Biological and Conference Opinion on the Registration of Malathion Pursuant to the Federal Insecticide, Fungicide, and Rodenticide Act

Prepared by:

U.S. Fish and Wildlife Service

Ecological Services Program, Headquarters

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INTRODUCTION

This document represents the U. S. Fish and Wildlife Service's (Service) Biological Opinion (Opinion) based on our review of the Environmental Protection Agency's (EPA) proposed national registration of malathion and its effects on endangered and threatened species and designated critical habitat in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). On January 18, 2017, EPA submitted a section 7 consultation initiation package, which requested initiation of formal consultation.

This Opinion is based on information provided in the final Biological Evaluation (BE) for malathion, many interagency meetings, workshops and conference calls, and other sources of information as described herein. A complete record of this consultation is on file at the Services' Headquarters office in Falls Church, Virginia.

Due to the complexity and duration of consultation and the Action, and ongoing consideration of listing decisions anticipated during and immediately following the consultation period, EPA and the Service (the Agencies) agreed to evaluate effects to proposed species and critical habitat and candidate species via conferencing, using similar methods for their analyses of listed species and designated critical habitats in both the BE and Opinion.

CONSULTATION BACKGROUND

The ESA section 7(a)(2) consultation process regarding the registration of pesticides pursuant to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) has a long history as discussed below. For more than a decade, the Agencies struggled unsuccessfully to reach consensus on the approaches for assessing the risks of pesticides on endangered and threatened species and their critical habitat. This led to stalled discussions between EPA and the Service and bouts of inactivity on pesticide consultations. The lack of progress resulted in litigation by various non-governmental organizations. Subsequently, the Agencies asked the National Research Council of the National Academies of Science (hereafter, NAS) to evaluate scientific and technical aspects of determining the risks to endangered and threatened species. This section provides a short summary of pesticide litigation related to ESA compliance for FIFRA registration, and the NAS report that led to a path forward for the consultation process.

Pesticide Litigation Summary

The pesticide lawsuits against the Service were preceded by lawsuits against EPA for failure to consult on pesticide registrations. The first of these suits, filed in 2002, alleged failure to consult on the effects of 66 pesticides on the California red-legged frog in CBD v. Johnson, No. 02-cv-1580-JSW (N.D. Cal.). The Center for Biological Diversity and EPA settled this suit in 2006, and EPA agreed to make effect determinations on the 66 pesticides. Between October 2007 and October 2008, EPA requested initiation of formal consultation on the effects of more than 30 pesticides on the California red-legged frog. As mentioned above, the Agencies did not agree on the approach to assess the risk of pesticides on endangered and threatened species, and in a letter dated January 14, 2009, the Service informed EPA that we did not have the necessary information to initiate formal consultation.

The Center for Biological Diversity filed a second lawsuit in 2007, CBD v. EPA, No. 3:07-cv-02794-JCS (N.D. Cal.), in which the plaintiff sought to compel EPA to initiate consultation on the effects of 75 pesticides on 11 federally endangered and threatened species in the San Francisco Bay area and to enjoin EPA from permitting the use of the pesticides in the area until consultation was completed. In May 2010, EPA and the Center for Biological Diversity reached a settlement. EPA agreed it would complete effects determinations, under a set schedule, on the 75 pesticides and initiate consultation on pesticides for which "may affect" determinations were made. By July 2013, EPA had completed effects determinations for all but 16 of the 75 chemicals. In 2015, the parties amended their agreement to allow EPA to focus its effects determinations on four pesticides (atrazine, simazine, propazine, and glyphosate) for all endangered and threatened species and to complete BEs for the identified pesticides by June 30, 2020.

The Service became a part of the litigation in 2011 when the Center for Biological Diversity filed a complaint against the Service and EPA, (CBD v. FWS, No. 3:11-CV-5108-JSW [N.D. Cal.]). The suit alleged failure to consult on the effects of 64 pesticides on the California red-legged frog. On November 4, 2013, the Center for Biological Diversity, the Service, and EPA agreed to complete consultation on the effects of two pesticides on the California red-legged frog within a year of the court's approval of the agreement and on an additional five pesticides within 2 years. Following the NAS report and recommendations on the pesticide consultation process (described further below), the Agencies decided it would be more effective and efficient to conduct national consultations on the effects of individual pesticides on all protected resources pursuant to the ESA rather than consult on multiple pesticides considering only one or a few species at a time. On July 28, 2014, the Center for Biological Diversity agreed to amend the 2013 settlement agreement so that EPA and the Service could conduct nationwide consultations on five pesticides (chlorpyrifos, diazinon, malathion, carbaryl, and methomyl) rather than focus on the effects of seven pesticides on the California red-legged frog.

NAS Report and Path Forward

In September 2010, the Agencies, the National Marine Fisheries Service (NMFS) and the U.S. Department of Agriculture (USDA) jointly requested the NAS to examine scientific and technical issues associated with determining the risk of pesticide registration and use to endangered and threatened species protected under the ESA. The Agencies asked the NAS to provide advice on a range of subjects related to risk assessment and the consultation process, including:

(1) identifying best available scientific data and information;

(2) considering sublethal, indirect and cumulative effects;

(3) assessing the effects of chemical mixtures and inert ingredients;

(4) using models to assist in analyzing the effects of pesticide use;

(5) incorporating uncertainties into the evaluations effectively; and

(6) using geospatial information and datasets in the course of the assessments.

The NAS released its report, entitled "Assessing Risks to Endangered and Threatened Species from Pesticides," on April 30, 2013[1]. It had recommendations on scientific and technical issues related to pesticide consultations under the ESA and FIFRA. Since then, the Agencies worked to implement the recommendations. Joint efforts to date include collaborative relationship building between the Agencies; clarified roles and responsibilities for the Agencies; agency processes designed to improve stakeholder engagement and transparency during the review and consultation processes; multiple joint agency workshops and meetings resulting in interim approaches to assessing risks to endangered and threatened species from pesticides; a plan and schedule for applying the interim approaches to a set of pesticide compounds; and multiple workshops and meetings with stakeholders to improve transparency as the pesticide consultation process evolves. While the Agencies continue their efforts to improve the consultation process, this consultation has incorporated the report's overarching recommendation to implement a three-step risk assessment and consultation approach. This fundamental approach includes the following steps:

1. In Step 1, EPA makes the no effect/may affect determination. If EPA determines that a pesticide's registration will have no effect on any endangered or threatened species or their designated critical habitats, it may move forward with a pesticide's registration without further consultation with the Service or NMFS.

2. In Step 2, if EPA determines that a pesticide may affect a listed species or its designated critical habitat, the potential impact is assessed to determine whether species or their designated critical habitats are likely to be adversely affected. The EPA initiates formal consultation for species or their designated critical habitats that are likely to be adversely affected and seeks concurrence from the Service on its "not likely to adversely affect" determinations.

3. In Step 3, using the information provided by EPA in its Step 2 analysis, the Service and NMFS make jeopardy and destruction or adverse modification determinations for the species and designated critical habitats that EPA determined are likely to be adversely affected.

[1] The NAS report with recommendations is available on the National Academy of Sciences website using the following hyperlink: http://www.nap.edu/catalog.php?record_id=18344.

CONSULTATION HISTORY

The following timeline describes early coordination and informal consultation between the EPA and the Service and identifies key points in the consultation process for the proposed national registration of malathion. While many of the events related to the NAS report and subsequent activities discussed in the paragraphs above form the consultation history for this biological opinion, the listing below is focused on the more recent activities.

Early Coordination on EPA's Biological Evaluation:

January 2015	Draft Project Formulation, Effects Characterizations, Appendices, Fate assessment, and modeling documents were received from EPA for initial comments, edits and questions from the Service and NMFS.
April 15, 2015	4th Stakeholder Workshop on Joint Interim Approaches to NAS Recommendations - This workshop coordinated by EPA, NMFS, the Service, USDA provided a forum for all interested stakeholders to offer scientific and technical feedback on the ongoing efforts to develop draft Biological Evaluations (BEs) for the three pilot chemicals (malathion, diazinon, and chlorpyrifos).
June 2015	EPA provides Draft Problem Formulation, Effects Characterizations, Appendices, Fate assessment, and modeling approaches documents review.
July 2015-2017	Ongoing weekly ESA Steering Committee calls - EPA, NMFS, the Service, USDA staff.
October 2015	EPA provides the Service and NMFS with a final set of BE appendices for review.
April 4, 2016	Public Release of Draft BEs by EPA; the Service began initial stages of reviewing draft BEs and conducting analyses for their draft biological opinion.
June 29-30, 2016	5th Interactive Stakeholder Workshop coordinated by EPA, NMFS, the Service, USDA. The focus of this workshop was to form six breakout teams to answer specific questions from interested stakeholders related to areas of the BEs that needed more attention and what information may help inform the Opinions. (See Appendix A-A of this Opinion for more information.)
September 19-21, 2016	6th Interagency Workshop to discuss transition to Step 3 and Step 3 methods development. This workshop involved discussions about how the Service and NMFS would approach determining jeopardy based on requests from the EPA for a framework on this process.

November 29-December 1, 2016	7th Interagency Workshop to discuss Integration and Synthesis. The Agencies met for a 3-day Integration and Synthesis Workshop with the goal of developing and agreeing to a process for Step 3.
January 18, 2017	Submission of EPA's Final BEs to the Service/posting to website
February 2017	During review of an initial draft biological opinion for malathion, the Service determined it was necessary to search for, gather, and compile data to inform both use and usage from a variety of different sources throughout the country and territories, and began this effort with EPA, NMFS, and USDA.
December 5, 2017	Presentation to the Service on California's Prescribe and California Pesticide Use Reporting (PUR) program and to learn about California's Pesticide Regulation's Endangered Species Custom Realtime Internet Bulletin Engine.
January 4, 2018	Presentation to the Service on California's on CalPUR Prescribe and CalPUR programs and California's Pesticide Use Reporting database.
February 26th, 2018	Pesticide Usage Meeting to discuss the usage data provided to the Service and NMFS from US EPA and how to utilize them to assess effects on threatened and endangered species. Participants: staff, management, solicitors, and senior leadership from DOI, EPA, NMFS, and USDA, and Council on Environmental Quality (CEQ).
March-October 2018	Pesticide Usage Working Group Meetings - Bi-monthly meeting discussions involved pursuing data and information sources from states and other entities.
April 5, 2018	Interagency meeting to discuss Malathion State Use and Usage Summary (SUUM) usage report.
December 10, 2018	Briefing on Agricultural Usage Data - Meeting held to update interagency management on progress defining the agricultural portion of the action area incorporating usage data.
October 2018-November 2019	The Service participated in vs stakeholder meetings on several topics pertaining to a path forward for pesticide consultations.
July 9, 2019	The Service briefing on the path forward for malathion to EPA and Service management and EPA staff.

August 27th, 2019	Interagency meeting with Kynetec. Presentation to the Service and NMFS: 1) a general overview of the Agrotrak data, 2) the survey methodology and statistical methods used, and 3) address Service and NMFS questions submitted prior to the meeting regarding method variability, survey procedures/protocols, and the survey design and sampling.
August 2019 - December 2019	Service begins working on malathion timeline for Opinion completion and addressing new approaches for the following: • How to incorporate the various usage data sources into the action • How to analyze the effects to listed plants in a more concise and effects-based method • How to create a tool, using the programming language R, to better demonstrate the intersection of effects, use, and usage • How to determine malathion usage outside the continental United States • How to address mosquito adulticide usage
January 2020- September 2020	Service begins drafting the malathion Opinion using new approaches.
April 2021	Service provides draft malathion Opinion to EPA. EPA publishes draft Opinion for public comment.
April 2021- November 2021	Service reviews and addresses, as appropriate, comments submitted by EPA, registrants, and other stakeholders.
August - November 2021	Service holds weekly meetings with FMC, EPA, and USDA to discuss conclusions of the draft Opinion, and potential measures that could be included as Reasonable and Prudent Alternatives. The group also discussed whether any measures could be incorporated by EPA as changes to the *Description of the Action*, with support and commitment from the registrants. Topics included analyses used in the draft Opinion and conservation measures in the form of general changes to malathion agricultural, residential and mosquito control labels and species-specific conservation measures accessed through EPA's *Bulletins Live! Two* website. Two separate meetings included representatives from the American Mosquito Control Association, where input on mosquito control topics was needed (e.g., related to use, usage, and feasible conservation measures for mosquito control).
December 2021- February 2022	In coordination with the technical registrants, EPA worked with the Service to confirm the list of general and species-specific conservation

	measures that are to be incorporated into the Action. EPA provided confirmation of the addition of these measures as part of the *Description of the Action* via email dated February 23, 2022, as well as letters of commitment from the technical registrants (see Appendices A-B, A-C, A-D of this Opinion). The Service incorporated the conservation measures provided by EPA as part of the proposed action under consideration in the malathion Opinion and completed the final Opinion.
February 28, 2022	Pursuant to the Stipulated Partial Settlement in *Center for Environmental Health v. Ragan*, No. 4:18-cv-03197 (N.D. Cal.), the Service issues its Final Malathion Opinion.

CONCURRENCE

In their BE for malathion, EPA provided determinations of "no effect" for 16 listed species (see Appendix B, Table 1). The Service takes no position on these determinations except for the Hawaiian crow (alala) (*Corvus hawaiiensis*), which is extant in the wild due to recovery efforts involving reintroductions. This species is addressed in the Pacific Islands and Hawaii integration and synthesis section of this Opinion. The genus Achatinella, which includes 41 Oahu tree snails (9 with EPA "no effect" calls), is considered to be one listed entity; therefore, we have addressed all species in this group together in the Pacific Islands and Hawaii integration and synthesis section.

The EPA also made "may affect, not likely to adversely affect" determinations for 22 listed, proposed, and candidate species and 7 designated critical habitats under Service jurisdiction. For most of these species and critical habitats, the determinations were based on conclusions of insignificant effects that were supported by assumptions and analyses detailed in the evaluations and applicable appendices provided in the BE and included here by reference. During consultation, the Service worked closely with EPA to reach agreement on methodologies for arriving at their "may affect, not likely to adversely affect" determinations based on insignificant effects. The EPA also clearly delineated their rationale for their calls for species with solely discountable effects. For species considered extinct or extirpated from the United States and its territories, in most cases, exposure was either not expected (if presumed extinct) or extremely unlikely to occur (if presumed extirpated). Thus, based on our previous coordination and our review of EPA's analysis, we concur with EPA's determinations as listed in Appendix B, Table 2, with the exceptions discussed below.

For a few species that EPA presumed extinct or extirpated, we are unable to concur with their "may affect, not likely to adversely affect" determinations because the Service considers these species to be extant in the wild and likely to be adversely affected (desert slender salamander (*Batrachoseps aridus*), Pacific Hawaiian damselfly (*Megalagrion pacificum*), `O`u (honeycreeper) (*Psittirostra psittacea*), Morro Bay kangaroo rat (*Dipodomys heermanni morroensis and its critical habitat designation*). We are also unable to concur with EPA's "may affect, not likely to adversely affect" determinations for the Helotes mold beetle (*Batrisodes venyivi*) and Braken bat cave meshweaver (*Cicurina venii*) designated critical habitats based on an incomplete pathway for exposure of their cave ecosystems. These species and critical habitats are addressed in the Integration and Synthesis and Critical Habitat sections of the Opinion with their applicable taxa or geographic groups.

Additionally, we removed species from further consideration where EPA had made a “may affect, likely to adversely affect” determination, but since the time the BE was written, the species were either not listed (i.e., candidate or proposed species where listing was found to not be warranted), removed from the list of federally threatened and endangered species (i.e., delisted due to recovery or extinction), or the listed entity is no longer applicable (i.e., the Entity ID 160 for the Olive ridley sea turtle is no longer applicable as it is currently represented by other listed populations). The removed species are provided in Table 3 of Appendix B of this Opinion.

This concludes consultation for these species and critical habitats in which the Service has found that the action will have no effect, and they will not be addressed further in this document or appendices other than Appendix B.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

The proposed Federal action addressed in this Opinion (hereafter, the Action) is the registration of malathion under FIFRA. Pursuant to FIFRA, before a pesticide product may be sold or distributed in the U.S., it must be exempted or registered with a label identifying approved uses by EPA's Office of Pesticide Programs. Once registered, a pesticide may not legally be used unless the use is consistent with directions on its approved label(s). The EPA authorization of pesticide uses are categorized as FIFRA section 3 (new product registrations), section 18 (emergency use), or 24(c) Special Local Needs. FIFRA requires these chemicals to be reregistered every 15 years according to the section 3 and section 24(c) registration. Thus, the Service considers the duration of the Action to be 15 years. The following chemical-specific descriptions are taken largely from EPA's BE for malathion.

For this pesticide, the Action includes registration of the uses, as described by product labels, of all pesticide products containing: the active ingredient, its metabolites and degradates, any other active ingredients, other ingredients within the formulations (such as adjuvants and inert ingredients), and any recommended tank mixtures. The Action also includes all authorizations for use of pesticide products, including the use of existing stocks, and active labels of products containing the active ingredient. A complete listing of product uses is found in the *Agricultural and Non-agricultural Use* sections (Table 1 through **Error! Reference source not found.**).

In their BE, EPA considered the likely use types of the chemical over the duration of the Action, although the Agencies recognized that future uses are difficult to predict with either accuracy or precision, particularly as more time passes. Thus, future uses have been addressed to the extent possible in EPA's BE where the geographic distribution and magnitude of exposure (including application rate and methods of application) have been included in the scope of the assessment. If new uses, rate increases, or an application method that increases exposure beyond what was addressed in the BE and this Opinion are approved or proposed, re-initiation of consultation may be required.

The purpose of the Action, as noted in the BE, is to provide tools for pest control on food and feed crops as well as for other non-agricultural uses that do not cause unreasonable adverse effects to the environment throughout the United States and affiliated territories. For additional information on the registration and registration review processes, see section 1.1.1. in the Problem Formulation of the BE. The following sections describe the Action in greater detail and are taken largely from the BE for malathion.

Labeled Uses

Malathion is an organophosphate used as an insecticide on a wide variety of terrestrial food and feed crops, terrestrial non-food crops, aquatic food, non-agricultural indoor, outdoor sites, and for wide area public health uses. Malathion can be applied in a dust, liquid or encapsulated form. Aerial and ground application methods are allowed, including broadcast (uniform application to an entire area or field), fogger (misting pesticide into the air that falls onto the targeted surface), and chemigation (application through drip-irrigation) (see Appendix 1-3 of the BE for details of application methods allowed for specific uses). Products containing malathion are produced and/or sold in a variety of forms: technical grade; formulated products with a single active ingredient (i.e., malathion); or formulated products with multiple active ingredients (e.g., malathion and carbaryl). Formulated products generally contain additional ingredients (e.g., adjuvants, surfactants, or other “inert” ingredients).

Based on an Office of Pesticide Programs Information Network query (conducted Feb. 2015), there is currently one active technical registrant that sponsors guideline studies on malathion, and there are 96 active registrations (43 section 3, 53 section 24c Special Local Needs, and no section 18 Emergency Exemptions) from 21 registrants, which include formulated end-use products and technical grade malathion (see Appendix 1-2 of the BE). Currently, there are four malathion products that are co-formulated with other pesticidal active ingredients (a.i.’s). Other active ingredients co-formulated with malathion include: carbaryl (PC Code 056801), captan (PC Code 081301), and gamma-cyhalothrin (PC Code 128807) (Table 1).

Table 1. Multi-active ingredient products containing malathion.

REGISTRATION #	NAME	PERCENT ACTIVE INGREDIENT	ACTIVE INGREDIENT
4-122	Bonide A Complete Fruit Tree Spray	0.30	Carbaryl
		11.76	Captan
		6.00	Malathion
829-175	SA-50 Brand Malathion-oil Citrus & Ornamental Spray	75.00	Mineral Oil
		5.00	Malathion
67760-108	Fyfanon Plus ULV	1.47	Gamma-cyhalothrin
		92.20	Malathion
67760-131		1.11	Gama-cyhalothrin

REGISTRATION #	NAME	PERCENT ACTIVE INGREDIENT	ACTIVE INGREDIENT
	Malathion 851 g/L + Gamma-Cyhalothrin 12.8 g/L EC	73.70	Malathion

An inert ingredient is any substance (or group of structurally similar substances if designated by EPA), other than an "active" ingredient, which is intentionally included in a pesticide product. It is important to note, the term "inert" does not imply that the chemical is nontoxic.

Inert ingredients play a key role in the effectiveness of a pesticidal product. Pesticide products may contain more than one inert ingredient; however, Federal law does not require that these ingredients be identified by name or percentage on the label. All inert ingredients in pesticide products, including those in an inert mixture, must be approved for use by EPA. For those inert ingredients applied to food crops, a tolerance or tolerance exemption is required. Impurities are not included in the definition of inert ingredient. As part of the review process for all new ingredients, a screening-level ecological effects hazard assessment is conducted, in which available data on the toxicity of the inert ingredient to non-target organisms is considered.

For the most current list of inert ingredients approved for food use pesticide products, see the Electronic Code of Federal Regulations (e-CFR)[2]. The majority of inert ingredients can be found in "40 CFR 180.910-180.960." Several sections in "40 CFR Part 180" also include tolerances and tolerance exemptions[3] for specific inert ingredients where their use is usually significantly limited. The listing of nonfood use inert ingredients, including those that also have food uses, can be found in InertFinder[4].

Malathion may be applied as part of a tank mix with other pesticides (i.e., insecticides, miticides and fungicides). In general, active ingredients can be mixed with other products unless specifically prohibited on the label(s). Some of the current malathion labels specify that the malathion product can be tank mixed with other products/chemicals. Table 1-2 in the BE identifies the allowable, and in some cases, recommended, tank mixes specified on malathion labels based on EPA's Label Use Information System. More details on the specified tank mixes can be found in Appendix 4-2 of the BE. Examples include mixing malathion products with water, an oil-based carrier (such as kerosene, fuel oil, or diesel oil) or a synergized pyrethrin emulsifiable concentrate depending on use.

2 https://www.ecfr.gov

3 See https://www.epa.gov/pesticide-tolerance for details on what tolerances and tolerance exemptions are.

4 InertFinder is an online database for searching substances used as inert ingredients in pesticide products. It can be found at: https://iaspub.epa.gov/apex/pesticides/f?p=INERTFINDER:1:0::NO:1

Uses

The EPA developed a list of all current registered uses for malathion (Appendix 1-3 of the BE), which reflects all currently registered labels as well as any agreed upon changes to these labels from the registrant. EPA received a letter from the sole technical registrant clarifying ambiguous, non-agricultural use patterns (February 26, 2015) and outlining several uses it will and will not support through the registration review process (October 9, 2015) (Appendix 1-5 of the BE). While the current labels may not reflect all the agreed upon changes, the registrants have agreed to update the malathion labels to be reflective of the Master Use Summaries in the *Agricultural and Non-agricultural Use* sections below (Table 2 through **Error! Reference source not found.**) (Appendix 1-3 of the BE). These measures are described further in the *Conservation Measures* section below. In general, current single maximum malathion application rates do not exceed 3 pounds active ingredient/acre (lb a.i./A) nationwide; however, single application rates greater than 3 lb a.i./A are currently permitted for some specific use patterns. For example, a single malathion application of 7.5 lb a.i./A is permitted on citrus in California. Other high single application rates are for avocado (4.7 lb a.i./A), citrus outside California (4.5 lb a.i./A), kumquat (4.5 lb a.i./A), and pine seed orchards (4.5 lb a.i./A). All other agricultural applications are for 3 lb a.i./A or less. Though this use is limited to application inside storage bins and not for broadcast use across a field, the highest labeled use rate is for grain storage facilities and transport of 26.14 lb a.i./A. No limits in application rate or number of applications are specified for several uses, including beans, grain storage facilities and transport, and lentils.

Agricultural Uses

Malathion is currently registered for use on 115 agricultural crops. In general, these crops (or uses) include Christmas tree plantations, cotton, fencerows/hedgerows, forage, fruits (ground and tree), grains, grain storage and treatment, grasses, mushrooms, non-agricultural areas/soil, pine seed orchards, tree nuts, and vegetables (Table 2) (Table 1-4 and Appendix 1-7 of the BE).

Table 2. Malathion master use summary for agricultural uses with conventional application methods.

Table 2. Master Uses Conventional.xlsx

In addition, malathion is currently registered for use on 27 agricultural crops (subset of those described previously) for ultra-low volume (ULV) applications. It is also registered for use on pine seed orchards and wide area public use for ULV applications in non-agricultural areas (Table 3) (Table 1-5 and Appendix 1-7 of the BE).

Table 3. Malathion master use summary for uses with ultra-low volume applications.

Table 3. Master Use Summary ULV.xlsx

Non-agricultural Uses

Malathion is currently registered for use in a variety of non-agricultural settings, including for use on 47 homeowner garden fruit and vegetable varieties, outdoor nuisance insects (e.g., flies and mosquitos), and ornamental uses for commercial and homeowner applications (Table 4) (Table 1-3 and Appendix 1-7 of the BE).

Table 4. Malathion master use summary for non-agricultural uses.

Table 4. Master Use Summary Non-ag.xls›

Consideration of Usage Data

This Opinion considers the Action, specifically the registration of malathion according to its labeled uses. We recognize that the geographic areas authorized under the labels are intentionally broad to cover a variety of current and future, less predictable pest pressures and user needs throughout the action area (defined below) over the course of the 15-year duration of the Action. We also recognize that it is not realistic to assume the chemical will be used in every location in the action area where labeled uses allow, nor do we expect that the highest application rates and frequencies authorized under the label will occur in all these locations each year. Based on how the labels are currently written, we acknowledge the full range of uses and use sites allowed under the proposed registration. We also agree malathion will not be used everywhere, applied at the highest allowable frequency at each site, or applied at the highest application rates each time it is used (which would likely comprise more product than is currently manufactured or distributed), while also recognizing that malathion can be used anywhere the label allows, and at the highest rates and frequency specified for a given use. We also recognize that, while knowledge of past usage patterns and locations may be helpful in providing context for where some uses are likely to occur, the past does not necessarily predict future pest pressures, management, or pesticide uses.

Mindful of the limitations associated with usage data, we utilize usage data to inform our analysis, but it is not dispositive in determining “effects of the Action.” Because usage data represents historical patterns of how and where malathion is applied on the landscape, it is appropriately considered in determining “effects of the Action,” which, under ESA section 7 regulations and Administrative Procedure Act standards, respectively, must be "reasonably certain to occur" and rationally based. At the same time, particularly where there are informational gaps, we apply usage data in this Opinion using our best professional judgment to make assumptions that are not only reasonable but are appropriately conservative for the species and critical habitat to determine whether EPA's Action ensures against the likelihood of jeopardy or destruction and adverse modification. Although usage data is a portion of the best scientific and commercial data available, it is only one of many factors and points of data we consider in determining "effects of the Action."

Conservation Measures

The Action also includes conservation measures related to use patterns and label language, including several that were listed in EPA's BE, as well as measures that were added to the Action in late 2021-2022, after coordination efforts between the EPA, technical registrants, USDA, and the Service.

Measures from the BE:

- From the BE "Problem Formulation," (pg. 1-12, 1-26): "This document reflects all currently registered labels and any agreed upon changes to these labels from the registrants. The registrant has sent letters clarifying ambiguous non-agricultural use patterns (February 26, 2015) and a letter outlining several uses it will and will not support through the registration review process (October 9, 2015)." These letters are found in Appendix 1-5 of the BE.

- From the BE "Problem Formulation," (pg. 1-7, 1-8): Registered labels for agricultural use products require 25-foot (ground and non- Ultra Low Volume (ULV) aerial applications), or 50-foot (ULV aerial applications) no-spray buffer zones adjacent to "any water body." The interpretation of what constitutes a water body is left to the applicator and the state lead agency for pesticide label enforcement. All registered labels for agricultural use also include the following spray drift requirements when spraying in the vicinity of aquatic areas:

    - Droplet Size

    Use the largest droplet size consistent with acceptable efficacy. Formation of very small droplets may be minimized by appropriate nozzle selection, by orienting nozzles away from the air stream as much as possible, and by avoiding excessive spray boom pressure.

    For ground boom and aerial applications, use only medium or coarser spray nozzles according to American Society of Agricultural Engineers definition for standard nozzles, or a volume mean diameter of 300 microns or greater for spinning atomizer nozzles. In conditions of low humidity and high temperatures, applicators should use a coarser droplet size.

    - Wind Direction and Speed

    Make aerial or ground applications when the wind velocity favors on-target product deposition (approximately 3 to 10 mph). Do not apply when wind velocity exceeds 15 mph. Avoid applications when wind gusts approach 15 mph. For all non-aerial applications, wind speed must be measured adjacent to the application site on the upwind side, immediately prior to application.

- Temperature Inversion

Do not make aerial or ground applications into areas of temperature inversions. Inversions are characterized by stable air and increasing temperatures with increasing distance above the ground. Mist or fog may indicate the presence of an inversion in humid areas. Where permissible by local regulations, the applicator may detect the presence of an inversion by producing smoke and observing a smoke layer near the ground surface. In conditions of low humidity and high temperatures, applicators should use a coarser droplet size.

- Additional Requirements for Ground Applications

For ground boom applications, apply with nozzle height no more than 4 feet above the ground or crop canopy.

Additional Measures

As noted above, in addition to the conservation measures EPA provided in their original BE, the Action also includes additional general and species-specific measures that were provided by EPA in coordination with the technical registrants prior to finalization of this Opinion[5]. These measures will be incorporated into the labels and are described below.

General Conservation Measures:

These measures will be included for labeled uses as specified below. For all relevant label language, as well as associated commitment letters, see Appendix A-B and A-C of this Opinion.

- Aquatic measures – The following measures are intended to reduce run-off exposure into aquatic habitats from agricultural use:
  - Rain restriction – All agricultural labels will be changed to instruct users not to apply when soil is saturated, or when a storm event likely to produce runoff from the treated area is forecasted to occur within 48 hours following application.
  - Aquatic habitat buffer - New language on agricultural use labels stipulates minimum distances from water bodies (such as, but not limited to, lakes, reservoirs, rivers, streams, marshes, ponds, estuaries, and commercial fishponds) where malathion cannot be applied. Ground application buffers will be established at 25 feet from aquatic habitats

[5] After completion of the draft Opinion, we worked with EPA, USDA, and the applicants to develop measures to address effects to species and their critical habitats. Initially, our conversations were intended to identify implementable reasonable and prudent alternatives and reasonable and prudent measures related to effects described in our February 2021, draft Opinion. However, during our discussions, EPA and the registrants determined that the types of measures being discussed were suitable to include as changes to the *Description of the Action*, and would be adopted by EPA as changes to the Action through label restrictions (e.g., general changes to the labels, and species-specific measures added to *Bulletins Live! Two*, as appropriate).

and existing buffers for aerial applications will be extended to 50 feet for non-ultra-low volume aerial applications and 100 feet for ultra-low volume aerial applications.

- Residential label language changes – The following measures are intended to limit the extent of malathion usage and prevent spray drift and run-off to non-target terrestrial and aquatic habitats, and will appear on all labels for residential use:

    - Limiting application to spot treatments

    - Designating a maximum of 2 applications/year

    - Establishing retreatment intervals of 7-10 days between any repeated applications

    - Requiring that applicators maintain a 25 foot minimum distance from water bodies (such as, but not limited to, lakes, reservoirs, rivers, streams, marshes, ponds, estuaries, and commercial fishponds)

    - Instructing users not to apply when soil is saturated, or when a storm event likely to produce runoff from the treated area is forecasted to occur within 24 hours following application.

- Applications to crops in bloom.
    - The label will direct users not to apply malathion to certain crops in bloom.
    - New restrictions on crops within the orchards and vineyards, pasture, and the “Other Crops” UDLs will prohibit application of malathion within three days prior to tree bloom, during bloom, and until petal fall is complete on certain crops.

- Mosquito application – 2 hour dusk/dawn -

    - Conservation measures for mosquito adulticide use will prohibit application during most daylight hours (from two hours after dawn until two hours before sunset), when many diurnal insect pollinators are most active.

- Minimum retreatment intervals (Christmas trees, nurseries, various crops) – Minimum retreatment intervals of 7 days between any repeated applications are intended to reduce environmental concentrations by allowing initial residues to degrade prior to the next application.

- Application (reducing #’s of applications) and rate changes - Reduction in the number of applications for:
    - Cotton
    - Corn
    - Orchards and Vineyards
    - Pasture
    - Other crops
    - Vegetables and ground fruit

- Rate changes (only applies to orchards and vineyards) - The reduction in the maximum application rate for citrus (outside of California) is intended to reduce potential environmental concentrations to one-third of modeled values, reducing the effects to species, prey, host fish, and pollinators/seed dispersers on and adjacent to these use areas.
    - See below for selected crops where application rates were decreased (i.e., citrus only and outside California) or # of applications has been reduced are:
        - Cabbage (vegetables & ground fruit; from 6 to 3)
        - Chestnut (orchards & vineyards, from 3 to 2)
        - Citrus (orchards & vineyards; from 1 at higher rate to 3 at lower rate)
        - Grapefruit ULV (orchards & vineyards; from 10 to 3 at 0.175 rate)
        - Sweet corn (vegetables and ground fruit; from 5 to 3)
        - Cotton (Non- Boll Weevil Eradication Program) (from 3 to 2)
        - Currant (from 3 to 2)
        - Dandelion (from 3 to 2)
        - Oriental eggplant (vegetables & ground fruit; from 5 to 4)
        - Garlic (vegetables & ground fruit; from 3 to 2)
        - Grass/forage/hay/Bermuda grass = pasture (high rate (0.92) only for APHIS grasshopper suppression program; lower rate (0.61) applications limited to 4/year for both
        - Guava (from 13 to 4)
        - Hops (other row crops; from 3 to 2, only grown in selected areas of the contiguous United States (CONUS) = WA, OR, ID and FL (Gadsden County only) see also above for specific language
        - Horseradish (vegetables & ground fruit; from 3 to 2)
        - Mint (vegetables & ground fruit; from 3 to 2)
        - Nectarines (orchards & vineyards; from 3 to 2)
        - Okra (vegetables & ground fruit; from 5 to 4)
        - Parsnip (vegetables & ground fruit; from 3 to 2)
        - Peaches (orchards & vineyards; from 3 to 2)
        - Radishes (vegetables & ground fruit; from 3 to 2)
        - Rutabagas (vegetables & ground fruit; from 3 to 2)
        - Rye (other grains; from 3 to 2)
        - Salsify (vegetables & ground fruit; from 3 to 2)
        - Trefoil (other crops; 1 per cutting, no more than 2 cuttings per year)
        - Turnips (vegetables & ground fruit; from 3 to 2)
        - Vetch (vegetables & ground fruit; 1 per cutting, no more than 2 cuttings per year)

Species- and Critical Habitat-Specific Conservation Measures

In addition to general conservation measures, EPA has agreed to include a number of new species- and critical habitat-specific measures as part of the Action. As the measures are numerous and differ across listed species and their critical habitats, we provide a list of the types of species- and critical habitat-specific measures below (**Error! Reference source not found.**). A full list of measures by species and critical habitat are provided in Appendix A-D.

Table 5. Types of species- and critical habitat-specific measures that will be included as part of the action.

Type of Species Specific Measure	Measure Instructions	Expected Protection
Avoidance areas	Do not apply in specified areas (such as designated ranges, critical habitat, refuges, specific habitat types, geologic features, etc.)	Reduces direct exposure, reduces spray drift
Newly established or extended buffers	Create new buffers or extend general buffers specified on the labels for additional distances dependent on factors such as application type, application rate, crop type, whether application displacement is used, etc.	Reduces spray drift
Wind restriction	Apply only when wind is blowing away from specified areas (can include wind direction and speed)	Reduces direct exposure and spray drift
Timing restriction	Applications in specified areas are restricted for specific periods of the day or year	Reduces direct exposure during critical periods for the listed species
Irrigation restrictions	Do not irrigate crops after malathion application for a specified amount of time	Reduces concentrations in runoff
Application method restrictions	Do not apply in specified areas using specific application methods	Reduces spray drift
Field office coordination	Coordinate with Service Field Office staff to determine appropriate measures; used where avoidance of the species range or area is not feasible. Applicators must keep a record of coordination, including a list of the measures that were agreed upon and implemented.	Ensures no more than minor effects on the species

ACTION AREA

The action area is defined as all areas to be affected directly or indirectly by the Federal action, and not merely the immediate area involved in the action (50 CFR 402.02). Consistent with the ESA section 7 implementing regulations, in delineating the action area for malathion, we evaluated the physical, chemical, and biotic effects of the Action on the environment that would not occur but for the Action and are reasonably certain to occur. For the reasons mentioned below, the action area for this consultation, as delineated by these effects to the environment, consists of the entire United States and its territories.

Malathion is a widely used chemical with many registered uses and formulations (including wide area uses such as mosquito adulticide treatment). In order to lawfully use malathion, individuals are required to adhere to EPA's registered uses described on the label of products containing malathion. Pesticide labels are legally enforceable, with all labels containing the following statement: "It is a violation of Federal law to use this product in a manner inconsistent with its labeling." Therefore, because only malathion products registered under FIFRA may be lawfully used and registered malathion products may only be legally used in the manner specified on EPA's label, any effects on the landscape from malathion application would not occur but for EPA's registration.

The product labels for malathion do not generally contain discreet geographic restrictions, with the exception of certain generic buffer distances from sensitive areas. In the absence of geographic restrictions identified on the labels[6], and due to the wide variety of allowable agricultural, residential, commercial, and other uses for the chemical, the combination of uses on the label means that at least one labeled use (i.e., mosquito adulticide) covers the entirety of the United States and its territories. Furthermore, the method(s) of application (e.g., by aircraft, ground, irrigation/chemigation, etc.) is expected to result in varying amounts of drift/transport of malathion over and/or into terrestrial and aquatic habitats, as well as transport downstream/downcurrent via water bodies, such as wetlands, rivers, and lakes. Therefore, based on the labeled uses, transport from application sites, and absence of geographic restrictions, it is reasonable to assume one or more labeled uses could legally occur in any area of the United States and its territories throughout the duration of the Action. We recognize there may be some areas within the defined action area where applications would generally not occur. However, due to the uncertainty of future uses and expressed desire of the manufacturers to allow for addressing issues such as pesticide resistance and unforeseen pest or vector threats, the manufactures would like to reserve the right to allow usage per the current labels. Therefore, we considered usage information and commonly assumed use areas in our effects analyses, but we were unable to reduce the extent of the action area within the United States and its territories.

An evaluation of available information on past and present use and usage data further supports our conclusion that the action area encompasses the entirety of the United States and its territories. As explained in more detail in our analysis of species exposure and effects of the action, we identified some areas in which effects arising from a specific registered malathion use are not anticipated to occur, or alternatively, would occur, but in such low levels, that the effects to species from exposure are likely to be discountable and/or insignificant. For example, the Service received information indicating that the agricultural use of malathion for pine seeds is

[6] We recognize that the various PESTICIDE formulations are unlikely to be used evenly or consistently throughout the action area as defined. However, the labels describe all of the allowable uses, and it is both conceivable and reasonable to assume the products, as labeled, could be used legally throughout the action area as described above. Pesticide labels are legally enforceable, and all of them carry the following statement: "It is a violation of Federal law to use this product in a manner inconsistent with its labeling." Consequently, for the purposes of this consultation, we consider the labels to be the primary component of description of the proposed action that informs the extent of the Action area (i.e., "the label is the law").

confined to the continental United States, thus we limited our analysis of effects of the action with respect to pine seed use to that portion of the action area. Nevertheless, it is important to note that pine seed use is only one registered use of malathion products. Based upon information contained in EPA's BE, as well as additional information that the Service received from EPA, state departments of agriculture, malathion registrants, Federal land management agencies, and other entities describing the extent and amount of malathion usage for other particular uses, these data sources indicate that malathion products are broadly used throughout the United States and its territories and did not reveal any significant areas that could be removed from the action area.

During past agency and stakeholder workshops and communication, we were occasionally asked to consider whether the Agencies should eliminate certain Federal lands from the action area based on past or recent consultations where another action agency had already consulted on the use of the subject pesticide in their management plans or other actions. Examples include actions occurring on lands under the jurisdiction of the Service (e.g., national wildlife refuges), the National Park Service, Bureau of Land Management, and U.S. Forest Service. A review of past and recent consultations under section 7 of the ESA indicated that there has been use (although limited) of malathion on Federal lands. We are not aware of any agreements, plans, and/or other commitments by Federal agencies related to the use and/or restriction of use of malathion within their jurisdictions. For this reason, and because the labels allow use on Federal lands and is, in fact, being used on Federal lands, we determined it would be inappropriate to remove Federal lands from the action area. However, previous consultations involving malathion use on Federal lands are considered to be part of the environmental baseline.

Therefore, in light of multiple labeled uses for application on sites found throughout the United States and its territories, allowable methods of application that result in wide-spread transport of and exposure to malathion products, the absence of geographic restrictions on the label, and available data on past and present use and usage, we conclude that environmental effects are reasonably certain to occur in the entirety of the United States and its territories. As described in detail below, these environmental effects to the soil, air, and surface and ground waters, though generalized, are reasonably certain to occur on a nationwide basis.

Malathion can persist and move through the environment beyond the time and site of application. The major routes of degradation of malathion are aerobic and anaerobic biodegradation and hydrolysis. Under alkaline conditions (pH 9), hydrolysis of malathion occurs more rapidly, with a half-life of approximately 12 hours, than in acidic conditions (pH 5; 107 days). Malathion appears to degrade rapidly in soil under both aerobic and anaerobic conditions. The reported metabolic half-lives vary from 0.3 to 11 days in registrant submitted studies depending on soil type and soil moisture. Information on leaching and adsorption/desorption indicate that parent malathion is considered moderately mobile according to Food and Agricultural Organization mobility classification system. The environmental fate of the minor (i.e., occurs at less than 10% of malathion applied in environmental fate studies), yet toxic malathion transformation product, malaoxon, indicates that it has nearly identical persistence and mobility characteristics as parent malathion. Available terrestrial field dissipation data indicate that malathion has a dissipation half-life of less than one day on soils with pH 6.1 to 6.6, with little leaching observed. Given little observed leaching, degradation drives dissipation with aerobic soil metabolism being the most significant path of degradation. Additional details (including references) regarding the environmental fate of malathion are provided in Chapter 3 of the BE (Appendix 3-1).

The primary route for dissipation of malathion is metabolism to the less toxic malathion dicarboxylic and monocarboxylic acids. Malathion metabolizes readily in moist, microbially active soils. However, if malathion is in contact with metabolically inactive surfaces such as dry soils or impervious surfaces common in non-agricultural settings, photo-oxidation to the toxic degradate malaoxon can occur. Field data indicate that up to 10% of malathion can be transformed to malaoxon in these conditions. Malaoxon dissipates and degrades similarly to malathion with rapid metabolism in aerobic conditions and rapid hydrolysis in alkaline conditions. Therefore, short duration malaoxon concentration peaks (i.e., less than one day) may be expected in non-agricultural streams during run-off events.

With these generalized effects from the malathion registration defining the action area, we then delineated the proximity of these effects of specific malathion uses to the ranges of listed species and critical habitat designations throughout the United States and its territories and considered the extent of overlap, in combination with past usage data, in our effects analysis for specific species and critical habitat designations.

Overlap with Species Ranges and Critical Habitats

While we do not necessarily expect use of this pesticide will occur in all the areas included in the action area, it is difficult to determine with accuracy and precision where all labeled uses might occur over the duration of the Action. This is particularly difficult to predict beyond the next few years following completion of this consultation, as pest threats and pressures are difficult to foresee, and past use does not necessarily predict future use. The labels for this chemical:

(1) Allow for one or more uses among many land types in the United States and its territories.

(2) Do not prohibit all uses in any of these areas.

Thus, we are unable to eliminate overlap of any listed species[7] or designated critical habitats that occur within the action area, with the following exceptions[8]:

(1) listed species presumed extinct in the United States and its territories and their designated or proposed critical habitat;

(2) listed species presumed extirpated in the United States and its territories with no expectation of recolonization or plans for reintroduction over the duration of the action; or

[7] This Opinion does not consider foreign listed species, due to the extent of the action area as described in EPA's BE.
[8] It is our understanding that EPA recognizes reinitiation of consultation may be necessary if individuals of species presumed extinct or extirpated are discovered within the timeframe of the Action.

(3) listed species that occur only in captivity with no plans for reintroduction over the duration of the action.

This approach is consistent with the Step 1 framework in EPA's BE for malathion. Additional information on listed species and their designated critical habitats are found in the *Status of the Species and Critical Habitat* section below.

Analytical Framework for Jeopardy and Destruction or Adverse Modification Determinations

Jeopardy Determination

Section 7(a)(2) of the ESA requires that Federal agencies ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of listed species. "Jeopardize the continued existence of" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR § 402.02).

The jeopardy analysis in this Opinion considers the effects of the Action, and any cumulative effects, on the rangewide survival and recovery of the listed species. It relies on four components: (1) the *Status of the Species*, which describes the rangewide condition of the species, the factors responsible for that condition, and its survival and recovery needs; (2) the *Environmental Baseline*, which analyzes the condition of the listed species in the action area, without the consequences to the listed species caused by the proposed action; (3) the *Effects of the Action*, which includes all consequences to listed species that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action; and (4) the *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the species.

For purposes of making the jeopardy determination, the Service: (1) reviews all the relevant information, (2) evaluates the current status of the species and environmental baseline, (3) evaluates the effects of the Action and cumulative effects, (4) adds the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species, determines if the Action is likely to jeopardize listed species.

Destruction or Adverse Modification Determination

Section 7(a)(2) of the ESA requires that Federal agencies ensure that any action they authorize, fund, or carry out is not likely to destroy or to adversely modify designated critical habitat. A final rule revising the regulatory definition of "destruction or adverse modification" was published on August 27, 2019 (FR 44976). The final rule became effective on October 28, 2019 (84 FR 50333). The revised definition states:

> *"Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species."*

The destruction or adverse modification analysis in this Opinion relies on four components: (1) the *Status of Critical Habitat*, which describes the range-wide condition of the critical habitat in terms of the key components (i.e., essential habitat features, physical and biological features, or primary constituent elements) that provide for the conservation of the listed species, the factors responsible for that condition, and the intended value of the critical habitat overall for the conservation/recovery of the listed species; (2) the *Environmental Baseline*, which analyzes the condition of the designated critical habitat in the action area, without the consequences to the designated critical habitat caused by the proposed action; (3) the *Effects of the Action*, which includes all consequences to the critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action; and (4) *Cumulative Effects*, which evaluate the effects of future non-Federal activities that are reasonably certain to occur in the action area on the key components of critical habitat that provide for the conservation of the listed species and how those impacts are likely to influence the conservation value of the affected critical habitat.

For purposes of making the destruction or adverse modification determination, the Service: (1) reviews all relevant information, (2) evaluates the current status of the critical habitat and environmental baseline, (3) evaluates the effects of the proposed action and cumulative effects, (4) add the effects of the action and cumulative effects to the environmental baseline and, in light of the status of the critical habitat, determines if the proposed action is likely to result in the destruction or adverse modification of critical habitat.

STATUS OF THE SPECIES AND CRITICAL HABITAT

In their BE, EPA identified numerous listed, proposed and candidate species and proposed and designated critical habitats that may be affected by the Action. Species addressed in this Opinion are listed in Table 6 (animal species), Table 7 (plant species) and Table 8 (species and critical habitats added to the consultation and this Opinion due to listing rules or proposals after the BE was submitted). Species that were included in the BE but have been removed from this Opinion because the species are not currently listed are included in Table 3 of Appendix B of this Opinion. The detailed status of each listed, proposed and candidate species and their proposed or designated critical habitat is provided in Appendix C.

Table 6. Listed, proposed, and candidate animal species and proposed and designated critical habitats addressed in this Opinion included in the BE for malathion.[9]

Table 6. Animal species (BE).xlsx

Table 7. Listed, proposed, and candidate plant species and proposed and designated critical habitats addressed in this Opinion included in the BE for malathion.

Table 7. Plant species (BE).xlsx

Table 8. Listed, proposed and candidate species and proposed critical habitat included in this Opinion that were added to the consultation after the BE was submitted.

Table 8. Additional species.xlsx

The listed entities in Table 9 are designated non-essential experimental populations. They were included in EPA's BE, with all populations except one[10] given a "likely to adversely affect" determination by EPA. These populations were designated to support the recovery of listed species in taxa groups including birds, bivalves, fishes, insects, mammals, and snails. For the Opinion, we are not providing separate conclusions for individual experimental populations, as these were generally within the range of the species and included in the information about the species used in our assessments, and are therefore covered by our analysis. Federal agencies are not required to consult on non-essential experimental populations outside of national wildlife refuges or national parks. In this case, EPA would only be required to confer on these non-essential experimental populations if the Action was likely to jeopardize a species. Thus, while EPA was not required to confer on these non-essential experimental populations, the BE provided determinations for them.

[9] For calls and conclusions in Tables 6 and 7: LAA = "may affect, likely to adversely affect;" NLAA = "may affect, not likely to adversely affect;" NE = "no effect;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

[10] The BE indicated a "may affect, not likely to adversely affect" determination for the grizzly bear (entity ID 1302); this listed entity is addressed in the *Concurrence* section of this document preceding the Opinion.

Table 9. Listed entities comprised of experimental populations (all are non-essential populations).

Table 9. Experimental populations.xlsx

ENVIRONMENTAL BASELINE

The environmental baseline is defined as “the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline.” (50 CFR 402. 02, as revised August 27, 2019).

Due to the large size of the action area and the widespread distribution of species within the action area, a review of all past and present impacts to all of the species and critical habitats across taxa groups addressed in this Opinion is not feasible. Therefore, this Opinion relies on a general discussion of major categories of stressors to listed species and critical habitat that could occur anywhere in the action area. In addition to past and ongoing use of malathion and other registered pesticides, we explore factors that affect the environmental baseline for listed species and designated critical habitats including, among others, habitat degradation, invasive species, pollution, harvesting, water-related issues, and climate change.

Pesticides

Pesticides are used to kill or manage unwanted plants, animals and other pests (e.g., fungi, microbes). Pesticide use benefits forestry and public health, as well as agriculture. For example, benefits of pesticide use in agriculture are increased food production, increased profits for farmers, and the prevention of diseases. Pesticides benefit human health by killing pests such as mosquitos that that carry and transmit diseases (e.g., malaria, West Nile virus, and Zika). Pesticides are also used in non-agriculture sites for forestry and land management. For example, herbicides are used to control unwanted or invasive non-native plants in natural environments or to aid in the restoration of native habitat.

