the stressor is the release of chlorpyrifos to the environment. The following risk hypotheses are presumed for each assessed species in this assessment:

The labeled use of chlorpyrifos within the action area may:

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

2.9.2 Diagram

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the chlorpyrifos release mechanisms, biological receptor types, and effects endpoints of potential concern. The conceptual models for aquatic and terrestrial phases of the CRLF and SFB species and the conceptual models for the aquatic and terrestrial PCE components of critical habitat are shown in **Figures 2.3** and **2.4**. Although the conceptual models for direct/indirect effects and modification of designated critical habitat PCEs are shown on the same diagrams, the potential for direct/indirect effects and modification of PCEs will be evaluated separately in this assessment. Exposure routes shown in dashed lines are not quantitatively considered because the contribution of those potential exposure routes to potential risks to the CRLF and SFB species and modification to designated critical habitat is expected to be negligible.

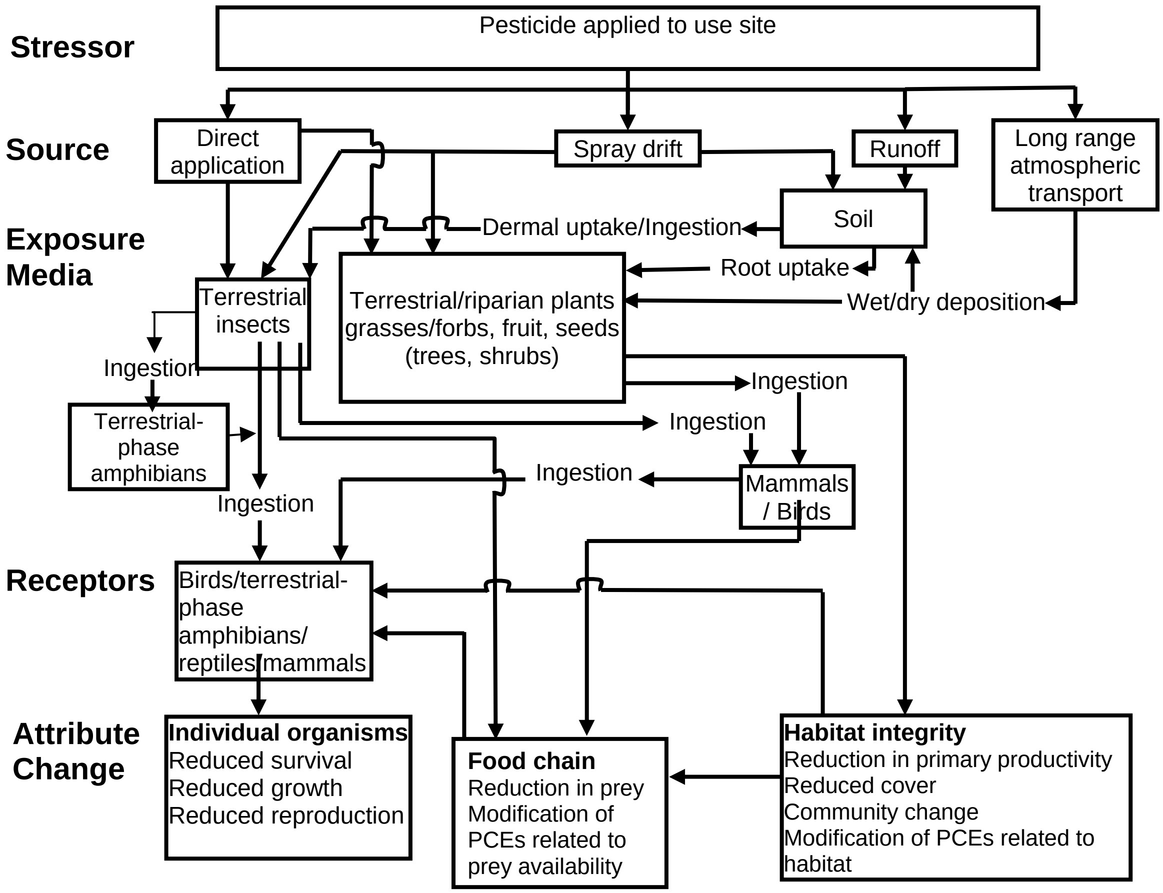


Figure 2.2 Conceptual Model for Terrestrial-Phase of the Assessed Species.

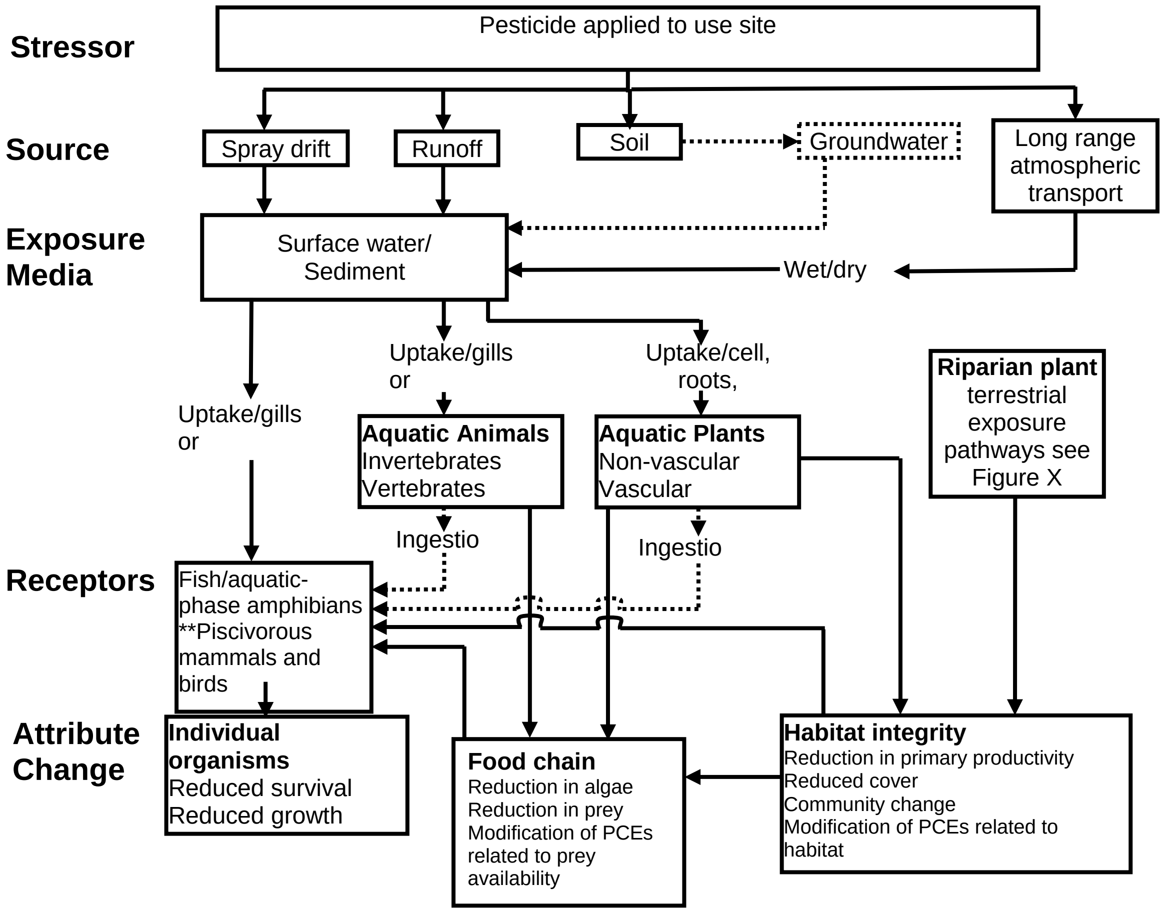


Figure 2.3 Conceptual Model for Aquatic-Phase of the Assessed Species.

2.10 Analysis Plan

In order to address the risk hypothesis, the potential for direct and indirect effects to the CRLF and SFB 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 chlorpyrifos 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 (U.S. EPA, 2004), the likelihood of effects to individual organisms from particular uses of chlorpyrifos is estimated using the probit dose-response slope and either the level of concern (discussed below) or actual calculated risk quotient value.

2.10.1 Measures to Evaluate the Risk Hypothesis and Conceptual Model

2.10.1.1 Measures of Exposure

The environmental fate properties of chlorpyrifos along with available monitoring data indicate that runoff and spray drift are the principle potential transport mechanisms of chlorpyrifos to the aquatic and terrestrial habitats of the CRLF and SFB Species. In addition, monitoring data for air and rain suggest the long range transport of chlorpyrifos and the formation of chlorpyrifos oxon cannot be precluded though the exact mechanism by which the oxon forms is uncertain. In this assessment, transport of chlorpyrifos through runoff and spray drift is considered in deriving quantitative estimates of chlorpyrifos exposure to CRLF and SFB Species, their prey and habitats. A semi-quantitative analysis of potential long range transport will be conducted using available monitoring data.

Measures of exposure are based on aquatic and terrestrial models that predict estimated environmental concentrations (EECs) of chlorpyrifos 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). The model used to predict terrestrial EECs on food items is T-REX. These models are parameterized using relevant reviewed registrant-submitted environmental fate data.

PRZM (v3.12.2, May 2005) and EXAMS (v2.98.4.6, April 2005) are screening simulation models coupled with the input shell pe5.pl (Aug 2007) to generate daily exposures and 1-in-10 year EECs of chlorpyrifos that may occur in surface water bodies adjacent to application sites receiving chlorpyrifos through runoff and spray drift. PRZM simulates pesticide application, movement and transformation on an agricultural field and the resultant pesticide loadings to a receiving water body via runoff, erosion and spray drift. EXAMS simulates the fate of the pesticide and resulting concentrations in the water body. The standard scenario used for ecological pesticide assessments assumes application to a 10-hectare agricultural field that drains into an adjacent 1-hectare water body, 2-meters deep (20,000 m^3 volume) with no outlet. PRZM/EXAMS was used to estimate screening-level exposure of aquatic organisms to chlorpyrifos. The measure of exposure for aquatic species is the 1-in-10 year return peak or rolling mean concentration. The 1-in-10-year 60-day mean is used for assessing chronic exposure to fish; the 1-in-10-year 21-day mean is used for assessing chronic exposure for aquatic invertebrates.

As discussed above, the primary degradate of chlorpyrifos is 3,5,6-trichloro-2-pyridinol or 'TCP'. Comparison of available toxicity information for TCP indicates that it is significantly less toxic than the parent for freshwater and estuarine/marine fish, invertebrates, birds, and mammals. TCP has been shown to form at up to roughly 1/3 of the applied parent and is more mobile and less persistent than chlorpyrifos and therefore is likely to occur in the environment. However this increased exposure is not expected to contribute significantly to overall risk because in general TCP is between 1 to 4 orders of magnitude less toxic. Therefore, TCP has not been quatitatively assessed in this evaluation.

As mentioned previously, chlorpyrifos may oxidize in the environment to form chlorpyrifos-oxon. Available data indicate that chlorpyrifos-oxon is more toxic to amphibians than the parent compound (Sparling and Fellers, 2007). Chlorpyrifos-oxon toxicity data for freshwater fish, freshwater invertebrates, and birds would reduce the amount of uncertainty in the ecological risk assessment. Submitted environmental fate studies for chlorpyrifos do not identify chlorpyrifos-oxon. However, chlorpyrifos-oxon has been detected in air, precipitation and surface water samples (Lenoir et al., 1999; Sparling et al., 2001; Landers et al., 2008), indicating that it is present in the environment.

In order to address this uncertainty the Agency has requested additional environmental fate data for chlorpyrifos oxon including studies to address the potential formation in the vapor phase. Submission of acceptable environmental fate data on adsorption/desorption and aerobic soil metabolism of the oxon will provide a minimal data set to allow the Agency to provide a more realistic estimate of chlorpyrifos oxon-specific concentrations using either Tier I or Tier II models. However, this oxon-specific environmental fate data has not been submitted to that Agency at this time and thus the Agency cannot conduct a quantitative assessment of risk from the oxon at this time. Therefore, in order to address potential exposure to aquatic organisms the Agency will qualitatively compare the risk conclusions from the parent relative to the possible range of toxicity noted for the oxon and assuming complete conversion describe how the risk might be influenced by that assumption.

Exposure estimates for the terrestrial animals assumed to be in the target area or in an area exposed to spray drift are derived using the T-REX model (version 1.3.1, 12/07/2006). This model incorporates the Kenega nomograph, as modified by Fletcher *et al.* (1994), which is based on a large set of actual field residue data. The upper limit values from the nomograph represented the 95th percentile of residue values from actual field measurements (Hoerger and Kenega, 1972).

For modeling purposes, direct exposures of the CRLF to and SFB Species chlorpyrifos through contaminated food are estimated using the EECs for the small bird (20 g) which consumes small insects. Dietary-based and dose-based exposures of potential prey (small mammals) are assessed using the small mammal (15 g) which consumes short grass. The small bird (20 g) consuming small insects and the small mammal (15 g) consuming short grass are used because these categories represent the largest RQs of the size and dietary categories in T-REX that are appropriate surrogates for the CRLF and one of its prey items. Estimated exposures of terrestrial insects to chlorpyrifos are bound by using the dietary based EECs for small insects and large insects.

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

Because there is some evidence of the potential for bioaccumulation of chlorpyrifos in aquatic organisms, an additional exposure pathway that was considered in this assessment is the consumption of contaminated fish or aquatic invertebrates that have bioaccumulated chhlorpyrifos dissolved in water and their aquatic diet. The potential risk from this pathway was evaluated using a food web bioaccumulation model (K_{ow}-based Aquatic Bioaccumulation Model, or KABAM), v.1.0. KABAM estimates potential bioaccumulation of hydrophobic organic pesticides such as chlorpyrifos in freshwater aquatic food webs and subsequent risks to mammals and birds via consumption of contaminated aquatic prey. The bioaccumulation portion of KABAM was based upon work by Arnot and Gobas (2004) who parameterized a bioaccumulation model based on PCBs and some pesticides (e.g., lindane, DDT) in freshwater aquatic ecosystems. KABAM relies on a chemical's octanol-water partition coefficient (K_{OW}) to estimate uptake and elimination constants through respiration and diet of organisms in different trophic levels. Chlorpyrifos tissue residues were calculated for different levels of the aquatic food web. The model then used chlorpyrifos tissue concentrations in aquatic animals to estimate dose- and dietary-based exposures and associated risks to mammals and birds consuming aquatic organisms, using an approach that is similar to the T-REX model (USEPA 2008).

KABAM incorporated 7 trophic levels to describe bioaccumulation of chlorpyrifos in a model aquatic food web: phytoplankton, zooplankton (e.g., *Daphnia sp.*), benthic invertebrates (e.g., *Chironomus sp*., crayfish), filter feeders (e.g., mussels, clams), small fish (e.g., young of the year), medium-sized fish (e.g., adult bluegill), and larger upper-trophic level fish (e.g., largemouth bass). Chlorpyrifos concentrations in organisms of the aquatic trophic levels listed above were used to estimate acute and chronic exposures of mammals and birds consuming aquatic organisms. Available pesticide-specific acute and chronic toxicity data for mammals and birds were used to calculate risk quotients for estimated exposures due to bioaccumulation of chlorpyrifos in an aquatic ecosystem.

Spray drift models, AGDISP and/or AgDRIFT are used to assess exposures of terrestrial animals to chlorpyrifos deposited on terrestrial habitats by spray drift. In addition to the buffered area from the spray drift analysis, the downstream extent of chlorpyrifos that exceeds the LOC for the effects determination is also considered.

At this time the Agency does not have tools for quantitatively predicting oxon formation and transport due to volatility. In order to account for the impact of offsite movement of chlorpyrifos oxon available monitoring data will be used as a surrogate for terrestrial exposure estimates with an understanding that these data are limited and may under-represent actual oxon exposure levels.

2.10.1.2 Measures of Effect

Data identified in Section 2.8 are used as measures of effect for direct and indirect effects to the CRLF and SFB Species. Data were obtained from registrant submitted studies or from literature studies identified by ECOTOX. The ecotoxicology database (ECOTOX) was searched in order to provide more ecological effects data and in an attempt to bridge existing data gaps. ECOTOX is a source for locating single chemical toxicity data for aquatic life, terrestrial plants, and wildlife. ECOTOX was created and is maintained by the U.S. EPA, Office of Research and Development, and the National Health and Environmental Effects Research Laboratory's Mid-Continent Ecology Division.

The assessment of risk for direct effects to the terrestrial-phase CRLF and terrestrial-phase tiger salamanders, Alameda whipsnakes, San Francisco garter snakes] makes the assumption that toxicity of chlorpyrifos to birds is similar to or less than the toxicity to terrestrial-phase amphibians and reptiles (this also applies to potential prey items).

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

It is important to note that the measures of effect for direct and indirect effects to the assessed species and their designated critical habitat are associated with impacts to survival, growth, and fecundity, and do not include the full suite of sublethal effects used to define the action area. According the Overview Document (U.S. EPA, 2004), the Agency relies on effects endpoints that are either direct measures of impairment of survival, growth, or fecundity or endpoints for which there is a scientifically robust, peer reviewed relationship that can quantify the impact of the measured effect endpoint on the assessment endpoints of survival, growth, and fecundity.

2.10.1.3 Integration of Exposure and Effects

Risk characterization is the integration of exposure and ecological effects characterization to determine the potential ecological risk from agricultural and non-agricultural uses of chlorpyrifos, and the likelihood of direct and indirect effects to CRLF and SFB 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. For the assessment of chlorpyrifos risks, the risk quotient (RQ) method is used to compare exposure and measured toxicity values. EECs are divided by acute and chronic toxicity values. The resulting RQs are then compared to the Agency's levels of concern (LOCs) (U.S. EPA, 2004) (see **Appendix B**).

For this endangered species assessment, listed species LOCs are used for comparing RQ values for acute and chronic exposures of chlorpyrifos directly to the CRLF and SFB Species. If estimated exposures directly to the assessed species of chlorpyrifos resulting from a particular use are sufficient to exceed the listed species LOC, then the effects determination for that use is "may affect". When considering indirect effects to the assessed species due to effects to prey, the listed species LOCs are also used. If estimated exposures to the prey of the assessed species of chlorpyrifos resulting from a particular use are sufficient to exceed the listed species LOC, then the effects determination for that use is a "may affect." If the RQ being considered also exceeds the non-listed species acute risk LOC, then the effects determination is a LAA. If the acute RQ is between the listed species LOC and the non-listed acute risk species LOC, then further lines of evidence (*i.e*. probability of individual effects, species sensitivity distributions) are considered in distinguishing between a determination of NLAA and a LAA. If the RQ being considered for a particular use exceeds the non-listed species LOC for plants, the effects determination is "may affect". Further information on LOCs is provided in **Appendix B**.

2.10.2 Data Gaps

A number of environmental fate and effects data have been requested as part of OPP's Registration Review process. These data are focused primarily on filling gaps in the assessment of the oxon of chlorpyrifos and include aerobic soil metabolism, adsorption/desorption (batch equilibrium), field volatility, acute freshwater fish toxicity, acute freshwater invertebrate toxicity, acute avian oral toxicity, and acute avian dietary toxicity for the oxon. In addition, photodegradation in air and Tier I Phytotoxicity studies have been requested for parent chlorpyrifos.

3 Exposure Assessment

Chlorpyrifos is formulated as a liquid, flowable concentrate, and granular formulations. Application equipment includes ground application, aerial application, band treatment, incorporated treatment, various sprayers (low-volume, hand held, directed), and spreaders for granular applications]. Risks from ground boom and aerial applications are considered in this assessment because they are expected to result in the highest off-target levels of chlorpyrifos due to generally higher spray drift levels. Ground boom and aerial modes of application tend to use lower volumes of application applied in finer sprays than applications coincident with sprayers and spreaders and thus have a higher potential for off-target movement via spray drift.

3.1 Label Application Rates and Intervals

Chlorpyrifos labels may be categorized into two types: labels for manufacturing uses (including technical grade chlorpyrifos and its formulated products) and end-use products. While technical products, which contain chlorpyrifos of high purity, are not used directly in the environment, they are used to make formulated products, which can be applied in specific areas to control insects. The formulated product labels legally limit chlorpyrifos's potential use to only those sites that are specified on the labels. The uses being assessed are summarized in **Table 3.1**.

Table 3.1 Summary of PRZM/EXAMS Exposure Assumptions for Chlorpyrifos							
PRZM Scenario	**Uses Represented**	**Formulation Type**	**Application Method**	**Maximum Application Rate (lbs ai/acre)**	**No. Apps.**	**Minimum Interval (days)**	**First Application Date**
CA alfalfa OP	Alfalfa Clover	Liquid	Air and ground	1	4	10	March 1
	Alfalfa Clover	Granular	Ground incorporated	1	1	NA	March 1
CA row crop RLF	Asparagus	Liquid	Air and ground	1.5	3	10	August 1
	Asparagus	Granular	Ground incorporated	1	3	10	August 1
	Peanut	Liquid	Ground	2	2	10	August 1
	Soybean	Liquid	Ground & ground incorporated	1	3	14	August 1
	Soybean	Flowable Concentrate	Seed treatment				
	Peanut	Granular	Ground incorporated	2	2	10	August 1
CA forestry RLF	Christmas trees	Liquid	Ground	1	3	7	June 1
CA citrus STD	Citrus	Liquid	Airblast	4	2	30	October 1
	Citrus Floor	Liquid	Ground	2	3	10	October 1
	Citrus Floor	Granular	Ground incorporated	1	3		October 1
CA cole crop RLF	Cole Crop Leafy Vegetable Rutabaga Turnip	Liquid	Ground & ground incorporated	3	3	10	March 1
	Radish	Liquid	Ground	2.75	1	NA	March 1
	Legumes	Liquid	Ground	0.5	1	NA	March 1

Table 3.1 Summary of PRZM/EXAMS Exposure Assumptions for Chlorpyrifos							
PRZM Scenario	**Uses Represented**	**Formulation Type**	**Application Method**	**Maximum Application Rate (lbs ai/acre)**	**No. Apps.**	**Minimum Interval (days)**	**First Application Date**
	Legumes	Flowable Concentrate	Seed treatment				
	Cole Crop Leafy Vegetable Rutabaga Turnip (in furrow)	Granular	Ground incorporated	2.75	1	NA	March 1
CA corn OP	Field and sweet corn	Liquid	Air and ground	1	3	10	May 1
	Field and sweet corn	Granular	Ground incorporated	1	3	10	May 1
	Field and sweet corn	Flowable Concentrate	Seed Treatment				
CA cotton STD	Cotton	Liquid	Air and ground	1	3	10	August 1
	Cotton	Flowable Concentrate	Seed Treatment				
CA grape STD	Grapes	Liquid	Ground	2.25	1	NA	March 1
OR mint STD	Mint	Liquid	Ground	2	3	10	April 1
CA onion STD	Dry bulb onion	Liquid	Ground & ground incorporated	1	1	NA	March 1
CA almond STD	Fig	Liquid	Ground & ground incorporated	2	1	NA	May 1
	Orchard Floor	Liquid	Ground	2	5	10	May 1
	Tree Fruit and Nuts (dormant)	Liquid	Airblast	2	1	NA	December 1

Table 3.1 Summary of PRZM/EXAMS Exposure Assumptions for Chlorpyrifos							
PRZM Scenario	**Uses Represented**	**Formulation Type**	**Application Method**	**Maximum Application Rate (lbs ai/acre)**	**No. Apps.**	**Minimum Interval (days)**	**First Application Date**
	Tree Fruit and Nuts (foliar)	Liquid	Air and ground	2	3	10	May 1
CA fruit STD	Pear	Liquid	Ground	2	1	NA	March 1
	Apple (dormant)	Liquid	Airblast	2	2	10	December 1
CA wheat RLF	Grain sorghum (milo)	Liquid	Air and ground	1	3	10	August 15
	Grain sorghum (milo)	Granular	Ground incorporated	1.5	1	NA	August 15
	Grain sorghum	Flowable Concentrate	Seed Treatment				
	Sunflower	Liquid	Ground & ground incorporated	1.5	3	10	August 15
	Wheat	Liquid	Air and ground	0.5	2	10	August 15
	Wheat	Flowable Concentrate	Seed Treatment				
	Sunflower	Granular	Ground incorporated	1.3	1	NA	August 15
CA strawberry RLF	Strawberry	Liquid	Ground & ground incorporated	1	2	10	August 15
CA sugarbeet OP	Sugarbeet (foliar)	Liquid	Air and ground	1	3	10	October 1
	Sugarbeet (soil incorporated)	Liquid	Ground & ground incorporated	2	3	10	October 1
	Sugarbeet (soil incorporated)	Granular	Ground incorporated	2	1	NA	October 1

Table 3.1 Summary of PRZM/EXAMS Exposure Assumptions for Chlorpyrifos

PRZM Scenario	Uses Represented	Formulation Type	Application Method	Maximum Application Rate (lbs ai/acre)	No. Apps.	Minimum Interval (days)	First Application Date
CA potato RLF	Sweet potato	Liquid	Ground & ground incorporated	2	1	NA	October 1
	Sweet potato	Granular	Ground incorporated	2	1	NA	October 1
CA rangeland RLF	Ant mounds	Liquid	Ground spot treatment	2	2	10	May 1
CA nursery	Ornamentals	Liquid	Ground	8	1	NA	March 1
	Ornamentals	Liquid	Ground	4	1	NA	March 1
	Ornamentals	Granular	Ground	6	1	NA	March 1
CA right of way RLF	Road median	Liquid	Ground	1	1	NA	June 1
	Road median	Granular	Ground	1	1	NA	June 1
CA turf RLF	Turfgrass for Sod	Liquid	Ground	4	1	NA	June 1
	Turfgrass	Granular	Ground	1	1	NA	June 1

3.2 Aquatic Exposure Assessment

3.2.1 Modeling Approach

Aquatic exposures are quantitatively estimated for all of assessed uses using scenarios that represent high exposure sites for chlorpyrifos use. Each of these sites represents a 10 hectare field that drains into a 1-hectare pond that is 2 meters deep and has no outlet. Exposure estimates generated using the standard pond are intended to represent a wide variety of vulnerable water bodies that occur at the top of watersheds including prairie pot holes, playa lakes, wetlands, vernal pools, man-made and natural ponds, and intermittent and first-order streams. As a group, there are factors that make these water bodies more or less vulnerable than the standard surrogate pond. Static water bodies that have larger ratios of drainage area to water body volume would be expected to have higher peak EECs than the standard pond. These water bodies will be either shallower or have large drainage areas (or both). Shallow water bodies tend to have limited additional storage capacity, and thus, tend to overflow and carry pesticide in the discharge whereas the standard pond has no discharge. As watershed size increases beyond 10 hectares, at some point, it becomes unlikely that the entire watershed is planted to a single crop, which is all treated with the pesticide. Headwater streams can also have peak concentrations higher than the standard pond, but they tend to persist for only short periods of time and are then carried downstream. Uncertainties related to modeling EECs in estuarine/marine environments, refer the reader to the Uncertainties Section.

Currently a suite of more than 80 PRZM scenarios are available for use in ecological risk assessments representing predominantly agricultural uses. A total of 28 California specific scenarios are available for this assessment. Each scenario is intended to represent a high-end exposure setting for a particular crop. Each scenario location is selected based on various factors including crop acreage, runoff and erosion potential, climate, and agronomic practices. Once a location is selected, a scenario is developed using locally specific soil, climatic, and agronomic data. Each PRZM scenario is assigned a specific climatic weather station providing 30 years of daily weather values. Specific scenarios were selected for use in this assessment using two criteria. First, an evaluation of all available PRZM scenarios was conducted, and those scenarios that represent chlorpyrifos uses (e.g. corn) were selected for modeling. Weather information was assigned to these scenarios at development. Of the 28 available scenarios 21 were selected for modeling purposes.
Further description (metadata) and copies of the existing PRZM scenarios may be found at the following websites.

http://www.epa.gov/oppefed1/models/water/index.htm#przmexamsshell

http://www.epa.gov/oppefed1/models/water/przmenvironmentdisclaim.htm

Use-specific management practices for all of the assessed uses of chlorpyrifos were used for modeling, including application rates, number of applications per year, application intervals, and buffer widths and resulting spray drift values modeled from AgDRIFT and AgDISP, and the first application date for each use. The date of first application was developed based on several sources of information including data provided by BEAD, a summary of individual applications from the CDPR PUR data, and Crop Profiles maintained by the USDA. A sample of the distribution of chlorpyrifos applications to grapes from the CDPR PUR data for 2007 used to pick a March 1 application date is shown in **Figure 3.1**

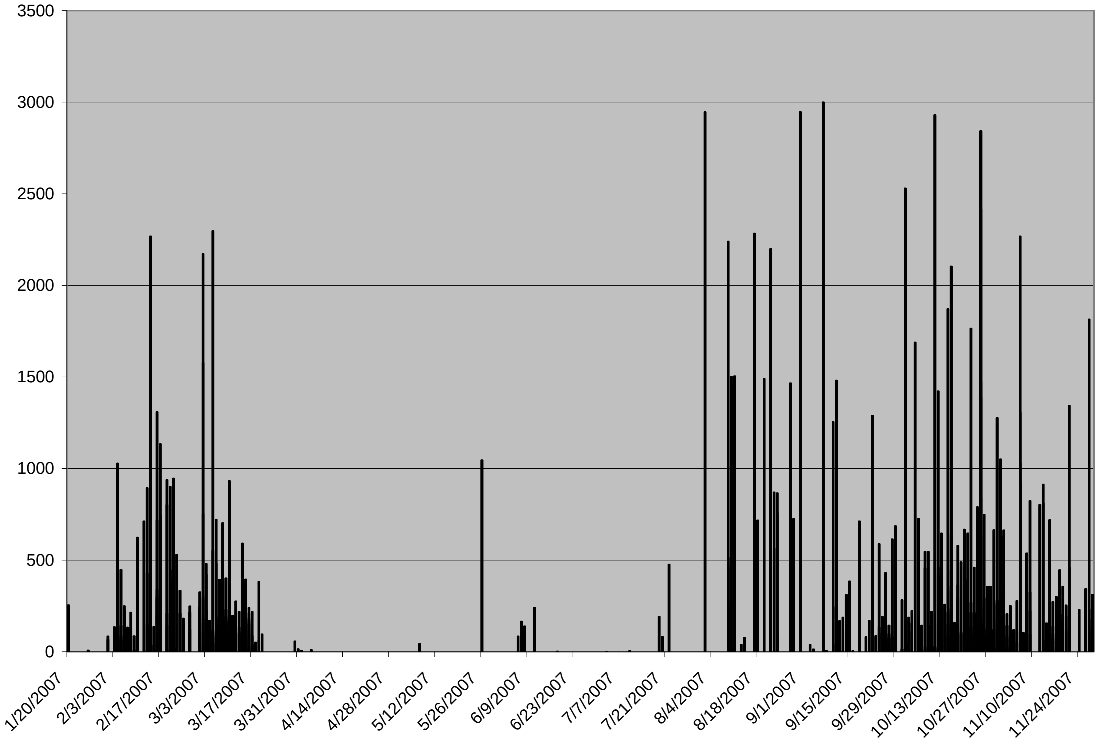


Figure 3.1 Summary of Applications of Chlorpyrifos to Grapes in 2007 from CDPR PUR data.

More detail on the crop profiles and the previous assessments may be found at: http://pestdata.ncsu.edu/cropprofiles/cropprofiles.cfm

3.2.2 Model Inputs

Chlorpyrifos is an insecticide used on a wide variety of food and non-food crops. Chlorpyrifos environmental fate data used for generating model parameters is listed in **Table 2.2**. The input parameters for PRZM and EXAMS are in **Table 3.2**.

Table 3.2 PRZM/EXAMS chemical specific input parameters for chlorpyrifos [a]		
Parameter	**Input Value and Unit**	**Source**
CAM	2 – Foliar 1 – Soil surface broadcast (no incorporation) 4 - Incorporated	
Soil Incorporation	0 cm – Foliar & granular surface broadcast (alfalfa, asparagus, ant mound, citrus, nursery, right of way, & turf) 5 cm incorporation – cole crop, corn, sorghum, soybean, sugarbeet, sunflower 7.5 cm incorporation – peanut 10 cm incorporation – sweet potato	Depths of incorporation determined from labels
Application efficiency	0.95 (aerial & airblast) 0.99 (ground) 1.00 (granular)	EFED Model Input Guidance, Version II (2002)
Spray drift[1]	3.9% (aerial) 0.6% (air-blast) 0.7% (ground) 0.0% (granular)	AgDrift Modeling Using Label Restrictions
Vapor pressure (25 °C)	1.82×10^{-5} torr	
Solubility in water	2 mg/L	Solubility
Molecular weight	350.6 g/moles	
Henry's Law constant	4.2×10^{-6} atm-m^3/mol	
Soil adsorption coefficient K_{oc}	6070 L/mg-OC	U.S. EPA 2002
Hydrolysis half-life	72 days (pH 7)	U.S. EPA 2002
Aqueous photolysis half-life	29.6 days @ pH7	U.S. EPA 2002
Aerobic soil metabolism	76.9 days[2]	U.S. EPA 2002
Aerobic aquatic metabolism ($t_{1/2}$)	153.8 days	2x the aerobic soil metabolism input value
Anaerobic aquatic metabolism ($t_{1/2}$)	81.5 days	2x the anaerobic soil metabolism rate
[a] *Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides, Version II"* dated February 28, 2002.		

