Effects Determinations for Malathion

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# Introduction

For 1835 listed species, including endangered, threatened, candidate and proposed species, and 794 designated critical habitats, a “No Effect” (NE), “Not Likely to Adversely Affect” (NLAA) or a “Likely to Adversely Affect” (LAA) determination is made. For each species and designated critical habitat, the effects determination is based on the methodology previously described in **Section 1.4** of the Problem Formulation or a more qualitative analysis, depending on the listed species’ life history, unique habitat attributes (*e.g.,* deep ocean habitat), and/or the chemical use pattern overlap. These determinations are described further below.

# Summary of Effects Determinations

**Table 4-2.1** and **Table 4-2.** below summarizes the effects determinations for all species and designated critical habitats including a count of the number of species by taxon in each effects determination category. Effects determinations are summarized for each individual species and critical habitat in **APPENDIX 4-1** (this table is provided in Excel format due to its large size). **APPENDIX 4-1 (‘Summary Table All Calls’ tab)** is organized into 8 major taxa: birds, mammals, reptiles, amphibians, terrestrial invertebrates, fish, aquatic invertebrates and plants. Species are listed by taxa, then alphabetically according to scientific name, then by species identification number. For each species, the table includes an effects determination for both the species and their critical habitat, if applicable, as well as an indication of how the effects determination was reached (*e.g.,* terrestrial weight of evidence analysis, qualitative analysis – sea turtles, etc.). Each group of effects determinations is further described below.

**TABLE. 4-2.1. Summary of Species Effects Determinations for Malathion (Counts by Taxon).**

|  |  |  |  |
| --- | --- | --- | --- |
| **TAXON** | **STEP 1 EFFECTS DETERMINATION** | **STEP 2 EFFECTS DETERMINATIONS** | **Totals** |
| **NO EFFECT** | **MAY AFFECT** | **NOT LIKELY TO ADVERSLY AFFECT** | **LIKELY TO ADVERSELY AFFECT** |
| Amphibians | 0 | 40 | 1 | 39 | 40 |
| Aquatic Invertebrates | 0 | 220 | 1 | 219 | 220 |
| Birds | 5 | 103 | 12 | 91 | 108 |
| Fish | 0 | 193 | 5 | 188 | 193 |
| Mammals | 2 | 107 | 20 | 87 | 109 |
| Plants | 0 | 961 | 2 | 959 | 961 |
| Reptiles | 0 | 48 | 0 | 48 | 48 |
| Terrestrial Invertebrates | 9 | 147 | 0 | 147 | 156 |
| Total | 16 | 1819 | 41 | 1778 | 1835 |
| Percent of Total Number of Species (%) | 1 | 99 | 2 | 97 |

**TABLE. 4-2.2. Summary of Critical Habitat Effects Determinations for Malathion (Counts by Taxon).**

|  |  |  |  |
| --- | --- | --- | --- |
| **DESIGNATED CRITICAL HABITAT TAXON** | **STEP 1 EFFECTS DETERMINATION** | **STEP 2 EFFECTS DETERMINATIONS** | **Totals** |
| **NO EFFECT** | **MAY AFFECT** | **NOT LIKELY TO ADVERSLY AFFECT** | **LIKELY TO ADVERSELY AFFECT** |
| Amphibians | 0 | 25 | 0 | 25 | 25 |
| Aquatic Invertebrates | 0 | 75 | 0 | 75 | 75 |
| Birds | 0 | 31 | 0 | 31 | 31 |
| Fish | 0 | 106 | 0 | 106 | 106 |
| Mammals | 0 | 32 | 5 | 27 | 32 |
| Plants | 0 | 462 | 3 | 459 | 462 |
| Reptiles | 0 | 17 | 0 | 17 | 17 |
| Terrestrial Invertebrates | 0 | 46 | 2 | 44 | 46 |
| Total | 0 | 794 | 10 | 780 | 794 |
| Percent of Total Number of Critical Habitats (%) | 0 | 100 | 2 | 98 |

# Effects Determinations of No Effect

The Step 1 “No Effect/May Affect” analysis determines if a listed species or its designated critical habitat requires further analysis due to the potential of co-occurrence with the action area. A critical habitat determination may differ from the species determination when the critical habitat extends outside of the species range. The spatial footprint of the action area includes the pesticide footprint based on all labeled uses for the chemical and offsite transport due to both spray drift and downstream dilution. Additional information on how the action area was developed can be found in **Attachment 1-3**, and additional information on the downstream dilution analysis can be found in **Appendix 3-5**. The species’ range geospatial files used in this analysis were provided by the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS).

When no co-occurrence is identified between the listed species range (including designated critical habitat) and the action area, the species and its designated critical habitat receives a “No Effect” determination. A “May Affect” determination is given if co-occurrence exists, moving the species and/or its designated critical habitat to Step 2 for further analysis. Co-occurrence is determined by overlaying the action area and with the species range and designated critical habitat using ArcGIS v10.4.

“No Effect” determinations were made for species with no designated critical habitat that met at least one of the following criteria: a) the species is presumed by the U.S. Fish and Wildlife Service (USFWS) to be extinct; b) the species no longer occurs in the US; or c) the species exists only in captivity. Species categorized as “presumed extinct” are often difficult to ascertain based on the frequent updates to information. It is possible that the effects determination for species in this category may change if new or different information becomes available.

“No Effect” determinations are made due to presumed extinction for 16 species including 5 species of birds, 2 species of mammals and 9 species of terrestrial invertebrates (**APPENDIX 4-1 (‘NE\_Extinct’ tab)**).

Of the remaining 1819 listed species not presumed to be extinct, all remaining species overlap with the malathion action area, and receive a “May Affect” determination and further consideration in Step 2 (**APPENDIX 4-1)**. All remaining 794designated critical habitat locations co-occur within the action areas for malathion, and receive a “May Affect” determination

# Effects Determinations of NLAA - No overlap

The Step 2 overlap analysis uses the results from the Step 1 analysis to calculate the percent overlap of the species range or its designated critical habitat with each use site included in the action area; see **Attachment 1-6** for results of the Step 1 and Step 2 analysis. Additional information on how the action area and use sites are developed can be found in **Attachment 1-3**.

Species of interest are identified by determining percent of the ranges and/or designated critical habitats of listed species that overlaps directly with the areas of effect (*i.e*., potential use sites plus the spray drift effects area). In order to calculate the percent overlap, first the total use site acres within the species range is calculated from the total number of co-occurring use site raster cells (*i.e*., pixel size at the limit of resolution). To calculate the percent overlap, the total use site acres is divided by the total acres of the species range occurring within the spatial extent of the use site.

One known source of error within spatial datasets is positional accuracy and precision. The National Standard for Spatial Data Accuracy outlines the accepted method for calculating the horizontal accuracy of a spatial dataset (FGDC 1998)[[1]](#footnote-1). To prevent false precision when calculating area and the percent overlap, only two significant digits should be considered for decision purposes given the reported 60 meters of horizontal accuracy for the Cropland Data Layer (CDL).

An effects determination of “Not Likely to Adversely Affect ” is reached for 14  species that were “presumed extinct” based on information gathered in review of the 5 year status review but did not meet the additional criteria to receive a no effect determination. “Not Likely to Adversely Affect” determinations are reached for 1 amphibian species, 8 species of birds, 3 species of mammals and 1 terrestrial invertebrate species (**APPENDIX 4-1 (‘NLAA\_Extinct’ tab)**). Critical habitat for “presumed extinct” species was assessed further before making a determination specific to the critical habitat.

“Not Likely to Adversely Affect” determinations are made for species and/or critical habitats occurring exclusively on the uninhabited Northwestern Hawaiian Islands of Nihoa and Laysan Island.  Based on the 2000 U.S Census, the human population of these islands is zero[[2]](#footnote-2).  As a result, human presence on these islands is expected to be zero to extremely low and the potential exposure to malathion is considered to be discountable. Consequently, ​​“Not Likely to Adversely Affect” determinations were made for 4 birds species, and 2 flowering plants species found only on these islands and their associated critical habitat,​and for the critical habitat for an additional flowering plant species(**APPENDIX 4-1 (‘NLAA\_OutsideUse’ tab)**)

Midway Islands, the pacific island coral atolls and Mona Island of Puerto Rico have low human populations ranging from 7-150 people, based on the 2000 U.S Census2. While human impact is expected to be low on these islands, the possibility of exposure is not discountable and the 5 species and/or critical habitats occurring exclusively on these islands are considered further.

Other minor outlaying U.S Islands such as, Wake Island, the additional Northwestern Hawaiian Islands and minor islands of Hawaii were also considered. However, none of the listed species occur exclusively in these locations.  Therefore, exposure is not discountable based on location alone**,** and these species were considered further before making a determination.

A “Not Likely to Adversely Affect” determination is made for those species and/or designated critical habitats for which the use site (including off-site transport) and range overlap is less than 1% after rounding for significant digits. All species with 1% or greater overlap were assessed further before assigning an effects determination. A critical habitat determination may differ from the species determination when the critical habitat extends outside of the species range or the location and size increases the impact due to spray to 1% or greater.

All of the remaining 1800 species and 794 designated critical habitat locations have greater than 1% overlap and are assessed further before assigning an effects determination.

Sea turtles, whales and deep sea fish, marine mammals (excluding whales), and cave dwelling invertebrate species were assessed in separate analyses and excluded from the weight of evidence analysis; additional information on these analyses can be found in **Sections** **7.1, 7.2, 7.3, and 7.4**, respectively.

# Effects Determinations of NLAA/LAA: Weight of Evidence Analysis

A weight-of-evidence (WoE) analysis, as described in **Section 1.4.2.2** of the Problem Formulation, is used to make effects determinations on 1819 species and 794 critical habitats. The weight of evidence analysis was completed by producing “matrices” that capture the multiple lines of evidence. Direct effects considered for listed animals included effects on mortality, growth, reproduction, behavior and sensory function and indirect effects considered included impacts to prey/dietary items, habitat and obligate organisms. For plants, lines of evidence considered included mortality, growth, and reproduction and indirect effects considered included impacts to pollinators, habitat and obligate organisms. Additional lines of evidence addressing direct and indirect effects due to chemical mixtures and stressors and effects due to abiotic stressors (see **ATTACHMENT 4-1**) were also considered if an effects determination could not be reached based on the direct and indirect lines of evidence alone (*i.e.,* if LAA determination was reached based on the direct/indirect lines, analysis of additional data was not conducted). Depending on the species primary habitat, a terrestrial or aquatic weight of evidence matrix was completed. Some species life history dictated the need for both a terrestrial and aquatic weight of evidence matrix to be created to fully characterize potential risk to the species. If the listed species spent limited time in a different habitat, a second matrix was not developed; rather, an indication of the additional aquatic or terrestrial exposure was included in the primary matrix (*e.g.,* the lower keys marsh rabbit, a terrestrial species which spends time in wetland/marsh environment). Information gathered from the species range, overlap with the chemical use patterns, dietary items, EECs for both terrestrial and aquatic exposures, and indirect relationships and effects are integrated into each species matrix to make the determination of risk and confidence in data with a corresponding high, medium or low rating. Criteria used to determine if a line of evidence warrants a high, medium or low rating are described in **ATTACHMENT 1-9**. For designated critical habitats, any potential for direct or indirect effects to a listed species, based on the lines of evidence, are considered for the effects determination, regardless if the listed species is present within and/or currently inhabits the designated critical habitat (as not all designated critical habitats are currently occupied by individuals of a listed species).

Summary results for the species determinations based on the weight of evidence matrices are contained in **APPENDIX 4-1 (‘Summary’ tab)** and are denoted as either “TerrWoE”, “AquaWoE” or “TerrWoE and AquaWoE” as the source of the effects determination. Additional worksheets in **APPENDIX 4-1** include total call counts for species, summary information on individual lines of evidence for each species and a key to file locations for each species. Detailed matrices for all species are located in **APPENDIX 4-3**, organized by species taxa and order. A detailed discussion of the weight of evidence matrices, including how exceedances of thresholds were determined and detailed discussion of each risk line, is included in **ATTACHMENT 4-1**. Criteria used to determine if a line of evidence warranted a high, medium or low rating are described in **ATTACHMENT 1-9**.

# Effects Determinations of LAA: Downstream dilution

Because of the widespread use of malathion and the uncertainty with where the mosquito adulticide use could occur, the entire United States is considered the action area for malathion for Step 1. For Step 2, again due to the uncertainty with where the adulticide use could occur, malathion use could potentially occur in any watershed, including the watershed encompassing the species range and/or critical habitat, resulting in pesticide contribution to a receiving stream, negating the need to assess downstream dilution for Step 2. A process is being developed to evaluate EECs in upstream reaches, as well as for the streams in the species ranges and critical habitat, for Step 3 in order to address the contribution of the upstream sources to the existing EECs (**Appendix 3-4)**.

# Effects Determinations of NLAA/LAA: Qualitative Analyses

Not all listed species were included in the WoE effects determinations presented in Section 5.  Section 7 contains the effect determinations for these listed species based on qualitative analyses. Potential risk to these listed species were assessed qualitatively because EPA does not currently have methods available to adequately estimate potential exposures for these species. In many cases, these species live exclusively (*i.e.,* whales, deep fish) or primarily (*i.e.,* sea turtles, marine mammals) in marine environments, or are cave dwellers (invertebrate species). Other qualitative analyses focus on certain uses (*i.e*., mosquito adulticide) for which reliable exposure methods are not available as current terrestrial methods are suited for foliar [flowable] applications.

## Sea Turtle Analysis

This assessment considers the effects of malathion on 9 listed species of sea turtles, including 2 listings of the loggerhead (different DPSs), 6 listings of the green, the leatherback, the hawksbill, kemp’s ridley and 2 listings of the olive ridley sea turtle. The biological information (*e.g.,* diet, habitat) used in this assessment for each species is included in **ATTACHMENT 1-14**.

Sea turtles spend the vast majority of their lives in aquatic habitats. Hatchling, juvenile and adult sea turtles forage in offshore and nearshore coastal habitats, including estuaries[[3]](#footnote-3). Adult sea turtles use ocean habitats during the majority of their lives. In addition, green sea turtles use freshwater streams and rivers during part of their lifecycle. None of the other listed sea turtles use freshwater habitats. While in aquatic habitats, exposure to malathion via contaminated dietary items is assessed. Other exposure routes (*e.g.,* dermal) are not assessed in aquatic habitats because methods are not available to estimate exposures via non-dietary routes. Other routes of exposure are assessed in terrestrial habitats, *i.e.,* beaches. Sea turtles utilize beaches to lay their eggs, while some species use beaches to bask. As a result, eggs, hatchlings and adults may be exposed to malathion from spray drift transport from treatment sites that are adjacent to nesting sites. Exposure routes of concern include inhalation and dermal interception of spray droplets on the day of the application. Since sea turtles do not forage while on land, dietary exposure while in terrestrial habitats is not expected. The dietary item categories of the 9 sea turtles are presented in **Table 4-7.1**. Additional biological information (*e.g.,* diet, habitat) used in this assessment for each species is included in **ATTACHMENT 1-14**.