The use of pesticides and pesticide mixtures as part of past Federal and non-Federal actions have resulted in impacts to listed species, their habitats, and other species on which they depend. When pesticides are applied, they are often mobile in the environment and can enter air, water, and soil. They can have adverse effects to the health of wildlife. Pesticides are stressors that have contributed to the current status of some listed species and designated critical habitats. We further discuss the current and past use of pesticides below.

Malathion Overview

Malathion is an organophosphate insecticide used on a wide variety of terrestrial food and feed crops, terrestrial non-food crops, aquatic food, non-agricultural indoor, outdoor sites, and for wide area public health uses. Malathion can be applied in a dust, liquid or encapsulated form. Aerial and ground application methods (including broadcast, fogger, and chemigation) are allowed by label language for malathion products.

Malathion has been used as a pesticide since the 1950s. In 2006, EPA completed a screening-level ecological risk assessment in support of the Registration Eligibility Decision (RED) for malathion (Appendix 1-1 of the BE). The ecological risk assessment in the RED concluded that use of malathion poses a high risk of mortality to fish and aquatic invertebrates from acute toxicity. Almost all uses are expected to pose a high risk of adversely affecting aquatic invertebrate populations, especially in urban streams and wetlands. High acute risk is also expected to fish and amphibians for uses with higher application rates or repeated applications. Numerous incidents of fish kills confirm the acute risk to fish. Use of malathion is generally not expected to pose a high risk of mortality to terrestrial vertebrate wildlife (birds, mammals, reptiles, and terrestrial stages of amphibians) although the acute level of concern (LOC) is exceeded for some uses with high application rates and repeated applications. Use of malathion poses a risk of impairing reproduction in birds and may cause other sublethal effects in wildlife. Although no risk assessment was conducted for beneficial insects, the RED concluded that use of malathion poses a hazard to bees and other insect pollinators based on evidence from toxicity studies, field studies, and incidents. Bees may be harmed from direct exposure, exposure to foliar residues, and exposure to residues on pollen brought back to the hive. The ecological risk assessment in the RED concluded that use of malathion could harm all taxa of threatened and endangered animals and terrestrial plants.

Based on 2012 data, usage on alfalfa, orchards and grapes, and vegetables and fruit are the crop groups with highest usage of malathion (Appendix 1-8 of the BE). Since crops with high malathion usage are varied, the geographic extent of malathion use across the United States is also widespread. Figure 1 illustrates agricultural use of malathion throughout the United States in 2012 and 2019. No national-level malathion usage data are available for registered non-crop uses sites, including homeowner uses, ornamental uses, and wide area public health uses.

Numerous Federal actions have undergone section 7 consultation, some of which are related to pesticide use. As the Action covers the U. S. and its territories and more than 1,500 species and their designated critical habitats, we are instead providing examples of a subset of consultations to provide context for the analysis, and are focusing largely on malathion, given the Action.

The USDA Animal and Plant Health Inspection Service (APHIS) uses pesticides to achieve its mission and has consulted regarding their use, including the use of malathion, on multiple occasions. An example of an APHIS consultation whose effects are considered part of the environmental baseline for the purposes of this consultation is APHIS's Boll Weevil Eradication

Program. This program involves one of the most significant agricultural uses of malathion, namely use on cotton to eradicate the boll weevil throughout cotton growing areas of the U.S. APHIS has also used malathion in some of their other pest programs, such as those involving the control of fruit flies, grasshoppers, and Mormon crickets. Most APHIS activities have occurred on non-Federal lands.

APHIS Pest Program activities have specifically focused on pest management and often included the use of pesticides as one of the program elements. APHIS's implementation of these activities are supported by a well-established program infrastructure that includes environmental compliance, training, monitoring, and reporting. Past and present malathion labels address a variety of use categories that pertain to APHIS programs, and include label language for some uses with higher allowable application rates and numbers of applications that are specific to APHIS (i.e., other users would not be anticipated to apply malathion at these rates and frequencies). Prior APHIS consultations with the Service have involved building avoidance and minimization measures into their proposed actions with the aim of obtaining the Service's concurrence for not likely to adversely affect determinations whenever possible.

As noted earlier, one of the primary uses of malathion has been the use on cotton under the APHIS boll weevil eradication program. The existing malathion label includes specific use directions for cotton under the APHIS boll weevil eradication program, allowing for up to 25 applications per year versus 3 times per year for other cotton uses, with a minimum application interval of 3 days versus 7 days for other uses on cotton. Since its inception in the 1970's, the National Boll Weevil Eradication program has successfully eradicated the boll weevil from most U.S. cotton growing areas, greatly reducing the program footprint. As of 2018, the Boll Weevil Eradication Program action area includes 37 counties in Texas, three counties in Arizona and three counties in New Mexico. Spot infestations of boll weevils detected through monitoring are generally treated with malathion or other pesticides. At this point, treatment activities are primarily anticipated to be limited to 10 counties in the Lower Rio Grande Valley of Texas, with the other select counties remaining in the program area in the unlikely event boll weevil are detected in those areas. ESA section 7(a)(2) consultations between APHIS and the Service have been ongoing on the boll weevil eradication program since 1992, and have been concentrated on malathion. APHIS reinitiated informal consultation in 2018, and the Service concurred with APHIS that the 2018 Boll Weevil Eradication Program is not likely to adversely affect listed species or designed or proposed critical habitat based on species protection measures designed to avoid exposure of these resources to malathion that are in place for the program (U.S. Department of Agriculture, 2018).

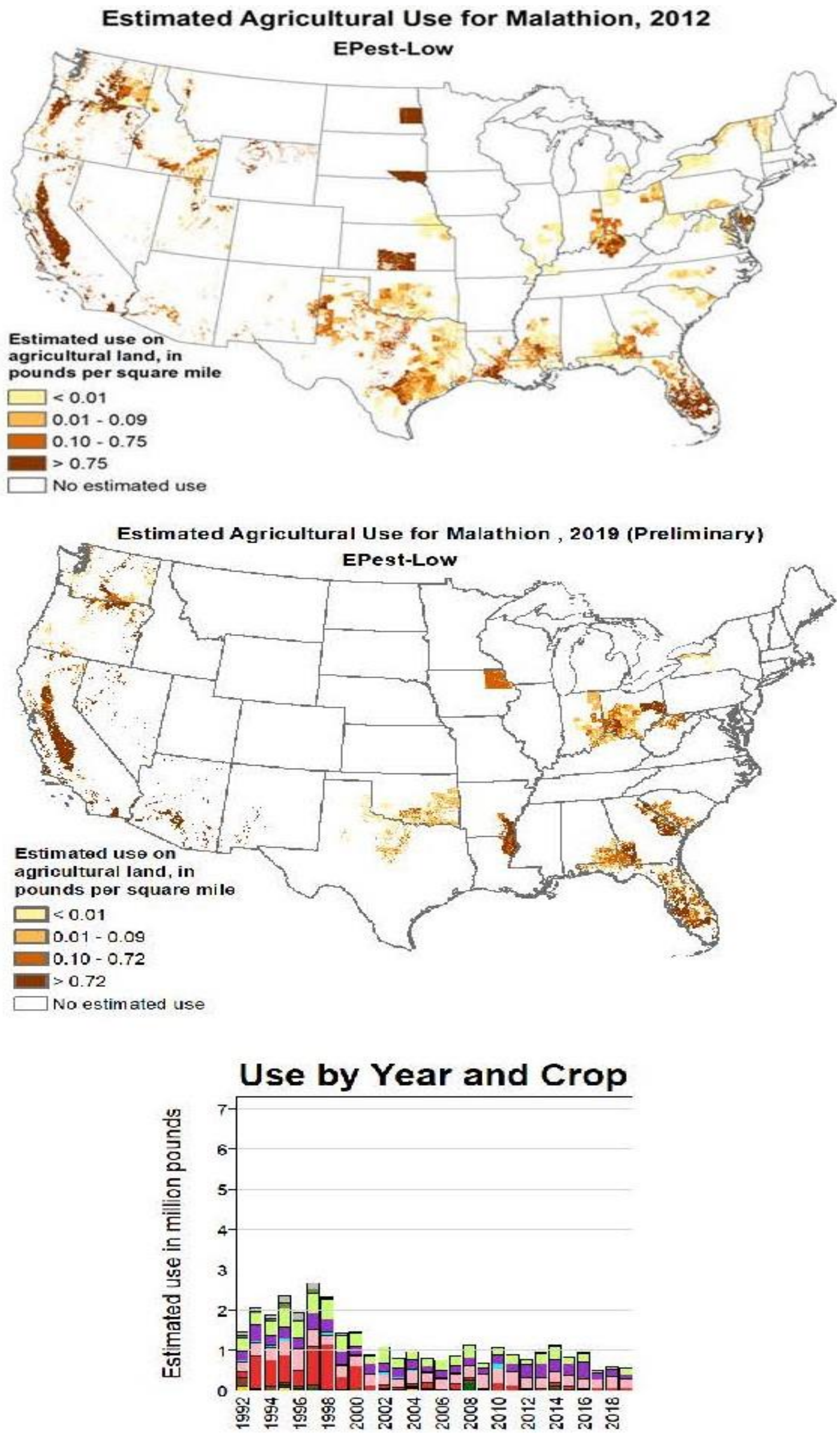

Figure 1. Malathion Use Spatial Distribution (2012 and 2019): Use by Year and Crop (1992-2019). (from:
https://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2012&map=MALATHION&hilo=L&disp=Malathion)

Habitat Degradation

One of the primary factors negatively affecting imperiled species are impacts or changes to their habitat. Human activities have significant and sometimes devastating effects on species and habitats, such as through the introduction of physical and chemical pollutants, or alternation of the environment and the complex ecological systems on which many species depend. There are many kinds of habitat modification activities that have occurred in the United States throughout human history. The earliest modifications likely included the use of fire to encourage or discourage the growth of certain plant communities. The types and extent of habitat changes have increased through time, with much of the land in the United States now used for agriculture, forestry, urban and industrial development, and mining. Each of these land-uses affects species and habitats somewhat differently. The following paragraphs discuss some of the general types of habitat impacts that have been caused by land use conversion and development. Subsequent sections will discuss impacts from various categories of land-use activities.

Data from the USDA (USDA, 2013) suggest that more than 398,000 acres of grasslands, forests, and other lands were converted to cropland between 2011 and 2012 (Figure 1Figure 2). Conversion of natural lands also occurs from urbanization, as population centers expand, or to meet demand for various products or resources. For example, beginning in the 1600s and continuing into the early twentieth century, forests of the United States were harvested at a high rate (Masek, et al., 2011). Over the last 100 years, the area of forest cover in the United States has been relatively stable (Masek, et al., 2011), though reforested areas may not provide the same quality of habitat as unharvested, old-growth forests for ESA-listed species.

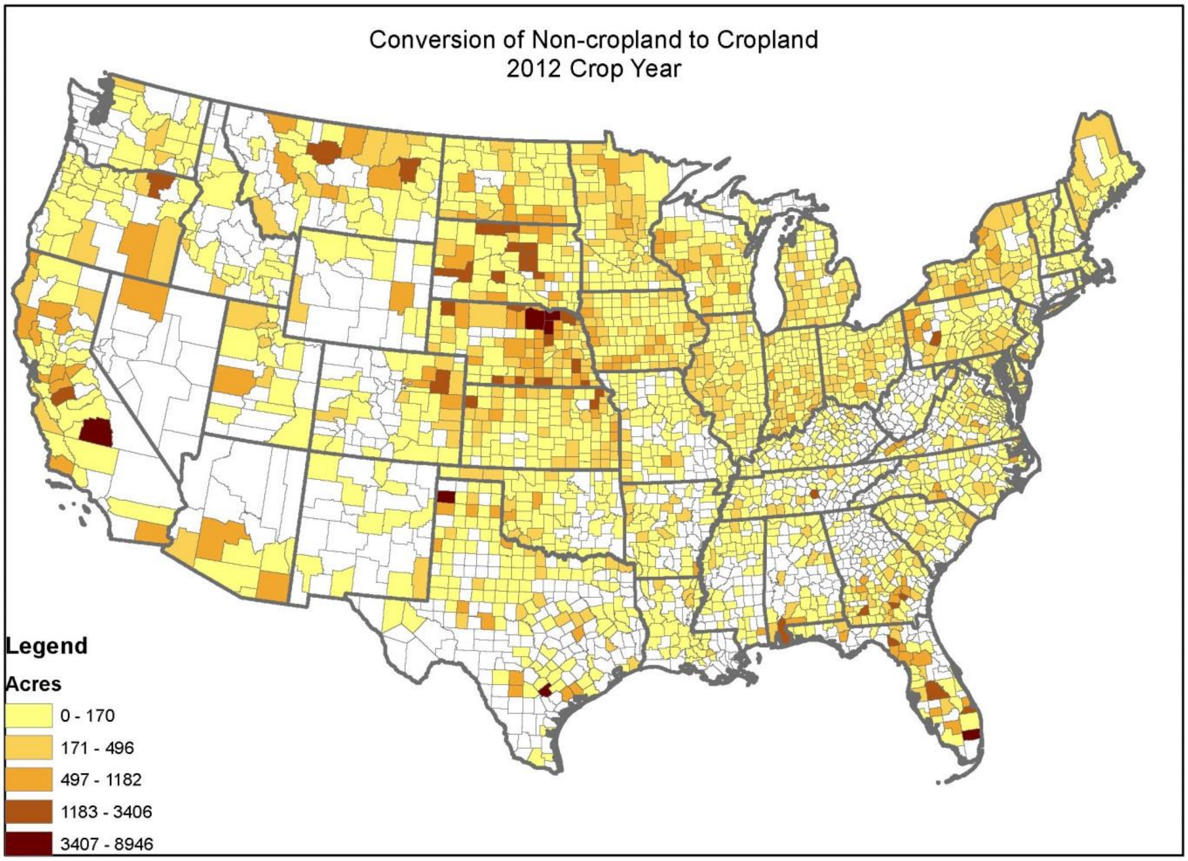

Figure 2. The conversion of land to cropland in 2012 (USDA, 2013).

Through an analysis of threat data compiled from Federal Register documents, Czech et al. (Czech, Krausman, & Devers, 2000) identified urbanization and agriculture as the second and third most common causes of species endangerment in the United States, behind non-native species interactions. Table 10 identifies the causes of endangerment to 877 ESA-listed species identified through Federal Register documents (Czech, Krausman, & Devers, 2000). Species may also be affected by multiple stressors at the same time.

Table 10. Causes of endangerment for ESA-listed species. Modified from Czech et al. 2000.

Cause	Number of species endangered by cause (% of species endangered by cause)
Non-native species	305 (35)
Urbanization	275 (31)

Cause	Number of species endangered by cause (% of species endangered by cause)
Agriculture	224 (26)
Recreation	186 (21)
Ranching	182 (21)
Reservoir and water diversions	161 (18)
Fire suppression	144 (16)
Pollution	144 (16)
Mining/oil & gas	140 (16)
Industry/military activities	131 (15)
Harvest	120 (14)
Logging	109 (12)
Roads	94 (11)
Loss of genetics viability	92 (10)
Aquifer depletion/wetland filling	77 (9)
Native species competition	77 (9)
Disease	19 (2)
Vandalism	12 (1)

ESA-listed species requiring ephemeral habitats, such as those maintained by fire or flooding, have experienced range reductions because the stochastic events that maintain their habitat are often incompatible with human infrastructure and other development. For example, suppression of wildfires and natural flood events that would occasionally disturb climax ecological communities and create early successional and transitory habitat have reduced habitat available for many species.

While human-induced impacts have occurred throughout history, some activities have also included strategies and actions to reduce these impacts such as the establishment of protected areas and reserves, and implementation of restoration or conservation activities to benefit listed species.

Loss and Degradation of Freshwater Habitats

Freshwater habitats are among the most threatened ecosystems in the world (Leidy & Moyle, 1998). Reviews of aquatic species' conservation status over the past three decades have documented the cumulative effect of anthropogenic and natural stressors on freshwater aquatic ecosystems, resulting in a significant decline in the biodiversity and condition of indigenous fish, mussel, and crayfish communities (Taylor, et al., 2007; Jelks, et al., 2008). Anthropogenic stressors, the result of many different impacts, are present to some degree in all waterbodies of the United States. These stressors often lead to long-term environmental degradation associated with lowered biodiversity, reduced primary and secondary production, and a lowered capacity or resiliency of the ecosystem to recover to its original state in response to natural perturbations (Rapport & Whitford, 1999).

Rivers and Streams

Many of our nation's rivers and streams have been affected by anthropogenic factors. Degradation of water quality, changes in water quantity (e.g., flows and/or timing), and habitat changes, such as impacts to riparian zones and in-stream features, often reduce habitat quality for listed species. Other changes have included the construction and operation of dams, stream channelization, and dredging to stabilize water levels or depths in rivers or lakes or for other purposes. When examining the impacts of large dams alone, for instance, it is estimated that 75,000 large dams have modified at least 600,000 miles of rivers across the country (IWSRCC, 2011). More than 400 dams exist in the Columbia River Basin alone (Columbia Basin Trust, 2012). Habitat loss coupled with other stressors has led to impacts on fish communities as well. By the early 1980s, Judy et al (Judy, Jr., et al., 1984) estimated that approximately 81% of the native fish communities in the United States had been impacted by human activities.

Wetlands

Wetlands provide habitat and perform functions that contribute to the health of ecosystems used by many species. There are many kinds of wetlands (e. g., bogs, fens, estuaries, marshes, etc.), each of which has different characteristics and functions. Wetlands are found in diverse landscapes, including forests, prairies, deserts, and within floodplains of streams (WDOE, 2000). They help maintain cool water temperatures, retain sediments, store and desynchronize flood flows, maintain base flows, and provide food and cover for fish and other aquatic organisms (Beechie, Beamer, & Wasserman, 1994; Mitsch & Gosselink, 1993; WDOE, 1998). Wetlands also can improve water quality through nutrient and toxic-chemical removal and/or transformation (Hammer, 1989; Mitsch & Gosselink, 1993).

The United States originally contained almost 392 million acres of wetlands. During the period between the 1780s and the 1980s, 118 million acres of wetlands were lost. Arkansas, California, Connecticut, Illinois, Indiana, Iowa, Kentucky, Maryland, Missouri and Ohio lost 70% or more of their original wetland acreage. California had an estimated loss of 91%. Florida lost approximately 9. 3 million acres or 46% of its 1780s total (Dahl, 1990). Additionally, the functions of existing wetlands have been reduced. Various factors have contributed to wetland loss and wetland function reduction including agricultural development, urbanization, timber harvest, road construction, and other land-management activities. Efforts to create and restore wetlands and other aquatic habitats by agencies of Federal, state, and local governments, non-governmental organizations, and private individuals have dramatically reduced the rate at which these ecosystems have been destroyed or degraded, but many aquatic habitats continue to be lost each year. Between 2006 and 2009, approximately 13,800 acres of wetlands were lost per year (Dahl, 2011). While this is significantly less than losses experienced in the previous decades (Figure 3), an estimated 72% of U. S. wetlands have already been lost when compared to historical estimates (Dahl, 2011).

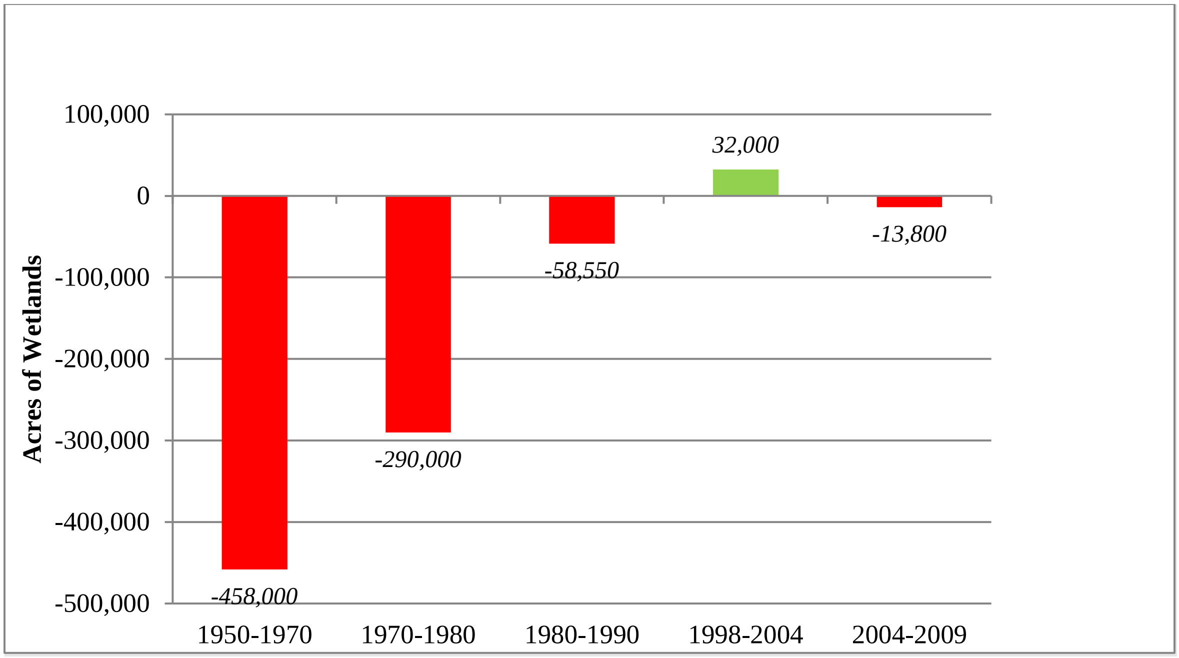

Figure 3. Average annual net wetland acreage loss and gain estimates for the conterminous United States (Dahl, 2011).

Estuaries

Estuaries are some of the most productive ecosystems in the world. Thousands of species of birds, mammals, fish, and other wildlife depend on estuarine habitats as places to live, feed, and reproduce. Many marine organisms, including most commercially important species of fish, depend on estuaries at some point during their development. Estuaries are important nursery and rearing habitat for fishes such as salmon and sturgeon, sea turtles, and many other species. For example, in estuaries that support salmon, changes in habitat and food-web dynamics have altered their capacity to support juvenile salmon (Bottom, Jones, Cornwell, Gray, & Simenstad, 2005; Fresh, Casillas, Johnson, & Bottom, 2005; Allen, Pondella, & Horn, 2006; LCFRB, 2010). Diking and filling activities have reduced the tidal prism, reduced freshwater inflows, reduced sediment inputs, and eliminated emergent and forested wetlands and floodplain habitats. Similarly, dredging activities in shallow coastal estuaries can increase the tidal prism, increase salinities, increase turbidity, release contaminants, lower dissolved oxygen, and reduce nutrient outflow from marshes resulting in a host of negative consequences to these ecosystems. These changes have: reduced fishery productivity; contributed to land losses (e.g., Louisiana, Florida); contributed to fish kills; reduced avian habitats and use; and reduced the resiliency of these areas to stochastic events (e.g., hurricanes). Restoration of estuarine habitats, particularly diked emergent and forested wetlands, reduction of avian predation by terns, and flow manipulations to restore historical flow patterns, may have begun to enhance estuarine productive capacity for salmon, although historical changes in population structure and salmon life histories may prevent salmon from making full use of the productive capacity of estuarine habitats. Mitigation of losses of estuarine marsh in the mid-Atlantic and Gulf of Mexico may roughly keep pace with the losses of the last two decades, but they have not reversed the large losses of the mid-twentieth century (Dahl, 2011).

Shorelines

Significant development and urbanization along shorelines have also occurred in many areas throughout the action area. Impacts have been to mainstem river channels, estuarine, and nearshore marine habitats, and sub-basins in the lower part of major watersheds have been altered as well. Impacts have also occurred in key areas that are important to fish and wildlife, such as coastal and inland avian habitats and salmonid spawning and rearing areas, which may be well upstream of the lowlands.

Portions of nearshore and shoreline habitats in estuarine areas and certain freshwater lakes have been altered with vertical or steeply sloping bulkheads and revetments to protect various developments and structures (e.g., railroads, piers) from wave-induced erosion, stabilize banks and bluffs, retain fill, and create moorage for vessels (BMSL (Battelle Marine Sciences Laboratory), Pentec Environmental, Striplin Environmental Associates, Shapiro Associates, Inc., & King County Department of Natural Resources, 2001). Habitats at risk from direct human alteration include riparian buffers, freshwater habitats (e.g., streams, lakes), and shallow subtidal, intertidal, and shoreline habitats known collectively as the “marine nearshore.” Depending on placement in relationship to drift cells, and other shoreline characteristics, armoring of the shoreline can interrupt the natural inputs of sand from landward bluffs, resulting in sediment deficits within the landscape.

Shoreline development has affected many sensitive habitats. One such sensitive habitat type is submerged aquatic vegetation such as seagrasses. For example, eelgrass beds on the Pacific and Atlantic coasts grow in the intertidal zone and in mud and sand in the shallow sub-tidal zone and support numerous aquatic species, from geese and dabbling ducks to spawning forage fish. Similarly, turtle grass, shoal grass, manatee grass, and wigeon grass occupy similar ecological niches in the estuaries of the northern Gulf of Mexico. Losses of these sensitive and highly productive habitats are estimated at 20% to 100% in northern Gulf of Mexico estuaries (Duke & Krucynski, 1992). Significant areas containing aquatic beds have been impacted due to harbor development, dock building, dredging, and bottom trawling. Shipping, docks, bulkheads, and other shoreline developments likely contribute to the reduction in submerged aquatic vegetation and other spawning and rearing areas for forage fish.

Agriculture and Grazing

Agriculture is one of the principal industries in many states. Agriculture operations include farming and animal operations and vary in size. Some geographic areas may produce large amounts of agricultural products. For example, according to the 2015 Crop Year Report from the California Department of Food & Agriculture, over a third of the nation's vegetables and two-thirds of the nation's fruits and nuts are grown in California.

Many animal husbandry operations exist across the country. Large operations include cattle (beef and dairy) and poultry. Other smaller operations raise horses, pigs, sheep, geese and ducks, dairy goats, rabbits, and exotic animals (e.g., llamas, emus, alpacas, ostriches). In 2019, the cattle inventory in the United States was approximately 95 million head. Texas is the state with the most cattle (13%) in the United States, followed by Nebraska and Kansas. Thirty-one states have over 1 million, fourteen have over 2 million and nine have over 3 million head of cattle (based on USDA NASS data as cited in (Cook, 2019)).

Past and present grazing activities have also occurred in a large portion of the action area. For example, grazing began in Washington in the mid-1800s, with sheep and cattle herds initially using the lush grasses that covered many parts of eastern Washington (Oliver, Irwin, & Knapp, 1994). Sheep grazing peaked in the 1930s and then rapidly declined, while cattle grazing increased steadily in most areas (Oliver, Irwin, & Knapp, 1994). In the early 1900s, livestock grazing was authorized on National Forest lands (Oliver, Irwin, & Knapp, 1994). Grazing fees and regulations were implemented in 1906, with grazing allotments initiated the following year, although enforcement efforts were not substantial enough to prevent trespass by unregulated livestock. Grazing resulted in a number of effects, including a general decline in range conditions; excessive use of available forage and resulting conflicts between livestock owners; removal of highly flammable fuels and reduction in ground fires; purposeful setting of fires (by livestock owners) leading to uncontrolled fires; establishment of invasive, non-native vegetation; and increase in siltation of water bodies (Oliver, Irwin, & Knapp, 1994).

As a result, the Bureau of Land Management began regulating grazing on public rangelands in the 1930s. Asian grasses were introduced as stabilizing vegetation for the erosion caused by overgrazing and other practices. The reduction in the number of sheep and localized declines in grazing pressure by cattle in some areas allowed recovery of some of the rangelands (which included forestlands; (Oliver, Irwin, & Knapp, 1994)). By the 1960s and 1970s, legislation allowed for monitoring, improvements, and better stewardship of rangeland (including those in National Forests).

Grassland, rangeland, pastureland and cropland forage resources of the conterminous United States include intensively managed pasturelands and croplands throughout the country, and the extensive management of arid and semi-arid regions in central and western United States. Rangelands, pasturelands, and meadows collectively comprise about 55% of the land surface of the United States (approximately 405 million hectares). Privately owned lands constitute about 45% of this total (approximately 260 million hectares). These lands represent the largest and most diverse land resources in the United States. Rangelands and pasturelands include the following areas: the annual grasslands of California, the tundra rangelands of Alaska, the hot arid deserts of the Southwest, the temperate deserts of the Pacific Northwest, the semi-arid cold deserts of the Great Basin, the prairies of the Great Plains, the humid native grasslands of the South and East, and the pastures and meadows (natural or semi-natural grasslands often associated with the conservation of hay or silage) within all 50 states.

Effects to Natural Resources

Agricultural lands also provide some benefits for fish and wildlife species. For example, there is generally less impervious surfaces associated with agricultural lands than in urbanized or industrial areas. However, there are several other types of impacts to listed species habitats that are sometimes associated with farms and animal operations. Agricultural practices have contributed to the loss of side-channel areas and riparian vegetation in the floodplain in some areas. The effects of livestock grazing, dairy operations, and crop production often extend many miles upstream or downstream of these activities.

Agricultural operations may also result in the degradation of water quality due to contaminants, such as through introduction or runoff of excess nutrients, fertilizers, pesticides, and other chemicals. For example, livestock production often degrades water quality with the addition of excess nutrients, while pesticides applied to crops can leach into the water table and enter streams from surface water runoff (Rao & Hornsby, 2001; Spence, Lomnicky, Hughes, & Novitzki, 1996). A number of pesticides have been detected in small streams and sloughs within agricultural and urban sites tested within Puget Sound (Bortleson & Davis, 1997). In periodic reconnaissance studies of streams in nine Midwestern states, the U. S. Geological Survey has documented that large amounts of herbicides and their degradate products are flushed into streams during post-application run-off (Scribner, Battaglin, Goolsby, & Thurman, 2003). In addition, elevated nutrient concentrations from animal manures and agricultural fertilizer application can contribute to excessive growth of aquatic plants and reduced levels of dissolved oxygen, which can adversely affect fish (Embrey & Inkpen, 1998) and other aquatic organisms.

Water quality can also be affected by increases in temperature and sediment loading from agricultural operations. Irrigation systems often result in warmer water temperatures in canals and streams. Warmer temperatures can result from the clearing of shade-providing riparian areas along streams or other waterways, and from solar heating of water flowing across fields or in shallow waterways.

Effects from livestock grazing can be considerable if management practices are not sufficient to protect habitat functions (WDOE, 1998; Wissmar, et al., 1994; Belsky, Matzke, & Uselman, 1999). For example, livestock grazing is currently the primary land use in existing eastern Washington shrub-steppe habitats; this grazing, together with fire suppression, has altered the nature of the habitat in several ways (WDOE, 1998). Shrubs are more numerous because many are not eaten by livestock, while bunchgrasses are less common because they are consumed or trampled by livestock. Trampling also damages the fragile moss and lichen layer that protects the soil against erosion and non-native invasive vegetation colonization (e.g., cheatgrass) and provides nutrients to the soil. Additional impacts to water quality may result from other practices such as improper spreading of manure and increased surface runoff from overgrazed pasture and/or other areas in which large numbers of animals are confined (Green, Hashim, & Roberts, 2000).

Other impacts result from the maintenance of grazing lands. Fencing can provide environmental benefits such as keeping cattle out of sensitive areas, although there can be periodic impacts from construction, reconstruction, and maintenance activities that require transport and staging of materials, digging of holes, and stringing or re-stringing wires or fences. Chemically treated-wood posts are often used at corners with braces, with interspersed metal posts, wooden posts, or live trees. On flat terrain, power equipment may be used to auger holes and construct fence. On steep terrain, hand tools and chain saws become more common. Rock cribs are often used when crossing areas of bedrock.

Attempts have been made to begin correcting some of the past impacts on the country's ecosystems from agricultural operations. In 1988, EPA began implementing the Federal Insecticide, Fungicide, and Rodenticide Act to regulate the registration and use of chemical pesticides, although some authors note challenges associated with its implementation (Edge, 2001). Additionally, State and Federal landowner-assistance programs have been organized to aid landowners in voluntarily managing their properties to improve water and habitat quality (Edge, 2001).

Forestry

In 1630, at the beginning of European settlement, it is estimated that 46%, or 423 million hectares, of what would become the United States was forest lands. In 2012, forests comprised 309 million hectares (USDA, 2014). From 1850 to 1997, forest land remained relatively stable across the country. According to the U.S. Forest Service, the most acreage of forest lands occurs in the western United States, followed by large areas in the southern and northern parts of the country. Forest lands have been converted to other uses such as agricultural and urban uses. Reserved forest land has doubled since 1953 and now stands at 7% of all forest land in the United States. This reserved forest area includes State and Federal parks and wilderness areas, but does not include conservation easements, areas protected by nongovernmental organizations, and most urban and community parks and reserves. Significant additions to Federal forest reserves occurred after the passage of the Wilderness Act in 1964 (USFS, 2001).

Forested areas that were considered unsuitable for agriculture were frequently managed for timber harvest. Pioneers used river systems to transport logs and other goods. Trees were felled directly into streams, rivers, and saltwater and floated to their destinations, or pulled to streams and trapped behind splash dams, which were dynamited or pulled away, causing logs to sluice downstream. Roads for oxen, then railroads, followed transportation by water. In railroad logging, powerful steam-powered "donkey" engines pulled logs across great distances on the ground, crossing streams and anything else in the way. Following World War II, truck road systems replaced railroads, but smaller streams continued to be used as transportation corridors (CH2M Hill, 2000). After 1930, the introduction of motorized trucks and chainsaws allowed for substantial increases in harvest. Fueled by the demand for new housing and development after World War II, harvest increased dramatically. Initially, harvest focused on large-diameter trees; smaller trees were then harvested, ultimately reducing the number of large-diameter trees.

Harvest of uneven-aged trees was practiced until 1940; by the 1950s, even-aged management was practiced.

Much of the lowlands initially harvested for timber were subsequently cleared for agriculture and residential development. While timber harvest continues to occur across the country, conversion of forest lands to other uses have become more common as the human population has grown. Comprehensive tracking of forest conversion rates began in the late 1970s, with the Forest Service Forest Inventory and Analysis data (Bolsinger, McKay, Gedney, & Alerich, 1997). These data, combined with limited data from the 1930s to the 1970s, indicate general trends in forest conversion. For example in Washington state, the earliest data indicate there were approximately 26.5 million acres of forest lands during the 1930s, with 25.2 million acres available for harvest; 15.2 million (60%) acres were found in western Washington, and 10 million (40%) acres in eastern Washington. By 2004, a net loss of approximately 3.5 million acres of forestland was reported, with 80% of this loss occurring in western Washington. The data indicated that reductions in the amount of privately-owned forestland accounted for the majority of this loss.

Effects to Forests

Forestlands have experienced effects related to many different changes, which often vary by area. These changes, which disrupt natural processes that influence forest health, are produced by direct and/or indirect human activities that have occurred in the past and present. These activities include timber harvest, grazing, fire suppression, road construction, and management practices and other influences that have resulted in increases in disease and pests. The impacts of grazing have been discussed previously and will not be addressed in this section.

Intensive forest management generally results in adverse effects such as loss of older forest habitats and habitat structures, increased fragmentation of forest age classes, loss of large contiguous and interior forest habitats, decreased water quality, degradation of riparian and aquatic habitats, and increased displacement of individual species members.

Intensive forest management on most private lands generally maintain these lands in an early seral stage (e.g., 40 to 50 years of age) with relatively few structures such as snags, down logs, large trees, variable vertical layers, and endemic levels of forest "pests" and "diseases," when compared to what was historically present prior to intensive management.

Timber Harvest

Timber harvest occurs across the nation. Patterns of timber harvesting are influenced by natural events (fire, ice, insects, and disease), management practices, public policies, and market conditions. The average size of harvest units depends on harvesting methods. Clearcutting is a common harvesting method in forests dominated by Douglas-fir in Washington State.

There are many kinds of activities associated with timber harvest, with varying degrees or types of impacts associated with each activity. Timber harvest and associated activities, such as road construction and skidding, can increase sediment delivery to streams, clogging substrate interstices, and decreasing stream channel stability and formation. Harvest in riparian areas decreases woody debris recruitment and negatively affects the stream's response to runoff patterns. Stream temperatures may rise with decreases in the forest canopy and riparian zone shading. Runoff timing and magnitude can also change delivering more water to streams in a shorter period, which causes increased stream energy and scour and reduces base flows during summer months.

Other impacts from logging practices include modifications to forest composition. For example, prior to Euro-American settlement of Washington in early 1800s, the different forest age classes were well represented across the State (WDOE, 1998). Since that time, declines in old-growth forests have occurred on both Federal and non-Federal lands. For example, since World War II, old growth in the Olympic National Forest has declined by 76% (Morrison, 1990).

In addition, studies have shown that large trees in temperate coastal rainforests collect moisture from fog, and this collection of moisture may contribute an estimated 35% of the annual precipitation (Quinault Indian Nation & USDA - USFS, 1999). Significant reductions in large trees in these habitats may result in less moisture retention, affecting future runoff and/or precipitation patterns.

Impacts from timber-harvest management have included the removal of large trees that support in-stream habitat structure ("large woody debris"), reduction in riparian areas, increases in water temperatures, increases in erosion and simplification of stream channels (Quigley & Arbelbide, 1997). Past timber harvest practices include the use of heavy equipment in channels, skidding logs across hill slopes, splash damming to transport logs downstream to mills, and road construction (USFS, 2002). Improvements in methodologies have reduced some of the effects from these practices (Oliver, Irwin, & Knapp, 1994). In some areas harvest units have been restricted in size, and greater consideration has been given to the health and appearance of forest landscapes and the biotic communities that depend on them. In some cases, equipment is used and/or engineered in ways to minimize soil disturbance and other habitat impacts. In other cases, however, the methods used may result in increased soil disturbance and extreme fire hazards (e.g., machine piling and burning, accumulation of dead slash from thinning activities, etc.; (Oliver, Irwin, & Knapp, 1994)).

Fire Suppression

Under historical fire regimes, natural disturbance to streams from forest fires resulted in a mosaic of diverse habitats. However, forest management and fire suppression over the past century have increased the likelihood of large, intense forest fires in some areas.

Prior to European settlement, both natural and human-initiated fires are believed to have affected forests. Eastern Washington forests consisted of open, park-like areas with fire-resistant trees in the lowlands, and Douglas-fir/western larch and true fir forests in the middle and high elevations, respectively (Oliver, Irwin, & Knapp, 1994). In the lowlands, most fires were frequent, and not highly destructive, primarily burning off revegetation; at higher elevations, and in cooler areas, fires were less frequent, and highly destructive. Fire suppression began in the late 1800s when a forestry commission was convened to begin studying the conditions of Forest Reserves (precursors of National Forests), which were created in 1891. Although fire suppression was viewed as necessary to protect resources and private property, some advocated the use of prescribed fire to reduce fuels and protect stands against damaging fires.

From 1930 to 1960, forest management began in earnest on National Forest lands, and many rural settlers moved to urban areas. Grazing occurred in previously burned areas, while other areas developed into dense stands. Fire-suppression efforts were intensified, with additional funding and crews made available to respond effectively to fight fires. The buildup of fuels likely led to larger, more-destructive fires. From the 1960s to the 1990s, fire prevention allowed the development of dense, closed stands of trees, which varies significantly from pre-management times. Oliver et al. (Oliver, Irwin, & Knapp, 1994) reported that this growth pattern makes stands increasing susceptible to disease and pests. In the 1960s, attitudes toward burning began to change, and the beneficial role of fire was recognized. The use of prescribed fire in certain environments was also encouraged, with certain precautionary measures.

Although scientists have recognized the value of prescribed burning as one of many tools to help return landscapes to natural conditions, some managers have been slow to embrace prescribed burning partially due to the issues surrounding liability. There are also other constraints upon prescribed burning including short-term expenses and air-quality regulations.

Disease and Pests

Pests and disease were present in forestlands prior to European settlement. Several kinds of defoliating insects have been documented, including, but not limited to: Tussock moths, pine butterflies, and bark beetles in Washington State (Oliver, Irwin, & Knapp, 1994). Starting in the 1930s, pest surveys and control were used to combat these pests. Pest control included selective harvesting/or salvage harvest to remove infested trees, the spraying of pesticides (e.g., ethylene dibromide, DDT, and other insecticides), and removal of host plants (e.g., currant [Ribes spp.], host of white pine blister rust).

Since the 1960s, integrated pest management (IPM) has been used to control insect outbreaks. With IPM, several different management and pest-control alternatives are rated against cost/benefit analyses, alternative strategies, ecological considerations, and other concerns to determine the best recourse against the target pest(s). Examples of IPM alternatives include favoring resistant stand structures and/or species in thinning and planting activities, fire prescription, selective use of pesticides, and salvage logging (Oliver, Irwin, & Knapp, 1994).

Urban and Industrial Development

In the United States, urban land acreage quadrupled from 1945 to 2007, with an estimated 61 million acres in urban areas in 2007 (Nickerson, Ebel, Borchers, & Carriazo, 2011). The Census Bureau estimated that urban area increased almost 8 million acres in the 1990s (Lubowski, Vesterby, Bucholtz, Baez, & Roberts, 2006), but despite similar increases for the last several decades, this still represents just 3% of the land area of the U.S. (Bigelow & Borchers, 2017). Figure 4 depicts the 2010 human population density by county and serves as a coarse representation of urbanization. In general, urbanization (including impervious land uses, manufacturing and waste, housing densities, and contributions to greenhouse gas emissions) concentrates effects of water, land, and mineral use, increases loads of pollutants in waters and on the land, increases the likelihood of noise and air pollution, contributes to degradation of ecosystems and habitat for fish, wildlife and plants, lessens biodiversity, and contributes to changes in climate at varying scales.

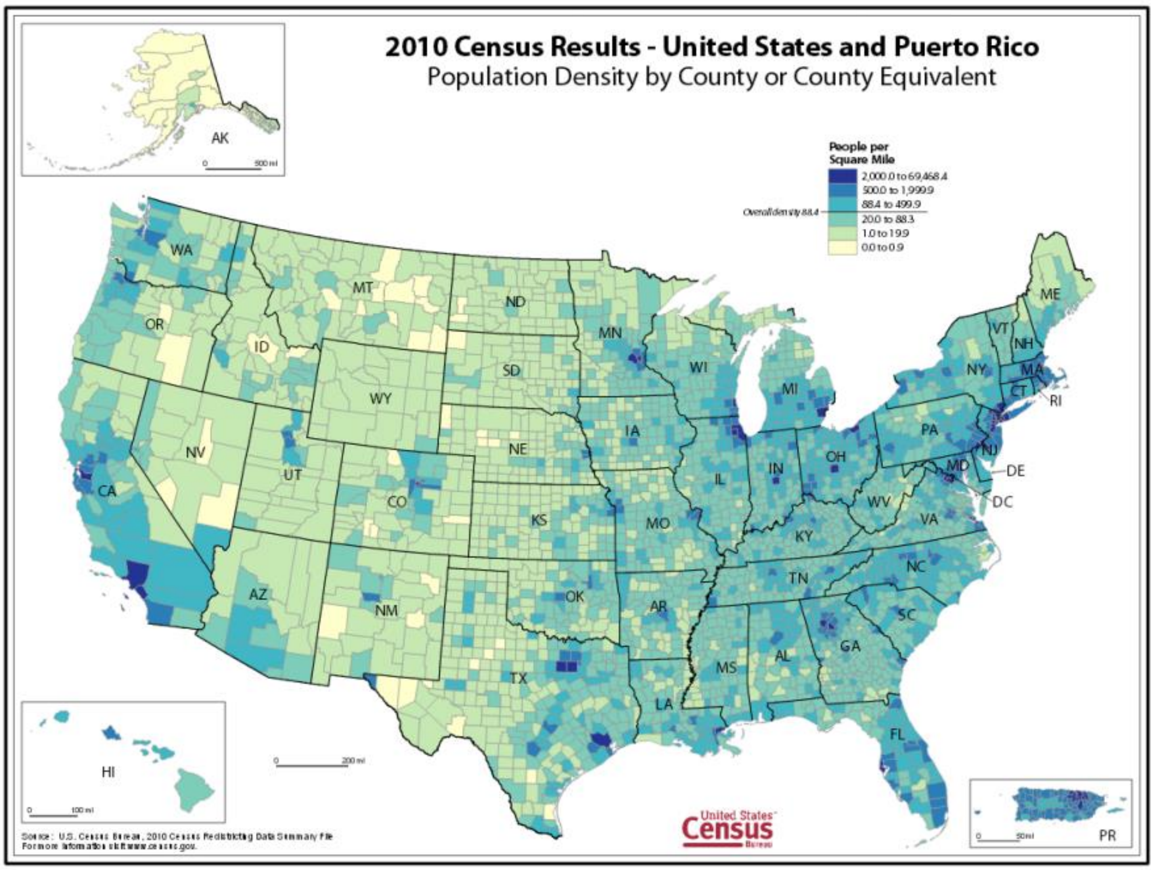

Figure 4. U. S. population density by county (USCB 2010).

<u>Impervious Surfaces</u>

Scientific studies indicate there is a strong relationship between the amount of forest cover, levels of impervious and compacted surfaces in a basin, and the degradation of aquatic systems (Klein, 1979; Booth, Hartley, & Jackson, 2002). Impervious surfaces associated with residential development and urbanization create one of the most-lasting impacts to stream systems. Changes to hydrology (increased peak flows, increased flow duration, reduced base flows) as a result of loss of forest cover and increases in impervious surfaces are typically the most-common outcomes of intensive development in watersheds (May, Horner, Karr, Mar, & Welch, 1997; Booth, Hartley, & Jackson, 2002). Increased peak flows and flow duration often lead to the need to engineer channels to address flooding, erosion, and sediment-transport concerns.

Stormwater runoff continues to be a significant contributor of non-point source water pollution in core spawning and rearing areas and foraging, migration, and overwintering habitat areas for salmonids (WSCC, 1999a; WSCC, 1999b; KCDNR and WSCC, 2000). Although not typically a direct measure of the influence of development, basin imperviousness is commonly used as an indicator of basin degradation (Booth, Hartley, & Jackson, 2002). Reduction in forest cover and conversion to impervious surfaces can change the hydrological regime of a basin by altering the duration and frequency of runoff, and by decreasing evapotranspiration and groundwater infiltration (May, Horner, Karr, Mar, & Welch, 1997; Booth, Hartley, & Jackson, 2002). Such changes can be detected when the total percentage of impervious surface in the watershed is as low as 5 to 10% (Booth, Hartley, & Jackson, 2002). Watershed degradation, however, likely occurs with incremental increases in impervious surfaces below these levels, and it is exacerbated by other factors such as reduced riparian cover and pollution (Booth, 2000; Karr & Chu, 2000; Booth, Hartley, & Jackson, 2002). Booth et al. (2002) state, "[t]he most commonly chosen thresholds, maximum 10% effective impervious area and minimum 65% forest cover, mark an observed transition in the downstream channels from minimally to severely degraded stream conditions." They further assert, "Development that minimizes the damage to aquatic resources cannot rely on structural best management practices (BMP) because there is no evidence that they can mitigate anything but the most egregious consequences of urbanization. Instead, control of watershed land cover changes, including limits to both imperviousness and clearing, must be incorporated."

The amount of new impervious surfaces has increased significantly in recent history, and this trend will likely continue this trend in the future. Nonetheless, several entities have implemented actions to begin to counter the effects of impervious surface water and stormwater runoff on natural resources. Projects using low-impact development technologies have been planned or constructed. Projects in various areas have included the construction of swales, rain gardens, and narrower roads, and the installation of permeable pavement, among other technologies. Land use planning, zoning, and parks and natural area acquisitions are being used in many communities to incorporate Green Infrastructure into developed landscapes that can help to maintain functional floodplains, stream flows, water quality, fish and wildlife habitat, and other ecosystem functions and public benefits.

<u>Loss of Riparian Buffers</u>

The riparian zone along a stream is a transitional area between the stream and uplands. These areas perform a variety of functions in the ecosystem (WDOE, 2000). Trees and shrubs along the bank provide shade and cover for fish and other aquatic biota, while their roots provide bank stabilization and help to control erosion and sedimentation into the stream. The riparian zone also contributes nutrients, detritus, and fallout insects into a stream, which supports aquatic life.

Vegetation and soils in the riparian zone protect the stream against excess sediments and can sequester pollutants. The riparian zone contributes to the reduction of peak stream flows during floods, and acts as a holding area for water, which is released back into the stream during times of low flow. The trees in the riparian zone serve the ecosystem even after they fall, many of them altering flow and creating habitat features (e.g., pools, riffles, slack areas and off-channel habitats) which benefit fish and other aquatic biota at various life stages.

Many kinds of human activities have impacted riparian zones along streams across the country. These activities include, but are not limited to, urbanization, agriculture, grazing, mining, channelization and damming of streams, logging, and recreational activities (Bolton & Shellberg, 2001). It is estimated that 70% of the original area of riparian ecosystems have been cleared in the United States (Swift, 1984).

While human-related activities conducted within the riparian zone can damage the integrity of a riparian system, activities that occur outside the riparian zone can also create impacts (Kauffman, Mahrt, Mahrt, & Edge, 2001). Riparian zones are often relatively flat and/or are situated at low elevations when compared to adjacent upland topography within a watershed; as a result, sediment and soils, nutrients, water, and substances carried by these vectors from upslope or upstream activities are often deposited by gravity within riparian zones. While the riparian zone helps to buffer streams against these materials, too large a volume can impact the riparian zone's ability to properly function in either the short or long term. The buffering ability of a riparian zone can be affected by landslides, erosion, altered flow regimes, degraded water quality, contaminant inputs, or other sources. Logging, agriculture and grazing, road construction, or other activities can generate these impacts, if appropriate safeguards are not in place.