1 – Alternate drift values for wheat are used based on different labeled buffers. The alternate values are 2.4% for aerial applications using a 300 ft buffer and 0.7% for ground applications using a 30 ft buffer.
2 – 90th % of all available aerobic soil metabolism data

In addition, chlorpyrifos is registered as a flowable concentrate which is used as a seed treatment use. EFED modeled these uses using the labels rates summarized in Table 3.3. These rates were adjusted from the labeled rates in ounces of product per 100 lbs of seed to lbs ai/acre. Each use was modeled as a soil applied application similar to granular applications and no drift was assumed. The resulting EEC are summarized with all other uses assessed in Table 3.4.

Table 3.3 Application Rates for Chlorpyrifos Pre-plant Seed Treatment (Mist, Slurry and Planter/Drill boxes)

Use Pattern	Application Rate (cwt [1])	Seeding Rate (lb/Acre)[8]	Application Rate (lb a.i./Acre)
Corn	0.059	18.3	0.010797
Cotton	0.059	10	0.0059
Soybean	0.059	60	0.0354
Cucumbers	0.059	3	0.00177
Sorghum	0.059	12	0.00708
Beans	0.059	0.5	0.000295
Wheat	0.059	89	0.05251

[1] cwt= hundredweight (i.e., lbs/100 lbs of seeds).

3.2.3 Results

The aquatic EECs for the various scenarios and application practices are listed in **Table 3.4.** Several labeled uses allow for both soil surface and soil incorporated applications. Where appropriate, both application types have been assessed. The incorporation depths have been selected based on label instructions. The majority of PRZM scenarios yielded peak EEC between 0.3 ppb and 8.0 ppb. Two exceptions to this were peak EEC for cole crops at 16.3 ppb and outdoor nursery uses with EEC between 22 ppb and 45 ppb depending on the formulation and use rate. The cole crop EEC is driven by the fact that these are coastal uses with a relatively high application rate (3 lbs applied 3 times per year). The nursery EEC are likely over-estimates because the modeling assumes a broadcast application across the use site while the label specifies that chlorpyrifos is typically applied directly to the target plant and not across the entire site. If the percent coverage for the target plant (e.g. ornamental trees) across the use site were 10 to 20% of the entire site these EEC would be consistent with the other uses modeled. In general, these modeled EEC are consistent with data in surface water monitoring particularly from the CDPR data (discussed below) that show chlorpyrifos detections as high as 4 ppb as recently as 2003.

[8] Barley: http://www.ag.ndsu.edu/procrop/bar/baseed04.htm
Corn, cotton, rice and wheat: http://www.hort.purdue.edu/newcrop/duke_energy/
Flax, rye, safflower sorghum: http://www.hort.purdue.edu/newcrop/afcm/flax.html
Oats: http://extension.oregonstate.edu/catalog/html/em/em8692/
Tomatoes: http://aggie-horticulture.tamu.edu/extension/vegetable/cropguides/tomato.html
Triticali: http://southeastfarmpress.com/news/90204Triticale-cover/
Other Reference: http://www.reimerseeds.com/Search.aspx?Keyword=Triticali

Table 3.4 Aquatic EECs (µg/L) for Chlorpyrifos Uses in California									
PRZM Scenario	**Uses Represented**	**Formulation Type**	**Application Method**	**Application Rate (lbs ai/acre)**	**No. Apps.**	**Minimum Interval (days)**	**Peak EEC**	**21-day average EEC**	**60-day average EEC**
CA alfalfa OP	Alfalfa Clover	Liquid	Air and ground	1	4	10	4.1	2.5	1.9
	Alfalfa Clover	Granular	Ground incorporated	1	1	NA	0.3	0.2	0.1
CA row crop RLF	Asparagus	Liquid	Air and ground	1.5	3	10	4.8	2.8	1.8
	Asparagus	Granular	Ground incorporated	1	3	10	2.0	0.9	0.5
	Peanut	Liquid	Ground	2	2	NS	2.6	1.2	0.7
	Soybean	Liquid	Ground & ground incorporated	1	3	14	2.9 2.1	1.6 1.0	1.2 0.6
	Soybean	Flowable Concentrate	Seed treatment	0.0354	3	14	0.07	0.03	0.02
	Peanut	Granular	Ground incorporated	2	2	10	0.8	0.4	0.2
CA forestry RLF	Christmas trees	Liquid	Ground	1	3	7	6.3	2.9	1.9
CA citrus STD	Citrus	Liquid	Airblast	4	2	30	2.8	1.3	0.7
	Citrus Floor	Liquid	Ground	2	3	10	1.8	1.0	0.6
	Citrus Floor	Granular	Ground incorporated	1	3		0.5	0.2	0.1
CA cole crop RLF	Cole Crop Leafy Vegetable Rutabaga Turnip	Liquid	Ground & ground incorporated	3	3	10	16.3	8.3	5.4
	Radish	Liquid	Ground	2.75	1	NA	5.9	2.9	1.9

Table 3.4 Aquatic EECs (µg/L) for Chlorpyrifos Uses in California									
PRZM Scenario	**Uses Represented**	**Formulation Type**	**Application Method**	**Application Rate (lbs ai/acre)**	**No. Apps.**	**Minimum Interval (days)**	**Peak EEC**	**21-day average EEC**	**60-day average EEC**
	Legumes	Liquid	Ground	0.5	1	NA	1.1	0.5	0.3
	Legumes	Flowable Concentrate	Seed treatment	0.000295	1	NA	0.0003	0.0001	0.00007
	Cole Crop Leafy Vegetable Rutabaga Turnip (in furrow)	Granular	Ground incorporated	2.75	1	NA	6.3	3.2	2.0
CA corn OP	Field and sweet corn	Liquid	Air and ground	1	3	10	3.9	2.3	1.6
	Field and sweet corn	Granular	Ground incorporated	1	3	10	1.1	0.6	0.3
	Field and sweet corn	Flowable Concentrate	Seed treatment	0.0108	3	10	0.01	0.006	0.003
CA cotton STD	Cotton	Liquid	Air and ground	1	3	10	5.1	2.5	2.0
	Cotton	Flowable Concentrate	Seed treatment	0.0059	3	10	0.007	0.005	0.004
CA grape STD	Grapes	Liquid	Ground	2.25	1	NA	1.2	0.6	0.3
OR mint STD	Mint	Liquid	Ground	2	3	NS	2.4	1.4	0.9
CA onion STD	Dry bulb onion	liquid	Ground & ground incorporated	1	1	NA	1.9	1.0	0.6
CA almond STD	Fig	Liquid	Ground & ground incorporated	2	1	NA	1.1 1.0	0.6 0.5	0.4 0.3
	Orchard Floor	Liquid	Ground	2	5	10	6.8	3.7	2.0
	Tree Fruit and Nuts (dormant)	Liquid	Airblast	2	1	NA	3.3	1.5	0.9

Table 3.4 Aquatic EECs (µg/L) for Chlorpyrifos Uses in California									
PRZM Scenario	**Uses Represented**	**Formulation Type**	**Application Method**	**Application Rate (lbs ai/acre)**	**No. Apps.**	**Minimum Interval (days)**	**Peak EEC**	**21-day average EEC**	**60-day average EEC**
	Tree Fruit and Nuts (foliar)	Liquid	Air and ground	2	3	10	7.1	4.2	3.0
CA fruit STD	Pear	Liquid	Ground	2	1	NA	1.3	0.6	0.3
	Apple (dormant)	Liquid	Airblast	2	2	10	3.2	1.8	0.8
CA wheat RLF	Grain sorghum (milo)	Liquid	Air and ground	1	3	10	5.3	2.5	1.8
	Grain sorghum (milo)	Granular	Ground incorporated	1.5	1	NA	0.9	0.5	0.3
	Grain sorghum	Flowable Concentrate	Seed treatment	0.00708	1	NA	0.004	0.002	0.002
CA strawberry RLF	Strawberry	Liquid	Ground & ground incorporated	1	2	10	4.5	1.9	1.2
CA sugarbeet OP	Sugarbeet (foliar)	Liquid	Air and ground	1	3	10	3.3	1.9	1.4
	Sugarbeet (soil incorporated)	Liquid	Ground incorporated	2	3	10	3.6	1.6	1.1
	Sugarbeet (soil incorporated)	Granular	Ground & ground incorporated	2	1	NA	0.5	0.2	0.1
CA wheat RLF	Sunflower	Liquid	Air and ground	1.5	3	10	7.9	3.8	2.7
	Wheat	Liquid	Ground & ground incorporated	0.5	2	NS	1.3	0.7	0.5
	Wheat	Flowable Concentrate	Seed treatment	0.05251	2	NS	0.07	0.04	0.03
	Sunflower	Granular	Ground incorporated	1.3	1	NA	0.8	0.4	0.3
CA potato RLF	Sweet potato	Liquid	Ground & ground incorporated	2	1	NA	1.7	0.7	0.4

Table 3.4 Aquatic EECs (µg/L) for Chlorpyrifos Uses in California									
PRZM Scenario	**Uses Represented**	**Formulation Type**	**Application Method**	**Application Rate (lbs ai/acre)**	**No. Apps.**	**Minimum Interval (days)**	**Peak EEC**	**21-day average EEC**	**60-day average EEC**
	Sweet potato	Granular	Ground incorporated	2	1	NA	0.4	0.2	0.1
CA rangeland RLF	Ant mounds	Liquid	Ground spot treatment	2	2	10	1.9	0.9	0.7
	Ant mounds	Granular	Ground	2	2	10	1.9	0.9	0.5
CA nursery	Ornamentals	Liquid	Ground	8	1	NA	45.1	20.1	11.9
	Ornamentals	Liquid	Ground	4	1	NA	22.6	10.1	6.0
	Ornamentals	Granular	Ground	6	1	NA	32.1	14.4	8.6
CA right of way RLF	Road median	Liquid	Ground	1	1	NA	1.5	0.8	0.5
	Road median	Granular	Ground	1	1	NA	1.5	0.8	0.5
CA turf RLF	Turfgrass for Sod	Liquid	Ground	4	1	NA	1.6	0.6	0.3
	Turfgrass	Granular	Ground – broadcast	1	1	NA	0.08	0.04	0.02

In addition, a limited set of sediment concentration were estimated using PRZM/EXAMS. The scenarios resulting in the highest and lowest water concentrations were used to predict both sediment and pore water. The scenarios selected were the outdoor nursery use, cole crop (selected to provide the next lowest EEC due to uncertainty with the nursery scenario), and the granular turf use. The granular turf yielded the lowest water EEC. Results for these three scenarios are presented in **Table 3.5.**

Table 3.5 Summary of Sediment and Pore Water EEC using selected PRZM scenarios

Scenario	Pore Water Concentration (µg/L)			Sediment Concentration (mg/kg)		
	Peak	21-day average	60-day average	Peak	21-day average	60-day average
CA Cole Crops	3.789	3.740	3.497	0.921	0.909	0.850
CA Nursery	5.898	5.799	5.341	1.431	1.411	1.296
CA Turf	0.018	0.018	0.017	0.004	0.004	0.004

Considering that the log K_{ow} value for chlorpyrifos exceeds 4, and that chlorpyrifos can persist for relatively long periods of time in aquatic ecosystems, the KABAM model was used to evaluate potential exposure and risk via bioaccumulation and biomagnification in aquatic food webs. Previous analyses using an earlier version of the KABAM model indicate relatively close agreement between its predicted bioconcentration factor (BCF) and those reported from experimental studies for chlorpyrifos (USEPA 2007; D346213). Details of the bioaccumulation assessment for chlorpyrifos in relation to the assessed species are provided in Section **5.2.4.1**.

Estimated Bioconcentration Factor values

In order to estimate Bioconcentration Factor (BCF) values for aquatic organisms accumulating chlorpyrifos, KABAM was run, using a log (Kow) of 4.7 to represent the partitioning of chlorpyrifos to aquatic organisms. The body characteristics of organisms in the model trophic levels are depicted in **Table 3.6**. The resulting BCF values for these trophic levels are depicted in **Table 3.7**. Output files from KABAM are provided in **Table 5.19** and **Appendix C**.

Table 3.6 Characteristics of aquatic biota of the model ecosystem.

Trophic Level	Wet Weight (kg)	% lipids	% Non-lipid Organic Matter	% Water
sediment*	N/A	0.0%	4.0%	96.0%
phytoplankton	N/A	2.0%	8.0%	90.0%
zooplankton	1.0E-07	3.0%	12.0%	85.0%
benthic invertebrates	1.0E-04	3.0%	21.0%	76.0%
filter feeders	1.0E-03	2.0%	13.0%	85.0%
small fish	1.0E-02	4.0%	23.0%	73.0%
medium fish	1.0E-01	4.0%	23.0%	73.0%
large fish	1.0E+00	4.0%	23.0%	73.0%

* N/A = not applicable Note that sediment is not a trophic level. It is included in this table because it is consumed by aquatic organisms of the KABAM foodweb.

Table 3.7 Total BCFand BAF values of Chlorpyrifos in aquatic trophic levels.		
Trophic Level	Total Bioconcentration Factor (µg/kg-ww)/(µg/L)	Total Bioaccumulation Factor (µg/kg-ww)/(µg/L)
Phytoplankton	2407	2312
Zooplankton	1715	1738
Benthic Invertebrates	1837	1894
Filter Feeders	1208	1245
Small Fish	2363	2618
Medium Fish	2363	2861
Large Fish	2409	3411

KABAM was run in default mode (see user's guide for full description), with a Log Kow = 4.7, a Koc = 6070 L/mg-OC (see **Table 3.2**); and surface water and pore water EECs of 5.36 and 3.31 ppb, respectively. These EECs were generated by PRZM/EXAMS and based on the cole crop ground application (See **Table 3.7**).

3.2.4 Existing Monitoring Data

A critical step in the process of characterizing EECs is comparing the modeled estimates with available surface water monitoring data. Included in this assessment are chlorpyrifos data from the USGS NAWQA program (http://water.usgs.gov/nawqa) and data from the California Department of Pesticide Regulation (CDPR) as well as a summary of data from open literature and registrant submitted studies. In addition, air monitoring data for chlorpyrifos are summarized.

3.2.4.1 USGS NAWQA Surface Water Data

The USGS NAWQA program database was accessed on May 27, 2009 and all chlorpyrifos related data was extracted including both parent chlorpyrifos and chlorpyrifos oxon in surface water. The data extraction was limited to NAWQA sites within California only. For parent chlorpyrifos a total of 2230 samples were available where chlorpyrifos had been analyzed for. Of these, there are 865 samples with detectable levels of chlorpyrifos and 286 samples with estimated concentrations below the limit of quantitation (LOQ). The combined detections and estimated detections yield a frequency of detection for chlorpyrifos of 52%. The maximum detected value was 0.4 ppb in 2001 from Merced county (Station ID #11261100). The NAWQA samples with the highest detections typically occur in a period between late winter and mid summer.

For chlorpyrifos oxon a total of 430 samples were analyzed and of these a total of 4 samples had estimated detections below the LOQ for a frequency of detection of 1%. The maximum estimated value was 0.0346 ppb from 2004 in Merced county (Station ID #373112120382901)

3.2.4.2 USGS NAWQA Groundwater Data

The USGS NAWQA program database was accessed on June 8, 2009 and all chlorpyrifos related data was extracted including both parent chlorpyrifos and chlorpyrifos oxon in groundwater. The data extraction was limited to NAWQA sites within California only. For parent chlorpyrifos a total of 828 samples were available where chlorpyrifos had been analyzed for. Of these, there are 1 sample with detectable levels of chlorpyrifos and no samples with estimated concentrations below the limit of quantitation (LOQ). The combined detections and estimated detections yield a frequency of detection for chlorpyrifos of 0.1%. The maximum detected value was 0.006 ppb in 1993 from Merced county (Station ID # 363805119345001). For chlorpyrifos oxon a total of 328 samples were analyzed and of these no samples had either detected or estimated detections.

While not conclusive these data suggest that groundwater is not a significant route of exposure for this chlorpyrifos.

3.2.4.3 California Department of Pesticide Regulation (CPR) Data

The California Department of Pesticide Regulation (CDPR) maintains a Surface Water Database of pesticide detections in surface waters of the entire state updated through June 2008. The Agency accessed this data base and extracted the chlorpyrifos specific results. The database is split into regional files which the Agency re-assembled into a single spreadsheet for analysis. In addition, the database contains data on sediment sampling and these also were extracted for chlorpyrifos. The data represents monitoring data collected between 1991 and 2005.

For surface water the database contained 7400 samples with 1857 detections of chlorpyrifos yielding a frequency of detection of roughly 25%. The maximum detection was 3.96 ppb in 2003 from a sample in Quail Creek (ID # 7929) in Monterey County. Overall, 10 samples had concentrations greater than 1 ppb though most of these were collected prior to 2000. However, three of the samples greater than one were collected post 2000 with most of the highest detections occurring in Monterey and Stanislaus counties. In addition, the samples with the highest concentratins typically occur in the spring and summer. The locations of the surface water sites are shown in **Figure 3.2.**

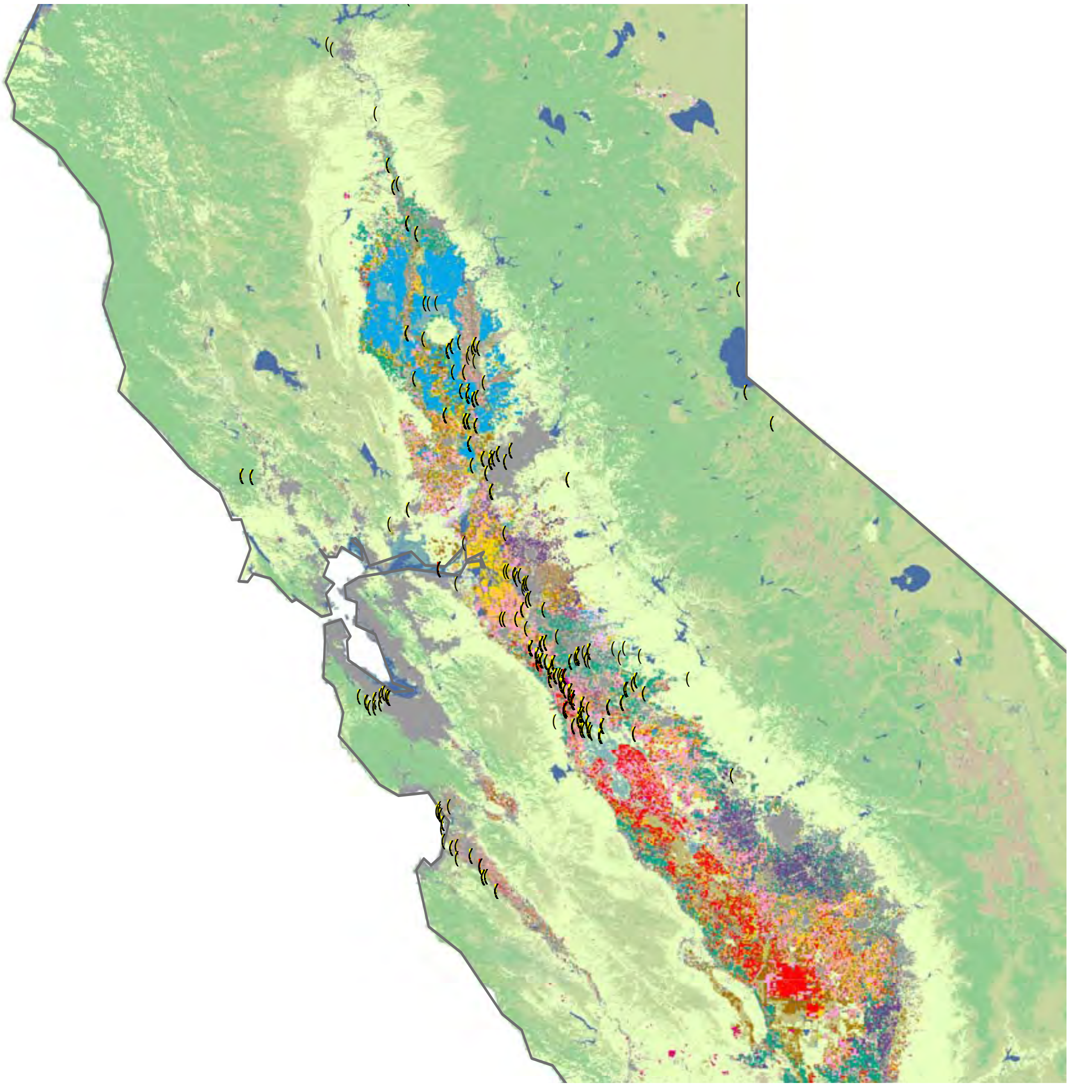


Figure 3.2 Location of CDPR surface water sites with chlorpyrifos detections relative to landcover.
Sites in red represent locations with detections greater than 1 ppb.

The Agency also accessed the sediment portion of the database. A total of 24 analytical results were available from 2004 in Placer County. Of these, 9 samples had detectable levels of chlorpyrifos in sediment. The highest concentration detected was 0.019 ppm.

3.2.4.4 Open Literature Data

The Agency has also completed a review of open literature data on the occurrence of chlorpyrifos in surface waters of the State of California (Bailey et al., 2000; Kozlowski et al., 2004; Schulz, 2004; Schiff and Tiefenthaler, 2003; Schiff and Sutual, 2004; Bacey and Spurlock, 2007; Bacey 2005; Starner et al., 2003; Spurlock, 2002; Giesy et al., 1999; and Poletika et al., 2002; and Ross et al., 2000). The focus of this review has been on occurrence data subsequent to 2000 although an overall CDPR summary review (Spurlock et al., 2002) provided an excellent summary of pre-RED exposures. In general, these studies cover a range of aquatic habitats from small highly vulnerable habitats such as irrigation ditches to rivers and coastal lagoons. Overall, chlorpyrifos exposures in these studies ranged from lows of 0.004 ppb to high of 3.8 ppb. Exceptions to this were high concentrations from Kozlowski et al., 2004; Schiff and Thiefenthaler, 2003; and Singhasemanon, et al., 1998. Kozlowski et al., 2004 documented a maximum concentration of 28.5 ppb, however the value in Kozlowski represented a total chlorpyrifos exposure including a water component of 0.85 ppb and chlorpyrifos bound to suspended sediment of roughly 27 ppb. In Schiff and Thiefenthaler, 2003 surface water concentrations from residential neighborhoods were documented in both wet and dry seasons with chlorpyrifos concentrations generally below 1 ppb although a single exposure period in 2001 yielded concentrations as high as 10 ppb from two of three sites. It should be noted that the residential values in Schiff represented a period prior to the phase out of urban uses of chlorpyrifos. In Singhasemanon et al., 1998 sampling was conduced from POTW influent and effluent sampling and chlorpyrifos was again generally below 1 ppb though a single effluent sample from a POTW with a pet grooming facility was as high as 38 ppb which again was from a period prior to the phase out of many non agricultural uses. Finally, a series of registrant sponsored edge of field runoff studies were considered which indicated generally higher exposures of up to 58 ppb in runoff. The overall trend is for decreasing exposures likely due to label changes and use limitations implemented in the RED process and that lower exposures are generally found in rivers relative to smaller habitats such as ditches and tributaries.

3.2.4.5 Atmospheric Monitoring Data

Both parent chlorpyrifos and chlorpyrifos-oxon have been detected in numerous studies indicating atmospheric transport is a significant concern (McConnell et al., 1998; Sparling et al., 2001; Lenoir et al., 1999; Fellers et al., 2004; Majewski and Capel, 1995; Zamora et al., 2003; Vogel et al., 2008; Landers et al., 2008; Aston and Seiber, 1997; Hageman et al., 2006; Zabik and Seiber, 1993; and Usenko et al., 2005). Evidence that these data represent long range transport and not edge of field spray drift events are noted in the studies and focus primarily on occurrence in areas far afield from agricultural sites where chlorpyrifos is likely applied. In fact, many of these studies document the occurrence of chlorpyrifos in various media (air, rain, and snow) at high elevations in the Sierra Nevada mountains where no applications occur. The following summarizes some of the key findings from selected studies with emphasis on occurrence data from California.

Majewski and Capel, 1995 summarized available literature documenting atmospheric transport across the United States and found chlorpyrifos in rain between 1.3 to 180 ng/l, in air between 0.005 to 199 ng/m^3, and in fog between 1.3 to 14,200 ng/l. Locally McConnell et al., 1998 detected chlorpyrifos up to 220 ng/l in high mountain lake water, in rain/snow samples in high Sierra mountain locations up to 180 ng/l, and in fog water up to 14,200. McConnell, 2005 found chlorpyrifos in Tahoe snow at approximately 4.5 ng/l, Yosemite snow at 11 ng/l, Sequoia snow at 9 ng/l, and in Sequoia National Park found chlorpyrifos oxon at 5.5 ng/l. Sparling et al., 2001 found chlorpyrifos in air at 25ng/g while LeNoir et al., 1999 found chlorpyrifos in air at up to 17.5 ng/m^3 and chlorpyrifos oxon at up to 30.4 ng/m3, in dry deposition samples found chlorpyrifos at up to 24 ng.m^2/day and the oxon at up to 80 ng/m^2/day, and LeNoir found parent above 1000 m > 100 ng/l and the oxon above 1000 m > 37 ng/l. Landers et al, 2008 found chlorpyrifos in vegetation samples from US National Parks between 1 to 31 ng/g lipid with increasing concentrations with elevation and the highest samples from Yosemite Park. Additional studies by USGS and the State of California (Zamora et al., 2003; Vogel et al., 2008; Spector et al., 2004) found local concentrations in agricultural settings of between 0.04 and 1.84 ppb in rainfall for parent and up to 0.1 ppb of chlorpyrifos oxon in the Central Valley..

3.2.4.6 Comparison of Modeling and Surface Water Monitoring Data

In general comparison of modeled and monitored surface water data suggests that EEC estimated by PRZM/EXAMS are providing a reasonable upper bound estimate of potential exposure from chlorpyrifos to CRLF and SFB species in most aquatic habitats. In addition a total of 28 PRZM scenarios are available for California and of these 21 were used in this assessment including the most vulnerable scenarios available which are associated with uses in Northern California and the coastal regions near San Francisco (where the CRLF and SFB species are located). With the exception of the nursery scenarios most modeled EEC are between 0.1 ppb and 16 ppb with the bulk of the use sites between 1 ppb and 6 ppb. By way of comparison most monitoring data yields exposures well below 1 ppb although individual results have yielded results as high as 10 ppb for water only and up to 28 ppb for water/sediment mixtures. Higher concentrations were seen in registrant sponsored edge of field runoff studies and while these may represent extreme exposures they will generally represent transient exposures that will ultimately be diluted once reaching aquatic habitats. Overall, these data suggest a general concurrence between modeling and lend credence to the use of the modeled EEC in estimating risk.

3.3 Terrestrial Animal Exposure Assessment

T-REX (Version 1.3.1) is used to calculate dietary and dose-based EECs of chlorpyrifos for birds, mammals, and terrestrial invertebrates. T-REX simulates a 1-year time period. For this assessment, spray and granular applications of chlorpyrifos are considered, as discussed below. RQ’s for granular and seed treatment applications are not based on EECs but rather calculated in terms of LD_{50} per square foot. Therefore, EECs for granular and seed treatments are not generated for these uses.

Terrestrial EECs for foliar formulations of chlorpyrifos were derived for the uses summarized in **Table 3.8**. Crop-specific decline data for residues of chlorpyrifos from submitted crop field trial studies are available for several commodities. Based on available data, foliar dissipation half-lives have been derived all commodities treated with liquid formulations. Using conservative assumptions, maximum half-life values from representative commodities were used for individual commodities (e.g., sugarbeet tops for leafy commodities, sorghum for grain crops and dormant tree crops, apple for fruit and nut commodities etc.) Use-specific input values, including number of applications, application rate, foliar half-life and application interval are provided in **Tables 3.8 to 3.10**. An example output from T-REX is available in **Appendix D**.

Table 3.8 Input Parameters for Foliar Applications Used to Derive Terrestrial EECs for Chlorpyrifos with T-REX				
Use (Application Method)	**Application rate (lbs ai/A)**	**Number of Applications**	**Application Interval (days)**	**Foliar Dissipation Half-Life**
Alfalfa (Foliar; Broadcast Aerial/Ground, Chemigation)	1	4	10	18 [1]
Almond, Sour Cherry, Filbert, Pecan, Walnut (Foliar; Broadcast Aerial/Ground)	2	3	10	22 [2]
Apple (Dormant/Delayed; Broadcast Ground)	2	2	10	5 [3]
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	1.5	3	10	18
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	2	1	NA	5
Christmas Trees (Foliar; Broadcast Ground)	1	3	7	18
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	4	2	30	11 [4]
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	1	3	10	5
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	3	3	10	18
Cranberry (Foliar; Broadcast Aerial/Ground)	1.5	2	10	22
Grape (Dormant; Broadcast Ground)	2.25	1	N/A	5
Mint (Foliar; Broadcast Ground)	2	3	N/A	18
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	1	3	14	5
Strawberry (Foliar; Broadcast Aerial/Ground)	2	1	N/A	22
Sugarbeet (Foliar; Broadcast Aerial/Ground)	1	3	10	18
Sunflower (Foliar; Broadcast Aerial/Ground)	1.5	3	10	5
Wheat (Foliar; Broadcast Aerial/Ground)	0.5	2	10	5
Ornamentals (Foliar; Broadcast Ground)	4	1 [5]	NA	18
Turf Grass (Foliar; Broadcast Ground)	4	2 [6]	7	18

[1] Alfalfa, Asparagus, Christmas Tree, Cole Crop, Mint, Strawberry, Sugarbeet, Ornamentals, Turf Grass – Representative commodity - Sugarbeet tops (MRID 00101566)
[2] Almond, Sour Cherry, Filbert, Pecan, Walnut, Cranberry, Strawberry – Representative commodity Apple (MRID 00095264)
[3] Apple, Cherry, Corn/Cotton, Grape, Fig, Sunflower, Wheat – Representative commodity Sorghum (MRID 00046785)
[4] Citrus – Representative commodity Orange (MRID 00095260)
[5] Number of applications and application intervals are not specified on the label; a single application is assumed
[6] Number of applications is not specified on the label; two applications at 7 day intervals are assumed
N/A = Non-applicable

Table 3.9 Input Parameters for Granular Applications Used to Derive Terrestrial EECs for Chlorpyrifos with T-REX			
Use (Application Method)	**Application rate (lbs ai/A)**	**Row Spacing (in) [1]**	**Band Width (in)**
Alfalfa, Onion (In-furrow)	1	18	4
Asparagus, Citrus Orchard Floors, Corn, Road Median, Turf Grass (Broadcast: Ground Lightly Incorporated)	1	NA	NA
Citrus Orchard Floor (Broadcast: Ground Unincorporated)	1	NA	NA
Cole Crop (Brassica) Leafy Vegetables and Radish, Rutabaga and Turnip (T-band: Lightly Incorporated)	2.25	18	4
Corn (Broadcast: Aerial)	1	NA	NA
Peanut, Sweet Potato, Tobacco (Broadcast: Ground Lightly Incorporated)	2	NA	NA
Sorghum - Grain Sorghum (Milo) (T-band; Lightly Incorporated)	1.5	18	6
Soybean (T-band; Lightly Incorporated)	2	18	4
Sugarbeet (T-band; Lightly Incorporated)	1.2	18	4
Sunflower (T-band; Lightly Incorporated)	1.3	18	4
Sweet Potato (Broadcast; Ground Incorporated)	2	NA	NA
Outdoor Nurseries (Broadcast; Unincorporated)	6[2]	NA	NA

[1] Row spacing and band width parameters based on label specifications
[2] 6 lb ai/A for commercial approved use only

Table 3.10 Input Parameters for Seed Treatment Applications Used to Derive Terrestrial EECs for Chlorpyrifos with T-REX	
Use	**Application rate (fl oz/100 lbs seed)**
Field Beans, Green Beans, Kidney Beans, Lima Beans, Navy Beans, Snap Beans, String Beans, Wax Beans, Black-Eyed Peas, Field Peas, Garden Peas, Corn, Cucumbers, Pumpkins	2.75
Cotton	5.5
Sorghum, Wheat	0.114

Upper-bound Kenega nomogram values reported by T-REX are used for derivation of dietary EECs for the CRLF, California clapper rail, CA tiger salamander and San Francisco garter snake, and their potential prey (**Table 3.11 & 3.12**). Potential direct effects of chlorpyrifos to the terrestrial-phase CRLF, juvenile California clapper rail, CA tiger salamander and San Francisco garter snake are derived by considering dose-based exposures modeled in T-REX for a small bird (20g) consuming small invertebrates. Potential direct effects to the adult California clapper rail are derived by considering dose-based EECs modeled in T-REX for a 100 g bird consuming a variety of dietary items.