**Table 4-7.1. Dietary Items for the 9 Listed Sea Turtles**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Scientific Name*** | **Common Name** | **Plants** | **Invertebrates** | **Fish** |
| *Caretta caretta* | Loggerhead sea turtle (North Pacific Ocean DPS) | Yes | Yes | Yes |
| *Caretta caretta* | Loggerhead sea turtle (Northwest Atlantic Ocean DPS) | Yes | Yes | Yes |
| *Chelonia mydas* | Green sea turtle (Central North Pacific DPS) | Yes | No | No |
| *Chelonia mydas* | Green sea turtle (Central South Pacific DPS) | Yes | No | No |
| *Chelonia mydas* | Green sea turtle (Central West Pacific DPS) | Yes | No | No |
| *Chelonia mydas* | Green sea turtle (East Pacific DPS) | Yes | No | No |
| *Chelonia mydas* | Green sea turtle (North Atlantic DPS) | Yes | No | No |
| *Chelonia mydas* | Green sea turtle (South Atlantic DPS) | Yes | No | No |
| *Dermochelys coriacea* | Leatherback sea turtle | No | Yes | No |
| *Eretmochelys imbricate* | Hawksbill sea turtle | Yes | Yes | No |
| *Lepidochelys kempii* | Kemp's ridley sea turtle | No | Yes | No |
| *Lepidochelys olivacea* | Olive ridley sea turtle (Mexican nesting population) | Yes | Yes | Yes |

This section provides the risk assessment used to assess exposures and potential effects to sea turtles on beaches and in their aquatic habitats. Indirect effects to prey and habitat are also assessed in aquatic habitats. Effects determinations for the species and their designated critical habitats are based on the risk assessments that integrate the weight of evidence based on exposure, available effects data and the uncertainties associated with these data.

### Risk Assessment for Aquatic Habitats: Direct Effects

*Dietary toxicity data*

As indicated above, dietary exposure is assessed for aquatic habitats. While there is an acute oral-based study with the green anole (*Anolis carolinensis*; Hall et al. 1982; E36970) and a chronic study (dosed via gavage) with the Western fence lizard (*Sceloporus coelestinus*) available for malathion (Holem *et al*. 2008; E104558), no dietary-based (via food) toxicity data are available for reptiles. As a result, toxicity data available for birds are used as a surrogate for reptiles. For dietary exposure, the avian thresholds for mortality and sublethal effects are 300 and 110 mg a.i./kg-diet, respectively (see **Table 2-6.1** of **Chapter 2**). Other endpoints considered in this analysis include the lowest avian LC50 (*i.e.,* 2022 mg a.i./kg-diet) and the NOEC and LOEC where effects to avian reproduction were observed (*i.e.,* 110 and 350 mg a.i./kg-diet, respectively).

When considering bioaccumulation in aquatic organisms, pesticide uptake occurs through two routes: respiration of water and consumption (dietary) of contaminated food items. Bioaccumulation is limited by the extent to which a pesticide is eliminated (through respiration or fecal elimination) or metabolized to non-toxic degradates. For chemicals with Log Kow < 4, exposure from food becomes insignificant because uptake and depuration through respiration controls the residue in the organism. For chemicals with Log Kow > 6, diet is the predominant uptake route, with little influence from respiration. Given that the Log Kow value of malathion is 2.8, Bioconcentration Factors (BCFs), which are based on studies involving respiratory uptake only, are considered representative of bioaccumulation because the dietary route is not substantial relative to respiration. Malathion is not expected to accumulate over time in prey because it is not persistent in aqueous environments (Chapter 3), and is readily excreted and metabolized by animals[[4]](#footnote-4),[[5]](#footnote-5). BCFs for malathion in aquatic plants, invertebrates and fish are used predict short term uptake of malathion in aquatic organisms that represent the prey of listed sea turtles.

Bioconcentration factors (BCFs) for malathion for the three relevant food items of sea turtles (*i.e.,* aquatic plants, invertebrates and fish), are used to translate toxicity thresholds to aquatic concentrations that would constitute a potential risk from dietary exposure. In this approach, the threshold is divided by the BCF. Since a BCF represents the ratio of the chemical concentration in animal tissue (mg a.i./kg-diet) to the concentration in water (mg a.i./L-water), this approach assumes that the threshold is equivalent to the chemical concentration in animal tissue.

As noted in **Chapter 3** (exposure characterization), an empirically-derived BCF for plants is 23, based on the results of one study testing three different aquatic plant species (BCF range of 1.2-23). For fish, several BCF values were reported for malathion, however there were uncertainties for many of the studies. Considering both the empirical and estimated BCF data for fish, the whole fish BCF value of 131 from the registrant submitted study (for which exposure was constant and residues were characterized and conducted using live fish) was used to estimate malathion concentrations in fish. For aquatic invertebrates, reliable empirically-derived BCF values were not available for malathion, therefore, the KABAM[[6]](#footnote-6)-estimated BCF based value was used (BCF of 24). This value is uncertain because it is based on a model estimate that does not account for metabolism of malathion by aquatic invertebrates. The BCF values for aquatic invertebrates, plants and fish are provided in **Table 4-7.2**. These BCFs were used to estimate aqueous concentrations sufficient to exceed the thresholds and endpoints where effects were observed (*i.e.,* lowest LC50 and reproduction LOEC). Given that these BCF values are based on steady state, it is necessary to compare EECs that are representative of the time to steady state for malathion. Based on the Log Kow of malathion (2.8), steady state is reached in approximately 2 days. Therefore, in this assessment, 1-day average water concentrations are compared to the values in **Table 4-7.2**.

**Table 4-7.2. Aqueous concentrations defining dietary exposures of concern for sea turtles (all ages).**

|  |  |  |  |
| --- | --- | --- | --- |
| **Food item** | **Description of BCF** | **BCF value** | **Aqueous concentration (ug a.i./L) above which there is concern for dietary exposure** |
| **Mortality threshold** | **Lowest LC50** | **Sublethal threshold\*** | **Lowest NOEC for repro** | **Lowest LOEC for repro** |
| Aquatic plants | Empirical | 23 | 13043 | 87913 | 4783 | 4783 | 15217 |
| Aquatic invertebrates | KABAM estimate  | 24 | 12500 | 84250 | 4583 | 4583 | 14583 |
| Fish | Empirical | 131 | 2290 | 15435 | 840 | 840 | 2672 |

*\*Based on Reproductive effects*

There is considerable uncertainty in using birds as surrogates for reptiles as it is assumed that they will have similar responses to malathion. The actual sensitivities of reptiles to malathion relative to birds is unknown. Given that malathion’s toxicity is attributed to metabolic transformation to the oxon degradate, differences in metabolic rates of birds and reptiles may lead to different sensitivities. Since birds are warm blooded and reptiles are cold blooded, it is expected that the metabolic rates of reptiles will be lower than those of birds. Limited data are available to examine the differences in toxicity of birds and cold-blooded species. For malathion, in an acute oral toxicity test with the green anole (*Anolis carolinensis*), a 24-hr LD50 value was 2324 mg/kg-bw (Hall et al. 1982; E36970), which is at the upper range of acute toxicity values for birds (136 to >2,400 mg/kg-bw). Additionally, in a study using Western fence lizards receiving three oral doses of malathion at 27 day intervals for 81 days reported no effects on food consumption or weight at doses up to 100 mg/kg-bw; however, mortality (23%) and clinical signs of acute OP toxicity (i.e., tremors/twitching), as well as motility effects were observed at 100 mg/kg-bw. There is also an acute oral toxicity study with a terrestrial-phase amphibian, a bullfrog

(*Lithobates catesbeianus*), in which a 14-d LD50 value was 1760 mg a.i./kg-bw (MRID 49693705). The sublethal threshold for birds was 87.4 mg/kg-bw and is based on AChE inhibition (E63276). Effects on body weight in birds after acute exposure were observed at doses of 63 and 300 mg/kg-bw. While there is limited data with terrestrial reptiles, data are not available for turtles or other reptiles which are primarily aquatic-based. Additionally, the available data were exposed via gavage whereas the exposure analysis uses dietary-based toxicity data. Therefore, the confidence associated with the robustness and relevance of use of the available avian toxicity data as a surrogate for reptiles is reduced.

*Exposures in estuaries and near shore areas*

There is a great deal of uncertainty in estimating potential malathion exposures in estuaries and near-shore areas of the ocean because the existing fate and transport models do not account for water stratification, tidal flux, and complex currents that occur in these habitats (*i.e.*, bins 8 and 9). As noted in the problem formulation (**Chapter 1**), estimates developed for aquatic Bin 2 are generally used as surrogate exposure levels for intertidal nearshore waterbodies (Bin 8), and estimates developed using aquatic Bin 3 are generally used as surrogate exposure levels for subtidal nearshore waterbodies (Bin 9). Additionally, aquatic Bin 5 is generally used as a surrogate for tidal pools occurring during low tide (aquatic Bin 8). EECs for bins 2, 3 and 5, which include both runoff and drift, are 6.5-1370, 3.6-562, and 0.07-9880 ug a.i./L, respectively (EECs are presented in **APPENDIX 3-4**; values based on HUCs 1-3, 8, 12, 13, 17-21, which are relevant to the species ranges). Except for the highest EECs in bin 5, these 1-in-15 year 1-d average EECs exceed only the concentrations that represent the sublethal threshold and reproduction NOAEC endpoint (they are the same endpoint) for fish listed in **Table 4-7.2**. The highest EEC, 9880 µg/L does overlap with both mortality and/or sublethal thresholds for all three dietary items. The highest 1-day average EECs were for bin 5 in HUC 13 with the next highest maximum 1-day average EEC being 1,410 µg/L (bin 5 in HUC18a). HUC 13 is located in the southwestern portion of the U.S. and only overlaps with coastal regions where the Rio Grande River flows into the Gulf of Mexico (**Figure 4-7.1**). The high bin 5 HUC 13 EEC values are associated with malathion use on cotton. **Figure 4-7.2** shows the time series peak EECs in bin 5 for malathion use on cotton in HUC 13 and 12 (HUC 12 is comprised of greater Texas including the western coast of the Gulf of Mexico). This figure shows that in comparison, the 1-d average EECs in HUC 13 are substantially greater than those in HUC 12.



**Figure 4-7.1. Location of HUC 13 (purple-shaded area) in the U.S.**

**Figure 4-7.2. Comparison of aquatic 1-day average EECs for malathion use on cotton for bin 5 in HUCs 12 and 13.** ULV= ultra-low volume.

It is noted that the green turtle does utilize freshwater habitats, and consumes aquatic plants. For aquatic plants, the HUC 13, bin 5 EECs only exceed the sublethal threshold (which is the same as the avian reproduction NOAEC). Additionally, the 1-day average EEC for other HUCs and both bin 2 and 5, exceed the sublethal threshold for fish. Dietary information indicates that only the olive ridley and the loggerhead sea turtle consumes fish. Available species range information indicates that all listed turtles except the olive ridley sea turtle inhabit the Gulf of Mexico. Therefore, all listed sea turtles, except the olive ridley, could be exposed to malathion residues if it enters the region where the waters of the Rio Grande river enters the Gulf of Mexico. However, except for the two sea turtles which consume fish (*i.e.*, loggerhead and olive ridley), this is anticipated to be the extent of the potential direct effect as all other EECs were below the toxicity thresholds. Given that the loggerhead and the olive ridley sea turtle consume fish, and EECs from several HUC/bin combinations exceed the sublethal threshold, there could be potential direct effects from this dietary item.

It should be noted that there is a great deal of uncertainty surrounding the EECs for listed sea turtles. The marine bins selected for these species (bins 8 and 9) cannot be modeled, so surrogate freshwater bins (2, 3, and 5) are used. Bins 2 and 3 are used to represent low and high tide periods, with bin 5 representing a tidal pool. The EECs for these bins reflect contributions from both runoff and spray drift from treated areas adjacent to the waterbodies, which may not typically occur for intertidal and subtidal nearshore waterbodies which have beaches between the treated area and the leading edge of the water. Limited fate data (e.g., hydrolysis, metabolism) are available for malathion in saltwater environments, so it is uncertain how representative the EECs are for a marine environment. Bourquin (1977)[[7]](#footnote-7) examined microbial interaction with malathion in an artificial saltmarsh ecosystem. In the study, it was observed that increased salinity increased degradation of parent malathion and formation of degradates, while levels of malaoxon remained constant. The authors concluded that both chemical and microbial processes will degrade malathion in saltmarsh environments. While the flowing bins (bins 2 and 3) are being used to represent the exchange of water expected in the marine bins due to the tides, there is uncertainty in how well these bins reflect the turbulent, mixing nature of the 12-hour tidal cycle and the EECs that may be present. The surrogate bins have lower depths and widths than the bins they are designed to represent: a 0.1 m depth and 1-2 m width for bins 2 and 5 compared to 0.5 m depth and 50 m width for bin 8 and a 1 m depth and 8 m width for bin 3 compared to 5 m depth and 50 m width for bin 9. While the smaller bins (bins 2 and 5) could be used for rearing juveniles, it is uncertain if these surrogate bins could hold sufficient volume to contain adult pinnipeds, mustelids and manatees. The additional depth and width assigned to bins 8 and 9 could also result in lower EECs based on the additional water volume and hence dilution.

Some monitoring data are available where malathion concentrations were measured in estuaries. Concentrations reported in CA in 2008-2009 were ≤5.5ug a.i./L[[8]](#footnote-8). Measured data include documented detections; however, values are below the aqueous concentrations of concern in **Table 4-7.2.** It should be noted that the utility of these data are limited in that they represent ambient monitoring data for which the applications of malathion in the watershed of the sampled estuaries are not defined and are not expected to capture peak exposures.

EECs resulting from drift only transport into estuaries are provided in **Tables 4-7.3** (maximum ground spray applications of 5.1 lb a.i./A) **and 4-7.4** (maximum aerial application of 2 lb a.i./A). Only bins 2 and 5 located at the edge of the treatment sites for the maximum use rate (5.1 lb/A) have EECs at levels that are above the threshold endpoints for aquatic invertebrate and fish dietary items. The EECs are below all thresholds, for all dietary items, well less than 30 meters off-field. As such, concern for potential direct effects for sea turtles exposed via diet is low for those consuming aquatic plants or aquatic invertebrates.