Although recent changes have been made to many regional and local development regulations to provide protection (i.e., buffers or conservation zones) for riparian areas and streams, the integrity of these areas is frequently compromised by encroachment (May, Horner, Karr, Mar, & Welch, 1997). There is no prescribed corridor size to protect a stream or other water body from all potential impacts. Different riparian widths are required depending on the characteristics of each potential pollutant and the integrity and/or quality of a particular riparian zone; therefore, unless riparian zone widths are carefully evaluated based on adjacent land use and threats, the success of the riparian zone in adequately buffering streams from pollutants is uncertain at best. For many small stream systems, riparian areas are highly degraded or no longer exist, and their restoration is precluded by existing development. Although functional riparian areas have the capacity to mitigate for some of the adverse impacts of development (Morley & Karr, 2002), they cannot effectively address significant impacts from changes to stream hydrology resulting from significant losses of forest cover (May, Horner, Karr, Mar, & Welch, 1997; Booth, Hartley, & Jackson, 2002).

Roads and Rights-of-Ways

Road (e.g., street and rail) and right-of-way (ROW; e.g., cleared surface and below grade utility lines, pipelines, transmission lines) construction in watersheds can promote simplification and channelization of streams, which reduce the connectivity of surface water and groundwater. Activities associated with road/ROW construction, maintenance, and use can also result in loss or degradation of riparian areas, loss, degradation and fragmentation of terrestrial plant and animal habitats, sedimentation, erosion and slope hazards, reduction of passage, dispersal, or migration (e. g, invertebrate, fish, amphibian, reptile, and mammalian) and increased strike hazards to many classes of animals to name but a few.

Historical methods of road construction were destructive to stream habitats (Palmisano, Ellis, & Kaczynski, 2003). Stream materials (e.g., sand, gravel and cobbles) were often used as fill, and excess excavation materials were pushed over the side of the road bank, where it frequently entered streams. Riparian vegetation and stream banks were damaged using heavy equipment adjacent to and in streams. Side channels were often cutoff or eliminated, and stream channels were confined, resulting in increased bank erosion in certain areas. Lack of adequate drainage led to saturation of roadside soils. In many parts of the action area, road and ROW siting, construction and maintenance practices have not changed significantly through time with regard to conservation of fish, wildlife, and ecosystems. Constriction of floodplains resulted in increased flooding, which continues today in certain areas.

Little specific information is available on the historical origins and use of roads in forested areas outside of the Forest Service lands. Within the Forest Service lands, most forest roads were originally constructed by harvesters for access to forested areas, who then deducted the costs of road construction from final payments to the Forest Service (Oliver, Irwin, & Knapp, 1994). Oliver et al. (Oliver, Irwin, & Knapp, 1994) reports that less than 150 miles of road existed in Washington National Forests in 1907; by 1920, this number had increased with 176 miles of road per million acres in the Yakima River Basin (Washington), and 287 miles per million acres in the Grand Ronde River Basin (Washington and Oregon). Beginning in the 1950s, the Forest Service began to assert more direct control over the road network on Forest Service lands, and the network increased.

Mining and Mineral Extraction

The U. S. has a history of mining that dates to the early 17th century when iron, lead, silver copper and coal were discovered and mined by the early colonial settlers of New England and the Mid-Atlantic states. Today, every state (and Puerto Rico) produces mined materials or extracts minerals from below the surface (e.g., fuels - coal, oil and gas, building materials – sand, gravel, clay; rare Earth minerals; and those used for industry – aluminum and copper). From the surface loss of habitats (land and water) associated with mining to the effects on (surface and ground) water quality and chemistry, air quality, and effects related to mining waste disposal, few human endeavors have such large scale and consequential effects on the environment as mining and mineral extraction. There are no readily available summary data to illustrate the scale of the various forms of mining; however, a 1975 Corps of Engineers study on strip mining estimated 4.4 million acres and approximately 13,000 miles of rivers and tributaries had been disturbed or adversely impacted by surface coal mining (USACE, 1979). There are surely additional millions of acres, collectively, of surface impacts to land and water given the many other forms of mineral mining and extraction.

Invasive Species

Invasive species are non-native species capable of causing great economic or ecological impacts in areas where they become established. Ecological impacts from biological invasion include predation, disease transmission, competition (for food, light, space), and hybridization. The rate of species invasion has increased over the past 40 or more years due to human population growth, alterations of the environment, and technological advances that allow for the rapid movement of people and products (Pimentel, Zuniga, & Morrison, 2004). Invasive species are considered a contributing factor in the decline of 49% of the imperiled species in the United

States (Wilcove, Rothstein, Dubow, Phillips, & Losos, 1998). Based on factors affecting species associated with island ecology (e.g., small populations, small ranges, high rates of endemism), the impact is often even greater. It is estimated that 75% of the world's threatened birds confined to islands face severe threats from introduced species (BirdLife International, 2008).

There are an estimated 50,000 or more non-native terrestrial and aquatic plant species established in the United States, many of which are outcompeting native plants for habitat (Pimentel, Zuniga, & Morrison, 2004). About half of these species are plants. In some cases, non-native plants are capable of completely dominating new habitats, forming dense monocultures, and completely excluding other native plants. Approximately 97 non-native birds exist in the United States. Many of these non-native birds compete with or displace native birds, and they are vectors for avian diseases. Approximately 53 species of reptiles and amphibians have been introduced to the United States, which often prey upon native species (Pimentel, Zuniga, & Morrison, 2004). More than 4,600 non-native invertebrate species inhabit the United States, some of which are well known for vast ecological impacts, including the decline or extirpation of native species (Pimentel, Zuniga, & Morrison, 2004).

Pollinator Decline

Insects have been experiencing a worldwide decline with potentially negative implications for plant pollination. The drastic declines in insect biomass, abundance and diversity reported in the literature have raised concerns. Extrapolated across the world, insect biomass losses of approximately 25% per decade project a potential little noticed catastrophe. The critical environmental functions of insects mean that consequences of their declines could impact ecosystems by reducing such services as pollination and seed dispersal (Dornelas & Daskalova, 2020). The scope of global and national pollinator decline has been evaluated in numerous studies, a few of which are summarized here.

A study in Illinois used historic data sets to determine the degree of change over 120 years in a temperate forest understory community. The results showed that 50% of bee species in the study area were extirpated and 46% of the original forb-bee interactions were lost (246 of 532) even though all 26 forbs remained present. Specialist pollinators were lost more than generalists even though their host plants were still present. Bees that were specialists, parasites, cavity-nesters, and/or those that participated in weak historic interactions were more likely to be extirpated. The richness of bee species visiting forb C. virginica did not change between 1891 and 1971 but declined by over half in the following 40 years. This decline appeared to be the result of changes in forested habitat (Burkle, 2013).

A second study in Illinois compared a survey of wild bees from 1970–1972 with a survey from 75 years earlier. The more recent survey found 140 bee species, implying a 32% reduction in biodiversity compared to historical records from the same location. Only 59 of the 73 prairie-inhabiting bees and 15 of the 27 forest-dwelling bees were found (Marlin & LaBerge, 2001).

Bumblebee surveys performed in 2004–2006 were compared to surveys from 1971 to 1973 at the same sites, and they were used to evaluate changes in community composition. This study showed quantitative evidence that a bumblebee diverse region of Eastern North America has undergone declines in bumblebee species richness, diversity and relative abundance. During the period ending in 1973, 14 bumblebee species were found, during the period ending in 2006, 11 species were found. No new species were identified. The rusty patched bumblebee (*B. affinis*) was previously widespread and common but has undergone drastic decline and has likely been extirpated throughout much of its range. Of 14 species collected in the first survey, 7 were found to be either absent or decreasing in relative abundance in the second survey, while 4 species exhibited increases in relative abundance (Colla & Packer, 2008).

Another study evaluated changes in the distribution of six bumblebee species by comparing historical records with intensive surveys across 382 locations in the USA. Half of the species declined in abundance by as much as 96% of their initial populations in the last 30 years, and their geographical range was reduced between 23 and 87% (Lozier, Strange, Stewart, & Cameron, 2011).

In Oklahoma, a study determined that only 5 of the 10 species of bumblebees that were present in 1949 were found in 2013 after extensive surveys in 21 counties. Additionally, the species B. variabilis was presumed extinct (Figueroa & Bergey, 2015).

Long term surveys in North America and Europe show terrestrial insects declined in abundance by an average of 9% per decade, whereas freshwater insects increased by 11%. The decline of terrestrial insects was estimated to be 0.92% per year while the increase of freshwater insects was estimated at 1.08% per year. The most compelling evidence for declines in terrestrial insect assemblages was found in North America. Strong evidence exists for both directional trends in temperate zone, Mediterranean and desert climates. The declines appear to be associated with changes in land use. Moderate evidence exists for a negative relationship between terrestrial insect abundance trends and landscape urbanization and may be explained by habitat loss and light and/or chemical pollution (Van Klink, 2020).

There is evidence of recent declines in both wild and domesticated pollinators, and parallel declines in the plants that rely upon them. In 54 studies covering 89 plant species, the most frequent proximate cause of reproductive impairment of wild plant populations in fragmented habitats was pollination limitation (Potts, et al., 2010).

Pollution

In addition to direct loss and alteration of aquatic habitat, various contaminants and pollutants have impacted many aquatic ecosystems. In 2008, the Heinz Center for Science, Economics and the Environment (Heinz Center) (Heinz, 2008) published a comprehensive report on the condition of our nation's ecosystems. In their report, the Heinz Center noted the following:

(1) From 1992 to 2001, benchmarks for the protection of aquatic life were exceeded in 50% of streams tested nationwide – 83% of streams in urbanized areas – and 94% of streambed sediments.

(2) Contaminants were detected in approximately 80% of sampled freshwater fish and most of these detected contaminants exceeded wildlife benchmarks (1992 to 2001

data) (Gilliom, et al., 2006). Nearly all saltwater fish tested had at least five contaminants at detectable levels, and concentrations exceeded benchmarks for the protection of human health in one-third of fish tissue samples—most commonly DDT, PCBs, PAHs, and mercury (USEPA, 2009).

(3) Toxic contaminants, as noted above have, been documented in the Lower Columbia River and its tributaries (LCREP, 2007). More than 41,000 bodies of water are listed as impaired by pollutants that include mercury, pathogens, sediment, other metals, nutrient, and oxygen depletion, and other causes (USEPA, 2013a). Pennsylvania reported the greatest number of impaired waters (6,957), followed by Washington (2,420), Michigan (2,352), and Florida (2,292). These figures likely underestimate the true number of impaired water bodies in the United States. For example, EPA's National Aquatic Resource Surveys (NARS) is a probability-based survey that provides a national assessment of the nation's waters and is used to track changes in water quality over time. Through this method, EPA estimates that 50% of the nation's streams (approximately 300,000 miles) and 45% of the nation's lakes (approximately seven million acres) are in fair to poor condition for nitrogen or phosphorus levels relative to reference condition waters (USEPA, 2013b). However, data submitted by the States indicates that only about half of the NARS estimate (155,000 miles of rivers and streams and about four million acres of lakes) have been identified on EPA's 303(d) impaired waters list for nutrient related causes (USEPA, 2013b).

Water quality problems, particularly the problem of non-point sources of pollution, have resulted from changes that humans have imposed onto the landscapes of the United States over the past 100 to 200 years. The mosaic or land uses associated with urban and suburban centers are cited as the primary cause of declining environmental conditions in the United States (Flather, Knowles, & Kendall, 1998) and other areas of the world (Houghton, 1994). Most land areas covered by natural vegetation are highly porous and have very little sheet flow; precipitation falling on these landscapes infiltrates the soil, is transpired by the vegetative cover, or evaporates. The increased transformation of the landscapes of the United States into a mosaic of urban and suburban land uses has increased the area of impervious surfaces such as roads, rooftops, parking lots, driveways, sidewalks, and others. Precipitation that would normally infiltrate soils in forests, grasslands and wetlands falls on and flows over impervious surfaces. That runoff is then channeled into storm sewers and released directly into surface waters (rivers and streams), which changes the magnitude and variability of water velocity and volume in those receiving waters.

Increases in polluted runoff have been linked to a loss of aquatic species diversity and abundance, which include many important commercial and recreational fish species. Nonpoint source pollution has also contributed to coral reef degradation, fish kills, seagrass bed declines and algal blooms (including toxic algae; (NOAA, 2013)). In addition, many shellfish bed and swimming beach closures can be attributed to polluted runoff. As discussed in EPA's latest National Coastal Condition Report (NCCR), nonpoint sources have been identified as one of the stressors contributing to coastal water pollution (USEPA, 2012). Since 2001, EPA has periodically released these reports detailing condition of the nation's costal bays and estuaries and assessing trends in water quality in coastal areas. The latest NCR report indicates that coastal water conditions have remained "fair" and the trend assessment demonstrates no significant change in the water quality of U. S. coastal waters since the publication of the NCCR II in 2004 (USEPA, 2012).

In many estuaries, agricultural activities are major source of nutrients to the estuary and a contributor to the harmful algal blooms in summer, although nearly one-third of the total nitrogen inputs and one-fourth of the total phosphorus inputs to the estuary are believed to be from atmospheric sources (McMahon & Woodside, 1997) (USEPA, 2006). The National Estuary Program Condition Report found that nationally, 37% of national estuary program estuaries are in poor condition[11].

Throughout the twentieth century, mining, agriculture, paper and pulp mills, and municipalities contributed large quantities of pollutants to many estuaries. For example, the Roanoke River and the Albemarle-Pamlico Estuarine Complex which receives water from 43 counties in North Carolina and 38 counties and cities in Virginia. This estuarine system supports an array of ecological and economic functions that are of regional and national importance. Both the lands and waters of the estuarine system support rich natural resources that are intertwined with regional industries including forestry, agriculture, commercial and recreational fishing, tourism, mining, energy development, and others. The critical importance of sustaining the estuarine system was reflected in its Congressional designation as an estuary of national significance in 1987. Even so, today the Albemarle-Pamlico Estuarine Complex is rated in good to fair condition in the National Estuary Program Coastal Condition Report despite that over the past 40-year period data indicate some noticeable changes in the estuary, including increased dissolved oxygen levels, increased pH, decreased levels of suspended solids, and increased chlorophyll a levels (USEPA, 2006).

Since 1993, EPA has compiled information on locally issued fish advisories and safe eating guidelines. This information is provided to the public to limit or avoid eating certain fish due to contamination of chemical pollutants. The EPA's 2010 National Listing of Fish Advisories database indicates that 98% of the advisories are due (in order of importance) to: mercury, PCBs, chlordane, dioxins, and DDT (USEPA, 2010). Fish advisories have been issued for 36% of the total river miles (approximately 1. 3 million river miles) and 100% of the Great Lakes and connecting waterways (USEPA, 2010). Fish advisories have been steadily increasing over the National Listing of Fish Advisories period of record (1993 to 2010), but EPA interprets these increases to reflect the increase in the number of water bodies being monitored by States and advances in analytical methods rather than an increase in levels of problematic chemicals (USEPA, 2010).

Water-quality concerns related to urban development include adequate sewage treatment and disposal, transport of contaminants to streams by storm runoff, and preservation of stream corridors. Water availability has been and will continue to be a major, long-term issue in many areas. It is now widely recognized that ground-water withdrawals can deplete streamflows

[11] National Estuary Program Condition Report http://water. epa. gov/type/oceb/nep/nepccr-factsheet.cfm

(Morgan & Jones, 1999), and one of the increasing demands for surface water is the need to maintain instream flows for fish and other aquatic biota.

Harvesting

Some ESA-listed species, such as salmonids and freshwater mussels, are economically important species harvested as food. Harvesting and exploitation, often associated with the pearl industry, is identified as a contributing factor to18% of the imperiled freshwater mussels of the United States (Strayer, et al., 2004). After species are listed as threatened or endangered under the ESA, they receive protection from overharvesting since this action would require a permit issued by the Service, with permits generally limited to certain categories of activities that would benefit the conservation and recovery of the species. Although harvest is a historical threat to many ESA-listed species and illegal harvests still likely occur to some degree, it, now, rarely affects species substantially, and it is not expected to greatly affect currently listed species in the action area in the future.

Water-Related Issues

As noted above in the sections related to rivers and streams, wetlands, and estuaries, impacts to species and their habitat have occurred in these habitats due to various human activities. Stream channels in many areas have been significantly altered by dredging, channelization, and the construction of dikes and revetments for flood control and bank protection. These activities have simplified once complex stream channels. More specifically these changes are degrading and eliminating important foraging and migration, as well as overwintering habitats for salmonids and other biota. Such changes can also result in the removal of riparian vegetation, thus precluding recruitment of large woody debris. Developments such as these can also reduce or preclude options for restoration of floodplain areas important for reestablishing off-channel habitats and maintaining groundwater recharge.

The following subsections briefly describe different impacts to features or characteristics of aquatic habitats.

Water Diversion

Dikes, levees, dams, and other diversions have reduced the level of watershed connectivity in several areas of the country. Diversion projects have been implemented for several human needs, including but not limited to, flood control, conversion of wetlands to agricultural lands, bank protection, water supply, road construction, or a combination of these objectives.

Impacts to species and habitats from these actions have been significant. Palmisano et al. (Palmisano, Ellis, & Kaczynski, 2003) report that the most-severe effects to wild anadromous salmonids from dams and other fish-passage barriers have occurred in the Columbia River Basin, although there are several problem areas in other parts of the west.

Many streams have been channelized, diverted, and confined through the construction of dikes, levees, berms, revetments, embankments, and other structures. The shapes and configurations of the structures vary based on their purpose; however, the construction of each kind of structure results in physical and biological impacts to the stream morphology and community (Bolton & Shellberg, 2001). The construction of flood-control structures, tide gates, and water-diversion structures have contributed to the degradation and fragmentation of migratory corridors, and elimination of historical foraging, migration, and overwintering habitats within the region. Channelization (and often its associated bank armoring) results in simplification of the stream, and has resulted in changes in flow, velocity, and movement of water in many streams. These changes are often at least a portion of the goal of a project, which may be designed to reduce flood damage to property, exclude water, or store water for future use. While these changes may be favorable to property owners or project proponents, such actions often result in substantial changes to aquatic and terrestrial habitats and their use by biota.

Dikes and levees result in several impacts to aquatic species and habitat. Aside from loss of estuarine habitat from construction, dikes reduce tidal flushing, sometimes resulting in increased sedimentation; dikes also may have marked effects on tidal channel biota on the seaward side of the structure (Hood, 2004). The construction of dikes may result in decreased sinuosity and complexity in certain channels and prevent energy dissipation during flood events.

Florida has two large restoration projects underway to address environmental problems caused by dikes. In 1992, the Kissimmee River Restoration Program was authorized by Congress. In 1999, the U. S. Army Corps of Engineers (USACE) and the South Florida Water Management District began construction in central Florida. Upon its completion in 2020, the project will restore 20,000 acres of wetlands and 44 miles of historic river channel (USACE, 2019).

The greater Everglades ecosystem historically encompassed 18,000 sq. miles from central Florida to the Florida Keys. Water flowed south into Lake Okeechobee and then spilled over its banks into the sawgrass plains, open water sloughs, rocky glades, and marl prairies and finally into the Gulf of Mexico and Florida and Biscayne Bays. The USACE installed a massive network of canals, levees, and water conservation areas that blocked sheet flow to urban areas and provided water for dry season use. The Comprehensive Everglades Restoration Plan was authorized by Congress in 2000. The plan will "restore, preserve, and protect the south Florida ecosystem while providing for other water –related needs of the region, including water supply and flood protection" (SFNRC, 2016).

Restoration efforts have focused on the benefits of restoring ecosystem functions affected by diversion structures. In 2002, the Nisqually Tribe removed a portion of a dike in Red Salmon Slough, reconnecting 31 acres of former pastureland to the Nisqually River Estuary (SPSSEG, 2002; Carlson, 2005). This action was undertaken to benefit juvenile salmonids, other fish species, and migratory birds. At Spencer Island in Snohomish County, two 250-foot-long breaches were made in an estuary dike to reconnect approximately 250 acres of estuarine marsh (Carlson, 2005).

Culverts and Other Fish-passage Barriers

Improperly installed, sized, or failed culverts have been identified as barriers for fish movement and migration. Although historically placed, fish-passage barriers continue to impede fish passage in many streams. Several groups have made efforts to inventory and remove fish barriers under their jurisdiction, often either removing barrier culverts or replacing them with a more-suitable structure (Peck, 2005). Removal of fish barriers may be achieved through several different kinds of activities (Peck, 2005). Removal of a barrier culvert is often undertaken when a crossing is no longer needed. If a crossing is necessary, other options include bridges or other specific methodologies: stream simulation, roughened-channel design, no-slope methodology, or hydraulic design.

Dams

There are currently approximately 1,025 dams obstructing the flow of water in Washington alone, with approximately 10 new dams added each year, generally small facilities on off-channel or side streams (Green, Hashim, & Roberts, 2000; WDOE, 2000). Dams are built for many purposes, including power generation, irrigation, flood control, recreation, and water supply (WDOE, 2000). These facilities have far-reaching effects on both aquatic and terrestrial habitat and biota. The controlled flow from a dam facility often slows the movement of the rivers, and changes the natural cycle of river flows, resulting in areas that are either drier than normal (because the water is being held behind the reservoir) or flooded by much higher levels of water. Changing the depth and flow of rivers also affects the water's temperature, either increasing or decreasing temperatures from the normal state. Dams affect the flow of many different materials (e.g., sediments, nutrients, and other materials such as large woody debris) carried in the river waters. Free-flowing rivers regularly flood and recede, collecting and depositing these materials both laterally and downstream. For example, rivers carry a great deal of sediment and nutrients down river, eventually depositing it in the deltas and estuaries where freshwater enters saltwater. Dams arrest this process; consequently, reservoirs eventually fill with sediments and inadequate amounts of sediment reach the downstream deltas and estuaries. Coastal beaches in turn lose the source of sand normally deposited on them by coastal currents that would ordinarily redistribute the sediments.

Dams often delay or block passage of anadromous fish to upstream reaches of the stream; such an obstacle can increase predation rates on these fish, cause injury or mortality as fish are trapped in unscreened canals or attempt to travel through turbines. In many cases, dams have likely been constructed at or near historical natural barriers to anadromous fish passage, as summarized in (U.S. Fish and Wildlife Service, 2015). The ability of anadromous fish to access areas above man-made barriers is important not only for the survival of individuals and populations of the species, but also for the integrity of the ecosystems they support (Cederholm, et al., 2000). Anadromous fish provide organic matter and nutrients to both aquatic and terrestrial habitats via their carcasses, eggs, milt, excrement, and fry. Staging and spawning adults are also consumed as prey by aquatic and terrestrial predators. The organic matter and nutrients contributed by anadromous fish enrich macroinvertebrate and terrestrial communities, which in turn provide food for other organisms, including anadromous salmonid fry and juveniles. Scavenging and predatory fish, birds, mammals, and other animals also consume fry, juvenile, and adult salmon, their eggs, and their carcasses, often leaving remnants of carcasses in a more-accessible form for smaller scavenging fauna. Rich marine-derived nutrients from anadromous fish are transported to the reach of stream in which they die, into the lower reaches of the stream and estuary through downstream drift, and across habitat or ecosystem boundaries by mobile mammals, birds, and fish.

Certain facilities have implemented fish-passage structures or transport systems to allow upstream movement of anadromous fish; however, the risk of disease, stress, and other interference with migration and reproduction may occur as a result of these systems.

The Pacific coast has many river restoration projects to deal with problems caused by dams. California has been very active in river restoration since the 1930s. River restoration programs in California include the CALFED Bay-Delta Ecosystem Restoration Program, which has invested $500 million in projects from 1996 to 2005 (Kondolf, et al., 2007). Some of the larger ongoing projects are the Trinity River Restoration Program and the San Joaquin River Restoration Program.

Water Quantity and Use

The diversion, storage, and use of water is based on increasing demand, fueled by population and economic growth. Water availability varies based on annual weather patterns and may change in the future as climate change affects weather patterns and water supply. Year-round water withdrawals are no longer available from many lakes and streams, to protect aquatic species and existing water rights in many western states.

A significant amount of water is used for irrigation of agricultural lands, which can affect ecosystems. Irrigation is used to maintain urban irrigated lands, forest nurseries, seed orchards, and recreational areas. Water withdrawal also occurs as a source for rural domestic use, stock watering, municipal and light industrial water supply, and for industrial use; however, the dominant off-channel water use is for irrigation (Wissmar, et al., 1994).

Effects associated with irrigation-water withdrawal includes effects from water storage and drainage, increased water temperatures (which can become thermal barriers for salmonids and other aquatic species), pollutants (such as runoff containing pesticides and fertilizers), high sediment levels, and lower stream flows (Krupka, 2005; Wissmar, et al., 1994). Lower flows and associated stream dewatering affect aquatic habitat and biota (Wissmar, et al., 1994). Diversions and fish ladders associated with irrigation also have a variety of effects since not all are screened or pass all life stages of fish; irrigation systems may also divert a substantial amount of stream flow. The effects of these structures in aggregate to anadromous fish and other aquatic biota can be severe. However, through permitting and the Federal Energy Regulatory Commission relicensing processes, several efforts have been initiated to reduce existing effects. These efforts include but are not limited to: proper screening of existing diversions and other structures; reduction of temperature, sediment, and pesticide effects to waterways; reduction of the quantity of water diverted to provide access; and reduction of fish-passage barriers.

There have been several attempts to reduce impacts from dams, irrigation-water withdrawal, and other water-diversion activities. Some of the efforts to minimize effects to anadromous fish were undertaken relatively early (Palmisano, Ellis, & Kaczynski, 2003). For example, irrigation diversions were screened in the 1930s, although the screens did not protect all life stages, nor were they adequately maintained. More recently, watershed-planning units have been organized in some areas in response to the Watershed Planning Act, to address issues regarding water availability and quality, instream flow, and habitat protection (WDOE, 2000). Some projects have been proposed specifically to address flow issues. For example, between 2000 and 2004, the Salmon Recovery Funding Board (SRFB, 2005) funded projects to alter river flows over 85 acres, slowing the stream flows to enhance salmon spawning and rearing habitats. As mentioned previously, certain dams have been slated for removal (e.g., Elwha, Glines Canyon, and Condit dams) because it has been determined that they are no longer necessary. In 2006, the San Joaquin River Restoration Program was established to restore a self-sustaining Chinook salmon fishery below Friant Dam in Fresno, California. This program will restore 153 miles of river below Friant Dam which was built between 1937 and 1942 to provide irrigation water to the southern San Joaquin Valley.

Water Quality

Good water quality is essential to the health of habitats and the biotic communities that depend on them. Poor water quality affects both aquatic terrestrial species and communities through the food chain. There are many kinds of pollutants or contaminants that affect water quality in waterways, many of which are direct results of the activities described elsewhere in the baseline discussion. In addition to contaminants, such as metals or fecal coliform, water quality is also determined by abiotic (temperature, dissolved oxygen levels, pH, turbidity, etc.), and biotic (invertebrates, fish, etc.) indicators.

This analysis will look at several contaminants in aquatic habitats, and then examine water quality from the perspective of abiotic and biotic indicators associated with marine and freshwater environments. It should be noted that analyses of many pollutants that "exceed recommended levels" are based on statistics for human exposure and health. While effects to animals (e.g., fish) are often used in acute and chronic tests, such tests generally are limited to observations of mortality or relatively short-term growth and development; they are not commonly performed on listed species. Sublethal effects, such as behavior and long-term survival, are also not generally analyzed.

Contaminants

Contaminants enter waterways through a variety of pathways. Contaminants in stormwater runoff, for example, may include oil, grease, and heavy metals from roadways and other paved areas, and pesticides from residential developments. Observations of high numbers of pre-spawn mortalities in coho salmon returning to small streams in urban and developing areas of Puget Sound have caused increasing concern over stormwater runoff (Ylitalo, Buzitis, Krahn, Scholz, & Collier, 2003). Other sources of toxic contaminants are discharges of municipal and industrial wastewater, leaching contaminants from treated wood (e.g., creosote) and other components of shoreline structures, and channel dredging, which can result in resuspension of contaminated sediments. Discharges from sewage-treatment plants may be treated prior to discharge into receiving waters. However, according to the literature, the treatment likely does not adequately remove potentially harmful compounds that are considered persistent, bio-accumulative, and toxic, or those that may have endocrine-disrupting properties (Bennie, 1999; CSTEE, 1999; Daughton & Ternes, 1999; Servos, 1999).

Many of the contaminants are associated with sediments, and they are taken up by bottom-dwelling biota and many of the organisms at the base of the food chain. Many sediment contaminants do not break down very quickly. According to studies in Puget Sound, approximately 5,700 acres of submerged habitat are considered highly contaminated, with many of these sediments present in industrial areas (Hinman, 2005); other areas covered by the survey showed 179,000 acres were of intermediate quality, while the remaining 400,000 acres of the areas surveyed were considered clean. While the areas that are considered contaminated are relatively small, the effects from these areas can be far-reaching. Animals that live in contaminated sediments can accumulate high levels of these substances, with concentrations in biota sometimes thousands of times higher than background levels in the surrounding habitat. As these animals move into other areas, or are preyed upon by more-mobile animals, the contaminants are transmitted up the food chain and may biomagnify. Consequently, predators can have very high contaminant levels, even if they have spent little or no time within the contaminated areas. For example, Chinook salmon in Puget Sound have levels of polychlorinated biphenyls (PCBs) that are three times higher than Chinook in other areas.

Contaminants (and their concentrations in the environment) vary by region and habitat type, and include inorganic (e.g., metals) and organic chemicals (e.g., certain pesticides, phthalates). Some chemicals, such as chlorinated organic compounds and their breakdown products, persist in the environment because bacteria and chemical reactions break them down slowly (PSWQAT, 2000). Although the effects from many of these chemicals have been at least partially analyzed, little is known about the synergistic effects of the chemicals; in many areas, multiple substances are present in the habitat and/or biota. The synergistic effects of these chemicals to aquatic and terrestrial biota are unpredictable at best.

Inorganic Chemicals

Inorganic chemicals include, among other substances, metals and certain pesticides. Sources of mercury, lead, and other metals in water bodies include hazardous material spills, pipes, vehicle emissions, discarded batteries, paints, dyes, and stormwater runoff and can cause neurological or reproductive damage in humans and other animals (Hinman, 2005). Metals, especially zinc, nickel, lead, and tri-butyl tins (used in some paints, for example), occur at relatively high concentrations at a few Puget Sound locations (Hinman, 2005). The presence of certain metals in marine waters have triggered fish and shellfish consumption advisories in many areas. Overall, however, levels of arsenic, copper, lead, and mercury have either declined or remained steady (as opposed to increasing) in sediments and shellfish tissues during the past decade (Hinman, 2005).

Organic chemicals

A variety of organic chemicals have been detected in waterways, including, but not limited to, polycyclic aromatic hydrocarbons (PAHs), polycarbonated biphenyls (PCBs), poly-bromated diphenyl ethers (PBDEs), chlorinated pesticides (e.g., DDT [(dichloro diphenyl trichloroethane]), dioxins, certain pharmaceuticals and other emerging compounds.

PAHs are present in fossil fuels and other sources; certain types of PAHs are formed when fossil fuels and other organic materials are burned. Other sources include coal, oil spills, leaking underground fuel tanks, creosote, and asphalt. PAHs are found in urban and industrial areas, and have been associated with liver lesions in English sole in small concentrated areas of sediment or “hot spots” (Hinman, 2005). Fish and shellfish consumption advisories have been issued in some areas due to the presence of this chemical. Exposure is linked to increased risks of cancer and to impaired immune function, reproduction, and development. Concentrations of PAHs in the Sound are often quite high compared to concentrations measured elsewhere around the United States.

Another group of organic chemicals of concern are PBDEs (e.g., flame retardants), members of a class of brominated chemicals. Flame retardants are added to some products to reduce the risk of the products catching fire if exposed to high heat or flame. PDBEs have been detected in several Pacific Northwest aquatic species and their predators, including Dungeness crab (west coast of Canada), bald eagle (Lower Columbia River) and heron eggs (British Columbia), orca (northeastern Pacific Ocean), mountain whitefish (Columbia River, Spokane River, British Columbia), rainbow trout (Spokane River), and largescale sucker (Spokane River) (Washington State Department of Ecology and Washington State Department of Health, 2006). Although there is still some debate as to the effects of these substances, the molecule is similar to the thyroid hormone, which affects growth and reproduction (Hinman, 2005). The growth and reproduction of fauna are factors that could be affected by this contaminant. WDOE and Washington State Department of Health (2004) indicate that there are differences in the way species either metabolize or accumulate PDBEs; although the overall risk to different species of biota is unknown, there is enough evidence to merit concern.

Chlorinated organic compounds, such as PCBs, dioxins, and DDT are found in solvents, electrical coolants and lubricants, pesticides, herbicides, and treated wood (Hinman, 2005). These compounds and their breakdown products persist in the environment because bacteria and chemical reactions break them down slowly (PSWQAT, 2000). The use of PCBs was common until the 1970s when they were phased out in the United States and Canada. These chemicals are now banned in the United States; however, they continue to leach from landfills, other disposal sites, and contaminated sediments. PCBs enter natural environments and biota from these sources and from airborne fallout deposited after circulating across the globe from continuing sources in Asia (WDOE, 2000). PCBs are slow to degrade, float in air and water, permeate soil, and accumulate in animal fat. Generally speaking, the higher an animal is on the food chain, and the longer lived, the greater the concentrations of these toxins. In Puget Sound, concentrations of PCBs are found primarily in urban and industrial areas. The concentrations of PCBs have not appeared to be declining in recent years despite many other chemicals that were introduced historically into the waters and sediments of Puget Sound. The sources of PCBs include certain solvents, electrical coolants and lubricants, pesticides, herbicides, and some types of treated wood (Hinman, 2005).

Chemicals, such as dioxins and furans, are generated as industrial process byproducts, and they are linked to cancer, liver disease, and skin lesions in humans. Chlorinated pesticides, such as DDT, are linked to liver disease, cancer, hormone disruption, the thinning of bird eggshells, and reproductive and developmental damage. Fry (1995) identified organochlorine compounds as a prevalent non-oil pollution threat within the range of the murrelet. Specifically, polychlorinated dibenzo-dioxins (PCDD) and polychlorinated dibenzo-furans (PCDF) which are contained in pulp-mill discharges, cause significant injury to fish, birds, and estuarine environments. PCDDs and PCDFs bio-accumulate in marine sediments, fish, and fish-eating birds and impair bird health and production. There has been no record of bio-accumulated residues or breeding impairment in marbled murrelets to date, although murrelets that feed in areas of historical or current discharge from bleached-paper mills could be at risk from eating fish with bio-accumulated organochlorine compounds.

Other chemicals include phthalates, which come from plastics, certain soaps, and other products. Much of the exposure from these chemicals to biota occurs via wastewater from treatment plants. The effects from these chemicals are not well known, but they may affect growth and development in fish (Hinman, 2005). Pharmaceuticals and personal-care products, such as oral contraceptives, antibiotics, and other prescription drugs, as well as soaps, fragrances, and other compounds, enter the aquatic environment through sewage and wastewater-treatment plants. Effects and risks to aquatic biota from these substances have not been fully analyzed; however, Daughton and Ternes (1999) note that even substances that are not persistent but are frequently or continually released may impact aquatic species, which may have exposure throughout entire lifecycles and multiple generations. Daughton and Ternes (1999) also note that many of these products are being released worldwide in volumes comparable to chemicals associated with agriculture.

Fecal Coliform

The presence of fecal coliform bacteria is a significant water-quality issue in some areas. Fecal waste enters waters from sources such as poorly managed septic systems, wastewater treatment facilities, stormwater (which washes fecal matter in upland areas into waterways), and animal operations, and contains bacteria and viruses that can result in the contamination of shellfish beds and other resources (Hinman, 2005; WDOE, 2000).

This water-quality issue is being addressed through a number of actions to limit the amount of fecal matter and associated bacteria and viruses that affects the waterways of Washington State, including education and outreach, modifications in the amount and types of treatment at treatment facilities, fencing of livestock away from streams, and other activities. Even with these measures being used in some areas, the problem continues to exist. During the past two years, 1,655 acres of shellfish growing areas were added to the list of approved growing areas, indicating improvement; however, the growing areas that are on the list of threatened shellfish beds doubled from 1997 (nine sites) to 2004 (18 sites).

Levels of fecal coliform in streams and rivers are measured along with other water-quality parameters. The WDOE (2000) reports that 52 freshwater monitoring stations have been consistently surveyed since 1995 for fecal coliform, and that, with one exception, the stations are indicating that stream conditions regarding this parameter are either improving or there has been no change (i. e. , no significant deterioration) in stream conditions.

Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present; swimming in water and eating shellfish are possible risks to the human and animal health. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff. In addition to this possible health risk, these pathogenic organisms can cause the occurrence of cloudy water, unpleasant odors, and an increased oxygen demand." (USEPA, 2012).

Excess Nutrients

Excessive amounts of nutrients can come from many sources, including lawn fertilizers applied to yards and other areas, agricultural chemicals applied to fields, and fecal matter from septic fields and failing septic systems. Excess nutrients can affect both surface water and groundwater. For example, WDOE (2005) reports that 7% of public-water-supply wells have high nitrate-nitrogen levels, with many of the affected sites clustered in highly populated and rural farming areas. As a result of the input of excess nutrients, aquatic systems and the biota that depend on them have experienced several effects (WDOE, 2000). Excessive nutrients in water cause algae and phytoplankton to grow prolifically. This prolific growth results not only in increased photosynthesis, but also in increased respiration by algae, phytoplankton, and other aquatic plants, which depletes the oxygen necessary for aquatic fauna survival. An increase in numbers of algae and phytoplankton decreases light penetration, reducing the depth to which freshwater and marine aquatic plants (e.g., eelgrass) can grow, especially in lacustrine and marine environments. In turn, there are fewer aquatic plants to provide oxygen and high volumes of decomposing organic matter further consumes valuable oxygen. Although Puget Sound has two tidal cycles per day, marine waters in some areas of Puget Sound (e.g., Hood Canal) appear to be sensitive to water-quality problems that might be caused by the excess addition of nutrients because of the physical mixing characteristics in these areas (PSWQAT, 2000).

Toxic algae blooms are another result of excess nutrient input into aquatic systems. In the past, toxic algae blooms occurred in warm summer months, and in the northern part of Puget Sound; more recently, toxic blooms have resulted in closures during the winter months, they and have been reported in other areas of Puget Sound (WDOE, 2000). Certain types of algae cause Paralytic Shellfish Poisoning, also known as red tide, which affects organisms (including humans) that consume shellfish, although they seem to be harmless to the shellfish themselves.

Other Pollutants

In addition to the pollutants listed above, other contaminants have impacted aquatic (and terrestrial) habitats around the country. Hazardous waste is generated by a variety of sources. Large industries, which generate most of the hazardous waste, include (in order of decreasing contributions) equipment manufacturing, primary and fabricated metals, chemicals and petroleum, lumber and wood products, and other sources. Smaller businesses, such as dry cleaners, printers, and auto repair shops, also generate hazardous waste, which can pollute aquatic and terrestrial habitats if the waste is not handled properly.

Solid waste (i.e., trash) is generated in almost all aspects of society. As populations have grown, the amount of solid waste generation has also increased. Solid waste is generated primarily from municipal sources, and to a lesser degree from industrial and commercial waste and other sources. Leakages from landfills as well as unauthorized dumping of garbage and waste chemicals can be a problem whether they occur directly into waters or on land with the potential to impact aquatic and terrestrial habitats and the species that inhabit them.

Abiotic Indicators

In addition to the presence of contaminants, other parameters are also indicative of water quality. These indicators include (but are not limited to) temperature, dissolved oxygen, pH, turbidity, and instream flow. Many of the activities discussed elsewhere in the *Environmental Baseline* section can have effects on these indicators. For example, sediment erosion may transport substances such as pesticides or fertilizers into a stream. The addition of excess nutrients from fertilizers often result in a decrease in the levels of dissolved oxygen as described above, potentially resulting in impaired function in the stream. The excess amount of sediments introduced during an acute or chronic erosion event may also result in suspended sediment and turbidity impacts to aquatic biota, which would further stress fauna experiencing low impact levels. An increase in temperature (as a result of removal of shading riparian vegetation, for example) is another type of stressor on aquatic biota, and when such an increase occurs in concert with other impacts, the result can be devastating to aquatic biota. If conditions do not result in lethal or sublethal effects to biota, they may influence the amount of time a mobile organism spends in the affected reach of a stream.

Biotic Indicators

Certain types of organisms have been used to indicate the health of aquatic systems. The species evaluated may focus on specific concerns, such as the effects of fisheries on certain fish populations, or they may provide general information regarding water-quality trends. For example, Rockfish and Pacific herring populations have been monitored for several years by the Puget Sound Action Team (Hinman, 2005). Some rockfish populations are at less than 7 to 12% of their historical levels; the causes for their decline are not fully understood, but fishing pressure is believed to be a contributor (WDOE, 2000).

Aquatic invertebrates can also provide site-specific information on the health of aquatic systems such as streams, lakes, or estuaries. For example, protocols have been designed to assess water quality and habitats by sampling benthic invertebrates in streams (Barbour, Gerritsen, Snyder, & Stribling, 1999) and in estuarine environments (Simenstad, Tanner, Thom, & Conquest, 1991). Biological monitoring was also conducted for 31 sites throughout Washington in 2003. Biological monitoring provides better information for aquatic biota because degradation of sensitive ecosystem processes is more often detected. This type of monitoring directly measures the most sensitive at-risk resources and looks at human influence on stream characteristics over time. Of the 31 sites, data on 24 reaches were reported (Butkus, 2004). The results of this monitoring indicated that 50% of the sites were not meeting the conditions necessary for supporting the aquatic community; it was recorded that only 21% of the sites were designated as fully supportive.

Climate Change

All species discussed in this Opinion are or may be threatened by the effects of global climatic change. The Intergovernmental Panel on Climate Change (IPCC) estimated that observed global mean surface temperature for the decade 2006-2015 was 0. 87 °C (likely between 0. 75°C and 0. 99°C) higher than the average over the 1850-1900 period (IPCC, 2018). This temperature increase is greater than what would be expected given the range of natural climatic variability recorded over the past 1,000 years (Crowley & Berner, 2001). The IPCC estimates that the last 30 years were likely the warmest 30-year period of the last 1,400 years, and that global mean surface temperature change will likely increase in the range of 0. 3 to 0. 7 degrees Celsius over the next 20 years.

Warming water temperatures attributed to climate change can have significant effects on survival, reproduction, and growth rates of aquatic organisms (Staudinger, et al., 2012). For example, warmer water temperatures have been identified as a factor in the decline and disappearance of mussel and barnacle beds in the Northwest (Harley, 2011). Shifts in migration timing of pink salmon (*Oncorhynchus gorbuscha*), which may lead to high pre-spawning mortality, have also been tied to warmer water temperatures (Taylor J. A., 2008). In Yellowstone National Park climate warming has resulted in wetland desiccation which has led to declines in four amphibian species (McMenamin, Hadly, & Wright, 2008). Increasing atmospheric temperatures have already contributed to changes in the quality of freshwater, coastal, and marine ecosystems. Also, they have contributed to the decline of populations of endangered and threatened species (Karl, Melillo, & Peterson, 2009; Littell, Elsner, Whitely-Binder, & Snover, 2009; Mantua, Hare, Zhang, Wallace, & Francis, 1997).

Climate change is also expected to impact the timing and intensity of stream seasonal flows (Staudinger, et al., 2012). Warmer temperatures are expected to reduce snow accumulation and increase stream flows during the winter, cause spring snowmelt to occur earlier in the year, and reduced summer stream flows in rivers that depend on snow melt. As a result, seasonal stream flow timing will likely shift significantly in sensitive watersheds (Littell, Elsner, Whitely-Binder, & Snover, 2009). Warmer temperatures may also have the effect of increasing water use in agriculture, both for existing fields and the establishment of new ones in once unprofitable areas (ISAB, 2007). This means that streams, rivers, and lakes will experience additional withdrawal of water for irrigation and increasing contaminant loads from returning effluent. Changes in stream flow due to use changes and seasonal run-off patterns may alter predator-prey interactions and change species assemblages in aquatic habitats. For example, a study conducted in an Arizona stream documented the complete loss of some macroinvertebrate species as the duration of low stream flows increased (Sponseller, Grimm, Boulton, & Sabo, 2010). As it is likely that intensity and frequency of droughts will increase across the southwest (Karl, Melillo, & Peterson, 2009), similar changes in aquatic species composition in the region are likely to occur.

Warmer water also stimulates biological processes which can lead to environmental hypoxia. Oxygen depletion in aquatic ecosystems can result in anaerobic metabolism increasing, thus leading to an increase in metals and other pollutants being released into the water column (Staudinger, et al., 2012). In addition to these changes, climate change may affect agriculture and other land development as rainfall and temperature patterns shift. Aquatic nuisance species invasions are also likely to change over time, as ecosystems become less resilient to disturbances (USEPA, 2008). Invasive species that are better adapted to warmer water temperatures would outcompete native species that are physiologically geared toward lower water temperatures; such a situation currently occurs along central and northern California (Lockwood & Somero, 2011).

In summary, effects of climate change include increases in atmospheric temperatures, decreases in sea ice, and changes in sea surface temperatures, patterns of precipitation, and sea level. Other effects of climate change include altered reproductive seasons/locations, shifts in migration patterns, reduced distribution and abundance of prey, and changes in the abundance of competitors and/or predators. Climate change is most likely to have its most pronounced effects on species whose populations are already in tenuous positions (Isaac, 2009).

EFFECTS OF THE ACTION

The ESA regulations define "Effects of the Action" as "all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the Action, and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the Action." (50 CFR 402.02). Action "means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States or upon the high seas. (50 CFR 402.02).

For this Opinion, our analysis of the effects of the proposed registration of malathion on listed resources under the Service's purview is presented using the Approach to the Analysis described previously and further defined below in this Opinion. The *Effects of the Action* section of this Opinion is divided into several sections and subsections. First, in the *General Effects* section, we briefly summarize the anticipated toxicological effects related to the Action, including the anticipated general pathways of exposure to listed species taxa groups and their designated critical habitat. We then describe how conservation measures, including both the original measures described EPA's BE, as well as the new general and species-specific measures identified previously in the *Description of the Action* section of this Opinion (and included in Appendices A-C, A-D and A-E), are anticipated to reduce exposure and effects. We also summarize the types of anticipated responses of terrestrial and aquatic animals and plants to these general effects in the preceding subsections. We follow this analysis with a review of any cumulative effects identified for the Action. Finally, we summarize the analysis of the effects of the Action in the *Integration and Synthesis* section in the context of the status of the species and critical habitat, environmental baseline, and cumulative effects.

General Effects

The risk of malathion use to listed species is evaluated below. To determine risk, we estimated exposure and effects after carefully examining factors that may influence those parameters. In the sections *Effects* and *Exposure* below, we describe those factors and how we chose to incorporate them into our analysis. Theses sections are broadly broken into sections for Terrestrial Animals, Aquatic Animals, and Plants due to fundamental differences in how these groups of species may be exposed, and in turn, respond to malathion use. Taxa-specific information that brought meaningful information to the analysis was included wherever possible. In these sections, we refer to two analysis tools used to estimate risk, the MagTool and the R-Plot Tool, so that links can be made directly from discussions of various factors to parameterization of these tools. The Magnitude of Effect Tool[12], referenced in short-hand as the "MagTool" in this Opinion, combines toxicological information, species traits, exposure analysis and spatial results into one tool and the output generated is the percent of individuals that could be impacted under the model assumptions (described further in Appendix D). The R-Plot is a graph that displays exposure and response information for individual species for comparison. In the *Approach to the Assessment* section and in Appendix D, we describe how each of these tools

[12] September 22, 2017 version.

are used in the various data analysis. In the *Effects by Taxa* section, we describe the methodology used to integrate exposure and effects information to determine and report risk for Terrestrial Animals, Aquatic Animals, and Plants. We made the approaches parallel across these groups to the extent possible, recognizing the inherent differences in exposure and effect pathways.

As described in further detail below (see *Influence of Conservation Measures on Exposure and Effects*), the additional general and species-specific conservation measures that were developed as part of the Action after the issuance of the draft Opinion are not considered in the initial quantitative analysis. Instead, after the analysis summary, we describe how each additional conservation measure is anticipated to reduce exposure and effects to species and critical habitat that were initially predicted using the MagTool, R-Plots, and other means from the action as originally proposed[13]. The final section, *Risk Characterization*, summarizes the general findings for each taxonomic group, which also incorporates the species' response in light of the general and species-specific label changes described in the conservation measures.

Toxicological Effects

As described in the BE, malathion is an organophosphate insecticide used to kill insects systemically and on contact. As a phosphorothioate organophosphate, malathion is subject to metabolic activation within an organism into its oxon form. The rate at which a phosphorothioate pesticide is transformed to its oxon, and the rate at which the oxon is subsequently detoxified, can influence toxicity. Organophosphate toxicity is based on the inhibition of the enzyme acetylcholinesterase, which cleaves the neurotransmitter acetylcholine (AChE). Inhibition of AChE interferes with proper neurotransmission in cholinergic synapses and neuromuscular junctions. This can lead to sublethal effects (e.g., increased respiration, lethargy) and mortality. This mechanism of action is highly conserved among animal taxonomic groups (i.e., fish, mammals, birds, amphibians, reptiles, and invertebrates all possess AChE and are subject to the effects of malathion). Plants also have AChE; however, its mechanism of action is not clearly understood. Figure 5 depicts the Adverse Outcome Pathway for animals exposed to organophosphates.

[13] Due to the nature of the conservation measures, we determined that incorporating the information about these measures into the MagTool, R-Plots, and other related analyses to develop outputs would not adequately capture how these measures would reduce the likelihood or risk of exposure to listed species and critical habitat designations. . Moreover, a quantitative analysis is not required; qualitatively considering the effect of these measures is adequate for this analysis and provides ample support for our conclusions in this Opinion.