Table 3.11 Chlorpyrifos Dietary and Dose-Based EECs for CRLF, Juvenile California clapper rail, CA tiger salamander and San Francisco garter snake and their Prey				
Use (Application method)	**EECs for SFB Listed Species**		**EECs for Prey (small mammals)**	
	Dietary-based EEC (ppm)	**Dose-based EEC [1] (mg/kg-bw)**	**Dietary-based EEC (ppm)**	**Dose-based EEC [2] (mg/kg-bw)**
Alfalfa (Broadcast Aerial/Ground, Chemigation)	332	378	590	563
Almond, Sour Cherry, Filbert, Pecan, Walnut, (Foliar; Broadcast Aerial/Ground)	611	696	1086	1035
Apple (Dormant/Delayed; Broadcast Ground)	338	384	600	572
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	434	494	772	736
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	270	308	480	458
Christmas Trees (Foliar; Broadcast Ground)	317	361	563	537
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	636	724	1130	1077
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	177	202	315	300
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	868	989	1543	1471
Cranberry (Foliar; Broadcast Aerial/Ground)	350	399	623	594
Grape (Dormant; Broadcast Ground)	304	346	540	515
Mint (Foliar; Broadcast Ground)	579	659	1029	981
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	157	179	279	266
Strawberry (Foliar; Broadcast Aerial/Ground)	270	308	480	458
Sugarbeet (Foliar; Broadcast Aerial/Ground)	289	330	514	490
Sunflower (Foliar; Broadcast Aerial/Ground)	266	303	473	451
Wheat (Foliar; Broadcast Aerial/Ground)	84	96	150	143
Ornamentals (Foliar; Broadcast Ground)	540	615	960	915
Turf Grass (Foliar; Broadcast Ground)	952	1085	1693	1614

[1] 20 g Avian Consuming Broadleaf Plants/sm Insects [2] 15 g Mammal Consuming Short Grass
(Size/class not used for dietary-based EECs)

Table 3.12 Chlorpyrifos Dose-Based EECs for the Adult California Clapper Rail	
Use (Application method)	**Dose-based EEC (mg/kg-bw)**
Alfalfa (Broadcast Aerial/Ground, Chemigation)	216
Almond, Sour Cherry, Filbert, Pecan, Walnut, (Foliar; Broadcast Aerial/Ground)	397
Apple (Dormant/Delayed; Broadcast Ground)	219
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	281
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	176
Christmas Trees (Foliar; Broadcast Ground)	206
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	413
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	115
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	564
Cranberry (Foliar; Broadcast Aerial/Ground)	228
Grape (Dormant; Broadcast Ground)	197
Mint (Foliar; Broadcast Ground)	376
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	102
Strawberry (Foliar; Broadcast Aerial/Ground)	176
Sugarbeet (Foliar; Broadcast Aerial/Ground)	188
Sunflower (Foliar; Broadcast Aerial/Ground)	173
Wheat (Foliar; Broadcast Aerial/Ground)	55
Ornamentals (Foliar; Broadcast Ground)	351
Turf Grass (Foliar; Broadcast Ground)	619
[1] 100 g Avian Consuming Broadleaf Plants/sm Insects	

Potential direct acute and chronic effects specifically to the Salt Marsh harvest mouse are derived by considering dose- and dietary-based EECs modeled in T-REX for a small mammal (15 g) consuming a variety of dietary items. Potential direct acute and chronic effects specifically to the San Joaquin fox are derived by considering dose- and dietary-based EECs modeled in T-REX for a large mammal (1,000 g) consuming a variety of dietary items (**Table 3.13**).

Table 3.13 Chlorpyrifos Dietary and Dose-based EECs for the Salt Marsh Mouse and San Joaquin Kit Fox			
Use (Application method)	San Joaquin Kit Fox	Salt Marsh Mouse	
	Dose-based EEC (mg/kg/bw) [1]	Dietary-based EEC (ppm)	Dose-based EEC (mg/kg-bw) [2]
Alfalfa (Broadcast Aerial/Ground, Chemigation)	90	590	563
Almond, Sour Cherry, Filbert, Pecan, Walnut, (Foliar; Broadcast Aerial/Ground)	166	1086	1035
Apple (Dormant/Delayed; Broadcast Ground)	92	600	572
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	118	772	736
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	73	480	458
Christmas Trees (Foliar; Broadcast Ground)	86	563	537
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	173	1130	1077
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	48	315	300
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	236	1543	1471
Cranberry (Foliar; Broadcast Aerial/Ground)	95	623	594
Grape (Dormant; Broadcast Ground)	83	540	515
Mint (Foliar; Broadcast Ground)	157	1029	981
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	43	279	266
Strawberry (Foliar; Broadcast Aerial/Ground)	73	480	458
Sugarbeet (Foliar; Broadcast Aerial/Ground)	79	514	490
Sunflower (Foliar; Broadcast Aerial/Ground)	72	473	451
Wheat (Foliar; Broadcast Aerial/Ground)	23	150	143
Ornamentals (Foliar; Broadcast Ground)	147	960	915
Turf Grass (Foliar; Broadcast Ground)	259	1693	1614
[1] 1000 g Mammal Consuming Short Grass; [2] 15 g Mammal Consuming Short Grass			

T-REX is also used to calculate EECs for terrestrial insects exposed to chlorpyrifos. Dietary-based EECs calculated by T-REX for small and large insects (units of a.i./g) are used to bound an estimate of exposure to bees. Available acute contact toxicity data for bees exposed to chlorpyrifos (in units of µg a.i./bee), are converted to µg a.i./g (of bee) by multiplying by 1 bee/0.128 g. The EECs are later compared to the adjusted acute contact toxicity data for bees in order to derive RQs. Dietary-based EECs for small and large insects reported by T-REX as well as the resulting adjusted EECs are available in **Table 3.14.** An example output from T-REX v. 1.4.1 is available in **Appendix D**.

Table 3.14 EECs (ppm) for Terrestrial Invertebrates		
Use	**Small Insect**	**Large Insect**
Alfalfa (Broadcast Aerial/Ground, Chemigation)	332	37
Almond, Sour Cherry, Filbert, Pecan, Walnut, (Foliar; Broadcast Aerial/Ground)	611	68
Apple (Dormant/Delayed; Broadcast Ground)	338	38
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	434	48
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	270	30
Christmas Trees (Foliar; Broadcast Ground)	317	35
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	636	70
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	177	20
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	868	97
Cranberry (Foliar; Broadcast Aerial/Ground)	350	39
Grape (Dormant; Broadcast Ground)	304	42
Mint (Foliar; Broadcast Ground)	579	64
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	157	18
Strawberry (Foliar; Broadcast Aerial/Ground)	270	30
Sugarbeet (Foliar; Broadcast Aerial/Ground)	289	32
Sunflower (Foliar; Broadcast Aerial/Ground)	266	30
Wheat (Foliar; Broadcast Aerial/Ground)	84	9
Ornamentals (Foliar; Broadcast Ground)	540	60
Turf Grass (Foliar; Broadcast Ground)	952	105

3.4 Terrestrial Plant Exposure Assessment

Since there are no terrestrial plant toxicity data available, exposures were not quantitatively estimated. See Section 5.2 for a qualitative discussion regarding the potential effects of chlorpyrifos on CRLF via effects to terrestrial plants.

4 Effects Assessment

This assessment evaluates the potential for chlorpyrifos to directly or indirectly affect the California red-legged frog, Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly, or modify their designated critical habitat. As previously discussed in Section 2.7, assessment endpoints for the effects determination for the assessed species include direct toxic effects on survival, reproduction, and growth, as well as indirect effects, such as reduction of the prey base and/or effects to habitat. In addition, potential effects to critical habitat were assessed by evaluating effects to the PCEs, which are components of the critical habitat areas that provide essential needs of each assessed species, such as water quality and food base (see Section 2.4). Direct effects to the Delta smelt and aquatic-phase of both California red-legged frog and California tiger salamander were based on toxicity information for freshwater fish and amphibian data, while terrestrial-phase amphibian effects (terrestrial-phase of both California red-legged frog and California tiger salamander) and reptiles (San Francisco garter snake) were based on avian toxicity data, given that birds are generally used as a surrogate for terrestrial-phase amphibians and reptiles.

As described in the Agency's Overview Document (U.S. EPA, 2004), the most sensitive endpoint for each taxon is used for risk estimation. For this assessment, evaluated taxa include the species listed in the previous paragraph, but their evaluation necessitated the evaluation of other freshwater fish (also used as a surrogate for aquatic-phase amphibians), freshwater invertebrates, estuarine/marine fish, estuarine/marine invertebrates, aquatic plants, birds (also used as a surrogate for terrestrial-phase amphibians and reptiles), mammals, terrestrial invertebrates, and terrestrial plants. Acute (short-term) and chronic (long-term) toxicity information was characterized based on registrant-submitted studies and a comprehensive review of the open literature on chlorpyrifos.

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) (U.S. EPA, 2004). Open literature data presented in this assessment were obtained from the Re-registration Eligibility Decision (RED) document (USEPA, 2002) as well as ECOTOX information obtained on October 23, 2007 and June 4, 2009. In order to be included in the ECOTOX database, papers must meet the following minimum criteria:

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

Data that pass the ECOTOX screen are evaluated along with the registrant-submitted data, and may be incorporated qualitatively or quantitatively into this endangered species assessment. In general, only effects data in the open literature that are more conservative than the registrant-submitted data are considered. In this case, all amphibian and copepod (the favorite food of the red-legged frog) data that passed the ECOTOX screening were considered. The degree to which open literature data are quantitatively or qualitatively characterized for the effects determination is dependent on whether the information is relevant to the assessment endpoints (*i.e.*, survival, reproduction, and growth; or, alteration of PCEs in the critical habitat impact analysis) identified in the problem formulation. For example, endpoints such as biochemical modifications are unlikely to be used to calculate risk quotients unless it is possible to quantitatively link these endpoints with reduction in survival, reproduction, or growth (e.g., the magnitude of effect on the biochemical endpoint needed to result in effects on survival, growth, or reproduction is known). Although the effects determination relies on endpoints measurably linked to assessment endpoints of survival, growth, or reproduction, please note that the full suite of sublethal endpoints available in effects literature (regardless of their significance to assessment endpoints) were considered to define the action area for chlorpyrifos.

Submitted studies and reviewed open literature are summarized in **Appendix E**. A bibliography of all open literature considered as part of this assessment regardless of whether the data were accepted or rejected by ECOTOX are included in **Appendices F and G**, respectively. Most open literature accepted by the ECOTOX screen were not used in this risk assessment because the endpoints were less sensitive than those already accepted from past assessments; these citations, as well as those that were included in **Appendix E**, are listed in **Appendix F. Appendix G** includes a list of citations that did not pass the ECOTOX screening and a rationale for rejection of those studies. A detailed spreadsheet of the available ECOTOX open literature data, including the full suite of lethal and sublethal endpoints is presented in **Appendix H**. **Appendix I** also includes a summary of the human health effects data for chlorpyrifos.

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, EC50, etc.), but rather are intended to identify a dose that maximizes a particular effect (e.g., EC100). Therefore, efficacy data and non-efficacy toxicological target insect data are not included in the ECOTOX open literature summary table provided in **Appendix H**. For the purposes of this assessment, 'target' insect species are defined as all terrestrial insects with the exception of bees, butterflies, beetles, and non-insect invertebrates (i.e., soil arthropods, worms, etc.) which are included in the ECOTOX data presented in **Appendix H**. The list of citations including toxicological and/or efficacy data on target insect species not considered in this assessment is provided in **Appendix G**.

In addition to registrant-submitted and open literature toxicity information, other sources of information, including reviews of the Ecological Incident Information System (EIIS), were conducted to further refine the characterization of potential ecological effects associated with exposure to chlorpyrifos. A summary of the available incident information for chlorpyrifos are provided in **Sections 5.5.1.1** and **5.5.1.2**.

Toxicity data for degradates of the chlorpyrifos parent compound, were sparse. The potential for additional risk to the California red-legged frog, California tiger salamander and Delta smelt, from exposure to chlorpyrifos oxon as a transformation product of applied chlorpyrifos is characterized in the risk description (**Section 5.2**), along with indirect effects to the other species of concern. A detailed summary of the available ecotoxicity information for chlorpyrifos oxon and citations that include studies using degradates and formulated products can be found in **Section 4.6** and **Appendices F**, and **G**, respectively.

As discussed in the problem formulation, toxicity data show that other pesticides may combine with chlorpyrifos to produce synergistic, additive, and/or antagonistic toxic interactions. Toxicity studies of mixtures of chlorpyrifos with other pesticides are listed in **Appendix A.** If chlorpyrifos is present in the environment in combination with other chemicals, the toxicity of the mixture may be increased relative to the toxicity of each individual chemical, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they were also present in the mixture. The variety of chemical interactions presented in the available data set suggest that the toxic effect of chlorpyrifos, 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 chlorpyrifos 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 taxon with confidence was beyond the capabilities of the available data.

4.1 Toxicity of Chlorpyrifos to Aquatic Organisms

A brief summary of open literature data considered relevant to this ecological risk assessment for the California red-legged frog, California tiger salamander, Delta smelt, California freshwater shrimp and listed species that rely on aquatic organisms for food, is presented in **Appendix E.** The most sensitive of these endpoints are listed in **Table 4.1;** this selection was based on an evaluation of both the submitted studies and the open literature, as previously discussed. These endpoints were used to calculate RQs that relied on aquatic data. Amphibian data were used to calculate acute and chronic RQs for direct effects on the aquatic-phase California red-legged frog and California tiger salamander and indirect effects on organisms that feed on aquatic-phase amphibians. Freshwater and estuarine/marine fish data were used to calculate RQs for direct effects on the Delta smelt and indirect effects on organisms that feed on fish. Freshwater crustacean data were used to calculate RQs for direct effects on the California freshwater shrimp. Freshwater and estuarine/marine invertebrate data were used to calculate RQs for indirect effects on organisms that feed on these aquatic invertebrates, respectively. The non-vascular plant datum was used to represent all plant groups and calculate potential indirect effects for all species studied.

Table 4.1 Aquatic toxicity profile for chlorpyrifos					
Taxon	**Exposure Duration**	**Most Sensitive Species Tested**	**Toxicity Value**	**Acute Toxicity Category**	**Reference**
Aquatic-phase Amphibians	Acute	African clawed frog tadpole, *Xenopus laevis*	LC50 = 0.6 ug/L	Very highly toxic	E86343 Richards, 2000
	Chronic	African clawed frog tadpole, *X. laevis*	LOAEC = 0.1 ug/L No NOAEC	N/A	E71867 Richards & Kendall, 2003
Freshwater Fish	Acute	Bluegill Sunfish *Lepomis macrochirus*	LC50= 1.8 µg/L	Very highly toxic	40098001 Mayer & Ellersieck, 1986
	Chronic	Fathead minnow, *Pimephales promelas*	Life-Cycle NOAEC = 0.57 ug/L	N/A	42834401 Mayes *et al.*, 1993
Estuarine/ Marine Fish	Acute	Tidewater silverside *Menidia peninsulae*	LC50= 0.70 µg/L	Very highly toxic	E11868 Borthwick *et al.*, 1985
	Chronic	Atlantic silverside *M. menidia*	NOAEC = 0.28 µg/L	N/A	00154718 Goodman *et al.* 1985
Freshwater Invertebrates	Acute Crustacean	Daphnid, *Ceriodaphnia dubia*	LC50 = 0.07 µg/L	Very highly toxic	E108483 Pablo *et al.*, 2008
	Acute Insect	Blackfly *Simulium vittatum IS-7*	LC50 = 0.06 µg/L	Very highly toxic	E80409 Hyder *et al.*, 2005
	Chronic	Daphnid, *C.* cf *dubia*	NOAEC = 0.025 ug/L	N/A	E65825 Rose *et al.*, 2002
Estuarine/ Marine Invertebrates	Acute	Mysid shrimp *Americamysis bahia*	LC50 = 0.035 µg/L	Very highly toxic	40228401 Mayer 1986
	Chronic	Mysid shrimp *A. bahia*	NOAEC < 0.0046 µg/L	N/A	42664901 Sved *et al.* 1993
Non-vascular plant	Acute	Alga *Isochrysis galbana*	EC50 = 140 µg/L	N/A	40228401 Mayer 1986

Toxicity to fish, aquatic invertebrates, birds, and mammals is categorized using the system shown in **Table 4.2** (USEPA, 2004). For non-target terrestrial insects, chemicals with LD_{50} values of <2, 2 – 11, and >11 µg/bee are classified as highly toxic, moderately toxic, and practically nontoxic, respectively Toxicity categories for terrestrial and aquatic plants have not been defined.

Table 4.2 Categories of Acute Toxicity for Terrestrial and Aquatic Animals.			
Toxicity Category	**Aquatic Animals [LC_{50}/EC_{50} (mg/L)]**	**Birds and Mammals [LD_{50} (mg/kg-bw)]**	**Birds [LC_{50} (mg/kg-diet)]**
Very highly toxic	< 0.1	<10	<50
Highly toxic	0.1 - 1	10 – 50	50 – 500
Moderately toxic	> 1 - 10	51 – 500	501 – 1000
Slightly toxic	> 10 - 100	501 – 2000	1001 – 5000
Practically nontoxic	> 100	>2000	>5000

4.1.1 Toxicity to Freshwater Fish and Aquatic-Phase Amphibians

Fish and aquatic-phase amphibian toxicity data were used to evaluate direct effects to the Delta smelt and to aquatic-phase California tiger salamander and California red-legged frog, as well as potential indirect effects to the California clapper rail and San Francisco garter snake. A summary of acute and chronic freshwater fish and aquatic-phase amphibian data, including data from the open literature, is provided below in Sections 4.1.1.1 through 4.1.1.3. Additional information is included in **Appendices E, F and G**.

4.1.1.1 Freshwater Fish: Acute Exposure (Mortality) Studies

Acceptable chlorpyrifos toxicity data were available for several fish species, including fathead minnows (*Oncoryncus mykiss*), guppies (*Poecilla reticulate*), rainbow trout *(Oncorhynchus mykiss)*, and bluegill sunfish *(Lepomis macrochirus)*. LC_{50} values were similar between most of these species, but a few species were quiet resistant, with freshwater values ranging from 1.8 to 280 ug/L chlorpyrifos in bluegill sunfish and channel catfish, respectively (MRID 40098001 and 40098001), **Appendix E** (also see USEPA, 2002). Chlorpyrifos is classified as very highly toxic to most fish on an acute exposure basis.

The most sensitive species among the freshwater and estuarine/marine fish species tested was used to calculate risk quotients and characterize the risk for the Delta smelt, regardless of the salinity environment because the Delta smelt enters both freshwater and saltwater environments. No acceptable acute LC_{50} values for fish were located in the open literature, that were more sensitive than those already accepted from former assessments. Therefore, the lowest LC_{50} reported for fish, which was 1.8 ug/L chlorpyrifos for bluegill sunfish (MRID 40098001*)*, was used for risk quotient (RQ) calculations for the Delta smelt (**Table 4.1**).

4.1.1.2 Freshwater Fish: Chronic Exposure (Growth/Reproduction) and Sublethal Effects Studies

The collection of chronic studies reviewed in the most recent chlorpyrifos RED (USEPA, 2002, summarized in **Appendix E**) provide enough data to show that reproductive effects are likely to result from chlorpyrifos exposures. The fathead minnow NOAEC value was selected as the fish chronic endpoint in that RED, because survival was significantly reduced at 1.09 ppb (the LOAEC; MRID 42834401); the NOAEC was 0.57 ppb chlorpyrifos. This test reported significant ($P < 0.05$) effects on adult length and adult body weight. These effects were determined to be temporal and/or non-dose related, hence they were not used for the LOAEC determination. Rather, the LOAEC of 1.09 ppb was based on significant reduction in survival for adults (14 % by Day 12) and offspring (35% by Day 5). This life-cycle study showed that the second generation was more sensitive than the first generation. This study fulfilled guideline requirement for a chronic freshwater fish study with technical grade chlorpyrifos and was used to calculate chronic RQs for the Delta smelt (**Table 4.1**)

Sublethal effects were also reviewed in the open literature where the exposure duration was sub-chronic (**Appendix E**). One such study (De Silva & Samayawardhena, 2002) using a typical end-use product, reported mortality, paralysis and histological abnormalities in juvenile guppies exposed to chlorpyrifos. This study showed guppies to be more sensitive to chlorpyrifos than fathead minnows, but the study did not produce an NOAEC. Authors looked at behavioral and histological effects of low concentrations of Lorsban to early life stages of guppies (*Poecilla reticulate*). The test concentrations were expressed as ug/L Lorsban, rather than ug/L chlorpyrifos. The Lorsban used in the study contained.400 ug/L chlorpyrifos, purity 98%. It may be assumed that the actual LC_{50} and LOAEC were approximately 60% lower than those reported but since concentrations were not measured, it was not possible to confirm these data, and, thus the data could not be used to calculate the risk quotient. Concentrations as low as 1 ug/L caused changes in swimming behavior within 96 h. Authors stated that from the onset of the experiment, the initial quick swimming behavior shifted to unusual swimming behavior. By day-14 signs of paralysis and hemorrhaging were recorded in the lowest concentration tested 0.5 ug/L Lorsban, which calculates to 0.2 ug/L chlorpyrifos. Therefore the LOAEC was 0.2 ug/L chlorpyrifos but no NOAEC was determined. This was the most sensitive endpoint for fish but could not be confirmed and so was not used to calculate RQs.

The dose:response relationships were a bit different between fish and amphibians in the data EPA reviewed. Explicitly, looking at fathead minnow data from the most recent RED (USEPA, 2002; **Appendix E**) chronic effects were measured in concentrations over 300 times lower than the concentration range where acute toxicity was measured. In guppies, also, chronic effects were seen in concentrations over 100 times lower than those where acute toxicity was measured. This indicates a dose:response relationship for fish that is not very shallow. This characteristic was used to compare chlorpyrifos toxicity between fish and amphibians in the risk characterization section (see **Sections 5.5.1.1. and 5.5.2.1**).

4.1.1.2 Aquatic-phase Amphibian: Acute and Chronic Studies

Toxicity tests on amphibians are typically not required. It was assumed that acute oral toxicity data for birds and acute toxicity data for fish will protect adult and aquatic life stages of amphibians, respectively. Studies reviewed in the most recent chlorpyrifos RED (USEPA, 2002) showed that chlorpyrifos via oral exposure is at most moderately toxic to amphibians, suggesting that avian acute toxicity data are protective of adult amphibians. The results from that aquatic data showed however, that chlorpyrifos is very highly toxic to larval amphibians. Small tadpoles appeared to be more sensitive to chlorpyrifos than older life stages. The fact that young tadpoles were equal to or more sensitive to chlorpyrifos than the most sensitive fish species raises concerns for risks in shallow waters which are a typical habitat for frogs and tadpoles. The tadpole 96-hour LC_{50} value (0.6 ppb) was slightly more sensitive than the most sensitive fish species (bluegill LC_{50} 1.8 ppb; **Table 4.1**).

Table 4.3 Amphibian Toxicity Profile for Chlorpyrifos

- all frog tests supplemental, no current EPA approved method.

Assessment Endpoint	Acute/ Chronic	Species of Tadpole	Toxicity Value Used in Risk Assessment (ug a.i./L)	MRID/ ECOTOX Ref.	Comment
Aquatic-Phase Amphibians	Acute	African clawed frog tadpole, *Xenopus laevis*	96-h LC50 = 0.6	E86343 Richards, 2000	Not native species.
		X. laevis	96-h LC50 = 560 for metamorphs 96-h LC50 = 146 for premetamorphs	E68227 Richards and Kendall, 2002	Not native species.
		Indian bullfrog tadpole, *Rana tigrina*	24-h LC50 = 19	E61878 Abbasi, and Soni, 1991	Not native species. Missing information.
		Yellow-legged frog tadpole, *Rana boylii*	24-h LC50 = 3000	E92498 Sparling & Fellers 2007	Test concentrations not confirmed.
		R. boylii Northern Pacific treefrog tadpole, *Pseudacris regilla*	40-d toxicity LC50 = 67 LC50 = 365	Sparling & Fellers 2009 (too recent for an ECOTOX number)	Test concentrations not confirmed.
		X. laevis	LOAEC = 0.1 No NOAEC (NOAEC=<0.1)	E71867 Richards & Kendall, 2003	No NOAEC, not native species.
		Southern leopard frog tadpole, *Rana sphenocephala*	LOAEC = 100 NOAEC = 10	E101289 Widder & Bidwell, 2006	None.

Table 4.3 Amphibian Toxicity Profile for Chlorpyrifos - all frog tests supplemental, no current EPA approved method.					
Assessment Endpoint	**Acute/ Chronic**	**Species of Tadpole**	**Toxicity Value Used in Risk Assessment (ug a.i./L)**	**MRID/ ECOTOX Ref.**	**Comment**
	Chronic	North American anuran frog tadpoles, *Hyla chrysoscelis,*	12-d Growth: LOAEC= 200 NOAEC=100 ChE Activity[1]: LOAEC= 1 NOAEC=<1	E101727 Widder & Bidwell, 2008	None.
		Rana sphenocephala,	12-d Growth: LOAEC= 10 NOAEC=1 ChE Activity: LOAEC= 100 NOAEC=10		
		Acris crepitans	12-d Growth: LOAEC= >200 NOAEC=200 ChE Activity: LOAEC= 10 NOAEC= 1		
		Gastrophyne olivacea	12-d Growth: LOAEC= 200 NOAEC= 100 ChE Activity: LOAEC= 10 NOAEC=1		
		X. laevis	TC50[2] = 162	E76738 Bonfanti, et al. 2004	Not native species.
		R. boylii *P. regilla*	LOAEC = 200 NOAEC = 50	Sparling & Fellers 2009	Test concentrations not confirmed.
		R. boylii	LOAEC = 200 NOAEC = 50	E92498 Sparling & Fellers 2007	Test concentrations not confirmed.

[1] ChE Activity: Cholinesterase activity impairment.
[2]TC50 – Teratogenic concentration affecting 50% of test organisms.

Acute and chronic studies with amphibians were reviewed in the open literature (**Table 4.3**). Since EPA does not have an approved method for amphibian toxicity tests, all studies reviewed were considered supplemental. Chlorpyrifos toxicity data were available for several aquatic phase amphibian species, including three species of the same genus as the California red-legged frog -- the Yellow-legged frog, *Rana boylii*, Southern leopard frog, *R. sphenocephala*, and Indian bullfrog, *R. tigrina*. The yellow-legged frog datum was used to calculate the acute risk quotient for the California red-legged frog and tiger salamander (**Table 4.1**). Also available were data on the Northern Pacific treefrog, *Pseudacris regilla* and other North American anuran frogs, *Hyla chrysoscelis, Acris crepitans* and *Gastrophyne olivacea*, as well as the much-studied African clawed frog, *Xenopus laevis*. *X. laevis*, a non-native species had the most sensitive endpoints for both acute and chronic, with an LC50 of 0.6 ug/L and an NOAEC of <0.1 ug/L chlorpyrifos. Even though this species was non-native, both acute and chronic studies were determined to be scientifically sound and these endpoints were used to calculate risk quotients for the California red-legged frog and California tiger salamander (**Table 4.1**). The steep dose:response relationship for *X. laevis* is compared to the much more shallow dose:response relationship for fish in the risk characterization section (see **Sections 5.5.1.1. and 5.5.2.1).**

4.1.2 Toxicity to Freshwater Invertebrates

Aquatic invertebrate toxicity studies were used to assess direct effects to California freshwater shrimp and potential indirect effects to the California red-legged frog, San Francisco garter snake, California clapper rail, California tiger salamander and Delta smelt. A summary of acute and chronic freshwater invertebrate data, including data published in the open literature, is provided below in **Sections 4.1.2.1** through **4.1.2.2**.

4.1.2.1 Freshwater Invertebrates: Acute Exposure Studies

The best data for assessing direct effects to the California freshwater shrimp was determined to be that of another freshwater crustacean, a daphnid, *Ceriodaphnia dubia*, which had a 96-hr LC_{50} of 0.07 ug/L chlorpyrifos (Pablo, *et al*., 2008). For the indirect effects assessment, the most sensitive aquatic invertebrate species was used to estimate the risk to the food source of several species of concern (see previous paragraph), which is consistent with USEPA (2004). The most sensitive aquatic invertebrate tested was the freshwater blackfly (*Simulium vittatum* IS-7), with an LC_{50} of 0.06 ug/L chlorpyrifos (Hyder *et al*., 2005). The sensitivity range in these data is very narrow and both of these acute endpoints have similar sensitivity to that used in the most recent RED (USEPA, 2002); chlorpyrifos is considered very highly toxic to aquatic invertebrates.

4.1.2.2 Freshwater Invertebrates: Chronic Exposure Studies

Toxicity data from chronic exposure to chlorpyrifos were available for freshwater daphnids, insects and one freshwater shrimp. The sensitivity range was very narrow. The most sensitive endpoint was found in the daphnid, *Ceriodaphnia* cf *dubia* (a non-native sub-species of *C. dubia*) which had a 33-d NOAEC of 25 ug/L chlorpyrifos (Rose *et al*., 2002). This endpoint was used for risk estimations of indirect effects from chronic toxicity to food items of species listed in **Section 4.1.2.** Midge studies showed that midges can be affected by 0.02 ug/L chlorpyrifos in the water column or 0.32 ug/Kg chlorpyrifos in the sediment (see **Appendix E**). A few aquatic invertebrate studies had both acute and chronic data available, showing that the range of acute to chronic effects concentrations were very close, indicating a steep dose:response relationship. This is similar to the relationship found in amphibian studies but different from that found in fish studies; fish studies had a much shallower dose:response relationship with the acute effects concentrations being two orders of magnitude greater than the chronic effects concentrations. This information helps describe the risks from toxicity by giving insights into toxicity profiles (see **Sections 5.5.1.1 and 5.5.2.1**).

The most important food organism for all sizes of the Delta smelt has been reported to be the copepod, *Eurytemora affinis* (USFWS, 1995 and 2004), which was a marine copepod. Supplemental toxicity data were available from the open literature for copepods. In one mesocosm study (Rene, *et al*., 1996), the NOAEC for copepods was <0.1 ug/L chlorpyrifos, which was similar to that of the African clawed frog as seen in Table 4.3. This does raise some concerns, although this study was not designed to fulfill FIFRA requirements and did not produce an acceptable LOAEC or NOAEC.

4.1.3 Toxicity to Estuarine/Marine Fish

Estuarine and marine fish toxicity data were used to evaluate direct effects to the Delta smelt and potential indirect effects to the California clapper rail (**Table 4.1**). A summary of acute and chronic estuarine/marine fish data, including data published in the open literature shows that the LC_{50} values for estuarine/marine fish were less sensitive than for freshwater species, ranging from 96 to 520,000 ug/L chlorpyrifos in Tidewater silversides and Gulf toadfish, respectively (MRID 40228401 and 40228401, **Appendix E**; also see USEPA, 2002). Chlorpyrifos is classified as very highly toxic to most fish on an acute exposure basis.

As mentioned in **Section 4.1.1.1**, the Delta smelt enters both freshwater and saltwater environments. The most sensitive species among the freshwater and estuarine/marine fish species tested was used to calculate risk quotients, which was in this case a freshwater species, the bluegill sunfish (**Table 4.1**).

4.1.4 Toxicity to Estuarine/Marine Invertebrates

Estuarine and marine invertebrate toxicity data were used to evaluate potential indirect effects to the California clapper rail and Delta smelt. A summary of acute and chronic estuarine/marine invertebrate data, including data published in the open literature, shows that chlorpyrifos is very highly toxic to marine and estuarine invertebrates. The mysid shrimp, *Americamysis bahia*, had a 96 h LC50 of 35 ug/L and an NOAEC of 0.0046 ug/L chlorpyrifos (Mayer, 1986 and Sved et al., 1993, respectively). This data was used to estimate risk from indirect effects to the rail and smelt (**Table 4.1**).