**Table 4-7.3. Aquatic EECs (ug a.i./L) resulting from spray drift from ground application at 5.1 lb a.i./A (maximum rate allowed). Distances represent different distances between application site and water body. EECs are instantaneous values.**

|  |  |
| --- | --- |
| **Distance (m)** | **EEC by Bin** |
| **2** | **3** | **5** |
| 0 | 4119.10 | 192.53 | 4667.13 |
| 30 | 144.55 | 13.03 | 147.20 |
| 60 | 64.44 | 6.09 | 65.07 |
| 90 | 39.70 | 3.82 | 39.96 |
| 120 | 28.06 | 2.72 | 28.20 |
| 150 | 21.40 | 2.09 | 21.49 |
| 180 | 17.14 | 1.68 | 17.20 |
| 210 | 14.20 | 1.40 | 14.24 |
| 240 | 12.06 | 1.19 | 12.09 |
| 270 | 10.44 | 1.03 | 10.47 |
| 300 | 9.18 | 0.91 | 9.20 |
| 304 | 9.03 | 0.89 | 9.05 |

**Table 4-7.4. Aquatic EECs (ug a.i./L) resulting from spray drift from aerial application at 2 lb a.i./A (maximum rate allowed). Distances represent different distances between application site and water body. EECs are instantaneous values.**

|  |  |
| --- | --- |
| **Distance (m)** | **EEC by Bin** |
| **2** | **3** | **5** |
| 8\* | 483.78 | 41.12 | 498.29 |
| 30 | 198.47 | 18.41 | 201.08 |
| 60 | 109.05 | 10.44 | 109.86 |
| 90 | 74.86 | 7.26 | 75.25 |
| 120 | 56.87 | 5.55 | 57.10 |
| 150 | 45.79 | 4.49 | 45.93 |
| 180 | 38.28 | 3.77 | 38.39 |
| 210 | 32.87 | 3.24 | 32.95 |
| 240 | 28.78 | 2.84 | 28.84 |
| 270 | 25.59 | 2.53 | 25.64 |
| 300 | 23.03 | 2.28 | 23.07 |
| 304 | 22.72 | 2.25 | 22.76 |
| 330 | 20.93 | 2.07 | 20.96 |
| 360 | 19.17 | 1.90 | 19.20 |
| 390 | 17.69 | 1.75 | 17.71 |
| 420 | 16.41 | 1.63 | 16.43 |
| 450 | 15.30 | 1.52 | 15.32 |
| 480 | 14.34 | 1.42 | 14.35 |
| 510 | 13.48 | 1.34 | 13.50 |
| 540 | 12.72 | 1.27 | 12.73 |
| 570 | 12.04 | 1.20 | 12.05 |
| 600 | 11.43 | 1.14 | 11.44 |
| 630 | 10.88 | 1.08 | 10.89 |
| 660 | 10.38 | 1.03 | 10.38 |
| 690 | 9.92 | 0.99 | 9.92 |
| 720 | 9.50 | 0.95 | 9.50 |
| 750 | 9.11 | 0.91 | 9.12 |
| 780 | 1.11 | 0.11 | 1.11 |
| 793 | 1.09 | 0.11 | 1.09 |

\*Minimum distance off-site is eight meters due to aerial application buffer restrictions for non-ULV uses of 25 feet.

*Exposures in Off-Shore Habitats*

It is expected that, given the large volume of water in oceans, and the lack of persistence of malathion, this chemical will be sufficiently diluted to not be of concern for adult sea turtles in deep water ocean habitats. In addition, since malathion is readily metabolized and does not accumulate in aquatic organisms, exposure via consumption of aquatic plants, invertebrates and fish is not of concern.

It should be noted that this approach differs from that taken above for smaller, near shore habitats (*e.g.,* estuaries). In these areas, short term concentration of malathion in aquatic prey of sea turtles is considered because concentrations may be higher in water and malathion could concentrate for a short term period in prey of sea turtles. The use of empirically based bioconcentration factors allows for consideration of metabolism and for uptake in prey (fish, invertebrates) via the major route of exposure (*i.e.,* respiration).

*Exposures in freshwater environments (for Green Sea Turtle only)*

Aquatic bins that are used as surrogates for estimating exposures to green sea turtles in freshwater habitats are bins 3 and 4 (**ATTACHMENT 1-10**). The 1-in-15 year 1 d average EECs, which include both runoff and drift,are 3.6-562 and 3.5-576 µg a.i./L, respectively based on HUCs 1-3, 8, 12, 13, 17-21. None of these 1-in-15 year 1-d average EECs exceed the concentrations that represent threshold and endpoint exceedances listed in **Table 4-7.2**. Therefore, there is no concern for potential direct effects to green sea turtles exposed via diet while in freshwater habitats.

### Risk Assessment for Aquatic Habitats: Indirect Effects

**Table 4-7.5** summarizes the thresholds used to assess indirect effects to sea turtles through impacts to diet (aquatic plants, invertebrates and fish) or habitat (plants). Details of how these values were derived are provided in **Chapter 2**.

**Table 4-7.5. Thresholds for indirect effects (µg a.i./L).**

|  |  |  |
| --- | --- | --- |
| **Taxa** | **Mortality threshold** | **Sublethal threshold** |
| Aquatic plants | 2500 | 2500 |
| Aquatic invertebrates | 0.54 | 0.1 |
| Fish | 7.8 | 16 |

For estuaries and near shore ocean habitats, 1-in-15 year 1-day EECs estimated for bins 2, 3 and 5 are 0.07-9880ug a.i./L . These values are above thresholds for mortality and sublethal thresholds for aquatic plants, aquatic invertebrates and fish (**Table 4-7.5**).

For sea turtles in the off shore habitats, indirect effects due to loss of prey or habitat are not expected. This is due to the effect of dilution in deep water ocean environments in which the adult sea turtles are found.

For freshwater habitats used by the green sea turtle, 1-in-15 year 1-day EECs estimated for bins 3 and 4 are 3.5-576ug a.i./L. These values are above thresholds for mortality and sublethal thresholds for aquatic invertebrates and fish dietary items, suggesting indirect effects may occur due to possible reductions in these resources (**Table** **4-7.5**).

### Risk Assessment for Terrestrial Habitats (*i.e.*, Beaches)

Spray drift transport from use sites adjacent to beaches could potentially result in exposures to eggs, hatchlings (leaving the nest) and adults (laying eggs or basking).

*Exposures to eggs*

When considering exposures to eggs, no toxicity data are available where reptile eggs were exposed to malathion. On study was available where bird eggs were directly treated with malathion. In Hoffman and Eastin, 1981 (ECOTOX#35250), 60% mortality and a 11% decrease was reported in weight of mallard embryos of eggs treated with 125 lb a.i./A malathion in an aqueous emulsion, with no effect at 12.5 lb/A. When treated at 14 lb a.i./A as a malathion oil, a 9% decrease in weight was observed, with no effects to growth observed at 1.4 lb/A. Plasma ChE was also decreased in embryos at 125 and 14 lb/A. There is a great deal of uncertainty associated with the reported application rates because the extrapolation to field rate is unverifiable as no math was provided by the study authors. The exposure rates at which effects were reported are greater than maximum label rates. Furthermore, 1) sea turtle nests are unlikely to be located near treated fields as these areas are likely to be disturbed, 2) it is expected that spray drift deposition will also be intercepted by sand that covers sea turtle nests, substantially decreasing the exposure of eggs to malathion transported via spray drift; and 3) since eggs are laid most frequently at night and malathion applications occur during the day, eggs are not expected to be uncovered at times when spray drift exposure occurs. Therefore, the available information indicates that malathion does not pose a risk to sea turtle eggs. This approach discussed above assumes that the 100% of the pesticide transported via spray drift infiltrates through the sand covering the nest. Pesticide transport via runoff is not considered here because methods are not available to translate concentrations in water to an exposure relevant to eggs.

*Dermal exposures to hatchlings and adults*

When considering exposures to hatchlings and adults on beaches, dermal exposure due to spray drift transport is considered to be of concern. Limited toxicity data are not available for dermal exposures involving reptiles or other cold-blooded species. A single study with tree lizards, *Anolis coelestinus*, reported no effects on AChE after exposure in the field at a rate of 4.5 ounces/A (McLean et al. 1975, E89523). For terrestrial-phase amphibians, no effects on behavior were reported for the slimy or Eastern red backed salamander (*Plethodon glutinosus* and *P. cinereus*, respectively) exposed in cages treated with malathion solutions at a rate of 5.6 or 8.97 kg/ha (5 and 8 lb/A; unclear if rates were adjusted to malathion); decreases in ChE were reported (Baker 1985, E40014). Additionally, the study authors stated that a companion set of field studies in North Carolina indicated that after 10 applications of malathion (5 lb/A), adult and juvenile *P. glutinosus* showed no ChE inhibition, decreases in abundance or effects on lipid storage patterns. Therefore, while the available data for reptiles and other cold-blooded species suggests limited observed effects, extrapolating these exposures (i.e., treated cages) to environmentally relevant exposures for sea turtles on beaches is difficult. There are data available to suggest that this route may cause effects in birds and mammals. For birds, growth was affected for passerines exposed in the field at a rate of 0.53 lb/A, however, no effects on mortality or brood development was reported (Howe *et al.* 1996; E89113). In this study, as the prey base was reduced (arthropods), the relative influence of the dermal route compared to the dietary route cannot be quantified. In other studies in which birds were exposed to malathion as a drench (10 mg/kg-bw; Sodhi et al. 1996, E89387) or spray (600 µg/L; Johnston, 1996; E40317), effects on weight and ChE were reported, but these results and exposure units are difficult to relate to an environmentally-relevant exposure.

While dermal toxicity data for reptiles (or avian surrogates) is limited, there is a high degree of uncertainty associated with concluding that dermal exposures of malathion will pose a risk to sea turtles. First, in order for an exposure to occur, the application must occur either on the day when turtles are basking, when a female lays eggs or when the hatchlings leave the nest. Second, there is additional uncertainty associated with the likelihood of exposure because on the day of application, pesticide must be transported by wind blowing from the application site toward the beach. **Table 4-7.6** provides a summary of the percentage of time the wind is blowing from a certain direction. These data suggest that prevailing winds blow from inland toward the ocean up to 30% of the time (independent of when malathion is likely to be applied). Third, the duration of potential exposures would be limited. For hatchlings, the potential for dermal exposures would only occur during their movement from their nesting site to the water – which occurs fairly rapidly (for predator avoidance). Once in the water, it is expected that any residues not immediately absorbed would be washed off. For females that are laying eggs, potential dermal exposures would occur for one night during their movement from the water to the nesting site, and then from the nesting site to the water. The number of clutches laid per year varies by species (*e.g.,* Loggerhead and green sea turtles nest 2-5 times per year, Leatherbacks will nest 7-10 times per year), so, there may be differences in the likelihood of exposure among species. Another important uncertainty to consider in the likelihood of effects is associated with the available toxicity data. As noted above, the data available for reptiles or other cold-blooded animals, as well as for birds, suggest limited effects. In the available data, there is uncertainty in comparing exposures in the laboratory or the field (likely a combination of dermal and dietary exposure) to potential risk from dermal exposure. Taken together, the chances of dermal exposure to malathion and resulting effects are expected to be low.

**Table 4-7.6. Wind Direction Percentage Summary for meteorological stations on the coast of the Continental US.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Station** | **North** | **South** | **East** | **West** |
| **East Coast** |
| Miami FL | 24 | 23 | 40 | **12\*** |
| Vero Beach FL | 15 | 21 | 31 | **15\*** |
| Charleston SC | 24 | 25 | 20 | **25\*** |
| Wilmington NC | 24 | 22 | 18 | **25\*** |
| Norfolk VA | 25 | 26 | 21 | **24\*** |
| Atlantic City NJ | 26 | 22 | 14 | **29\*** |
| Boston MA | 26 | 17 | 17 | **39\*** |
| Portland ME | 30 | 24 | 13 | **31\*** |
| **West Coast** |
| San Diego CA | 33 | 18 | **8\*** | 33 |
| Santa Barbara CA | **11\*** | 23 | 17 | 26 |
| San Francisco CA | 25 | 13 | **10\*** | 48 |
| Astoria OR | 15 | 26 | **25\*** | 28 |

Source: EPA’s SCRAM website (<http://www3.epa.gov/ttn/scram/surfacemetdata.htm>).

North – 304 to 34 degrees, East – 34 to 124 degrees, South – 124 to 214 degrees, West – 214 to 304 degrees

\*Winds blow from inland toward the ocean. Due to calm winds (winds < 1 m/s), where wind directions can be uncertain, percentages may not sum to 100%.

*Inhalation exposures to hatchlings and adults*

Toxicity data are not available for inhalation exposures involving reptiles nor are data available for the typical surrogate taxa (*i.e.*, birds). In an acute inhalation study (4-hour exposure) with laboratory rats, no mortality was observed at 5.2 mg a.i./L-air (equivalent to 5.2 x 106 µg a.i./mg3) (MRID 00159878). Clinical signs at this concentration included signs of ataxia (females only) and abnormal respiratory during the first day of testing, along with a reduction in male body weight and food consumption one day after exposure (only one test concentration tested). Under chronic durations, in a 90-day inhalation study with rats, histopathological lesions of the nasal cavity and larynx in males and females was observed at 0.1 mg/L (equivalent to 105 µg a.i./mg3) with inhibition of red blood cell AChE at 0.45 mg/L (equivalent to 4.5 x 105 µg a.i./mg3) (MRID 43266601). The relative sensitivities of reptiles and mammals are unknown, leading to uncertainty associated with the representativeness of the available toxicity data for sea turtles. Based on the limited available data, inhalation exposure is not considered to be of concern.

### Effects Determinations

The effect determination is “likely to adversely affect” (LAA) based on exposures in near shore saltwater habitats (for all listed sea turtles) and freshwater habitats (for the green sea turtle) based on indirect effects through impacts to prey and to a much more limited extent, from direct effects from diet. For sea turtles that do not consume fish, risk for direct effects via diet is medium because the exposure estimates (1-d averages from runoff and spray drift) only overlap the thresholds for a limited geographical area (Rio Grande river region) or only extend well less than 30 meters off-field for instantaneous spray drift EECs. For the olive ridley sea turtle, the risk is also medium because it does not inhabit the Rio Grande river region, and the only EEC exceedance was for the avian sublethal threshold (reproduction NOAEC) based on the fish dietary item, and for which spray drift EECs of concern extend less than 30 meters off-field. For the loggerhead sea turtle, the risk is greater (high) than the other sea turtles given that it inhabits the Gulf of Mexico and the sublethal threshold exceedance for the fish dietary item. While risk from dermal exposure resulting from spray drift transport cannot be precluded, it is expected to be low for adult and juvenile turtles on beaches. The confidence associated with the LAA determination is low due to uncertainties associated with the available toxicity data and the exposure estimates. In cases where critical habitat has been designated for a listed sea turtle, an LAA determination is also made for the critical habitat, based on the same considerations for direct and indirect effects (**Table 4-7.7**).