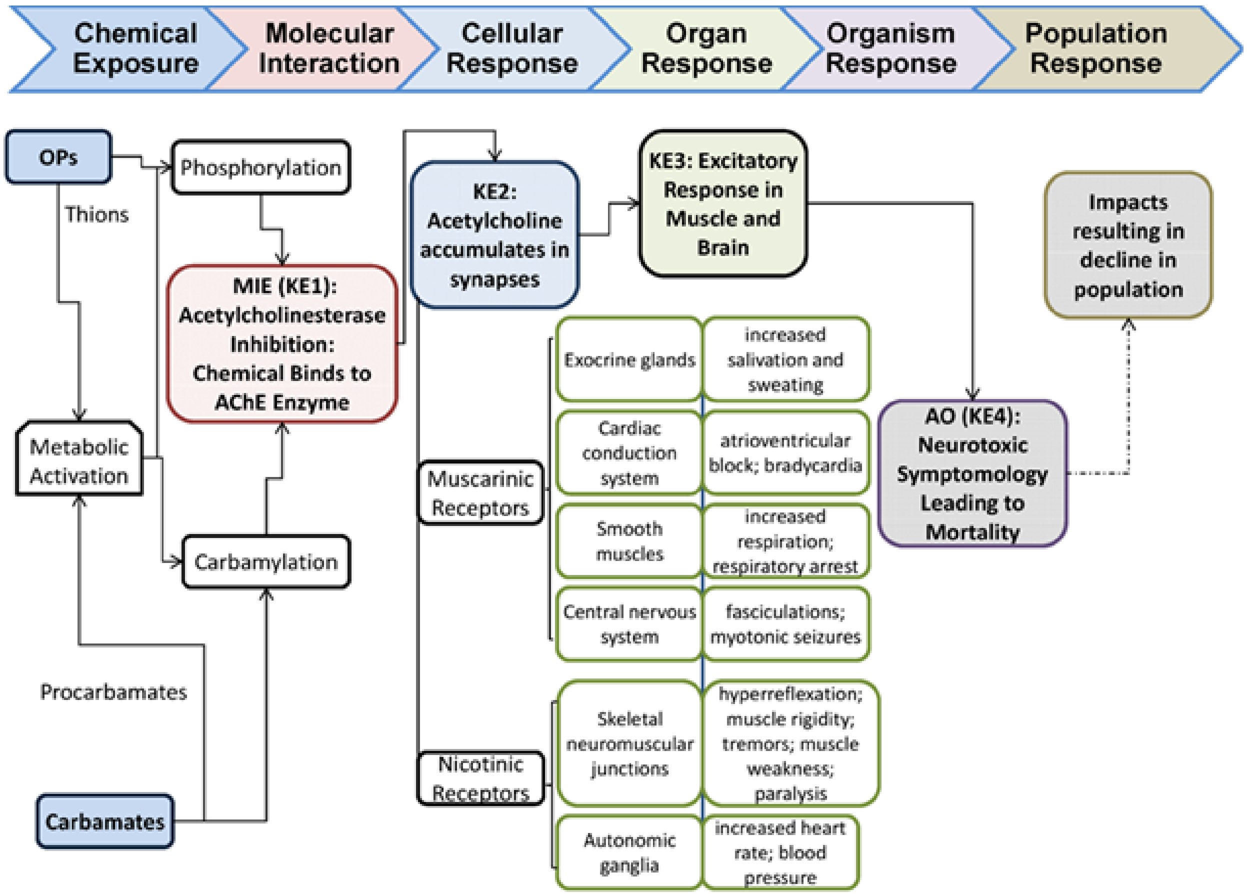

Figure 5. Adverse Outcome Pathway for Organophosphates and Acetylcholinesterase Inhibition (the figure is from (Russom, LaLone, Villeneuve, & Ankley, 2014))

Effects by Taxa

The effects of malathion have been studied extensively in many taxa, particularly in fish and aquatic and terrestrial invertebrates. Studies include acute and chronic laboratory and field studies from both registrant-submitted studies and the open literature, with either technical or formulated malathion. A technical pesticide is the pure form of a pesticide as it is manufactured prior to being formulated into an end-use product (e.g., wettable powders, granules, emulsifiable concentrates). Toxicity to taxa from exposure to other chemical stressors of concern (i.e., malathion oxon, mixtures [e.g., tank mixtures, formulated products, and environmental mixtures]), and non-chemical stressors (e.g., temperature) were also considered.

For population-level analysis, the magnitude of response of individuals to pesticide exposure is an integral piece of toxicological information. The magnitude of response or dose-response relationship describes the range of effects an organism may exhibit at different concentrations of a given chemical. This relationship can be used to assess the responses of individuals within a species, to explore differences among taxonomic levels within a given group to determine sensitivities (e.g., among fish, are Perciformes more sensitive to a given stressor than

Salmoniformes or Cypriniformes?), or to explore differences across taxonomic groups (e.g., is a fish more sensitive to a specific stressor than a bird or an insect?). The toxicity data used in Steps 1 and 2 (to inform EPA's BE) as well as other sources of relevant literature considered acceptable for the BE may be used to determine the magnitude of response in Step 3. Steps 1-3 are previously described in the section *NAS Report and Path Forward* within this opinion.

Toxicity data were divided into eight taxonomic group (i.e., mammals, birds, fish, reptiles, amphibians, aquatic invertebrates, terrestrial invertebrates, and plants) similar to those assessed in the BE. Depending on availability, we identified dose-response curves, quantitative endpoints, or other qualitative information to assess the expected biological response for multiple endpoints (i.e., direct and indirect effects[14], including mortality, behavior, reproduction and others) at predicted exposures. Where these analyses have already been performed in the BE, they have been directly carried over.

For each taxonomic group, endpoints for mortality and their accompanying slopes were selected with the goal of ensuring the sensitivity of the species being assessed was captured. Mortality endpoints include the LD_{50} ("Lethal Dose" that causes 50% mortality of test subjects), LC_{50} ("Lethal Concentration" that causes 50% mortality of test subjects), and HC values ("Hazardous Concentration" extrapolated from Species Sensitivity Distribution (SSD) curves). For LD_{50} and LC_{50} data, the most sensitive endpoint was generally chosen. For taxa with SSDs, HC_{05} values (representing the LD_{50} or the LC_{50} of the 5th percentile most sensitive species of the SSD) are generally chosen. Slopes for dose-response curves were derived from information in the BE and were either contained in the studies that generated the toxicity endpoint, contained in one of studies near the HC_{05} in the case of SSDs, or using EPA's default slope of 4.5. Data were also examined to determine if species-specific data were available or if sufficient information existed to group into finer taxonomic categories (e.g., Order or Family level) that may be more or less sensitive to toxicological effects, and therefore more or less susceptible to the impacts of the pesticide. Within the finer taxonomic groups, factors considered included the number of species, how representative they may be of listed species within the taxa, and the variability of response. The data were also examined for information related to specific life-stages and it was noted if no data were found.

A similar process was conducted for each sublethal line of evidence (i.e., growth, behavior, reproduction, and sensory). For these lines of evidence toxicity data are generally derived from hypotheses-based testing (i.e., effects observed at a limited number of doses). For this reason, rather than constructing dose-response curves, information about the magnitude of response was generally gathered from effects described at different pesticide exposure concentrations. For some taxonomic groups, a large number of studies were available for one or more line of evidence, and the entire data array presented in the BE was used. For other taxonomic groups,

[14] While our Opinion considers all consequences of the proposed action (per the definition of effects of the action at 50 CFR Part 402.02), the terms "direct" and "indirect" effects were used in EPA's BE, and are used in environmental risk assessment terminology in general, and do not have the same meaning as used in the prior ESA regulations. As used in the effects analysis section, direct effects to species are those caused by the pesticide itself through dietary, dermal, or inhalation routes of exposure. Indirect effects occur when the pesticide acts on elements of the ecosystem that are required by the species, such as alterations to prey or shelter. Thus, in the effects analysis section, we may sometimes continue to use these terms to link back to the analysis in EPA's BE.

few studies were available to describe effects for one or more line of evidence, and the magnitude of response was wholly based on those data. In other cases, no data were available to describe a line of evidence. In these cases, effects were either extrapolated from data from another taxonomic group, or that line of evidence was not carried forward, as applicable.

A description and analyses of the data available for taxonomic groups are presented below. All data referenced below are from EPA's BE. Citations in descriptions below that begin with "MRID" (Master Record Identifier) are studies submitted by registrants, and those that begin with "E" are from EPA's ECOTOXicology knowledgebase (ECOTOX). Full citations for these references can be found in EPA's BE.

General Effects to Terrestrial Species

Terrestrial species may be exposed to pesticides such as malathion through one or more routes of exposure, including ingestion, dermal absorption, or inhalation. Effects from each type of exposure can be predicted by extrapolating the results of laboratory studies. However, the difficulty in recreating natural settings and exposure routes in the laboratory limits the relevance of these studies when assessing affects to species in their natural environment. Some of these limitations, especially for terrestrial vertebrates, are discussed below, followed by a description of the available data for each taxonomic group.

Mortality

For terrestrial vertebrates, the majority of laboratory studies measure effects of toxicity from the ingestion route of exposure. This is accomplished either by providing subjects with contaminated food (concentration based, for derivation of LC_{50}'s) or by administering a single dose such as oral gavage or injection (dose-based, for derivation of LD_{50}s). Generally, only orally administered routes are considered to be environmentally relevant and directly comparable to estimated environmental concentrations (EECs), as the route of transport in the body is equivalent to how individuals would be exposed to these concentrations in the wild. However, the intraperitoneal exposure route has been demonstrated to have an absorption route with a similar circulatory pathway (initial absorption into portal system) as ingested substances for organic compounds and may be selected toxicity testing (for derivation of LD_{50}s) to avoid potential regurgitation of the administered dose in certain cases (Lukas, Brindle, & Greengard, 1971). Both dietary endpoints (LC_{50}'s) and dose-based endpoints (e.g., LD_{50}s) produced from these tests are derived in a manner that is reflective of certain aspects of how species are likely to be exposed in the wild. Both assess the sensitivity of species to potentially toxic food sources only, but not other routes of exposure (i.e., dermal or inhalation) nor other methods of ingestion such as drinking water. (We discuss our assessment of these routes of exposure below.) The LC_{50} studies provide an estimate of toxicity based on constant exposure to a set concentration of pesticide in food over a series of days, while the LD_{50} studies provide an estimate of toxicity based on a single potentially lethal exposure. Both of these methods capture a subset of conditions in which terrestrial species may be exposed to pesticides. Species in some feeding guilds such as granivores or insectivores are likely to feed and ingest pesticide throughout the day if confined to a contaminated area, while predatory or scavenging species may be exposed to a dose of a pesticide from an exposed carcass and not feed again for one or more days. However, listed species may undertake a large variety of feeding styles beyond those emulated in toxicity testing. Species with high mobility may receive intermittent doses of pesticides from feeding at different locations with varying levels of contamination. Secondary predators may get a large dose of pesticide that is neither biologically incorporated nor on the surface of prey, but in the gastrointestinal tract in its parent form (i.e., unmetabolized) (Hill & Mendenhall, 1980). Frequency or types of dietary items vary throughout the year, depending on availability, needs for migration, or reproduction. Long-distance migrators such as the red knot may gorge feed at stopover locations, then travel long distances on food stores from these events.

Laboratory tests are limited in other manners regarding representation of field exposure and effects. Most toxicity studies, including those required under FIFRA, are single stressor/single species toxicity tests that are designed to rule out the effects of all other stressors: food is accessible, mates are proximate, predators and competitors are absent, no migration is required, etc. Thus, acute sensitivity of species is determined under conditions that are largely artificial. In addition, these tests are generally not designed to capture and illustrate the consequences of sublethal responses to individual fitness. Sublethal responses, such as decreased olfactory ability, altered schooling behavior for fish, etc., may affect behaviors that cannot adequately be measured in these tests (e.g., feeding, selecting a mate, escaping predation, migrating, etc.) that would otherwise be deleterious to an individual's survival and reproduction (Golden, Noguchi, Paul, & Buford, 2012). In this sense, laboratory toxicity tests designed to be conservative in one manner (constant exposures to chemicals) do not consider many other factors when extrapolated to natural settings. It is not uncommon when reviewing field-based or mesocosm studies, including those for malathion as described in the BE, to see effects that are not measurable in standard toxicity testing (e.g., changes in community composition due to increased or decreased competition) or effects at concentrations below which have been identified in lab studies that attributable to the presence of other stressors (e.g., increased or decreased predation).

We recognize that it is not possible to emulate all exposure regimes or recreate all stressors in a laboratory setting. We acknowledge that current toxicity testing can provide some estimate of the sensitivity of species for a given exposure route and source. For the assessment of acute toxicity, where both dose-based and concentration-based data exist, while we consider all data, we often rely on the results of dose-based exposures (i.e., LD_{50}s) to produce an estimate of mortality for birds and mammals. In many cases, data exist for a greater number of species within these taxonomic groups for dose-based toxicity testing than for concentration-based testing, increasing the likelihood of including data from species with a greater range of sensitivities. This helps to reduce the uncertainty that we have captured the sensitivity of listed species, as often data exist for only a small number of species (e.g., as few as six for FIFRA-required studies) that must be extrapolated across all listed species representing varying taxonomic groups and ecological guilds. In many cases, these data vary widely, even within taxonomic groups and for individuals of the same species, suggesting that sensitivity is not easily captured by a small number of species. Dose-based studies are also coupled with taxa-specific conversion factors that have been generated from available data to convert acute mortality values across species based on body weight and food ingestion rate, increasing their accuracy when extrapolating to species with different physiological characteristics. Dose-based studies often, but not always, result in effects at lower concentrations for these taxa. This is likely attributable to a number of factors, including the greater number of species available as surrogates. This helps to account for some of the conservatism that is lost when extrapolating to field conditions, and thus provide a more accurate representation of the breadth of effects to species being assessed in the Opinion.

For reptiles and amphibians, greater uncertainty in predicting effects than for other taxonomic groups results from both a lack of toxicity testing in these species, and as well as two important values in assessing dose-based acute mortality in these taxa: (1) a scaling factor to adjust LD_{50} values across species, and (2) ingestion rates for different types of amphibians and reptiles to adjust doses across species, as described in the following paragraphs.

1. For LD_{50} values, an adjustment is made at the individual species level to account for the differences in body weight between the tested species and the assessed species. Based on our knowledge from bird and mammal studies, a straight conversion based solely on body weight will likely overestimate or underestimate the true sensitivity of the assessed species, and scaling factors have been generated for these taxonomic groups to account for this (see Attachment 1-7 of the BE for a detailed discussion). However, no scaling factors are available for amphibians and reptiles, so we make the adjustment based solely on the difference in body weight. The effect of this adjustment is illustrated in Table 11 for generic species at body weights above and below the weight of tested species. For birds and mammals, adjusted LD_{50}s for these species are within a factor of two of the LD_{50} for the test species. For amphibians and reptiles, adjusted LD_{50}s differ by a factor of 10, resulting in much higher and lower mortality estimates. Depending on what the true adjustment should be, this may result in overestimation of effects for smaller amphibians and reptiles, and underestimation for larger amphibians and reptiles.

Table 11. Scaling factor to adjust LD_{50} values across species.

TAXA	MAMMAL			BIRD			AMPHIBIANS AND REPTILES		
Body weight[15]	10 g	100 g	1,000 g	10 g	100 g	1,000 g	10 g	100 g	1,000 g
LD_{50}[16]	1.78	1	0.56	0.70	1	1.4	0.10	1	10
% Mortality[17]	13%	50%	87%	76%	50%	26%	100%	50%	0%

[15] 100 g individuals represent the weight of the tested species, and 10 g and 1,000 g individuals represent assessed species
[16] LD_{50} (calculated) for 100 g species, LD_{50} (adjusted for 10 g and 1,000 g species)
[17] Based on a slope of 4.5 and a dose of 1

2. To calculate the dose received by individual species, taxa specific factors are used to account for the individual body weight of a species and its rate of food ingestion. These values, and equations used to calculate ingestion rate and dose are provided in Attachment 1-7 of the BE. For birds and mammals, a greater breadth of species was used to derive these factors, with enough data to derive passerine- and rodent-specific factors. No factors were derived for amphibians, and a single factor was derived for reptiles, all based on iguanid lizards. This factor is used for all amphibians and reptiles. The effect of these factors is illustrated in Table 12, where ingestion rates based on these factors for generic 10 g, 100 g, and 1,000 g species of different taxa have been used to calculate a dietary dose of terrestrial invertebrates. Resulting doses for amphibians and reptiles are much lower than for birds and mammals, with less variation across body weights.

Table 12. Scaling factor to adjust ingestion rate across species.

TAXA	BIRD			MAMMAL			AMPHIBIANS AND REPTILES		
Body weight	10 g	100 g	1,000 g	10 g	100 g	1,000 g	10 g	100 g	1,000 g
Ingestion rate[18]	9.09	30.8	174	7.34	33.4	222	0.25	1.47	8.74
Dietary dose[19]	91	31	17	73	33	22	3	1	1

The effect of the uncertainty regarding these two factors for amphibians and reptiles is unknown. However, taken together, the above suggests that effects to larger species within these taxa may be underestimated using dose-based values, compared to the information we have for birds and mammals. Therefore, for these taxa we may estimate mortality from dietary-based values when they reveal greater effects.

For all taxonomic groups, we generally assess mortality using a toxicity endpoint and its corresponding slope based on either 1) the most sensitive LD_{50} or LC_{50}, or 2) the HC_{05}, where an SSD is available. While we acknowledge that listed species are generally not likely to be more inherently sensitive to pesticides than non-listed species, in most cases we lack the information to ascertain what that sensitivity may be. By choosing toxicity values that represent the most sensitive of those tested, we are more likely to ensure that we have captured the sensitivity of the species being assessed and not missed potential effects. The likelihood that we have, in fact, captured the sensitivity of any species is influenced by the number of species tested and the breadth of responses among those species.

[18] Calculated using passerine-specific values for birds weighing 10 g, rodent-specific factors for mammals weighing 10 g, and the fraction of water in an insect diet from Table A 1-7.4. in the BE
[19] Assuming a concentration in food of 100.

Sublethal endpoints: For sublethal endpoints, while all data are considered, analyses often rely on concentration-based studies. Most studies that are designed to examine sublethal effects such as growth, behavior, and reproduction are chronic dietary studies. Many endpoints carried over into our analysis are derived from registrant-submitted studies that examine these endpoints as part of long-term reproduction studies (e.g., 20 weeks for birds). Since these studies incorporate many aspects of the reproductive cycle (e.g., litter size, copulation, egg formation, parental care, growth of young), one or more responses to pesticide exposure may be incorporated into ultimate effects to reproduction. In this way, many parts of the reproductive cycle are examined, but it is often difficult to tease out specific effects or which aspect of the reproductive process was compromised. In addition, we observed some tests referenced below resulted in very high effects at the Lowest Observed Adverse Effect Concentration (LOAEC). In these cases, it is especially important to consider that effects could occur in the span of concentrations between the No Observed Adverse Effect Concentration (NOAEC) and the LOAEC.

Effects to Birds

For birds, we brought forward the mortality, growth, reproduction, and behavior lines of evidence from the BE. We are unaware of any sensory data that exist for this taxa. All data referenced below is from the Effects Characterization chapter of the BE.

<u>Mortality Line of Evidence</u>

Dose-based oral exposure

The available bird LD_{50} toxicity data for malathion represents seven species over three taxonomic Orders (Anseriformes, Galliformes, Passeriformes; see Appendix E). Reported LD_{50}s range from 136 (ring-necked pheasant; *Phasiansus colchicus*) to >2,400 mg/kg bw (canary; *Serinus canaria*), and the HC_{05} from the SSD (as presented in Appendix 2-9 of the BE) was 108 mg/kg body weight. Only one of the studies (in which age was reported) was from juveniles; that study was excluded from the SSD to achieve uniformity in age class (all adults). Toxicity data used in the SSD were sorted by Order and are displayed in Figure 6, below. Given the small number of species represented (N=6), it is difficult to draw conclusions regarding comparative sensitivity among Orders. Given the inability to discern relative sensitivity among Orders, one dose-response relationship, based on the HC_{05}, will be generally used to describe all listed bird species when considering dose-based toxicity. The only exception for this taxonomic group is the masked bobwhite (*Colinus virginianus ssp. Ridgwayi*), an endangered subspecies of the northern bobwhite (*Colinus virginianus*), which has a reported LD_{50} value of 361 mg/kg. For this species, the HC_{50} (331 mg/kg based on 100 g bird; 361 mg/kg adjusted to mass of masked bobwhite) was used to assess acute mortality.

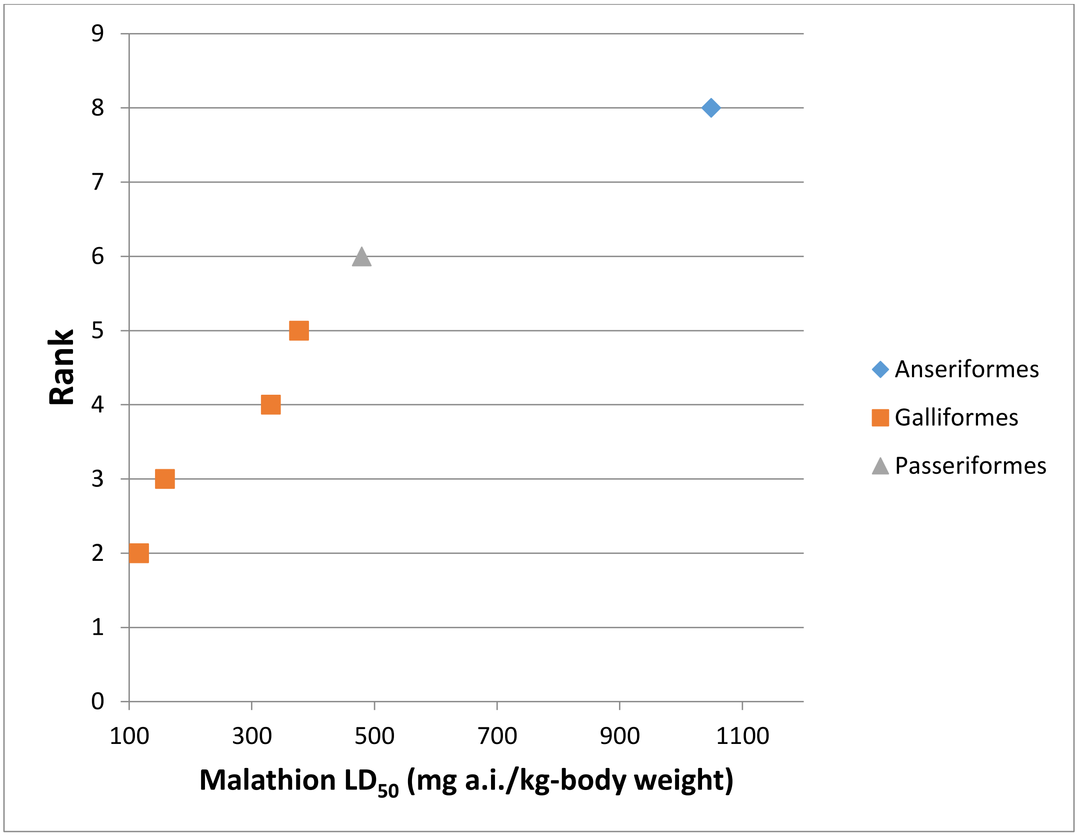

Figure 6. Rank order of bird Malathion LD_{50} values, grouped by order.

Concentration-based oral exposure

The available bird LC_{50} toxicity data for malathion represent four species over two taxonomic Orders (Anseriformes and Galliformes). Thus, there are too few species to construct an SSD (see Appendix E). Reported LC_{50}s range from 2022 (bobwhite quail) – >5850 mg/kg (mallard duck). Toxicity data were sorted by Order and are displayed in Figure 7. Given the small number of species tested, it is difficult to draw conclusions regarding comparative sensitivity between Orders. While the two LC_{50}s for Anseriformes both reveal less sensitivity to malathion, both studies represent a single species, the mallard duck. Given the inability to discern relative sensitivity among Orders, one dose-response relationship will generally be used to describe all listed bird species, based on the lowest LC_{50}. The only exception for this taxonomic group is the masked bobwhite (*Colinus virginianus* ssp. *ridgwayi*), an endangered subspecies of the northern bobwhite (*Colinus virginianus*), which is represented by two LC_{50} values of 2022 and 3497 mg/kg. For this species, the lowest LC_{50} of 2022 mg/kg available for bobwhite quail will be used when considering concentration-based toxicity.

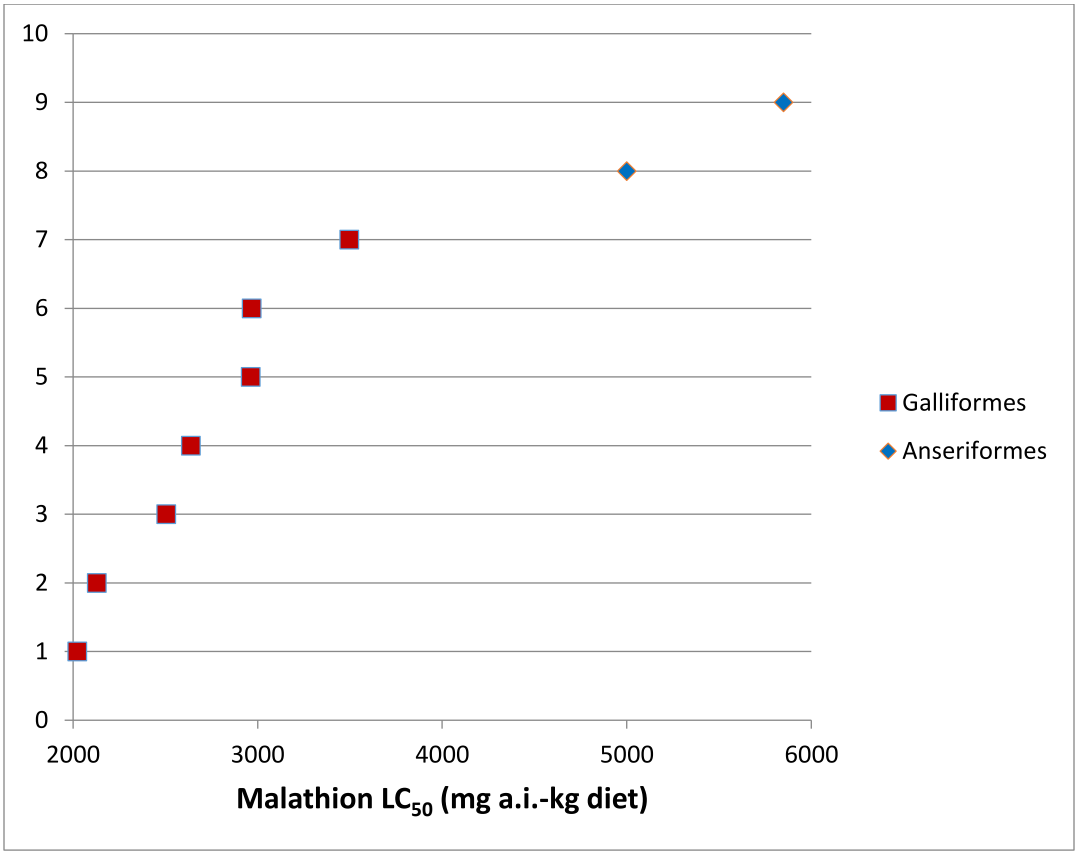

Figure 7. Rank order of bird Malathion LC_{50} values, grouped by Order.

Reproduction Line of Evidence

The chronic toxicity of malathion was evaluated in laboratory-based avian reproduction studies using the bobwhite quail and mallard duck; these studies are designed to estimate the quantity of toxicant required to adversely affect the reproductive capabilities of a test population of birds. Malathion is administered by incorporating it into the mixture of the breeding birds' diets throughout their breeding cycle. Test birds approach their first breeding season at 18 to 23 weeks old. The onset of the exposure period is at least 10 weeks prior to egg laying. Exposure period during egg laying is generally 10 weeks with a withdrawal period of three additional weeks if reduced egg laying is noted. Results from these studies, as well as one study from the open literature carried over from the BE, are summarized below (Table 13). One study with northern bobwhite observed effects in adults at necropsy in birds fed 350 ppm malathion, including regressed ovaries and abnormally enlarged/flaccid gizzards. At 1,200 mg a.i./kg-food, in addition to the above effects, decreases of approximately 75% from the untreated control group were observed in egg production and egg viability, and eggshell thickness was decreased by about 15%, which may have caused the increased number of cracked eggs. Endpoints and effect levels from this study were the primary source of information used to characterize reproductive effects of malathion to birds. One study in mallards found no effects at concentrations up to 1,200 ppm, and effects to egg viability and eggshell thickness at 2,400 ppm. An additional study in domestic chickens observed only hen-day egg production. It was determined that no effects on egg production were observed when domestic chickens were exposed to concentrated feed of 15 - 475 mg a.i./kg-food between day 28 to day 252.

Table 13. Reproductive effects in birds exposed to malathion (from BE Table 6-7).

Test species	Reproductive effects observed at LOEC (percent of control)	NOEC/LOEC (mg a.i./kg-food)	Test material	Source
Bobwhite Quail	1. Regressed ovaries and enlarged flaccid gizzards during necropsy	110/350	TGAI	MRID 43501501
(This study found effects at one dosing level higher than the LOEC)	2. Decrease in number of eggs laid (75%) 3. Decrease in egg viability (~75%) 4. Decrease in eggshell thickness (15%)	1,200 (dosing level above LOEC)		
3. Decrease in egg viability (~75%)	1. Decrease in male body weight 2. Decrease in eggshell thickness 3. Decrease in egg viability	1,200/2,400	TGAI	MR2101
4. Decrease in eggshell thickness (15%)	1,200 (dosing level above LOEC)	100/none	TGAI	ECOTOX 38417

Summary for MagTool Input – Reproduction

We combined the above data regarding reproductive effects in birds to create four categories of effects based on exposure concentrations, as shown in Table 14 below.

Table 14. Four Categories of Reproductive Effects in Birds Based on Exposure Concentrations.

Exposure Concentration (mg of chemical/kg of body mass)	Avian Reproductive Effects
0 - 110 mg/kg	No effects
110 - 350 mg/kg	Regressed ovaries and abnormally enlarged/flaccid gizzard possible
350 - 1200 mg/kg	Regressed ovaries and abnormally enlarged/flaccid gizzards. Possible reductions in egg production and egg viability (<75%), embryo survival, and eggshell thickness (<15%).
1,200 mg/kg and above	Regressed ovaries and abnormally enlarged/flaccid gizzards. Decreases in egg production and egg viability (≥75%), embryo survival, and eggshell thickness (≥15%). Increased number of cracked eggs.

Growth Line of Evidence

The available avian growth data for malathion include twelve studies representing five species – the domestic chicken, mallard, northern bobwhite, ring-necked pheasant, and canary (see Appendix E). Effects on body weight were observed at dietary concentrations as low as 475 and 551 mg/kg for the domestic chicken and pheasant, respectively. Decreased body weight was observed with dietary concentrations as low as 800 mg/kg in the chicken, 1,010 mg/kg in the pheasant, 1,200 mg/kg in the bobwhite, and 2,400 mg/kg in the mallard. Acute oral exposure as low as 105 mg/kg body weight resulted in decreased female body weight in pheasants, and a reduction in food consumption at 600 mg/kg in the canary.

Summary for MagTool Input – Growth

We combined the above data regarding growth effects in birds to create three categories of effects based on exposure concentrations, as shown in Table 15 below.

Table 15. Three Categories of Growth Effects in Birds Based on Exposure Concentrations

Exposure Concentration (mg of chemical/kg of body mass)	Avian Growth Effects
0 -304 mg/kg	No effects

Exposure Concentration (mg of chemical/kg of body mass)	Avian Growth Effects
304 - 551 mg/kg	Possible decrease in body weight gain
551 mg/kg	Decreased body weight gain

Behavior Line of Evidence

The available avian behavior data for malathion includes information from two dietary exposure studies, in the domestic chicken and ring-necked pheasant. Behavioral effects to birds were assessed using data from the ring-necked pheasant study, where no effects were observed in individuals exposed at 1,010 mg/kg-diet and numerous effects observed at 1,730 mg/kg-diet, including ruffled appearance, lethargy, wing droop, loss of coordination, depression, lower limb weakness, loss of righting reflex, and prostrate posture.

Summary for MagTool Input - Behavior

We combined the above data regarding behavioral effects in birds to create three categories of effects based on exposure concentrations, as shown in Table 16 below.

Table 16. Three Categories of Behavioral Effects in Birds Based on Exposure Concentrations

Exposure Concentration (mg of chemical/kg of body mass)	Avian Behavioral Effects
0 - 1,010 mg/kg	No effects
1,010-1,730 mg/kg	Effects to behavior possible, including ruffled appearance, lethargy, wing droop, loss of coordination, depression, lower limb weakness, loss of righting reflex, and prostrate posture
1,730 mg/kg	Effects to behavior anticipated, including ruffled appearance, lethargy, wing droop, loss of coordination, depression, lower limb weakness, loss of righting reflex, and prostrate posture

Incident Reports

EPA’s BE described two incident reports of mortality related to malathion for birds. In one reported incident, 17 western sandpipers were killed, and the birds also were exposed to temephos, an insecticide that is much more toxic to birds than malathion. It is uncertain how much exposure to malathion contributed to these mortalities. In another incident, in Georgia, 37 grackles exhibited severe neurologic signs and died. Ten additional grackles were reportedly found dead approximately three miles west of the area the following day. Malathion was detected in the gastrointestinal content of the birds. Brain cholinesterase activity was not reduced. Corn and grit were observed in the proventriculum and ventriculum of the four birds examined. The possibility that the birds were intentionally poisoned is possible as very little corn is grown in this area.

Effects to Reptiles

Insufficient toxicity data are available for reptiles exposed to malathion to extrapolate to listed species within this class. Therefore, the toxicity data for birds will be used as a surrogate for reptiles since reptiles are more closely related to birds than other broad taxa groups (such as mammals, arthropods, etc.). There is a notable uncertainty in this approach as the relative sensitivities between birds and reptiles are unknown.

<u>Incident Reports</u>

EPA's BE described one incident for malathion for reptiles from a spill of this pesticide (alleged dumping in North Carolina) in 2003 in which mortality was observed for turtles, snakes (species and number unknown), and fish.

Effects to Terrestrial Amphibians

Insufficient toxicity data are available for terrestrial amphibians exposed to malathion to extrapolate to listed species within this class. Therefore, the available toxicity data for birds will be used as a surrogate for terrestrial amphibians as the science indicates effects to birds are more representative for amphibians than effects observed in other broad taxa groups (such as mammals, arthropods, etc.). There is notable uncertainty in this approach as the relative sensitivities between birds and amphibians are unknown. We are unaware of any incident data related to terrestrial amphibians.

Effects to Mammals

For mammals, the mortality, growth, reproduction, and behavior lines of evidence are brought forward from the BE. No sensory data exist for mammals. The majority of the studies were conducted with standard mammalian test species (i.e., mice or rats) for human health risk assessments. All data referenced below is from the Effects Characterization chapter of the BE. Additionally, an overview of incident reports is also included in this section.

<u>Mortality Line of Evidence</u>

Dose-based oral exposure:

The available data set for mortality effects to mammals includes 22 studies, representing four species (rat, mouse, domestic sheep, and water buffalo). The LD_{50} values within the available data generally spanned a large range of concentrations. As the mammalian acute toxicity data was only available for four species, this did not allow for a calculation of a species sensitivity distribution. Based on the available data, the most sensitive mammalian LD_{50} for malathion with known chemical purity is 1,560 mg/kg-bw based on a rat acute mortality study (MRID 49127003). We converted a concentration-based mortality value from the lowest dose-based to dietary-based using the method described in the BE.

Growth Line of Evidence

Effects on growth are observed in several registrant-submitted studies, including effects on body weight and body weight gain. Additionally, alterations in organ weights are reported for several studies. There were 22 studies with reported effects for three species (i.e., rat, mouse, rabbit Figure 9-3 of the BE). The most sensitive growth endpoint from malathion dietary-based studies (excluding alterations in organ weight) was a 14% decrease in pup body weight on lactational day 21 at 5,000 mg a.i./kg-diet (NOAEL of 1,700 mg a.i./kg-diet) in the two-generation reproduction study in the rat (MRID 41583401).

Summary for MagTool Input – Growth

We combined the above data regarding growth effects in mammals to create three categories of effects based on exposure concentrations, as shown in Table 17 below.

Table 17. Three Categories of Growth Effects in Mammals Based on Exposure Concentrations

Exposure Concentration (mg of chemical/kg of body mass)	Mammalian Growth Effects
0-1,700 mg/kg	No effects
1,700 - 5,000 mg/kg	Effects to growth possible
5,000 mg/kg and above	Effects to growth

Reproduction Line of Evidence

Several studies are available that investigate the reproductive effects of malathion on mammals (Figure 9-4 in the BE). The effects (from 7 different studies) were primarily concerning alterations in sperm or developmental endpoints regarding alterations in implantations or reabsorbed embryos (MRID 00152569, 40812001). The endpoints used to parameterize the terrestrial MagTool for assessing reproductive effects to mammals showed an increase in mean percent of reabsorbed embryos in rabbits (NOAEC 825 mg/kg, LOAEC 1,650 mg/kg, MRID 00152569).

Summary for MagTool Input – Reproduction

We combined the above data regarding reproductive effects in mammals to create three categories of effects based on exposure concentrations, as shown in Table 18 below.

Table 18. Three Categories of Reproductive Effects in Mammals Based on Exposure Concentrations

Exposure Concentration (mg of chemical/kg of body mass)	Mammalian Reproductive Effects
0 – 825 mg/kg	No effects
825 - 1,650 mg/kg	Effects to reproduction possible, increase in mean percent of reabsorbed embryos in rabbits
5,000 mg/kg and above	Effects to reproduction, increase in mean percent of reabsorbed embryos in rabbits

Behavior Line of Evidence

Behavioral effects in mammals are reported for nine studies in the rat and two in the mouse. The effects include alterations in general activity, feeding behavior, and grip strength. All reported behavior effects endpoints are displayed in Figure 9-5 of the BE. The available data on effects to behavior generally spanned a large range of concentrations, from 32 mg a.i./kg-bw (E153607), to 4,395 mg a.i./kg-bw (MRID 43146701). The data used to parameterize the terrestrial MagTool for behavioral effects captured the most sensitive endpoint, which was a LOAEL of 32 mg a.i./kg-bw based on alterations in general activity in the Norway rat (adjusted for dose-based and a 15-g animal: 640 mg/kg in study diet-based) (E153607).

The highest behavior effect endpoint reported was also alterations in general activity in the rat at 4,395 mg a.i./kg-bw (adjusted for 15 g (2,000 mg a.i./kg-bw; NOAEL=1,000 mg a.i./kg-bw, MRID 43146701). A 49% decrease in muscular strength/coordination (grip strength) were reported at 100 mg/kg-bw in rats after 4 days of exposure to malathion (49.7% formulation) by oral gavage compared to control (E162509); a 50% decrease reported at high dose of 200 mg/kg-bw.

Summary for MagTool Input – Behavior

We combined the above data regarding behavioral effects in mammals to create two categories of effects based on exposure concentrations, as shown in Table 19 below.

Table 19. Two Categories of Behavioral Effects in Mammals Based on Exposure Concentrations

Exposure Concentration (mg of chemical/kg of body mass)	Mammalian Behavioral Effects
0 – 640 mg/kg	Effects to behavior (i.e., alterations in general activity in rats) possible
640 mg/kg and above	Effects to behavior (i.e., alterations in general activity in rats)

Incident Reports

As described in the BE, EPA's Ecological Incident Information System (EIIS) database, accessed October 26, 2015, contained only one incident associated with malathion use and mortality of mammals with a certainty level of "possible," as defined in the EIIS database. Mortality of 10 fox squirrels was reported, and the squirrels also were exposed to zinc phosphide, a rodenticide which frequently causes mortality of nontarget mammals. Additionally, the Aggregate Incident Reports database identified an additional four incidents linked to malathion use as aggregated counts of minor fish/wildlife incidents (accessed October 26, 2015). Because details about these incidents were not reported, no information was available on the use site, the certainty level, or on the types of organisms that were involved.

Effects to Terrestrial Invertebrates

Malathion is an insecticide used to kill a broad range of insects. As an insecticide, malathion's effects on terrestrial invertebrates have been well documented in the literature. Most available studies have focused on mortality endpoints; however, there are also data available for describing sublethal effects, including those related to growth, behavior, and reproduction. EPA designated all terrestrial invertebrates as a taxonomic group in the BE and described the group as: all insects with a terrestrial lifecycle, spiders and their relatives, and strictly terrestrial gastropod mollusks.

Given the wide breadth of taxa within this category, we made several assumptions based on the known effects of the action to this wide array of species. First, we assumed that the toxicity data available were applicable to all three taxa groups within this category based on data from the available literature. Similar to our approach for other taxa (i.e., mammals, birds) assessed for this Opinion, we chose the most sensitive LD_{50} (48-hour LD_{50} from a study on Hymenoptera, discussed in more detail below) to parameterize the terrestrial R-plots (see General Definition in *General Effects*) for direct effects to terrestrial invertebrates. We chose this endpoint for the following reasons: limited toxicity data for some invertebrate groups (i.e., families, sub-families), which may not be sufficient enough to explain the range of effects (or sensitivity) to all the listed species within that taxa group; insufficient data for taxonomic groups to construct an SSD; a wide range of within-Order variability across a limited number of studies; insufficient data reported for a particular unit of exposure; and, in some cases, concentration units that could not be converted to units comparable to the exposure units this taxa group would see on the landscape (EECs).

Given that terrestrial invertebrates are the target organism for the effects of malathion, these species are likely to experience mortality prior to any sublethal effects occurring. As such, sublethal effects were not pursued for this analysis at this time, although in some instances we list this information below when it was available. The mortality toxicity data we used to assess the effects of malathion are provided below, along with a discussion of the available incident reports for malathion and terrestrial invertebrates.

The available toxicity data for terrestrial invertebrates are based on experimentally determined endpoints for malathion based on varying durations, exposure routes, and study designs. All data referenced below are from the Effects Characterization chapter (and appendices) of the BE.

<u>Mortality Line of Evidence (µg/g-bw)</u>

The majority of the toxicity data available for malathion and terrestrial invertebrates involve mortality endpoints. In all cases, mortality is the most sensitive endpoint available for the different environmentally relevant exposure units. EPA based the toxicity values and data arrays in the BE on endpoints expressed in, or readily converted to, the following exposure units: microgram per gram body weight (µg/g bw), microgram per organism (e.g., µg/bee or µg/larvae), microgram per gram substrate (µg/g substrate), or microgram per gram dry food (µg/g dry food). These are the only units considered in this Opinion.

For the exposure unit ‘µg/g-bw’, the most sensitive endpoint available for terrestrial invertebrates is an LD_{50} value of 0.156 µg a.i./bee for the honey bee (*Apis mellifera*) (MRID 49270301), converted to 1.22 µg a.i./g-bw based on the standard body weight of the honey bee.

Mortality and sublethal effects, including immobility and lethargy, were observed at 2.25, 3, 24 and 48 hours. Results are provided in Table 10-2 from the BE (see also in Appendix E).

<u>Registrant-submitted Terrestrial Invertebrate Toxicity Data</u>

Because of the complexities associated with the terrestrial invertebrate toxicity data available in the open literature and screened through ECOTOX (e.g., variable methodologies, exposure routes, exposure units, species), we provide a brief discussion of the available guideline studies conducted with honey bees and submitted by the registrants below. This discussion is meant to provide context for the available terrestrial invertebrate toxicity values for malathion.

Based on the submitted data, malathion is classified as very highly toxic to bees. The LD_{50} values from the acceptable acute honey bee (contact) studies are 0.27 µg a.i./bee (MRID 05001991), 0.25 µg a.i./bee (MRID 05001451), 0.709 µg a.i./bee (MRID 0001999), 0.46 µg a.i./bee (MRID 05008990), 0.189 µg a.i./bee (MRID 49270301) and 0.3662 µg product/bee (MRID 49051205; 42% a.i.) (Table 10-7 from the BE). Additionally, the LC_{50} values from the acceptable acute honeybee (oral) studies are 0.38 µg a.i./bee (MRID 05001991), 0.38 µg a.i./bee (MRID 05001451), 1.66 µg a.i./bee (MRID 49270302) and 0.9635 µg product/bee (MRID

49051205; 42% a.i.). Results are provided in Table 10-7, are taken from the BE (see also Appendix E in this Opinion; Toxicological Data from the Malathion BE).

Incident Reports for Terrestrial Invertebrates

In their BE, EPA reported 11 terrestrial invertebrate incident reports (all for bees) in the EIIS with a certainty index of “unlikely,” “possible,” “probable,” or “highly probable.” Of these 11 incidents, three are from a registered use; in eight of the incidents, the legality of use was undetermined. The dates of the incident reports range from 1985 to 2015. All of the terrestrial invertebrate incident reports involve honey bees with honey bees being exposed via spray drift. Most of the honey bee incidents are associated with agricultural uses; however, there is one honey bee incident reported in a residential area and one honey bee incident reported in a greenhouse. In most cases, the malathion product involved in the incident is not specified.

General Effects to Aquatic Species

Listed aquatic species that may be affected by malathion in aquatic habitats include fish, amphibians (aquatic phases), and various taxa of aquatic invertebrates (i.e., aquatic insects, crustaceans, and mollusks). For those species that are exclusively aquatic, all life stages may be affected by exposure to malathion in water. Some species of aquatic insects (e.g., dragonflies, damselflies, and stoneflies) and amphibians (e.g., frogs, toads, and some salamanders) have both aquatic and terrestrial life stages and may therefore be affected by exposures in either aquatic or terrestrial habitats, or both. Certain species also have obligate relationships with other species. For example, early life stages of freshwater mussels (glochidia) are parasitic and require a host fish to complete their development. Consequently, we also assess the potential effects of malathion on host fish in the effects analyses for mussels. Similarly, effects to a listed species from impacts to their food items (such as aquatic invertebrates or prey fish) were included in our analyses.

Most of the available toxicity data provided in the BE for aquatic species are from laboratory tests, conducted under controlled conditions where organisms are exposed to malathion in water (typically over a range of concentrations) for set durations (e.g., 1 hour, 1 day, 4 days, 21 days, or full life cycle) and the desired measurement endpoints (e.g., mortality, growth, behavioral response, sensory function, olfaction, fecundity, spawning/hatching success) are reported. These types of tests are valuable for establishing causal relationships between exposure to the pesticide and response of the organism to that exposure. At the same time, such tests are limited regarding representation of field exposure and effects. Most toxicity studies, including those required under FIFRA, are single stressor/single species toxicity tests that are designed to rule out the effects of all other stressors: food is accessible, mates are proximate, predators and competitors are absent, no migration is required, etc. Thus, acute sensitivity of species is determined under somewhat ideal conditions. In addition, these tests are generally not designed to capture and illustrate the consequences of sublethal responses to individual fitness. Sublethal responses such as decreased olfactory ability, altered schooling behavior, etc., may affect fitness in ways that cannot be adequately measured in these tests (e.g., feeding, selecting a mate, escaping predation, migrating, etc.) (Golden, Noguchi, Paul, & Buford, 2012). In this sense, laboratory toxicity tests that are designed to be conservative in one manner (constant exposures to chemicals) do not consider other factors when extrapolated to natural settings. It is not uncommon when reviewing field-based or mesocosm studies, including those for malathion as described in the BE, to see effects that are not measurable in standard toxicity testing (e.g., changes in community composition due to increased or decreased competition) or effects at concentrations below which have been identified in lab studies that attributable to the presence of other stressors (e.g., increased or decreased predation).

The breadth of toxicity data, in terms of species and taxa representation, available for our effects assessment for listed species (from the BE) was based on studies generated by registrants as well as open literature studies and government reports retrieved through ECOTOX. As a result, there tends to be an abundance of data for taxa that are more commonly tested or required for regulatory purposes (i.e., fish, aquatic insects, and aquatic crustaceans), compared to less well-studied taxa, such as mollusks (including mussels and snails) and amphibians. Similarly, within taxa, there may be numerous studies for common aquatic test species, such as rainbow trout (*Oncorhynchus mykiss*), fathead minnow (*Pimephales promelas*), bluegill (*Lepomis macrochirus*), sheepshead minnow (*Cyprinodon variegatus variegatus*) , water flea (*Daphnia* spp.), or the amphipod *Hyalella azteca*, but fewer studies for species representing other genera, families, or orders. As a result, the taxa for which toxicity data are available may or may not be strong surrogates for listed species. Considering the high variability in toxicity values between species for some taxa groups (e.g., four orders of magnitude difference between the highest and lowest fish acute mortality data or LC_{50}'s), it is important that we take this uncertainty into account when assessing risks to listed species.

Our approach to applying the acute mortality data (LC_{50}s) for assessing lethal effects to listed species in the mortality line of evidence relies on the SSDs developed in the BE (Attachment 1-5 of the BE), when available. The HC_{05} (from the SSD) and its corresponding slope is generally used to assess mortality for each taxonomic group. When an SSD was not available we used the lowest (most sensitive) LC_{50}. While we acknowledge that listed species are not likely to be more inherently sensitive to pesticides than non-listed species, in most cases, we lack the information to ascertain what that sensitivity may be. By choosing these values, we are more likely to ensure that we have captured the sensitivity of a species and not missed effects. The likelihood that we have, in fact, captured the sensitivity of any species is influenced by the number of species tested and the breadth of responses among those species.

Unlike the acute mortality data, sublethal effects endpoints were largely reported as NOAECs and LOAECs for a variety of measurement endpoints and species within each effect category (i.e., growth, reproduction, behavior, sensory function). Consequently, EPA organized these data as effects arrays in the BE. Depending on the taxonomic group, we used these arrays to assess the likelihood or risk of species experiencing sublethal effects as a result of exposure to malathion.

Effects to Fish and Aquatic-Phase Amphibians

Malathion has been well studied in fish and to a lesser extent in aquatic-phase amphibians. For our effects analysis, we are relying on toxicity data carried forward from the BE. Overall, there were numerous reports on the acute lethality of malathion to fish and several studies that addressed sublethal effects on growth and behavior. Relatively few studies reported effects on reproduction, and there was only one study from the BE that tested effects on sensory function. For aquatic-phase amphibians, there were limited numbers of studies, and few species tested; for some lines of evidence, no data were available. Consequently, we generally applied the fish toxicity endpoints as surrogates for aquatic-phase amphibians and will discuss both taxa groups together in this section. The toxicity data utilized to assess the effects of malathion are provided below, along with a discussion of the available incident reports for malathion for these species. All data referenced in the following sections are from the *Effects Characterization* chapter of the BE.