4.1.5 Toxicity to Aquatic Plants

Aquatic plant toxicity studies were used as one of the measures of effect to evaluate whether chlorpyrifos may affect primary production. Aquatic plants may also be part of food chains for the California red-legged frog, San Francisco garter snake, California clapper rail, Salt marsh harvest mouse, California tiger salamander, Delta smelt and California freshwater shrimp. In addition, freshwater non-vascular plant data were used to evaluate a number of the PCEs associated with the critical habitat impact analysis. Plant toxicity studies using chlorpyrifos were extremely sparse in the open literature. The endpoint used in the most recent RED (USEPA, 2002) was also used to estimate risks in this assessment; the EC50 for the alga, *Isochrysis galbana*, was 140 ug/L chlorpyrifos (Mayer, 1986, **Table 4.1**).

4.1.6 Freshwater Field/Mesocosm Studies

Three mesocosm studies were reviewed from the open literature. Biever *et al*. (1994) found that chlorpyrifos when sprayed in a single dose had a half-life of approximately 4 days (**Table 4.4**). Most freshwater invertebrate and fish communities were able to recover within a few weeks with the possible exception of Chironominae, a subfamily of Chironomidae. Van den Brink *et al*. (1996) found that the NOAEC for zooplankton/macroinvertebrate communities was 0.1 ug/L chlorpyrifos. Van Wijngaarden *et al*. (1996) compared in-lab single species tests with outdoor mesocosm test results and found that the lab and caged studies differed by a factor of approximately 3. Also notable were copepod data; total copepods had an NOAEC of <0.1 ppm, but copepod nauplii had a NOAEC of 0.9 ppm. Copepod data is especially important to this risk assessment since it is the chief food of the California red-legged frog, as mentioned earlier.

Table 4.4 Mesocosm Studies				
Application	**Communities**	**Effects Concentration in Water (ug a.i./L)**	**ECOTOX Ref.**	**Comment**
Spray Drift – single application of 0.05 to 5% of a 1.12 kg Al/ha application (to yield 0.03 to 3.0 ug/L chlorpyrifos in water)	FW Insects Chironomids Ephemeroptera FW Zooplankton Copepods Ostracods Cladocera FW Fish	LOAEC = 0.10 NOAEC = 0.03 LOAEC = 0.10 NOAEC = 0.03 LOAEC = 0.10 NOAEC = 0.03 LOAEC = 0.3 NOAEC = 0.1 LOAEC = 0.3 NOAEC = 0.1 LOAEC =>3.0 NOAEC = 3.0 LOAEC = 0.3 NOAEC = 0.1 LOAEC = 1.0 NOAEC = 0.3	E62037 Biever *et al*., 1994	Supplemental; Ostracods were the LEAST sensitive taxon (LOAEC = >3.0). Chironominae was the MOST sensitive macroinvertebrate taxon, with significant affects in all treatments. The NOAEC may have been <0.03 but was not confirmed. Also, this group did not recover in the highest treatment by the end of the study, whereas most other communities did recover after two and a half months.
Spray Drift – One application of 0.05 to 5% of a 1.12 kg Al/ha app	Total macroinvertebrate/ zooplankton community.	LOAEC = 0.9 NOAEC = 0.1	E17218 Van den Brink *et al*., 1996	Supplemental; recovery was seen in 24 weeks. Some copepods and other crustacea recovered within 12 weeks.
Lab data vs. Field data	Copepods: All ages Nauplii	NOAEC = <0.0001 NOAEC = 0.0009	E17254 Van Wijngaarden *et al*., 1996	Supplemental

4.2 Toxicity of Chlorpyrifos to Terrestrial Organisms

Table 4.5 summarizes the most sensitive terrestrial toxicity endpoints, based on an evaluation of both the submitted studies and the open literature. In addition to the parent chlorpyrifos, toxicity data on metabolites and degradates are also considered when available. The major chlorpyrifos degradate, 3,5,6-trichloro-2-pyridinol (TCP), forms a large percent of the recoverable active ingredient in various compartments of the environment. However, OPP has determined that TCP is not of toxicological concern to mammals as a plant metabolite based on available mammalian toxicity data. TCP also exhibits low toxicity in birds based on available avian toxicity data. Available fate data indicates that the chlorpyrifos-oxon may be an environmental degradate in soil and water. Based on available toxicity data, the oxon may be significantly more toxic than the parent. However, there are currently insufficient data on toxicity and expected environmental concentrations available to support a quantitative assessment of potential risks to listed species from exposure to the oxon via water and soil intake routes. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment is presented below.

Table 4.5 Terrestrial Toxicity Profile for Chlorpyrifos

Endpoint	Acute/ Chronic	Species	Toxicity Value Used in Risk Assessment	Citation MRID#	Classification
Birds (surrogate for terrestrial-phase amphibians and reptiles)	Acute Dose-based	Common Grackle	LD50 = 5.62 mg/kg	40378401	Supplemental
	Acute Dietary-based	Mallard Duck	LC50 = 136 ppm	00095007	Acceptable
	Chronic Dietary-based	Mallard Duck	NOAEC = 25 ppm	00046952	Acceptable LOAEC = 60 ppm based on reduced number of eggs & reduced body weight of rakes & hens
Mammals	Acute Dose-based	Rat	LD50 = 118 mg/kg	EcoRef No.: 37866	Supplemental
	Acute Dietary-based	Rat	LC50 = 1330 ppm	44585409	Acceptable
	Chronic Dietary-based	Rat	NOAEC = 20 ppm [1] NOAEL = 1 mg/kg	41930301	Acceptable LOAEC = 100 ppm based reduced pup weight and increased pup mortality in F1 generation.
Terrestrial invertebrates	Acute	Honey Bee	LD50 = 0.059 µg a.i./bee	05001991	Acceptable
Terrestrial plants	N/A	Seedling Emergence Monocots	No Data Available		
	N/A	Seedling Emergence Dicots			
	N/A	Vegetative Vigor Monocots			
	N/A	Vegetative Vigor Dicots			

[1] A scaling factor of 20x (FDA, 1959) was applied to the NOAEL of 1 mg/kg to derive the NOAEC (ppm in diet)
N/A: not applicable

Acute toxicity to terrestrial animals is categorized using the classification system shown in **Table 4.6** (U.S. EPA, 2004). Toxicity categories for terrestrial plants have not been defined.

Table 4.6 Categories of Acute Toxicity for Avian and Mammalian Studies		
Toxicity Category	**Oral LD_{50}**	**Dietary LC_{50}**
Very highly toxic	< 10 mg/kg	< 50 ppm
Highly toxic	10 - 50 mg/kg	50 - 500 ppm
Moderately toxic	51 - 500 mg/kg	501 - 1000 ppm
Slightly toxic	501 - 2000 mg/kg	1001 - 5000 ppm
Practically non-toxic	> 2000 mg/kg	> 5000 ppm

4.2.1 Toxicity to Birds, Reptiles, and Terrestrial-Phase Amphibians

As specified in the Overview Document, the Agency uses birds as a surrogate for reptiles and terrestrial-phase amphibians when toxicity data for each specific taxon are not available (U.S. EPA, 2004). No terrestrial-phase amphibian or reptile data are available for chlorpyrifos; therefore, acute and chronic avian toxicity data are used to assess the potential direct effects of myclobutanil to terrestrial-phase CRLFs. A summary of acute and chronic bird data, including data published in the open literature is provided below in Sections 4.2.1.1 through 4.2.1.4.

4.2.1.1 Birds: Acute Exposure (Mortality) Studies

Extensive acute and subacute dietary avian test data are available on technical grade chlorpyrifos. Acute LD50 values for technical grade chlorpyrifos are available for 15 avian species with a range of LD50 values from 5.62 to 476 mg/kg. Two avian species have LD50s less than 10 mg/kg (very highly toxic), eight species have LD50s less than 50 mg/kg (highly toxic), and 5 species have LD50s less than 500 mg/kg (moderately toxic). The most acutely sensitive avian species are common grackle (5.62 mg/kg), ring-necked pheasant (8.41 mg/kg), common pigeons (10 mg/kg) and house sparrow (10 mg/kg). Based on the submitted acute oral toxicity study for the common grackle house (MRID 40378401), chlorpyrifos is categorized as very highly toxic to birds on a dose basis with an acute LD_{50} of 5.62 mg/kg bw (3.16-10 mg/kg, 95% C.I.).

Avian acute toxicity values are also available for microencapsulated and granular chlorpyrifos products and the major degradate, TCP. Avian toxicity data on these two products and the major degradate indicate that they are less toxic (i.e., less hazardous) than technical grade chlorpyrifos.

Table 4.7 Chlorpyrifos Avian Acute Oral Toxicity Findings					
Surrogate Species	**% AI**	**LD50 (mg/kg ai)**	**MRID**	**Toxicity Category**	**Classification**
Ring-necked Pheasant (male) *Phasianus colchicus* (female)	94.5	8.41 17.7	00160000	very highly toxic	Acceptable
Northern Bobwhite (male & female) *Colinus virginianus*	Tech.	32	41043901	Highly toxic	Acceptable
Mallard Duck (female) *Anas platyrhynchos*	99	75.6	00160000	moderately toxic	Acceptable
Mallard Duck *Anas platyrhynchos*	96.3	476	40854701	moderately toxic	Acceptable
Common Grackle *Quiscalus quiscula*	94.5	**5.62**	40378401	very highly toxic	Supplemental
Common Pigeon *Columba livia*	94.5	10.0	40378401	highly toxic	Supplemental
House Sparrow *Passer domesticus*	94.5	10.0	40378401	highly toxic	Supplemental
House Sparrow (male) *Passer domesticus*	94.5	21	00160000	highly toxic	Supplemental
House Sparrow *Passer domesticus*	99.6	122	440571-02	moderately toxic	Supplemental
Red-winged Blackbird *Agelaius phoeniceus*	94.5	13.1	40378401	highly toxic	Supplemental
Coturnix Quail Coturnix japonica	94.5	13.3	40378401	highly toxic	Supplemental
Coturnix Quail (males) Coturnix japonica	94.5	15.9 17.8	00160000	highly toxic	Supplemental
Sandhill Crane (male) Grus canadensis	99.9 94.5	25 50	00160000	highly toxic	Supplemental
Rock Dove (male & female) Columba livia	94.5	26.9	00160000	highly toxic	Supplemental
White Leghorn Cockerel Gallus domesticus	99.9	34.8	00242149	highly toxic	Supplemental
Canada Goose (male & female) Branta canadensis	94.5	40 - 80	00160000	highly toxic	Supplemental
Chuckar (female) Alectoris chukar (male)	99.9	60.7 61.1	00160000	moderately toxic	Supplemental
California Quail (female) Callipepla californica	94.5	68.3	00160000	moderately toxic	Supplemental
Starling Sturnus vulgaris	94.5	75	40378401	moderately toxic	Supplemental
Mallard Duck (duckling) Anas platyrhynchos (male & female)	99	112	00160000	moderately toxic	Supplemental

Endpoint used in risk assessment is in bold

Avian subacute dietary studies are available for four bird species. The lowest avian subacute LC_{50} value used for assessing dietary risks is 136 ppm (84-212 ppm, 95% C.I.) for mallard ducklings (moderately toxic) (MRID 00144288). Results from these acceptable and supplementary studies indicate that chlorpyrifos is moderately to highly toxic to avian species on a subacute dietary basis. Reduced food consumption and was evident in several studies especially at higher test concentrations. There were mortalities in six studies. Most deaths occurred on Days 3 to 5 for bobwhite and Days 3 to 7 for mallards. In some cases, deaths continued to Day 8, the last day of the test.

Table 4.8 Formulation Avian Acute Oral Toxicity Findings

Surrogate Species	% AI	LD_{50} (mg/kg ai)	MRID No.	Toxicity Category	Classification
Northern Bobwhite *Colinus virginianus* (male & female)	25.65 Dursban ME 20	545	41885201	slightly toxic	Acceptable
Northern Bobwhite *Colinus virginianus* (male & female)	15 Lorsban 15 G	108	41043901	moderately toxic	Acceptable
House Sparrow *Passer domesticus* (male & female)	15 Lorsban 15 G	109	44057101	moderately toxic	Supplemental

Table 4.9 Chlorpyrifos Avian Subacute Dietary Toxicity Findings

Surrogate Species	% AI	LC_{50} (ppm ai)	MRID No.	Toxicity Category	Classification
Mallard Duck *Anas platyrhynchos*	99	**136**	00095007	highly toxic	Acceptable
Mallard Duck *Anas platyrhynchos*	96.8	203	40854702	highly toxic	Acceptable
Northern Bobwhite *Colinus virginianus*	96.8	423	00046955	highly toxic	Acceptable
Northern Bobwhite *Colinus virginianus*	99	505	00095123	moderately toxic	Acceptable
Northern Bobwhite *Colinus virginianus*	96.8	506	40854703	moderately toxic	Acceptable
Northern Bobwhite *Colinus virginianus*	Assumed Tech.	531	44585401	moderately toxic	Acceptable
Ring-necked Pheasant *Phasianus colchicus*	97.0	553	00022923	moderately toxic	Acceptable
Mallard Duck *Anas platyrhynchos*	96.8	590	00046954	moderately toxic	Acceptable
Northern Bobwhite *Colinus virginianus*	94	863	44585403	moderately toxic	Acceptable
Northern Bobwhite *Colinus virginianus*	Assumed Technical	283	44585401	highly toxic	Supplemental
Coturnix Quail *Coturnix japonica*	97	293	00115301	highly toxic	Supplemental
Coturnix Quail *Coturnix japonica*	97.0	299	00022923	highly toxic	Supplemental
Mallard Duck *Anas platyrhynchos*	97.0	940	00022923	moderately toxic	Supplemental
Coturnix Quail *Coturnix japonica*	41	492	00115301	highly toxic	Supplemental

Endpoint used in risk assessment is in bold

Avian dietary toxicity values for formulations (i.e., emulsified concentrate (4 EC) and microencapsulated (ME 20) indicate less toxicity than technical grade chlorpyrifos.

Table 4.10 Formulation Avian Subacute Dietary Toxicity Findings

Surrogate Species	% AI	LC_{50} (ppm ai)	MRID No.	Toxicity Category	Classification
Coturnix Quail *Coturnix japonica*	40.7 Lorsban 4 EC	492	00115301	highly toxic	Supplemental
Northern bobwhite *Colinus irginianus*	25.65 Dursban ME 20	387	41965502	moderately toxic	Acceptable
Mallard Duck *Anas latyrhynchos*	25.65 Dursban ME 20	803	41965501	slightly toxic	Acceptable

The major chlorpyrifos degradate, 3,5,6-trichloro-2-pyridinol (TCP), forms a large percent of the recoverable active ingredient in various compartments of the environment. Therefore, a special (70-2) 8-day subacute oral test with either waterfowl or upland game bird was required to address these concerns. Test results are provided below

Table 4.11 TCP Degradate Avian Subacute Dietary Toxicity Findings

Surrogate Species	% AI	LC_{50} (ppm ai)	MRID No.	Toxicity Category	Classification
Mallard Duck *Anas platyrhynchos*	99.9 % 3,5,6-TC-2-P	> 5,620	41829002	slightly toxic	Supplemental LC50 uncertain due to high reduction in food consumption

4.2.1.2 Birds: Chronic Exposure (Growth, Reproduction) Studies

Five avian chronic toxicity studies are available for chlorpyrifos. While some of the avian reproduction studies are inadequate to assess risks alone, together the studies are adequate to assess effects on avian reproduction. All 5 studies indicate reductions in the number of eggs laid. Other reproductive effects found were eggshell thinning and fewer young. Chronic effects identified include increased adult mortality and adult body weight reduction. Mallard ducks were the most sensitive species and show a pattern of lethal effects on adults, reduced egg production, eggshell thinning, reduced body weight of hatchlings and reduced number of young at 60, 100, and/or 125 ppm. One reproductive study on mallard ducks indicates that chlorpyrifos reduces the number of eggs laid and the adult body weights at 60 ppm (MRID 42144901). The dietary concentration in this study was reduced from 90 ppm to 60 ppm at the beginning of week 8 due to body weight losses and mortality. A second mallard duck study showed 84 percent reduction in the number of eggs and 89 percent reduction in the number of young at 125 ppm, the LOAEC. Bobwhite quail reproduction results suggest that the LOAEC is 130 ppm based on reduced number of eggs produced. The risk assessment endpoint for avian reproduction is a NOAEC of 25 ppm.

Table 4.12 Avian Reproduction Findings					
Surrogate Species	**% A.I.**	**NOAEC-LOAEC (ppm)**	**Statistically ($P < 0.05$) Significant Endpoints**	**MRID No.**	**Classification**
Mallard Duck *Anas platyrhynchos* (8-week prelim study)	96.7	NOAEC 46 LOAEC 100	100 ppm - 84% reduction in # of eggs	00046953	Supplemental
Mallard Duck *Anas platyrhynchos*	96.8	NOAEC 30 LOAEC 60	60 ppm - 46% red. # eggs red. body weight of rakes & hens	42144901	Supplemental
Mallard Duck *Anas platyrhynchos*	96.8	NOAEC **25** LOAEC 125	125 ppm - 40% drakes & 16% hens died; 84% red. # eggs; 9% red. Eggshell thickness; 89% fewer young	00046952	Acceptable
Northern Bobwhite *Colinus virginianus*	96.8	NOAEC 40 LOAEC 130	130 ppm- 27% red. # eggs	42144902	Supplemental
Northern Bobwhite *Colinus virginianus*	96.8	NOAEC 25 LOAEC > 125	125 ppm - 12% reduction in # of eggs; not stat. sign.	00046951	Supplemental

Endpoint used in risk assessment is in bold

4.2.1.3 Birds: Terrestrial Field Studies

Three submitted terrestrial field studies are available on corn, citrus, and golf courses and a large pen, simulated field study was conducted on turf with bobwhite quail. In an Iowa field study on corn, chlorpyrifos was applied as either Lorsban 4E, an emulsifiable concentrate formulation, to 4 fields (4 applications per field; 1.7 to 3.4 kg/ha [1.5 - 3 lbs ai/A]) or as Lorsban 15G, a granular formulation, to 4 fields (3 applications per field; 1.1 to 2.9 kg/ha [1 - 2.6 lbs ai/A]). Chlorpyrifos levels were measured in various environmental samples. Field investigators considered any death likely to be treatment-related if analytical analyses tested positive for chlorpyrifos residues in samples. Carcass searches made in the corn field study found evidence of 14 avian post-treatment casualties.

In a California orange grove field study, chlorpyrifos (i.e., Lorsban 4 E) was applied with two spray regimes. Under regime A, 4 fields were treated with 2 applications each: 1.5 lbs ai/A followed about 30 days later by a treatment at 6.0 lbs ai/A. Regime B also treated each of 4 fields twice (sprayed once at 3.5 lbs ai/A followed about 30 days later by a second treatment at 4.0 lbs ai/A). Searches for dead wildlife identified 192 carcasses. Twenty one carcasses were analyzed for the presence of chlorpyrifos. Six of tested carcasses tested positive for chlorpyrifos residues (28.6%). Consequently, those deaths may be presumed to be associated with chlorpyrifos treatments. Species that tested positive for chlorpyrifos were a mockingbird, an unidentified passerine nestling, house mouse, ground squirrel, pocket gopher, and a western rattlesnake. While the number of dead wildlife found during carcass searches does not show a dose-relationship with treatment levels, the number of carcasses testing positive for chlorpyrifos suggests that there could be a dose-relationship (i.e., 4 carcasses at 6 lbs ai/A, 1 each at 3.5 and 4 lbs ai/A, and none at 1.5 lbs ai/A). However the number of positive carcasses is too small to verify this conclusion.

Results of the third study, a Central Florida golf course field study indicated that, in general, turf areas on golf courses are not attractive habitat to many wildlife species. Most wildlife observed in the study lived and fed in areas adjacent to the golf courses.

A large pen, simulated field study was conducted on turf with bobwhite quail. The turf and food (seeds) were treated with two applications of Pyrinex 4 E at 3 lbs ai/A (applied at a 2 week interval), another area was treated at 6 lbs ai/A. The maximum measured chlorpyrifos levels 470, 570 and 1400 ppm on grass and 18, 21 and 30 ppm on seeds. The maximum, measured residue levels on the turf approximate the chlorpyrifos EECs (720 and 1440 ppm). Statistically significant effects were reported for abnormal behavior in bobwhite exposed to the 6 lbs ai/A treatment. According to the author, the NOAEL and LOAEL for this turf study are 3 and 6 lbs ai/A, respectively, based on abnormal behavior.

4.2.1.4 Reptile and Terrestrial-phase Amphibian Studies

No species-specific studies available on reptiles or terrestrial-phase amphibians. However, results from terrestrial field studies in total provide evidence of chlorpyrifos-related mortality in reptiles and terrestrial-phase amphibians (i.e., snakes, turtles, toads).

4.2.2 Toxicity to Mammals

A summary of acute and chronic mammalian data, including data published in the open literature, is provided below in Sections 4.2.2.1 through 4.2.1.2.

4.2.2.1 Mammals: Acute Exposure (Mortality) Studies

The available mammalian acute oral LD50 values indicate that chlorpyrifos is moderately toxic to small mammals on an acute oral basis. In acute oral studies on chlorpyrifos, LD50 values range from 118-245 mg/kg bw (EcoRef No.: 37866). The most sensitive endpoint for the technical formulation, the rat LD50 of 118 mg/kg is used estimate risk via direct effects mammals and indirect effects to birds, reptiles and terrestrial-phase amphibians. [Note The lowest LD50 of 118 mg/kg from a literature study (EcoRef No.: 37866) is used in place of the LD50 value of 97 mg/kg used in previous chlorpyrifos assessments. Based on the information provided in this study, the previously used LD50 of 97 mg/kg is actually the lower bound of a 95% confidence limit from Dow-Wister rat study (MRID 41043901). The LD50 from Dow-Wister study is actually 163 mg/kg (97-276 mg/kg 95% CI). Given that a study on Sherman rats results in a lower LD50 of 118 mg/kg compared to the correct LD50 of 163 in Dow-Wister rats, the lower LD50 is more appropriately used to assess risk to mammals.]

Table 4.13 Mammalian Acute Oral Toxicity Findings					
Surrogate Species	**% AI**	**LD_{50} (mg/kg ai)**	**MRID No.**	**Toxicity Category**	**Classification**
Albino Rat (Male) *Rattus norvegicus*	97.2	**118**	EcoRef No.: 37866	moderately toxic	Supplemental
Albino Rat (Male) *Rattus norvegicus*	97.2	135	EcoRef No.: 37866	moderately toxic	Supplemental
Albino Rat (Female) *Rattus norvegicus*	Unknown	135	EcoRef No.: 37866	moderately toxic	Supplemental
Rat (Female) *Rattus norvegicus*	Tech.	137	00000179	moderately toxic	Acceptable
Albino Rat (Male) *Rattus norvegicus*	99.0 %	151	00160000	moderately toxic	Acceptable
Albino Rat (Female) *Rattus norvegicus*	97.2	155	EcoRef No.: 37866	moderately toxic	Supplemental
Albino Rat (Male) *Rattus norvegicus*	Unknown	163	41043901 EcoRef No.: 37866	moderately toxic	Acceptable
Albino Rat (Male) *Rattus norvegicus*	Unknown	245	EcoRef No.: 37866	moderately toxic	Acceptable

Endpoint used in risk assessment is in bold

Mammalian subacute dietary test data are useful to assess short-term risks to small mammals in addition to using an estimated 1-day LD50s from acute oral studies. The subacute dietary data are based on 14-day studies with a 5-day exposure period followed by a 9-day untreated, observation period (McCann *et al*. 1981). Mammalian LC_{50}'s are reported below. These mammalian subacute dietary LC_{50} values indicate that chlorpyrifos is slightly toxic to small mammals.

Table 4.14 Mammalian Subacute Dietary Toxicity Findings					
Surrogate Species	**% AI**	**LC_{50} (ppm ai)**	**MRID No.**	**Toxicity Category**	**Classification**
Albino Rat *Rattus norvegicus* (male & female)	97.1 %	**1330**	44585409	slightly toxic	Acceptable
Albino Rat *Rattus norvegicus* (male & female)	97.1 %	1390	44585410	slightly toxic	Acceptable
Albino Rat *Rattus norvegicus* (male & female)	97.1 %	1780	44585411	slightly Toxic	Acceptable
Albino Rat *Rattus norvegicus* (male & female)	Unknown	2970	44585413	slightly toxic	Acceptable
Albino Rat *Rattus norvegicus* (male & female)	97.1 %	3500	44585414	slightly toxic	Acceptable

Endpoint used in risk assessment is in bold

The major chlorpyrifos degradate, 3,5,6-trichloro-2-pyridinol (TCP), forms a large percent of the recoverable active ingredient in various compartments of the environment. Therefore, acute oral tests with rats and mice were required by HED to address these concerns. Results of those studies are provided below.

Table 4.15 TCP Degradate Mammalian Acute Oral Toxicity Findings					
Surrogate Species	**% AI**	**LD_{50} (mg/kg)**	**MRID**	**Toxicity Category**	**Classification**
Mice (Male/Female) *Mus* sp.	Tech. 3,5,6-TC-2-P	380/415	3F2884 4/1/91	Moderately toxic	Acceptable
Rats (Male/Female) *Rattus* sp.	Tech. 3,5,6-TC-2-P	794/870	3F2884 4/1/91	Slightly toxic	Acceptable

4.2.2.2 Mammals: Chronic Exposure (Growth, Reproduction) Studies

Two rat reproduction (2-generation and 3-generation) studies are available for chlorpyrifos (MRIDs 41930301 and 00029064). The chronic exposure endpoint used in the assessment is from the 2-generation rat reproduction study. The NOAEC/NOAEL in the 2-generation study is 20 ppm (1 mg/kg bw/day) with a LOAEC/LOAEL of 100 ppm (5 mg/kg bw/day). Reproductive effects in 100 ppm F1 pups included reduced pup weights and increased pup mortality that corresponded to slightly but significantly reduced body weight gain in F0 Dams during lactation days 1-21. In the 3-generation reproduction study, reproductive effects were not seen at the highest dose tested. While parental toxicity (cholinesterase inhibition) at lower doses in both reproduction studies (2 and 6 ppm), the selected reproduction endpoint is used in the risk assessment because the parental systemic toxicity endpoints are not considered to be relevant to either growth or reproductive effects.

Table 4.16 Mammalian Chronic Toxicity Data					
Common Name	**%AI**	**Study Parameters**	**NOAEC/LOAEC**	**MRID**	**Classification**
Laboratory rat *Rattus norvegicus*	97.8-98.5	2-Generation reproduction study 30 rats/sex/group 0, 2, 20 or 100 ppm 0.1, 1 or 5 mg/kg bw/day	Parental NOAEC/NOAEL: 2 ppm/0.1 mg/kg bw/day Parental LOAEC/LOAEL: 20 ppm/1 mg/kg bw/day based on significant plasma and red blood cell cholinesterase inhibition Offspring/Reproductive NOAEC/NOAEL: **20 ppm/1 mg/kg/day** Offspring/Reproductive LOAEC/LOAEL: 100 ppm/5 mg/kg/day based reduced pup weight and increased pup mortality in F1 generation.	41930301	Acceptable
Laboratory rat *Rattus norvegicus*	Presumed Technical	3-Generation reproduction study 10 M rats/sex/group 20 M rats/sex/group 0, 0.03, 0.1 or 0.3 mg/kg/day 1st Generation 0, 0.1, 0.3 or 1.0 mg/kg/day 2nd 3rd Generations	Parental NOAEL: 0.1 mg/kg bw/day Parental LOAEL: 0.3 ppm/1 mg/kg bw/day based on plasma and red blood cell cholinesterase inhibition Offspring/Reproductive NOAEC/NOAEL: > 1 mg/kg (HDT) Offspring/Reproductive LOAEL: not identified.	00029064 00064934	Acceptable
[1] **Bold** value is the value that will be used to calculate risk quotients					

4.2.2.3 Mammals: Terrestrial Field Toxicity Studies

Three submitted terrestrial field studies are available on corn, citrus, and golf courses. In an Iowa field study on corn, chlorpyrifos was applied as either Lorsban 4E, an emulsifiable concentrate formulation, to 4 fields (4 applications per field; 1.7 to 3.4 kg/ha [1.5 - 3 lbs ai/A]) or as Lorsban 15G, a granular formulation, to 4 fields (3 applications per field; 1.1 to 2.9 kg/ha [1 - 2.6 lbs ai/A]). Chlorpyrifos levels were measured in various environmental samples. Field investigators considered any death likely to be treatment-related if analytical analyses tested positive for chlorpyrifos residues in samples. Carcass searches made in the corn field study found evidence of 10 mammalian post-treatment casualties. The supplementary corn field study provides useful information which generally supports other available data on residue levels and mammalian mortality.

In a California orange grove field study, chlorpyrifos (i.e., Lorsban 4 E) was applied with two spray regimes. Under regime A, 4 fields were treated with 2 applications each: 1.5 lbs ai/A followed about 30 days later by a treatment at 6.0 lbs ai/A. Regime B also treated each of 4 fields twice (sprayed once at 3.5 lbs ai/A followed about 30 days later by a second treatment at 4.0 lbs ai/A). Searches for dead wildlife identified 192 carcasses. Twenty one carcasses were analyzed for the presence of chlorpyrifos. Six of tested carcasses tested positive for chlorpyrifos residues (28.6%). Consequently, those deaths may be presumed to be associated with chlorpyrifos treatments. While the number of dead wildlife (including birds) found during carcass searches does not show a dose-relationship with treatment levels, the number of carcasses testing positive for chlorpyrifos suggests that there could be a dose-relationship (i.e., 4 carcasses at 6 lbs ai/A, 1 each at 3.5 and 4 lbs ai/A, and none at 1.5 lbs ai/A). However the number of positive carcasses are too few to verify this conclusion.

Results of the third study, a Central Florida golf course field study indicated that, in general, turf areas on golf courses are not attractive habitat to many wildlife species. Most wildlife observed in the study lived and fed in areas adjacent to the golf courses.

4.2.3 Toxicity to Terrestrial Invertebrates

A summary of acute terrestrial invertebrate data, including data published in the open literature, is provided below in Sections 4.2.3.1 through 4.2.3.2.

4.2.3.1 Terrestrial Invertebrates: Acute Exposure (Mortality) Studies

Chlorpyrifos is classified as very highly toxic to bees based on the three available acute toxicity studies. The acute contact LD50 of 0.059 µg/bee or 0.46 ppm (MRID 05001991). This endpoint will be used to quantitatively assess risk via indirect effects to terrestrial invertebrates.

Table 4.17 Nontarget Insect Acute Contact Toxicity Findings

Surrogate Species	% AI	LD_{50} (µg a.i./bee)	MRID	Toxicity Category	Classification
Honey Bee *Apis mellifera*	Tech.	0.059	05001991	highly toxic	Acceptable
Honey Bee *Apis mellifera*	Tech.	0.114	00066220	highly toxic	Acceptable
Honey Bee *Apis mellifera*	Tech.	< 0.1 100% dead at 0.01 % solution LD_{50} not determined	05011163	highly toxic	Supplemental

4.2.3.2 Terrestrial Invertebrates: Foliar Residue and Field Studies

Foliar residue studies indicate that chlorpyrifos has short-term residual toxicity to bees. Based on two laboratory studies of chlorpyrifos residues on alfalfa foliage following application of two formulation indicate residual toxicity which may remain high as long as 24 hours to honey and alfalfa leaf-cutter bees on alfalfa or may decline significantly between 8 and 24 hours posttreatment. Residues on alfalfa foliage samples from application of Dursban 4EC at 0.5 and

1.0 lb ai/A were highly toxic through 8 hours to three bee species (honey bee, *Apis mellifera*; alkali bee, *Nomea melanderi*; and alfalfa leaf-cutter bee, *Megachile rotundata*). At 24 hours, residues on alfalfa foliage remained highly toxic to the honey bee and alfalfa leaf-cutter bee and moderately toxic to the alkali bee (MRID 00040602). Alfalfa foliage samples with chlorpyrifos residues from an application of Dursban 2 EC on alfalfa fields at 1 lb ai/A were highly toxic to the honey bees at 3 hours when placed in cages with bees, but foliage samples were not toxic at 24 hours (MRID 00060632).

In the only available field study, honey bee visitation was suppressed 46 percent for three days in alfalfa fields treated with Dursban 4EC at 0.5 lb ai/A. The overall hazard to bees was low (MRID 00074486).

There is also sufficient information available to characterize chlorpyrifos as toxic to lady beetles when beetles are exposed to direct application. In the submitted study, survival of adult lady beetles (*Stethorus punctum*) was reduced to 30 percent, 48 hours after direct application of Dursban 4EC at 0.25 lb ai per 100 gallons of water (MRID 00059461).