**Table 4-7.7.** **Summary of the Effects Determinations for Malathion and Listed sea turtles and Their Designated Critical Habitat(s).**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Scientific Name*** | **Common Name** | **Listing Status\*** | **FWS/NMFS Species ID (ENTITY\_ID)** | **Risk (Direct Effects)** | **Confidence (Direct Effects)** | **Risk (Indirect Effects)** | **Confidence (Indirect Effects)** | **Species Call?** | **Critical Habitat Call?** |
| *Caretta caretta* | Loggerhead sea turtle (North Pacific Ocean DPS) | E | 9941 | High | Low | High | Low | LAA | NA\*\* |
| *Caretta caretta* | Loggerhead sea turtle (Northwest Atlantic Ocean DPS) | T | 9707 | High | Low | High | Low | LAA | LAA |
| *Chelonia mydas* | Green sea turtle (Central North Pacific DPS) | T | 168 | Medium | Low | High | Low | LAA | LAA |
| *Chelonia mydas* | Green sea turtle (Central South Pacific DPS) | E | 169 | Medium | Low | High | Low | LAA | LAA |
| *Chelonia mydas* | Green sea turtle (Central West Pacific DPS) | E | 170 | Medium | Low | High | Low | LAA | LAA |
| *Chelonia mydas* | Green sea turtle (East Pacific DPS) | T | 167 | Medium | Low | High | Low | LAA | LAA |
| *Chelonia mydas* | Green sea turtle (North Atlantic DPS) | T | 171 | Medium | Low | High | Low | LAA | LAA |
| *Chelonia mydas* | Green sea turtle (South Atlantic DPS) | T | 172 | Medium | Low | High | Low | LAA | LAA |
| *Lepidochelys olivacea* | Olive ridley sea turtle | T | 160 | Medium | Low | High | Low | LAA | NA\*\* |

\*E = endangered, T = threatened

\*\*Not applicable because critical habitat has not been designated for this species.

## Whale and Deep Sea fish Analysis

### Cetaceans

There are currently 12 cetaceans found in the U.S. that are federally listed as endangered or threatened or that are candidates for listing (*i.e., Balaena mysticetus, Balaenoptera borealis, Balaenoptera edeni, Balaenoptera musculus, Balaenoptera physalus, Delphinapterus leucas, Eubalaena glacialis, Eubalaena japonica, Megaptera novaeangliae, Orcinus orca, Physeter microcephalus(=icrocephalus),* and *Pseudorca crassidens*) (see **Table 4-7.8** and **ATTACHMENT 1-13** for details). Four of these species have designated critical habitat(s) (*i.e*., *Delphinapterus leucas, Eubalaena glacialis*, *Eubalaena japonica,* and *Orcinus orca*). All of these species are large mammals (ranging from 1,500 to 320,000 lb) and are found entirely in marine environments. Because EPA does not currently have methods available to adequately estimate potential exposures to listed cetaceans, potential risks to listed cetaceans are assessed qualitatively. Additionally, because it is not possible with current methodologies to adequately estimate exposures for these species, the effects determinations will be based on weighting for general risks and confidence (*i.e*., it is not possible to apply weights for risk and confidence associated with each specific line of evidence).

**TABLE 4-7.8. Listed Cetacean Species (Found in the US).**

| **Scientific Name** | **Common Name** | **Size (Adult) (lb)** | **Diet** | **Habitat** |
| --- | --- | --- | --- | --- |
| *Balaena mysticetus* | Bowhead whale | 150,000 – 200,000 | Invertebrates (*e.g*., krill, copepods, amphipods) and fish | Circumpolar (summer in ice-free waters adjacent to the Arctic Ocean, and are otherwise associated with sea ice) |
| *Balaenoptera borealis* | Sei whale | 100,000 | Invertebrates (*e.g*., copepods, krill, and cephalopods) and small-schooling fish | Subtropical to subpolar waters; usually found in deeper waters of oceanic areas far from the coastline |
| *Balaenoptera edeni* | Bryde’s whale | 90,000 | Plankton (like krill and copepods), crustaceans (like red crabs and shrimp), schooling fish (like anchovies, herring, mackerel, pilchards, and sardines) | Circumglobal (tropical, subtropical, and temperate ocean waters from 40o South to 40o North) |
| *Balaenoptera musculus* | Blue whale | 320,000 | Krill and pelagic crabs | Marine waters (primarily offshore distribution) |
| *Balaenoptera physalus* | Fin whale | 165,000 | Pelagic crustaceans (*e.g*., krill) and schooling fish (*e.g*., herring) | Marine waters (globally) |
| *Delphinapterus leucas* | Beluga whale (Cook Inlet DPS)\* | 3,000 - 3,300 | Marine invertebrates (*e.g*., crabs, shrimp, clams) and marine and anadromous fish (*e.g*., cod and salmon) | Circumpolar (found in shallow coastal waters; spend the ice-free months in the upper Cook Inlet, and expand their distribution south into more offshore waters of the middle Cook Inlet) |
| *Eubalaena glacialis* | North Atlantic Right Whale\* | 140,000 | Copepods and other small invertebrates (*e.g*., krill) | Primarily found in coastal or shelf waters in temperate to subarctic latitudes, but may go into deeper waters |
| *Eubalaena japonica* | North Pacific Right Whale\* | 140,000 | Zooplankton (*i.e*., copepods, euphausids, and cyprids) | Shallow coastal waters. Though movements over deep waters are known to occur |
| *Megaptera novaeangliae* | Humpback whale | 77,000 | Small schooling fish (*e.g*., herring) and large zooplankton (*e.g*., krill) | Marine waters over and near edges of continental shelves throughout all ocean basins |
| *Orcinus orca* | Killer whale (Southern resident DPS)\* | 8,400 - 12,275 | Fish (*e.g*., Pacific salmon and herring), squid, and marine mammals) – obligate with Pacific salmon | Coastal marine waters (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound) |
| *Physeter microcephalus(=icrocephalus)* | Sperm whale | 30,000 – 90,000 | Large animals that occupy deep waters of the ocean (*e.g*., squid, sharks, and skates) | Temperate and tropical waters with depths > ~2,000 ft (preference for deep waters) |
| *Pseudorca crassidens* | false killer whale (Main Hawaiian Islands Insular DPS) | 1,500 | Fishes (*e.g*., tuna) and cephalopods | Waters within 140 km of the main Hawaiian islands |

\*Has designated critical habitat.

Direct effects to listed cetaceans from malathion are not expected due to dilution in the marine environments (very low potential for exposure) and the cetaceans’ very large size (very low potential for effects). Additionally, some of the listed cetaceans are found primarily in deep, ocean waters [*i.e*., Sei whale (*Balaenoptera borealis*), Bryde’s whale (*Balaenoptera edemi*), blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), and sperm whale (*Physeter microcephalus(=icrocephalus*)], and/or are circumpolar [*i.e*., the bowhead whale (*Balaena mysticetus*)]. Species that are found primarily in deep waters or are circumpolar (*i.e.,* found at high latitudes around the earth’s Polar Regions) are expected to range far from any potential application sites – further limiting the potential for exposure. In addition, since malathion is readily metabolized and do not accumulate in aquatic organisms (see **section 7.1.1**), dietary exposure for these species is of very low concern (see **APPENDIX 3-1**). Therefore, for direct effects, the risk is considered low (due to limited exposure and potential for effects) and the confidence is considered high. The same conclusions and rationale apply to the designated critical habitats associated with these species (see **Table 4-7.9**).

For indirect effects (*i.e*., reductions in whales’ prey), due to the effect of dilution in the types of marine environments in which the listed cetaceans are found and distance from potential use sites, risks from the potential loss of marine invertebrate and vertebrate prey are not expected. Therefore, for the listed cetaceans that rely wholly on marine prey [*i.e*., bowhead whale, Bryde’s whale, Sei whale, blue whale, fin whale, North Atlantic right whale, North Pacific right whale, humpback whale, sperm whale, false killer whale (Main Hawaiian Islands Insular DPS)], indirect effects from the potential loss of prey are not expected. For these species the risk for indirect effects is considered low (due to limited exposure) and the confidence is considered high. The same conclusions and rationale apply to the designated critical habitats associated with these species. Therefore, a Not Likely to Adversely Affect (NLAA) effects determination is made for the bowhead whale, Bryde’s whale, Sei whale, blue whale, fin whale, North Atlantic right whale, North Pacific right whale, humpback whale, sperm whale, false killer whale (Main Hawaiian Islands Insular DPS), and for the designated critical habitat associated with the North Atlantic Right Whale DPS and the North Pacific Right Whale DPS.

There are currently two listed species of cetaceans that feed on both marine and anadromous prey items - Beluga whale (Cook Inlet DPS) and the killer whale (Southern resident DPS). The Beluga whale relies on a variety of aquatic invertebrate and vertebrate prey items. Many of its prey species are wholly marine, while some of its fish prey are anadromous species. While many Beluga whales are circumpolar, the Cook Inlet DPS of Beluga whales is found primarily in the Cook Inlet (off the Gulf of Alaska in Southcentral Alaska). These Beluga whales are found in both shallow coastal areas and in deeper waters, depending on the time of year. Although, there are some potential malathion use sites found in Southcentral Alaska, they are limited and largely removed from coastal areas. Therefore, the likelihood that exposures will reach the estuarine/marine environments at concentrations high enough to impact a large marine mammal, such as a Beluga whale, is expected to be very low. Furthermore, as stated earlier, since malathion is readily metabolized and does not accumulate in aquatic organisms, dietary exposure for this species is of very low concern. Therefore, direct effects from the use of these chemicals are not expected. Additionally, the Beluga whales rely on several prey items (most of which are wholly marine), and, the potential use sites are limited and largely removed from coastal areas. Because of these factors, for the Beluga whale the risk for indirect effects is considered low (due to limited exposure potential) and the confidence is considered high. The same conclusions and rationale apply to the designated critical habitat associated with this species. Therefore, a Not Likely to Adversely Affect (NLAA) effects determination is made for the Beluga whale and its designated critical habitat.

The killer whale (Southern resident DPS), is found in the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound, and is an obligate with Pacific salmon (which are anadromous). As discussed previously, direct effects to listed killer whales are not expected. However, because the Pacific salmon, on which the killer whales depend, may be exposed to and adversely impacted by malathion in the Pacific Northwest before reaching the marine environment, there is a potential for indirect effects to this species due to a loss of prey items. Because the listed killer whales are obligates with Pacific salmon, the potential risk associated with a loss of this prey item is considered high, and the confidence is considered high. The same conclusions and rationale apply to the designated critical habitat associated with this species. Therefore, a Likely to Adversely Affect (LAA) determination is made for the killer whale (Southern resident DPS) and its designated critical habitat from the use of malathion based on indirect effects (*i.e*., potential impacts to prey).

**Table 4-7.9. Summary of the Effects Determinations for Malathion and Listed Cetaceans and Their Designated Critical Habitat(s).**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scientific Name** | **Common Name** | **Listing Status\*** | **FWS/NMFS Species ID (ENTITY\_ID)** | **Risk (Direct Effects)** | **Confidence (Direct Effects)** | **Risk (Indirect Effects)** | **Confidence (Indirect Effects)** | **Species Call?** | **Critical Habitat Call?** |
| *Balaena mysticetus* | Bowhead whale | E | 3133 | Low | High | Low | High | NLAA | NA\*\* |
| *Balaenoptera borealis* | Sei whale | E | 1769 | Low | High | Low | High | NLAA | NA\*\* |
| *Balaenoptera edemi* | Bryde’s whale | C | 178 | Low | High | Low | High | NLAA | NA\*\* |
| *Balaenoptera musculus* | Blue whale | E | 3199 | Low | High | Low | High | NLAA | NA\*\* |
| *Balaenoptera physalus* | Fin whale | E | 3096 | Low | High | Low | High | NLAA | NA\*\* |
| *Delphinapterus leucas* | Beluga whale (Cook Inlet DPS) | E | 10144 | Low | High | Low | High | NLAA | NLAA |
| *Eubalaena glacialis* | North Atlantic Right Whale | E | 2510 | Low | High | Low | High | NLAA | NLAA |
| *Eubalaena japonica* | North Pacific Right Whale | E | 10145 | Low | High | Low | High | NLAA | NLAA |
| *Megaptera novaeangliae* | Humpback whale | E | 5623 | Low | High | Low | High | NLAA | NA\*\* |
| *Orcinus orca* | Killer whale (Southern resident DPS) | E | 9126 | Low | High | High | Medium | **LAA** | **LAA** |
| *Physeter microcephalus(=icrocephalus)* | Sperm whale | E | 4719 | Low | High | Low | High | NLAA | NA\*\* |
| *Pseudorca crassidens* | false killer whale (Main Hawaiian Islands Insular DPS) | E | 10700 | Low | High | Low | High | NLAA | NA\*\* |

\*E = endangered; C = candidate species

\*\*Not applicable because critical habitat has not been designated for this species.

### Sharks

There is currently one listed shark species (including three DPSs found in US waters) [*i.e*., the scalloped hammerhead shark (Eastern Pacific DPS; Central and Southwest Atlantic DPS, and Indo-West Pacific DPS) (*Sphyrna lewini*)] and three candidate shark species found in the US [*i.e*., the cusk shark (*Brosme brosme*); oceanic whitetip shark (*Carcharhinus longimanus*); and porbeagle shark (*Lamna nasus)*] (**Table 4-7.10**). None of these species have designated critical habitat. All four of the species (including all three scalloped hammerhead shark DPSs) are found entirely in marine environments. Because EPA does not currently have methods available to adequately estimate potential exposures to ocean-dwelling species, potential risks to listed sharks are assessed qualitatively, and the effects determinations will be based on weighting for general risks and confidence (*i.e*., it is not possible to apply weights for risk and confidence associated with each specific line of evidence).

**TABLE 4-7.10. Listed and Candidate Shark Species (Found in the US).**

|  |  |  |  |
| --- | --- | --- | --- |
| **Scientific Name** | **Common Name** | **Diet** | **Habitat** |
| *Sphyrna lewini* | Scalloped hammerhead shark (Eastern Pacific DPS) | Crustacean, teleosts, cephalopods, and rays | Coastal pelagic species that can also be found in ocean waters (to depths up to 1,000 m); found in temperate and tropical seas |
| Scalloped hammerhead shark (Central and Southwest Atlantic DPS) |
| Scalloped hammerhead shark (Indo-West Pacific DPS) |
| *Brosme brosme* | Cusk shark | Crustaceans, fish, and echinoderms | Marine; deep water with depths > 100m and water temperatures of 30 to 50oF |
| *Carcharhinus longimanus* | Oceanic whitetip shark | Fish, sea turtles, sea birds, gastropods, squid, crustaceans, and mammalian carrion (dead whales and dolphins) | Usually found offshore in waters >600 ft deep |
| *Lamna nasus* | Porbeagle shark | Fish and squids | Usually found offshore |

Direct effects to the listed and candidate sharks from malathion are not expected due to dilution in the marine environments (very low potential for exposure). Additionally, the cusk, oceanic whitetip, and porbeagle sharks are only (or primarily) found in deep waters and, thus, are expected to range far from any potential application sites – further limiting the potential for exposure. In addition, since malathion is readily metabolized and does not accumulate in aquatic organisms, dietary exposure for shark species is of very low concern. Therefore, for direct effects, the risk is considered low (due to limited exposure and potential for effects) and the confidence is considered high (see **Table 4-7.11**).