Mortality Line of Evidence

Acute mortality data (96-hour LC_{50} data) that EPA compiled for the BE included LC_{50} values for 13 orders of fish with 66 different species, and 1 order of aquatic-phase amphibians (Anura) with 8 different species (Appendix E). For fish, the acute mortality data encompassed a wide concentration range, from 4.1 to 448,000 µg/L. Toxicity values for amphibians ranged from 0.59 to 38,000 µg/L. There was also considerable variation within taxa orders as well as substantial overlap between orders. The Salmoniformes, Perciformes, Gasterosteiformes, and Cyprinodontiformes orders had the lowest fish toxicity values.

In Chapter one of the BE, EPA described uncertainties regarding malathion toxicity data due to toxic impurities that have been identified in malathion source material. They conducted an analysis of this uncertainty and concluded that there was not compelling information to exclude toxicity data at this time solely due to source of technical malathion or date of study conduct. However, when developing the SSD for acute mortality, EPA only used LC_{50} values from toxicity studies where information about the test material source/impurity profile was known. The available data for the SSD became limited to 10 species (9 fishes and 1 amphibian).

Because of the limited number of species included in the SSD, the large range in LC_{50} values for fish and aquatic-phase amphibians, the high variability within orders, and the overlap among orders, we relied on the HC_{05} value from the SSD for all aquatic vertebrates from EPA's BE (20.9 ug/L) as an input to the R-Plots for estimating acute lethal effects on listed fish and aquatic-phase amphibian species (see Table 20 and Table 23) for fish and aquatic-phase amphibians, respectively).

Growth Line of Evidence

There were 40 studies in the BE for effects of malathion on fish growth representing 14 species of fish (BE Appendix 2-1). The growth endpoints reported in the BE included: alterations in weight, length, biomass, condition factors; changes in growth rates; morphological changes in organ weight; and abnormal development were also reported. Effects on metamorphosis were reported for aquatic-phase amphibians.

For fish, the range of exposure concentrations with reported growth effects range from 10.9 µg/L to 3,510 µg/L. The lower value is from a life-cycle study using the freshwater flagfish (*Jordanella floridae*) where the mean body length in the parental (F0) generation, after 30 days of exposure, was significantly reduced by 11% or more at ≥10.9 µg/L with a NOAEC value of 8.6 µg/L. We used both the lowest LOAEC (10.9 ug/L) and the geometric mean of the LOAECs (923 µg/L) as inputs for estimating the risk of growth effects to listed fish species using the R-Plots (see Table 21 below).

For aquatic-phase amphibians, we use the most sensitive toxicity value for growth of 320 ug/L (i.e., no effect on survival, growth [body weight/length], metamorphosis stage after 21-day exposure at all test concentrations for the African clawed frog, *Xenopus laevis*) from BE Table 2-2, as well as the growth endpoints for fish (see Table 24 below).

Reproduction Line of Evidence

There are limited data evaluating malathion effects on reproduction for fish. Reproduction data were not available for aquatic-phase amphibians; therefore, toxicity data for fish will be used as a surrogate for amphibians. In a 21-day screening assay with newly sexually mature fathead minnows (*Pimephales promelas*), fecundity was significantly decreased by 48% at 690 µg a.i./L compared to control; no significant difference in fecundity was observed at 220 µg a.i./L (MRID 48617506). In this study, at 690 µg a.i./L, alterations in male and female gonadal histopathology, increases (21%) in female gonadal-somatic weight, and decreases in male secondary sex characteristics were also observed, as well as clinical signs of toxicity including erratic swimming, loss of color, and lethargy. We used the NOAEC (690 ug/L) and the LOAEC (220 µg/L) as inputs for estimating the risk of reproductive effects to listed fish and aquatic-phase amphibian species using the R-Plots (see Table 21 and Table 24 for fish and aquatic phase amphibians, respectively).

Behavior Line of Evidence

Reported behavioral endpoints include alterations in swimming, activity, and ability to perform an acquired task such as pursuing and capturing prey items. Effect concentrations range from 20 or 40 µg/L for locomotion (distance moved, swimming) in rainbow trout and up to 4750 µg/L for accuracy of learned task for goldfish. We used the lowest fish LOAEC (20 µg/L) and geometric mean of the LOAECs (269 µg/L) as inputs for estimating the risk of behavioral effects to fish and aquatic-phase amphibians using the R-Plots (see Table 21 below).

Sensory Line of Evidence

The sensory line of evidence was not included in the BE and was therefore not assessed in our Opinion. There is only one sensory study in which no effect on chemical avoidance in sheepshead minnow was reported at 1.0 mg/L (1-hour duration), and resulted in an unbounded NOAEC; no test organisms showed a response.

Summary of R-Plot Inputs

The following information was included in the R-Plot inputs (Tables 20-25).

Table 20. Fish: Risk of Mortality

Inputs[20]		Description of Effect	
Endpoint*	**µg/L**	**Slope**	
All Aquatic Vertebrates HC_{05}	20.9	3	Risk of mortality to individuals (based on the HC_{05} LC_{50} from the All Aquatic Vertebrates SSD from the BE)

Table 21. Fish: Sublethal Effects

Sublethal Effect	Endpoint	µg/L	Description of Effect	Risk
Growth	Lowest LOAEC	10.9	mean body length reduced 11% or greater at concentrations ≥ 10.9 ug/L (flagfish) (E995, MRID 4878002)	EECs > 10.9 µg/L: individuals may be at risk of experiencing effects on growth
Growth	Geometric Mean LOAECs	923		EECs > 923 µg/L: individuals may be at high risk of experiencing effects on growth
Behavior	Lowest LOAEC	20	general behavior changes and effects on swimming: rainbow trout	EECs > 20 µg/L: individuals may be at risk of experiencing behavioral effects
Behavior	Geometric Mean LOAECs	269		EECs > 269 µg/L: individuals may be at high risk of experiencing behavioral effects
Reproduction	NOAEC	220		EECs > 220 µg/L: it's possible that individuals may be at risk of experiencing effects on reproduction

[20] the HC_{50} values for All Aquatic Vertebrates from the BE (315 µg/L: slope 4.5) will be included.

Sublethal Effect	Endpoint	µg/L	Description of Effect	Risk
Reproduction	LOAEC	690	statistically significant 48% decrease in fecundity: 21-d reproduction screening assay w/fathead minnow	EECs > 690 µg/L: individuals may be at risk of experiencing effects on reproduction

Table 22. Fish: Effects to Prey

Inputs				
Indirect Effect	**Endpoint**	**µg/L**	**Slope**	**Description of Effect**
Aquatic Invertebrate Prey – Mortality	All Aquatic Invertebrate HC_{10} LC_{50}	1.7	4.5	Risk of mortality to aquatic invertebrate prey
Fish Prey – Mortality	All Aquatic Vertebrates HC_{10} LC_{50}	34	4.5	Risk of mortality to prey fish

Table 23. Aquatic-phase amphibians: Mortality

Inputs			
Endpoint	**µg/L**	**Slope**	**Description of Effects**
All Aquatic Vertebrate HC_{05}	20.9	3	Risk of mortality to individuals (based on All Aquatic Vertebrate HC_{05} LC_{50})

Table 24. Aquatic-phase amphibians: Sublethal effects

Inputs				Risk
Sublethal Effect	**Endpoint**	**µg/L**	**Description**	
Growth	Lowest fish LOAEC	10.9	mean body length reduced 11% or greater at concentrations ≥ 10.9 ug/L (flagfish) (E995, MRID 4878002)	EECs > 10.9 µg/L: individuals may be at risk of experiencing effects on growth
	Geometric Mean fish LOAECs	923		EECs > 923 µg/L: individuals may be at high risk of experiencing effects on growth
	No effect	320	no effect on survival, growth (body weight/length), metamorphosis stage after 21- d exposure at all test concentrations (African clawed frog)	N/A
Behavior	Lowest fish LOAEC	20	general behavior changes and effects on swimming: rainbow trout	EECs > 20 µg/L: individuals may be at risk of experiencing behavioral effects
	Geometric Mean fish LOAECs	269		EECs > 269 µg/L: individuals may be at high risk of experiencing behavioral effects
Reproduction	Fish NOAEC	220		EECs > 220 µg/L : it's possible that individuals may be at risk of experiencing effects on reproduction
	Fish LOAEC	690	statistically significant 48% decrease in	EECs > 690 µg/L : individuals may be at risk of

Inputs				Risk
Sublethal Effect	**Endpoint**	**µg/L**	**Description**	
			fecundity: 21-d reproduction screening assay w/fathead minnow	experiencing effects on reproduction

Table 25. Aquatic-phase amphibians: Effects to Prey

Input				
Indirect Effect	**Endpoint**	**µg/L**	**Slope**	**Description of effect**
Aquatic Invertebrate Prey - Mortality	All Aquatic Invertebrate HC_{10}	1.7	4.5	Risk of mortality to aquatic invertebrate prey

<u>Incident Reports</u>

As reported in the BE, the EIIS (Ecological Incident Information System database; accessed October 26, 2015) contains 23 fish mortality incidents, excluding incidents associated with misuses or spills and those with a certainty level less than "possible," (as defined in the EIIS database) that are associated with malathion (BE Table 2-8). There were no identified incidents with aquatic-phase amphibians. Aquatic incidents occurred in both freshwater and saltwater habitats. Incidents were associated with both agricultural uses and mosquito control uses of malathion. For both of these use types, there were numerous incidents with a high certainty level ("probable" or "highly probable"), providing evidence that both agricultural and mosquito control uses of malathion sometimes result in mortality of fish. In several of the incidents, particularly in the southern United States when temperatures were higher, depletion of oxygen (which may be exacerbated by higher water temperatures) was often cited as another potential stressor source. There were six additional aquatic incidents with a certainty level of at least "possible" that were associated with known misuses of malathion.

Effects to Aquatic Invertebrates

Malathion is an insecticide used to kill a broad range of insects. The effects of malathion on aquatic invertebrate species has been well-documented in the literature. The aquatic invertebrates taxonomic group was designated in the BE and include species that occur in aquatic habitats during all or a portion of their life cycle, including certain insects (such as dragonflies, damselflies, stoneflies, aquatic beetles, etc.), aquatic or semi-aquatic snails and limpets, mussels and clams, and aquatic crustaceans, such as isopods and amphipods. The effects of malathion on aquatic invertebrates have been studied extensively, including both freshwater and estuarine/marine invertebrates. There are registrant-submitted studies involving aquatic invertebrates, including acute and chronic laboratory studies with either technical or formulated malathion.

Given that several invertebrate taxonomic groups are the target group for the use of this chemical, we made certain assumptions on the known effects of the malathion to the wide array of aquatic invertebrates we analyzed. Similar to the approach for other taxa where an SSD could be described, a single dose-response relationship, based on the HC_{05}, was used to describe all listed aquatic invertebrate species except mussels and snails, when considering mortality. The reasons for using this approach include: the span of the available data; the lack of Order-level sensitivity that is likely insufficient to explain the range of effects (or sensitivity) to all the listed species within that taxa group; and a wide range of within-Order variability across a limited number of studies. We evaluated mussels using a different approach (described below) due to differences in sensitivity of mussels compared to other aquatic invertebrates.

Invertebrates are the target organisms for the effects of this chemical. The relatively high EECs aquatic invertebrates are likely to experience will elicit mortality prior to any sub-lethal effects. Therefore, sub-lethal effects were not pursued for the analysis at this time. The mortality toxicity data utilized to assess the effects of malathion are provided below, along with a discussion of the available incident reports for malathion and aquatic invertebrates. When sufficient data are available for malathion, different toxicity values or lines of evidence are identified for freshwater and estuarine/marine invertebrates.

<u>Mortality Line of Evidence</u>

Aquatic Insects and Crustaceans:

Mortality data were available (submitted by registrants or available in ECOTOX database) for 38 different orders of aquatic invertebrates. Studies coded as "population" in ECOTOX were included in the data arrays for mortality, although it is noted that other effect types may have contributed to the overall population effect. Additionally, community-based studies (generally conducted outdoors) were also available with invertebrates and are included in these arrays. Discussions regarding community-based studies are in the aquatic community effects characterization section.

Acute mortality data (48- and 96-hour EC/LC_{50}s) were available for 38 different orders of aquatic invertebrates and 83 species (some studies only denote to genus level), (see Appendix E); a 48- or 96-hour test duration is common for acute mortality toxicity testing. The toxicity value from the BE to describe mortality as an endpoint for all aquatic invertebrates, also used for the Opinion, was the overall freshwater HC_{05} LC_{50} of 1 µg/L; slope of 4.5. Thus, we used these values for both aquatic insects and crustaceans.

Mollusks (mussels and aquatic snails):

Mollusks made up 9 of the 38 different orders of aquatic invertebrates for which mortality data are available (as noted above). There were mortality values for 5 orders of mollusks which range from 6 µg/L to 311,040 ug/L. For non-mollusks, the mortality data reported for malathion encompassed acute LC_{50} toxicity values of 0.06 to 67,750 µg/L (see Appendix E).

Mussels:

Due to the sensitivity differences among mussels as compared to other aquatic invertebrate species, the effects to mussels were assessed separately from the rest of the aquatic invertebrates. There are approximately 100 listed species of freshwater mussels that are considered in this consultation. Freshwater mussel diversity is greatest in the southeastern United States.

We used mortality values for the freshwater unionid mussel, *Lampsilis siliquoidea*, in its glochidium life stage, as the ecological receptor for all freshwater mussels, both Unionidae and Margaritiferidae families. *Lampsilis siliquoidea* is a common and abundant freshwater mussel that tolerates a wide range of habitat and water quality conditions. We determined that the toxicity data for this species would more accurately represent the freshwater mussel community (i.e., similar biology and ecology, see above) than that of a broader categorization of marine and freshwater bivalves, marine and freshwater mollusks, or all aquatic invertebrates. Using the LC_{50} value of 26,880 µg/L and slope of 4.5, the probability of mortality to individuals would range from 1% at 6,720 µg/L to 99% at 56,640 µg/L.

For effects to mussel species via their host fish, which are needed to complete the mussel species' life cycles, the HC_{05} LC_{50} for fish toxicity (20.9 µg/L) was used.

Aquatic Snails (Assimineidae, Hydrobiidae, Lymnaeidae, Physidae, Planorbidae, Pleuroceridae, Viviparidae):

Due to the lower sensitivity to malathion that snails exhibit compared to other aquatic invertebrates, snails were considered separately from other aquatic invertebrates in our analyses. There are 35 species of freshwater snails from the mainland United States considered in this consultation. Freshwater snails live in permanent freshwater sources of varying sizes and characteristics and do not tolerate drought conditions nor brackish or marine conditions. In general, endangered and threatened freshwater snails live in springs or flowing waters such as streams and rivers, however, individuals may survive in lentic conditions where the waterbodies maintain adequate food and water quality resources.

Freshwater snails are generally divided into two subclasses Prosobranchia and Pulmonata (Dillon 2000). Prosobranchs share a few characteristics: breath through gills, have an operculum, and reproductive strategies include separate sexes with occasional parthenogenesis (i.e., reproduction without fertilization or cloning), and rare hermaphroditism. Pulmonates do not have gills, use the mantle surface for respiration, and may carry a surface derived, air bubble in their mantle cavity; do not have an operculum; and are hermaphrodites.

Freshwater snails use their radula to scrape algae and organic debris from firm substrates like rocks, woody debris, root mats, and submerged plants. However, some can feed on algae and organic debris imbedded within fine sediments, collecting the food in a fine mucus stream that flows directly into the mouth. Another mode of feeding can occur in rivers with large volumes of suspended organic matter. The snail may lie on their side, turning their foot up into the water column to collect food which is then moved by a mucus stream into the mouth. Because all freshwater snails feed on algae and organic debris, we do not expect differences in exposure rates due to food resources or the method used to feed.

For aquatic invertebrates overall, when considering the acute mortality data from 96-hour exposure duration, there was a large range in sensitivity with a six-order of magnitude difference in the values from 0.06 µg/L to 311,040 µg/L. However, data for aquatic snails consistently showed these species to be relatively tolerant to malathion. After examination of the studies involving this group of species, we used a 96-hour LC_{50} value of 6,136 µg/L from a study on the freshwater snail, *V. bengalensis* (Panwar, Gupta, Joshi, & Kapoor, 1982) and slope of 4.5 to assess effects to freshwater snails.

Incident Reports for Aquatic Invertebrates

As reported in the BE, EPA's EIIS database included one incident which involved the death of 500 blue crabs (*Callinectes sapidus*) along with eel and shad in Beaufort, South Carolina (B0000-300-30, 6/25/1981). The Aggregate Incident Reports database identified an additional four incidents linked to malathion use as aggregated counts of minor aquatic invertebrates/wildlife incidents. Because details about these incidents were not reported, no information was available on the use site, the certainty level, or on the types of organisms that were involved.

Additionally, in 1999, the population of the American lobster (*Homarus americanus*) in Long Island Sound suffered a severe mortality event that appeared to be at least partially related to malathion use. This die-off occurred following extensive aerial spraying of pesticides for vector control in the summer of 1999, which was undertaken in response to a widespread outbreak of West Nile Virus that was occurring at that time in the Northeast. Malathion had been applied in New York, while two pyrethroids (resmethrin and sumithrin) and methoprene were applied in both New York and Connecticut. Extensive research was undertaken after this event to identify the cause and to determine the role of exposure to these pesticides, if any, in the mortality event. The research ultimately concluded that an outbreak of a parasitic amoebae, *Neoparamoeba pemaquidensis*, was the proximal cause of the lobster mortality, but that multiple other stressors, including pesticide exposure, may have contributed to the die-off by physiologically weakening the lobsters, making their immune response too weak to fend off the disease (Pearce & Balcom, 2005).

General Effects to Plants

Malathion, unlike many other organophosphate pesticides, is toxic to both terrestrial and aquatic plants and this toxicity manifests itself as reductions in biomass, which may translate to reductions in growth and some mortality (see data for terrestrial plant species below). However, the mechanism of action of malathion in plants is not well-understood. Several studies have explored the evidence of acetylcholinesterase (AChE; the target enzyme upon which malathion will act in animal taxa groups) activity in plants and bryophytes (Riov & Jaffe, 1973; Roshchina & Semenova, 1990; Tretyn & Kendrick, 1991; Gupta & Gupta, 1997; Miura, Broomfield, Lawson, & Worthley, 1982; Kashyap, 1996; Hartmann & Gupta, 1989; Gupta, Vijayaraghavan, & Gupta, 1998). Several choline substrates were tested with the AChE sequenced from plants and inhibition of activity was noted. Therefore, the authors suggest the function is similar to animal AChE. However, the protein structure of this enzyme is unlike that of animal AChE with respect to the nucleotide sequence and may be specific to only the plant kingdom (Sagane, et al., 2005).

The effects of malathion have been studied for both monocotyledon plants (monocots) and dicotyledon plants (dicots), and while the mechanism of action in plants is not well understood, the available data suggest that malathion is toxic to terrestrial plants, primarily dicots. Effects of malathion resulting in plant mortality are limited to terrestrial dicots and have been observed at concentrations ranging from 2.9 to 4.6 lbs/acre in one species of carnivorous plant. Mortality in aquatic plants from exposure to malathion has not been observed. While growth effects are observed at a wide range of concentrations (from 0.2 to 645 lbs/acre), the majority of effects, including effects on biomass and weight, are observed at 1 lb/acre.

Effects of Malathion on Terrestrial Plants

Most of the available malathion toxicity studies for plants focus on growth endpoints; however, data are also available for mortality. The available toxicity data for malathion are provided below for terrestrial plants along with a discussion of available incident reports, which describe any exposure or effect from a pesticide's use that is not expected or intended. Pesticide incidents may involve humans, wildlife, plants, domestic animals (e.g., pets) and bees. Pesticide spills can also be a type of incident.

The discussion of the following data is formatted to broadly follow the lines of evidence, specifically those related to mortality and growth. These data are used to help assess the potential for direct effects (i.e., mortality and sublethal impacts) to listed terrestrial plants and their designated critical habitats (if applicable), and the indirect effects (i.e., impacts to pollinators or seed dispersal biota) for any listed species or critical habitat that relies on listed plants.

Toxicity Data for Terrestrial Plants

The toxicity values for terrestrial plants are based on experimentally determined endpoints for malathion based on varying durations, exposure routes, and study designs. Toxicity values in this assessment are based on endpoints expressed in, or readily converted to, environmentally relevant exposure concentrations (i.e., lb a.i./acre). Across the exposure unit of lb a.i./acre, toxicity data are available for malathion and one order of monocotyledon plants (monocots) (i.e., Poales), represented by one family (i.e., Poaceae), six genera, and seven species. For dicotyledon plants (dicots), toxicity data are available for the lb a.i./acre exposure unit and 10 orders (i.e., Brassicales, Caryophyllales, Ericales, Fabales, Malvales, Plantaginales, Rosales, Scrophuliarales, Solanales, and Violales), represented by 11 families (i.e., Brassicaceae, Chenopodiaceae, Cucurbitaceae, Droseraceae, Ericaceae, Fabaceae, Malvaceae, Pedaliaceae, Rosaceae, and Solanaceae), 22 genera, and 23 species.

Because of the variability in study designs and endpoints, it is not possible to derive a species sensitivity distribution with the available plant data. Therefore, the terrestrial plant toxicity values are based on the lowest values available for the taxon, and the discussion below. Toxicity values are provided in exposure units of 'lb a.i./acre' and are provided for pre-emergence (e.g., seedling emergence studies) and post-emergence (e.g., vegetative vigor studies) exposures. Toxicity values for all terrestrial plants, as well as for separate values for monocots and dicots, are provided in Table 26 below.

Table 26. Toxicity Values for Malathion and Terrestrial Plant Species (Table 11-1 from the BE)

TAXON	THRESHOLD	EXPOSURE	ENDPOINT (lb a.i./acre)	EFFECT(S)	SPECIES	STUDY ID	COMMENTS
All Terrestrial Plants	**NOAEC/ LOAEC**	Pre-emergence	4.64 / >4.64	N/A	N/A	MRID 49076001	For all species tested, no endpoints were significantly inhibited compared to the control
	NOAEC/ LOAEC	Post-emergence	NOAEC/ LOAEC: 1.17 / 2.39; IC_{25}: >4.86	Reduced weight	Cabbage (*Brassica oleracea*)	MRID 49076002	The LOAEC is 2.39 lb a.i./acre (12% inhibition in dry weight at this treatment concentration)
Dicots	**NOAEC/ LOAEC; IC_{25}**	Pre-emergence	N/A	N/A	MRID 49076001	For all species tested, no endpoints were significantly inhibited compared to the control	N/A
Dicots	**NOAEC/ LOAEC; IC_{2}**	Post-emergence	NOAEC/ LOAEC:	Reduced weight	Cabbage (*Brassica oleracea*)	MRID 49076002	The LOAEC is 2.39 lb a.i./acre (12% inhibition in dry weight at this treatment concentration)

TAXON	THRESHOLD	EXPOSURE	ENDPOINT (lb a.i./acre)	EFFECT(S)	SPECIES	STUDY ID	COMMENTS
Monocots	**NOAEC/ LOAEC; IC25**	Pre-emergence	NOAEC/ LOAEC: 4.64 / >4.64; IC_{25}: >4.64	N/A	N/A	MRID 49076001	For all monocot species tested, no endpoints were significantly inhibited compared to the control
Monocots	**NOAEC/ LOAEC; IC25**	Post-emergence	NOAEC/ LOAEC: 4.7 / >4.7;	N/A	N/A	MRID 49076002	For all monocot species tested, no endpoints were significantly inhibited compared to the control

Effects on Mortality of Terrestrial Plants

While the majority of the malathion terrestrial plant dataset is focused on growth endpoints, there is one open literature study that evaluated the effects of malathion exposure on plant survival (E162475). This study, using a combination of lab and field-based experiments, tested the effects of technical grade and formulated malathion (Spectracide, 50% a.i.) on the survival of pink sundews (*Drosera capillaris*) and Venus flytraps (*Dionaea muscipula*). It also evaluated the effects of technical grade and formulated malathion on the expression of carnivorous traits (e.g., the number of mucilage-producing leaves in pink sundews or the number of traps in Venus flytraps; this data is captured in the summary arrays presented above). The study authors found that pink sundews are more sensitive to malathion exposure than Venus flytraps under field conditions and that the formulated malathion is more toxic than the technical grade under both lab and field conditions. Table 27 below presents the results of the study for malathion.

Table 27. Effects of Malathion on Pink Sundew and Venus Flytrap Survival (Table 1126 from the BE).

Experiment	Test Species	Test Material	Lab or Field	NOAEC	LOAEC
I	Pink Sundew	Formulated product	Lab	--	4.63 lb a.i./A
II	Pink Sundew	TGAI	Lab	4.63 lb a.i./A	>4.63 lb a.i./A
III	Pink Sundew	Formulated product	Field	--	2.94 lb a.i./A
		TGAI	Field	2.94 lb a.i./A	> 2.94 lb/A

<u>Growth of Terrestrial Plants – Pre-emergent exposure</u>

No effects to terrestrial plants (monocot or dicot) are reported from pre-emergence exposure to malathion in either the unpublished submitted studies or open literature studies. Therefore, the toxicity value of 4.64 lbs a.i./A is based on the study where the highest concentration was tested, which is an unpublished seedling emergence study (MRID 49076001). In this study, the effect of malathion (Cheminova malathion 57%, EPA reg no. 67760-40) on the seedling emergence of monocot (corn, *Zea mays*; onion, *Allium cepa*; ryegrass, *Lolium perenne*; and wheat, *Triticum aestivum*) and dicot (oilseed rape, *Brassica napus*; cabbage, *Brassica oleracea*; soybean, *Glycine max*; lettuce, *Lactuca sativa*; tomato, *Lycopersicon esculentum*, and carrot, *Daucus carota*) crops was measured at application rates of 0.20, 0.35, 0.88, 2.23 and 4.91 lbs a.i./A for corn, wheat, oilseed rape, soybean and tomato and 0.28, 0.54, 1.15, 2.26 and 4.64 lbs a.i./A for onion, ryegrass, carrot, cabbage, and lettuce. On day 21, the surviving plants per pot were recorded; plant emergence, height, and dry weight were measured weekly. No treatment-related effects on percent survival or emergence, or height or dry weight were reported.

<u>Growth of Terrestrial Plants – Post-emergent exposure</u>

In this study, the effect of malathion (Cheminova malathion 57%, EPA reg no. 67760-40) on the vegetative vigor of monocot (corn, *Zea mays*; onion, *Allium cepa*; ryegrass, *Lolium perenne*; and wheat, *Triticum aestivum*) and dicot (oilseed rape, *Brassica napus*; cabbage, *Brassica oleracea*; soybean, *Glycine max*; lettuce, *Lactuca sativa*; tomato, *Lycopersicon esculentum*;, and carrot, *Daucus carota*) crops was studied at nominal concentrations of 0 (negative control), 0.29, 0.59, 1.2, 2.4 and 4.7 lbs a.i./A. Measured application rates were <LOQ (<0.000045 lbs a.i./A negative control), 0.29, 0.56, 1.19, 2.32 and 4.72 lbs a.i./A for onion, ryegrass, corn, carrot, and tomato; <LOQ (< 0.000045 lbs a.i./A negative control), 0.29, 0.58, 1.17, 2.39 and 4.86 lbs a.i./A for wheat, oilseed rape, cabbage, soybean, and lettuce. On day 21, the surviving plants per pot were recorded; plant dry weight and height were measured. No treatment-related effects on height were reported; however, there were adverse effects for dry weight for cabbage, lettuce and soybean. Cabbage dry weight was significantly reduced ($p < 0.05$) from the negative control by 12% and 16%, in the 2.39 and 4.86 lbs a.i./A treatment groups, respectively. Soybean weight was significantly reduced ($p < 0.05$) by 19% at the 4.86 lbs a.i./A treatment group compared to the negative control. Based on the results of this study, the most sensitive dicot species was cabbage, with NOAEC, LOAEC and IC_{25} values of 1.17, 2.39, and >4.86 lb a.i./A, respectively.

There is an additional study with reported NOAEC and LOAEC values that are more sensitive than those described in the above study; however, the malathion formulation used in the study was not reported. Therefore, this study is included in the data arrays and details of the study are described below.

The lowest NOAEC and LOAEC values for post-emergent exposure to terrestrial plants are for a percent reduction in fresh weight in soybean (*Glycine max*; dicot), with a reported NOAEC value of 0.25 lb a.i./acre and LOAEC value of 0.5 lb a.i./acre (E068422). In this study, soybeans were exposed to single chemicals (thifensulfuron, carbaryl, malathion, malathion, and methomyl) and combinations of these insecticides with thifensulfuron (an herbicide) – formulations were not specified. Pesticidal combinations were also tested with kochia and yellow foxtail (species not specified). At harvest, injury was estimated visually (0% = no injury to 100% = complete necrosis), and fresh weight of shoots was determined after removal at soil level. For malathion, there were no statistically significant differences from control in percent injury at any concentration tested. There was, however, a 5, 5, and 12% reduction in weight at the 0.125, 0.25, and 0.5 lb/acre malathion concentrations, respectively, when compared to controls. The differences were statistically significant from controls at the 0.5 lb/acre concentration, resulting in NOAEC and LOAEC values of 0.25 lb/acre and 0.5 lb/acre, respectively, based on a reduction in weight.

Sublethal Effects to Terrestrial Plants (Monocots)

The toxicity values for monocot terrestrial plants are the same as the 'All Terrestrial Plant' thresholds for pre-emergent exposure with NOAEC and LOAEC values determined to be 4.64 and >4.64 lbs a.i./acre, respectively and the IC_{25} >4.64 lbs a.i./acre (MRID 49076001). For post-emergent exposure there were no effects observed in any of the available studies; therefore, the thresholds are based on the highest concentration tested across the studies. The NOAEC and LOAEC values are set at 4.86 and >4.86 lbs a.i./A, respectively and the IC_{25} >4.86 lbs a.i./A (MRID 49076002).

Sublethal Effects to Terrestrial Plants (Dicots)

The toxicity values for dicot terrestrial plants and malathion are the same as the 'All Terrestrial Plant' thresholds [i.e., Pre-emergence: NOAEC and LOAEC values were determined to be 4.64 and >4.64 lbs a.i./acre, respectively and the IC_{25} >4.64 lbs a.i./acre (MRID 49076001); Post-emergence: NOAEC and LOAEC values of 1.17 lb a.i./acre and 2.39 lb a.i./acre based on reduced weight in cabbage (*Brassica oleracea*) (MRID 49076002) and the IC_{25} was determined to be >4.86 lbs a.i./acre (MRID 49076002)].

Summary of Effects to Terrestrial Plants

Toxicity data available from open literature and registrant-submitted studies suggest that malathion is toxic to certain types of terrestrial plants (i.e., dicots). Effects on mortality are observed at concentrations ranging from 2.9 to 4.6 lbs/acre in one species of carnivorous plant. While growth effects are observed at a wide range of concentrations (from 0.2 to 645 lb/acre), the majority of effects, including effects on biomass and weight, are observed at 1 lb/acre.

Approach to the Effects Analysis for Plants

Plant Assessment groups, Plant life history strategy considerations, and Plant Effects Methodology

All data that were provided in the BE were reviewed to determine which studies were applicable to the assessment and then evaluated based on which endpoints were most applicable to listed plant species. Due to the limited amount of data available on direct mortality for both terrestrial and aquatic species, the lowest terrestrial toxicity values provided in the BE were used for the plant effects analysis, for both aquatic and terrestrial species. Upon further review of the more than 900 listed plant species, there are only 26 that we consider aquatic. While these species do require an aquatic habitat, their flowering takes place above water and therefore would be most susceptible to the impacts of malathion from a terrestrial exposure directly or due to spray drift. Therefore, we did not consider aquatic exposure (run off to the aquatic environment) in our analysis in this Opinion. Experimental data shows no impacts are observed to monocot plants, even at the highest application rate tested. Data for impacts to dicot biomass are provided in the BE and listed above in the toxicity data section; however, there is uncertainty regarding what a reduction in biomass of an agricultural test species indicates to the continuing survival of a listed plant species.

<u>Plant Assessment Groups</u>

We assessed the plant taxa group, consisting of more than 900 individual species, based on 11 groupings categorized by taxonomy and reproductive strategy. As observed from the toxicity data above for malathion, impacts to plants demonstrate effects on biomass for dicot species; however, the ramifications of this impact on growth to the continued survival of the wide variety of listed dicot plants is unknown at this time and there are no direct impacts from malathion exposure on monocot species. Therefore, the effects analysis from malathion to listed plant species will address the resultant effects on the plants themselves based on their embryonic seed leaf (dicot or monocot), however the focus of the effects analysis will be on impacts to pollinators and seed dispersers, particularly insect pollinators and seed dispersers. It is well known that flowering plants that rely on pollination, would likely be impacted by any reduction in the pollinators on which they depend (Potts, et al., 2010; Thomas, et al., 2004; Biesmeijer, et al., 2006).

While the majority of listed plants are flowering dicot plants with insect pollinators, many are monocots or use differing mechanisms other than seed development or pollination for propagation. We determined that the most effective approach to analyzing effects for all listed plants was to sort them into assessment groups based on their reproductive strategies due to the likelihood of malathion exposure impacting this aspect of a given plant's life history. Plant Assessment Groups 1-3 are those listed species that are not flowering plants, and, therefore, do not rely on a pollination mechanism for continued survival. They reproduce asexually via spores, rhizomes, bulbets, or clones. The remaining Assessment Groups (4-11) are monocots and dicots that have varying pollination and propagation strategies, including a grouping where some of the information on these aspects of life history are unknown at this time.

Plant Assessment Group 1 – Lichens

There are two listed species of lichen: the Florida perforate cladonia and the rock gnome lichen. Lichen are composite organisms formed from algae and fungi living in a mutualistic relationship. Lichens do not produce flowers or seeds, and therefore, they do not rely on pollinators or seed dispersers for reproduction. The primary means of reproduction of the lichens in this group is asexual, with colonies or organisms spreading clonally through vegetative reproduction. There is little to no information regarding the impacts of pesticides on lichens, however, some data suggested a reduction in the organism's ability to photosynthesize when exposed to phosphate (as a degradate of malathion) (Brown, Beckett, & Legaz, 1987).Other studies showed that lichens are sensitive to micropollutants in their environment (Domingguez-Morueco, Moreno, Barreno, & Catala, 2014). Therefore, we assume there are no indirect impacts because there is no reliance on a biotic pollinator. We assessed this group based on direct impacts to dicot plants.

Plant Assessment Group 2 – Ferns and Fern Allies

Ferns and Fern Allies are a diverse group of seedless plants that do not have flowers and reproduce sexually via spores pollinated and dispersed by wind. Ferns and their allies can also reproduce asexually by means of vegetative reproduction in the form of bulbets or rhizomes. During sexual reproduction, ferns produce two free-living generations, a diploid sporophyte (what we think of as a fern plant) and a haploid gametophyte. The gametophytes are typically very small (around ½ inch), are fragile and have very specific requirements for growth, such as damp soil conditions and high humidity. Early studies on ornamental ferns exposed to malathion indicated that they are somewhat sensitive to malathion. Malathion injured some of the ferns studied and thus classified it as phytotoxic (Kerr, 1956; Forsyth, Colton, & Maynard, 1969). In addition, the malathion label does indicate the following statement: "Do not allow spray to contact ferns, hickory viburnum, lantana, crassula, or canaetri juniper as injury may result to plants." Because there is little to no information beyond these older studies regarding the impacts of pesticides on this group of plants, and we assume no indirect impacts occurred due to no reliance on a biotic pollinator, we assessed this group based on direct impacts to dicot plants.

Plant Assessment Group 3 – Conifers and Cycads

Conifers and cycads are gymnosperms; vascular plants, usually trees or shrubs, that reproduce by means of an exposed seed, or ovule. Gymnosperms do not produce flowers and their pollen is dispersed by wind. With the exception of whitebark pine, all species have very restricted ranges and limited dispersal capabilities. Santa Cruz cypress and Florida torreya rely on squirrels for seed dispersal, and whitebark pine relies on the Clark's nutcracker (*Nucifraga columbiana*). The whitebark pine's cones will not open on their own and are completely dependent upon the nutcracker to break apart their cones and disperse the seeds. There is little information on the mechanisms of seed dispersal for the other species in this group. The malathion label indicates the following statement: "Do not allow spray to contact ferns, hickory viburnum, lantana, crassula, or canaetri juniper as injury may result to plants"[21] and may therefore cause injury to some conifer species (Straw, Fielding, & Waters, 1996; Malkonen, Kellomaki, & Holm, 1980). Because there is little to no information beyond these older studies regarding the impacts of pesticides on this group of plants, and we assume no indirect impacts occurred due to no reliance on a biotic pollinator; we assessed this group based on direct impacts to dicot plants.

Plant Assessment Groups 4 through 7 – Monocot angiosperms with varying pollination and propagation strategies

Plant Assessment Groups 4-7 are monocot flowering plants. They are grouped based on their pollination vector and the ability of the plant to rely on alternate forms of propagation. Assessment group 4 includes those listed monocot plants that rely on abiotic pollination (wind, water), while Assessment Groups 5 and 6 include monocots with biotic pollination vectors that require outcrossing for successful reproduction or are capable of self-fertilization or asexual/clonal reproduction, respectively. Assessment group 7 includes monocot angiosperms where there was not enough information available to determine pollination vector (beyond it being biotic) or propagation strategy at this time. As discussed above, we assumed no direct impacts to monocot plants. Indirect effects were assessed based on pollination vector (insect, bird, mammal, abiotic, etc.) and ability to rely on alternative reproductive mechanisms to different pollinating species (see discussion below).

Plant Assessment Groups 8 through 11 – Dicot angiosperms with varying pollination and propagation strategies

Plant Assessment Groups 8-11 include dicot plants. Assessment group 8 is defined by those dicots with abiotic pollination agents, while Assessment Groups 9 and 10 include dicots with biotic pollination mechanisms that require outcrossing for successful reproduction or are capable of self-fertilization or asexual/clonal reproduction, respectively. Assessment group 11 includes dicot angiosperms where there was not enough information available to determine pollination vector (beyond it being biotic) or propagation strategy at this time. We assessed these groups based on direct impacts to dicot plants from the toxicity data discussed above and indirect effects to different pollination vectors (see discussion below).

Plant life history strategy considerations

<u>Effects to pollinators and seed dispersers (insects, mammals, birds)</u>

Of the approximately 250,000 extant species of angiosperms, possibly >90% are pollinated by animals, especially insects (Buchmann & Nabhan, 1996). A plant's reproductive system is highly reliant on plant pollinator interactions, and there is clear evidence of recent declines in insect

[21] http://www.ctx-cenol.com/Pages/Specimen%20Labels/45385_43speclbl.html (CTX- CENOL, 2001)

pollinators in particular that parallels declines in the plants that rely upon them (Potts, et al., 2010).

The plant's reproductive system also influences how sensitive a population is to disrupted plant–pollinator interactions. When a pollinator is lost, self-pollination may become an option for some species. However, this can decrease a plant's seed set and in turn have impacts on population viability due to reduced fitness (Johnston & Schoen, 1996).

Habitat fragmentation and isolation may also lead to increased self-pollination (Olesen & Jain, 1994; Johnston & Schoen, 1996), which can in turn lead to a reduction in seed set and in-breeding depression (Lennartson, 2002). Currently, many listed plant species are affected by habitat fragmentation, and the loss of pollinators is noted as a significant threat to listed species recovery. Listed species of the Pacific and Caribbean islands are particularly affected by these threats.

The ability of a listed plant species to recover could be further reduced if the availability of insect pollinators or seed dispersers is impacted by pesticide applications.

Khan et al. (2016) observed that malathion exposure in particular caused significant effects to pollinator species, especially to insects such as bees, butterflies, and flies. Flowering plant species' dependency on pollinators led us to focus the effects analysis of plants on the impacts that exposure to malathion would have on a potential pollinator species, as well as the resultant effects on the plants themselves.

When considering the above information, pollinator mortality or lack of pollinator presence has been shown to have significant adverse effects to plant species. We considered the impact of loss of pollinators to be a significant contribution to impacts to listed plant species from exposure to malathion.

Insects

The terrestrial invertebrates taxonomic group was designated in the BE and described as all insects with a terrestrial lifecycle, spiders and their relatives, and strictly terrestrial gastropod mollusks. Given the wide breadth of taxonomic groupings within this category, assumptions were made based on the known effects of the action to this wide array of species. It was assumed that the toxicity data available were applicable to all taxonomic groups within this category based on data from the available literature. Similar to the approach for other taxa (i.e., mammals, birds) assessed for this Opinion, we chose the most sensitive LD_{50} (1.22 µg/g-bw; from a 48-hour LD_{50} from a study on Hymenoptera, discussed in more detail in section *General Effects to Terrestrial Species – Effects to Terrestrial Invertebrates*) to address toxicity to insect pollinators/seed dispersers and subsequent impacts to plants requiring insect pollination.

Mammals

A 20-gram mammal was chosen to represent a generic mammal pollinator (for example, pollinating bat species). While nectar is a main dietary item for pollinating mammals, many also consume arthropods as a regular part of their diet. Since consumption of arthropods is expected to produce a higher dose of malathion than nectar, this scenario was chosen to represent alternate feeding habits of these species, and to be conservative. Effects to mammalian pollinators/seed dispersers were calculated using the lowest LD_{50} value previously described for mammals (1560 mg/kg-bw) and the expected dose on each use site for 20-gram mammals from the MagTool. Spray drift mortality was calculated as previously described for terrestrial vertebrates. Based on these values, mortality is not anticipated from malathion exposure either on use sites or from spray drift.

Mammals that act as seed dispersers may consume other dietary items in addition to those assessed for pollinating mammals. However, we do not generally anticipate mortality from malathion exposure for mammals of this size or larger, regardless of the dietary item. Thus, the assessment endpoints chosen to represent pollinators are expected to be sufficiently protective of mammalian seed dispersers.

Birds

A 20- gram bird was chosen to represent a generic avian pollinator/seed disperser. While nectar is a main dietary item for pollinating birds, many may also consume arthropods as a regular part of their diet. Since consumption of arthropods is expected to produce a higher dose of malathion than nectar, this scenario was chosen to represent alternate feeding habits of these species, and to be sufficiently conservative. The magnitude of mortality was calculated using the HC_{05} (108 mg/kg-bw) previously described for birds, and the expected dose on each use site for 20-gram birds from the MagTool. Use of the HC_{50} was considered to represent a wider array of birds that might be affected, but as the SSD consisted of values for only six species, we decided that the HC_{05} was a better indicator of capturing the breadth of sensitivity inherent to these pollinators. We do not anticipate mortality to pollinating birds from exposure to spray drift.

For comparison, birds consuming nectar on use sites with higher allowable application rates (e.g., developed, open space developed, nurseries, orchards and vineyards) could experience similar rates of mortality from consumption of nectar as compared to arthropods. Those consuming nectar on agricultural crops with lower allowable application rates (e.g., pasture, corn, wheat, pine seed orchards, other crops) are not expected to experience significant levels of mortality.

Birds that act as seed dispersers may consume dietary items that result in either lower effect levels (e.g., fruit) or higher effect levels (e.g., leaves) following malathion exposure than dietary items chosen to assess pollinating birds (i.e., arthropods). However, due to the conservative nature of other endpoints (small body weight and HC_{05}), the assessment of pollinating birds is expected to be protective of avian seed dispersers.

Pollination or Seed Dispersal by an Obligate or Specific Species

Plants that depend upon an obligate pollinator or a few specific pollinator species may see a disproportionately greater negative effect from the action since these species of plants cannot use other species for pollination if the specific pollinator(s) they rely upon has been reduced or temporarily extirpated from the area due to pesticide use.

Wicock and Neiland (2002) found that risk of pollination failure is high in specialist insect pollination where there is a 1:1 plant to pollinator relationship. Examples of these type of species are yucca (which rely on yucca moths, *Tegeticulla* sp.), figs (pollinated by Agaonidae wasps), and orchids (that rely on Euglossine bees). They also determined that risk of pollination failure is intermediate when the plant can rely on insect pollination by a few closely related species or limited diversity of pollinators, including examples such as plants in the family Fabaceae, and many tropical trees. The authors also concluded that risk of pollination failure was intermediate to low where insect pollination is accomplished by a wide taxonomic diversity of pollinators.

Similarly, for listed plant species that have obligate or a few specific seed-disperser species, we would expect some limitation to these types of plants ability to propagate. In these cases, we may see a disproportionately greater negative effect from the action since these species of plants cannot utilize another species for seed dispersal if the specific seed disperser they rely upon has been reduced or temporarily extirpated from the area due to pesticide use.

<u>Abiotic Seed Dispersal</u>

Seed dispersal that is not linked to an animal vector is a common strategy among plants. Most frequently, abiotic seed dispersal occurs via wind, water, or gravity. Successful seed dispersal is often a critical mechanism for the long-term persistence of many plant species. Dispersal allows for a mechanism for plant species to move to additional suitable sites, resulting in an increase in the size of a population, or in the origin of new populations. Larger populations and well-developed meta-population dynamics among populations can maintain genetic diversity in these already rare plant species and prevent inbreeding depression among isolated populations. Declines in dispersal distance or ability may prevent these plant species from finding additional suitable sites and limit successful reproduction.

Biotic methods of dispersal via vectors other than insects can occur through external or internal transport by a variety of species including birds, bats, rodents, and even humans. For mammalian seed dispersers, we assume that the malathion exposure is not expected to result in mortality or sublethal effects to mammals of this size, or larger, regardless of the dietary item (see discussion above). Bird vectors may see effects from malathion exposure (see discussion above for bird pollinator / seed dispersers) and reductions in these seed dispersers can have adverse effects to the plant species, particularly when they have no other dispersal strategy on which to rely.

We do not expect the effects of malathion will impact the seed dispersal capabilities of plant species that rely solely on abiotic seed dispersal vectors.

<u>Flowering duration</u>

We expect that plant species will have varying responses to malathion based on differences in their life histories. For example, plant life history strategies may include annual, biennial, or perennial life cycles. Plant species can be either monocarpic, with one reproductive event per life cycle, or polycarpic, with many reproductive events per life cycle. The risk to plant species based on life history is linked to the number of flowering opportunities available and the need for recruitment from any one years' seed set. Annual species have only one opportunity to grow, flower, and reproduce during their life cycle. Often these species respond quickly to favorable environmental conditions and may lie dormant in the seedbed during unfavorable conditions. Depending on the longevity of the seedbed, the continued persistence of these species may depend on seed set during the prior year or a limited number of favorable prior periods. If pollinators are negatively impacted during the flowering period of an annual species, there may be a notable decline in pollination and seed production that could cause a depletion of the seedbed and a reduction of the population. Multiple events over time can compound this effect. Monocarpic species, while they may grow for decades, also only have one opportunity to flower and reproduce during their life cycle and can experience similar reductions in the seedbed and long-term declines in populations as annual species. The degree of the negative effect will be most notable for species that have a larger degree of synchrony across individuals for flowering events as a reduction in pollinators during one critical period cannot be offset by successful reproduction in intervening years. For those species that are perennial and polycarpic, a reduction in pollinators during any one year will reduce the production of seeds during that year. Species that have more turnover in individuals from year-to-year may have a decline in the recruitment needed to replace reproductive individuals over time and will experience the most negative effects from a loss of pollinators. Species with more long-lived and stable populations that have low recruitment rates in any one year will be the least likely to be impacted by a loss of pollinators in any one year.

However, as described earlier in this Opinion, there is lack of specificity on information on timing of application of malathion. There is often insufficient information for specific areas of the country and specific crops where malathion may be applied that may be in proximity to when a listed species may begin to flower, fruit or for the length of time that species may be in these stages. Therefore, we expect that, regardless of a plant's life history for flowering/fruiting duration, it is reasonable to expect that malathion could be applied during these critical periods. Since malathion tends to be applied during the growing season of a given crop, which in the majority of cases will also correspond to the growing season of listed plants, we anticipate that malathion could impact flowering and fruiting in listed plant species.

<u>Utilization of Agricultural Areas</u>

While we expect to see listed plants growing in such use sites as pasture, developed, and open space developed areas, among others, we are less confident of their presence in agricultural areas. However, information we gathered from Service Field Offices indicated some species of plants may be found in or near agricultural areas for all or a portion of their life cycle. These species could see greater negative effects of the action as they may experience higher exposures than plants that are found outside of agricultural areas. In addition, we assume pollinator and seed dispersers will experience effects in all use areas equally due to their mobility across use sites, and ability to forage in all use sites.

Plant Effects Methodology

Flowering plants rely heavily on pollinators and seed dispersers for successful reproduction and survival. In order to have the best chance of survival, many flowering plant species, including listed species, have developed a variety of alternative reproductive mechanisms, in the event a pollinator is not present when the species' flowering or fruiting window occurs. As discussed in the plant life history strategy section above, however, those plant species that require outcrossing and have obligate pollinators are more likely to experience declines, more so in areas with habitat fragmentation, which many listed plant species also are currently experiencing (Biesmeijer, et al., 2006). For the effects analysis for plants, we focus on the impacts of malathion to pollinator and seed dispersal vector species where applicable. We made additional assumptions based on how a listed plant's reproductive strategy may help the species continue to successfully reproduce and potentially avoid a certain degree of impact on their population numbers from pesticide exposure.

Toxicity Data

In **Error! Reference source not found.**, we show the data provided in the BE for effects to g rowth on plants, based on embryonic seed leaf number (monocot or dicot). The data demonstrate that very little impact to growth is observed in monocot plants if exposed to malathion at the highest concentration tested (see *Toxicity Data for Terrestrial Plants* above). R-Plots for plants exposed to malathion used toxicity data for pollinator type such as insects, birds, and mammals.

Table 28. Toxicity Inputs for Plants and Pollinators/Seed Dispersers of Plants

Taxa group	Endpoint	Effect	Seed type	Pre/post emergence	Value (units)
Plant	NOAEC	Growth	dicot	post-emergence	2.39 (lbs a.i./acre)
Plant	NOAEC	Growth	monocot	pre-emergence	4.64 (lbs a.i./acre)
Plant	**NOAEC**	**Growth**	**Monocot**	**Post-emergence**	**Value (units)**
Insect	LD_{50}	Mortality	-	-	1.22 µg/g bw
Bird	HC_{05}	Mortality	-	-	108 mg/kg-bw
Mammal	LD_{50}	Mortality	-	-	1560 mg/kg-bw

We incorporated the pollinator magnitude of mortality toxicity values and the magnitude of mortality spray drift effects to pollinators/seed dispersers into the R code. This data was then displayed on the Plant R-Plot for each plant species. We also considered whether or not a species could rely on an alternate mechanism for reproduction (see *Plant Assessment Groups* section).