4.2.4 Toxicity to Terrestrial Plants

There were no registrant submitted terrestrial plant toxicity data and no data in available literature studies for chlorpyrifos. Therefore, a quantitative assessment of the potential for indirect effects to the aquatic- and terrestrial-phase listed species via effects to riparian vegetation or effects to the primary constituent elements (PCEs) relevant to the aquatic- and terrestrial-phase listed species could not be conducted. In the absence of vegetative vigor and seedling emergence toxicity data, the potential risk to the listed species via indirect effects to terrestrial plants is described in a qualitative manner (**Section 5.2**).

4.3 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 (U.S. EPA, 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 Chlorpyrifos 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.

4.4 Incident Database Review

A review of the EIIS database for ecological incidents involving chlorpyrifos was completed on August 31, 2009. The results of this review for aquatic and terrestrial incidents are discussed below in **Sections 5.5.1.1.** and **5.5.1.2.**, respectively. A complete list of the incidents involving Chlorpyrifos including associated uncertainties is included as **Appendix J**.

4.5 Toxicity of Chlorpyrifos Oxon

Toxicity of chlorpyrifos oxon, a degradate of the parent chlorpyrifos, was sparse. A detailed summary of the available ecotoxicity information for all chlorpyrifos degradates and formulated products can be found in **Appendices E, F** and **G**.

Table 4.18 Toxicity Profile for Chlorpyrifos Oxon				
Species	Substance Tested; Comparison	Toxicity Value Used in Risk Assessment (ug a.i./L)	ECOTOX Ref.	Comment
Foothill yellow-legged frog, *Rana boylii*	Chlorpyrifos Chlorpyrifos oxon Oxon **>100x** more toxic	LC50 = 3000 LC50 = [< 5]	E92498 Sparkling and Fellers, 2007	Supplemental, missed range, too much mortality for chronic test and bimodal results for oxon mortality, LC50 questionable.
Channel catfish, *Ictalurus punctatus*	Chlorpyrifos Chlorpyrifos oxon Oxon **30x** more toxic	LOAEC = 250 (No NOAEC) NOAEC = <250 LOAEC = 7 (No NOAEC) NOAEC = <7	E67666 Carr *et al.*, 1995	Supplemental; test set up to evaluate AChE levels over time, only one concentration used; no confirmable NOAEC.
Australian coral, *Acropora millepora* (Ehrenberg), 7-8 d old larvae	Chlorpyrifos Chlorpyrifos oxon Oxon **3x** more toxic	LOAEC = 1.0 NOAEC = 0.3 LOAEC = 0.3 NOAEC = 0.1	E100575 Markey *et al.*, 2007	Supplemental, non-native species, no measured concentrations
Rat, *Ratus* sp.	Chlorpyrifos Chlorpyrifos oxon Oxon **1.7x** more toxic	LOAEC = 50 (mg/kg) NOAEC = <50 (mg/kg) LOAEC = 30 (mg/kg) NOAEC = <30 (mg/kg)	E91393 Chambers and Carr, 1993	Supplemental; test substance was injected in rats, not realistic environmental exposure; not set up to derive a dose:response, no NOAEC.

Data from the open literature show a wide range in the comparison between chlorpyrifos toxicity and chlorpyrifos oxon toxicity (Table 4.6). In one study with the Foothills yellow-legged frog, a species closely related to the California red-legged frog, authors claimed that chlorpyrifos oxon was 100 times more toxic than chlorpyrifos parent, but the results were a bit confusing due to bimodal mortality data in the oxon results. This certainly does raise concerns for the red-legged frog. Other studies with aquatic species showed that chlorpyrifos oxon was between 3 and 30 times more toxic than chlorpyrifos parent. In rats, chlorpyrifos oxon was approximately 2 times more toxic, though the exposure was via injection, which was not an environmentally realistic exposure route.

The other major degradate of chlorpyrifos, 3,5,6-trichloro-2-pyridinol (TCP), was found in the most recent RED (USEPA, 2002) to be moderately to slightly toxic to freshwater fish species, considerably less toxic than chlorpyrifos parent. It was slightly toxic to freshwater invertebrates, also considerably less toxic than chlorpyrifos parent. Effects from TCP were, therefore, not evaluated in this risk assessment.

5 Risk Characterization

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 B**). For acute exposures to the aquatic animals, as well as terrestrial invertebrates, the LOC is 0.05. For acute exposures to the birds (and, thus, reptiles and terrestrial-phase amphibians) and mammals, 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 using 1-in-10 year EECs based on the label-recommended chlorpyrifos usage scenarios summarized in **Table 3.1** and the appropriate aquatic toxicity endpoint from **Table 4.1**. Acute and chronic risks to terrestrial animals are estimated based on exposures resulting from applications of chlorpyrifos (**Tables 3.8 through 3.9**) and the appropriate toxicity endpoint from **Table 4.3**. Exposures are also derived for terrestrial plants, as discussed in Section 3.3, based on the highest application rates of chlorpyrifos use within the action area.

5.1 Exposures in the Aquatic Habitat

The species considered in this risk assessment include several diverse taxa: a frog, a salamander, a fish, a snake, a bird, a mouse, a fox, a shrimp and two insect species. Direct effects were estimated by using toxicity data from each taxonomic group or a similar surrogate taxon (**Table 5.1**). Indirect effects were estimated by reviewing the life history of each species to see which taxa represent their staple food source, and assessing the risk to those taxa. Direct effects to the Delta smelt were evaluated using the lowest acute and chronic toxicity values across freshwater and saltwater fish species, since the Delta smelt's life history includes both habitats. Direct effects to the California red-legged frog and California tiger salamander were evaluated using aquatic-phase amphibian data, and indirect effects to the San Francisco garter snake, were evaluated using freshwater fish and aquatic-phase amphibian data. Indirect effects to the clapper rail were evaluated using all fish and amphibian toxicity data. Direct effects to the California freshwater shrimp and indirect effects to the California red-legged frog, California tiger salamander and San Francisco garter snake were assessed using freshwater invertebrate data; one difference was the use of freshwater crustacean data only for direct effects to the California freshwater shrimp. All freshwater and estuarine/marine invertebrate toxicity data were used to assess indirect effects to the Delta smelt and California clapper rail. Non-vascular plant toxicity data were not nearly as sensitive as animal data. This was used to assess indirect risks to all species of concern except the two insect species, whose food chains were considered to be all terrestrial.

Table 5.1 Types of Data Used to Assess Direct Risk to Listed Species and Indirect Risk to these Species through the Food Chain

Type of Toxicity Data	Direct Risk	Indirect Risk
Freshwater Fish and Aquatic-phase Amphibians	California red-legged frog California tiger salamander Delta smelt	California clapper rail San Francisco garter snake
Estuarine/Marine Fish	Delta smelt	California clapper rail
Freshwater Invertebrates	California freshwater shrimp	California red-legged frog California tiger salamander Delta smelt California clapper rail San Francisco garter snake
Estuarine/Marine Invertebrates		Delta smelt California clapper rail
Non-vascular Plants		California red-legged frog California tiger salamander Delta smelt California clapper rail San Francisco garter snake California freshwater shrimp Salt marsh harvest mouse

5.1.1 Freshwater Fish and Aquatic-phase Amphibians

Acute risk to fish and aquatic-phase amphibians is based on peak EECs in the standard pond and the lowest acute toxicity value for freshwater fish or aquatic-phase amphibians (**Table 5.2**). Chronic risk is based on 21- or 60-day EECs and the lowest chronic toxicity value for freshwater fish or aquatic-phase amphibians. Based on acute toxicity data from studies with the bluegill sunfish and African clawed frog, chlorpyrifos poses very high risks to both fish and aquatic-phase amphibians. For species directly affected by chlorpyrifos concentrations acutely toxic to freshwater fish, risk exceeded the level of concern (LOC) in all but one use, the turfgrass granular broadcast use. Only this use did not exceed the acute LOC (0.05) for endangered fish. For species directly affected by chlorpyrifos concentrations acutely toxic to aquatic-phase amphibians, risk exceeded the level of concern (LOC) in all uses. Therefore, all uses have the potential to directly affect the California red-legged frog and California tiger salamander, and all uses, except one, have the potential to directly affect the Delta smelt. Indirect effects using the acute LOC of species that are not endangered (0.5) is not shown in the table since the chronic RQs were exceeded for all but one use (below) and was more conservative.

Table 5.2 Summary of Acute RQs for Freshwater Amphibians and Fish.			
Uses/Application Rate	**Species**	**Peak EEC (μg/L)**	**Acute RQ[1]**
Fish Data			
Ornamentals - liquid, ground, 8 lbs a.i./acre	Bluegill Sunfish *Lepomis macrochirus*	45.1[2]	**25.0**
Missing uses here had RQs (EECs between 0.3 and 45.1ug/L) that exceeded the LOC.			
Alfalfa Clover -granular, incorporated, 1 lb a.i./acre	Bluegill Sunfish *Lepomis macrochirus*	0.3[3]	**0.17**
Turfgrass - granular, broadcast, 1 lb a.i./acre	Bluegill Sunfish *Lepomis macrochirus*	0.08	0.04
Amphibian Data			
Ornamentals - liquid, ground, 8 lbs a.i./acre	African clawed frog, *Xenopus laevis*	45.1	**75.2**
Missing uses here had RQs (EECs between 0.08 and 45.1ug/L) that exceeded the LOC.			
Turfgrass - granular, broadcast, 1 lb a.i./acre	African clawed frog, *Xenopus laevis*	0.08	**0.13**

[1]LOC exceedances (acute RQ $\geq$ 0.05 for direct effects to endangered species) are bolded and shaded. Acute RQ = use-specific peak EEC / 1.8 for fish and 0.6 for amphibians (lowest acute value, bluegill or African clawed frog LC50). [2]Highest Peak EEC. [3]Lowest Peak EEC with an exceedance. **All uses not shown in this table had exceedances.**

Based on sublethal and chronic toxicity data from studies with the African clawed frog and fathead minnow, chlorpyrifos poses higher chronic risks to amphibians than fish (**Table 5.3**), although acute data (**Table 5.2**) showed slightly higher risks to fish. Only one use, Turfgrass – granular broadcast, did not exceed the chronic LOC (0.10) for either amphibians or fish. Twenty-one uses (**Table 5.3)** showed potential for direct effects to amphibians but not fish. Twenty-five uses exceeded chronic RQs for both fish and amphibians and have the potential to directly affect the California red-legged frog, California tiger salamander and Delta smelt. All uses, but the turfgrass use mentioned above, have the potential to directly affect the Delta smelt. For species indirectly affected by loss of fish or aquatic-phase amphibians (the San Francisco garter snake and California clapper rail) the LOC was 0.5 for acute toxicity and 1 for chronic toxicity. The chronic LOC (1.0) for indirect effects is the same as the chronic LOC for endangeres species, which caused RQ exceedances in all uses but one, the turfgrass use.

Table 5.3 Summary of Chronic RQs for Freshwater Amphibians and Fish.			
Uses/Application Rate	**Species**	**60-day EEC (µg/L)**	**Chronic RQ[1]**
Fish Data			
Ornamentals - liquid, ground, 8 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	11.9	**21**
Missing uses here had RQs (EECs >0.5 to 11.9 ug/L) that exceeded the LOC for fish.			
Asparagus - granular, incorporated, 1 lb a.i./acre	Fathead minnow, *Pimephales promelas*	0.5[2]	0.9
Ant mounds – granular, ground, 2 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.5	0.9
Road median – liquid, ground, 1 lb a.i./acre	Fathead minnow, *Pimephales promelas*	0.5	0.9
Road median – granular, ground, 1 lb a.i./acre	Fathead minnow, *Pimephales promelas*	0.5	0.9
Wheat – liquid, ground and incorporated, 0.5 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.5	0.9
Sweet potato – liquid, ground and incorporated, 2 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.4	0.7
Fig – liquid, ground, 2 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.4	0.7
Turfgrass – liquid, ground, 4 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Field and sweet corn, granular, incorporated, 1 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Grapes – liquid, ground, 2.25 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Pear – liguid, ground, 2 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Legumes – liquid, ground, 0.5 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Legumes – liquid, ground, 0.5 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Fig – liquid, incorporated, 2 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Grain sorghum – granular, incorporated, 1.5 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Sunflower – granular, incorporated, 1.3 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.3	0.5
Peanut – granular, incorporated, 2 lbs a.i./acre	Fathead minnow, *Pimephales promelas*	0.2	0.4
Alfalfa Clover -granular, incorporated, 1 lb a.i./acre	Fathead minnow, *Pimephales promelas*	0.1	0.2
Citrus Floor – granular, incorporated, 1 lb a.i./acre	Fathead minnow, *Pimephales promelas*	0.1	0.2
Sugarbeet – granular, ground and incorporated, 2 lb a.i./acre	Fathead minnow, *Pimephales promelas*	0.1	0.2
Sweet potato – granular, incorporated, 2 lb a.i./acre	Fathead minnow, *Pimephales promelas*	0.1	0.2

Table 5.3 Summary of Chronic RQs for Freshwater Amphibians and Fish.			
Uses/Application Rate	**Species**	**60-day EEC (µg/L)**	**Chronic RQ[1]**
Turfgrass - granular, broadcast, 1 lb a.i./acre	Fathead minnow, *Pimephales promelas*	0.02	0.04
Amphibian Data		**21-day EEC (µg/L)**	
Ornamentals - liquid, ground, 8 lbs a.i./acre	African clawed frog, *Xenopus laevis*	20.1	**>201**
Missing uses here had RQs (EECs between 0.2 and 20.1 ug/L) that exceeded the LOC for amphibians.			
Sweet potato – granular, incorporated, 2 lb a.i./acre	African clawed frog, *Xenopus laevis*	0.2	**>2**
Turfgrass - granular, broadcast, 1 lb a.i./acre	African clawed frog, *Xenopus laevis*	0.04	>0.4
[1]LOC exceedances (chronic RQ $\geq$ 1.0) are bolded and shaded. Chronic RQ = use-specific 21-day EEC / <0.1 (lowest chronic value, amphibian NOAEC) or use specific 60-day EEC/ 0.57 (lowest fish value, fathead minnow life cycle NOAEC). [2]Highest 60-day EEC without an exceedance. **All uses not shown had exceedances for both 21- and 60-day EECs.**			

5.1.2 Freshwater Invertebrates

Acute risk to freshwater invertebrates was based on peak EECs in the standard pond and the lowest acute toxicity value for freshwater invertebrates. Chronic risk is based on 21-day EECs and the lowest chronic toxicity valued for freshwater crustaceans (used for the shrimp only) and other invertebrates. All uses have the potential to directly affect the California freshwater shrimp and indirectly affect the California red-legged frog, California tiger salamander, Delta smelt, San Francisco garter snake and California clapper rail (**Table 5.4)**.

Table 5.4 Summary of Acute RQs for Freshwater Invertebrates.			
Uses/Application Rate	**Species**	**Peak EEC (µg/L)**	**Acute RQ[1]**
Crustacean Data			
Ornamentals - liquid, ground, 8 lbs a.i./acre	Daphnid, *Ceriodaphnia dubia*	45.1	**644**
Turfgrass - granular, broadcast, 1 lb a.i./acre	Daphnid, *Ceriodaphnia dubia*	0.08	**1.1**
All Invertebrate Data			
Ornamentals - liquid, ground, 8 lbs a.i./acre	Blackfly *Simulium vittatum IS-7*	45.1	**752**
Cole crops, Leafy Vegetable, Rutabaga, Turnip – liquid, ground and incorporated, 3 lbs a.i./acre	Blackfly *Simulium vittatum IS-7*	16.3	**272**
Turfgrass - granular, broadcast, 1 lb a.i./acre	Blackfly *Simulium vittatum IS-7*	0.08	**1.3**
[1]LOC exceedances (acute RQ $\geq$ 0.05) are bolded and shaded. Acute RQ = use-specific peak EEC / 0.07 for lowest crustacean acute value (Ceriodaphnia LC50) or 0.06 lowest acute value for all other taxa (blackfly LC50). **Note: For freshwater invertebrates all acute RQs exceeded the LOC, only highest and lowest Peak EECs are shown.**			

Table 5.5 Summary of Chronic RQs for Aquatic Invertebrates.			
Uses/Application Rate	**Species**	**21-day EEC (µg/L)**	**Chronic RQ[1]**
Ornamentals - liquid, ground, 8 lbs a.i./acre	Water Flea *Daphnia magna*	20.1	**503**
Turfgrass - granular, broadcast, 1 lb a.i./acre	Water Flea *Daphnia magna*	0.04	**1**
[1]LOC exceedances (chronic RQ $\geq$ 1.0) are bolded and shaded. Chronic RQ = use-specific 21-day EEC / 0.04 (lowest chronic value, daphnid NOAEC). **Note:** For freshwater invertebrates **all** chronic RQs exceeded the LOC, only highest and lowest 21-day EECs are shown.			

Based on chronic data using *Daphnia magna*, another crustacean, chlorpyrifos has the potential to directly affect the California freshwater salamander. Additionally, since the acute and chronic RQs were exceeded, there is a potential for indirect effects to those listed species that rely on freshwater invertebrates during at least some portion of their life-cycle; this list includes the California red-legged frog, California tiger salamander, Delta smelt, California clapper rail and San Francisco garter snake (**Table 5.5**).

5.1.3 Estuarine/Marine Fish

Acute risk to estuarine/marine fish is based on peak EECs in the standard pond and the lowest acute toxicity value for estuarine/marine fish. Chronic risk is based on 60-day EECs and the lowest chronic toxicity value for estuarine/marine fish is used. For species directly affected by chlorpyrifos concentrations acutely toxic to estuarine/marine fish, risk exceeded the LOC (0.05) in all but two uses, the Turfgrass granular broadcast and Alfalfa clover granular incorporated uses. All uses except these two have the potential to directly affect the Delta smelt (**Table 5.6**).

Table 5.6 Summary of Acute RQs for Estuarine/Marine Fish.

Uses/Application Rate	Species	Peak EEC (μg/L)	Acute RQ[1]
Ornamentals - liquid, ground, 8 lbs a.i./acre	Tidewater silverside, *Menidia peninsulae*	45.1[2]	**64**
Missing uses here had RQs (EECs between 0.4 and 45.1 ug/L) that exceeded the LOC.			
Sweet Potato – granular, incorporated, 2 lb a.i./acre	Tidewater silverside, *Menidia peninsulae*	0.4	**0.6**
Alfalfa Clover -granular, incorporated, 1 lb a.i./acre	Tidewater silverside, *Menidia peninsulae*	0.3	0.4
Turfgrass - granular, broadcast, 1 lb a.i./acre	Tidewater silverside, *Menidia peninsulae*	0.08	0.1

[1]LOC exceedances (acute RQ ≥ 0.5) are bolded and shaded. Acute RQ = use-specific peak EEC / 0.7 (lowest acute value, Tidewater silverside LC50). [2]Highest EEC. [3]Lowest EEC with an exceedance. **All uses not shown had exceedances.**

Table 5.7 Summary of Chronic RQs for Estuarine/Marine Fish.

Uses/Application Rate	Species	21-day EEC (μg/L)	Chronic RQ[1]
Ornamentals - liquid, ground, 8 lbs a.i./acre	Atlantic silverside *Menidia menidia*	20.1	**72**
Missing uses here had RQs (EECs between 0.4 and 20.1 ug/L) that exceeded the LOC.			
Peanut – granular, incorporated, 2 lbs a.i./acre	Atlantic silverside *Menidia menidia*	0.4[2]	**1.4**
Sugarbeet – granular, incorporated, 2 lbs a.i./acre	Atlantic silverside *Menidia menidia*	0.2	0.7
Citrus Floor – granular, incorporated, 1 lbs a.i./acre	Atlantic silverside *Menidia menidia*	0.2	0.7
Sweet potato – granular, incorporated, 2 lbs a.i./acre	Atlantic silverside *Menidia menidia*	0.2	0.7
Alfalfa Clover – granular, incorporated, 1 lbs a.i./acre	Atlantic silverside *Menidia menidia*	0.2	0.7
Turfgrass - granular, broadcast, 1 lb a.i./acre	Atlantic silverside *Menidia menidia*	0.04	0.1

[1]LOC exceedances (chronic RQ ≥ 1.0) are bolded and shaded. Chronic RQ = use-specific 21-day EEC / 0.28 (lowest chronic value, Atlantic silverside NOAEC). [2]Lowest 21-day EEC with an exceedance. **All uses not shown had exceedances.**

Based on sublethal and chronic toxicity data from studies with estuarine and marine fish, chlorpyrifos has the potential to directly affect the Delta smelt. Only five uses did not exceed the chronic LOC (1.0): Turfgrass granular broadcast, and Alfalfa clover, Sweet potato, Citrus Floor and Sugarbeet granular, incorporated. All uses, except these five, have the potential to directly affect the Delta smelt, as well as the food source relied upon by the California clapper during at least some portion of its life-cycle (**Table 5.7**).

5.1.4 Estuarine/Marine Invertebrates

Acute risk to estuarine/marine invertebrates is based on peak EECs in the standard pond and the lowest acute toxicity value for estuarine/marine invertebrates. Chronic risk is based on 21-day EECs and the lowest chronic toxicity value for estuarine/marine invertebrates. For species directly or indirectly affected by chlorpyrifos concentrations acutely or chronically toxic to estuarine/marine invertebrates, risk exceeded the level of concern (0.05 for acute and 0.10 for chronic) for all uses. All uses have the potential to indirectly affect the California clapper rail (**Table 5.8**).

Table 5.8 Summary of Acute and Chronic RQs for Estuarine/Marine Invertebrates.

Uses/Application Rate	Species	Peak EEC (µg/L)	21-day EEC (µg/L)	Acute RQ[1]	Chronic RQ[1]
Turfgrass - granular, broadcast, 1 lb a.i./acre	Mysid shrimp *Americamysis bahia*	0.08[2]	0.04[2]	**2.2**	**8.7**

[1]LOC exceedances (acute RQ ≥ 0.05; chronic RQ ≥ 1.0) are bolded and shaded. Acute RQ = use-specific peak EEC / 0.035 (lowest acute value, mysid LC50). Chronic RQ = use-specific 21-day EEC / 0.0046 (lowest chronic value, mysid NOAEC). [2]Lowest EECs – **all uses had exceedances.**

Since all acute and chronic RQs are exceeded, there is a potential for indirect effects to any listed species that relies on estuarine/marine invertebrates during at least some portion of its life-cycle (*i.e.*, the California clapper rail).

5.1.5 Non-vascular Aquatic Plants

Acute risk to aquatic non-vascular plants is based on peak EECs in the standard pond and the lowest acute toxicity value. For species directly or indirectly affected by chlorpyrifos concentrations acutely toxic to non-vascular aquatic plants, risk did not exceed the level of concern (0.10) for any uses. No uses have the potential via this route to indirectly affect the California red-legged frog, California tiger salamander, Delta smelt, California freshwater shrimp, California clapper rail and San Francisco garter snake (**Table 5.9**).

Table 5.9 Summary of Acute RQs for Non-Vascular Aquatic Plants.

Uses	Application rate (lb ai/A) and type	Peak EEC (µg/L)	RQ[1]
Ornamentals - liquid	8 lbs a.i./acre, Ground	45.1[2]	0.3

[1]LOC exceedances (RQ > 1) are bolded and shaded. RQ = use-specific peak EEC/140 (endpoint, Alga, *Isochrysis galbana* EC50). [2]Highest Peak EEC – **no uses had exceedances.**

Since the acute RQs are not exceeded, these data show no measurable potential for indirect effects to those listed species that rely on non-vascular aquatic plants during at least some portion of their life-cycle (*i.e*., California red-legged frog, California tiger salamander, Delta smelt, California freshwater shrimp, California clapper rail and San Francisco garter snake). No acceptable data were found for chlorpyrifos effects to aquatic vascular plants. Incident data, however, did show some severe effects due to chlorpyrifos, which will be covered more in the uncertainties section.

5.2 Exposures in the Terrestrial Habitat

5.2.1 Birds (surrogate for Reptiles and Terrestrial-phase amphibians)

As previously discussed in **Section 3.3**, potential direct effects to terrestrial species are based on foliar, granular and seed treatment applications of Chlorpyrifos. Potential risks to birds (and, thus, reptiles and terrestrial-phase amphibians) are derived using T-REX, acute and chronic toxicity data for the most sensitive bird species for which data are available, and a variety of body-size and dietary categories.

Potential direct acute effects specifically to the California clapper rail are derived by considering dose- and dietary-based EECs modeled in T-REX for a small bird [20 g (for juveniles) and 100 g (for adults)] consuming a variety of dietary items (**Table 3.8**) and acute oral and subacute dietary toxicity endpoints for avian species. Potential direct acute effects to the terrestrial-phase CRLF San Francisco garter snake and terrestrial-phase California tiger salamander are derived by considering dose- and dietary-based EECs modeled in T-REX for a small bird (20 g) consuming small invertebrates (**Table 3.9**) and acute oral and subacute dietary toxicity endpoints for avian species.

Potential direct chronic effects to the California clapper rail are derived by considering dietary-based EECs modeled in T-REX for a small bird [20 g (juveniles) and 100 g (adults)] consuming a variety of dietary items and acute oral and subacute dietary toxicity endpoints for avian species. Potential direct chronic effects of chlorpyrifos to the terrestrial-phase CRLF San Francisco garter snake and CA tiger salamander are derived by considering dietary-based exposures modeled in T-REX for a small bird (20g) consuming small invertebrates. Chronic effects are estimated using the lowest available toxicity data for birds. EECs are divided by toxicity values to estimate chronic dietary-based RQs. As previously noted, RQ's for granular and seed treatment applications are not based on EECs but rather calculated in terms of LD_{50} per square foot. Therefore, EECs for granular and seed treatments are not generated for these uses.

Table 5.10 Acute Dose-Based RQs for Chlorpyrifos California Red Legged Frog, Clapper Rail, Tiger Salamander and San Francisco Garter Snake

Use (Application Method)	Small SFB Species RQ [1]	Adult CA Clapper Rail RQ [2]
Alfalfa (Broadcast Aerial/Ground, Chemigation)	87	38
Almond, Sour Cherry, Filbert, Pecan, Walnut, (Foliar; Broadcast Aerial/Ground)	159	70
Apple (Dormant/Delayed; Broadcast Ground)	87	38
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	113	49
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	70	32
Christmas Trees (Foliar; Broadcast Ground)	83	36
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	165	72
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	46	21
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	224	99
Cranberry (Foliar; Broadcast Aerial/Ground)	91	40
Grape (Dormant; Broadcast Ground)	78	34
Mint (Foliar; Broadcast Ground)	150	65
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	41	17
Strawberry (Foliar; Broadcast Aerial/Ground)	70	32
Sugarbeet (Foliar; Broadcast Aerial/Ground)	76	34
Sunflower (Foliar; Broadcast Aerial/Ground)	70	30
Wheat (Foliar; Broadcast Aerial/Ground)	22	11
Ornamentals (Foliar; Broadcast Ground)	141	61
Turf Grass (Foliar; Broadcast Ground)	248	108

[1] Based on house sparrow acute oral LD50 of 10 mg/kg and bw of 20 g
[2] Based on house sparrow acute oral LD50 of 10 mg/kg and bw of 100 g
LOC exceedances (RQ $\geq$ 0.1) are bolded and shaded

Table 5.11 Acute and Chronic Dietary-Based RQs for Chlorpyrifos and California Red Legged Frog, Clapper Rail, Tiger Salamander and San Francisco Garter Snake

Use (Application Method)	Acute RQ [1]	Chronic RQ [2]
Alfalfa (Broadcast Aerial/Ground, Chemigation)	**2**	**13**
Almond, Sour Cherry, Filbert, Pecan, Walnut, (Foliar; Broadcast Aerial/Ground)	**5**	**24**
Apple (Dormant/Delayed; Broadcast Ground)	**3**	**14**
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	**3**	**17**
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	**2**	**11**
Christmas Trees (Foliar; Broadcast Ground)	**2**	**13**
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	**5**	**25**
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	**1**	**7**
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	**6**	**35**
Cranberry (Foliar; Broadcast Aerial/Ground)	**3**	**14**

Table 5.11 Acute and Chronic Dietary-Based RQs for Chlorpyrifos and California Red Legged Frog, Clapper Rail, Tiger Salamander and San Francisco Garter Snake		
Grape (Dormant; Broadcast Ground)	**2**	**12**
Mint (Foliar; Broadcast Ground)	**4**	**23**
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	**1**	**6**
Strawberry (Foliar; Broadcast Aerial/Ground)	**2**	**11**
Sugarbeet (Foliar; Broadcast Aerial/Ground)	**2**	**12**
Sunflower (Foliar; Broadcast Aerial/Ground)	**2**	**11**
Wheat (Foliar; Broadcast Aerial/Ground)	**1**	**3**
Ornamentals (Foliar; Broadcast Ground)	**4**	**22**
Turf Grass (Foliar; Broadcast Ground)	**7**	**38**

[1] Based on Mallard Duck LC50 of 136 ppm
[2] Based on Mallard Duck NOAEC of 25 ppm
LOC exceedances (acute RQ $\geq$ 0.1, chronic RQ $\geq$ 1) are bolded and shaded.

Table 5.12 LD50/sq ft for Granular Applications Chlorpyrifos California Red Legged Frog, Clapper Rail, Tiger Salamander and San Francisco Garter Snake

Use (Application Method)	Small SFB Species LD50[1]	Adult CA Clapper Rail LD50[2]
Alfalfa, Onion (In-furrow [3])	**6**	**0.8**
Asparagus, Citrus Orchard Floors, Corn, Road Median, Turf Grass (Broadcast: Ground Lightly Incorporated [4])	**18**	**2.8**
Citrus Orchard Floor (Broadcast: Ground Unincorporated [5])	**119**	**19**
Cole Crop (Brassica) Leafy Vegetables and Radish, Rutabaga and Turnip (T-band: Lightly Incorporated)	**181**	**28**
Corn (Broadcast: Aerial)	**119**	**19**
Peanut, Sweet Potato, Tobacco (Broadcast: Ground Lightly Incorporated)	**36**	**6**
Sorghum - Grain Sorghum (Milo) (T-band; Lightly Incorporated)	**81**	**13**
Soybean (T-band; Lightly Incorporated)	**161**	**25**
Sugarbeet (T-band; Lightly Incorporated)	**97**	**15**
Sunflower (T-band; Lightly Incorporated)	**98**	**16**
Sweet Potato (Broadcast; Ground; Incorporated [6])	**3**	**0.4**
Outdoor Nurseries (Broadcast; Unincorporated)	**700**	**100**

[1] Based on common grackle oral LD50 of 5.62 mg/kg and bw of 20 g
[2] Based on common grackle oral LD50 of 5.62 mg/kg and bw of 100 g
[3] In-furrow = 1% unincorporated
[4] Lightly incorporated = 15% unincorporated
[5] Unincorporated = 100% unincorporated
[6] Incorporated = 1% unincorporated
LOC exceedances (RQ $\geq$ 0.1) are bolded and shaded

Table 5.13 Acute and Chronic RQs Seed Treatment and California Red Legged Frog, Clapper Rail, Tiger Salamander and San Francisco Garter Snake		
Use	**Acute RQ mg ai ft ^{2} / (LD50*bw)**	**Chronic RQ (mg/kg seed) /NOAEC**
Field Beans, Green Beans, Kidney Beans, Navy Beans, String Beans, Wax Beans,	**34**	**72**
Black-Eyed Peas	**11**	**72**
Cucumbers, Pumpkins [1]	**0.2**	**72**
Corn	**5**	**72**
Cotton	**8**	**143**
Field Peas, Garden Peas	**39**	**72**
Lima Beans, Snap Beans	**21**	**72**
Sorghum	**0.07**	**3**
Wheat	**1**	**3**
[1] Maximum seeding rate = 5 lb ai/A (HED ExpoSAC SOP 15) LOC exceedances (acute RQ $\geq$ 0.1, chronic RQ $\geq$ 1) are bolded and shaded.		

Results of the dose-based EEC analysis of direct effects to the terrestrial phase species evaluated indicate acute LOC exceedances (acute RQ $\geq$ 0.1, chronic RQ $\geq$ 1) for all uses of chlorpyrifos (**Table 5.10**; also see **Tables 5.11** through **5.13**). Based on these results, Chlorpyrifos does have the potential to directly affect the CRLF, California Clapper Rail, California tiger salamander and San Francisco garter snake. Additionally, since the acute and/or chronic RQs are exceeded, there is a potential for indirect effects to those listed species that rely on birds (and, thus, reptiles and/or terrestrial-phase amphibians) during at least some portion of their life-cycle (*i.e.*, CLRF, California Clapper Rail, California tiger salamander and San Francisco garter snake.).

5.2.2 Mammals

Potential risks to mammals are derived using T-REX, acute and chronic rat toxicity data, and a variety of body-size and dietary categories.