For indirect effects (*i.e*., reductions in sharks’ prey), due to the effect of dilution in the types of marine environments in which the listed sharks are found, risks from the potential loss of marine invertebrate and vertebrate prey are not expected. Therefore, for the listed and candidate sharks, which rely wholly on marine prey, indirect effects from the potential loss of prey are not expected. For these species the risk for indirect effects is considered low (due to limited exposure) and the confidence is considered high. Therefore, a Not Likely to Adversely Affect (NLAA) effects determination is made for the scalloped hammerhead shark (Eastern Pacific DPS; Central and Southwest Atlantic DPS; and Indo-West Pacific DPS), the cusk shark, the oceanic whitetip shark, and the porbeagle shark.

**Table 4-7.11. Summary of the Effects Determinations for Malathion and Listed and Candidate Sharks.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scientific Name** | **Common Name** | **Listing Status\*** | **ID number** | **Risk (Direct Effects)** | **Confidence (Direct Effects)** | **Risk (Indirect Effects)** | **Confidence (Indirect Effects)** | **Species Call?** | **Critical Habitat Call?** |
| *Sphyrna lewini* | Scalloped hammerhead shark (Eastern Pacific DPS) | E | 10733 | Low | High | Low | High | NLAA | NA\*\* |
| *Sphyrna lewini* | Scalloped hammerhead shark (Central and Southwest Atlantic DPS) | E | 10734 | Low | High | Low | High | NLAA | NA\*\* |
| *Sphyrna lewini* | Scalloped hammerhead shark (Indo-West Pacific DPS) | T | 10736 | Low | High | Low | High | NLAA | NA\*\* |
| *Brosme brosme* | Cusk shark | C | NMFS137 | Low | High | Low | High | NLAA | NA\*\* |
| *Carcharhinus longimanus* | Oceanic whitetip shark | C | NMFS175 | Low | High | Low | High | NLAA | NA\*\* |
| *Lamna nasus* | Porbeagle shark | C | NMFS176 | Low | High | Low | High | NLAA | NA\*\* |

\*E = endangered, T = threatened, C = candidate

\*\*Not applicable because critical habitat has not been designated for this species.

## Marine Mammals (excluding Whales) Analysis

This assessment considers the effects of malathion on 11 listed species of seals, sea lion, and walrus (pinnipeds), sea otters (mustelids), a manatee (sirenid), and the polar bear (**Table 4-7.12**). The biological information (*e.g.,* diet, habitat) used in this assessment for each species is included in **ATTACHMENT 1-13**. This assessment does not consider listed whales (which were addressed above in **section 7.2**).

**Table 4-7.12. Listed pinniped, mustelid and other marine mammal species considered in this analysis.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Scientific Name*** | **Common Name** | **Listing Status\*** | **Critical Habitat?** | **FWS/NMFS Species ID (ENTITY\_ID)** |
| *Arctocephalus townsendi* | Guadalupe fur seal | T | No | 3318 |
| *Enhydra lutris kenyoni* | Northern sea otter (Southwest Alaska DPS) | T | Yes | 5232 |
| *Enhydra lutris nereis* | Southern sea otter | T | No | 45 |
| *Erignathus barbatus* | Bearded Seal (Beringia) | T | No | 10381 |
| *Eumetopias jubatus* | Steller sea lion (Western DPS) | E | Yes | 7115 |
| *Neomonachus schauinslandi* | Hawaiian monk seal | E | Yes | 2891 |
| *Odobenus rosmarus ssp. Divergens* | Pacific walrus | C | No | 9709 |
| *Phoca largha* | Spotted seal (Southern DPS) | T | No | NMFS182 |
| *Phoca vitulina richardii* | Pacific harbor seal (Iliamna lake) | C | No | NMFS159 |
| *Trichechus manatus* | West Indian Manatee | E | Yes | 7 |
| *Ursus maritimus* | Polar bear | T | No | 8861 |

\*E=endangered; T=threatened, C = candidate

Species specific exposures to malathion are determined based on habitat use. All of the species considered here utilize marine habitats, especially to forage. Manatees and Steller sea lions forage in freshwater, as well as marine, habitats. While in aquatic habitats, exposure to malathion via contaminated dietary items is assessed. Other exposure routes (*e.g.,* dermal) are not assessed in aquatic habitats because methods are not available to estimate exposures via non-dietary routes. When considering the pinnipeds and mustelids, all 9 listed species consume invertebrates (*e.g., cephalopods*, crabs) that are considered benthic. All 9 species also consume fish. In addition, one species (Steller sea lion) eats birds and marine mammals. The pacific walrus also eats marine mammals (seals). The polar bear primarily consumes marine mammals, such as seals. The manatee is unique among the marine mammals in that it is an herbivore, consuming algae and aquatic plants. This species is also unique in that it forages in freshwater, as well as marine, habitats. With the exception of the manatee, all of the species assessed here also utilize terrestrial habitats, especially for breeding. Exposure routes of concern in terrestrial habitats include inhalation and dermal interception of spray droplets on the day of the application. **Table 4-7.13** summarizes the diets and habitats of the species included in this assessment.

**Table 4-7.13. Summary of diets and habitats of listed marine mammals included in this assessment.**

|  |  |  |
| --- | --- | --- |
| **Listed species** | **Habitat(s)** | **Diet** |
| Seals (pinnipeds) and sea otters (mustelids) | terrestrial (haul-outs), intertidal nearshore, subtidal nearshore  | Benthic invertebrates, fish |
| Steller sea lion and Pacific walrus (pinnipeds) | terrestrial (haul-outs), intertidal nearshore, subtidal nearshore, and offshore marine | Benthic invertebrates, fish, marine mammals, birds |
| Polar bear | terrestrial, intertidal nearshore, subtidal nearshore, and offshore marine, offshore marine | Marine mammals |
| Manatee | freshwater habitats, marine nearshore, subtidal nearshore, offshore marine | Algae, aquatic plants |

This qualitative analysis provides the risk assessment used to assess exposures and potential effects to marine mammals (excluding whales) in their aquatic and terrestrial habitats. Indirect effects to prey and habitat are also assessed in aquatic habitats. Effects determinations for the species and their designated critical habitats are based on the risk assessments that integrate the weight of evidence based on exposure, available effects data and the uncertainties associated with these data.

### Risk Assessment for Aquatic Habitats: Direct Effects

*Dietary toxicity data*

As indicated above, dietary exposure is assessed for aquatic habitats. Dose-based mammalian thresholds reported in Chapter 2 are converted to dietary based values[[9]](#footnote-9) using standard laboratory conversion factors (WHO 2009[[10]](#footnote-10)). These values are included in **Table 4-7.14**. These values are used in combination with BCF values for aquatic prey in order to calculate aquatic concentrations that would constitute a potential risk from dietary exposure. In this approach, the threshold or endpoint (dietary based) is divided by the BCF. Since a BCF represents the ratio of the chemical concentration in animal tissue (mg a.i./kg-diet) to the concentration in water (mg a.i./L-water), this approach assumes that the threshold is equivalent to the chemical concentration in animal tissue.

**Table 4-7.14. Dietary based endpoint values calculated from dose-based thresholds and endpoints.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Threshold or endpoint** | **Effect** | **Dose-based Value (mg a.i./kg-bw)** | **Dietary-based value (mg a.i./kg-food)\*** | **Test species** | **Source\*\***  |
| Direct (1/million) | Mortality | 137 | 2740 | Rat (*Rattus norvegicus*) | Calculated from LD50 = 1460 ug/g bwAnd Slope = 4.5MRID 49127003 |
| Indirect (1/10) | Mortality | 810 | 16200 |
| LD50 | Mortality | 1460 | 29200 |
| Direct | Sublethal AChE inhibition) | 9.1 | 20 | Rat (*Rattus norvegicus*) | MRID 46822201 |
| Indirect | Sublethal (AChE inhibition) | 13.3 | 20 |
| Direct and indirect | Reproduction NOEC | 25 | 825 | Rabbit  | MRID 00152569, 40812001 |
| Reproduction LOEC | 50 | 1650 |

\*Calculated using standard laboratory conversion factors of 20x for adult rats, 10x for young rats, and 33x for rabbits (WHO 2009). AChE = acetyl-cholinesterase \*\* See **Chapter 2** for additional information on these data.

When considering bioaccumulation in aquatic organisms, pesticide uptake occurs through two routes: respiration of water and consumption (dietary) of contaminated food items. Bioaccumulation is limited by the extent to which a pesticide is eliminated (through respiration or fecal elimination) or metabolized to non-toxic degradates. For chemicals with Log Kow < 4, exposure from food becomes insignificant because uptake and depuration through respiration controls the residue in the organism. For chemicals with Log Kow > 6, diet is the predominant uptake route, with little influence from respiration. Given that the Log Kow value of malathion is 3.3, Bioconcentration Factors (BCFs), which are based on studies involving respiratory uptake only, are considered representative of bioaccumulation because the dietary route is not substantial relative to respiration. Malathion is not expected to accumulate over time in prey because it is not persistent in aqueous environments (**Chapter 3**), and is readily excreted and metabolized by animals[[11]](#footnote-11),[[12]](#footnote-12). BCFs for malathion in aquatic plants, invertebrates and fish are used predict short term uptake of malathion in aquatic organisms that represent the prey of listed marine mammals. Malathion exposures to listed marine mammals that eat air breathing animals that consume fish or other aquatic organism (*e.g.,* birds, seals) are considered discountable because they are not expected to take up malathion through respiration, malathion does not accumulate through the diet, and once they consume malathion through prey, it is expected that it will be metabolized by the birds and mammals.

As noted in **Chapter 3** (exposure characterization), an empirically-derived BCF for plants is 23, based on the results of one study testing three different aquatic plant species (BCF range of 1.2-23). For fish, several BCF values were reported for malathion, however there were uncertainties for many of the studies. Considering both the empirical and estimated BCF data for fish, the whole fish BCF value of 131 from the registrant submitted study (for which exposure was constant and residues were characterized and conducted using live fish) was used to estimate malathion concentrations in fish. For aquatic invertebrates, reliable empirically-derived BCF values were not available for malathion, therefore, the KABAM[[13]](#footnote-13)-estimated BCF based value was used (BCF of 72). This value is uncertain because it is based on a model estimate that does not account for metabolism of malathion by aquatic invertebrates. The BCF values for aquatic invertebrates, plants and fish are provided in **Table 4-7.15**. These BCFs were used to estimate aqueous concentrations sufficient to exceed the thresholds and endpoints where effects were observed (*i.e.,* lowest LC50 and reproduction LOEC). Given that these BCF values are based on steady state, it is necessary to compare EECs that are representative of the time to steady state for malathion. Based on the Log Kow of malathion (3.3), steady state is reached in approximately 4 days. Therefore, in this assessment, 4-day average water concentrations are compared to the values in **Table 4-7.15**.

**Table 4-7.15. Aqueous concentrations defining dietary exposures of concern for marine mammals (excluding whales).**

|  |  |  |  |
| --- | --- | --- | --- |
| **Food item** | **Description of BCF** | **BCF value** | **Aqueous concentration (ug a.i./L) above which there is concern for dietary exposure** |
| **Mortality threshold** | **Lowest LC50** | **Sublethal threshold** | **Lowest NOEC for repro** | **Lowest LOEC for repro** |
| Aquatic plants | Empirical | 23 | 119130 | 704348 | 870 | 35870 | 71739 |
| Aquatic invertebrates | KABAM estimate | 24 | 114167 | 675000 | 833 | 34375 | 68750 |
| Fish | Empirical | 131 | 20916 | 123664 | 153 | 6298 | 12595 |

There are notable uncertainties in using the available toxicity data for mammals to represent those of pinnipeds, mustelids, manatees and bears. The available toxicity data are primarily based on rodent or rabbit test species. No data are available for orders represented by the marine mammal species considered in this assessment. There is uncertainty in the relative sensitivities of laboratory rats and rabbits to the assessed species.

*Exposures in estuaries and near shore areas*

There is a great deal of uncertainty in estimating potential malathion exposures in estuaries and near-shore areas of the ocean because the existing fate and transport models do not account for water stratification, tidal flux, and complex currents that occur in these habitats (*i.e.*, bins 8 and 9). As noted in the problem formulation (**Chapter 1**), estimates developed for aquatic Bin 2 are generally used as surrogate exposure levels for intertidal nearshore waterbodies (Bin 8), and estimates developed using aquatic Bin 3 are generally used as surrogate exposure levels for subtidal nearshore waterbodies (Bin 9). Additionally, aquatic Bin 5 is generally used as a surrogate for tidal pools occurring during low tide (aquatic Bin 8).

The 1-day average EECs for bins 2, 3 and 5, which include both runoff and drift, are, are 6.5-1370, 3.6-562, and 0.07-9880 ug a.i./L, respectively (EECs are presented in **APPENDIX 3-4**; values based on HUCs 1-3, 8, 12, 13, 17-21, which are relevant to the species ranges). Generally, except for the highest EECs in bin 5, these 1-in-15 year 1-d average EECs exceed only the concentrations that represent the sublethal threshold (AChE inhibition) for all three dietary items listed in **Table 4-7.15**. The highest EEC, 9880 µg/L does overlap with the NOAEC value for reproduction for the fish dietary item. The highest 1-day average EECs were for bin 5 in HUC 13, based on use on cotton, with the next highest maximum 1-day average EEC being 1370 µg/L (bin 5 in HUC18a; primarily CA). HUC 13 is located in the southwestern portion of the U.S. and only overlaps with coastal regions where the Rio Grande River flows into the Gulf of Mexico (**Figure 4-7.1**). **Figure 4-7.2** depicts EECs for HUC 13 along with the adjacent HUC 12 in the Gulf of Mexico; the 1-d EECs in HUC 13 are substantially greater than those in HUC 12. Available species range information indicates that for marine mammals (excluding the whales) only the manatee inhabits the Gulf of Mexico (resides in HUCs 3, 8, 12, 13, and 21). For aquatic plants (diet of the manatee), the EECs for most relevant HUCs only exceed the sublethal threshold. Therefore, it is anticipated that the risk for potential direct effect is low as all other EECs were below the toxicity thresholds. For the other species, using the next highest EEC for a HUC (1,370 µg/L), this value only exceed the sublethal threshold. Therefore, the potential risk is medium for direct effects in estuaries or near shore environments.