Use site application rates – When considering direct impacts to plant species, including effects on biomass, we also consider the application rate for a particular use site. For plants, we equate the application rate to the anticipated direct impact to the plant based on the exceedance of the application rate for a particular agricultural or non-agricultural use. For example, if we know a listed plant species has a range that overlaps with a particular use, and the maximum or typical application rates (as determined from usage data) for that use may exceed the toxicity value at which we observe direct impacts to the plant (2.39 lbs/acre), then we would anticipate and assume this listed plant species would be directly impacted and effects on biomass would be observed. We consider this information as one of many lines of evidence to help determine overall impacts to a given listed plant species.

Mosquito control use of malathion and direct effects to plants – Much of the discussion regarding the effects of malathion to plants has focused on agricultural uses, as the bulk of the toxicity data are derived from registrant-provided studies that focus on how an insecticide could inadvertently impact the crops it is intended to protect. Malathion use as a mosquito adulticide is also considered for exposure to listed plant species for this Opinion. The application rate of malathion use for mosquito control (0.23 lb/acre) is well below the threshold for direct effects to plant growth based on the toxicity data discussed above (2.39 lbs/acre). However, the relatively low rate for mosquito control applications of malathion does not preclude the potential for any indirect impacts to listed plant species that rely on insect pollinators for successful reproduction. We discuss exposure and effects to pollinators and seed dispersers and any resulting effects to listed plants from this use in the following sections.

Exposure

Malathion enters the environment via direct application to use sites and may be sprayed directly onto soil, foliage, or impervious surfaces. Spray drift and runoff are primary routes of offsite transport, with volatilization and leaching occurring under certain conditions. Rainfall transports malathion off-field through runoff, soil erosion, and leaching. These mechanisms may transport malathion to surface water. In waterbodies, it will be primarily present in the water column as well as substantially in sediment. Microbial metabolism to malathion dicarboxylic and monocarboxylic acids is the primary transformation occurring in natural systems. Hydrolysis rates of malathion vary dramatically with pH, with reduced hydrolysis in acidic environments. Based on aerobic aquatic metabolism half-lives ranging from 0.5 to 10 days, it is the degradates that are typically available in sediment and water column for longer periods of time. Malathion is moderately mobile, and unlikely to reach ground water except in vulnerable soils with low organic-carbon content and/or the presence of shallow groundwater. Log KOW values (octanol/water coefficient, a measure of water solubility that is used to predict the distribution of a substance in environmental compartments such as water, soil, air, and biota) range from 2.3 to 3.3, suggesting it is not likely to have the potential to accumulate in terrestrial organisms. EPA provided physical chemical properties and dissipation parameters for malathion and its major degradates of concern (BE Table 3-1).

In general, EPA derived exposure estimates for listed species using fate and transport models. The methodology used to derive these geographically specific EECs are described and presented in Chapter 3 of EPA's BE. EPA used combinations of several transport models including the

Pesticide Root Zone Model (PRZM5), the Variable Volume Water Model (VVWM), Terrestrial Residue Exposure (T-REX), and AgDrift (version 2.2.1) to estimate concentrations in aquatic and terrestrial habitats used by listed species, assuming pesticides were applied according to label specifications.

Rate, Frequency, and Number of Applications

EECs are influenced, in part, by the allowable manner of pesticide use as described by the label, including the application rate, frequency of application, and the maximum number of applications per season or year. For each use category, EPA modeled EECs in a number of ways. For our analyses, we chose the combination of application rate, frequency, and number of applications allowed by the label that produced the highest EECs to create an upper bound. The highest application rate was not necessarily always the rate that produced the highest EEC if a lower rate could be applied a greater number of times and/or more frequently. We recognize that malathion will not always be used in a manner that produces maximum concentrations in the environment. Where we found these concentrations result in effects to listed species, we looked to usage data to determine whether is it reasonable to assume that malathion is used in a manner to produce such concentrations.

<u>Determining Percent of the Population That Could Be Exposed to malathion</u>

Overlap with species range: We derive the estimate of exposure for each species, in part, by determining the extent that the range of a species overlaps with use site categories for which the pesticide is registered, combined with anticipated off-site transport. The process for establishing the use site footprint is generally described in Attachment 1-3 of EPA's BE. Briefly, malathion use sites were binned (i.e., categorized) by the general land cover class that best represents the use pattern (e.g., grapes are categorized with orchards and vineyards while cole crops – e.g., cabbage, broccoli, Brussels sprouts, and kale – are binned with vegetables and ground fruit; see Table 29). EPA lists information on crop or use, application timing, application rates, method and any geographic restriction in the Master Use Summary Table (Appendix 1-3 of the BE). To map use sites on the landscape, EPA used the 2014 National Agricultural Statistics Service (NASS) Census of Agriculture (CoA) crop acreage reports and the 2012 NASS CoA crop harvested data to confirm the presence or absence of individual use sites or crops within a county. Unless the label limits a use pattern to a particular geographic area, all regions are modeled where there are crop acres or harvested data. For those crops/use sites where NASS harvested data are unavailable, the crop or use site was assumed to occur within that county based on the information provided by the crop data layer (CDL) representing the landcover groups. Limited data are available for crops grown in the Pacific Islands and Caribbean.

Table 29. Composition of Use Data Layers (UDLs) for malathion.

Use Data Layers for Malathion
Corn: Sweet Corn, Pop, or Ornamental Corn
Cotton

Use Data Layers for Malathion
Rice
Wheat: Durum Wheat, Winter Wheat, Spring Wheat
Vegetables and ground fruit: Mint, Mustard, Dry Beans, Potatoes, Sweet potatoes, Miscellaneous Vegs & Fruits, Watermelons, Onions, Cucumbers, Chick Peas, Lentils, Peas, Tomatoes, Caneberries, Herbs, Carrots, Asparagus, Garlic, Cantaloupes, Honeydew Melons, Broccoli, Peppers, Greens, Strawberries, Squash, Lettuce, Pumpkins, Blueberries, Cabbage, Cauliflower, Celery, Radishes, Turnips, Eggplants, Gourds, Cranberries, Artichokes, Blackberries, Logan Berries, Radish, Black Raspberries, Red Raspberries, Vetch, Brussels sprouts
Orchards and vineyards: Cherries, Peaches, Apples, Grapes, Other Tree Crops, Citrus, Pecans, Almonds, Walnuts, Pears, Pistachios, Prunes, Olives, Oranges, Pomegranates, Nectarines, Plums, Apricots
Other grains: Sorghum, Barley, Other small Grains, Rye, Oats, Millet, Spelt, Canola, Flaxseed, Safflower, Rape Seed, Camelina, Buckwheat, Sugarcane, Triticale
Other row crops: Sunflower, Peanuts, Tobacco, Sugarbeets, Hops
Other Crops: Clover/Wildflowers, Sod/Grass Seed, Fallow/Idle Cropland, Aquaculture
Pasture: Alfalfa,
Developed: areas with low to high intensity constructed materials; impervious surfaces account for 20 to 100% of total cover (e.g., small-lot single family homes, row houses, commercial/industrial, etc.)
Nurseries
Open Space Developed: areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses; impervious surfaces account for less than 20% of total cover (large-lot single family homes, parks, etc.)
Christmas Trees
Pine Seed Orchards
Mosquito Control

The "percent overlap" for each use site typically refers solely to the footprint of the site itself; spray drift overlap is calculated separately when applicable. When mapping use sites, EPA found redundancies among various use sites. That is, mapped use sites are not mutually exclusive of one another. For instance, there may be landcover that is considered to be part of both the "vegetables and ground fruit" category and the "other grains" category. For this reason, combining the percent overlap for use sites may overestimate the total amount of a species' range that is overlapping with use sites.

To further identify malathion use areas, we made the following refinements and deviations from the methods described in EPA's BE:

- We incorporated the most recent data available by using the NASS Agricultural Surveys to identify crops that will fall under the use categories for the years 2013-2018 to describe the overlap with species range.

- Based on usage information, we did not consider overlap on use sites that fell on Federal lands, rather we consider potential usage on Federal lands qualitatively due to the limited amount of anticipated usage in these areas (see *Approach to Usage Analysis* section of this Opinion for more details).

- We removed portions of overlapping landcover from the analysis based on the Census of Agriculture if no registered label use of malathion was grown in a given county. As this process was performed after overlap values were calculated, results are reflected in the calculation of the percent of the species' range treated for each UDL.

- The "Other Row Crops" UDL layer is composed of sunflower, peanuts, tobacco, sugar beets, and hops, of which, only hops is a registered use site on malathion labels and is thus the only crop in this layer that is relevant in our analysis. USDA data shows that 96% of hops are grown in the Pacific Northwest region (in Idaho, Oregon, and Washington), with some small farms in Florida (Gadsden County) reporting occasional hop production. Given the highly specific regions that hops are grown in, we can assume that potential exposure to malathion from "other row crops" use sites is 0 outside of these areas. This information was considered qualitatively where the Other Row Crops UDL was found to be a driver for species.

- Based on discussions with malathion's primary registrant, FMC[22], we concluded, that for landcovers among the pasture category as defined in the BE, malathion is consistently used for pest control on alfalfa. Other uses of pasture were deemed to be extremely limited and unlikely to cause effects to listed species. To determine effects to listed species, we mapped this category with only the alfalfa layer of the CDL.

- Based on expert opinion from the U.S. Forest Service (Alex Mangini, Southern Region, Forest Health Protection, Alexandria Field Office, personal communication, 2018), we concluded that the following counties/states are the most likely to have pine seed orchards and malathion use: Alabama (Baldwin, Escambia, Covington, Coffee, Geneva, Dale, Henry, and Huston counties), Florida (Escambia, Santa Rosa, Okaloosa, Walton, Washington, Holmes, Gadsden, and Leon counties), and Georgia (Seminole, Decatur,

[22] This information is considered Confidential Business Information (CBI) by FMC, and thus is discussed only at a coarse level in this Opinion and summarized in combination with other information.

Lowndes, Echols, Clinch, Ware, Charlton, and Camden counties). In light of this information, we revised EPA's pine seed orchard use layer, which initially included areas from east Texas across the southern seaboard, large areas of Florida and northward along the Atlantic coast states into North Carolina, to the counties identified above. We anticipate our new pine seed orchard layer is more reflective of where this use site category actually occurs for the purposes of this consultation and our assumptions related to usage data.

- Mosquito adulticide applications of malathion are not restricted spatially nor temporally (i.e., can be used year-round) by product labels. Several potential sources of information were evaluated for their utility in constructing a map of mosquito control; however, there was not a single definitive source to describe where usage of malathion is likely to be applied for this purpose. Given that the epidemiology of arboviruses is difficult to predict and that malathion is a critical tool in managing pesticide resistance in mosquito populations, we combined the best available data sources to create a map of counties with the highest likelihood to conduct mosquito control over the 15-year period of the action, relying on data sets from three sources:

    1. County-level sales data[23] provided by malathion registrant, FMC, for the years 2012 to 2018.

    2. Information from the American Mosquito Control Association (AMCA), including a county-level map of mosquito control districts, a map of municipalities with known mosquito surveillance or control, and responses from a 2014 AMCA member survey;

    3. Publicly available state data (i.e., California, New Jersey, Florida, Vermont) when available and not captured by other data sources.

We developed the basis for our approach to refining the overlap for mosquito adulticide use in an interagency mosquito adulticide usage subcommittee in 2018. This approach to refinement was similar to methodology developed by the AMCA and presented to the EPA, the Service, FMC, and USDA, at a meeting May 16, 2019. The AMCA is a professional association whose membership largely consists of professionals in public health at municipal, county, state and federal levels, but also includes members from industry and academia. Its services are provided mainly to public agencies and their principal staff members engaged in mosquito control, mosquito research and related activities (AMCA, 2020).

Distribution of individuals within the range:

We determined the exposure of species to pesticides at a population level by considering the overlap of pesticide use sites and associated off-site transport with individuals within the landscape, as determined by the range of the species and the anticipated distribution of individuals within the range. We estimate the distribution of individuals by several types of factors, including: habitat preference, life history traits, behaviors such as colonial nesting or

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flocking, type of water body (flowing or static), size of water body (for aquatic or semi-aquatic species), and known areas of high or low density of individuals of the species. Distribution can also include areas where species may congregate to breed or roost on a short-term basis, such as leks or spawning sites. Areas of high densities of individuals can increase the vulnerability of a species if they overlap with pesticide use sites. However, specific information regarding the distribution of species varies. Where information is readily available for individual species or taxonomic groups, it is incorporated into the analysis in a qualitative manner. For species where no information is available, we will assume that species are uniformly distributed throughout the range. However, we may consider that species may be more or less likely to be in use areas based on the suitability of habitat and availability of resources. The assumption of a uniform distribution can either increase potential exposure by artificially expanding the area of exposure to the whole range, or decrease the potential exposure by failing to identify high density areas that overlap with pesticide use sites.

Seasonal exposure:

Species may be precluded from exposure to a pesticide due to life history factors such as migration, estivation, or hibernation. EPA provided a geographic-based seasonal analysis derived from application timing as inferred from target pests described on product labels (see Appendix F, uses with no restriction; e.g., “apply as needed,” are assumed to be allowable year-round in any HUC). Further discussions with malathion’s primary registrant, FMC, confirmed that there are no restrictions on the timing of applications, and malathion use is expected to be based primarily on growing season. FMC indicated that further information on a geographic scale fine enough to be relatable to specific species would vary based on locality and current practices, and such information is not readily available in a broad scale manner. Information that could inform a specific analysis for a species would most likely be obtained from direct contact with one or more of the approximately 2,900 individual agricultural extension offices in the action area in proximity to the species range, an effort that is beyond the scope of this analysis.

Thus, for our assessment of seasonal exposure, we relied on EPA’s analysis of application timing based on target pest pressure. As that analysis showed very little seasonal restriction in use when considering the full suite of malathion uses, there were no species that were completely precluded from exposure. However, where species may be precluded for a particular life stage or life event, it was considered in the analysis. For example, whooping cranes in the Aransas-Wood Buffalo National Park population do not breed in the action area (they only winter and migrate within the action area) and therefore, effects to breeding were not anticipated to occur from the action under consideration. When species may not be present during pesticide applications, consideration was made as to whether residues were likely to remain in the environment when the species returns to the site. As our analysis generally evaluated the effect of a single exposure per year, we did not modify the anticipated risk based on the percent of the time spent in the action area, as each species could be exposed at least once per year regardless of that factor.

Volatilization and Atmospheric Drift

Based on a relatively low Henry's Law Constant (1.2*10-7 atm-m^3/mol) and moderate soil/water partitioning, malathion has low volatilization potential from soil. However, malathion has been detected in air and rain water in several studies in various locations. Non-agricultural malathion uses involving impervious surfaces or ultra-low volume (ULV) applications may have an increased tendency toward volatilization due to slower degradation and less sorption to surfaces.

Of special concern for listed species that may not otherwise be exposed to organophosphate pesticides on or near use sites is volatilization from lowland application and drift sites resulting in deposition within the cloud and fog zone in the form of condensation, fog drip, and rainfall. For pesticides that have been studied in California, the amounts detected are on the order of nanograms per cubic meter (ng/m^3) of air for organophosphates, including malathion, as well as diazinon and chlorpyrifos. These volatilized pesticides adhere to particulates and become absorbed into fog. The measured concentrations in fog are orders of magnitude higher than the concentrations in air, with Glotfelty et al. (Glotfelty, Seiber, & Liljedahl, 1987) measuring concentrations of diazinon, parathion, methidathion and chlorpyrifos of 20-50 µg/L, indicating that fog or clouds will concentrate pesticides that volatilize from sprayed crops. These data were corroborated by Turner et al. (1989) with a study of pesticide deposition from fog onto dill plants in California, which found that residues of four organophosphates carried in fog for at least 0.4 km from a sprayed orchard. This study demonstrated the occurrence of both dry deposition from volatile drift and fog deposition, with fog deposition generally causing greater pesticide accumulation on the dill plants. Aston and Seiber (1997) measured two organophosphates (chlorpyrifos and methidathion) in air samples up-slope from Central Valley pesticide use in citrus groves and found levels as high as 243 ng/m^3 adjacent to orchards sprayed 48 hours earlier and levels as high as 25 ng/m^3 for 24 hour air samples collected 22 km up-slope from sprayed orchards. Pine needles clipped from the trees adjacent to the citrus groves contained total organophosphate levels greater than 200 ng/g. Both Aston and Seiber (1997) and Turner et al. (1989) demonstrated significant pesticide deposition onto plants at distance from the spray application. This was not spray drift, but volatilization after application from pesticides carried in dry air and in fog, and adhered to plants. The volatilization, air transport, and subsequent deposition on foliage, either in dry air or in fog, demonstrate the risk to listed insects at considerable distance from the application site. Urlacher et al. (2016) demonstrated adverse effects on learning behavior at 0.05 ng/bee, a much lower residue level than found on pine needles 22 km distant from the chlorpyrifos application sites by Aston and Seiber (1997).

The persistent trade winds, cloud formations, and rain on the high islands of Hawai'i create environmental conditions similar to the Central Valley and Sierra Nevada mountains of California. However, as volatilization of pesticides is a function of the vapor pressure of the pesticide and the air temperature at the spray location, the higher temperatures in Hawai'i may result in even greater volatilization. In California, significant volatilization occurred during winter spray events in almond orchards with 24-hour air temperatures varying between 0˚C and 12° C as well as summer applications in citrus groves at temperatures of 12-25°C. The annual variation in air temperatures in Hawai'i range between 23°C and 27°C with daily variations of 5-11°C.

Other evidence points to similar effects from deposition of pesticides within other mountain ranges such as the Smoky Mountains in southern Appalachia. Researchers have observed pesticide deposited from upwind farmland, and the wind can carry volatilized pesticides from spring crop plantings for long distances (Lenoir, McConnell, Fellers, Cahill, & Seiber, 1999), allowing them to travel to distant ecosystems by wet (McConnell, LeNoir, Datta, & Seiber, 1998) and dry deposition (Majewski, Zamora, Foreman, & Kratzer, 2006). Spring and summer prevailing winds are predominantly southwesterly in the southern Appalachians. Freake and Lindquist (2008) describe pesticide exposure to amphibian populations in the Great Smoky Mountain National Park in North Carolina. They predicted a similar pattern for deposition from pesticide use in this area. The overall geographic pattern was heterogeneous and did not clearly match predictions, so they observed no consistent eastward decrease in number or level of agrichemical residues. However, they observed pesticide residues at elevation, indicating amphibians and potentially other species in these habitats are exposed to current and legacy agrichemicals (Freake & Lindquist, 2008).

Terrestrial-specific Exposure Factors

Terrestrial organisms can be exposed to pesticides in the environment through diet, direct spray, preening, drinking water, and inhalation at different life stages. Various factors influence the likelihood and extent of this exposure at both the individual and population level including both properties of the pesticide (e.g., number of applications, persistence) and life history factors of the species (e.g., dietary preference, feeding habits, species distribution, and local and long-distance movement). As described below, we consider dietary and dermal routes of exposure in this analysis. However, we are unable to combine the contribution of each route to produce a total dose to individuals, so we considered exposure via each route separately.

Routes of Exposure

Ingestion - dietary exposure

A primary route of exposure to pesticides for terrestrial organisms is from ingestion, either by feeding on food items that have been contaminated after a pesticide application or through direct consumption of the pesticide (e.g., in the granular or bait form). For contaminated food items, exposure may be to pesticide residues that have either been biologically incorporated into plant or animals, or deposited on the surface or the plant or animal. Secondary predators may also be exposed to pesticide within prey that has not yet been biologically incorporated, but resides within the gastrointestinal tract of prey (Hill & Mendenhall, 1980).

The frequency of food ingestion can vary by species. Some species may hunt or graze on dietary items daily, either at certain times (e.g., dawn and dusk), or throughout the day. Other species, such as predators and scavengers (e.g., California condor, snakes) may ingest a prey item or carcass and not feed again for one or more days. Life stage may also affect the frequency of feeding, as young of altricial species may be reliant on parents to bring food back to the nest site one or more times per day. Long-distance migrators such as the red knot may gorge feed at stopover locations, then travel long distances on food stores from these events.

For terrestrial species, EPA’s BE provides EECs based on output from the T-REX model on and in food items of terrestrial vertebrates as both concentration-based and dose-based values (as described in Attachment 1-7) for exposure on use sites and via spray drift. Pesticide concentrations vary by dietary item and use (i.e., incorporating use-specific application rates and frequency). Therefore, individual species may be associated with multiple EECs based on the number of food items consumed and the number of use sites that the species overlaps with.

For our analysis, listed terrestrial species have been documented to consume from 1 to 11 dietary items. For many species, dietary preferences are unknown or the information is not readily available. For these species, we assume that individuals are equally likely to consume any of the dietary items identified. Some species may have known dietary preferences. In these cases, we have increased confidence in the likelihood of exposure to the pesticide concentration associated with preferred dietary items. However, even if a dietary item is less preferred, it should be considered whether it may be consumed at a high enough rate to cause effects even once over the course of the entire year. In some cases, prey exposed to pesticides could be taken preferentially, as such exposure may make it more susceptible to predation (e.g., (Hunt, Bird, Mineau, & Schutt, 1992)).

The breadth of EECs that are likely to be encountered by individuals may also be influenced by the degree of mobility of the species. The EECs derived from the T-REX model are based on empirical values of dietary items collected from fields following pesticide applications that vary both across and within application sites. As such, a range of potential EECs is generated based on these values and the designated application rate. The BE provides two EECs from this range, the mean and upper bound. The mobility of a species can influence which EEC is appropriate for analysis. Many terrestrial species are at least moderately mobile when they feed, foraging not at a single point, but in numerous locations throughout their foraging site(s). For these species, we would expect them to be exposed to a range of residues during any foraging event. While there is a chance that all residues encountered could be on the high or low end of the range, the greatest likelihood is that some residues would be high and others would be low. Therefore, we use the mean values from T-REX to estimate their daily exposure. Animals such as terrestrial invertebrates that are more localized in their feeding or may feed extensively in one spot could be exposed exclusively to values from any one point in the distribution. For these species we would use the upper bound EEC to ensure that we have captured the maximum concentration to which they could be exposed. Some terrestrial vertebrates, such as the California condor, are highly mobile but can derive all of their food for one or more days from a single carcass, thus being exposed to a single point at the distribution. For these species, we would use the upper bound EEC to evaluate the risk to individuals, but we would assume that within the species some individuals would eat carcasses with lower residues and some with higher residues, and therefore assess the effects to the species based on mean EECs.

For each application of malathion, T-REX produces a time series of concentrations on each dietary item, starting immediately after application and progressing on a daily basis. For our assessment, we have chosen to look at the peak EECs from this time series. For some dietary items, such as plants, peaks will occur immediately after an application and decrease through time. For other dietary items, such as small mammals and birds, peaks may not occur until days after an application as the prey item itself continues to be exposed to pesticide residues prior to it being preyed upon by the listed species under consideration. Peak values can also be influenced by multiple applications and the length of time between those applications. For mobile species, we acknowledge that looking at peak values may overestimate exposure, as individuals may not be present or may be foraging in a different location when peak values occur. However, mobile individuals may also have more opportunities for exposure to peak values if their foraging areas pass through multiple areas of pesticide use. For instance, wood storks typically forage 5 to 12 miles from nesting sites, but have been documented foraging as far as 80 miles. Species such as this may be exposed to malathion as a consequence of multiple application events (i.e., from different fields or use sites, or from multiple applications on the same field), or from feeding multiple days on the same use site where concentrations may remain high enough to result in adverse effects. Our analysis does not capture the risk to species that may be exposed repeatedly or on multiple occasions throughout the year; we assess the risk of effects to individuals following a single exposure event. In this manner, we are less conservative, but by using peak EECs we hope to capture the breadth of effects that may occur to species regardless of the manner in which they are exposed. For species with little to no movement, individuals on or near use sites have a high likelihood of seeing peak EECs following an application, as well as subsequent EECs from the same application that may result in adverse effects. However, they may be unlikely to experience exposure from spray events from other use sites and therefore are likely to have less chance of exposure from applications to different sites.

Peak EECs are used to assess mortality and sublethal effects from both acute and chronic exposure. As described above (Effects to Terrestrial Species), most toxicity studies that are designed to examine sublethal effects such as growth, behavior, and reproduction are chronic studies in which test subjects may be exposed to pesticides for long periods of time (e.g., 20-week reproduction studies for birds). Endpoints measured in these studies aggregate the combined effects of that exposure that may be a result of one or more responses (e.g., parental behavior of adults versus developmental effects to young that combined result in reducing hatching). It is not generally possible to ascertain the specific response, or timing of that response, that caused the ultimate effects. For reproduction in birds, for example, it is possible that short exposures at some point during the 20-week exposure cycle were ultimately responsible for effects. Without information to suggest that effects are only likely to result from longer exposures, we assess the potential for malathion to affect individuals based on a single peak EEC value.

<u>Contact exposure – direct spray or contact with contaminated media</u>

Terrestrial species may be exposed to pesticides through direct contact with a pesticide followed by dermal absorption. Exposure may occur from pesticides directly deposited on an individual during a spray or individuals contacting contaminated media after a spray, such as walking on a treated field or brushing against treated foliage. Studies have shown that for birds, in particular, this can be a significant route of pesticide exposure to cholinesterase-inhibiting pesticides through direct exposure to the pesticides (Hudson, Haegele, & Tucker, 1979; Schafer, Brunton, Lockyer, & De Grazio, 1973; Henderson, Yamamoto, Fry, Seiber, & Wilson, 1994). Dermal exposure through the feet of raptors roosting in almond orchards was demonstrated by Fry et al. (1998), and Wilson (1994), when raptors selectively hunted for debilitated prey (birds and rodents in sprayed orchards). Both dermal absorption and secondary exposure from ingestion of pesticide-exposed prey occurred. Dermal absorption was also demonstrated by Vyas et al. (2006) in Canada geese exposed in the field. Diazinon residues measured on skin, feathers, and feet suggested that higher mortality of geese exposed in the field versus the lab was likely attributable to additional routes of exposure, including dermal absorption.

For terrestrial invertebrates, we estimate contact exposure in the same manner as dietary exposure, but use the species being assessed in place of the dietary item. Specifically, the output from the T-REX model contains the concentration of pesticide on the surface of the terrestrial invertebrate and we use this value as the contact dose for the listed species.

For terrestrial vertebrates, Attachment 1-7 of the BE provides estimates for two different types of dermal exposure: direct spray at the time of application (for all terrestrial vertebrates) and contact with contaminated foliage (for birds and mammals only). Mean and upper bound values are provided for each exposure type, converted to oral equivalents so these exposures can be evaluated by existing toxicity data. In lieu of dermal dose estimates based on use-specific application rates, a single application rate was used to represent an estimated maximum rate for all uses and an estimated minimum rate for all uses. For all taxa, we based analyses on mean values to represent exposure expected across many individuals of a species. For birds and mammals, we based analyses on estimated doses resulting from contact with contaminated media. We expected this route would be a more likely exposure scenario than exposure from direct spray, as animals may be absent, underground, or sheltered, or may flush during an application if they are able, and application is a one-time event as compared to contact with media on which residues may persist and increase the likelihood of exposure. Contact with contaminated media also produced higher estimated dermal doses than direct spray, and thus would be inclusive of any effects anticipated from that route of exposure.

Ingestion from preening or grooming

Birds and mammals exposed to pesticides on their feathers or fur through direct spray or contact with contaminated media can ingest that pesticide through preening. In one study, dermal exposure, including preening, was found to be a greater contributor to toxicological response from 8 to 48 hours post-spray than oral exposure in northern bobwhite exposed to simulated aerial crop applications of the cholinesterase-inhibiting pesticide methyl parathion (Driver, et al., 1991).

EPA did not assess exposure of birds and mammals through preening or grooming in the BE; therefore, no values exist for our assessment in this Opinion. We consider the likelihood of dermal exposure, though the absence of a quantitative assessment of these routes adds additional uncertainty to this estimate.

Inhalation

Exposure via inhalation can occur from spray droplets at the time of the application and volatilized residues under the crop's canopy. In a controlled study with the cholinesterase-inhibiting pesticide methyl parathion, inhalation was found to be the major contributor to toxicological response in the hours immediately following spray compared to other routes of exposure (Driver, et al., 1991).

For this analysis, estimated doses for spray inhalation were one to four orders of magnitude lower than mean dietary doses and dermal doses, and doses for vapor inhalation were two to five orders of magnitude lower. As such, we did not further assess exposure from inhalation as we considered its contribution to be minor compared to other routes of exposure, and we would have already captured any effects.

Ingestion - drinking water

Terrestrial species may be exposed to pesticides in water consumed beyond what is ingested from food items. In the BE, pesticide dose in drinking water is estimated under the assumption that the animal is consuming 100% of its daily diet from an individual food item and 100% of the remaining water need from either puddles or dew. If the diet of a species includes multiple food items (e.g., yellow-billed cuckoo), drinking water rates for each of these food items is calculated, for dew and for puddles, independent of each other. This is a kind of "what-if" approach, where the question is: "What is the dose if the animal is consuming 100% of its diet as this single food item with residues representative of the treated field and 100% of its remaining water from either dew or puddles on the treated field?"

For this analysis, estimated doses for drinking water from puddle or dew were several orders of magnitude lower than mean dietary and dermal doses. As such, we did not further assess exposure from drinking water, as its contribution was considered to be minor compared to other routes of exposure, and any effects were already captured.

Probabilistic Exposure Assessment for Exposure on Use Sites

We generally carried forward terrestrial EECs and overlap values for exposure on use sites from the BE, with two notable exceptions. The BE used generic maximum EECs to assess the likelihood of effects to species. That is, one application rate was chosen that represented the maximum rates across most uses. This rate underestimates exposure in some cases and over-estimates it in others. For the Opinion, the MagTool (previously described in the *Approach to Assessment* and earlier discussions) incorporates the specific uses that overlap with a species ranges and the individual rates that apply to those uses to calculate EECs. For the overlap with species range, the BE considers the aggregate of the six years of available Cropland Data Layers (CDL) data for pesticide use categories to ensure the full footprint is captured for each use. For the Opinion, a probabilistic exposure assessment is performed based on each of the 6 years of CDL data. This assessment is described further in Appendix D, but in short, the assessment produced 5th, 50th, and 95th percentile effect levels for mortality and sublethal effects based on the differential extent of overlap with each year of CDL data. For example, if the 5th, 50th, and 95th percentile magnitude of mortality was 1%, 5%, and 10%, that would mean there is a 5% probability the magnitude of mortality would be less than 1%, a 50% probability the mortality will be below (or above) 5%, and a 95% probability the mortality will be below 10%. In other words, there is a high probability mortality will be above 1%, a low probability the mortality will be above 10%, and on average the mortality will be 5%. However, in practice, we found this aspect of the exposure assessment accounted for little variability, and differences between 5th, 50th, and 95th percentile values were often within 1-2%. For this reason, we chose to carry forward only the 50th percentile values.

Exposure Assessment for Exposure via Spray Drift

Terrestrial EECs and overlap values for exposure via spray drift were generated in 30-m increments from use sites, up to 300 m or 750 m, depending on whether ground or aerial applications were considered likely to occur. These estimates assume drift extends these distances off fields, and typically represents open areas with flat topography. Pesticides may drift farther in some instances. In other instances, drift may be minimized by application methods, timing, or landscapes that impede its movement (e.g. forest).

For analysis of direct effects to terrestrial invertebrates, we generated concentration-based exposure for each use and the corresponding application rate associated with that use. For analysis of direct effects to terrestrial vertebrates from spray drift, we generated dose-based EECs in the same manner as in the BE (i.e., based on a generic maximum application rate), and lack the additional refinement described for exposure on use sites as described above. In addition, we based spray drift overlap with species ranges on the aggregated six years of CDL data as in the BE, as opposed to the 50th percentile or mean values used to assess effects on use sites, as described above. We expect that these methods combined would tend to overestimate effects of spray drift to terrestrial vertebrates. However, we found that malathion was not a driver in effects to these species, and that further refinement was not needed.

In all cases, effects are assessed in 30-m increments, starting at 15 m from the use site. Exposure to spray drift is modified by the assumption that each application is likely to produce drift primarily dependent on the direction of the prevailing wind, and not uniformly around the use site. For each application allowed by the label, the overlap for each 30m increment is adjusted by a factor of 0.25, to a maximum of 1 for uses with 4 or more applications allowed per year. Note that the generation of an additional set of EECs for spray drift is unique to the terrestrial exposure analysis, as the aquatic analysis aggregates the contribution of all inputs into waters when generating aquatic EECs.

For all species, we assume spray drift will increase the area of overlap with the species range, with this assumption particularly important for species that are not anticipated to enter use sites, as it may represent the only exposure to malathion that is likely to occur. However, it is important to note that spray drift areas from different uses can overlap with one another, or even overlap with use sites, depending on their proximity on the landscape. For this reason, combining areas from different uses where spray drift exposure could occur without accounting for this proximity could overestimate the total overlap with the species' range.

Chemical Persistence

Malathion appears to degrade in soil with a metabolic half-life from 0.3 to 7 days in registrant-submitted studies depending on soil type and soil moisture. The environmental fate of the toxic malathion transformation product, malaoxon, indicates that it has nearly identical persistence and mobility characteristics as parent malathion. Values for foliar half-lives ranged from 0.3 to 11 days. In addition, for most registered uses of malathion, either two or more applications per year are permitted, or a maximum number of applications is not specified. As a result, EECs at a given use site that are expected to result in adverse effects to species may persist days to weeks following an application, with the length of time depending on the food item, application rate, and number of applications. Alternatively, depending on the length of time between applications, species may experience multiple periods where malathion residues on food items reach levels sufficient to cause adverse effects.

While chemical persistence is not explicitly incorporated into the analysis of terrestrial exposure (i.e., number of days that EECs may cause adverse effects), we have chosen to consider peak values as a way to capture the breadth of potential effects to species, as discussed above.

Factors to Determine Percent of the Population Exposed

Utilization of pesticide use site

Concentrations of pesticides on food items and contaminated media such as plants are generally higher on pesticide use sites than on adjacent areas contaminated only by off-site transport from spray drift. Individuals that are predicted to experience effects from pesticide exposure on use sites may have reduced effects, or in some cases no effects, from exposure to pesticide as a result of spray drift. For this reason, the tendency of individuals to enter or forage within a use site, when known, can affect the likelihood of exposure and effects. Species experts within Service field offices were asked to comment on whether species will enter, forage, roost, breed, pass through, or otherwise utilize pesticide use sites that overlap with the range of the species. Where this information was available, we incorporated it into the analysis to verify or limit potential exposure as appropriate. For example, if a species may breed or forage on a use site, dietary and contact exposure were considered both on the use site and as a result of spray drift. If a species is only likely to travel through a use site, we considered contact exposure on the use site, and dietary and contact exposure from spray drift. If a species was deemed unlikely to enter a use site, we considered dietary and dermal exposure from spray drift only. Where data were lacking on whether or not use sites would be avoided, we assumed that a species could enter, forage, roost, breed, pass through, or otherwise utilize sites of pesticide use based upon their location within the species range. More specific information regarding a species' behavior on or near use sites results in better exposure assessments and reduced need for conservatism.

Mobility of individuals

The percent of a population exposed to a pesticide may be influenced by the distance an individual travels to forage. As a default, we assume the proportion exposed is roughly equivalent to the percent of overlap between pesticide use sites and the species range. We may have more confidence in this assumption for species that have limited mobility compared to those with high mobility. For species that travel large distances to forage, this overlap is likely to be less predictive of pesticide exposure, depending on the manner in which use sites are distributed throughout the range. For instance, wood storks have about 15% overlap with malathion use sites within their range. However, storks can travel large distances to forage, and use sites occurs throughout their range such that any individual could access that landcover type. In these cases, we would have less confidence that the percent overlap equates to the proportion exposed, as individuals from outside of the overlap area are may be likely to enter the area to forage. However, we would still consider and acknowledge that these use sites only represent a certain fraction of their range.

Aquatic-Specific Exposure Factors

Aquatic species are likely to be exposed to pesticides that are deposited in surface waters through runoff and drift transport pathways. Our analysis focuses on exposure from contact with contaminated surface water. While dietary exposure may also be a relevant route of exposure, response data to the dietary exposure route is generally not available for these species or related surrogates. Furthermore, contact with surface water is expected to be the primary route of exposure for aquatic species and is likely to capture any effects that may occur from the dietary route. Consequently, exposure was only evaluated using surface water concentrations estimates derived by EPA in the BE.

Aquatic Habitats

Aquatic species are dependent upon a variety of aquatic habitats which vary in size, volume, flow, etc. To better estimate pesticide exposure in these different types of surface waters, ten generic habitat types were defined (Table 30): one to simulate aquatic-associated terrestrial habitats (bin 1); three to simulate flowing waterbodies (bins 2-4); three to simulate static waterbodies (bins 5-7) and three to simulate estuarine/marine habitats (bins 8-10). The habitats vary in depth, volume, and flow. Aquatic-associated terrestrial habitats (bin 1) include riparian habitats or other land-based habitats adjacent to waterbodies that may occasionally be inundated with surface water, provide habitat used by aquatic organisms and semi aquatic organisms, or influence the quality of the aquatic habitats.

The Service identified the bin(s) representative of habitats utilized by each listed species. A single species may occur in range of habitats represented by multiple bins. Bin 2 is intended to represent habitats with flow rates occurring of 0.001-1 m^3/second including springs, seeps, brooks, small streams, and a variety of floodplain habitats (oxbows, side channels, alcoves, etc.). Bin 3 flow rates are representative of small to large streams (1-100 m^3/second) and bin 4 definitions (larger volumes and flow rates exceeding 100 m^3/second) correspond with larger riverine habitats. Bins 5, 6, and 7 represent freshwater habitats that are relatively static, where flow is less likely to substantially influence the rate of pesticide dissipation. Examples of bin 5 habitats (volumes <100 m^3) include vernal pools, small ponds, floodplain habitats that are cut off from main channel flows, and seasonal wetlands. Bin 6 volumes (100 – 20,000 m^3) correspond with many ponds, vernal pools, wetlands, and small shallow lakes and bin 7 represents larger volume habitats (>20,000 m^3) such as lakes, impoundments, and reservoirs. Bins 8, 9, and 10 were designed to characterize marine habitats. The EPA does not currently have models designed to estimate EECs for the estuarine/marine systems. Therefore, surrogate freshwater flowing or static systems were used to evaluate exposure in estuarine/marine bins as appropriate.

Table 30. Generic aquatic habitats (BE Table 1-7).

Generic habitat	Depth (meters)	Width (meters)	Length (meters)	Flow (m3/second)
1 - Aquatic-associated terrestrail habitats	NA	NA	NA	NA
2 - Low-flow	0.1	2	length of field[1]	0.001
3 - Moderate-flow	1	8	length of field	1
4 - High-flow	2	40	length of field	100
5 - Low-volume	0.1	1	1	0
6 - Moderate-volume	1	10	10	0
7 - High-volume	2	100	100	0
8 - Intertidal nearshore	0.5	50	length of field	NA
9 - Subtidal nearshore	5	200	length of field	NA
10 - Offshore marine	200	300	length of field	NA

[1] length of field - The habitat being evaluated is the reach or segment that abuts or is immediately adjacent to the treated field. The habitat is assumed to run the entire length of the treated area. Exposure concentrations in surface water and benthic sediment pore water, downwind from the chemical's use are evaluated using AgDRIFT and AGDISP, as previously described in Section 1.5.1.1.c.1 NA indicates that concentrations were not calculated.

Aquatic Exposure Modeling and Exposure Estimates

The EPA derived estimates of pesticides in surface waters and benthic sediment pore water by incorporating the bin parameters (Table 30) into exposure models. Combinations of several fate and transport models including the Pesticide Root Zone Model (PRZM5), the Variable Volume Water Model (VVWM), and AgDrift (version 2.2.1) were used to estimate concentrations in aquatic habitats of variable sizes and flow rates representative of habitats used by listed species (BE Chapter 3). The methodology used inputs consistent with application requirements specified on product labels. Additionally, inputs representing application site characteristics (e.g., meteorological conditions) were selected at the HUC2 regional scale (Figure 8) to generate geographically specific EECs (USEPA, 2017).

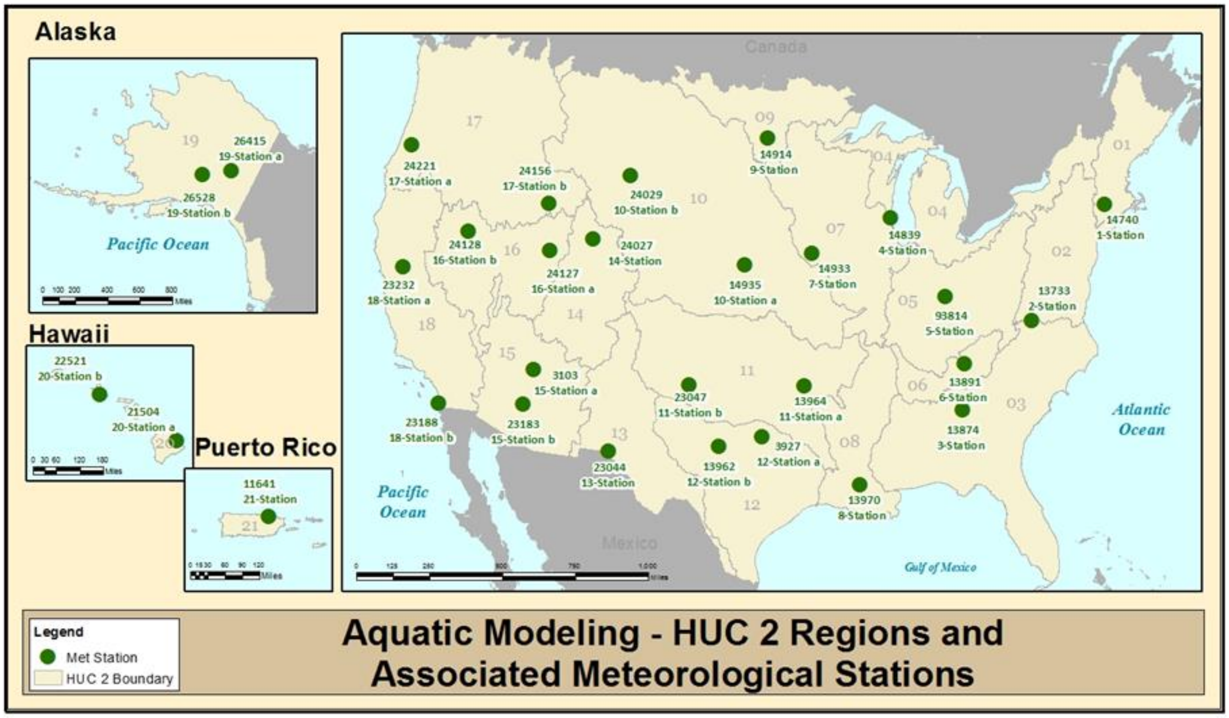


Figure 8. Hydrologic Unit Code (HUC) 2-digit Regions and Associated Metrological Data.

Probabilistic Exposure Assessment

As mentioned above, we carried forward EECs generated for the BE into the Opinion. However, in the Opinion, we report aquatic exposures probabilistically for all uses except for mosquito adulticide. The probabilistic method we use captures the variability in EECs derived by incorporating geographically specific estimates that are accounted for from two sources: (1) the occurrence of pesticide use sites within the species range (six-year data set), and (2) daily precipitation (30-year data set). In brief, this analysis was based on the 30-year annual maximum EECs for different averaging periods (i.e., 1-day, 4-day, 21-day, 60-day) from the 30-year annual time series (1-day time step) generated for each pesticide use/scenario/HUC2/bin combination. From that distribution of EECs, for each pesticide use/scenario/HUC2/bin combination, the 5th, 50th, and 95th percentile EECs were provided on the R-Plot. The probabilistic exposure assessment for aquatic species, which incorporated variability from both the overlap data as well as modeled EEC data, produced outputs that when reviewed from the R-Plot accounted for little variability and differences between the 5th, 50th, and 95th percentile values. They were often within 1-2%, similar to what was observed for terrestrial species. For aquatic species, we carried forward only the 50th percentile.

EECs for Aquatic Habitat Bins

We delineated aquatic species ranges by HUC12s (subwatershed), and based exposure of aquatic species to malathion on the overlap of malathion use sites with the HUC12(s) that comprised their ranges. For the static-water bins (5, 6, 7) and the smallest flowing-water bin (2) within

HUC12s, EECs are calculated for each overlapping use site (e.g., corn, pasture). We modeled each use as if the water body was immediately adjacent to the site (i.e., edge of field). However, bins 3 and 4 (medium and large streams/rivers) were modeled at the subwatershed/HUC12 scale (USEPA, 2017). We scaled EECs for all use sites within a HUC12 based on percent overlap (of the use site) and aggregated EECs to generate a single malathion EEC for the bin (3 or 4).

Determining Percent of the Population Exposed

Proximity to Pesticide Use Sites

The likelihood that individuals will be exposed to malathion will be influenced by many factors including the proximity of populations to pesticide use sites. For our analysis, we consider that exposures may occur if pesticide use sites overlap with HUC12(s) that comprise the species range. For some species, there may be specific information regarding the location of populations within their range (i.e., occurrence in specific waterbodies or waterbody segments). Further spatial refinement of species locations within their range, such as narrowing the number of HUC12s or evaluating the proximity to use sites within HUC12s, was generally beyond the scope of this assessment. Therefore, we assumed the species would occur throughout its range (i.e., in all HUC12s), and individuals to be uniformly distributed within and between HUC12s. For species that occur in waterbodies represented by bins 2, 5, 6, and 7, under the uniform distribution assumption, we approximate the percentage of individuals in the population that are likely to be exposed by the percent overlap of pesticide use sites within the range. For species that occur in medium and large rivers (bins 3 and 4), we assume 100% of individuals in populations within HUC12s (where there is overlap with pesticide use sites) are assumed to be exposed because the exposures in these bins were modeled at the subwatershed scale. As previously noted, the EECs for bins 3 and 4 are scaled to consider the percent overlap for each pesticide use site (within HUC12s) and aggregated to generate a single malathion EEC.

Mobility of Individuals

Some aquatic species, including many aquatic invertebrates and narrow endemic fish species, do not (or cannot) move large distances and are more likely to be exposed as a result localized pesticide use. However, highly mobile or migratory species, such as anadromous fish (e.g., Atlantic salmon and Atlantic (Gulf) sturgeon), travel great distances and individuals could be exposed to pesticides from multiple use sites along the migratory corridor. Alternately, these species may be absent from any particular area at the time of pesticide use. For these reasons, the percentage of the population exposed may be lesser or greater than would be predicted based solely on overlap of use sites in individual HUC12s within the range depending on the presence of the species.

Chemical Persistence

Degradation of malathion can vary depending on environmental conditions in water (hydrolysis half-life 107, 6, and 0.5 days at pH 5, 7, and 9, respectively) and soil (under both aerobic (aerobic half-life: 0.5 - 10 days; anaerobic half-life: 2.5 days). In addition, for most registered uses of malathion, either two or more applications per year are permitted, or a maximum number of applications is not specified. These properties were incorporated into the fate and transport models and reflected in the annual maximum EECs. However, because of the multiple applications and persistence, individuals may be exposed multiple times during a year. While those exposures would be at lower concentrations (submaximal), they may be sufficiently high to cause adverse effects and contribute to risk. However, we do not have information or predict where and when multiple applications may occur.

Plant-specific Exposure Factors

Based on our review of the possible effects of the action to plant species covered under this consultation, we make two assumptions regarding effects to plants: (1) reductions in biomass represent impacts to growth due to phytotoxicity, and (2) reductions in pollinators and reductions in seed dispersers would affect reproductive success. The latter also corresponds to "indirect effects" in risk assessment terminology. While such indirect effects are also anticipated for other taxa, we discuss the potential exposure of insect pollinators in greater depth in this section due to the high toxicity of malathion to these species, and the dependence of many plants on insect pollinators for successful reproduction.

Routes of Exposure for Pollinators

Insecticides help to rid gardens, agricultural areas, forests, nurseries, and other areas from the harmful effects of unwanted or pest insects. However, insecticides also impact non-target insects with effects dependent on the timing of application (seasonal, daily, and temporal), environmental factors, and concentration of the chemical, among other factors. Pesticides, combined with other contributing stressors, is a cause for decline in bee populations (Le Conte, Ellis, & Ritter, 2010; Maxim & van der Sluijs, 2010). Bees (superfamily Apoidea) are the most dominant animal pollinator and prominent agricultural crop pollinator in North America (Cutler, Purdy, Giesy, & Solomon, 2014), making bees the focus of most literature review and studies. Honey bees (*Apis* species) are the most well-studied as they are the pollinator to major crops and are managed by humans (primarily nonnative honey bees). However, non-*Apis* bees may also be exposed to malathion but are different than honeybees due to their differing routes of exposure. Most non-*Apis* bees are solitary nesters and use soil and/or vegetation for nest construction, or to nest in the soil (Michener, 2007).

As an insecticide, malathion's effects on terrestrial invertebrates has been well documented in the literature. Khan et al. (2016) studied the residual effects of malathion on pollinator abundance (i.e. honey bees, butterflies, syrphid flies, and bumble bees) visiting marigold (*Calendula officinalis*) fields. The study suggested that with a field dose of malathion (0.002 g/mL) applied to marigold fields, visiting honey bees were adversely affected (Delaplane, Mayer, & Mayer, 2000). Plants treated with malathion in this and other studies (Pike, Mayer, Glezer, & Kious, 1982; Shires, Leblanc, Debray, Forbes, & Louveaux, 1984; Khan, et al., 2016) were avoided by pollinators, in part due to potential olfactory, visual, gustatory, or chemical cues (Ramirez-Romero, Chaufaux, & Pham-Delègue, 2005). Other studies show malathion, may have a mild effect on pollinators, allowing them to resume their nectaring and visiting activity promptly (Delaplane, Mayer, & Mayer, 2000). Khan et al. (2016) found that after 20 hours of a spray application, mortality in visiting honey bees was 100% and showed that after 24 hours of application residual toxicity of malathion was high but with time, the toxic effects decreased (effects still present after day 10). Suhail et al. (2001) found that malathion applied to cucumber plants caused 67% mortality after 48 hours. Studies by Johansen and Mayer (1990) and Atkins and Anderson (1967) suggested that malathion remained highly toxic to honey bees from 1-12 hours after application or and that toxic effects disappeared after five days, respectively. The length of time that malathion remains toxic is likely dependent upon a number of factors including application rate, application method, environmental factors, and which species are exposed. However, it remains a very toxic insecticide to several invertebrate species, and has been shown to have significant impacts on honeybee mortality (Sharma & Abrol, 2014).