Potential direct acute effects specifically to the Salt Marsh harvest mouse are derived by considering dose- and dietary-based EECs modeled in T-REX for a small mammal (15 g) consuming a variety of dietary items (**Tables 5.14 and 5.15**) and acute oral and subacute dietary toxicity endpoints for rats. Potential direct acute effects specifically to the San Joaquin fox are derived by considering dose- and dietary-based EECs modeled in T-REX for a large mammal (1,000 g) consuming a variety of dietary items and acute oral and subacute dietary toxicity endpoints for rats. RQ's for granular and seed treatment applications are not based on EECs but rather calculated in terms of LD_{50} per square foot. Therefore, EECs for granular and seed treatments are not generated for these uses.

Table 5.14 Acute Dose-Based RQs for Salt Marsh Harvest Mouse and San Joaquin Fox

Use (Application Method)	SMH Mouse RQ [1]	SJ Fox RQ [1]
Alfalfa (Broadcast Aerial/Ground, Chemigation) Apple, Grape (Dormant/Delayed; Broadcast Ground) Cherry, Nectarine, Peach, Pear, Plum, Fig (Dormant/Delayed; Broadcast Ground) Christmas Trees (Foliar; Broadcast Ground) Cranberry, Strawberry, Sugarbeet Sunflower (Foliar; Broadcast Aerial/Ground)	**2**	**1**
Almond, Sour Cherry, Filbert, Pecan, Walnut, Citrus (Foliar; Broadcast Aerial/Ground) Mint (Foliar; Broadcast Ground) Ornamentals (Foliar; Broadcast Ground)	**4**	**2**
Asparagus, Sunflower (Foliar; Broadcast Aerial/Ground)	**3**	**1**
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	**1**	**0.5**
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground) Turf Grass (Foliar; Broadcast Ground)	**6**	**3**
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	**1**	**0.5**
Wheat (Foliar; Broadcast Aerial/Ground)	**0.6**	**0.3**

[1] Based on rat LD50 = 118 mg/kg and bw of 15g
[2] Based on rat LD50 = 118 mg/kg and bw of 1000 g
LOC exceedances (RQ $\geq$ 0.1) are bolded and shaded.

Table 5.15 Acute and Chronic Dietary-Based RQs for Chlorpyrifos and Salt Marsh Harvest Mouse and San Joaquin Fox

Use (Application Method)	Acute RQ[1]	Chronic RQ[2]
Alfalfa (Broadcast Aerial/Ground, Chemigation)	**0.4**	**30**
Almond, Sour Cherry, Filbert, Pecan, Walnut, (Foliar; Broadcast Aerial/Ground)	**0.8**	**54**
Apple (Dormant/Delayed; Broadcast Ground)	**0.5**	**30**
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	**0.6**	**39**
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	**0.4**	**24**
Christmas Trees (Foliar; Broadcast Ground)	**0.4**	**28**
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	**0.9**	**57**
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	**0.2**	**16**
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	**1.2**	**77**
Cranberry (Foliar; Broadcast Aerial/Ground)	**0.5**	**31**
Grape (Dormant; Broadcast Ground)	**0.4**	**27**
Mint (Foliar; Broadcast Ground)	**0.8**	**51**
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	**0.2**	**14**
Strawberry (Foliar; Broadcast Aerial/Ground)	**0.4**	**24**
Sugarbeet (Foliar; Broadcast Aerial/Ground)	**0.4**	**26**

Table 5.15 Acute and Chronic Dietary-Based RQs for Chlorpyrifos and Salt Marsh Harvest Mouse and San Joaquin Fox		
Use (Application Method)	**Acute RQ[1]**	**Chronic RQ[2]**
Sunflower (Foliar; Broadcast Aerial/Ground)	**0.4**	**24**
Wheat (Foliar; Broadcast Aerial/Ground)	**0.1**	**8**
Ornamentals (Foliar; Broadcast Ground)	**0.7**	**48**
Turf Grass (Foliar; Broadcast Ground)	**1.3**	**85**

[1] Based on rat LC50 = 1330 ppm
[2] Based on rat NOAEC = 20 ppm
LOC exceedances (acute RQ $\geq$ 0.1; chronic RQ $\geq$ 1) are bolded and shaded

Table 5.16 LD50/sq ft for Granular Applications for Chlorpyrifos and Salt Marsh Harvest Mouse and San Joaquin Fox		
Use (Application Method)	**SMH Mouse LD50[1]**	**SF Fox LD50[2]**
Alfalfa, Onion (In-furrow [3])	**0.1**	0.01
Asparagus, Citrus Orchard Floors, Corn, Road Median, Turf Grass (Broadcast: Ground Lightly Incorporated [4])	**0.4**	0.02
Citrus Orchard Floor (Broadcast: Ground Unincorporated [5])	**3**	**0.1**
Cole Crop (Brassica) Leafy Vegetables and Radish, Rutabaga and Turnip (T-band: Lightly Incorporated)	**4**	**0.2**
Corn (Broadcast: Aerial)	**3**	**0.1**
Peanut, Sweet Potato, Tobacco (Broadcast: Ground Lightly Incorporated)	**0.8**	0.03
Sorghum - Grain Sorghum (Milo) (T-band; Lightly Incorporated)	**2**	**0.1**
Soybean (T-band; Lightly Incorporated)	**4**	**0.2**
Sugarbeet (T-band; Lightly Incorporated)	**2**	**0.1**
Sunflower (T-band; Lightly Incorporated)	**2**	**0.1**
Sweet Potato (Broadcast; Ground; Incorporated [6])	0.05	<0.01
Outdoor Nurseries (Broadcast; Unincorporated)	**4**	**0.2**

[1] Based on rat LD50 = 118 mg/kg and bw of 15g
[2] Based on rat LD50 = 118 mg/kg and bw of 1000 g
[3] In-furrow = 1% unincorporated
[4] Lightly incorporated = 15% unincorporated
[5] Unincorporated = 100% unincorporated
[6] Incorporated = 1% unincorporated
LOC exceedances (RQ $\geq$ 0.1) are bolded and shaded

Table 5.17 Acute and Chronic RQs for Seed Treatment for Chlorpyrifos and Salt Marsh Harvest Mouse and San Joaquin Fox		
Use	**Acute RQ mg ai ft ^{2} / (LD50*bw)**	**Chronic RQ (mg/kg seed) / NOAEC**
Field Beans, Green Beans, Kidney Beans, Navy Beans, String Beans, Wax Beans	**0.8**	**90**
Cucumbers, Pumpkins [1]	< 0.01	**90**
Black-Eyed Peas	**0.9**	**90**
Corn	**0.1**	**90**
Cotton	**0.2**	**179**
Field Peas, Garden Peas	**0.2**	**90**
Lima Beans, Snap Beans	**0.5**	**90**
Sorghum	< 0.01	**4**
Wheat	**0.03**	**4**

[1] Maximum seeding rate = 5 lb ai/A (HED ExpoSAC SOP 15)
LOC exceedances (acute RQ $\geq$ 0.1; chronic RQ $\geq$ 1) are bolded and shaded

Results of the dose-based EEC analysis of direct effects to the mammalian species evaluated indicate acute LOC exceedances (acute RQ $\geq$ 0.1, chronic RQ $\geq$ 1) for all uses of chlorpyrifos. (**Tables 5.14** through **5.17**). Based on these results, Chlorpyrifos does have the potential to directly affect the Salt Marsh Harvest Mouse and San Joaquin Fox. Additionally, since the acute and/or chronic RQs are exceeded, there is a potential for indirect effects to those listed species that rely on mammals during at least some portion of their life-cycle (*i.e*., CRLF, California Clapper Rail, California tiger salamander and San Francisco garter snake).

5.2.3 Terrestrial Invertebrates

In order to assess the risks of Chlorpyrifos to terrestrial invertebrates, the honey bee is used as a surrogate for terrestrial invertebrates. The toxicity value for terrestrial invertebrates is calculated by multiplying the lowest available acute contact LD_{50} of 0.059 µg a.i./bee by 1 bee/0.128g, which is based on the weight of an adult honey bee. EECs (µg a.i./g of bee) calculated by T-REX for small and large insects are divided by the calculated toxicity value for terrestrial invertebrates, which is 0.46 µg a.i./g of bee. Larvae for both the Bay checkerspot butterfly and the Valley elderberry longhorn beetle are considered ‘small insects’ in this assessment, while the adults of these species are considered ‘large insects’ (**Table 5.18**).

Table 5.18 Acute and Chronic Dietary-Based RQs for Chlorpyrifos and Terrestrial Invertebrates		
Use (Application Method)	Small Insect RQ*	Large Insect RQ*
Alfalfa (Broadcast Aerial/Ground, Chemigation)	**722**	**80**
Almond, Sour Cherry, Filbert, Pecan, Walnut, (Foliar; Broadcast Aerial/Ground)	**1328**	**148**
Apple (Dormant/Delayed; Broadcast Ground)	**735**	**83**
Asparagus, Sunflower (Foliar Broadcast Aerial/Ground)	**943**	**104**
Cherry, Nectarine, Peach, Pear, Plum/Prune, Fig (Dormant/Delayed; Broadcast Ground)	**587**	**65**
Christmas Trees (Foliar; Broadcast Ground)	**689**	**76**
Citrus Fruits (Foliar; Broadcast Aerial/Ground)	**1383**	**152**
Corn/Cotton (Foliar; Broadcast Aerial/Ground; Chemigation)	**385**	**43**
Cole Crop -Cauliflower Brussels Sprouts, Corn, Cotton, Broccoli, Cabbage, Chinese Cabbage, Collar, Kale, Kohlrabi, Rudabaga, Radish, Turnip (Foliar; Broadcast Aerial/Ground)	**1887**	**211**
Cranberry (Foliar; Broadcast Aerial/Ground)	**761**	**85**
Grape (Dormant; Broadcast Ground)	**661**	**91**
Mint (Foliar; Broadcast Ground)	**1259**	**139**
Sorghum, Soybean (Foliar; Broadcast Aerial/Ground)	**341**	**39**
Strawberry (Foliar; Broadcast Aerial/Ground)	**670**	**80**
Sugarbeet (Foliar; Broadcast Aerial/Ground)	**628**	**70**
Sunflower (Foliar; Broadcast Aerial/Ground)	**578**	**65**
Wheat (Foliar; Broadcast Aerial/Ground)	**183**	**20**
Ornamentals (Foliar; Broadcast Ground)	**1174**	**130**
Turf Grass (Foliar; Broadcast Ground)	**2070**	**228**
[1] Based on bee LD50 = 0.46 ppm LOC exceedances RQ $\geq$ 0.05 are bolded and shaded		

Results of the dose-based EEC analysis of direct effects to the mammalian species evaluated indicate acute LOC exceedances (acute RQ $\geq$ 0.1, chronic RQ $\geq$ 1) for all uses of chlorpyrifos. Based on these results, Chlorpyrifos does have the potential to directly affect the Bay checkerspot butterfly and Valley elderberry longhorn beetle. Additionally, since the acute and/or chronic RQs are exceeded, there is a potential for indirect effects to those listed species that rely on terrestrial invertebrates during at least some portion of their life-cycle (*i.e.*, CRLF, California Clapper Rail, California tiger salamander and San Francisco garter snake).

5.2.4 Terrestrial Plants

No useable quantitative or qualitative data was found in this search of the open literature for terrestrial plants. Because of the absence of terrestrial plant effects data for chlorpyrifos, the Agency turned to other lines of evidence to evaluate the potential for chlorpyrifos to affect terrestrial vegetation. Available incident data provide some insight into the potential for chlorpyrifos to affect terrestrial plants. Among the incident reports for chlorpyrifos there are 19 of 43 incidents that classify chlorpyrifos as a probable or highly probable causative agent for adverse effects in crop plants (**Section 5.5.1.2**). These data suggest that, in the absence of actual controlled terrestrial plant effects studies, there is evidence that the pesticide can and does adversely affect terrestrial vegetation, although the chemical exposure threshold for such damage is not presently quantifiable.

5.2.4.1 Bioconcentration of Chlorpyrifos in Terrestrial Animals via Foodborne Uptake from Aquatic Sources

The KABAM model was used to estimate potential bioaccumulation of chlorpyrifos in aquatic food webs and subsequent risks to mammals and birds via consumption of contaminated fish. KABAM incorporated 7 trophic levels to describe bioaccumulation of chlorpyrifos in a model aquatic food web: phytoplankton, zooplankton (e.g., *Daphnia sp.*), benthic invertebrates (e.g., *Chironomus sp*., crayfish), filter feeders (e.g., mussels, clams), small fish (e.g., young of the year), medium sized fish (e.g., adult bluegill), and larger upper-trophic level fish (e.g., largemouth bass). Chlorpyrifos concentrations in these aquatic trophic levels were used to estimate acute and chronic exposures of mammals and birds consuming aquatic organisms.

Table 5.19 Calculation of RQ values for mammals and birds consuming fish contaminated by Chlorpyrifos.

Wildlife Species	Acute		Chronic	
	Dose Based	Dietary Based	Dose Based	Dietary Based
Mammalian				
fog/water shrew	0.02	N/A	**2.8**	0.51
rice rat/star-nosed mole	0.03	N/A	**3.5**	0.51
small mink	0.04	N/A	**4.8**	0.77
large mink	0.05	N/A	**5.3**	0.77
small river otter	0.05	N/A	**5.7**	0.77
large river otter	0.06	N/A	**7.4**	0.91
Avian				
sandpipers	**0.18**	0.02	N/A	0.08
cranes	0.01	0.03	N/A	0.08
rails	0.10	0.03	N/A	0.09
herons	0.02	0.03	N/A	0.09
small osprey	0.03	0.04	N/A	0.11
white pelican	0.01	0.04	N/A	0.13

LOC exceedances (acute RQ $\geq$ 0.1; chronic RQ $\geq$ 1) are bolded and shaded.

Based on results of KABAM (**Table 5.19**) LOCs (acute = 0.1 and chronic = 1.0) were exceeded via foodborne uptake of aquatic organisms in terrestrial-phase frogs, rats, sandpipers and other types of animals. These results apply directly to the California red-legged frog, California tiger salamander, California clapper rail; and San Francisco garter snake.

5.3 Primary Constituent Elements of Designated Critical Habitat

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

5.4 Spatial Extent of Potential Effects

An LAA effects determination applies to those areas where it is expected that the pesticide's use will directly or indirectly affect the CRLF Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly or their designated critical habitats. To determine this area, the footprint of chlorpyrifos's use pattern is identified, using land cover data that correspond to chlorpyrifos's use pattern. The spatial extent of the effects determination also includes areas beyond the initial area of concern that may be impacted by runoff and/or spray drift. The identified direct/indirect effects and/or modification to critical habitat are anticipated to occur only for those currently occupied core habitat areas, CNDDB occurrence sections, and designated critical habitat for the CRLF that overlap with the initial area of concern plus 1000 feet from its boundary. The identified direct/indirect effects and/or modification to critical habitat for the listed species with designated critical habitat are anticipated to occur only for the designated critical habitat areas that overlap with the initial area of concern plus 1000 feet from its boundary. It is assumed that non-flowing waterbodies (or potential habitat) are included within this area.

In addition to the spray drift buffer, the results of the downstream dilution extent analysis result in a distance of 283 kilometers which represents the maximum continuous distance of downstream dilution from the edge of the initial area of concern. If any of these streams reaches flow into the listed species habitat, there is potential to affect either the listed species or modify its habitat. These lotic aquatic habitats within the CRLF and SFB Species (Delta smelt, California Tiger Salamander, California freshwater shrimp, California clapper rail and San Francisco garter snake) core areas and critical habitats potentially contain concentrations of chlorpyrifos sufficient to result in LAA determination or modification of critical habitat.

The determination of the buffer distance and downstream dilution for spatial extent of the effects determination is described below.

5.4.1 Spray Drift

In order to determine terrestrial and aquatic habitats of concern due to Chlorpyrifos 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. An analysis of spray drift distances was completed using AgDrift.

For Chlorpyrifos use relative to the aquatic-phase species, the results of the screening-level risk assessment indicate that spray drift using the most sensitive endpoints for aquatic invertebrates exceeds the 1,000 foot range of the AgDrift model for the Tier I ground mode (no higher tier modeling for ground applications is available in AgDrift).

Because chlorpyrifos is used on a number of use sites and because the action area represents the entire state of California no additional efforts have been attempted to quantify the extent of off-site effects. The maximum distance for buffers has been set to 1,000 feet

5.4.2 Downstream Dilution Analysis

The downstream extent of exposure in streams and rivers is where the EEC could potentially be above levels that would exceed the most sensitive LOC. To complete this assessment, the greatest ratio of aquatic RQ to LOC was estimated. Using an assumption of uniform runoff across the landscape, it is assumed that streams flowing through treated areas (i.e. the initial area of concern) are represented by the modeled EECs; as those waters move downstream, it is assumed that the influx of non-impacted water will dilute the concentrations of Chlorpyrifos present.

Using a LC_{50} value of 0.06 ug/L for aquatic invertebrates (the most sensitive species) and a maximum peak EEC for applications to ornamentals of 45.1 ug/L yields an RQ/LOC ratio of 15040. Using the downstream dilution approach (described in more detail in **Appendix K**) yields a target percent crop area (PCA) of 0.006%. This value has been input into the downstream dilution approach and results in a distance of 285 kilometers which represents the maximum continuous distance of downstream dilution from the edge of the initial area of concern. Because there is uncertainty associated with the EEC derived from modeling chlorpyrifos use on ornamentals (assumes 100% application by broadcast across a nursery setting when most applications will be applied by hand on a subset of the site) a second downstream evaluation was completed for the use site with the next lowest EEC (cole crops at 16 ppb). The RQ/LOC ratio for this use is 5440 yielding a target PCA of 0.02%. This ratio also yields a maximum downstream extent of 285 kilometers.

5.4.3 Overlap between CRLF and SFB Species habitat and Spatial Extent of Potential Effects

An LAA effects determination is made to those areas where it is expected that the pesticide's use will directly or indirectly affect the CRLF, Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly, or their designated critical habitats and the area overlaps with the core areas, critical habitat and available occurrence data for CRLF and critical habitat for the Delta smelt, California clapper rail, Salt marsh harvest mouse, California tiger salamander, San Francisco garter snake, California freshwater shrimp, San Joaquin kit fox, Valley elderberry longhorn beetle, or Bay checkerspot butterfly.

For chlorpyrifos, the use pattern in the following land cover classes cultivated cropland, orchards, residential, and forestry also includes areas beyond the initial area of concern that may be impacted by runoff and/or spray drift overlaps with listed species habitat. **Appendix K** provides maps of the initial area of concern, along with listed species habitat areas. It is expected that any additional areas of critical habitat that are located 1000 ft (to account for offsite migration via spray drift) and 285 kilometers of stream reach (to account for downstream dilution) outside the initial area of concern may also be impacted and are part of the full spatial extent of the LAA/modification of critical habitat effects determination.

5.5 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 chlorpyrifos use in California. 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 chlorpyrifos. A summary of the risk estimation results are provided in **Table 5.20** for direct and indirect effects to the listed species assessed here and in **Table 5.21** for the PCEs of their designated critical habitat.

Table 5.20 Risk Estimation Summary for chlorpyrifos - Direct and Indirect Effects

Taxa	LOC Exceedances (Y/N)	Description of Results of Risk Estimation	Assessed Species Potentially Affected
Freshwater Fish and Aquatic-phase Amphibians	Non-listed Species (**Y**)	Bluegill Sunfish, *Lepomis macrochirus* LC50 =1.8 ug/L **LOC exceeded for 46/47 uses** African clawed frog, *Xenopus laevis* LC50 = 0.6 ug/L **LOC exceeded for ALL uses**	<u>Indirect Effects</u>: California clapper rail San Francisco garter snake
	Listed Species (**Y**)	African clawed frog, *Xenopus laevis* NOAEC = <0.1 ug/L **LOC exceeded for 46/47 uses** Fathead minnow, *Pimephales promelas* NOAEC = 0.57 ug/L **LOC exceeded for 25/47 uses**	<u>Direct Effects</u>: California red-legged frog California tiger salamander Delta smelt

Table 5.20 Risk Estimation Summary for chlorpyrifos - Direct and Indirect Effects			
Taxa	**LOC Exceedances (Y/N)**	**Description of Results of Risk Estimation**	**Assessed Species Potentially Affected**
Freshwater Invertebrates	Non-listed Species (**Y**)	Daphnid, *Ceriodaphnia dubia* LC50 = 0.07 ug/L **LOC exceeded for ALL uses** Blackfly, *Simulium vittatum IS-7* LC50 = 0.06 ug/L **LOC exceeded for ALL uses** Daphnid, *Daphnia magna* NOAEC = 0.04 ug/L **LOC exceeded for ALL uses**	Indirect Effects: California red-legged frog California tiger salamander Delta smelt California clapper rail San Francisco garter snake
	Listed Species (**Y**)		Direct Effects: California freshwater shrimp
Estuarine/Marine Fish	Non-listed Species (**Y**)	Tidewater silverside, *Menidia peninsulae* LC50 = 0.7 ug/L **LOC exceeded for 45/47 uses** Atlantic silverside *Menidia menidia* NOAEC = 0.28 ug/L **LOC exceeded for 42/47 uses**	Indirect Effects: California clapper rail
	Listed Species (**Y**)		Direct Effects: Delta smelt
Estuarine/Marine Invertebrates	Non-listed Species (**Y**)	Mysid shrimp *Americamysis bahia* LC50 = 0.035 ug/L **LOC exceeded for ALL uses** NOAEC = 0.0046 ug/L **LOC exceeded for ALL uses**	Indirect Effects: Delta smelt California clapper rail
Non-Vascular Aquatic Plants	Non-listed Species (**N**)	Alga, *Isochrysis galbana* EC50 = 140 ug/L **LOC was NOT exceeded for ANY use**	Indirect Effects: California red-legged frog California tiger salamander Delta smelt California clapper rail San Francisco garter snake California freshwater shrimp Salt marsh harvest mouse
Birds, Reptiles, and Terrestrial-Phase Amphibians	Non-listed Species (**Y**)	Acute dose-based and acute and chronic dietary-based RQs for non-listed species are exceeded for all uses.	Indirect Effects: California red-legged frog San Francisco garter snake California clapper rail California tiger salamander
	Listed Species (**Y**)	Acute dose-based and acute and chronic dietary-based RQs for listed species are exceeded for all uses.	Direct Effects: California re-legged frog San Francisco garter snake California clapper rail California tiger salamander

Table 5.20 Risk Estimation Summary for chlorpyrifos - Direct and Indirect Effects			
Taxa	**LOC Exceedances (Y/N)**	**Description of Results of Risk Estimation**	**Assessed Species Potentially Affected**
Mammals	Non-listed Species (**Y**)	Acute dose-based and acute and chronic dietary-based RQs for non-listed species are exceeded for the majority of uses.	Indirect Effects: Salt marsh harvest mouse San Joquin kit fox
	Listed Species (**Y**)	Acute dose-based and acute and chronic dietary-based RQs for listed species are exceeded for the majority of uses.	Direct Effects: Salt marsh harvest mouse San Joquin kit fox
Terrestrial Invertebrates	Listed Species (**Y**)	Acute and chronic dietary-based RQs for listed species are exceeded for all uses.	Direct/Indirect Effects: California red-legged frog San Francisco garter snake California clapper rail California tiger salamander Salt marsh harvest mouse San Joquin kit fox Bay checkerspot butterfly Valley elderberry longhorn beetle California freshwater shrimp
Terrestrial Plants - Monocots	Non-listed Species (**Y**)	No vegetative vigor or seedling emergence plant toxicity data were available. A qualitative discussion of risk is provided. Based on includent data risk is assumed.	Indirect Effects: California red-legged frog San Francisco garter snake California clapper rail California tiger salamander Salt marsh harvest mouse San Joquin kit fox Bay checkerspot butterfly Valley elderberry longhorn beetle California freshwater shrimp
Terrestrial Plants - Dicots	Non-listed Species (**Y**)	No vegetative vigor or seedling emergence plant toxicity data were available. A qualitative discussion of risk is provided. Based on includent data risk is assumed.	Indirect Effects: California red-legged frog San Francisco garter snake California clapper rail California tiger salamander Salt marsh harvest mouse San Joquin kit fox Bay checkerspot butterfly Valley elderberry longhorn beetle California freshwater shrimp
	Non-listed Species (**Y**)	No vegetative vigor or seedling emergence plant toxicity data were available.	Indirect Effects: California red-legged frog San Francisco garter snake

Table 5.20 Risk Estimation Summary for chlorpyrifos - Direct and Indirect Effects			
Taxa	**LOC Exceedances (Y/N)**	**Description of Results of Risk Estimation**	**Assessed Species Potentially Affected**
	Non-listed Species (cont.)	A qualitative discussion of risk is provided. Based on includent data risk is assumed.	California clapper rail California tiger salamander Salt marsh harvest mouse San Joquin kit fox Bay checkerspot butterfly Valley elderberry longhorn beetle California freshwater shrimp

Most of the RQs for chlorpyrifos exceeded the listed species LOCs (acute and chronic) for aquatic-phase amphibians, freshwater fish and estuarine/marine fish. All of the RQs for 20 g birds that eat short grass (used as a screening-level surrogate for terrestrial-phase amphibians in this assessment) also exceeded LOCs. All of the RQs for chlorpyrifos exceeded the LOCs (acute and chronic) for freshwater invertebrates. Therefore, a potential exists for direct effects to aquatic-phase and terrestrial-phase California red-legged frog and California tiger salamander, and for the Delta smelt from all chlorpyrifos uses except one (turfgrass), and for the California freshwater shrimp from all uses.

All of the RQs for chlorpyrifos exceeded the LOCs (acute and chronic) for freshwater invertebrates; therefore, the potential exists for indirect effects to the California red-legged frog, California tiger salamander, Delta smelt, California clapper rail and San Francisco garter snake. Since most of the RQs were exceeded for freshwater fish and aquatic-phase invertebrates, and all of the RQs were exceeded for marine invertebrates, the potential exists for indirect effects to the California clapper rail, San Francisco garter snake and Delta smelt.

Table 5.21 Risk Estimation Summary for chlorpyrifos – Effects to Designated Critical Habitat. (PCEs)			
Taxa	**LOC Exceedances (Y/N)**	**Description of Results of Risk Estimation**	**Species Associated with a Designated Critical Habitat that May Be Modified by the Assessed Action**
Vascular Aquatic Plants	Non-listed Species (**N**)	Data not available so based on non-vascular plant data. .	California red-legged frog, California tiger salamander, Delta smelt
Non-Vascular Aquatic Plants	Non-listed Species **(N**)	Alga, *Isochrysis galbana* EC50 = 140 ug/L **LOC was NOT exceeded for ANY use**	California red-legged frog, California tiger salamander, Delta smelt
Terrestrial Plants - Monocots	Non-listed Species (**Y**)	No vegetative vigor or seedling emergence plant toxicity data were available. A qualitative discussion of risk is provided. Based on includent data risk is assumed.	California red-legged frog, California tiger salamander, Delta smelt
Terrestrial Plants - Dicots	Non-listed Species (**Y**)	No vegetative vigor or seedling emergence plant toxicity data were available. A qualitative discussion of risk is provided. Based on includent data risk is assumed.	California red-legged frog, California tiger salamander, Delta smelt Bay checkerspot butterfly, Valley elderberry longhorn beetle – if dicots harmed, harm to these two spp. is likely.

The California red-legged frog, California tiger salamander, Delta smelt, Bay checkerspot butterfly and Valley elderberry longhorn beetle have designated critical habitat. This includes both aquatic and terrestrial plants for the three aquatic or semi-aquatic species and dicot terrestrial plants for the two insects (**Tables 5.20. and 5.21**). None of the RQs for chlorpyrifos exceeded the listed species LOCs (acute and chronic) for aquatic non-vascular plants. Because of the absence of terrestrial plant effects data for chlorpyrifos, the Agency turned to other lines of evidence to evaluate the potential for chlorpyrifos to affect terrestrial vegetation. Available incident data suggest that, in the absence of actual controlled terrestrial plant effects studies, there is evidence that the pesticide can and does adversely affect terrestrial vegetation, although the chemical exposure threshold for such damage is not presently quantifiable. The potential for direct and/or indirect effects from the animal data also shows that chlorpyrifos use “may affect” **all** the species listed in this assessment and/or their designated critical habitat.

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

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

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

A description of the risk and effects determination for each of the established assessment endpoints for the assessed species and their designated critical habitat is provided in **Sections 5.5.1. through 5.5.2.** The effects determination section for each listed species assessed will follow a similar pattern. Each will start with a discussion of the potential for direct effects, followed by a discussion of the potential for indirect effects. For those listed species that have designated critical habitat, the section will end with a discussion on the potential for modification to the critical habitat from the use of chlorpyrifos.

5.5.1 Direct Effects

5.5.1.1 Aquatic Species

Effects to aquatic-phase amphibians, as well as both freshwater and saltwater fish are significant and not discountable. Runoff may cause effects wherever chlorpyrifos is used near sites inhabited by the California red-legged frog, California tiger salamander, Delta smelt or California freshwater shrimp.

Based on the weight-of-evidence, a quite marked potential does exist for direct effects to both aquatic- and terrestrial-phase of the California red-legged frog and California tiger salamander, and the Delta smelt.

Aquatic-Phase Amphibians and Fish

The aquatic-phase of the California red-legged frog and California tiger salamander consists of life stages in which they are obligatory aquatic organisms; these are mainly the egg and larval stages. The aquatic-phase also includes, to a lesser degree, submerged terrestrial-phase juveniles and adults, which spend a portion of their time in water bodies that may receive runoff and spray drift containing chlorpyrifos.

Toxicity tests on aquatic-phase amphibians are typically not required. It is assumed that acute toxicity data for fish will protect aquatic life stages of amphibians, just as oral toxicity data for birds is expected to protect the terrestrial-phase. Studies reviewed in the most recent chlorpyrifos RED (USEPA, 2002) showed that chlorpyrifos is very highly toxic to larval amphibians. Small tadpoles appeared to be more sensitive to chlorpyrifos than older life stages. Water pH had little effect on the toxicity of chlorpyrifos to tadpoles. The fact that young tadpoles were equal to or more sensitive to chlorpyrifos as the most sensitive fish species in the 1999 RED data, raised concerns for assessing risks.

A comparison of the dose:response relationships for various taxa is somewhat revealing from the data reviewed for this risk assessment. In fish, acute effects were seen at concentrations two orders of magnitude greater than concentrations where chronic effects were seen (**Table 4.1**); however, for amphibians (**Table 4.3**) and freshwater invertebrates (**Appendix E**), acute effects concentrations were much closer to chronic effects concentrations (within the same order of magnitude) suggesting perhaps different toxicity mechanisms at work in fish than in amphibians and aquatic invertebrates. Acute fish toxicity data was less similar to acute aquatic-phase amphibian data than chronic data from the two classes, but this may be due to life stages tested. As mentioned earlier, Richards and Kendall (2002 and 2003) found that when tadpoles were exposed to chlorpyrifos while still drawing nutrients from the yolksac (premetamorph stage) they were particularly resistant; this data raises the steepness of the dose:response relationship for *X. laevis* drastically. These data suggest that tadpoles are particularly resistant as premetamorphs and thus, toxicity data should be used from more sensitive life stages. Fish fry also obtain nutrition from a yolksac; however, since amphibians metamorphose and fish grow with much less morphological change, any assessment to aquatic-phase amphibians should be conducted with data from sensitive amphibian life stages or with fish data as surrogates. Data from more resistant life-stages of amphibians may not adequately assess the risk.

Aquatic-Phase California Red-Legged Frog and California Tiger Salamander

All but one (turfgrass use) of the RQs for aquatic-phase amphibians exceeded the chronic LOCs for listed amphibians. The listed species acute LOC of 0.05 is associated with a probability of an individual effect of approximately 1 in 418,000,000 (using a default slope of 4.5). A more detailed look was taken at amphibian data by reviewing all amphibian studies in the ECOTOX accepted papers list (**Appendix F**). Supplemental chlorpyrifos toxicity data were available for several aquatic phase amphibian species including the African clawed frog, *Xenopus laevis*, the Southern leopard frog, *Rana sphenocephala* and other North American anuran frogs, *Hyla chrysoscelis, Acris crepitans* and *Gastrophyne olivacea*.