It should be noted that there is a great deal of uncertainty surrounding the EECs for listed pinnipeds, mustelids and manatees. The marine bins selected for these species (bins 8 and 9) cannot be modeled, so surrogate freshwater bins (2, 3, and 5) are used. Bins 2 and 3 are used to represent low and high tide periods, with bin 5 representing a tidal pool. The EECs for these bins reflect contributions from both runoff and spray drift from treated areas adjacent to the waterbodies, which may not typically occur for intertidal and subtidal nearshore waterbodies which have beaches between the treated area and the leading edge of the water. Limited fate data (e.g., hydrolysis, metabolism) are available for malathion in saltwater environments, so it is uncertain how representative the EECs are for a marine environment. Bourquin (1977)[[14]](#footnote-14) examined microbial interaction with malathion in an artificial saltmarsh ecosystem. In the study, it was observed that increased salinity increased degradation of parent malathion and formation of degradates, while levels of malaoxon remained constant. The authors concluded that both chemical and microbial processes will degrade malathion in saltmarsh environments. While the flowing bins (bins 2 and 3) are being used to represent the exchange of water expected in the marine bins due to the tides, there is uncertainty in how well these bins reflect the turbulent, mixing nature of the 12-hour tidal cycle and the EECs that may be present. The surrogate bins have lower depths and widths than the bins they are designed to represent: a 0.1 m depth and 1-2 m width for bins 2 and 5 compared to 0.5 m depth and 50 m width for bin 8 and a 1 m depth and 8 m width for bin 3 compared to 5 m depth and 50 m width for bin 9. While the smaller bins (bins 2 and 5) could be used for rearing juveniles, it is uncertain if these surrogate bins could hold sufficient volume to contain adult pinnipeds, mustelids and manatees. The additional depth and width assigned to bins 8 and 9 could also result in lower EECs based on the additional water volume and hence dilution.

Some monitoring data are available where malathion concentrations were measured in estuaries. Concentrations reported in CA in 2008-2009 were ≤5.5ug a.i./L[[15]](#footnote-15). Measured data include documented detections; however, values are below the aqueous concentrations of concern in **Table 4-7.15.** It should be noted that the utility of these data are limited in that they represent ambient monitoring data for which the applications of malathion in the watershed of the sampled estuaries are not defined and are not expected to capture peak exposures.

EECs resulting from drift only transport into estuaries are provided in **Tables 4-7.3** (maximum ground spray applications of 5.1 lb a.i./A) and Table **4-7.4** (maximum aerial application of 2 lb a.i./A). Exceedances of thresholds vary by bin and distance. EECs for water bodies located near treated fields are most likely to exceed sublethal and mortality thresholds.

*Exposures in Off-Shore Habitats*

It is expected that, given the large volume of water in oceans, and the lack of persistence of malathion, this chemical will be sufficiently diluted to not be of concern for marine mammals in deep water ocean habitats. In addition, since malathion is readily metabolized and does not accumulate in aquatic organisms, exposure via consumption of aquatic plants, invertebrates, fish and marine mammals is not of concern.

It should be noted that this approach differs from that taken above for smaller, near shore habitats (*e.g.,* estuaries). In these areas, short term concentration of malathion in aquatic prey of marine mammals is considered because concentrations may be higher in water and malathion could concentrate for a short term period in prey of marine mammals. The use of empirically based bioconcentration factors allows for consideration of metabolism and for uptake in prey (fish, invertebrates) via the major route of exposure (*i.e.,* respiration).

*Exposures in freshwater environments (for Manatee and Steller sea lion only)*

Aquatic bins that are used as surrogates for estimating exposures to manatees and Steller sea lions in freshwater habitats are bins 3 and 4 (**ATTACHMENT 1-10**). The 1-in-15 year 1 d average EECs, which include both runoff and drift, derived for these bins are ug a.i./L 3.6-562 and 3.5-576 µg a.i./L, respectively, based on HUCs 1-3, 8, 12, 13, 17-21). None of these 1-in-15 year 1-d average EECs exceed the concentrations that represent threshold and endpoint exceedances listed in **Table 4-7.15**, except for the sublethal threshold for fish (158 µg/L). Therefore, there is no concern for potential direct effects to manatees exposed via diet while in freshwater habitats. For the Steller sea lion, the EECs only exceeded the sublethal threshold (AChE inhibition) for one of its dietary items (consumes a variety of prey). Therefore, while there is concern for potential direct effects to the Steller sea lion exposed via diet while in freshwater habitats, the risk is considered low.

### Risk Assessment for Aquatic Habitats: Indirect Effects

**Table 4-7.16** summarizes the thresholds used to assess indirect effects to marine mammals through impacts to diet (aquatic plants, invertebrates and fish) or habitat (plants). Details of how these values were derived are provided in **Chapter 2**.

**Table 4-7.16. Thresholds for indirect effects (µg a.i./L).**

|  |  |  |
| --- | --- | --- |
| **Taxa** | **Mortality threshold** | **Sublethal threshold** |
| Aquatic plants | 2500 | 2500 |
| Aquatic invertebrates | 0.54 | 0.1 |
| Fish | 7.8 | 16 |

For estuaries and near shore ocean habitats, 1-in-15 year 1-day EECs estimated for bins 2, 3 and 5 are 0.07-9880ug a.i./L . These values are above thresholds for mortality and sublethal thresholds for aquatic plants, aquatic invertebrates and fish (**Table 4-7.16**). Therefore, there is concern for indirect effects to marine mammals in near shore habitats.

For marine mammals in the off shore habitats, indirect effects due to loss of prey or habitat are not expected. This is due to the effect of dilution in deep water ocean environments in which the mammals are found.

For freshwater habitats used by the manatee and Steller sea lion, 1-in-15 year 1-d EECs estimated for bins 3 and 4 are 3.6-562 and 3.5-576 ug a.i./L. These values are above thresholds for mortality and sublethal thresholds for aquatic invertebrates and fish (dietary items of the Steller sea lion), but not for the aquatic plant dietary item (dietary item of the manatee), suggesting indirect effects may occur due to possible reductions in these resources for the Steller sea lion but not the manatee (**Table 4-7.16**).

### Risk Assessment for Terrestrial Habitats

This section considers potential exposures to marine mammals (excluding whales) in terrestrial habitats. Relative to risks due to dietary exposures in aquatic habitats, risks in terrestrial habitats are expected to be lower.

*Dermal exposures*

Dermal exposure due to spray drift transport is of potential concern for mammals in terrestrial areas adjacent to treated sites. Toxicity data from dermal exposure to mammals are available for malathion for several different species (rat, rabbit, mouse, water buffalo, sheep, goat, and American bison). For acute mortality from dermal exposure in rats, the LD50 is greater than 2000 mg/kg (MRID 00159877); effects on AChE inhibition were noted in this study. In a 21-day study with female rabbits (MRID 46790501), effects on AChE were observed with a reported benchmark dose (BMDL) level of 80 mg/kg/d (this dose is the lower 95% confidence interval for the estimated mean dose at which 10% red blood cell AChE inhibition is observed). Additional studies in the open literature reported genetic effects or alterations in biochemical markers (histamine, Glutamic-oxaloacetic transaminase) after dermal exposure to malathion. Other studies which reported results in units of % were also available; however, these results could not be translated to environmentally relevant units, therefore, the relationship between these toxicity data and exposure levels is unknown. Dermal spray doses were calculated using the rabbit and rat body weight (350 and 2000 g, respectively; WHO 2009) and application rates of 2 and 5.1 lb a.i./A (see exposure attachment (1-7, section 7c) for methodology). The doses are 9.6 and 24.6 mg a.i./kg-bw, respectively, for the rabbit and 18 and 45 mg a.i./kg-bw for the rat. These exposure values are less than the BMDL endpoint in the rabbit and the acute LD50 value, therefore, risk from dermal exposure while on land is anticipated to be low.

Field studies with mammals are also available for malathion. Joseph *et al*., 1972, reported no mortality at 0.38 lb a.i./acre in mice that were placed in cages in the field (E56947). Additionally, for the Jamaican fruit eating bat no effect on acetylcholinesterase was reported at 4.5 oz/acre (McLean *et al*. 1975; E89523). In Giles and Robert, 1970, aerial application of malathion (2 lbs/acre with 4 applications) to 2 adjoining Ohio watersheds (primarily deciduous forests) was conducted. Up to a 45% reduction in population of white footed mice *Peromyscus leucopus novaboracensis* was estimated for the treated areas, based on pre and post treatment trapping counts. However, no difference in populations of shorttailed shrews or black-tailed shrews was determined, though malathion residues were detected in costal cartilage, kidney, and heart tissues samples. Chipmunk populations were reduced 55% in treated areas following applications. Larger mammals appeared unaffected. Using an application rate of 5.1 lb a.i./A (highest application rate used in the terrestrial exposure assessment), the distance off-field to be below 2 lb a.i./A is only 7 feet. There is considerable uncertainty in using the field data for the purpose of quantifying effects due to dermal exposure as these endpoints are likely due to a combination of dietary and dermal exposure.

It is expected that there is no dietary exposure to pinnipeds and otters while on beaches because they consume aquatic organisms (*i.e.*, aquatic plants, invertebrates and/or fish).

There is uncertainty associated with concluding that dermal exposures of malathion will pose a risk marine mammals. There is uncertainty associated with the likelihood of exposure because on the day of application, pesticide must be transported by wind blowing from the application site toward the beach. **Table 4-7.6** provides a summary of the percentage of time the wind is blowing from a certain direction. These data suggest that prevailing winds blow from inland toward the ocean up to 30% of the time (independent of when malathion is likely to be applied).

*Inhalation exposures*

In an acute inhalation study (4-hour exposure) with laboratory rats, no mortality was observed at 5.2 mg a.i./L-air (equivalent to 5.2 x 106 µg a.i./mg3) (MRID 00159878). Clinical signs at this concentration included signs of ataxia (females only) and abnormal respiratory during the first day of testing, along with a reduction in male body weight and food consumption one day after exposure (only one test concentration tested). Under chronic durations, in a 90-day inhalation study with rats, histopathological lesions of the nasal cavity and larynx in males and females was observed at 0.1 mg/L (equivalent to 105 µg a.i./mg3) with inhibition of red blood cell AChE at 0.45 mg/L (equivalent to 4.5 x 105 µg a.i./mg3) (MRID 43266601). However, for these species, chronic exposure in terrestrial environments under the conditions observed in the 90-day rat study are not anticipated. These concentration are assumed to be orders of magnitude above what is expected in the air of marine mammals in terrestrial habitats (air monitoring data from CA conducted over four years (CDPR 2013a, 2013b, 2014, 2015; **Chapter 3**) reported no detections above trace concentrations (*i.e.*, 12.6 ng/m3)). As a result, inhalation exposure is not considered to be of concern. As noted above, there is uncertainty associated with the available surrogate test species and their relative sensitivities to the assessed species.

### Effects Determinations

The effect determinations for the Guadalupe fur seal, southern sea otter, Steller sea lion, Hawaiian monk seal, and Pacific harbor seal are “likely to adversely affect” (LAA) based on exposures in near shore saltwater habitats based primarily from indirect effects through impacts to prey. The determination for the West Indian Manatee is also LAA based primarily on potential indirect effects in saltwater and freshwater habitats used by this species. Although there is a high degree of overlap of exposure estimates and thresholds for indirect effects (*i.e.,* “high risk”), the confidence associated with the LAA determination is low due to uncertainties associated with the available toxicity data and the exposure estimates. In cases where critical habitat has been designated (*i.e.*, for Steller sea lion, Hawaiian monk seal and West Indian Manatee), an LAA determination is also made for the critical habitat, based on the same considerations for direct and indirect effects (**Table 4-7.17**).

Several of the species included in this assessment only occur in waters of the US and terrestrial areas that are in Alaska. These species include the northern sea otter, the bearded seal, the pacific walrus, the spotted seal and the polar bear. When considering USDA’s census of agriculture data for Alaska (2012), a limited amount of land was used for grains and fruits and vegetables, with most use acres for forage crops (e.g., hay, alfalfa, silage). Most of these crops are grown in the interior of the state (*e.g.*, near Fairbanks). Although, there are some potential malathion use sites found in Southcentral Alaska (e.g., forage (hay, alfalfa)), they are limited and largely removed from coastal areas[[16]](#footnote-16). Additionally, while malathion is registered as a mosiquitocide, as this use is intended to protect public health usually in urban areas, use of malathion in these areas where these species are located (ice shelfs, Federal wildlife refuges (Aleutian Islands)), is anticipated to be unlikely. Therefore, the potential malathion use sites are limited in nature in areas that may be near the northern sea otter, the bearded seal, the pacific walrus, the spotted seal and the polar bear. Therefore, NLAA determinations are made for these five species (**Table 4-7.17**). For the designated critical habitat of the northern sea otter, an NLAA determination is also made.

**Table 4-7.17.** **Summary of the Effects Determinations for Malathion and Listed Marine Mammals (excluding whales) and Their Designated Critical Habitats.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Scientific Name*** | **Common Name** | **Listing Status\*** | **FWS/NMFS Species ID (ENTITY\_ID)** | **Risk (Direct Effects)** | **Confidence (Direct Effects)** | **Risk (Indirect Effects)** | **Confidence (Indirect Effects)** | **Species Call?** | **Critical Habitat Call?** |
| *Arctocephalus townsendi* | Guadalupe fur seal | T | 3318 | Medium | Low | High | Low | LAA | NA\*\* |
| *Enhydra lutris kenyoni* | Northern sea otter (Southwest Alaska DPS) | T | 5232 | Low | High | Low | High | NLAA | NLAA |
| *Enhydra lutris nereis* | Southern sea otter | T | 45 | Medium | Low | High | Low | LAA | NA\*\* |
| *Erignathus barbatus* | Bearded Seal (Beringia) | T | 10381 | Low | High | Low | High | NLAA | NA\*\* |
| *Eumetopias jubatus* | Steller sea lion (Western DPS) | E | 7115 | Medium | Low | High | Low | LAA | LAA |
| *Neomonachus schauinslandi* | Hawaiian monk seal | E | 2891 | Medium | Low | High | Low | LAA | LAA |
| *Odobenus rosmarus ssp. Divergens* | Pacific walrus | C | 9709 | Low | High | Low | High | NLAA | NA\*\* |
| *Phoca largha* | Spotted seal (Southern DPS) | T | NMFS182 | Low | High | Low | High | NLAA | NA\*\* |
| *Phoca vitulina richardii* | Pacific harbor seal (Iliamna lake) | C | NMFS159 | Medium | Low | High | Low | LAA | NA\*\* |
| *Trichechus manatus* | West Indian Manatee | E | 7 | Low | Low | High | Low | LAA | LAA |
| *Ursus maritimus* | Polar bear | T | 8861 | Low | High | Low | High | NLAA | NA\*\* |

\*E = endangered, T = threatened, C = candidate

\*\*Not applicable because critical habitat has not been designated for this species.