Secondary routes of exposure can affect both social pollinating adults and offspring of honey and bumble bees if the pesticide is brought back to the hive or nest, deposited in food, or transferred to other individuals (Cutler, Purdy, Giesy, & Solomon, 2014). The main pathway of exposure is transfer of residues in pollen or nectar into hives or nest (Cutler, Purdy, Giesy, & Solomon, 2014). Since some plants have flowers that provide pollen or nectar for several days after opening, these present the most susceptible source for oral exposure for pollinators.

Little information is available on the effects of ground nesting bees to pesticides or simply nesting habits of these bees within agricultural ecosystems (Julier & Roulston, 2009; Kim, Williams, & Kremen, 2006; Wuellner, 1999).

Water can also be a significant exposure pathway for pollinators. Bees typically rely on wet foliage, puddles, soil saturated with water, or other small areas for water (Winston, 1987; Samson-Robert, Labrie, Chagnon, & Fournier, 2014; Gary, 1975). The amount of water consumed by a honey bee varies by life stage and role within the hive. Water requirements within a honey beehive vary depending on outside air temperature, humidity, and amount of brood (Thompson, 2010).

Exposure Pathways for Cave Species

We do not anticipate that direct application or drift would be likely pathways for cave species when they are in subterranean habitats. However, we do anticipate cave species would be exposed to malathion from contaminated food sources entering the cave or pesticides leaching through porous substrate, such as karst. Cave-dwelling organisms may be directly exposed to pesticides in water from the leaching of pesticides from agricultural practices over or near lava tubes, sinkholes, or other porous features near the surface of cave habitats.

Cave dwelling organisms may also be exposed from dietary items. Many of the listed cave dwelling species rely on surface-derived nutrients that include leaf litter fallen or washed in, animal droppings, and animal carcasses. Several studies cite that nutrients in cave ecosystems are derived from exterior sources (Poulson & White, 1969; Howarth, 1983; Culver, 1986), particularly from organic material washed in or brought in by animals. Bats are usually the major source of these nutrients, as well as the major source of contaminants (Kunz, 1982). Pesticides can be introduced into caves by bats from their exposed carcasses that decay in caves or from bats defecating in caves (McFarland, 1998; Sandel, 1999; Land, 2001; Eidels, Whitaker, & Sparks, 2007). Bats within a population/colony may consume pesticide-exposed insects while foraging in or near use areas and guano accumulated from multiple bats within the cave will reflect that exposure. Therefore, we anticipate that cave-dwelling organisms that forage on guano are exposed to pesticides.

Given the overlap of areas directly above these species, the documented studies providing information that these caves are porous, and documented studies providing examples of pesticide-contaminated dietary items, we anticipate there is exposure to listed cave species from applications occurring outside the cave.

Approach to Usage Analysis

The overlap information above describes the footprint of the malathion use based on the product label and any off-site transport based on the application method of that use. We apply usage data to describe how the pesticide has been applied in the past to the use sites based on available data sources. The key difference between use and usage is that use data extends to all the uses as they are authorized by EPA, whereas usage refers to how they are actually applied on the landscape.

To determine effects to listed species, we sought to refine the scope of analysis undertaken in the BE from any area where malathion is authorized to be applied, to those areas where applications are reasonably certain to occur. To this purpose, we pursued the acquisition of data describing past malathion usage. While we recognize that past usage data may not fully predict future usage, this information would nonetheless better inform where we would expect usage to occur in the future and provide more context for our assumptions related to uncertainty.

In 2017, in response to our request for information, EPA provided us with 5 years of survey data for malathion usage obtained from a combination of commercial and public sources (Appendix G). Overall, the survey methodologies for these data were designed to assess nationwide usage for a subset of crops and non-agricultural uses for which malathion is registered. However, due to the broad geographic scope of these surveys, we found it difficult to relate the results to potential exposure to listed species, which often inhabit more narrow areas. To better inform our analysis, we sought additional information, including data from other sources, to provide a more geographically refined estimate of exposure (i.e., compatible with the ranges of listed species, many of which are at a sub-state level) and to fill data gaps where no information for a registered use was provided. Subsequently, we identified, collected, and evaluated additional usage data for its utility in informing the consultation, in coordination with EPA, USDA, and NMFS. Sources of data included state departments of agriculture, pesticide registrants, and federal land agencies. Although we identified no sources that would broadly inform our analysis of all labeled uses of malathion, we did obtain data for a subset of uses that help us better predict the anticipated exposure of species and their critical habitats to malathion. Data sources we considered in our analysis for this purpose are described below.

Agricultural Usage (excluding Caribbean and Pacific Islands)

EPA's Malathion: Revised National and State Use and Usage Summary (SUUM; Appendix G)

These data are provided at the state level and indicate how many acres of a crop has been treated with malathion over a 5-year period. Acres that are reported as "treated" are compared to the total number of acres grown for each crop at the state level, to produce a "percent crop treated (PCT)" value. EPA provided the Service with PCT values at the national and state level (mean, minimum, and maximum) over a 5-year period. The data are not comprehensive of all crops for which malathion is registered, and do not address every state in which surveyed crops are grown.

Data provided in EPA's Use and Usage Summary report are obtained by EPA from USDA, the state of California, and a commercial source (Kynetec), as described in more detail in Appendix G. The majority of the data provided for states outside of California are from the proprietary source Kynetec. According to materials provided by the company, Kynetec data is "designed to address market questions asked most often by senior executives, and those involved in product development, sales, and marketing." Surveys are designed to reach a particular percentage of the total crop grown at a national level, though statistics are reported at the state and Crop Reporting District (CRD) level when sample size is adequate. The data provided to the Service is lacking the statistical foundation to understand the robustness at the state level or any geographic specificity at the sub-state level. Neither EPA nor Kynetec was able to provide us with this information (e.g., how many applicators responded to the survey, how many acres are represented by the survey at the state level), nor any standards used to determine an adequate sample size at these levels, nor the minimum threshold required for reporting these values. Our understanding is that this varied on a case-by-case basis, according to the surveyor, crop, and state.

Analysis of this data by EPA indicated that the yearly average agricultural application of malathion was approximately 1 million pounds in the five most recent survey years available (2011 to 2015). Approximately 85% of the pounds of malathion applied agriculturally were to eight crops: oranges, alfalfa, winter wheat, strawberries, cherries, caneberries, walnuts, and cotton. In terms of total acres treated, approximately 85% of the acres treated with malathion are for nine crops: alfalfa, oranges, winter wheat, cherries, strawberries, cotton, caneberries, walnuts, and lettuce. The remaining 15% of malathion usage is spread over 138 other crops. While the majority of malathion is only applied to a handful of crops, examination of the percent of individual crops grown by state that are treated with malathion indicates that it is an important pest control tool for certain crops in certain states.

For all states, the number of crops surveyed ranged between 0 and 21 (with the exception of California, for which usage was reported for 79 crops). No crops were surveyed in Hawaii, Alaska, New Hampshire, Rhode Island, or Vermont. An additional 15 states had usage surveyed for 1 to 5 crops only. From these data points, malathion usage was often variable across state, crop, and year. For individual crops, usage changed by as much as 100% over the 5-year survey period at the state level. Where surveyed, crops that showed higher usage in at least a subset of states included onion, cherries, blueberries, caneberries, strawberries, watermelon, pumpkin, cotton, and citrus. Major crops that generally showed low usage were corn and wheat, though exceptions exist for both. Detailed information is available in EPA's Use and Usage Summary (Appendix G).

Data from State Departments of Agriculture

In May of 2018, the industry stakeholder group Federal Endangered Species Task Force (FESTF, 2020) compiled a list of contacts for each state's Department of Agriculture and sent email inquiries regarding the availability of landcover and usage information collected at the state level. FESTF provided us with the results of their inquiry (Appendix H). We combined these results with information provided directly by Washington States and the three state sources identified by our interagency working group (California, New Jersey, New York) for a total of nine states that had either yearly, periodic, or one-time reports of pesticide usage for a subset of pesticide users in the state.

Data derived from these states is summarized below and compared to results obtained from EPA (with the exception of California, which is discussed separately below). These reports were often consistent with information provided by EPA, but in some cases, provided novel information (i.e., new or additional evidence of pesticide use) where surveys were lacking, or evidence of pesticide use when EPA's data indicated otherwise.

Maryland

Surveys conducted by the State of Maryland estimated that Maryland farm operators, certified private pesticide applicators, commercially licensed businesses, and public agencies applied 691 pounds of malathion in 2011 and 737 pounds in 2014 (Maryland Department of Agriculture, 2013; Maryland Department of Agriculture, 2016).

Comparison to EPA-submitted data:

Of the five crops that were surveyed in Maryland from 2011 – 2015 in EPA's Use and Usage Report (lima beans, cucumber, pumpkins, watermelon, and field corn), no usage was reported. We do not know whether usage data collected by the state is for these or other crops, but this information confirms that at least some usage has occurred that was not identified by EPA.

Minnesota

No malathion usage was reported for corn or hay in 2011, 2013 or 2015, or on wheat in 2011 or 2013 (Minnesota Department of Agriculture, 2014; Minnesota Department of Agriculture, 2016; Minnesota Department of Agriculture, 2019). Information on soybeans was also provided but deemed not relevant to this assessment as malathion is not registered for use on this crop.

Comparison to EPA-submitted data:

These data are consistent with a finding of "surveyed but no usage reported" for corn and wheat from 2011 – 2015.

New Hampshire

A total of 192.10 pounds of malathion usage was reported by commercial and private pesticide license holders in 2012 (New Hampshire Department of Agriculture, 2012).

Comparison to EPA-submitted data:

No crops were surveyed in New Hampshire from 2011 – 2015. We do not know whether usage data collected by the state is for crops or other uses, but it confirms that at least some usage has occurred in the state that was not identified by EPA.

New Jersey

New Jersey obtains pesticide usage data through surveys performed under the authority of state law that requires applicators to maintain pesticide application records for three years and submit them to the state when requested. This regulatory requirement to report provides an accuracy and level of response not found in a voluntary survey. New Jersey surveys four categories of pesticide users: agriculture, golf course, lawn care, and mosquito control. Surveys of these four categories are conducted every three years on a rotating basis. The Service acquired usage reports for agriculture from 2012 and 2015, mosquito control from 2013 and 2016, golf course from 2014 and lawn care from 2013 and 2016. A total of 2,839 pounds of malathion were applied to agricultural crops by licensed applicators in 2012, and 7,201 pounds were applied in 2015. These amounts are the sum of pounds applied on numerous crop types, including alfalfa/other hay and ornamentals. A total of 1,692 pounds was applied for mosquito control in 2013, and 1,600 pounds in 2016. No use of malathion was reported for lawn care in 2016 and, a total of 0.188 pounds were reported for this category in 2013. Application on golf courses is not an approved use for malathion and none was reported from New Jersey.

Comparison to EPA-submitted data:

A detailed comparison by crop is summarized below (Table 31). We found some degree of consistency for certain crops that were surveyed (i.e., blueberries, pepper, and sweet corn), although for other crops, reporting in New Jersey indicated usage where none was reported in EPA's Use and Usage Summary (i.e., cucumbers, peaches). In 2017, NASS Census of Agriculture data indicated that 3,362 acres of peaches were grown in New Jersey. No data was available in the NASS for 2015. Assuming a minimum application rate of 1 lb/acre, the data from New Jersey indicates that approximately 2% of the crop was treated with malathion.

Table 31. Annual Malathion Usage in Pounds: New Jersey vs. Report in EPA's Use and Usage Summary

Crop	EPA Use and Usage Summary[24]	New Jersey
	average annual pounds used	pounds (year) --total for all years listed unless otherwise indicated
pumpkins	200	Not surveyed as separate crop, included in 'Other' crop category
blueberries	3,750	3,950 (average for 2 years)
peppers	SNUR	no use reported
cucumbers	SNUR	0.14 (2015)
squash	SNUR	Not surveyed as separate crop, included in 'Other' crop category
peaches	SNUR	70 (2015)
sweet corn	SNUR	no use reported
field corn	NS	8 (2012, 2015)
potatoes	NS	2.38 (2012)
asparagus	NS	871 (2012, 2015)
grapes	NS	44 (2012, 2015)
strawberries/brambles	NS	39 (2012, 2015)
apples	NS	14 (2012, 2015)
Chinese vegetables	NS	51 (2012, 2015)
small grains (wheat, barley)	NS	34 (2012, 2015)
alfalfa/other hay	NS	16 (2012)
cauliflower	NS	4 (2012)

[24] SNUR = Surveyed, no use reported

Crop	EPA Use and Usage Summary[24]	New Jersey
	average annual pounds used	pounds (year) --total for all years listed unless otherwise indicated
cabbage	NS	4 (2012)
tomatoes	NS	7 (2012)
leafy greens (mustards, collard, kale)	NS	68 (2012, 2015)
other tree fruit	no comparable category	37 (2012, 2015)
ornamentals	national data only	332 (2012, 2015)

New York

Data are reported annually and include total pounds of malathion reported per zip code for use on agriculture, ornamental and turf, and public health uses combined. While these data cannot be broken down by individual uses, the data we examined from 2013 – 2016 shows broad geographic usage across the State, with reports from almost every county.

Comparison to EPA-submitted data:

Of 12 crops surveyed, usage was reported on only two (pumpkins and strawberries). While the New York State data is inclusive of more than just agricultural uses, it demonstrates wider usage than would be captured by the footprint of these two crops alone.

North Dakota

A total of 0.9 acres of alfalfa were reported to be treated with malathion in 2012 in a single application (North Dakota State University, 2014).

Comparison to EPA-submitted data:

This finding is consistent with reports of low usage on alfalfa from 2011 – 2015 (0.0 – 0.7 PCT).

Vermont

The Vermont Agency of Agriculture requires annual reporting of pesticide usage by certified commercial, non-commercial, and government applicators. Malathion usage (pounds) for the years 2010 – 2018 is summarized below in Table 32 (Vermont Agency of Agriculture, 2010-2018). Note that several categories differed after 2013.

Table 32. Annual Malathion Usage (in Pounds) from Years 2010-2018 for Certified Commercial, Non-commercial, and Government Applicators. (Source: Vermont Agency of Agriculture, 2010-2018.)

Usage/Year	2018	2017	2016	2015	2014	2013	2012	2011	2010
Mosquito	199.98	719				465.3			148.9
Lawn Care, Ornamentals	0.3125	0.032	1.9	11.9	0.465				
Greenhouse, Nursery	2.8	2.5	3.125						
Produce Production	0.009	0.07	0.036	0.1	144				
Ornamental, shade trees							2.5	0	80
Plant propagation, greenhouse, nursery, Christmas trees					1.25	1.5	0.56	0.56	1.25
Small fruits, vegetables						0			
Tree fruits						0.29	0	0	0

Comparison to EPA-submitted data:

No crops were surveyed in Vermont from 2011 – 2015 in EPA's report. This reporting by the State of Vermont confirms that usage has occurred in this State that was not captured by EPA.

Washington

Washington State Department of Agriculture submitted the results of a data collection effort of growers conducted in 2012 (Appendix 1-5 of EPA's BE). The results indicated malathion usage on 5 crops (PCT): alfalfa (5), asparagus (10), blueberry (100), caneberry (100), and onion (19). Treatments to blueberry and caneberry were reported to be for control of spotted wing drosophila.

Comparison to EPA-submitted data:

The data reported by Washington State identify PCTs that are consistently higher than maximum PCTs reported for these crops by EPA from 2011 – 2015 (Table 33).

Table 33. PCT Reports: Washington State vs. EPA's Use and Usage Report

Crop	EPA – Use and Usage Summary - PCT[25]	Washington State Department of Agriculture (2012) - PCT
Asparagus	SNUR	10
Alfalfa	SNUR	5
Blueberry	75	100
Caneberry	87	100
Onion	17	19

Conclusions on agricultural usage data and application to effects analysis:

With no indication of the robustness of the agricultural data provided by EPA at the state level, there is particularly high uncertainty associated with this dataset and we are unable to evaluate how representative these data are of past usage in these states. The review of information provided by State Departments of Agricultural indicated that, with the exception of California, no state provides continual annual reporting of specific categories of pesticide usage. Data available from eight states varied from one-time reports, to investigations of specific uses, and to summaries of required reporting by applicators. While a direct comparison was not always possible, overall the data from state agricultural authorities was often consistent with data provided by EPA, but revealed instances where usage was not captured by the voluntary surveys contained in the EPA data. While we were not able to fully examine the methods and robustness of the various surveys from the Department of Agriculture, we took any reported usage as positive evidence that malathion had been applied in the time period of the survey. In some cases, usage was reported for a crop or other use that was not otherwise surveyed by EPA's sources. In other cases, usage was reported by a state agricultural agency for a crop that had been surveyed and no usage was reported in data provided by the EPA, or was reported at a higher level than the maximum usage reported in EPA's submission. These results are not surprising in that surveys, by definition, sample only a portion of any given population, and in most cases, surveys rely on voluntary, rather than compulsory, reporting. In instances from EPA's data where crops were surveyed and no usage was reported, PCTs for state data were generally below the 2.5% PCT value that EPA recommends when no usage is reported, supporting the

[25] SNUR = Surveyed, no use reported

protectiveness of that assumption. These comparisons help us to evaluate the suitable application of the data for estimating exposure to listed species that is reasonably certain to occur.

Rather than using the data from individual state submissions to directly characterize effects to species, we used the additional usage evidenced in these reports in the derivation of a methodology to apply EPA's submitted data, particularly for agricultural crops. We concluded that, while usage values were often similar to the state issued reports, EPA's data did not consistently detect usage on a crop where it was occurring or capture the maximum amount of a usage on a crop during the time period surveyed. We took this into consideration when selecting PCT values from EPA's data to use in our assessment at the state level and in extrapolation across states. We employed the following assumptions to estimate the number of acres treated for each Use Data Layer (UDL) during the 5 years for which data were provided:

- For states with available data for a UDL, we took the average of the maximum values for surveyed crops within the UDL.

- For states with no surveyed crops in a UDL, we applied the highest average calculated from surveyed states.

- For states with crops that were surveyed and reported <2.5% PCT or no usage, we assumed a PCT of 2.5%.

Where we have usage data for more than one crop within a UDL, we chose to average the maximum PCTs for surveyed crops. As each crop represents a portion of the landcover within the UDL, taking the average of the available data allows the reported usage of each surveyed crop to be represented in the chosen PCT for the UDL (i.e., we do not simply take the maximum of any crop within the UDL if data indicate that usage does not reach this value for each crop).

The high variability in yearly estimates and additional usage reported from other data sources influenced our decision to use the maximum PCT for individual crops to characterize usage, and to assume a low PCT (2.5%) for instances where a crop was surveyed and no usage was reported (and where other information was not available). We chose a 2.5% PCT for crops where no usage was reported based on differences between EPA submitted data and data acquired from State Departments of Agriculture, as described above, and to be consistent with EPA's current methodology of setting the lowest possible PCTs at 2.5% to buffer against the uncertainty associated with these surveys and low usage estimates. For states with no surveyed crops in a UDL, we chose to apply the highest average calculated value from surveyed states as we had no information to indicate that pest pressure would be lower for these crops in states with no surveys. According to discussions with Kynetec, for states with no surveyed crops within a UDL, the total acreage for the associated crops within the state is likely to be small, and thus the extrapolation of maximum PCT values is unlikely to result in high estimates of treated acres within those states. We anticipate these assumptions reasonably estimate how many acres are likely to be treated with malathion in a single year, understanding that this usage may not be consistent from year to year, as malathion may be used rotationally or sporadically in certain crops. We chose to average the maximum PCTs within a UDL because each surveyed crop represents just one fraction of acres within the UDL and not the entire UDL itself.

For corn, we determined that available information allowed us to deviate from this process for selecting PCTs. The PCT for corn was based on that of Michigan (0.2). Corn was widely surveyed (34 states) and no usage was reported for any other state. When the Service met with representatives of EPA's BEAD and USDA to discuss the malathion Use and Usage Summary (April 5, 2018), several reasons were cited for the lack of usage on corn including:

- Resistance of target organisms to the pesticide
- Preferred use of neonicotinoid and pyrethroid insecticides on this crop due to fewer restrictions on their use
- Increased use of seed treatments
- Increased use of corn genetically modified with the bacterium *Bacillus thuringiensis* (Bt corn) for pest control

As the location of the treated acres within the state is unknown, we compare the total treated acres for the state to the total number of acres within a species' range that overlaps with that UDL. If the number of treated acres in a state is greater than the number of acres in the UDL overlapping the species range, we assume that all acres within the species range that overlap with the UDL are treated. If the number of treated acres is less than the total overlapping with the species' range, we use that percentage and calculate the percent of the species range that has been treated with malathion for each UDL. This approach is applied to all CONUS species occurring in states other than California and is similar to EPA's "upper bound" methodology as described in their Revised Method for National Level Listed Species Biological Evaluations of Conventional Pesticides[26]. We describe methodology for species occurring in California in the following paragraphs.

California

In California, annual reporting of pesticide usage is required for all agricultural and certain non-agricultural uses. California Department of Pesticide Regulation maintains a highly robust dataset of Pesticide Use Reporting (CalPUR). For the purposes of reporting, agriculture is broadly defined and includes usage on parks, golf courses, cemeteries, rangeland, pastures, and along roadside and railroad rights-of-way. Unlicensed, non-professional, residential pesticide applications around a home or garden are not required to be reported, though licensed professional pesticide applications in or around the immediate environment of a household are reported as non-agricultural use (usually "structural pest control" or "landscape maintenance"). Agriculture pesticide usage is reported per square mile and non-agricultural usage is reported at the county level. Data is available from 1990 to 2016. Information is publicly available and can be downloaded from their website[27]:

[26] March 2020, https://www3.epa.gov/pesticides/nas/revised/revised-method-march2020.pdf
[27] http://www.cdpr.ca.gov/docs/pur/purmain.htm

Conclusions on CalPUR data and application to effects analysis:

Because of the robust nature of this data set, we exclusively apply CalPUR data to estimate agricultural usage within California for species wholly or partially within California. Six years (2012-2017) of CalPUR agricultural usage data were downloaded from their publicly accessible website described above. Agricultural usage data is reported as lbs a.i. applied and acres treated. Each malathion application recorded in CalPUR is associated with a site name (e.g., corn, grapes, structural pest control), which was cross walked to align with EPA's use site categories. Based on this crosswalk, we performed an overlap analysis for each UDL and determined the average annual acres treated and percent of range treated for species that occur in California. Approximately 256 species ranges fall entirely within California and 40 additional species that occur in California occur in other states as well. For these other 40 species which also occur in other states, we determined the average annual acres treated and percent of range treated for the portion of the range that occurs in California, and considered this information in addition to range-wide usage estimates based on EPA's data. CalPUR reports agricultural usage data by square mile (section). If any portion of a section overlapped with a species range, we included usage data from that section as occurring entirely within the species' range.

Direct application of CalPUR usage data generally produced lower treated acres within a species range than would have been estimated by applying data from EPA's Use and Usage Summary as described above. However, treated acres were sometimes comparable or larger for UDLs such as cotton, and vegetables and ground fruit. It is possible that our analysis of CalPUR data may overestimate the number of acres treated. When applying usage data to a species range, the entire section may not fall within the species range, and thus only a portion of that usage would be applicable. In addition, our analysis does not account for multiple application to the same acres. However, we have attempted to utilize the available data in a way that minimizes the likelihood of underestimating effects to species.

Non-agricultural usage (excluding Caribbean and Pacific Islands)

<u>EPA's Malathion: Revised National and State Use and Usage Summary:</u>

Usage estimates for non-agricultural applications (e.g., nurseries, ornamentals, mosquito adulticide) were based on sales information (manufacturer and retail) and end-user surveys, though neither sources nor methodologies were identified for individual estimates. For each use category, only one year of data was provided (2009 or 2012). Data were not geographically specific, as they were reported at either the national or regional (multi-state) level. Data provided indicated that usage likely occurred in the year specified for Christmas trees (600 pounds reported on 507 acres nationwide), ornamentals (21,900 pounds reported nationwide), nurseries (27,600 pounds reported nationwide), household/domestic dwellings (outdoor; 1.7 million pounds reported nationwide), and mosquito control (188,000 pounds reported on 4,455,000 acres nationwide). No information was available for pine seed orchards.

These limited sources indicate that more pounds of malathion are applied to non-agricultural than agricultural use sites, approximately 1.7 million pounds per year. The available data indicate that consumer application (garden, lawn, ornamental, and non-plant) and mosquito control application account for approximately 85% of non-agricultural malathion usage.

Conclusions on EPA's non-agricultural data and application to effects analysis:

These data indicate that malathion has been used to some extent on the crops indicated. However, since usage can vary greatly on a yearly basis, as shown in the agricultural data, we do not know if the values provided for a single year only are representative of minimum, maximum, or average usage. In addition, these data are only available at a regional or national scale and information is lacking on how the data were derived. As a result of these uncertainties, we cannot predict the location or extent of non-agricultural uses relative to listed species from these data. We relied on this information where no other data were found to refine our estimates. For mosquito adulticide, pine seed orchard, and home and garden uses, we relied primarily on information from other sources to estimate usage. Each use is discussed individually below.

Christmas Trees:

For Christmas trees, we considered information provided by EPA and reports from CalPUR (0 - 4 lbs/year from 2009 – 2016; 0-2 application per year) to assess usage on the approximate 350,000 acres of Christmas Tree farms in the United States (National Christmas Tree Association). These sources indicate that malathion is applied for this use, and the limited data suggest that usage may be low. However, for species outside of California, we are unable to estimate the range or extent of its use. As this use layer has relatively low overlap with many listed species, we assigned this use category a PCT of 100 for the analysis of acres treated (i.e., application on all use sites), and with the intent of qualitatively assessing the potential for exposure when effects to species were anticipated. However, due to the relatively small footprint of this use compared to others, malathion use on Christmas trees was not found to cause substantial effects to species, even when usage was considered to occur on all use sites.

Nurseries

For nurseries, we considered the information from this report, including the usage data regarding ornamentals (assuming a subset of treated ornamentals may occur on nurseries). The states of New Jersey and Vermont also indicate that malathion usage has occurred on ornamentals. While these reports indicate that usage is likely to have occurred on nurseries, we are unable to estimate the range or extent of its use. As this use layer has relatively low overlap with many listed species, we assigned this use category a PCT of 100 for the analysis of acres treated (i.e., application on all use sites), and with the intent of qualitatively assessing the potential for exposure when effects to species were anticipated. However, due to the relatively small footprint of this use compared to others, malathion use in nurseries was not found to be causing substantial effects to species, even when usage was considered to occur on all use sites.

<u>Pine Seed Orchards – U.S. Forest Service</u>

Expert opinion solicited from the U.S. Forest Service indicated that the usage of malathion in slash pine orchard seed production was likely to be minimal (Alex Mangini, Southern Region, Forest Health Protection, Alexandria Field Office, personal communication, 2018). Based on feedback from tree improvement cooperative directors and members, the use of malathion has declined in recent years and is estimated to be no more than 25 acres spread across several counties (described further in description of the overlap analysis). A decrease in the damage caused by slash pine flower thrips (*Gnophothrips fuscus*) was cited as a mitigating factor in this decline. Projecting out 15 years, managers of slash pine seed orchards will very likely not be using more malathion than is used at present. Orchards are now much smaller in acreage and the trend is to use "Mass Controlled Pollination" (MPC), where flowers are bagged early in spring and artificially pollinated with a known pollen so both parents are of known genetic history. Pest management is still under development for this scenario, but the use of more biopesticides is anticipated.

The Forest Service recommended retaining the malathion registration for use in slash pine against *G. fuscus* for the following reasons:

1. The amount used, even in outbreak years, is so insignificant that it would have little environmental impact.

2. The time of application, late winter, reduces potential impact on non-target species.

3. Malathion is the only insecticide registered for this pest. It should be available until a newer product can be evaluated and registered.

In coordination with the registrants, EPA will be revising the label language to more specifically capture how malathion is used to control the slash pine flower thrip with the following:

- For use in slash pine seed orchards in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina and Texas only.
- Malathion may be used to control thrips from mid-December to mid-March.
- Do not apply more than two applications per year.
- Minimum retreatment interval is 7 days.
- Maintain the 400-ft buffer built into the spray program to prevent cross-pollen contamination

While this language indicates a larger area for pine seed use in the continental U.S., we expect usage to remain at low levels and any offsite movement to be adequately mitigated by the standard 400-ft buffers used in this program to prevent cross-pollen contamination. Therefore, we expect the measures incorporated in these label changes to address the types of effects described in our analysis, and no other types of effects are expected.

Conclusions on pine seed orchards and application to effects analysis:

We assume malathion usage on pine seed orchards would be minimal over the course of the action. Consistent with other uses where low or no usage is reported, we used a PCT of 2.5% to estimate the number of acres that could be treated for this use.

Mosquito Adulticide – Sales Data and State Reporting Data:

Data used to determine overlap with potential mosquito adulticide use sites consisted of past usage data and areas with current capacity of mosquito control (see description of overlap analysis above). A subset of these sources directly indicated past usage of malathion to control mosquitoes:

1. County-level sales data provided by malathion registrant FMC for the years 2012 to 2018.

2. Publicly available state data (i.e., California, New Jersey, Florida, Vermont) when available and not captured by other data sources.

As with other forms of usage data, states which require direct reporting remain the best sources of this information. Unlike agriculture, there is no survey data available to provide estimates of usage at a sub-regional level (i.e., state or lower) for states where this information is not collected. For those states, we use the sales data as a proxy for usage. Malathion registrant FMC has indicated that, unlike agricultural pesticides, which are shipped to a central location and then locally distributed, malathion for mosquito adulticide is generally shipped directly to the site of application. We used these data sources in combination to determine the counties for which past usage of malathion has been reported to derive a PCT within species' ranges. Where we had information within a county based on both sales and usage, we relied more heavily on the usage data rather than sales data.

To estimate past usage of malathion for use as a mosquito adulticide, we determined the number of acres that could have been treated within a species range for each year of data available from the above data sources by summing the acres treated for each county within a species range. For sources that only reported pounds applied or pounds sold within a county, we estimated the total number of acres that could have been treated within the county with that amount of malathion. To do this, we divided the pounds applied or sold by the minimum (0.03 lb/acre) and maximum (0.23 lb/acres) allowable application rates listed in EPA's Master Use Table (Appendix 1-3 of the BE) for each year of data available. For all data sources, if the number of acres treated exceeded the number of acres within the species range for any county, we capped the acres treated at the number of acres in the county within the species range (i.e., we don't consider more acres in the county than are in the species range). Treated acres for all counties within a species range are summed and divided by the total number of acres in the species range to calculate the total percent of the species range that was potentially treated in the past. We repeated this process for each year of data available, and calculated minimum, maximum, and average values.

From these calculations we chose to carry the maximum values into our analysis for consistency with agriculture data and to represent the extent that a species' range is likely to be treated over the course of the action. However, we do not expect malathion to be used to this maximum extent every year and acknowledge that our data often indicated no treatment for at least one year within a species' range. For data reported as pounds applied or sold, we chose to carry forward values associated with the minimum application rate (0.03 lbs/acre). Choosing the lowest application rate results in calculating the highest number of acres treated, minimizing the likelihood of underestimating exposure to species. In making this choice, we acknowledge that maximum application rates were used in EPA's BE and our subsequent analysis to capture the full extent of potential toxicological effects to listed species, prey, pollinators, and hosts. Because we lack information on which application rate will ultimately be selected at any given use site, we have selected rates appropriate to describing the full breadth of both exposure and effects. Considered together, these approaches are a consistent, reasonable way of estimating effects to listed species from mosquito adulticide over the duration of the Action.

Conclusions on mosquito adulticide usage data and application to effects analysis:

There is considerable uncertainty in estimating past usage of malathion as a mosquito adulticide. Both sources of information are at the county level, which likely overestimates the geographic extent of usage. In addition, assuming all treated acres are within the species range could overestimate the percent of the species' range treated. For sales data, we lack information on whether the pesticide was used in the year it was bought, and if so, how much and at what application rate. We assume that all pounds associated with the sale were applied in one county in the year it was purchased, and not across multiple counties or over multiple years. All of these sources of uncertainty are considered when analyzing effects to species. In instances where mosquito control is found to be driving the effects analysis, we will consider the uncertainty with this estimate, and take a closer look at particular areas where applicable.

<u>Developed and Open Space Developed Usage:</u>

EPA's Use and Usage Summary for malathion indicated that the 1.17 million pounds of malathion applied for outdoor household use exceeded the average pounds applied per year for all of agriculture during 2011-2015 (about 1 million pounds per year). However, since no further information was available to qualify this usage, we sought further information on this potentially influential use.

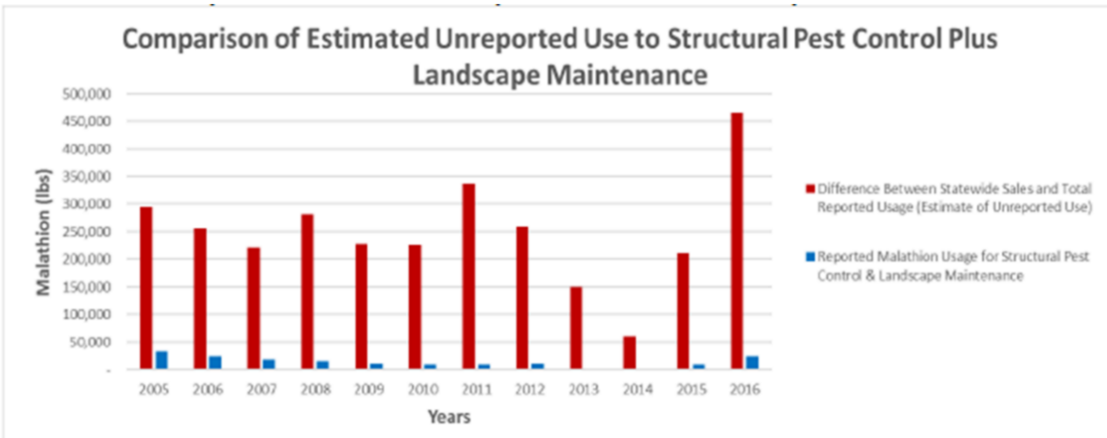
Residential Exposure Joint Venture (REJV) database –

The Residential Exposure Joint Venture (REJV) is a consortium of pesticide industry companies formed in 1997 to address residential pesticide usage in the United States. The REJV National Pesticide Use Survey (2012-2013) was submitted in 2014 as a result of an EPA Data Call-In (DCI) outlined in Pesticide Registration Notice (PRN) 2011-11. The survey was intended to address gaps in understanding residential pesticide usage and frequency in the United States, particularly related to co-occurrence of chemical active ingredients and/or pesticide products across various residential pesticide use scenarios. In its 2016 review, EPA concluded that the survey and its resulting database of residential pesticide usage is acceptable and reliable to support human health exposure and risk assessments that are part of pesticide registration decisions. To our knowledge, this information has not previously been used for estimation of ecological risk. The basic survey design was a simple tally of pesticide usage using a diary approach over the course of 12 months. This consisted of two components: an inventory diary and use/application diary where respondents recorded how they used product in their inventory. The application diary recorded information on the site of application, how the application was made, type of application, and location/pest (for professional applications). The final sample consisted of more than 8,700 U.S. households (prescreened as pesticide-using households) that submitted at least 1 monthly diary of pesticide usage, and 4,573 households, whose diaries covered the entire 12 months.

Due to the propriety nature of the database, malathion registrant FMC provided us with a report of the findings related to malathion. In the case of malathion-containing consumer products, less than 2% of households across all regions reported applying this active ingredient during the REJV 12-month survey period. A slightly higher percentage owned malathion-containing products (3.4% nationally) but did not necessarily use them. Most households reported using malathion-containing consumer products to treat outdoors pervious application sites. These sites are described as fruit/nut trees, shrubs/bushes, flowers and potted plants and vegetable gardens. On average, 4 outdoor applications of malathion occurred per household in one year. In the continental US, malathion applications mostly occurred during the spring and summer. Based on conservative estimates of malathion usage quantity for each household that applied malathion products, the average area of a house lot treated was 1.78%.

California Stormwater Quality Association (CASQA)

The CASQA submitted comments regarding the detection of malathion in urban waterways in response to the National Marine Fisheries Service biological opinion on malathion (2017). According to the CASQA's comments, malathion has been found in California in many urban watersheds at concentrations above EPA's malathion water quality criterion, resulting in multiple 303(d) Clean Water listings for impaired water bodies. CASQA analyzed statewide sales in California vs total reported usage, and found that a high percentage of malathion usage occurring in the state was likely a result of uses that do not require reporting (e.g., residential users) (Figure 9, reproduced from CASQA comment letter). This lends weight to urban usage as a factor in waterway impairments.



Source: California Department of Pesticide Regulation pesticide use report data, https://www.cdpr.ca.gov/docs/pur/purmain.htm

Figure 9. Comparison of Estimated Unreported Use to Structural Pest Control Plus Landscape Maintenance (reproduced from CASQA comment letter).

Conclusions on home and garden usage data and application to effects analysis:

At present, no states require the reporting of residential usage of pesticides, and no widescale surveys are conducted on a recurring basis. Data provided by EPA suggests that home and garden is a significant usage pattern for malathion, and the occurrence of malathion in urban waterways at levels exceeding water quality criterion also suggests uses in non-agricultural settings. With no geographically specific information outside of monitoring data, we chose to use a nationwide 5% PCT to represent the percentage of potential malathion use in the Developed and Open Space Developed landcovers. This is based on the 2% of households estimated to be applying malathion and expanded for other considerations, as follows. First, it considers that the geographic estimates from the database are broad, and there are likely areas with higher usage and areas with lower usage. We anticipate that a 5% PCT is likely to capture areas with higher usage. In addition, these landcovers include other sources of usage in addition to single-family residential areas where pesticide usage may occur, such as office parks and apartment complexes in the developed class, and parks and other open spaces in the open space developed class. The only other information available that could be applied to these land classes is data described above for ornamentals (21,900 pounds nationwide for a single year of reporting, reported usage in the states of New Jersey and Vermont), and data from the California PUR database, which reports non-residential malathion usage such as landscape maintenance and structural pest control in developed and open space developed area. We anticipate the 5% estimate adequately captures the likely extent of this additional usage. We apply this value directly to the acres within the species range (i.e., we assume that 5% of the overlapping acres in each of the developed and open space developed use sites have been treated). Note: in instances where developed and/or open space developed landcovers are found to be a major driver in effects to the species or critical habitat, we will consider the uncertainty associated with this estimate, and take a closer look at particular areas where applicable.

Caribbean and Pacific Islands Usage Data

For malathion, we reviewed available usage data and concluded that there are no comprehensive, chemical-specific usage data for Caribbean or Pacific islands (including Hawai‘i, Puerto Rico, the Virgin Islands, the Commonwealth of the Northern Mariana Islands (CNMI), Guam, and America Samoa) that are considered suitable for incorporating quantitatively. Some data are available through the state of Hawai‘i; however, these data represent only RUP (restricted use products) usage on Kauai by select entities (Dow AgroSciences, Pioneer, Syngenta, BASF, and Kauai Coffee Company). Therefore, these data are not expected to represent usage of malathion, which is not a RUP, but a general use pesticide.

USDA’s agricultural census collects pesticide usage data for these areas, but data are reported in broad land use categories and are neither chemical-specific nor location-specific within regions. Data on chemical use for agriculture are reported as broad categories, such as insecticide, herbicide and fungicide. Although these data are not chemical specific, they are useful in defining the proportion of agricultural areas where insecticides may be applied.

<u>Agricultural data</u>

Agricultural usage data are collected for Hawai’i and Puerto Rico as part of USDA’s agricultural census. To determine the PCT, the acreage treated for the total amount of insecticide applied from USDA’s agricultural census was divided by the total crop acreage for that region (see Pacific and Caribbean Island, Table 34). This method relies upon the 2017 agricultural census for Hawai’i and the 2012 census data for Puerto Rico.

For other Pacific Islands and the U.S. Virgin Islands, no information was available for usage for a general insecticide class except for America Samoa. However, acreage for total cropland for these islands was available. We applied the PCT value for Hawai‘i to the Pacific Island territories, and the PCT value for Puerto Rico to the U.S. Virgin Islands. Where data were available for America Samoa, we used this value to represent the PCT. For all of the island territory cropland acreage, the reported information is from the limited available data, in most cases, the Census of Agriculture from 2007, except for America Samoa, which was obtained from the 2009 Census of Agriculture.

The agricultural census data reports the number of acres of agriculture that were treated for insect pests for Hawai‘i and Puerto Rico. Table 34 includes the total cropland acres treated with insecticides and the total cropland acres that were reported in the 2017 census for Hawai‘i only. We used these values to derive PCT values for potential use sites represented by agriculture located in Hawai‘i (4.8%). For Puerto Rico, we calculated the values to derive the PCT similarly, but only the 2012 census data were available for our analysis.

This approach may appear to be an overly conservative way to represent the usage of a single active ingredient because it assumes that all applications of insecticides (which include multiple active ingredients) are represented only by malathion. However, there is much uncertainty in these estimates based on several assumptions: 1) the 1 year of data available is representative of typical insecticide usage; 2) the usage data for all insecticides applies to all the agricultural land for the islands being represented; and 3) the use of the generalized PCT from Hawaiʻi is an appropriate surrogate for the Pacific Island territories and the generalized PCT for Puerto Rico is an appropriate surrogate for the U.S. Virgin Islands. Therefore, we use these data in the absence of more specific information to estimate usage on the islands surveyed, and on nearby islands with similar habitats where no data exist to indicate that pest pressure would be significantly different. We expect that in doing so, we minimize the likelihood of underestimating effects to species.

Table 34. Census data for acres treated with insecticide and total acres grown of crops in Hawai'i, America Samoa, Guam, CNMI, Puerto Rico, and the U.S. Virgin Islands.

Location	Acres treated	Total acres of cropland	PCT
Hawai'i, Honolulu, Kauai, Maui & Kilwao	28,809 + 10,413 + 2,267 + 8,891 = 50,380[28]	1,046,539[29]	4.8
America Samoa	633	70,367[30]	0.9[31]
Commonwealth of the Northern Mariana Islands	37	773[32]	4.8
Guam	59	1,230[33]	4.8
Puerto Rico[34]	47,356	421,043	11.2
U.S. Virgin Islands	55	493[35]	11.2

In addition to the above usage data, the State of Hawaiʻi Department of Agriculture maintains a 2015 Statewide Agricultural Land Use report[36] (State of Hawaii, 2020). The report's website states: "Using a combination of satellite imagery, related geospatial datasets, and statewide farm interviews, the 2015 Statewide Agricultural Land use report provides a new digital GIS layer to

[28] https://www.nass.usda.gov/Quick_Stats/CDQT/chapter/2/table/40/state/HI/county/009/year/2017
[29] 2017 Census of Agriculture State Profile – Hawai'i
[30] Total acreage of cropland on America Samoa 2009 Census of Agriculture - www.nass.usda.gov › Full Report › Outlying Areas › AmericanSamoa
[31] Same as above.
[32] Total acreage of cropland on Commonwealth of the Northern Mariana Islands 2007 Census of Agriculture - www.nass.usda.gov › AgCensus › Full_Report › Outlying Areas › cnmi
[33] Total acreage of cropland on Guam 2007 Census of Agriculture - www.nass.usda.gov › AgCensus › Full_Report › Outlying_Areas › guam
[34] 2012 Census of Agriculture Profile – Puerto Rico Island and Municipio Data June 2014
[35] Total acreage of cropland on U.S. Virgin Islands 2007 Census of Agriculture - www.nass.usda.gov › AgCensus › Full_Report › Outlying_Areas › usvi
[36] SDAV; http://hdoa.hawaii.gov/salub/

identify commercial agricultural crops grown in the state." An accompanying report to the digital data contains a collection of maps and graphics to depict the current state of crop production statewide. The 2015 baseline dataset updates the 1980 Agricultural Land Use Map (ALUM), the previous statewide agricultural GIS layer[37]. While this information only provides a snapshot in time for 2015, in comparison to the older 1980 ALUM data, it demonstrates the change in land use and the diversification and decentralization (i.e., shift to local farming) of crop use Hawai‘i has experienced over the past 40 years and will likely continue to do so into the future. The report indicates that in 1980, Hawai‘i had 350,830 acres in cropland and another 1.1 million acres in pasture use. In 2015, active crop land fell to 151,830 acres and pasture fell to 751,430 acres. The report also states that Hawai‘i is moving to increase the supply of fresh, local foods to minimize import, leading to the greater diversification at the local level. The central agricultural areas on the island of Oahu have become the primary location for the diversified crop farms with Oahu having the most crop acres (9,860 acres) compared to any of the other islands combined (7,000 acres). With this agricultural shift in focus to a very diverse base group of crops, there will most likely be a representative shift in pesticide use and usage across the State.

Non-agricultural Data

Non-agricultural PCTs for Hawai‘i, Puerto Rico and the territories are evaluated with the same values as the PCTs observed in the conterminous 48 states. The malathion Use and Usage Report describes non-agricultural data in the conterminous 48 states regionally or by year. Other sources of information we used were the REJV database, which collects, organizes, and analyzes label and usage information for pesticide products used in and around the home. Values from the lower 48 states will be applied to the developed, open space developed, nursery and Christmas trees landcovers, as described above.

Mosquito Control

No sales or survey data are available for mosquito control for the Caribbean and Pacific Islands territories and including the State of Hawai‘i. We provide a further discussion of mosquito control in the *General Effects* sections for each of these island groups below.

Federal Lands

Federal lands cover about 640 million acres, which equates to 28% of land in the U.S. Of these Federal lands, 65% are managed by DOI agencies, 30% by the U.S. Forest Service (USFS), 2% by the Department of Defense (DOD), and 3% by other Federal agencies (Congressional Research Service, 2020). DOI land management agencies (the Service, National Park Service [NPS] and Bureau of Land Management [BLM]) and the USFS each employ designated pesticide coordinators, provide policy and direction on pesticide use, have a process in place to review and approve pesticide use proposals and maintain reports on usage. Similarly, the Armed Forces Pest Management Board (AFPMB) recommends policy, provides guidance, and

[37] http://geoportal.hawaii.gov/datasets/agricultural-land-use-maps-alum

coordinates the exchange of information on all matters related to pest management throughout the DOD (AFPMB, 2020).

The label language for malathion is broad and allows for a variety of malathion uses that could occur on Federal lands. During our efforts to identify usage information, as described above, we obtained usage data from DOI agencies and the USFS to better understand usage on Federal lands. These data indicated that past malathion usage has occurred on public lands for a variety of uses, but usage has been minimal, with only localized applications occurring on a rare basis in relatively small areas. For example, reports show that malathion was used on BLM lands in 7 of the 13 years from 2003-2015, but the largest total area treated in a given year was 14,534 acres. This area is far less than 1% of the approximately 244 million acres of public lands BLM manages (Bureau of Land Management, 2019). Additionally, malathion was used on NPS lands every year from 2013-2017, but no NPS site treated was over 142 acres, and while USFS pesticide use reports from 2000-2004 showed annual malathion usage, the largest area treated was 178 acres. Usage reported by these Federal agencies occurred in multiple states, but very few sites were treated in a given year and collectively, the areas where usage has occurred would only comprise a very small fraction of a percent of the Federal land base (USFS, 2001-2004; USFS, 2008; USFWS, 2018; BLM, 2018; NPS, 2018).

Based on the available data, we anticipate that malathion usage is likely to occur on Federal lands over the duration of the Action, but only in very localized areas and on a limited basis, as it has in the past. We do not have any information suggesting that future usage on Federal lands is expected to increase. We expect any adverse effects to listed resources will likely be minimal, considering the small scale and low levels of past usage and in light of Federal agency programs that are designed to understand, avoid, and minimize the effects to listed species and their designated critical habitat. For these reasons, we determined that it is not necessary to include Federal lands in the quantitative analysis described in the *Exposure* section (i.e., comparing overlap of species ranges and critical habitat with use sites and usage information) to adequately characterize anticipated effects to listed resources from malathion applications on Federal lands. Thus, we removed Federal lands from our overlap analysis and qualitatively assessed the consequences of usage on Federal lands by considering the portions of species ranges and critical habitats that occur on Federal lands, together with the probable effects of the anticipated low levels of usage. This allowed us to refine the rest of our assessment and focus on areas where the vast majority of malathion applications are anticipated to occur, while still considering the very limited usage anticipated on Federal lands.

Usage data: Application rates

For agricultural crops, past usage data was provided by EPA on the average rate applied for a single application (Appendix G, summarized below in Table 35). The report cautions that application rates changed as a result of reregistration near or during the sampling period and therefore may not be representative of current rates. However, analysis of the information reveals that average rates applied for many of the use categories were at or near the current maximum labeled rates. This provides some indication that deriving EECs from maximum labeled rates is a reasonable means to estimate exposure for this pesticide. Details for each use category, including exceptions to this assumption, are discussed below. Information on average application rates was provided only at a national level, so there is additional uncertainty regarding local, state, or even regional trends from these data. While these averages of application rate on a national level can be employed in a general fashion to assess assumptions used in generating EECs, we lack information on the variability of the data used to derive national averages of the application rates, such as minimum and maximum values, and standard deviation from the mean. In light of the uncertainty in understanding how national averages are derived and given the fact that these averages are primarily provided at a national level, conservative assumptions are made in assessing the application rates for current and future uses at a more geographically-refined scale, especially in those cases in which national averages on the rate of application are the only information available.

Table 35. Comparison of labeled maximum application rate vs national average reported rate from EPA's Use and Usage Report. The maximum labeled rate was used to generate EECs for the exposure analysis.