Richards and Kendall (2003) examined changes in body length, mass and swimming ability of two developmental stages (premetamorph and metamorph) of the African clawed frog, and found that metamorphs were more sensitive than premetamorphs. Metamorph body length and swimming ability were significantly impaired by 0.1 ug/L chlorpyrifos, the LOAEC and the lowest concentration tested. Authors also calculated that chlorpyrifos has a 0.1-32.8%

probability of exceeding a 96-h time-weighted average of 0. 1 ug/L in U.S. surface waters. Widder and Bidwell (2006) found cholinesterase (ChE) activity in a North American anuran frog, *Rana sphenocephala* tadpoles to be significantly inhibited by 100 ug/L chlorpyrifos in 12 days. The NOEC was 10 ug/L chlorpyrifos, which was not as sensitive as the chronic effects level for the fathead minnow, 0.57 ug/L chlorpyrifos. These authors in a later study (Widder and Bidwell, 2008) compared chlorpyrifos toxicity in four species of North American anuran frogs, *Hyla chrysoscelis*, *Rana sphenocephala*, *Acris crepitans* and *Gastrophyne olivacea*. Exposure durations were 4- and 12-days. Authors analyzed growth, cholinesterase activity (ChE) inhibition and swim speed. NOAECs showed a very wide range among frog species tested, ranging from <1 to >200 ug/L chlorpyrifos. *R. sphenocephala* was the least sensitive species as measured by ChE activity staying above 50% of control levels except in the highest concentration tested. Growth (mass), however, was significantly impaired in the 10 ug/L non-sediment treatment, and so the LOEC for this species is 10 ug/L and the NOEC 1 ug/L chlorpyrifos. R. sphenocephala was actually the most sensitive species tested in the growth study. This is important since it is of the same genus as the California red-legged frog (*Rana aurora draytonii)* and since growth is an endpoint which is accepted by EPA for use in determining risk quotients.

Acute toxicity data from the genus, *Rana*, was fairly consistent, with LC50s ranging from 19 to 67 ug/L chlorpyrifos, and NOAECs from 1 to 50 ug/L chlorpyrifos. Acute toxicity data for all frog studies reviewed was much more varied, with LC50s ranging from 0. 6 to 14,600 ug/L chlorpyrifos (both high and low from the African clawed frog, *X. laevis*). If the data point 14,600 is removed as an outlier, however, the data are somewhat more consistent, but still ranges from 0.6 to 560 ug/L chlorpyrifos. Interestingly, the 14,6000 data point was obtained from a test using premetamorph tadpoles, which still depend on a yolksac for nourishment and absorb very little from their environment. Since chlorpyrifos chief toxicity mechanism is the inhibition of acetylcholinesterase, a lack of toxicity is not surprising if uptake is not yet occurring in the tadpole. Chronic toxicity data for all frog studies reviewed was also quite varied, with NOAECs ranging from <0. 1 to 100 ug/L chlorpyrifos. These data suggest that age of test organisms, frog taxa and perhaps additional factors can greatly influence frog toxicity endpoints.

Delta Smelt

All but one (turfgrass use) of the RQs for freshwater fish exceeded acute LOC for listed fish; and more than half exceeded the chronic LOC for listed fish. All but two (turfgrass and alfalfa clover uses) of the RQs for saltwater fish exceeded the acute LOC for listed fish; and all but five exceeded the chronic LOC for listed fish. Toxicity data for freshwater and saltwater fish were fairly consistent (in studies considered), ranging from 1.8 to 2.9 ug/L chlorpyrifos for acute freshwater and 0.70 ug/L to 0.96 ug/L for acute saltwater LC50s, and from <0.20 to 0.56 ug/L chlorpyrifos for chronic freshwater; the only data point included for chronic saltwater NOAECs was also consistent, 0.28 ug/L for the Atlantic silverside.

New supplemental data were available from the open literature for freshwater fish to help characterize effects to aquatic species of concern (see **Appendix E**). One such study (De Silva and Samayawardhena, 2002) using a typical end-use product, reported mortality, paralysis and histological abnormalities in juvenile guppies exposed to chlorpyrifos. This study showed guppies to be more sensitive to chlorpyrifos than fathead minnows, but the study did not produce an NOAEC. Authors looked at behavioral and histological effects of low concentrations of Lorsban to early life stages of guppies (*Poecilla reticulate*). The test concentrations were expressed as ug/L Lorsban, rather than ug/L chlorpyrifos. The Lorsban used in the study contained 400 ug/L chlorpyrifos, purity 98%. The LC_{50} and LOAEC were approximately 60% lower than those reported and were recalculated to convert to ug chlorpyrifos/L; however, since concentrations were not measured, it was not possible to confirm these data, and, thus the data could not be used to calculate the risk quotient. Concentrations, as low as 1 ug/L, caused changes in swimming behavior within 96 h. Authors stated that from the onset of the experiment, the initial quick swimming behavior shifted to unusual swimming behavior. By day-14 signs of paralysis and hemorrhaging were recorded in the lowest concentration tested 0. 5 ug/L Lorsban, which calculates to 0. 2 ug/L chlorpyrifos. Therefore the LOAEC was 0. 2 ug/L chlorpyrifos but no NOAEC was determined. This was the most sensitive endpoint for fish but could not be confirmed.

Carr, *et al*. (1995) sought to better understand the process by which chlorpyrifos and parathion are taken up and metabolized to their oxidized forms which affect acetylcholinesterase (AChE) activity. They exposed fingerling channel catfish (*Ictalurus punctatus*) to single concentrations of high doses each of chlorpyrifos (250 ug/L), chlorpyrifos-oxon (7 ug/L), parathion (2.5 mg/L) and paraoxon (30 ug/L) and then measured inhibition and aging of AChE in brain tissue. The AChE activity in all treatments was significantly different from controls at all times sampled. This study was not designed to produce toxicity endpoints that EPA could use for a risk assessment. Rather, it was designed to study AChE trends over time in response to pesticide exposure and gives an interesting perspective on the patterns of AChE activity following exposure, useful in effects characterization. Chiefly, authors found that aging of inhibited AChE did not appear to cause the persistent inhibition following chlorpyrifos exposure (as compared to parathion exposure), but rather attributed the persistence to the lipophilicity of chlorpyrifos.

The toxicities of chlorpyrifos and chlorothalonil (a fungicide) were compared in a study by Sherrard *et al*. (2002) using *Ceriodaphnia dubia* and the fathead minnow, *Pimephales promelas*. Daphnia were more sensitive to chlorpyrifos and fathead minnows were more sensitive to chlorothalonil. For the fathead minnow, the 10-d LC50 was 150 ug/L chlorpyrifos. For surviving fish, no significant difference was found between treatment groups and the control. For daphnia, even though there was significant mortality in the 0.09 ug/L treatment an LC50 was not determined. The lower and upper thresholds for mortality in this study were 0.05 and 0.09 ug/L chlorpyrifos, with an estimated 10-d LC50 of 0.07 ug/L chlorpyrifos. Despite this, there was no significant reproductive impairment in the lowest concentration tested, 0.05 ug/L chlorpyrifos. The most salient point from this study may be that fish seem to be more sensitive to chlorothalonil, and daphnids to chlorpyrifos, which is not surprising, given the sensitivity of invertebrates to chlorpyrifos found in data reviewed for this assessment.

California Freshwater Shrimp

In general, all aquatic invertebrate data reviewed (**Section 5.2.1.2**) had similar effect levels. Comparing freshwater shrimp data to other invertebrate data, both freshwater and saltwater, we see that freshwater shrimp toxicity levels are consistent with those from other aquatic invertebrates combined. The California freshwater shrimp RQs were calculated using acute and chronic freshwater crustacean data. Endpoints were so similar that several good endpoints were available for calculating these RQs. The Ceriodaphnia dubia endpoint used (LC50, 0.07 ug/L chlorpyrifos) was only minutely different from the blackfly endpoint (LC50, 0.06 ug/L chlorpyrifos) used for freshwater invertebrates, in general (indirect effects calculations for aquatic-phase amphibians and fish). The most sensitive chronic endpoint turned out to be another freshwater crustacean (*D. magna*, NOAEC, 0.04 ug/L chlorpyrifos). Therefore, the same chronic endpoint was used for RQ calculations for the shrimp as for other freshwater invertebrates. Either way, RQs for ALL uses exceeded the LOC for endangered species (0.05 for acute and 0.10 for chronic).

Olima *et al*. (1997) compared the tolerance for chlorpyrifos among three naturally occurring populations of freshwater shrimp (*Paratya australiensis*) by conducting 96-h toxicity tests. Acetylcholinesterase activity (AChE) and mortality were measured. The populations from an unpolluted site were less tolerant than the organisms from polluted sites. The authors attributed the chlorpyrifos tolerance to previous exposure to pollutants including pesticides, and in one site with a long human presence to evolution of resistant organisms. Shrimp from the unpolluted site were the most sensitive, with an LC50 of 0.08 ppb, NOAEC of 0.04 ppb and LOAEC of 0.07 ppb. Shrimp from the polluted sites had LC50s ranging from 0.14 – 0.28 ppb, NOAECs ranging from 0.09 – 0.20 ppb, and LOAECs ranging from 0.12 – 0.27 ppb. Van Wijngaarden et al. (1996, reviewed above) found that within crustacea, the toxicity range differed by a factor of 10^3, with the freshwater shrimp, *P. coxalis,* having a 96-hr LC10 of >20 ug/L. This data is somewhat inconsistent with the data found in this review; this review, however only concerned aquatic invertebrate papers identified by the ECOTOX database as being the most sensitive endpoints. Undoubtedly, some variation in sensitivity exists among crustacea and other invertebrate taxa.

A strong potential exists for significant effects to the California freshwater shrimp and these are not discountable. Runoff may cause effects wherever chlorpyrifos is used near sites inhabited by the California freshwater shrimp.

Aquatic Incidents

A review of the incident databases shows a total of 280 reported ecological incidents associated with the use of chlorpyrifos (see **Appendix J**). Chlorpyrifos has been reported as the ‘probable’ or ‘highly probable’ causative agent for 110 (of the reported 123) adverse aquatic incidents (*e.g.*, fish kills). These incidents were reported over the period of 1974 to 2009. These incidents resulted from the legal, registered uses of chlorpyrifos as well as misuses. In addition, in some cases it could not be determined if the incident resulted from the legal use of chlorpyrifos or misuse. Although the number of reported incidents has dropped considerably since mitigation measures were implemented following the 2002 IRED, the absence of reported incidents in 2006 and 2007 should not be construed as the absence of incidents. EPA's changes in the registrant reporting requirements of incidents or other factors may account for the reduced number of reported incidents. Overall, the incident data that are available indicate that exposure pathways for chlorpyrifos are complete and that exposure levels are sufficient to result in field-observable effects.

Five incidents were attributed to chlorpyrifos since EPA's most recent review of the EIIS database (10/16/07 new use – need to add the reference), four involved mostly aquatic organisms. In 2007, Koi carp (*Cyprinus carpio*,<17 individuals) were killed (EIIS Incident No. I019051-003) from a backyard pond in a residential area, after 2-3 days exposure to Mosquitomist 1.5 ULV Concentrate (active ingredient Chlorpyrifos). A wide area had been sprayed in the vicinity of the pond. The legality was undetermined and certainty probable; chlorpyrifos is highly toxic to fish and the spray could have caused the mortality. The route of exposure was spray drift.

In 2008, the Iowa Department of Natural Resources reported a large fish kill (EIIS Incident No. I020252-001) in which dead fish were found along a five mile stretch of a stream in Louisa County, Iowa. The total number of dead fish were approximately 15,300 including an estimated 7000 minnows (Cyprinidae), 3000 stonerollers, 2700 Johnny darters (Percidae), 800 green sunfish (*Lepomis cyanellus*), 800 bullheads (*Ameiurus sp*), 1000 white suckers (*Catostomus commersomi*), 40 bluegills (*Lepomis macrochirus*), and 2 largemouth bass (*Micropterus salmoides*). Iowa Department of Natural Resources has not been able to determine exactly how the chemicals entered the stream; however, the report states that there was both aerial and ground spraying of Headline (active ingredient, pyraclostrobin, a fungicide, 099100), Lorsban (active ingredient, chlorpyrifos), and Cobalt (active ingredient, chlorpyrifos) on corn and soybean fields in the vicinity prior to the incident. Chlorpyrifos was measured at 1.8 ppb (which, coincidentally, is the 96-hr LC50 for bluegill sunfish, the acute endpoint for freshwater fish, used in this risk assessment) using in a water sample taken close to the field that had been sprayed. Pyraclostrobin was measured in water samples at 29 ppb close to the field and at 13 ppb a couple of miles downstream. These levels were also greater than the LC50 for freshwater fish (6.2 - 11.4 ppb). No evidence was found of other stressors, including ammonia, low dissolved oxygen, manure runoff, or other pesticides (there were only "trace amounts" of other pesticides in the water samples). Legality was undetermined, certainty probable, but the role of chlorpyrifos vs. that of pryaclostrobin was unclear. Use was for corn and soybeans.

More recently, two large fish kills occurred in Iowa. In July, 2009, in which approximately 540 fish were killed: 480 bluegills, 43 minnows, 9 largemouth bass, 8 Johnny darters, and 1 each slender madtom and yellow bullhead. Chlorpyrifos was almost certainly the primary cause if this kill. Measured concentrations of chlorpyrifos were as high as 12 ppb, several times the LC50 for bluegill sunfish (1.8 ppb). Pyraclostrobin was also present and cannot be ruled out as a possible contributing factor. Measured concentrations were as high as 1 ppb, which compares to a bluegill LC50 11.4 ppb. Myclobutanil was also detected at low levels but probably was not a factor considering its low toxicity to fish (bluegill LC50 2400 ppb). Causes for this incident were deemed "highly probable" for chlorpyrifos, "possible" for pyraclostrobin, and "unlikely" for myclobutanil.

Then in an August 21, 2009 incident, approximately 945 fish were killed in a stream near Kanawha, Iowa. The dead fish were mostly suckers, along with darters, catfish, sunfish and minnows The stream ran through soybean and corn farms with little to no buffers. The incident was attributed to the ariel spraying of chlorpyrifos. Chlorpyrifos was measured in the stream at concentrations as high as 1.7 ppb, which is very close to the LC50 for bluegill sunfish.

5.5.1.2 Terrestrial Species

As stated in the Risk Estimation section (**Section 5.1.2.1**), the acute and chronic avian and mammalian dose and dietary-based RQs estimated with T-REX exceed the LOCs listed species for all uses of chlorpyrifos, including granular and seed treatment uses. Since the T-REX model is designed to assess direct effects to birds and mammals, results of the T-REX analysis are considered appropriate for assessing potential effects to the California Clapper Rail, the salt marsh harvest mouse and the San Joaquin fox from exposure to chlorpyrifos. No additional refinements to the T-REX assessments for these species are required. However, further evaluation of potential direct impact to the non-avian species of concern is required. To refine the acute dose-based risk estimates for non-bird species, the T-REX model was modified to account for the lower metabolic rate and lower caloric requirement of amphibians (compared to birds). Acute dose- and dietary-based RQs were recalculated for using the T-HERPS (Ver. 1.0) model with species-specific body weights for frog, snake, and salamander species.

There were no avian or amphibian studies available in the ECOTOX open literature for chlorpyrifos. Relevant data from mammalian studies available in ECOTOX have been incorporated into the mammalian ecological assessment. Reported incidents involving chlorpyrifos exposures to birds, terrestrial-phase amphibians, and mammals have been reviewed, documented and considered as part of this assessment.

California Clapper Rail

The acute avian dose and dietary-based RQs estimated using the T-REX model exceed the acute and chronic listed LOCs of 0.1 and 1 respectively for the California Clapper Rail for all uses of chlorpyrifos, including granular and seed treatment uses. Extensive available acute avian toxicity data for chlorpyrifos indicate that chlorpyrifos is highly toxic to a number of bird species. There are 19 available acute toxicity studies on technical grade chlorpyrifos covering 15 different avian species. Adverse effects were observed in the available acute studies at levels ranging from moderate to very highly toxic. The majority of the available acute studies resulted in effects categorized as highly or very highly toxic for a variety of species (12 of 19 studies). Subacute dietary studies in several bird species also indicate that chlorpyrifos can be highly toxic to birds. Results from the 14 available subacute toxicity studies representing four different avian species indicate that effects occurred at exposure levels categorized as moderately to highly acutely toxic. Of the available subacute studies, results from at least one study for each of the four avian species tested resulted in effects at levels categorized as highly toxic. Additionally, mortalities occurred in two species in six avian subacute dietary studies. Adverse growth and reproduction effects were consistently observed within a relatively narrow dose range (60 – 125 ppm) in studies in mallard duck and bobwhite quail species. Adverse growth/reproductive effects were seen in both species in four of the five available reproduction studies. The evidence from a number studies on a range of avian species indicates potential for direct effects to the CCR. The effects determination is likely to adversely affect.

California Red Legged Frog

In a refined assessment for the CRLF, dose-based RQs were recalculated for all application scenarios using the T-HERPS model for small (1 g), medium (37 g), and large (238 g) frogs.

The range of dose-based RQs generated by T-HERPS (**Table 5.22**). The highest dose-based RQs are associated with use of chlorpyrifos on cole crops. For this use, the acute RQs exceed the acute listed species LOC of 0.1 for small, medium and large frogs for all but two of the food consumption scenarios assessed. Use of chlorpyrifos on wheat generated the lowest RQs for agricultural uses. RQ's for use on wheat exceed the acute LOC for three of the seven dietary exposure scenarios assessed. For the non-agricultural uses of chlorpyrifos on ornamentals and turf grass, RQs exceed the acute LOC for all weight classes of frogs for all but two of the feeding scenarios assessed. As noted, the evidence from a number of surrogate toxicity studies on a range of avian species which are considered indicates potential for direct effects to the CRLF. The effects determination is likely to adversely affect.

Table 5.22 T-HERPS Dose-based RQs for CRLF

Use/Application Rate (lbai/A)	Diet	S (1 g)		M (37 g)		L (238 g)	
		EEC	RQ	EEC	RQ	EEC	RQ
Cole Crop 3 lb aiA	Short Grass	60	**11**	59	**10**	39	**7**
	Tall Grass	27	**5**	27	**5**	18	**3**
	Broadleaf plants/sm Insects	34	**6**	33	**6**	22	**4**
	Fruits/pods/seeds/lg insects	4	**1**	4	**1**	2	**0.4**
	Small herbivore mammals	N/A	N/A	962	**171**	150	**27**
	Small insectivore mammals	N/A	N/A	60	**11**	9	**2**
	Small terrestrial phase amphibian	N/A	N/A	1	**0.2**	1	**0.1**
Wheat 0.5 lb aiA	Short Grass	6	**1.0**	6	**1.0**	4	**0.7**
	Tall Grass	3	**0.5**	3	**0.5**	2	**0.3**
	Broadleaf plants/sm Insects	3	**0.6**	3	**0.6**	2	**0.4**
	Fruits/pods/seeds/lg insects	0	**0.1**	0	**0.1**	0	< 0.1
	Small herbivore mammals	N/A	N/A	93	**16.6**	15	**2.6**
	Small insectivore mammals	N/A	N/A	6	**1.0**	1	**0.2**
	Small terrestrial phase amphibian	N/A	N/A	0	**0.0**	0	< 0.1
Ornamentals 4 lb aiA	Short Grass	37	**7**	37	**7**	24	**4**
	Tall Grass	17	**3**	17	**3**	11	**2**
	Broadleaf plants/sm Insects	21	**4**	21	**4**	14	**2**
	Fruits/pods/seeds/lg insects	2	**0.4**	2	**0.4**	2	**0.3**
	Small herbivore mammals	N/A	N/A	598	**106**	93	**17**
	Small insectivore mammals	N/A	N/A	37	**7**	6	**1**
	Small terrestrial phase amphibian	N/A	N/A	1	**0.1**	0	**0.1**
Turf Grass 4 lb aiA	Short Grass	66	**12**	65	**12**	42	**8**
	Tall Grass	30	**5**	30	**5**	19	**3**
	Broadleaf plants/sm Insects	37	**7**	36	**6**	24	**4**
	Fruits/pods/seeds/lg insects	4	**1**	4	**1**	3	**0**
	Small herbivore mammals	N/A	N/A	1055	**188**	164	**29**
	Small insectivore mammals	N/A	N/A	66	**12**	10	**2**
	Small terrestrial phase amphibian	N/A	N/A	1	**0.2**	1	**0.2**

Bold indicates that the RQ exceeds the listed species LOC (0.1 acute, 1 chronic)

San Francisco Garter Snake

T-HERPs was used to refine the SFGS assessment. Dose-based RQs were recalculated for all use scenarios using the T-HERPS model for juvenile (2 g), adult male (113 g), and adult female (227 g) snakes. The range of dose-based RQs for the SFGS generated by T-HERPs for agricultural applications and ornamental and turf uses are presented in **Table 5.23**. With the exception of three dietary exposure scenarios for use of chlorpyrifos on wheat and ornamentals, the acute RQs exceed the acute listed species LOC of 0.1 for all dietary exposure scenarios assessed for snakes. As noted, the evidence from a number of surrogate toxicity studies on a range of avian species which are considered indicates potential for direct effects to the SFGS. The effects determination is likely to adversely affect.

Table 5.21 T-HERPS Dose-based RQs for SFGS

Use/AR (lbai/A)	Diet	Juvenile (2 g)		Adult M (113 g)		Adult F (227 g)	
		EEC	RQ	EEC	RQ	EEC	RQ
Cole Crop 3 lb aiA	Short Grass	55.3	**10**	45.7	**8**	39.0	**7**
	Tall Grass	25.3	**5**	21.0	**4**	17.9	**3**
	Broadleaf plants/sm Insects	31.1	**6**	25.7	**5**	22.0	**4**
	Fruits/pods/seeds/lg insects	3.5	**1**	2.9	**1**	2.4	**0**
	Small herbivore mammals	N/A	**N/A**	315.0	**56**	156.8	**28**
	Small insectivore mammals	N/A	**N/A**	19.7	**4**	9.8	**2**
	Small terrestrial phase amphibian	N/A	**N/A**	0.9	**0.1**	0.8	**0.1**
Wheat 0.5 lb aiA	Short Grass	5.4	**1.0**	4.4	**0.8**	3.8	**0.7**
	Tall Grass	2.5	**0.4**	2.0	**0.4**	1.7	**0.3**
	Broadleaf plants/sm Insects	3.0	**0.5**	2.5	**0.4**	2.1	**0.4**
	Fruits/pods/seeds/lg insects	0.3	**0.1**	0.3	**0.0**	0.2	< 0.1
	Small herbivore mammals	N/A	**N/A**	30.6	**5.4**	15.2	**2.7**
	Small insectivore mammals	N/A	**N/A**	1.9	**0.3**	1.0	**0.2**
	Small terrestrial phase amphibian	N/A	**N/A**	0.1	**0.1**	0.1	< 0.1
Ornamentals 4 lb aiA	Short Grass	34.4	**6**	28.4	**5**	24.3	**4**
	Tall Grass	15.8	**3**	13.0	**2**	11.1	**2**
	Broadleaf plants/sm Insects	19.3	**3**	16.0	**3**	13.7	**2**
	Fruits/pods/seeds/lg insects	2.1	**0.4**	1.8	**0**	1.5	**0**
	Small herbivore mammals	N/A	**N/A**	195.9	**35**	97.5	**17**
	Small insectivore mammals	N/A	**N/A**	12.2	**2**	6.1	**1**
	Small terrestrial phase amphibian	N/A	**N/A**	0.6	**0.1**	0.5	**0.1**
Turf Grass 4 lb aiA	Short Grass	60.7	**11**	50.2	**9**	42.8	**8**
	Tall Grass	27.8	**5**	23.0	**4**	19.6	**3**
	Broadleaf plants/sm Insects	34.1	**6**	28.2	**5**	24.1	**4**
	Fruits/pods/seeds/lg insects	3.8	**1**	3.1	**1**	2.7	**0**
	Small herbivore mammals	N/A	**N/A**	345.6	**61**	172.0	**31**
	Small insectivore mammals	N/A	**N/A**	21.6	**4**	10.8	**2**
	Small terrestrial phase amphibian	N/A	**N/A**	**1.0**	**0.2**	0.8	**0.2**

Bold indicates that the RQ exceeds the listed species LOC (0.1 acute, 1 chronic)

California Tiger Salamander

Dose-based RQs were recalculated for all use scenarios using the T-HERPS model for average weight salamander species. T-HERPs dose-based RQs for the CTS are presented in **Table 5.24**. These RQs were recalculated for all use scenarios using the T-HERPS model and average body weight assumptions for the salamander. The evidence indicates potential for direct effects to the CTS. The effects determination is likely to adversely affect.

Table 5.23 T-HERPS Dose-based RQs for CTS

Use/Application Rate (lbai/A)	Diet	Average (50 g)	
		EEC	RQ
Cole Crop 3 lb aiA	Short Grass	55	**11**
	Tall Grass	25	**4.5**
	Broadleaf plants/sm Insects	31	**5**
	Fruits/pods/seeds/lg insects	3	**0.55**
	Small herbivore mammals	712	**128**
	Small insectivore mammals	45	**8**
	Small terrestrial phase amphibian	1	**0.2**
Wheat 0.5 lb aiA	Short Grass	5	**1.0**
	Tall Grass	3	**0.5**
	Broadleaf plants/sm Insects	3	**0.5**
	Fruits/pods/seeds/lg insects	>1	**0.2**
	Small herbivore mammals	69	**1**
	Small insectivore mammals	4	**0.7**
	Small terrestrial phase amphibian	>1	**0.2**
Ornamentals 4 lb aiA	Short Grass	34	**6**
	Tall Grass	16	**3**
	Broadleaf plants/sm Insects	19	**3**
	Fruits/pods/seeds/lg insects	2	**0.4**
	Small herbivore mammals	443	**79**
	Small insectivore mammals	28	**5**
	Small terrestrial phase amphibian	1	**0.1**
Turf Grass 4 lb aiA	Short Grass	60	**55**
	Tall Grass	28	**5**
	Broadleaf plants/sm Insects	34	**6**
	Fruits/pods/seeds/lg insects	4	**0.7**
	Small herbivore mammals	781	**141**
	Small insectivore mammals	49	**9**
	Small terrestrial phase amphibian	1	**0.2**

Bold indicates that the RQ exceeds the listed species LOC (0.1 acute, 1 chronic)

Salt Marsh Harvest Mouse

The acute and chronic mammalian dose and/or dietary-based RQs estimated using the T-REX model exceed the acute and chronic LOC for the salt mouse harvest mouse for all spray applications of chlorpyrifos and for the majority of granular and seed treatment uses. Based on available toxicity data, chlorpyrifos is moderately toxic to small mammals on an acute oral basis and slightly toxic to mammals via subacute exposure. Reproductive effects observed in a 2-generation rat study included reduced pup weights and increased pup mortality. The evidence indicates potential for direct effects to the SMHM. The effects determination is likely to adversely affect.

San Joaquin Kit Fox

The acute and chronic mammalian dose and/or dietary-based RQs estimated using the T-REX model exceed the acute and chronic LOC for the San Joaquin kit fox for all spray applications of chlorpyrifos and for the majority of granular and seed treatment uses. The evidence indicates potential for direct effects to the SJKF. The effects determination is likely to adversely affect.

Bay Checkerspot Butterfly and Valley Elderberry Longhorn Beetle

The RQs for both small and large insects significantly exceed the acute LOC for listed species for all chlorpyrifos uses. The acute RQs for small insects range from 180 (wheat) to 2070 (turf) and the acute RQs for large insects range from 20 to 228 for wheat and turf respectively. The highest terrestrial invertebrate endpoint from the available acute toxicity studies is 0.114 µg ai/bee. The lowest RQ, using the endpoint from this study is xx (wheat) which still exceeds the acute list species LOC of 0.05. There are also two laboratory studies that evaluate toxicity to honey, alfalfa leaf-cutter and alkali bees from residues on of chlorpyrifos on alfalfa foliage after application of the 4EC formulation. These studies indicate high residual toxicity to all bee species through 8 hours post-application and continued high toxicity to honey and leaf-cutter bees at 24 hours post-treatment. A submitted study on adult lady beetles also indicates chlorpyrifos toxicity to beetles from direct application of the 4EC chlorpyrifos formulation based on a 70% reduction in survival of adult lady beetles 48 hours after application. The only available field study on bees showed significantly suppressed visitation (46%) for three days post-treatment but indicated low overall toxicity to bees. The evidence indicates potential for direct effects to the BCB and VELB. The effects determination is likely to adversely affect.

Terrestrial Incidents

As stated in **Section 5.5.1.1.**, a review of the incident databases shows a total of 280 reported ecological incidents associated with the use of chlorpyrifos (see **Appendix J**). Chlorpyrifos has been reported as the ‘probable’ or ‘highly probable’ causative agent for 80 (of the reported 108) terrestrial incidents, many of which were bird and honey bee kills. These incidents were reported over the period of 1974 to 2009 and resulted from the legal, registered uses of chlorpyrifos as well as misuses. Some cases were never resolved as to whether the cause was legal use of chlorpyrifos or misuse. Although the number of reported incidents has dropped considerably since mitigation measures were implemented following the 2002 IRED, the absence of reported incidents in 2006 and 2007 should not be construed as the absence of incidents since EPA's registrant reporting requirements changed for incidents Overall, the incident data that are available indicate that exposure pathways for chlorpyrifos are complete and that exposure levels are sufficient to result in field-observable effects.

Three incidents were attributed to chlorpyrifos since EPA's most recent review of the EIIS database (October 16, 2007), two involved mostly aquatic organisms and are described above. The third involved mostly terrestrial organisms. In 2008, a corn field was sprayed via aerial applicator with Lorsban-4E and caused mortality in nearby bee colonies (this is covered in more detail in the terrestrial section). Other notable aquatic incidents from past data include an incident in 1992 (EIIS Incident No. I000087-001) in which an unknown number of frogs were killed by chlorpyrifos, but misuse was suspected in this case. Incident data clearly show chlorpyrifos' potential for causing toxicity to aquatic animals.

A query of the American Bird Conservancy Database, on September 1, 2009 showed 3,630 incidents attributed to chlorpyrifos, resulting in the deaths of 430,718 birds (see **Appendix J**). The EIIS database had one new study to report. In 2008, a corn field was sprayed via aerial applicator with Lorsban-4E emilsifiable concentrate (active ingredient chlorpyrifos) at Sacramento County, California (EIIS Incident No. I020441-001**)**. The aircraft was spraying for armyworms. One hundred and eighty (180) beehives (*Apis millifera*) were on levees or roadways on each side of the corn field. The majority of the bees in these hives were completely killed with only sealed brood remaining. Three hundred hives, within a mile from the main kill location, also were found to have mortality; dead field bees were noticed around these hives. These hives were not directly sprayed and had adequate food supplies for the winter. Report authors attributed the bee kill and the slow die off to Lorsban residue in the corn pollen that continued to kill bees after the spraying. Corn pollen was the only pollen source in drought years which the bees brought back to the hives. Corn pollen contaminated with chlorpyrifos was the most likely explanation of bee mortality. The aerial applicator that applied Lorsban agreed to pay for the loss in a settlement agreement. The bee kill was determined to be due to a legally registered use and certainty was probable. Other notable items include a fox killed by runoff (EIIS Incident No. I000962-001) and a raccoon, rat, squirrel and lobster killed by drift (EIIS Incident No. I010831-005) of chlorpyrifos.

No terrestrial plant phytotoxicity data were available to quantitatively assess the potential risk to terrestrial plants; however evidence from the EIIS suggests that chlorpyrifos poses a risk to terrestrial plants. Chlorpyrifos had been reported (at the time of the last RED, USEPA, 2002) as the 'probable' or 'highly probable' causative agent for 19 (of the reported 43) incidents of plant (agricultural crop) damage. Chlorpyrifos was linked as a 'possible' causative agent in 22 (of the reported 43) plant incidents. No new incidents were found in this query.

5.5.2 Indirect Effects

Potential Loss of Prey

5.5.2.1 Aquatic Organisms

Pesticides have the potential to indirectly affect listed species by causing changes in structural or functional characteristics of affected communities. Structural changes usually mean those changes that involve the loss of a plant or animal from the community that the listed species relies upon for food or shelter. Functional changes involve rates, for example, primary productivity, which can be impaired by pesticides. Reduction in such a rate can affect the food source of the listed species. These are considered indirect effects of the pesticide, and can be part of the critical habitat modification evaluation. To assess indirect effects, direct effects LOCs were used from taxonomic groups (*e.g.*, freshwater fish, invertebrates and aquatic plants) essential to the life history of the listed species, to infer the potential for indirect effects upon listed species (USEPA, 2004); this approach has been endorsed by the Services (USFWS/NMFS, 2004).