## Cave Dwelling Invertebrate Species Analysis

Currently, there are 22 terrestrial invertebrate species that are only found in caves; all of them only use terrestrial environments and rely wholly on terrestrial food sources [*i.e*., Kauai cave wolf or pe'e pe'e maka 'ole spider, Coffin Cave mold beetle, Helotes mold beetle, Robber Baron Cave meshweaver, Madla's Cave meshweaver, Braken Bat Cave meshweaver, Government Canyon Bat Cave meshweaver, Tooth Cave spider, Government Canyon Bat Cave spider, Clifton Cave beetle, Icebox Cave beetle, Tatum Cave beetle, Louisville Cave beetle, Ground beetle [unnamed (Rhadine exilis)], Ground beetle [unnamed (Rhadine infernalis)], Tooth Cave ground beetle, Kauai cave amphipod, Tooth Cave pseudoscorpion, Kretschmarr Cave mold beetle, Cokendolpher Cave harvestman, Bee Creek Cave harvestman, and Bone Cave harvestman*].*  None of these species are known to have obligate relationships. Eleven of the species have designated critical habitats [*i.e*.,Kauai cave wolf or pe'e pe'e maka 'ole spider, Helotes mold beetle, Robber Baron Cave meshweaver, Madla's Cave meshweaver, Braken Bat Cave meshweaver, Government Canyon Bat Cave meshweaver, Tooth Cave spider, Ground beetle [unnamed (*Rhadine exilis*)], Ground beetle [unnamed (*Rhadine infernalis*)], Kauai cave amphipod, and Cokendolpher Cave harvestman].

Because EPA does not currently have methods available to precisely estimate potential exposures to listed cave-dwelling terrestrial invertebrates, potential risks are assessed qualitatively and characterized using exposure estimates for potential forage items outside the cave. The likelihood of exposure is dependent in part upon foraging behavior (*e.g*., subterranean only versus inside and outside the cave) and the potential for transport of contaminated forage or substrates into the cave. Additionally, although none of the listed species of cave-dwelling terrestrial invertebrates discussed in this section have aquatic life stages, it is uncertain whether and to what extent they may be exposed to pesticide residues in water which percolate through permeable soils in karst cave systems. Thus, the following effects determinations are based on weighting for general risks and confidence (*i.e*., it is not possible to apply weights for risk and confidence associated with each specific line of evidence).

For animals found only in cave interiors, exposure via spray drift is not likely due to multiple drift interception areas typically associated with caves (both outside and within cave systems). Additionally, potential runoff events that could transport pesticides to the interior of a cave system are not expected to result in significant exposure to terrestrial animals found within most caves. Therefore, direct pesticide exposures to most cave-dwelling terrestrial invertebrates from pesticide applications made outside of their cave systems are not generally expected. The exception is for those species that are found in cave systems with permeable substrates (*e.g*., karst cave formations or sink holes) where pesticide contamination via runoff and recharge is more likely if pesticides are used in the vicinity of the cave systems. All of the currently listed cave-dwelling terrestrial invertebrates live in such environments, *i.e*., karst systems, sinkholes, or similar subterranean habitats overlain by permeable substrates) (see **ATTACHMENT 1-20**). For all of these species, pesticides have been listed as a cause of concern by the US Fish and Wildlife Service (*e.g*., see <http://ecos.fws.gov/docs/federal_register/fr3497.pdf>).

For terrestrial cave-dwelling species, there is also a potential for exposure to pesticides from the ingestion of food items that originate from outside of a cave. Based on the available information (see the species profiles, **ATTACHMENT 1-20** **Supplemental Information 3**for details), all of the currently listed terrestrial cave-dwelling invertebrate species appear to rely, to some degree, on dietary items that originate from exterior sources (**Table 4-7.18**).**Table 4-7.18. Listed Cave-Dwelling Terrestrial Invertebrates and Their Diets.**

| **Scientific Name** | **Common Name** | **Diet** | **Origin of the Dietary Item(s)** |
| --- | --- | --- | --- |
| *Adelocosa anops* | Spider, Kauai cave wolf or pe'e pe'e maka 'ole | Kauai cave amphipod, other cave-inhabiting arthropods, and alien species of arthropods that enter the cave system. | Exterior to the cave; Within the cave |
| *Batrisodes texanus* | Beetle, Coffin Cave mold | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Batrisodes venyivi* | Beetle, Helotes mold | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Cicurina baronia* | Meshweaver, Robber Baron Cave | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Cicurina madla* | Meshweaver, Madla's Cave | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Cicurina venii* | Meshweaver, Braken Bat Cave | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Cicurina vespera* | Meshweaver, Government Canyon Bat Cave | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Neoleptoeta myopica* | Spider, Tooth Cave | Examples of nutrient sources include leaf litter fallen or washed in, animal droppings, and animal carcasses | Exterior to the cave |
| *Neoleptoneta microps* | Spider, Government Canyon Bat Cave | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Pseudoanophthalmus caecus* | Beetle, Clifton Cave | Small invertebrates and cave cricket eggs | Exterior to the cave; Within the cave |
| *Pseudoanophthalmus frigidus* | Beetle, Icebox Cave | Small invertebrates and cave cricket eggs | Exterior to the cave; Within the cave |
| *Pseudoanophthalmus parvus* | Beetle, Tatum Cave | Small invertebrates and cave cricket eggs | Exterior to the cave; Within the cave |
| *Pseudoanophthalmus troglodytes* | Beetle, Louisville Cave | Small invertebrates and cave cricket eggs | Exterior to the cave; Within the cave |
| *Rhadine exilis* | Ground beetle, [unnamed] | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Rhadine infernalis* | Ground beetle, [unnamed] | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Rhadine persephone* | Beetle, Tooth Cave ground | A variety of troglobites are known to feed on cave cricket eggs, feces, and/or on the adults and nymphs directly. | Exterior to the cave; Within the cave |
| *Spelaeorchestia koloana* | Kauai cave amphipod | Roots of *Pithecellobium dulce* (Manila tamarind) and *Ficus* sp. (fig), rotting roots, sticks, branches, and other plant material washed into, or otherwise carried into caves, as well as the fecal material of other arthropods | Exterior to the cave; Within the cave  |
| *Tartarocreagris texana* | Pseudoscorpion, Tooth Cave | Examples of diet nutrient sources for these species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Texamaurops reddelli* | Beetle, Kretschmarr Cave mold | Examples of nutrient sources include leaf litter fallen or washed in, animal droppings, and animal carcasses | Exterior to the cave |
| *Texella cokendolpheri* | Harvestman, Cokendolpher Cave | Examples of diet nutrient sources for this species include leaf litter fallen or washed in, animal droppings, and animal carcasses. | Exterior to the cave |
| *Texella reddelli* | Harvestman, Bee Creek Cave | Leaf litter, animals’ droppings and carcasses. | Exterior to the cave |
| *Texella reyesi* | Harvestman, Bone Cave | Leaf litter, animals’ droppings and carcasses. | Exterior to the cave |

Kauai cave wolf spidersmay ingest some arthropods that originate from outside of the cave, however, its diet is primarily made up of the Kauai cave amphipod (and other cave-inhabiting arthropods). For the Kauai cave amphipod, roots of terrestrial plants that extend into subterranean habitats serve as a primary food source, however, some nutritional sources that originate from outside the cave (*e.g*., washed in vegetative matter and feces) may also be ingested. Additionally, the Tooth Cave ground beetle is assumed to eat primarily cave crickets (eggs, nymphs, and adults). Cave cricket adults may forage outside of their cave system at night. In addition to cave cricket eggs, Clifton Cave, Icebox Cave, Tatum Cave, and Louisville Cave beetles eat cave invertebrates which originate primarily, but perhaps not exclusively, from within their caves. Therefore, Kauai cave wolf spiders, Kauai cave amphipods, Tooth Cave ground beetles, Clifton Cave beetles, Icebox Cave beetles, Tatum Cave beetles, and Louisville Cave beetles rely primarily, but not exclusively, on food items that originate from within their cave systems. Thus, there is a potential for exposure from the ingestion of contaminated prey/forage items, but current methods which assume that 100% of the diet is contaminated are not adequate for estimating such exposures.

Although the potential for exposure (*i.e*., the chance of a contaminated food item is washed into a cave and then ingested) is likely low, because malathion is a broad spectrum insecticides that are highly toxic to a wide range of invertebrates, the potential for effects to a single individual of Kauai cave wolf spiders, Kauai cave amphipods, Tooth Cave ground beetles, Clifton Cave beetles, Icebox Cave beetles, Tatum Cave beetles, and Louisville Cave beetlescannot be precluded if they ingest a dietary item(s) that is contaminated with one of these pesticides (see analysis below). Therefore, for direct effects to Kauai cave wolf spiders, Kauai cave amphipods, Tooth Cave ground beetles, Clifton Cave beetles, Icebox Cave beetles, Tatum Cave beetles, and Louisville Cave beetles from the use of malathion, the potential for risk is ‘medium’ (*i.e*., there is a potential for effects if exposure occurs, but it’s not clear what effects would occur at the exposure concentrations), and the confidence is ‘low’ (*e.g*., potential exposures cannot be estimated, but they also cannot be precluded). The same is true for indirect effects related to the loss of potential prey items (that originate from outside of the caves). The same conclusions and rationale apply to the designated critical habitats associated with these species. Therefore, for Kauai cave wolf spiders, Kauai cave amphipods, Tooth Cave ground beetles, Clifton Cave beetles, Icebox Cave beetles, Tatum Cave beetles, and Louisville Cave beetles a Likely to Adversely Affect (LAA) determination for malathion was made. Additionally, for the designated critical habitats associated with Kauai cave wolf spiders, Kauai cave amphipods, and Tooth Cave ground beetles, a Likely to Adversely Affect (LAA) determination is made for malathion.

The remaining listed cave-dwelling terrestrial invertebrate species appear to rely primarily on food items that are derived from exterior sources (*i.e*., leaf litter, animal droppings, and carcasses that may fall or be washed into their cave systems). Therefore, there is a potential for exposure if their food item(s) is contaminated with a pesticide. The EPA does not currently have methods for estimating the concentration of pesticides in leaf litter, animal feces, or carcasses that are found within cave systems. Again, because malathion is a broad spectrum insecticides that are highly toxic to a wide range of invertebrates, the potential for effects to a single individual of a cave-dwelling invertebrate cannot be precluded if it ingests a contaminated food item.

For leaf litter, the foliar dissipation half-lives for malathion is estimated to be 6.1 days. However, because of the sensitivity of terrestrial invertebrates to these chemicals, the EECs on leaves are estimated to be high enough to exceed effects thresholds for weeks after spraying. For example, based on analyses using the TED tool, the dietary-based upper bound EECs on leaves sprayed with malathion the EECs exceed the mortality threshold for 35 days with an application rate of 0.5 lb a.i./acre and 47 days at a rate of 2 lb a.i./acre. For the animal food items, the daily fraction retained in mammals and birds is 0.27 and 0.81 for malathion, respectively. Therefore, if a food item is contaminated with one of these chemicals outside of the cave, it could contain residues high enough to cause concern for several days, if not weeks, after exposure. Thus, there is a potential for exposure to and effects from malathion to cave-dwelling invertebrates from the ingestion of contaminated leaf litter and carcasses.

Additionally, there is evidence in the literature indicating that animal feces (*e.g*., guano) and carcasses contaminated with pesticides (including some organophosphates) have been found in cave systems (*e.g*., Eidels, *et al.* 2007[[17]](#footnote-17); Land 2001[[18]](#footnote-18); MacFarland 1998[[19]](#footnote-19); and Sandel 1999[[20]](#footnote-20)). Therefore, the potential for exposure is medium and the potential for exposure from the ingestion of contaminated feces and carcasses cannot be precluded. Furthermore, malathion is highly toxic to a wide range of invertebrates. Therefore, for direct effects to Coffin Cave mold beetle, Helotes mold beetle, Robber Baron Cave meshweaver, Madla's Cave meshweaver, Braken Bat Cave meshweaver, Government Canyon Bat Cave meshweaver, Tooth Cave spider, Government Canyon Bat Cave spider, Ground beetle [unnamed (Rhadine exilis)], Ground beetle [unnamed (Rhadine infernalis)], Tooth Cave pseudoscorpion, Kretschmarr Cave mold beetle, Cokendolpher Cave harvestman, Bee Creek Cave harvestman, and Bone Cave harvestman*,* from the use of malathion, the potential for risk is ‘medium’ (*i.e*., there is a potential for effects if exposure occurs, but it’s not clear what effects would occur at the exposure concentrations), and the confidence is ‘medium’ (*e.g*., potential exposures cannot be estimated, but they also cannot be precluded). The same conclusions and rationale apply to the designated critical habitat associated with these species.

For potential indirect effects, malathion use would have the potential to impact the availability of animal feces (by impacting the animals), carcasses, and leaf litter (by impacting terrestrial plants. The chance that the impacts on the availability of animal feces, carcasses, and leaf litter would reach a level that would adversely affect the listed terrestrial invertebrates due to the loss of food, is very low, but cannot be precluded. Therefore, for indirect effects to Coffin Cave mold beetle, Helotes mold beetle, Robber Baron Cave meshweaver, Madla's Cave meshweaver, Braken Bat Cave meshweaver, Government Canyon Bat Cave meshweaver, Tooth Cave spider, Government Canyon Bat Cave spider, Ground beetle [unnamed (Rhadine exilis)], Ground beetle [unnamed (Rhadine infernalis)], Tooth Cave pseudoscorpion, Kretschmarr Cave mold beetle, Cokendolpher Cave harvestman, Bee Creek Cave harvestman, and Bone Cave harvestman from the use of malathion, the potential for risk is ‘medium’ (*i.e*., there is a potential for effects if exposure occurs, but it’s not clear what effects would occur at the exposure concentrations), and the confidence is ‘low’ (*e.g*., potential exposures cannot be estimated, but they also cannot be precluded). The same conclusions and rationale apply to the designated critical habitat associated with this species.

Therefore, based on the potential for direct and indirect effects, for Coffin Cave mold beetle, Helotes mold beetle, Robber Baron Cave meshweaver, Madla's Cave meshweaver, Braken Bat Cave meshweaver, Government Canyon Bat Cave meshweaver, Tooth Cave spider, Government Canyon Bat Cave spider, Ground beetle [unnamed (Rhadine exilis)], Ground beetle [unnamed (Rhadine infernalis)], Tooth Cave pseudoscorpion, Kretschmarr Cave mold beetle, Cokendolpher Cave harvestman, Bee Creek Cave harvestman, and Bone Cave harvestman we make a Likely to Adversely Affect (LAA) determination for malathion. Additionally, for the designated critical habitat associated withHelotes mold beetle, Robber Baron Cave meshweaver, Madla's Cave meshweaver, Braken Bat Cave meshweaver, Government Canyon Bat Cave meshweaver, Ground beetle [unnamed (Rhadine exilis)], Ground beetle [unnamed (Rhadine infernalis)], and Cokendolpher Cave harvestman, we make a Likely to Adversely Affect (LAA) determination for malathion (**Table 4-7.19**).

**Table 4-7.19. Summary of the Effects Determinations for Malathion and Listed Terrestrial Cave-Dwelling Invertebrates and Their Designated Critical Habitat(s).**

| **Species name** | **Common name** | **Listing Status\*** | **FWS Species ID (ENTITY\_ID)** | **Risk (Direct Effects)** | **Confidence (Direct Effects)** | **Risk (Indirect Effects)** | **Confidence (Indirect Effects)** | **Species Call?** | **Critical Habitat Call?** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Adelocosa anops* | Spider, Kauai cave wolf or pe'e pe'e maka 'ole | E | 463 | Medium | Low | Medium | Low | **LAA** | **LAA** |
| *Batrisodes texanus* | Beetle, Coffin Cave mold | E | 447 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Batrisodes venyivi* | Beetle, Helotes mold | E | 460 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Cicurina baronia* | Meshweaver, Robber Baron Cave | E | 472 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Cicurina madla* | Meshweaver, Madla's Cave | E | 471 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Cicurina venii* | Meshweaver, Braken Bat Cave | E | 474 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Cicurina vespera* | Meshweaver, Government Canyon Bat Cave | E | 473 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Neoleptoneta myopica* | Spider, Tooth Cave | E | 467 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Neoleptoneta microps* | Spider, Government Canyon Bat Cave | E | 470 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Pseudoanophthalmus caecus* | Beetle, Clifton Cave | C | 5064 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Pseudoanophthalmus frigidus* | Beetle, Icebox Cave | C | 2862 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Pseudoanophthalmus parvus* | Beetle, Tatum Cave | C | 7134 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Pseudoanophthalmus troglodytes* | Beetle, Louisville Cave | C | 3379 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Rhadine exilis* | Ground beetle, [unnamed] | E | 461 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Rhadine infernalis* | Ground beetle, [unnamed] | E | 459 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Rhadine persephone* | Beetle, Tooth Cave ground | E | 449 | Medium | Low | Medium | Low | **LAA** | NA\*\* |
| *Spelaeorchestia koloana* | Kauai cave amphipod | E | 485 | Medium | Low | Medium | Low | **LAA** | **LAA** |
| *Tartarocreagris texana* | Pseudoscorpion, Tooth Cave | E | 466 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Texamaurops reddelli* | Beetle, Kretschmarr Cave mold | E | 448 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Texella cokendolpheri* | Harvestman, Cokendolpher Cave | E | 469 | Medium | Medium | Medium | Low | **LAA** | **LAA** |
| *Texella reddelli* | Harvestman, Bee Creek Cave | E | 464 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |
| *Texella reyesi* | Harvestman, Bone Cave | E | 465 | Medium | Medium | Medium | Low | **LAA** | NA\*\* |

\*E = endangered, T = threatened, C = candidate

\*\*Not applicable because critical habitat has not been designated for this species.

## Mosquito Adulticide Analysis

Malathion has a use that result in potential overlaps with most listed species ranges and designated critical habitats (*i.e*., mosquito adulticide). Mosquito adulticide applications is unique for this chemical in that the pesticide is applied as an ultra-low volume (ULV) spray designed to target the flying adult vector, with a goal to suspend the pesticide in the air for a prolonged period of time. Due to the unique characteristics of this application, this analysis was conducted separately (**APPENDIX 4-5**).

The application rates for the mosquito adulticide uses are generally lower than those for other uses (*e.g.* agricultural and non-agricultural uses).  Therefore, if a listed species range or critical habitat overlaps with other potential use sites, those uses are expected to be protective of the mosquito adulticide uses (*i.e*., potential exposures are expected to be higher with most of the non-mosquito adulticide uses). Two terrestrial species [*i.e.,* Langford's tree snail (*Partula langfordi*) and the Pacific sheath-tailed Bat (*Emballonura semicaudata rotensis*)] are identified where the only use that overlaps with the species range is the mosquito adulticide.

As described in **APPENDIX 4-5**, for both of these species, a weight of evidence matrices is created for the mosquito adulticide use patterns. For the mosquito adulticide analysis, the TEDtool is modified to adjust for different spray drift properties associated with the ULV application and an application efficiency factor (*e.g.*, a measure of how much active material lands on the spray block) is applied to the labeled application rate. Based on this analysis, an LAA determination is made for both species.

# Refined Risk Analysis for 13 Listed Bird Species: TIM-MCnest Analysis

One of the major recommendations of the National Academy of Sciences was to utilize probabilistic methods for assessing risks of pesticides to listed species. A refined analysis was conducted to explore the utility of currently available probabilistic, refined methods for use in biological evaluations of listed species. There is also potential utility for use of these methods in the biological opinions for these species. Only a subset of species were selected to explore applications of the models that may inform future method development and to identify data needs. A detailed description of this refined analysis is included in **APPENDIX 4-7**.

Two refined risk assessment models available for birds were used in this analysis, including the Terrestrial Investigation Model (TIM) and the Markov Chain Nest Productivity Model (MCnest) TIM estimates the probability and magnitude of mortality to exposed birds. MCnest estimates declines in fecundity associated with exposure. Both models incorporate species-specific life history parameters (*e.g.,* diet), pesticide use information (*e.g.,* crop, application rate), fate data (*e.g.,* foliar dissipation half-life) and toxicity data. These models integrate toxicity data for mortality, growth, reproduction and behavioral effects.

*TIM results*

TIM was run to examine the likelihood of mortality to birds exposed to malathion from spray drift from orchard crops, ground fruit and vegetables and nurseries. As noted in section 2, the most sensitive input parameters for TIM include the LD50 and the foliar dissipation half-life. When median estimates of these parameters are used (*i.e.,* LD50 = 331 mg a.i./kg-bw and foliar dissipation half-life = 6.1 d), the following conclusions can be drawn:

* There is a high probability (99% or greater) of mortality to an exposed individual for six of the 13 species, *i.e.,* Kirtland’s warbler, black-capped vireo, golden-cheeked warbler, southwestern willow flycatcher, California gnatcatcher, and least Bell’s vireo.
* There is a low probability (8% or less) of mortality to an exposed individual for 7 of the 13 species evaluated, *i.e.,* Attwater’s prairie-chicken, Inyo California towhee, San Clemente sage sparrow, Florida grasshopper sparrow, yellow-billed cuckoo, lesser prairie-chicken, and masked bobwhite.

Probability distribution functions for different uses were compared to investigate the relative risks associated with different assumptions of toxicity and foliar dissipation half-life for the different species. The magnitude of mortality associated with malathion applications on pasture and other crops varies widely among the assessed species. In general, the largest magnitude of mortality, based on median assumptions of toxicity and half-life, are observed for Kirtland’s warbler (15-35%), black-capped vireo (5-25%), golden-cheeked warbler (5-25%), southwestern willow flycatcher (1-18%), California gnatcatcher (25-50%), and least Bell’s vireo (10-30%). This information is considered useful in estimating the magnitude of effect in the portion of the population that is exposed and may be used in evaluating potential population-level impacts of malathion on listed birds.

*MCnest results*

When considering reproduction, fecundity declines were observed for all species throughout the breeding season. While mortality contributes to the declines observed for some species (*e.g.,* golden-cheeked warbler), the majority of species are experiencing reproductive effects in the form of decreased egg production and viability. Effects may be ameliorated by avoiding malathion applications during the breeding season. Fecundity declines based on median estimates of toxicity and half-life are provided in **Table 4-8.1.**

**Table 4-8.1. Fecundity declines estimated from applications of malathion on pasture and other crops using central estimates of toxicity and foliar dissipation half-life.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species**  | **1-Mar** | **29-Mar** | **26-Apr** | **24-May** | **21-Jun** | **19-Jul** | **16-Aug** | **13-Sep** |
| Attwater's Prairie Chicken | 0% | 7% | 65% | 70% | 11% | -2% | -- | -- |
| Black-capped Vireo | 19% | 27% | 50% | 49% | 37% | 5% | -- | -- |
| California Gnatcatcher | 43% | 54% | 52% | 40% | 35% | 16% | -- | -- |
| Florida Grasshopper Sparrow | 18% | 21% | 21% | 19% | 16% | -2% | -- | -- |
| Golden-cheeked Warbler | 13% | 44% | 99% | 32% | -- | -- | -- | -- |
| Inyo California Towhee | 0% | 1% | 1% | 0% | 0% | -- | -- | -- |
| Kirtlands Warbler | 6% | 6% | 10% | 39% | 39% | 6% | -- | -- |
| Least Bell's Vireo | 22% | 38% | 41% | 39% | 26% | 19% | 2% |  |
| Lesser Prairie Chicken | -6% | -9% | 3% | 47% | 71% | 71% | 50% | 9% |
| Masked Bobwhite | 4% | -1% | -3% | 2% | 24% | 49% | 32% | 26% |
| San Clemente Sage Sparrow (Bell's) | -1% | 11% | 29% | 28% | 30% | 5% | -- | -- |
| Southwestern Willow Flycatcher | 9% | 7% | 8% | 21% | 52% | 27% | 3% | -- |
| Yellow-billed Cuckoo | 0% | 0% | -1% | -1% | 7% | 7% | 2% | -1% |

**--** Indicate the application occurs outside of the breeding season.

# Additional Information relevant for Step 3: ECx and Web-ICE Analyses

Two additional analyses were conducted that may provide relevant information for the Step 3 process, though they did not factor into the weight of evidence approach employed for Step 2. The first analysis was an evaluation of available chronic toxicity data for malathion for use in estimating ECx values based on regression models in the Toxicity Response Analysis Program (TRAP) v1.22. More details on this analysis can be found in **ATTACHMENT 4-2**.

The second analysis was an evaluation of the Web-based Interspecies Correlation Estimation (Web-ICE) tool for use in assessing risks to listed species. This evaluation consisted of two separate analyses. The first evaluated the ability of Web-Ice to predict toxicity values for each listed species of fish using data for standard test specie (*i.e.,* rainbow trout, bluegill sunfish, and fathead minnow. While Web-ICE is able to predict direct toxicity of a chemical to 17 species of listed fish, the majority of listed species would rely on the availability of genus and family level models for toxicity predictions. An analysis of genus and family level models indicates that when these models were developed from the most sensitive value for each chemical they were generally protective of the most sensitive species within predicted taxa, including listed species, and were more protective than geometric means models. The second analysis explored the appropriateness of using tools such as Web-ICE to develop SSDs, in cases where empirical datasets for particular taxa are limited, by comparing empirically derived SSDs for chemicals with large datasets (*e.g.,* chlorpyrifos, diazinon, and malathion) to SSDs derived from predicted datasets. More details on these analyses can be found in **ATTACHMENT 4-3**.

1. Federal Geographic Data Committee. FGDC-STD-001-1998. Content standard for digital geospatial metadata (revised June 1998). Federal Geographic Data Committee. Washington, D.C. [↑](#footnote-ref-1)
2. Hawaii. Dept. of Business, Economic Development and Tourism. Research and Economic

Analysis Division. Statistics and Data Support Branch. State of Hawaii data book; a statistical abstract. Honolulu: 2006. [↑](#footnote-ref-2)
3. There are differences between the species in habitat use by life stage and some are primarily offshore during certain stages. For example, leatherback and olive ridley turtles spend the majority of their time as juveniles and adults in the open ocean and use the nearshore habitats far less frequently than other species. Habitat descriptions for each species can be found at http://www.nmfs.noaa.gov/pr/species/esa/listed.htm#turtles. [↑](#footnote-ref-3)
4. In a chicken metabolism study (MRID 42715401), 29% of residues were excreted after 24 hours (other excretory pathways, (i.e., volatiles) while not measured may have represented a significant route of elimination). Malathion was completely metabolized and reincorporated into non-toxic residues. [↑](#footnote-ref-4)
5. In a rat metabolism study (MRID 41367701), ≥73% of residues were excreted after 24 hours. [↑](#footnote-ref-5)
6. Kow (based) Aquatic BioAccumulation Model. See Chapter 3 for discussion of how the aquatic invertebrate BCF was estimated. [↑](#footnote-ref-6)
7. Bourquin, A.W. (1977). Effects of malathion on microorganisms of an artificial salt-marsh environment. *J. Environ. Qual.* 4. 373-378. [↑](#footnote-ref-7)
8. Smalling, K.L., and Orlando, J.L., 2011, Occurrence of pesticides in surface water and sediments from three central California coastal watersheds, 2008–09: U.S. Geological Survey Data Series 600, 70 p. [↑](#footnote-ref-8)
9. Given the uncertainty in scaling the toxicity value across 2-6 orders of magnitude from tested species (0.02-0.35 kg) to assessed species (20-1620 kg), dose-based exposures are not generated. Concentration-based exposures are compared directly to available concentration-based dietary toxicity endpoints. [↑](#footnote-ref-9)
10. World Health Organization. 2009. Principles and methods for the risk assessment of chemicals in food, Annex 2, dose conversion table. Environmental health criteria 240. [↑](#footnote-ref-10)
11. In a chicken metabolism study (MRID 42715401), 29% of residues were excreted after 24 hours (other excretory pathways, (i.e., volatiles) while not measured may have represented a significant route of elimination). Malathion was completely metabolized and reincorporated into non-toxic residues. [↑](#footnote-ref-11)
12. In a rat metabolism study (MRID 41367701), ≥73% of residues were excreted after 24 hours. [↑](#footnote-ref-12)
13. Kow (based) Aquatic BioAccumulation Model. See Chapter 3 for discussion of how the aquatic invertebrate BCF was estimated. [↑](#footnote-ref-13)
14. Bourquin, A.W. (1977). Effects of malathion on microorganisms of an artificial salt-marsh environment. *J. Environ. Qual.* 4. 373-378. [↑](#footnote-ref-14)
15. Smalling, K.L., and Orlando, J.L., 2011, Occurrence of pesticides in surface water and sediments from three central California coastal watersheds, 2008–09: U.S. Geological Survey Data Series 600, 70 p. [↑](#footnote-ref-15)
16. An overlap analysis was not conducted for aquatic species, therefore, the extent of overlap in ranges and potential malathion use sites is not available. [↑](#footnote-ref-16)
17. Eidels, R.R., J.O. Whitaker Jr., and D.W. Sparks 2007. Insecticide residues in bats and guano from Indiana. Proceedings of the Indiana Academy of Science, 116 (1): 50 – 57. [↑](#footnote-ref-17)
18. Land, T.A. 2001. Population Size and Contaminant Exposure of Bats Using Caves on Fort Hood Military Base, Texas. M.S. thesis, Texas A&M University, College Station, Texas. [↑](#footnote-ref-18)
19. McFarland, C.A. 1998. Potential Agricultural Insecticide Exposure of Indiana Bats (*Myotis sodalis*) in Missouri. M.S. thesis, University of Missouri, Columbia, Missouri. [↑](#footnote-ref-19)
20. Sandel, J.K. 1999. Insecticides and Bridge-Roosting Colonies of Mexican Free-Tailed Bats (*Tadarida brasiliensis*) in Texas. M.S. thesis, Texas A&M University, College Station, Texas. [↑](#footnote-ref-20)