The California red-legged frog's diet consists mainly of algae during its earliest stages and then freshwater aquatic invertebrates and fish. In its terrestrial-phase, the frog's diet consists of terrestrial invertebrates, small mammals, and frogs. The California tiger salamander's diet during the aquatic-phase consists of algae, snails, zooplankton, small crustaceans, aquatic larvae and invertebrates, smaller tadpoles of Pacific tree frogs and California red-legged frogs. As an adult, its diet consists of terrestrial invertebrates, insects, frogs, and worms. The Delta smelt's diet consists of small zooplankton, primarily planktonic copepods, cladocera, amphipods, and insect larvae. However, the most important food organism appears to be *Eurytemora affinis,* which is a euryhaline copepod (USFWS, 1995 and 2004). Since the potential for direct effects to fish and amphibians have been described, this section will focus on potential effects to aquatic and terrestrial invertebrates and plants, and on small mammals and worms. Special emphasis is placed on copepod effects since it is the favorite food of the Delta smelt.

Freshwater invertebrate toxicity studies were reviewed for this assessment (**Appendix E**). The Delta Smelt also needs saltwater invertebrates as a food source. No new, more-sensitive saltwater invertebrate studies were found in this review; however, several freshwater studies were reviewed. Freshwater studies showed a very narrow range of toxicities among invertebrate taxa, ranging from 0.06 ug/L chlorpyrifos for blackfly to 0.08 ug/L for ceriodaphnia and freshwater shrimp; acute sediment test results ranged from 32 to 180 ug/Kg (midge and daphnid, respectively). Invertebrate NOAECs ranged from 0.025 to 0.04 ug/L chlorpyrifos (both daphnids); chronic sediment toxicity test results ranged from 32 to 52 ug/Kg. Acute to chronic values so close suggest a threshold concentration and that acute and chronic toxicity result from the same, or similar, mechanisms; however, in at least one case this may be in part due to low dissolved oxygen concentrations, making the acute value lower than it should be.

Such a narrow effects range may help to explain findings of Van der Hoeven and Gerritsen (1997), that exposed daphnids removed to clean water, still died. They tested acute and chronic effects of chlorpyrifos, and recovery from exposure in *Daphnia pulex*. Chlorpyrifos-ethyl was the test substance. The CAS number for chlorpyrifos-ethyl is 39475-55-3; the CAS number for chlorpyrifos is 2921-88-2. Both chlorpyrifos-ethyl and chlorpyrifos are common names, however, for EPA PC Code 059101. Lab and field tests were conducted and compared. Authors also noticed that daphnids became immobilized several days before death and that when immobilized daphnids were removed from exposure to the test substance, they did not recover, but died. The lowest NOAEC found was 0.05 ug/L chlorpyrifos in the 17 d study, and the LOEC was 0.10 ug/L chlorpyrifos. In this study, the EC50 at day 3 was 0.09 ug/L chlorpyrifos. This was from the 17-d laboratory test using the technical grade of chlorpyrifos. Both acute and chronic endpoints from this test were more sensitive than those which EPA used in the last risk assessment (USEPA, 2002), 0.04 ug/L chlorpyrifos as the NOAEC and 0.10 ug/L chlorpyrifos as the LC50. However, the results are reported in nominal concentrations, rather than measured concentrations and data was not available to confirm these concentrations.

Crustaceans and aquatic insects had similar sensitivities. Hyder *et al.* (2005) compared the sensitivities between two blackfly sibling species, *Simulium vittatum* Zetterstedt cytospecies *IS-7* and *S. vittatum* Zetterstedt cytospecies *IIIL-1*, to chlorpyrifos. Authors also looked at sensitivities at different life stages. Authors concluded that the two sister species did not have significantly different susceptibility among instar groupings and recommend the mid-instars for use in toxicity tests since they are more sensitive than the late instars but easier to handle than the early instars. The most sensitive data point found was with *S. vittatum IS-7* early instars (second and third instars), which had an LC50 of 0.06 ug/L chlorpyrifos. The test duration was only 24-h. EPA recommends that acute test duration be 96-h except for daphnids, mysids and oyster larvae, which can be 48-h. This endpoint, however, should only be more sensitive if the test duration were greater. Therefore, this study was used to calculate RQs in this assessment.

Bailey et al. (1996) compared the responses of three pesticides, carbofuran, diazinon and chlorpyrifos, to procedures used in toxicity identification evaluations (TIEs). The effect of a metabolic inhibitor, piperonyl butoxide, on the toxicity of each pesticide was determined. All three pesticides eluted separately in characteristic methanol/water fractions. Chlorpyrifos was not effectively reduced by acid or base conditions. Chlorpyrifos was also not effectively removed by solid-phase extraction. Its toxicity, however, was ameliorated by piperonyl butoxide. Chlorpyrifos recoveries were not affected by pH, but hydrolysis was found to be favored by alkaline conditions, but authors cited other work that concluded that the half-lives associated with such reactions were generally days in duration unless a catalyst is present. Similar recoveries were found in all three pesticides from C-8 and C-18 columns when 100% methanol was used to elute the columns. Chlorpyrifos, however, had lower overall recoveries in methanol than the other two pesticides, especially at lower methanol concentrations. Piperonyl butoxide was effective in reducing toxicity of chlorpyrifos and diazinon, both metabolically activated organophosphorous insecticides. Authors derived an endpoint, 96-h LC50 of 0.06 ug/L chlorpyrifos. This study, however, does not meet the criteria for acceptance for use in calculating RQs due to lack of a range of test concentrations; however, it helps confirm the blackfly endpoint used, which was also 0.06 ug/L chlorpyrifos.

Van Wijngaarden et al. (1993) compared increasing levels of realism in testing techniques by using single species toxicity tests, then indoor and outdoor microcosm tests, then outdoor mesocosm tests. Sixteen species were used; test organisms were all indigenous to the

Netherlands. Dursban (chlorpyrifos) was the test substance. Data derived in this study show a broad range of sensitivities to chlorpyrifos. *Gammarus pulex* had the most sensitive endpoint tested, with a 96-hr LC10 of 0.02 ug/L chlorpyrifos, a 48-hr LC50 of 0.08 ug/L and a 96-hr LC50 of 0.07 ug/L chlorpyrifos, using Dursban 4E and tap water. Within crustacea, the toxicity range differed by a factor of 10^3, with the freshwater shrimp, *P. coxalis,* having a 96-hr LC10 of >20 ug/L. The level seen in *G. pulex* (96-hr LC50 of 0.07 ppb) was similar in sensitivity to the blackfly endpoint used to calculate RQs.

Andersen et al. (2006) investigated causes of toxicity and macroinvertebrate impacts in the Salinas River. They conducted toxicity tests with amphipods (*Hyalella azteca*), baetid mayflies (*Procloeon* sp.) and midges (*Chironomus dilutus*, Shobanov, formerly *Chironomus tentans*). They looked at the toxicity of two organophosphate and two pyrethroid pesticides, and at the effects caused by increasing particle loads. Chlorpyrifos was only tested on the mayflies in this study. They used data from another published study to compare amphipod and midge LC50s to Salinas River concentrations. The two chief stressors turned out to be chlorpyrifos and permethrin. The mayfly was sensitive to chlorpyrifos and permethrin within the range of concentrations of these pesticides measured in the river and the midge was sensitive to chlorpyrifos within the ranges of concentrations measured in the river. The LC50 for chlorpyrifos toxicity to *Procloeon* was 81 ng/L (0.08 ppb). The most contaminated station in the Salinas River had a mean chlorpyrifos concentration of 183 ng/L (50-520 ng/L), more than twice the LC50 for the mayfly.

Foster and Korth (1998) investigated toxicity in an irrigation area in New South Wales, Australia, by conducting acute toxicity tests using ten individual pesticides that were routinely used in the area: atrazine, bensulfuron-methyl, bromacil, chlorpyrifos, diuron, malathion, metolachlor, molinate, simazine and thiobencarb. Toxicity testing was done in the lab using the cladoceran, *Ceriodaphnia dubia*. Chlorpyrifos and malathion were the most toxic pesticides tested. In their discussion, they compared findings to those by other authors and found *C. dubia* ten times more sensitive to chlorpyrifos than *Daphnia longispina*. For atrazine, chlorpyrifos, metolachlor, simazine and malathion, 48 h toxicity was greater in the reconstituted water than the ambient water. Authors speculated that particles in the ambient water may have adsorbed more hydrophobic compounds and decreased bioavailability. Exceptions to this trend were molinate and diuron, which were more toxic in ambient water. The 48-h EC50 in the reconstituted water was 0.08 ug/L chlorpyrifos.

Rose et al. (2002) studied the effect on *Ceriodaphnia* cf. *dubia* of three chemicals with different mechanisms of action (3,4-dichloroaniline, fenoxycarb, and chlorpyrifos) under both limited and abundant food conditions. Limited food significantly increased the toxicity of chlorpyrifos. This was attributed to the tendency of organophosphates to bind irreversibly to acetylcholinesterase (AChE), requiring the organism to use more energy to destroy and synthesize more AChE. Organophosphates also cause uncontrolled muscle contractions, which use energy. Data derived in this study show that chlorpyrifos is more toxic to daphnia under low food conditions than high food conditions. Well-fed *Ceriodaphnia* had an NOEC of 0.045 ug/L, but combined with low-food stress, *Ceriodaphnia* had an NOEC of 0.025 ug/L.

A few studies were found that tested sediment toxicity from chlorpyrifos runoff. Hootfman *et al*. (1993) purposed to develop a set of acute and chronic test systems with both sediment/water and pore water as matrices, for testing contaminated sediments for the Netherlands Integrated Soil Program (PCBB). Acute and chronic protocols were tested on *Daphnia magna* and *Chironomus riparius*. *D. magna* acute and chronic (reproduction) tests were conducted at three institutes. Subchronic tests with *C. riparius* were conducted at two of the institutes. The general conclusion was that most of the toxicity was attributable to the aqueous phase.

Rakotondravelo et al. (2006) studied effects of long-term (45-d) exposure of atrazine, DDT and chlorpyrifos on Chironomus tentans. Chironomids exposed to 0.1 ug/L chlorpyrifos, had 67% reduction in survivorship by day 20, but a 1.5-fold increase in ash-free dry weight and an 81% increase in adult emergence rate, though actual numbers that emerged were significantly lower. Authors attributed the increased weight gain and emergence rate to less competition for resources due to mortality. Data derived in this study show sediment toxicity from chlorpyrifos at a level of 20 ug/Kg.

As previously mentioned, the most important food organism the Delta is the copepod, Eurytemora affinis which is euryhaline (can survive in fresh- or saltwater). Copepod data from the ECOTOX database were reviewed in this assessment regardless of whether the endpoints were more sensitive than those previously used for invertebrates (**Table 4.4**). One particularly sensitive endpoint was found by Rene, *et al* (1996); the NOAEC for one copepod was <0. 1 ug/L chlorpyrifos, which was similar to that of the African clawed frog as seen in **Table 4.3**. This does raise concerns, for the food source of the Delta smelt. Biever *et al*. (1994) found that chlorpyrifos when sprayed in a single dose had a half-life of approximately 4 days but did partition in the sediment when treatments produced water column concentrations as low as 0.3 ug/L chlorpyrifos. Most freshwater invertebrate and fish communities were able to recover within a few weeks with the possible exception of Chironominae, a subfamily of Chironomidae. Using multivariate ordination analysis, Van den Brink *et al*. (1996) found that the NOAEC for zooplankton/macroinvertebrate communities was 0.1 ug/L chlorpyrifos. Copepods and other crustacea recovered by week 12 after single application treatments and other invertebrate taxa by week 24. Van Wijngaarden *et al*. (1996) compared in-lab single species tests with outdoor mesocosm test results. Standard species and those indigenous to the Netherlands were used. In mesocosms, dosing was done once and macroinvertebrates and zooplankton were sampled, along with several species exposed via in-situ cages. In general, the lab and caged studies differed by a factor of approximately 3. Also notable were copepod data; total copepods had an NOAEC of <0.1 ppm, but copepod nauplii had a NOAEC of 0.9 ppm.

The California freshwater shrimp is dependent on algae and detritus as its food source. Chlorpyrifos is not very toxic to algae (**Section 5.2.1.2**) and no RQs exceeded the LOC for endangered species. These data show that no significant indirect effects on the shrimp from food source reduction are expected from chlorpyrifos use.

These data show, however, that significant effects are expected on the food source of the California red-legged frog, California tiger salamander and Delta smelt and that these effects are not discountable. These effects also apply to the food source of the San Francisco Garter Snake and California Clapper Rail. Runoff may cause effects wherever chlorpyrifos is used near sites inhabited by the California red-legged frog, California tiger salamander or Delta smelt.

5.5.2.2 Terrestrial Invertebrates

The diets of terrestrial-phase juvenile and adult CRLF and SFGS consist largely of terrestrial invertebrates. The CCR and terrestrial phase CTS also consume terrestrial invertebrates as part of their diets. As previously noted, the RQs for both small and large insects significantly exceed the acute LOC for listed species for all chlorpyrifos uses and available laboratory studies provide evidence of high toxicity to multiple bee species from exposure to chlorpyrifos. Based on the weight-of-evidence, there is a potential indirect impact to the CCR, CRLF, SFGS, and CTS based on this endpoint. The effects determination is likely to adversely affect

5.5.2.3 Mammals

Life history data for CCR, SFGS and terrestrial-phase SFGS indicate that large adults of those species consume terrestrial vertebrates, including mice. As previously noted, the acute and chronic mammalian dose and/or dietary-based RQs estimated using the T-REX model exceed the acute and chronic LOC for the salt mouse harvest mouse for all spray applications of chlorpyrifos and for the majority of granular and seed treatment uses. Based on the weight-of-evidence, uses for chlorpyrifos may indirectly impact the CCR, CRLF, SFGS, and CTS through effects to the mammalian prey base. The effects determination is likely to adversely affect.

5.5.2.4 Terrestrial-phase Amphibians

Listed species that consume frogs include the terrestrial-phase adult CRLFs, juvenile and adult SFGS, and terrestrial phase CTS. The T-HERPs RQ values representing direct exposures of chlorpyrifos to these species are used to represent exposures of chlorpyrifos to frogs in terrestrial habitats. Based on the assessment of risk to the terrestrial-phase amphibians (direct effects), the Agency concludes that chlorpyrifos may indirectly impact the terrestrial phase adult CRLF, juvenile and adult SFGS, and terrestrial phase CTS through effects to the terrestrial-phase amphibian prey base. The effects determination is likely to adversely affect (see Section 5.2.1.2 for more details).

5.5.3 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 streambanks. In addition, vascular aquatic plants are important as attachment sites for egg masses of aquatic species.

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.

Chlorpyrifos is an insecticide and not expected to significantly affect either aquatic or terrestrial plants. Chlorpyrifos was not very toxic to the freshwater green alga (*Pseudokirchneriella subcapitata*, formerly *Selenastrum capricornutum)*, with a 120-hr EC_{50} of 140 ug a.i./L, based on reduced cell density (MRID40228401, Mayer, 1986). This level is not expected to be exceeded by the current uses of chlorpyrifos.

There are no registrant-submitted studies, ECOTOX literature studies available for assessment of the potential for indirect effects to the terrestrial-phase species of concern for chlorpyrifos via effects to riparian vegetation or effects to the relevant primary constituent elements (PCEs). The only potentially relevant data available in the ECOTOX literature are efficacy studies on food crops and turf. The available plant studies do not show adverse effects to the terrestrial plants assessed. The labeled uses of chlorpyrifos include direct application to a variety of terrestrial plants (agricultural and ornamental) at multiple growth stages (e.g., seed treatment, pre-bloom, bloom, foliar, post-bloom etc.) and there are no label restrictions pertaining to the potential for chlorpyrifos to elicit phytotoxic effects. Consequently, it is probable that the damage to the crops is not so extensive to inhibit the use of this pesticide by applicators.

An examination of the completed CRLF assessments for nine other organophosphates indicates that the majority of the effects determinations for terrestrial plants were either “no effect” or “not likely to adversely affect”. For some of these organophosphates there is the potential for some damage to plants. Two were determined to be “LAA”; however, one had herbicidal activity from a known mechanism and the other used surrogate data from another pesticide. The conclusions in those cases were generally that while effects to terrestrial plants may affect the CRLF via habitat modification, they are not likely to adversely affect the CRLF based on the type and extent of damage as observed.

As discussed previously, evidence from the EIIS suggests that chlorpyrifos poses a risk to terrestrial plants. However, due to the lack of compound-specific terrestrial plant study data, the potential for adverse effects to terrestrial plants from use of chlorpyrifos cannot be definitely determined. Therefore, the effects determination is unlikely to effect. However, absent sufficient data, adverse effects cannot be ruled out.

5.5.4 Modification of Designated Critical Habitat

Based on the lack of toxicity to plants there is little potential for the modification of the California red-legged frog, California tiger salamander or Delta smelt designated critical habitat based on this analysis. This finding also applies to the California freshwater shrimp, San Francisco garter snake, California clapper rail and Salt-marsh harvest mouse. Based on the lack of toxicity to plants there is little potential for the modification of the California freshwater shrimp's designated critical habitat based on this analysis. Any effects are expected to be insignificant and discountable.

6 Uncertainties

6.1 Exposure Assessment Uncertainties

6.1.1 Oxon Exposure and Risk

The screening-level risk assessment focuses on characterizing potential ecological risks resulting from chlorpyrifos only. Evidence suggests that chlorpyrifos oxon may form in the environment; however the Agency has no means to quantitatively predict these exposures at this time. There is evidence of higher toxicity associated with the oxon at least to some taxa though no data is available for the specific species being assessed here. However, because the evidence suggests greater toxicity for the oxon it is possible that where the oxon is present the risk conclusions presented above may underestimate risk to the listed species covered by this assessment.

6.1.2 Maximum Use Scenario

The screening-level risk assessment focuses on characterizing potential ecological risks resulting from a maximum use scenario, which is determined from labeled statements of maximum application rate and number of applications with the shortest time interval between applications. The frequency at which actual uses approach this maximum use scenario may be dependant on pest resistance, timing of applications, cultural practices, and market forces.

6.1.3 Aquatic Exposure Modeling of Chlorpyrifos

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

The Agency acknowledges that there are some unique aquatic habitats that are not accurately captured by this modeling scenario and modeling results may, therefore, under- or over-estimate exposure, depending on a number of variables. For example, some organisms may inhabit water bodies of different size and depth and/or are located adjacent to larger or smaller drainage areas than the EXAMS pond. In addition, the Services agree that the existing EXAMS pond represents the best currently available approach for estimating aquatic exposure to pesticides (USFWS/NMFS 2004).

This assessment includes a comparison of modeled EEC and available surface water monitoring data. This analysis shows a reasonable concurrence between the model predictions and the available monitoring data. It is worth noting though that most monitoring data are from flowing waters while the PRZM/EXAMS estimates are derived from a static water body. This is particularly important for the longer term average concentrations which do not account for flow out of the system and are likely over-estimates for flowing waters.

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, embayments, and coastal marine areas because chemicals in runoff water (or spray drift, etc.) should be diluted by a much larger volume of water than would be found in the 'typical' EXAMS pond. However, as chemical constituents in water draining from freshwater streams encounter brackish or other near-marine-associated conditions, there is potential for important chemical transformations to occur. Many chemical compounds can undergo changes in mobility, toxicity, or persistence when changes in pH, 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 (e.g., Means 1995; Swarzenski et al., 2003; Jordan et al. 2008), changes in pH (e.g., Wood and Baptista, 1993; Parikh et al., 2004; Fernandez et al., 2005), Eh changes (Wood and Baptista, 1993; Velde and Church, 1999), and other factors. Thus, although chemicals in discharging rivers may be diluted by large volumes of water within receiving estuaries and embayments, the hydrochemistry of the marine-influenced water may negate some of the attenuating impact of the greater water volume; for example, the effect of dilution may be confounded by changes in chemical mobility (and/or bioavailability) in brackish water. In addition, freshwater contributions from discharging streams and rivers do not instantaneously mix with more saline water bodies. In these settings, water will commonly remain highly stratified, with fresh water lying atop denser, heavier saline water – meaning that exposure to concentrations found in discharging stream water may propagate some distance beyond the outflow point of the stream (especially near the water surface). Therefore, it is not assumed that discharging water will be rapidly diluted by the entire water volume within an estuary, embayment, or other coastal aquatic environment. 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.

In general, the linked PRZM/EXAMS model produces estimated aquatic concentrations that are expected to be exceeded once within a ten-year period. The Pesticide Root Zone Model is a process or "simulation" model that calculates what happens to a pesticide in an agricultural field on a day-to-day basis. It considers factors such as rainfall and plant transpiration of water, as well as how and when the pesticide is applied. It has two major components: hydrology and chemical transport. Water movement is simulated by the use of generalized soil parameters, including field capacity, wilting point, and saturation water content. The chemical transport component can simulate pesticide application on the soil or on the plant foliage. Dissolved, adsorbed, and vapor-phase concentrations in the soil are estimated by simultaneously considering the processes of pesticide uptake by plants, surface runoff, erosion, decay, volatilization, foliar wash-off, advection, dispersion, and retardation.

Uncertainties associated with each of these individual components add to the overall uncertainty of the modeled concentrations. Additionally, model inputs from the environmental fate degradation studies are chosen to represent the upper confidence bound on the mean values that are not expected to be exceeded in the environment approximately 90 percent of the time. Mobility input values are chosen to be representative of conditions in the environment. The natural variation in soils adds to the uncertainty of modeled values. Factors such as application date, crop emergence date, and canopy cover can also affect estimated concentrations, adding to the uncertainty of modeled values. Factors within the ambient environment such as soil temperatures, sunlight intensity, antecedent soil moisture, and surface water temperatures can cause actual aquatic concentrations to differ for the modeled values.

Unlike spray drift, tools are currently not available to evaluate the effectiveness of a vegetative setback on runoff and loadings. The effectiveness of vegetative setbacks is highly dependent on the condition of the vegetative strip. For example, a well-established, healthy vegetative setback can be a very effective means of reducing runoff and erosion from agricultural fields. Alternatively, a setback of poor vegetative quality or a setback that is channelized can be ineffective at reducing loadings. Until such time as a quantitative method to estimate the effect of vegetative setbacks on various conditions on pesticide loadings becomes available, the aquatic exposure predictions are likely to overestimate exposure where healthy vegetative setbacks exist and underestimate exposure where poorly developed, channelized, or bare setbacks exist.

6.1.4 Usage Uncertainties

County-level usage data were obtained from California's Department of Pesticide Regulation Pesticide Use Reporting (CDPR PUR) database. Four years of data (2002 – 2005) were included in this analysis because statistical methodology for identifying outliers, in terms of area treated and pounds applied, was provided by CDPR for these years only. No methodology for removing outliers was provided by CDPR for 2001 and earlier pesticide data; therefore, this information was not included in the analysis because it may misrepresent actual usage patterns. CDPR PUR documentation indicates that errors in the data may include the following: a misplaced decimal; incorrect measures, area treated, or units; and reports of diluted pesticide concentrations. In addition, it is possible that the data may contain reports for pesticide uses that have been cancelled. The CPDR PUR data does not include home owner applied pesticides; therefore, residential uses are not likely to be reported. As with all pesticide usage data, there may be instances of misuse and misreporting. The Agency made use of the most current, verifiable information; in cases where there were discrepancies, the most conservative information was used.

6.1.5 Terrestrial Exposure Modeling of Chlorpyrifos

The Agency relies on the work of Fletcher et al. (1994) for setting the assumed pesticide residues in wildlife dietary items. These residue assumptions are believed to reflect a realistic upper-bound residue estimate, although the degree to which this assumption reflects a specific percentile estimate is difficult to quantify. It is important to note that the field measurement efforts used to develop the Fletcher estimates of exposure involve highly varied sampling techniques. It is entirely possible that much of these data reflect residues averaged over entire above ground plants in the case of grass and forage sampling.

It was assumed that ingestion of food items in the field occurs at rates commensurate with those in the laboratory. Although the screening assessment process adjusts dry-weight estimates of food intake to reflect the increased mass in fresh-weight wildlife food intake estimates, it does not allow for gross energy differences. Direct comparison of a laboratory dietary concentration-based effects threshold to a fresh-weight pesticide residue estimate would result in an underestimation of field exposure by food consumption by a factor of 1.25 – 2.5 for most food items.

Differences in assimilative efficiency between laboratory and wild diets suggest that current screening assessment methods do not account for a potentially important aspect of food requirements. Depending upon species and dietary matrix, bird assimilation of wild diet energy ranges from 23 – 80%, and mammal's assimilation ranges from 41 – 85% (U.S. Environmental Protection Agency, 1993). If it is assumed that laboratory chow is formulated to maximize assimilative efficiency (*e.g.,* a value of 85%), a potential for underestimation of exposure may exist by assuming that consumption of food in the wild is comparable with consumption during laboratory testing. In the screening process, exposure may be underestimated because metabolic rates are not related to food consumption.

For the terrestrial exposure analysis of this risk assessment, a generic bird or mammal was assumed to occupy either the treated field or adjacent areas receiving a treatment rate on the field. Actual habitat requirements of any particular terrestrial species were not considered, and it was assumed that species occupy, exclusively and permanently, the modeled treatment area. Spray drift model predictions suggest that this assumption leads to an overestimation of exposure to species that do not occupy the treated field exclusively and permanently.

6.1.6 Spray Drift Modeling

Although there may be multiple Chlorpyrifos applications at a single site, it is unlikely that the same organism would be exposed to the maximum amount of spray drift from every application made. In order for an organism to receive the maximum concentration of Chlorpyrifos from multiple applications, each application of Chlorpyrifos would have to occur under identical atmospheric conditions (*e.g.*, same wind speed and – for plants – same wind direction) and (if it is an animal) the animal being exposed would have to be present directly downwind at the same distance after each application. Although there may be sites where the dominant wind direction is fairly consistent (at least during the relatively quiescent conditions that are most favorable for aerial spray applications), it is nevertheless highly unlikely that plants in any specific area would receive the maximum amount of spray drift repeatedly. It appears that in most areas (based upon available meteorological data) wind direction is temporally very changeable, even within the same day. Additionally, other factors, including variations in topography, cover, and meteorological conditions over the transport distance are not accounted for by the AgDRIFT model (*i.e.*, it models spray drift from aerial and ground applications in a flat area with little to no ground cover and a steady, constant wind speed and direction). Therefore, in most cases, the drift estimates from AgDRIFT may overestimate exposure even from single applications, especially as the distance increases from the site of application, since the model does not account for potential obstructions (*e.g.*, large hills, berms, buildings, trees, *etc*.).

6.2 Effects Assessment Uncertainties

6.2.1 Age Class and Sensitivity of Effects Thresholds

It is generally recognized that test organism age may have a significant impact on the observed sensitivity to a toxicant. The acute toxicity data for fish are collected on juvenile fish between 0.1 and 5 grams. Aquatic invertebrate acute testing is performed on recommended immature age classes (e.g., first instar for daphnids, second instar for amphipods, stoneflies, mayflies, and third instar for midges).

Testing of juveniles may overestimate toxicity at older age classes for pesticide active ingredients that act directly without metabolic transformation because younger age classes may not have the enzymatic systems associated with detoxifying xenobiotics. Conversely, it may, in some cases, underestimate toxicity as seen in a study by Richards and Kendall (2002) where chlorpyrifos was less toxic to an earlier developmental stage of tadpole than to a later stage that had used up the yolksac and was more likely to uptake chlorpyrifos, causing acetylcholinesterase inhibition. In so far as the available toxicity data may provide ranges of sensitivity information with respect to age class, this assessment uses the most sensitive life-stage information as measures of effect for surrogate aquatic animals, and is therefore, considered as protective.

6.2.2 Use of Surrogate Species Effects Data

Guideline toxicity tests and open literature data on chlorpyrifos are not available for frogs or any other aquatic-phase amphibian; therefore, freshwater fish are often used as surrogate species for aquatic-phase amphibians. Although no submitted data are available for chlorpyrifos, the available open literature information on chlorpyrifos toxicity to aquatic-phase amphibians shows that acute and chronic ecotoxicity endpoints for aquatic-phase amphibians are generally similar in sensitivity to freshwater fish. In this open literature query using ECOTOX, only studies with the most sensitive fish endpoints were reviewed, but all pertinent frog studies were reviewed. This artifact of procedure made it look like frogs have a higher acute to chronic ratio than fish, with higher acute and lower chronic endpoints. This is an uncertainty that was not fully investigated in this study. Endpoints based on freshwater fish ecotoxicity data are often assumed to be protective of potential direct effects to aquatic-phase amphibians including the California red-legged frog and California tiger salamander, and extrapolation of the risk conclusions from the most sensitive tested species to aquatic-phase amphibians is likely to overestimate the potential risks to those species. In this risk assessment sufficient amphibian data were found to use frog data for the California red-legged frog and fish data were used for the Delta smelt; however no salamander data were found to use for the California tiger salamander assessment. No terrestrial-phase amphibian data was found to use in the terrestrial-phase amphibian assessments, so bird data was used, which inputs a fair amount of uncertainty due to amphibians' pokeliothermic and bird's homeothermic physiologies. Efforts are made to select the organisms most likely to be affected by the type of compound and usage pattern; however, there is an inherent uncertainty in extrapolating across phyla. In addition, the Agency's LOCs are intentionally set very low, and conservative estimates are made in the screening level risk assessment to account for these uncertainties.

6.2.3 Sublethal Effects

When assessing acute risk, the screening risk assessment relies on the acute mortality endpoint as well as a suite of sublethal responses to the pesticide, as determined by the testing of species response to chronic exposure conditions and subsequent chronic risk assessment. Consideration of additional sublethal data in the effects determination t is exercised on a case-by-case basis and only after careful consideration of the nature of the sublethal effect measured and the extent and quality of available data to support establishing a plausible relationship between the measure of effect (sublethal endpoint) and the assessment endpoints. However, the full suite of sublethal effects from valid open literature studies is considered for the purposes of defining the action area.

To the extent to which sublethal effects are not considered in this assessment, the potential direct and indirect effects of chlorpyrifos on listed species may be underestimated. Perhaps the greatest area of uncertainty at present is the effects of chlorpyrifos on plants. Effects to aquatic and terrestrial plants have not been researched carefully since chlorpyrifos is an insecticide and not a suspected plant toxin. Incident data, however, lists chlorpyrifos as a probable plant toxin in several cases of plant damage. Another area of uncertainty is chlorpyrifos' potential to act as an endocrine disruptor. Of the studies reviewed in the open literature (all frog and copepod studies, and other studies with the most sensitive endpoints) no endocrine disruption studies were found. These areas of uncertainty should be addressed in future assessments.

6.2.4 Location of Wildlife Species

For the terrestrial exposure analysis of this risk assessment, a generic bird or mammal was assumed to occupy either the treated field or adjacent areas receiving a treatment rate on the field. Actual habitat requirements of any particular terrestrial species were not considered, and it was assumed that species occupy, exclusively and permanently, the modeled treatment area. Spray drift model predictions suggest that this assumption leads to an overestimation of exposure to species that do not occupy the treated field exclusively and permanently.

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 Chlorpyrifos to the California red-legged frog *(Rana aurora draytonii*), California tiger salamander *(Ambystoma californiense),* San Francisco garter snake *(Thamnophis sirtalis tetrataenia),* California clapper rail, *(Rallus longirostris obsoletus),* Salt marsh harvest mouse *(Reithrodontomys raviventris),* Bay checkerspot butterfly *(Euphydryas editha bayensis),* Valley elderberry longhorn beetle *(Desmocerus californicus dimorphus),* San Joaquin kit fox *(Vulpes macrotis mutica),* California freshwater shrimp *(Syncaris pacifica),* Delta smelt *(Hypomesus transpacificus)* and their designated critical habitat.

Based on the best available information, the Agency makes a May Affect, Likely to Adversely Affect determination for the all species covered by this assessment from the use of chlorpyrifos. Additionally, the Agency has determined that there is the potential for modification of the designated critical habitat for the California red-legged frog, California tiger salamander, San Francisco garter snake, California clapper rail, Salt marsh harvest mouse, Bay checkerspot butterfly, Valley elderberry longhorn beetle, San Joaquin kit fox, California freshwater shrimp, and Delta smelt from the use of the chemical. Given the LAA determination for the listed species described above and potential modification of designated critical habitat, HM, a description of the baseline status and cumulative effects for the CRLF is provided in **Attachment 2** and the baseline status and cumulative effects for the California tiger salamander, San Francisco garter snake, California clapper rail, Salt marsh harvest mouse, Bay checkerspot butterfly, Valley elderberry longhorn beetle, San Joaquin kit fox, California freshwater shrimp, and Delta smelt are provided in **Attachment 4**.

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 to seek concurrence with the LAA determinations and to determine whether there are reasonable and prudent alternatives and/or measures to reduce and/or eliminate potential incidental take.

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

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

- Enhanced information on the density and distribution of California red-legged and California tiger salamander, San Francisco garter snake, California clapper rail, Salt marsh harvest mouse, Bay checkerspot butterfly, Valley elderberry longhorn beetle, San Joaquin kit fox, California freshwater shrimp, and Delta smelt 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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