Use category (CDL or UDL)	# uses in SUUM	# with usage data	Average rate reported (lbs/acre)[38]	Maximum labeled rate (lbs/acre)
Corn (field)	1	1	0.625	1
Cotton	1	1	1.5	1.5
Orchards and Vineyards	26	18	0.415 - 3.921	7.5
Other Crops	12	0	no data	1.25
Other Grains	5	1	0.938	1
Other Row Crops	1	0	no data	1.25
Pasture (alfalfa)[39]	1	1	0.935	1.25
Rice	1	1	0.944	1.25
Vegetables and Ground Fruit	82	24	0.663 - 1.892	2

[38] Rates exceeding the maximum labeled rate may reflect existing stocks of products remaining on the market after maximum rates were reduced for crops in conjunction with malathion's 2009 re-registration.
[39] For our analysis, we are limiting the pasture UDL to alfalfa. Data shown here represent alfalfa. Other grasses in the pasture UDL were not surveyed.

Use category (CDL or UDL)	# uses in SUUM	# with usage data	Average rate reported (lbs/acre)[38]	Maximum labeled rate (lbs/acre)
Wheat	3	3	0.979 - 1.198	1

For several uses (corn, rice, pasture, and wheat), national average single application rates were similar to maximum single use rates used to develop EECs. No usage data regarding application rate were available for the categories, "other crops," "other row crops," and "other grains." EPA derived EECs for these categories using application rates from 1 - 1.25 lbs/acre.

For cotton, available usage data on application rate comported with rates used to calculate EECs. However, EECs are also based on 15 allowable applications per year. This appears to be influenced by the number of applications allowable by USDA in their boll weevil eradication program (up to 25 applications per year). According to EPA's BE, the maximum number of applications would be 3 per year for use on cotton outside of this program. As discussed in the *Environmental Baseline* section, as of 2018, the APHIS boll weevil eradication program area has been reduced from all cotton growing areas in the U.S. to 37 counties in Texas, three counties in Arizona and three counties in New Mexico. Species protection measures are in place that are designed to ensure malathion usage from the APHIS boll weevil eradication program is not likely to adversely affect listed species (APHIS 2018). We considered whether or not usage was likely to be associated with the APHIS program and its species protection measures, primarily based on the geography of the APHIS program area where species ranges overlap with the cotton UDL, when evaluating the effects of malathion on listed species.

The vegetables and ground fruit UDL represents a total of 82 individual crops in the EPA's Use and Usage Summary, the largest use category. Single use national average application rates were available for 24 of these crops and ranged from 0.663 - 1.892 lbs/acre. Of these, crops with average application rates of 1.8 lbs/acre or above accounted for 54% of the annual pounds applied, 41% of the average annual total acres treated, and included strawberries and caneberries, two of the crops with the greatest malathion usage. Because this significant percentage of the applications were reported near the maximum rate and we cannot distinguish where these applications were made, we considered assessment at the maximum rate of 2 lbs per acre to be representative of this UDL.

The orchards and vineyards UDL is the second largest use category, with 26 crops represented in the EPA's Use and Usage Summary. Of those, national average single application rates were reported for 18 crops, ranging from 0.415 - 3.92 lbs/acre. For this UDL, all EECs represent the maximum labeled rate of 7.5 lbs/acre. However, this rate only applies to citrus crops in California. In other states, the single maximum application rate is 4.5 lbs/acre for citrus. National average application rates ranged from 0.55 – 1.571 lbs/acre for citrus crops surveyed within the timeframe of this report. Maximum application rates for other crops in this use category range from 0.94 – 3 lbs/acre, with the exception of avocado (4.7 lbs/acre), were more similar to the respective average national application rates reported for each crop (0.415 – 3.805 lbs/acre). For species that have significant overlap with this use category or potential anticipated effects, we considered the possibility that effects may be overestimated based on available data that indicate that EECs modeled on the 7.5 lbs/acre application are likely to be higher than expected in many use areas.

For non-agricultural uses, usage data were not available for application rates.

Approach to the Effects Analysis

Where the BE showed effects to listed species, we carried forward lines of evidence to the Opinion for population level assessment. We assessed the lines of evidence listed below for each listed species, where applicable. These lines of evidence were first considered quantitatively, as described below, prior to the development of additional general and species-specific conservation measures that became part of the Action after the issuance of the draft Biological Opinion. We then considered each line of evidence again qualitatively, accounting for any reduction in exposure and effects expected to occur from implementation of the conservation measures. Thus, these reductions are not reflected in the MagTool and R-Plot outputs, but are qualitatively considered in the jeopardy analysis.

<u>Direct effects to species:</u>

These lines of evidence include effects of malathion on the listed species that result in mortality or sublethal (growth, reproduction, behavior, and sensory) endpoints:

1. Mortality to portions of the population(s) of a listed species from direct, acute exposure from the use of malathion according to registered labels (includes parent active ingredient, formulations, and degradates of concern)

2. Altered growth among portions of the population(s) (potential for decreased survival and/or reproduction) from the use of malathion according to registered labels

3. Reduced or impaired reproduction among portions of the population(s) from the use of malathion according to registered labels

4. Impaired behavior that could result in increased mortality or decreased growth or reproduction among portions of the population from the use of malathion according to registered labels

5. Impaired sensory function that could result in increased mortality or decreased growth or reproduction among portions of the population from the use of malathion according to registered labels

<u>Indirect effects to species:</u>

These lines of evidence include effects of malathion on the listed species through impacts to other species they rely on or to their habitat:

1. Decline in availability of other organisms on which the species depends to complete its life history (e.g., prey/food of a listed species, host fish for mussel glochidia)

2. Impacts to suitability and/or quality of habitat on which the listed species depends

<u>Factors that could affect the magnitude of both direct and indirect effects:</u>

1. Differences in effects observed when exposed to chemical mixtures (formulations, tank mixtures, environmental mixtures)

2. Impacts of non-chemical stressors on the effects of the assessed pesticide, such as bacterial/viral prevalence, temperature, or pH in the environmental baseline

To assess each line of evidence, we determined what percentage of the individuals were anticipated to be exposed to malathion at concentrations that may cause adverse effects, and when possible, the expected magnitude of those effects. To determine the proportion of individuals exposed, we considered the overlap of the species range with pesticide use sites, incorporating life history information when available and relevant. To determine the magnitude of effect, we used the most applicable dose-response relationship for each species to assess direct mortality to listed species, and indirect mortality via their prey or host species. For sublethal effects, we used the magnitude of effect, when available, associated with endpoints derived from hypothesis-based toxicity (e.g., NOAEC, LOAEC). These processes are described in greater detail above in the *Toxicological Effects* and *Exposure* sections. We summarize our approach in Table 36.

Table 36. Summary of Approach to Effects Analysis

Key Questions	Information	Risk Metrics
What is the evidence supporting risk to individual fitness? What is the anticipated magnitude of the risk to individuals? What proportion of the population is likely to be affected?	Supported lines of evidence from the BE. Anticipated exposures and concentration-response relationships Overlay exposure and species distribution in space and time. Species-specific demographic and life history information when available.	Active Ingredient Risk of the population experiencing mortality Risk of the population experiencing reproductive effects Risk of population experiencing effects to growth

Key Questions	Information	Risk Metrics
		Risk of population experiencing effects to behavior Other Stressors Tank Mixtures/Formulated products adding to toxicity Toxicity increased due to temperature

Methodology

The following methods for terrestrial animals, aquatic animals, and plants apply to most species within the continental United States. Species not included in this methodology include those where overlap of malathion use sites do not provide the best indication of exposure due to available landcover data or large portions of their range occurring in marine areas: sea turtles, marine mammals, and species located in Alaska, the Pacific Islands, Puerto Rico, and the U.S. Virgin Islands. We followed a more qualitative approach to address those species, which are summarized in the *Integration and Synthesis* section of the Opinion.

To carry out these analyses for the majority of species within the continental United States, we employed two tools to assess many of the effects related to the lines of evidence described above, the MagTool and the R-Plot Tool, described in greater detail below. Both of these tools compare EECs with toxicity endpoints for individual species. We chose the R-Plot tool to display and interpret these parameters for terrestrial invertebrates, plants (and their pollinators/seed dispersers), and aquatic species, where exposure concentrations were largely independent of species-specific parameters other than presence or absence in a potentially contaminated environment. For terrestrial vertebrates, we chose to assess effects using the MagTool due to the added complexity of calculating individual doses and responses based on species-specific factors such as body weight, food ingestion rate, and multiple dietary items. We have concluded that both of these tools allow us to predict effects to species in a comparable manner and are appropriate for our analyses (see Appendix I).

Approach for Terrestrial Vertebrate Species

For terrestrial vertebrates, we analyzed the consequences of the action by evaluating several different factors. We evaluated the direct and indirect effects of aggregated uses from dietary and contact exposure on use sites and from spray drift. We assess effects from mosquito adulticide use separately, as this use may overlap with other pesticide use sites. We discuss the potential for additional exposure from volatilization. We assess the mixtures and abiotic line of evidence generally, below in this section. Figure 10 lists the components of the terrestrial effects analysis.

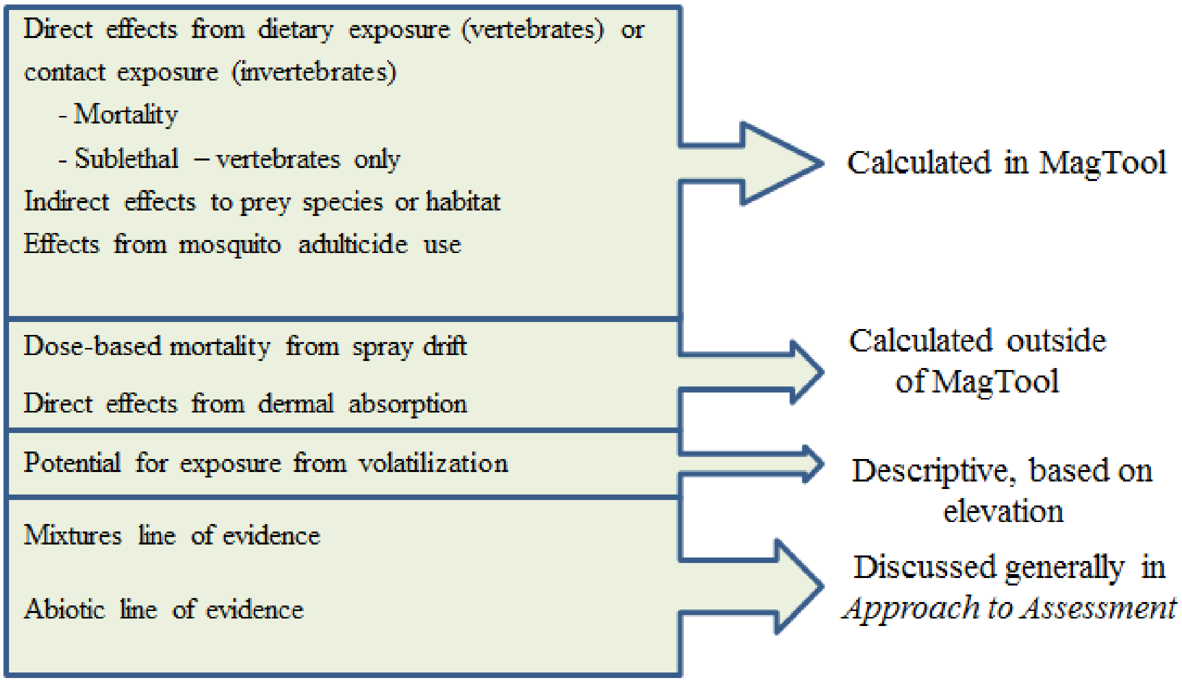


Figure 10. Components of the terrestrial effects analysis.

The following sections provide more detailed information about the questions or thought processes that were considered as we analyzed species with the terrestrial MagTool, or through other means. These considerations and decision pathways helped guide the process of analyzing each taxonomic group, or specific species, while maintaining consistency and transparency through documentation of the approach. We include detailed guidelines on each parameter of interest to consider in this document. Justification for decisions by taxonomic group or specific species are provided either here, or in supporting sections such as the *General Effects by Taxonomic Groups* (e.g., the toxicological parameters used for each line of evidence in the MagTool: LD_{50}, LC_{50}). Detailed guidelines for parameterizing the MagTool are also included.

Terrestrial MagTool

The EPA developed the MagTool as a method to integrate species exposure (i.e., modeled exposure concentrations), the overlap of the species' range with potential use sites, and effects data (i.e., dose-response relationships) to assist in the determination of the magnitude of the effect of potential pesticide use to the species on a population scale. The terrestrial MagTool integrates this information with available species data, including dietary items and life history information, to predict the anticipated proportion of the population that may experience mortality, sublethal (i.e., growth, reproduction, behavior, or sensory) effects, or indirect effects via their prey or forage base, pollinators, or habitat. Inputs allow for the use of multiple toxicity endpoints, allowing a range of effects data to be considered, including those from a species sensitivity distribution (SSD) or surrogate data more closely related to a species when available. The terrestrial MagTool also includes the ability to limit pesticide use sites when species are unlikely to enter. See Appendix D for a detailed description of the MagTool (September 22, 2017 version).

We used the MagTool to assess the effects of all uses of malathion for terrestrial vertebrates. We aggregated the effects of all uses, except those resulting from mosquito adulticide. Because mosquito adulticide applications may occur in other use areas, thereby resulting in instances where overlap with the species range exceeded 100%, an individual analysis was performed for the mosquito adulticide use, and results are reported separately. Prior to running the MagTool, input tables were parameterized with mortality and sublethal toxicity parameters for each taxa as described in the *Effects* section above.

<u>Inputs:</u>

In addition to toxicity data, the terrestrial MagTool parameterization for terrestrial vertebrates (i.e., mammals, birds, reptiles) and amphibians (terrestrial phase) includes several input considerations specific to the taxa groups or their life history characteristics. The following parameters or adjustments can be made for each MagTool run. While examples are presented below for illustrative purposes, settings for each species/run are captured with the MagTool output and presented in Appendix M.

EEC designation: The mean or upper bound EECs were selected according to extent of movement during foraging: mean EECs for species with moderate to great movement during foraging, and upper bound EECs for species with limited movement. Birds, reptiles, terrestrial amphibians, and mammals were generally set to run with mean EECs, with the possibility for species-specific deviations when available information suggests limited ability for the species to forage outside of concentrated areas of malathion exposure.

<u>Use overlap and species-specific considerations:</u>

We requested additional species information from Service species experts to determine the tendency of a species to use a site (i.e., enter, never enter, forage, breed, pass through). Where available, we considered this information to determine if particular use sites should be "on" or "off" during a MagTool run. The citation "pers. comm. 2016 co-occurrence information, Service field office request" indicates information was used from a Service Field office species expert. In the absence of this information, we calculated the effects for all malathion uses overlapping with the species range and considered the likelihood of use qualitatively, where applicable.

For the subset of birds for which a refined risk analysis was performed in the BE, we chose to rely on this supplemental information from our species experts. As such, the same analysis described herein was used for those species rather than the approach used in the BE.

<u>Outputs:</u>

- Estimation of mortality across the species' range based upon exposure on use sites. Where applicable, mortality is presented for each dietary item. Due to the low variability in the probabilistic outputs, only the 50th percentile (mean of the probabilistic analysis) value is carried forward into the analysis.

- Spray drift mortality across the species' range for terrestrial invertebrates and vertebrates from concentration-based exposure.

- Percentage of population exceeding sublethal endpoints for growth, reproduction, and behavior.

- Indirect effects based on the estimated mortality to prey items or forage base across the species range based upon exposure on use sites. Effects to prey animals or forage base are modeled based upon parameters from representative prey species or forage (e.g., 15-gram mammal consuming grass, 20-gram bird consuming insects) for each taxa.

- For our assessment of indirect effects to plants, we looked at application rates that were expected to cause adverse effects due to phytotoxicity. The extent of effects to plants can be calculated by summing the overlap of the species' range with uses that have a maximum application rate that is higher than the application at which effects to plants have been found.

- Other outputs that may be carried over into the analysis include the risk to individuals if exposed on each use site, overlap of each use site, and the spray drift overlap per use site.

<u>Mosquito adulticide use:</u>

The malathion label does not specify a maximum number of permissible mosquito adulticide applications per year, nor a minimum interval of application. For our analysis, we modeled the effects that may result from a single mosquito adulticide spray. Deposition of malathion was assumed to be 100% (i.e., a drift fraction of 1.0). That is, all of the pesticide sprayed over a given area is expected to be deposited on the use site below. While a uniform application of pesticide is desired for effective pest control, deposition does not occur uniformly across the application site (i.e., there will be areas of higher and lower deposition). Drift fractions greater than 1.0 (i.e., greater than 100% deposition) are expected to occur in some areas of the use site and fractions greater than 2.0 (200% deposition) are commonly observed. The deposition is expected to average out over larger areas.

Components Assessed Outside the MagTool

<u>Spray drift:</u>

For dose-based endpoints for terrestrial vertebrates, in our estimation of mortality from exposure via spray drift, we used exposure values from the MagTool but this mortality estimation was not calculated by the MagTool. Doses anticipated for each species, per dietary item, at 30-m increments from the use site were generated from the MagTool. These doses are based on a single generic maximum application rate for malathion, as was calculated for the BE, and thus may over- or underestimate the actual spray drift dose depending on the maximum application rates contributing to the spray drift. We employed dose response relationships selected to assess effects from dietary exposure for acute mortality (e.g., HC_{05} or lowest LD_{50} and corresponding slope) to estimate mortality at each 30-m increment, up to 300 m. At each interval, we multiplied the magnitude by the spray drift overlap for that interval, as extracted from the MagTool output for each species. We summed the results for each interval, and then adjusted in a similar fashion to the concentration-based spray drift mortality calculation from the MagTool to account for the fact that the wind generally only blows in a single direction (see Appendix D). We used a generic 0.5 adjustment factor for all calculations, as the maximum number of allowable applications, on average, was two (see Appendix D for further discussion of how spray drift calculations were adjusted).

Effects from Dermal Absorption:

For terrestrial vertebrates, we assessed dermal toxicity from direct spray or contact with contaminated media using oral equivalent doses calculated by EPA for maximum application rates as described in Attachment 1-7 of the BE. Parameters selected to assess effects from dietary exposure for acute mortality (e.g., HC_{05} or lowest LD_{50} and corresponding slope) and sublethal effects (e.g., NOAEC and LOAEC) were adjusted for individual species and used to assess effects from dermal absorption and provide information about magnitude where applicable. The BE provided estimated doses following exposure via direct spray and exposure via contact with contaminated media for birds and mammals, and exposure via direct spray only for amphibians and reptiles due to differences in modeling and anticipated exposure for these species. While both routes of exposure are possible for birds and mammals, we used values for exposure via contact with contaminated media to assess effects for birds and mammals, both because this was deemed to be the more likely route of exposure to individuals, and because these values were protective of both routes of exposure. These calculations provide an estimate of an individual's response if it was to receive a dose of malathion via dermal absorption. As with any type of exposure, we combine this with information that may influence the likelihood that a species will come into contact with the pesticide in this manner, such as habitat preferences, behavioral traits, or other life history characteristics (e.g., animals may be absent, underground, sheltered, or may flush during an application if they are able, or may be anticipated to have little contact with contaminated media).

Volatilization:

The volatilization exposure pathway is described in detail above (*Exposure* section) for species in habitats where specific atmospheric dynamics will result in exposures that may or may not be in addition to on site exposures within a species' range. This includes species at higher elevations among the mountain ranges of Hawai'i, California, other western states and Appalachia. Any species where volatilization was likely an exposure route (known to inhabit areas at elevation within these regions) was mentioned in the effects analysis and assessed qualitatively outside of the MagTool. Where species would be exposed in addition to on site exposure where their range overlapped with pesticide use, we also acknowledge the effects qualitatively as an addition to any onsite effects.

Mixtures Line of Evidence

Pesticide mixtures can be divided into three categories: formulated products, tank mixes, and environmental mixtures. Formulated products are produced and sold as one product containing multiple active ingredients. We have the most confidence in species being exposed to these types of mixtures, as application of these products ensures that both active ingredients enter the environment at the same time. Several formulated products containing malathion have been identified as part of this action and are shown in Table 37. Tank mixes refer to a situation where the pesticide applicator applies multiple pesticides simultaneously at the use site. Unless explicitly prohibited on the pesticide labels, any two active ingredients may be combined in a tank mix. Though we have less certainty in these types of mixtures occurring, specific tank mixes are often described on product labels and their use may be encouraged to increase pesticide efficacy. Environmental mixtures result from unrelated pesticide use over the landscape and are typically detected in ambient water quality monitoring efforts. From monitoring efforts, we have high confidence that these types of mixtures occur. Monitoring data from state and Federal agencies described in the BE and elsewhere have indicated that multiple pesticides often co-occur in aquatic habitats located throughout the U.S. Studies conducted by the U.S. Geological Survey, under the National Water Quality Assessment program, have routinely detected the presence of multiple chemicals in surface water and groundwater samples.

Table 37. Formulated products containing malathion and another active ingredient.

Registration #	Product Name	Percent Active Ingredient	Active Ingredient
4-122	Bonide A Complete Fruit Tree Spray	0.30	Carbaryl
		11.76	Captan
		6.00	Malathion
829-175	SA-50 Brand Malathion-oil Citrus & Ornamental Spray	75.00	Mineral Oil
		5.00	Malathion
67760-108	Fyfanon Plus ULV	1.47	Gamma-cyhalothrin
		92.20	Malathion
67760-131	Malathion 851 g/L + Gamma-Cyhalothrin 12.8 g/L EC	1.11	Gamma-cyhalothrin
		73.70	Malathion

As described in Appendix 4-2 of the BE, species and their habitats exposed to pesticide mixtures may be at greater risk of adverse effects than when exposed to single pesticides. Recent review articles indicate that additivity (i.e., concentration- or response-addition) is the appropriate default assumption when considering mixture toxicity. However, experimental results from numerous studies indicate that exposure to organophosphate-containing mixtures produces both additive and synergistic toxicity, as measured by activity of the enzyme AChE, in several taxa groups including mammals, fish, birds, amphibians, and aquatic insects. Therefore the potential exposure to malathion mixtures through formulated products, tank mixes, and environmental mixtures is expected to cause increased toxicity compared to exposure to the active ingredient alone. However, the magnitude of that increase is uncertain because the composition of mixtures and concentrations of pesticides and their degradates in the environment is usually not known.

Abiotic Factors Line of Evidence

Environmental factors that are known to alter the toxicity of a chemical include pH, temperature, and low oxygen content. As discussed in the BE, while no data were available on the effect of pH or low oxygen content to the toxicity of organophosphates, changes in temperature have been found to enhance the susceptibility of some taxa to organophosphate pesticides. Multiple experimental results from separate studies indicate that increases in temperature can result in more pronounced toxic effects from organophosphates compared to exposures at non-elevated temperatures in some taxa, particularly freshwater fish and aquatic invertebrates. Most organophosphates studied show a two- to four-fold increase in toxicity for each 10◦ C rise in temperature. Conversely, organophosphates were found to have enhanced toxicity to birds at reduced temperatures. Less is known about the responses of other taxa following exposure to the three organophosphates under elevated or reduced temperatures.

Most listed species will likely be exposed to a range of temperatures in aquatic and/or terrestrial habitats. For our analyses, it is assumed that effects to individuals described by other lines of evidence could be greater when accounting for deviations in temperature. However, there is uncertainty in this assumption given the lack of data regarding both the effects of temperature on organophosphate toxicity for many taxonomic groups and the expected fluctuations in temperature within the range of each species.

Approach for Terrestrial Invertebrate Species

For terrestrial invertebrate species, we evaluated risks resulting from effects of exposure to malathion from uses that occur (overlap) with the species range. Our analysis combined the exposure and response data from the BE, geospatial data for pesticide use sites, pesticide usage information and species ranges, as well as life history information for the species. Table 38 lists the components of the terrestrial invertebrate effects analysis.

Table 38. Components of the Terrestrial Invertebrate effects analysis.

Component	Tool/method
Direct effects: All agricultural and non-agricultural uses Mortality	R-Plots (for all direct effects components)

Component	Tool/method
Indirect effects to prey species (mortality) Effects from mosquito adulticide use	
Effect of exposure – risk to individuals if exposed	R-Plots
Potential exposure from volatilization	Descriptive, based on elevation

In the following sections, we provide more detailed information about the issues and methods we considered as we analyzed species using terrestrial invertebrate R-Plots, and lines of evidence that were not included in the R-Plot methods. We used the following considerations and decision pathways to guide us through the process of analyzing each taxonomic group or specific species, while maintaining consistency and transparency. Detailed guidelines on each parameter of interest are included below. We provide our justification for decisions by taxonomic group or specific species either here, or in supporting sections such as the General Effects by taxonomic groups (e.g., the toxicological parameters used for the mortality line of evidence in the R-Plot: LD_{50} value and calculation of other values on the magnitude of mortality scale).

Malathion Uses Assessed Separately

Only one use, mosquito adulticide, required a separate analysis. We addressed this use within the R-plot, but usage was variable depending on the species (i.e., whether or not usage data was available for a given species; see mosquito adulticide discussion in *Approach to the Usage Analysis* section) or based on whether a species was located in California, as usage data for California species was obtained from Cal PUR data as opposed to other sources (see *Approach to Usage Analysis* section).

Routes of Exposure Assessed Outside the Terrestrial Invertebrate R-Plot Tool

Volatilization was the only route of exposure for terrestrial invertebrates that required assessment outside of the R-Plot tool – see *Approach to Terrestrial Analysis* for more information

R-Plot Tool

The R-Plot Tool was developed by NMFS for use by the Service in the national pesticide consultations and used to help characterize risk for listed terrestrial invertebrate species. R-Plots overlay toxicity data (i.e., values at which adverse effects are detected) with exposure information (i.e., EECs for differing types of dietary items).

The R-Plots summarize several types of information used as described in the *Risk Characterization* section. The R-Plot displays pesticide exposure output and toxicity data (

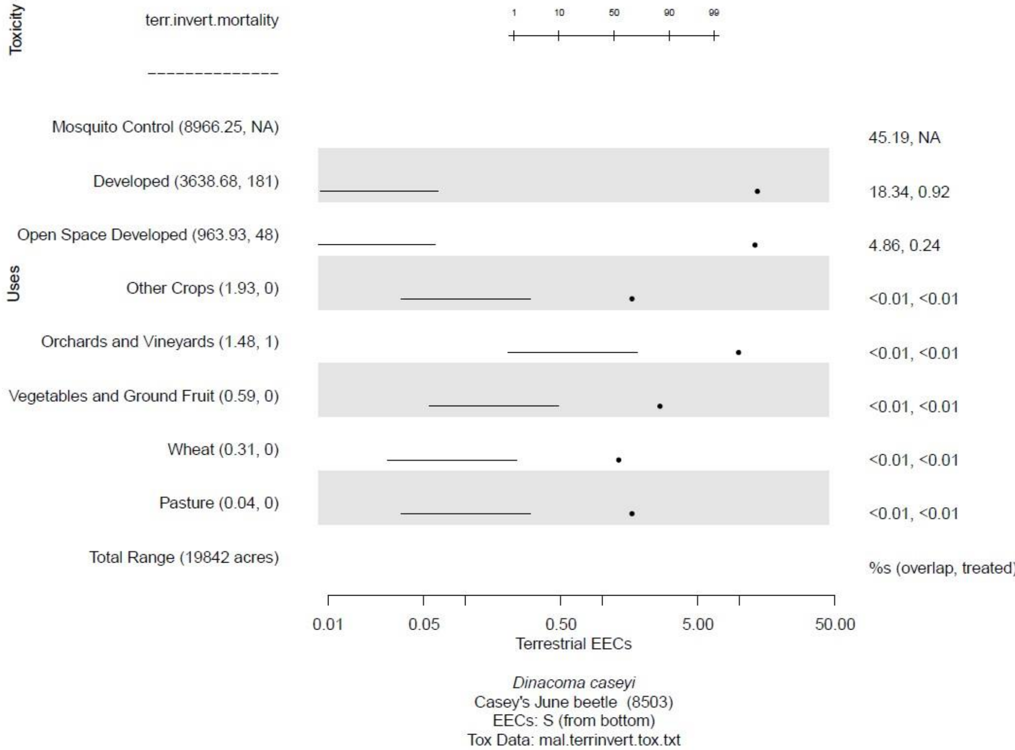


Figure 11) for various categories of uses. The exposure output and the toxicity data are taken from EPA's BE. We use the R-Plots to determine whether the effect of exposure to malathion is low, medium, or high for each use. We also use R-Plots to aid in evaluating the likelihood of exposure. The sample R-Plot below shows data for Casey's June beetle.

An R-Plot graphic is read by (1) selecting an EEC for a use from the center of the plot; (2) determining the corresponding effect of where the symbol for that EEC lies in relation to a toxicity row associated with an endpoint, such as mortality, to determine the level of effect predicted from the EEC; (3) looking at the first value on the right side of the plot to identify the percentage of area that overlaps with the species range; (4) looking on the second value on the right side of the plot to determine the usage associated with that EEC; and (5) looking at the third value on the right side of the plot to determine the spray mortality impacts to the species.

The bottom four lines of the R-Plot indicate the following:

- The first line shows the selected species' scientific name.
- The second line shows the species' common name and Entity ID number. Entity ID, an internal tracking number system from ECOS (the Service's Environmental Conservation Online System), is the number assigned to the listed entity (i.e. species) when listed as E or T under the ESA.

- The third line shows the EPA-generated EECs for each dietary item denoted by a shorthand code based on how the dietary items are arranged in the EEC file the R code is pulling from. The dietary item can be chosen by the user to display the correct spray mortality associated with a dietary item a species might consume, and these items are shown on the plot itself in bottom-to-top order (for the species listed in the R-plot below, the EEC dietary item is "S" or "Soil").

- The bottom line contains the toxicity data shown on the plot to show the magnitude of mortality.

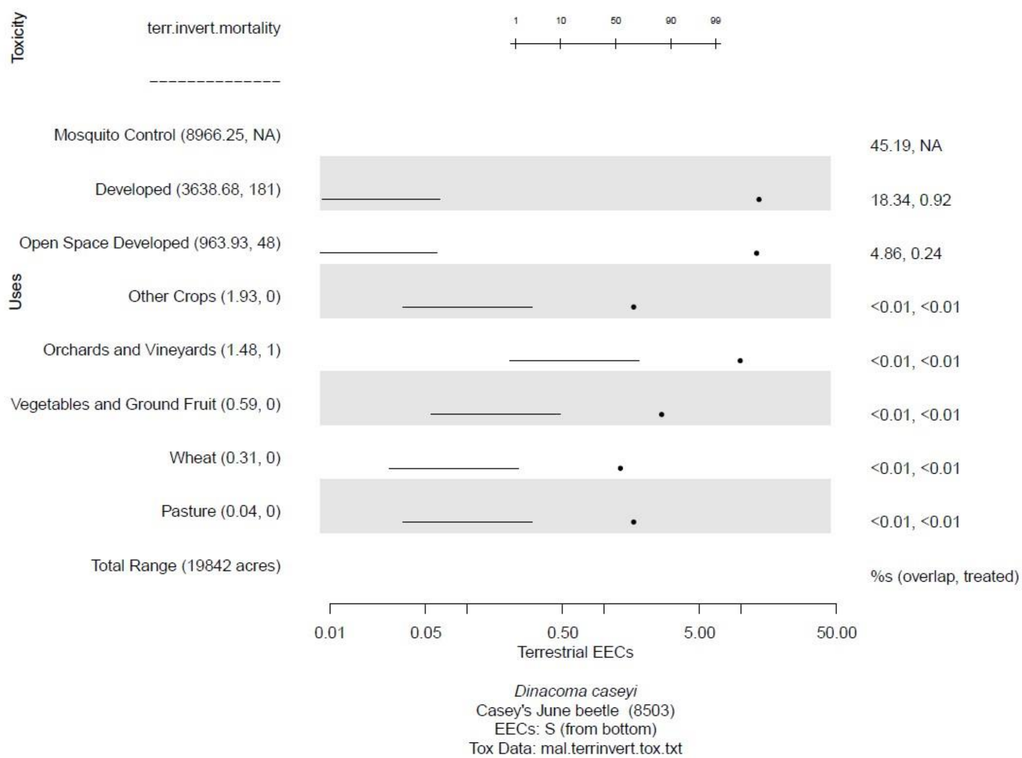


Figure 11. Example R-Plot for malathion and Casey's June beetle.

The remainder of the plot is organized into several components:

1. The upper portion of the plot presents the toxicity data based on the anticipated mortality to terrestrial invertebrates. The bar indicates concentrations that produce the specified effect levels (e.g., 90% mortality) based on the dose-response relationship applied). See discussion below and *General Effects to Terrestrial Species – Effects to Terrestrial Invertebrates*) to see how this dose-response curve was generated.

2. The center of the plot shows EECs grouped by use, dietary item, and spray drift mortality distance (i.e., 0-300 m; by 30-meter increments). Each dietary item EEC is depicted as a closed circle and read from bottom to top corresponding to the dietary item listed at the bottom of the plot on the third line. Each horizontal line corresponds to the spray drift

distance associated with the anticipated effect on the dietary item. The acreages for the uses and the PCTs are listed on the lower left Y-axis. The numbers display the 6-year mean value of the total acres for the particular use, or PCT, across the 6 years of Cropland Data Layer (CDL) data[40], shown in the parentheses.

3. The lower right portion of the Y-axis displays the mean percent of the total acres of the use for each of the 6 years, the mean for the PCT for each use for each of the 6 years, and the percent mortality associated with the spray drift for each use.

We evaluate each use to determine whether the anticipated effect of exposure would cause mortality based on the dietary item EECs and the toxicity information. We use the following rules:

- A "low" rank is achieved when all EECs are below the lowest effect level identified in EPA's BE.
- A "medium" is achieved when any EEC from a dietary item falls between the lowest effect level and the mean or the 50% effect level.
- A "high" is achieved when any EEC from a dietary item exceeds the mean or the 50% effect level for a given toxicity range.

We analyze effects to terrestrial invertebrates (terrestrial insects, terrestrial snails, and arachnids) by using the following methods:

- All species within a taxa group were run and information from the plot was recorded:
    - High, medium, and low effect levels for each use for each dietary item
    - Acreage and percentages for each use and their corresponding usage

Using the R-Plots as a guide, we determine effects for each use and compare to the magnitude of response scale on the R-Plots (see *Terrestrial Species Approach to the Effects Analysis*; Example R-Plot above). The effect was noted along with the percent overlap for a given use. This information was then integrated into a vulnerability assessment table, as described further in the *Integration and Synthesis* section of this Opinion.

Terrestrial Invertebrates

The terrestrial invertebrates taxonomic group was designated in the BE and described as all insects with a terrestrial lifecycle, spiders and their relatives, and strictly terrestrial gastropod mollusks. Given the wide breadth of taxonomic groupings within this category, assumptions were made based on the known effects of the action to this wide array of species. It was assumed that the toxicity data available were applicable to all taxonomic groups within this category

[40] National Agricultural Statistics Service GIS data layers on cropland for all the lower forty -eight conterminous states.

based on data from the available literature. Similar to the approach for other taxa (i.e., mammals, birds) assessed for this Opinion, we chose the most sensitive LD_{50} (1.22 µg/g-bw; from a 48-hour LD_{50} from a study on Hymenoptera, discussed in more detail in *General Effects to Terrestrial Species – Effects to Terrestrial Invertebrates*) to parameterize the R-Plot for terrestrial invertebrates. This value is then plugged into a dose-response formula to generate the magnitude of mortality scale used as the toxicity input file.

For terrestrial invertebrates, we determined that any effects from dose-based (dietary EECs) or contact based exposure (direct spray) will result in mortality. Thus, no sub-lethal effects would be observed nor are they indicated in the analyses, as concentrations at which sub-lethal effects are observed in the literature would not be expected for species on the landscape.

We analyzed effects to terrestrial invertebrates (terrestrial insects, terrestrial snails, and arachnids) by using the following methods:

- We compile the mean of the 6 years of overlap data for uses within a range for each species.
- We generated R-Plots to display 6-year mean values for overlaps and 6-year mean values for PCT.
- Using the R-Plots, effects were determined for each EEC dietary item and compared to the magnitude of response scale on the R-Plots (see Example R-Plot above).
- We note the effect along with the percent overlap for a given use and the PCT for a given use.
- We also compile totals for the acreage associated with the overlaps and the acreage associated with the PCT information.
- This information, along with mosquito adulticide information, is compiled into an Integration and Synthesis table. This information , along with vulnerability information, inform the environmental baseline and cumulative effects, as well as the risk to the species.

R-Plot Effects Analysis

We completed R-Plot analyses and effects summaries for terrestrial invertebrate species to provide detailed information to inform Integration and Synthesis Summaries (see *Integration and Synthesis* section and Appendix K). While terrestrial vertebrate species analyses and effects summaries are conducted using calculations from the MagTool, we compared these two (R-Plots and MagTool) methods and found that they provided comparable effects/risk results (see Appendix I). Individual R-Plots for each species are in the R-Plot appendices. The summary includes effects levels for pesticide uses (interpreted from the R-Plots) and the overlap of those uses in the species range.

Summary Tables

See Effects appendices for terrestrial invertebrate summary tables (insects, snails, and arachnids).

Approach for Aquatic Species

For aquatic species, we evaluated risks resulting from direct and indirect effects of exposure to malathion from uses that occurred (overlapped) within the species range. Our analysis combines the exposure and response data from the BE, geospatial data for pesticide uses sites, pesticide usage information, and species ranges, as well as life history information for the species. Table 39 lists the components of the aquatic effects analysis.

Table 39. Components of the aquatic effects analysis.

Component	Tool/method
Direct effects: All agricultural and non-agricultural uses besides mosquito adulticide - Mortality - Sublethal – vertebrates only Indirect effects to prey species (mortality) – vertebrates only Effects from mosquito adulticide use	R-Plots (for all direct effects components)
Effect of exposure – risk to individuals if exposed	R-Plots
Mixture line of evidence Abiotic factors line of evidence	Discussed generally in *Approach to the Effects Analysis*

The following sections provide more detailed information about the issues and methods we considered as we analyzed species using R-Plots for vertebrate and invertebrate aquatic species and lines of evidence that were not included in the R-Plot methods. We use the following considerations and decision pathways to guide us through the process of analyzing each taxonomic group or specific species, while maintaining consistency and transparency. Detailed guidelines on each parameter of interest are included below. We provide our justification for decisions by taxonomic group or specific species either here, or in supporting sections such as the General Effects by taxonomic groups (e.g., the toxicological parameters used for the mortality line of evidence in the R-Plot: LD_{50} value and calculation of other values on the magnitude of mortality scale).

Malathion Uses Assessed Separately

Only one use, mosquito adulticide, required a separate analysis. We address this use within the R-Plots, but usage is variable depending on the species (i.e., whether or not usage data was available within a given species' range or critical habitat boundary; see mosquito adulticide discussion in *Approach to the Usage Analysis*) or based on whether a species is located in California, as usage data for species that occur in California, either wholly or partially, was obtained from Cal PUR data as opposed to other sources.

R-Plot Tool

The R-Plot Tool was used to help characterize risk for listed aquatic species. R-Plots overlay toxicity data (i.e., values at which adverse effects are detected) with exposure information (i.e., EECs for differing aquatic habitats (displayed as bins)) that describe the type of aquatic habitat by size and flow amount, where a species occurs in the environment).

The R-Plot summarizes several types of information. An R-Plot displays pesticide exposure output (EECs for aquatic habitats) and toxicity data (Figure 12). The exposure output and the toxicity data are taken from EPA's BE. We use the R-Plots to determine whether the effect of exposure to malathion is low, medium, or high for each use. We also use R-Plots to aid in evaluating the likelihood of exposure. The sample R-Plot below shows data for the Owens pupfish. For the analysis, the R-Plots display the EECs for different peak time frames (1-day, 4-day, 21-day, and 60-day), and the mean percent overlaps for uses within the species' range (see also discussion on R-Plot Tool in *Approach to the Assessment* section).

An R-Plot graphic is read by: (1) selecting an EEC for a use from the center of the plot; (2) matching that information with a toxicity row associated with an endpoint (e.g., mortality), to determine the level of effect predicted from the EEC; and (3) looking on the right side of the plot to identify the percentage of area that overlaps with the species range.

The bottom four lines of the R-Plot indicate the following:

- The first line shows the chemical and the text file selected containing the toxicity data shown on the plot.

- The second line shows the aquatic EEC averaging periods that are being summarized.

- The third line provides the HUC-12 region(s)[41] and the aquatic habitats (bins) that individuals of a listed species occupy. EPA generated EECs for each aquatic bin using the models described in the *Exposure* section of this Opinion. Aquatic habitats, referred to as bins, include three static freshwater habitats of varying volume, three flowing water habitats of variable volume and flow rates, and three marine/estuarine habitats

[41] HUC stands for "hydrologic unit code," and refers to a hierarchical system of geographic units employed by the U.S. Geological Survey. HUC-12 is a sub-watershed level area.

representative of nearshore tidal, nearshore subtidal, and offshore habitats. These bins are also described in more detail in the *Exposure* section of this Opinion.

- The bottom line shows the species name, Entity ID number, and the spatial extent (number of HUC 12s) over which the data is summarized. In this example, data for the entire range for the Owens pupfish is aggregated, which consists of 68 HUC-12 regions.

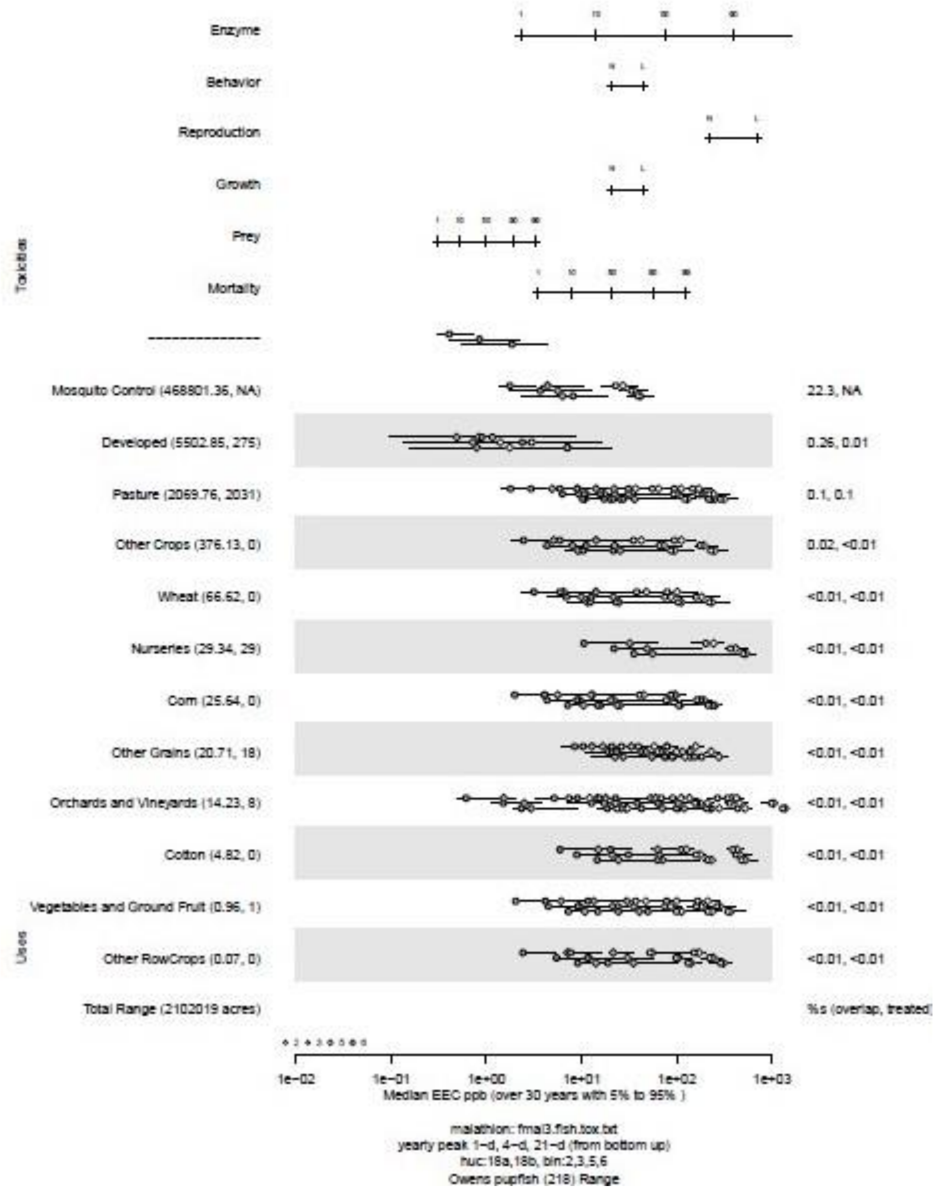


Figure 12. Example R-Plot for malathion and Owens pupfish.

The remainder of the plot is organized into several components:

- The upper portion of the plot presents the toxicity data in a series of rows based on toxicological endpoints e.g., growth, mortality, etc. For endpoints such as growth, along the row "L" the lowest observed effect concentration (LOAEC), "GM" the geometric mean of LOAECs, and "H" the highest LOAEC value for a given endpoint. For endpoints such as mortality, the bar indicates concentrations that produce the specified effect levels (e.g., 90% mortality) based on the dose-response relationship applied.

- The center of the plot shows EECs grouped by use, aquatic habitat (bin), and averaging period (i.e., 1-day, 4-day, 21-day). Each EPA Pesticide Water Calculator (PWC)[42] run for each use is shown as the mean EEC with the 5-95% confidence interval[43] depicted as a horizontal line. Each aquatic bin is shown as a different symbol. The legend at the bottom denotes the symbols assigned to each bin number. The four rows of points for each use show the different averaging periods for the aquatic EECs. From bottom to top, they are 1-day, 4-day, and 21-day.

- The acreages for the uses and the PCTs located within the HUC-12s are listed on the lower left Y-axis. The numbers display the 6 year mean value of the total acres across all the HUC-12s for the particular use or PCT across the 6 years of Cropland Data Layer (CDL)[44] data; shown in the parentheses.

- The lower right portion of the Y-axis displays, the mean percent of the total acres of the HUC-12s represented by the total acres of the use for each of the 6 years, and the mean for the PCT for each use for each of the 6 years.

R-Plot Effects Analysis

We completed R-Plot analyses and effects summaries for aquatic species to provide detailed information for the Integration and Synthesis Summaries (see *Integration and Synthesis* section and Appendix K). While terrestrial vertebrate species analyses and effects summaries are conducted using calculations from the MagTool, we compared these two (R-Plots and MagTool) methods and found that they provided comparable effects/risk results; see Appendix I MagTool R-Plot Comparison for Malathion.

Draft bin 3 & 4 Considerations

> In their initial modeling for the malathion BE, EPA generated use-specific EECs for bins 3 and 4, which were then aggregated across all uses for a species, based on the overlaps. Consideration of bins 3 and 4 were problematic, as these larger rivers and streams receive water from numerous use sites and will have EECs that aggregate the uses across the entire range of the species. The modeling for these bins overestimated expected malathion concentrations (e.g., by an order of magnitude). Due to the potential issues

[42] An integration of EPA pesticide fate models PRZM5 and VWM as described in EPA's BE.
[43] The 5-95% confidence interval line represents the range of values within which we are 95% confident that the true value falls, given the variability of the data.
[44] National Agricultural Statistics Service GIS data layers on cropland for all the lower forty-eight conterminous states.

inherent on relying on EPA's initial modeling for these bins, for our draft opinion, we instead relied on bin 2 estimates as an upper bound for bin 3 and 4 exposures, although we recognized this would also likely result in an overestimation of expected concentrations. Subsequent additional analyses from EPA indicated that EECs from bin 2 may be scaled down proportionately by an order of magnitude to generate an approximate bin 3 or 4 EEC value that now more accurately reflects anticipated environmental concentrations. This information was provided to us by EPA based on their use of the EPA Index Reservoir model (for use in modeling flowing water bodies) as an alternate to the previous modeling that overestimated bin 3 and 4 exposures (see EPA's March 2020 Revised Methods for National Level Listed Species Biological Evaluations of Conventional Pesticides[45]). After consideration, the Service agrees this is an appropriate interpretation of the modeling and expected EECs. To better illustrate how the revised assumptions were employed in our analysis for this final Opinion, several scenarios of species/bin combinations are discussed below. These scenarios address the previous modeling/presentation of EECs for bins 3 and 4 and the current, updated interpretation of the modeling/presentation of EECs for bins 3 and 4:

Previous bin 3 & 4 scenario interpretation:

1) Species in bins 2 and 3 and/or 4: If a species occurred in bin 2 as well as bin 3 and/or bin 4, we relied on the bin 2 estimate to address effects in bins 3 and 4.

2) Species in bins 3, 4, 5, 6, or 7 but not bin 2: For species that are not bin 2 but are in bins 3 and 4, we relied on bin 2 as an estimate of the bins 3 and 4 EECs. For the R-Plots, we plotted the bin 2 EEC estimates instead of bin 3 and 4 EECs. The values represented by bin 2 EECs were considered to be an upper bound of EECs for bins 3 and 4. The other bin EECs (5, 6, 7 for example) can be directly read from the R-Plots.

3) Species only in bins 3 and/or 4: For species that occur only in a bin 3 and/or only a bin 4 and no other bin, we used bin 2 EECs as an upper bound.

Current/updated bin 3 & 4 interpretation:

1) Species in bins 2 and bins 3 and/or 4: If a species occurs in bin 2 as well as bin 3 and/or bin 4, we now adjust bin 2 EECs by an order of magnitude to estimate bin 3 and 4 EECs.

2) Species in bins 3, 4, 5, 6, and/or 7 but not bin 2: For species that occupy bins 3 and 4, and any other bins that are not bin 2, we reduce bin 2 EECs by an order of magnitude to estimate bins 3 and 4 EECs. The other bin EECs (5,6,7, for example) can be directly read from the R-Plots.

[45] https://www.epa.gov/endangered-species/revised-method-national-level-listed-species-biological-evaluations-conventional

> **3) Species only in bins 3 and/or 4:** For species that occur only in a bin 3 and/or only a bin 4 and no other bin, we reduced bin 2 EECs by an order of magnitude to estimate bin 3 and 4 EECs.

Where concentrations for bins 3 and 4 were driving our determination of effects for a given aquatic species, we further evaluated if the adjusted bin 2 EECs would change our determination of effects for those species for the different uses. As mentioned above, adjusted bin 2 EECs provided a more realistic estimate of concentration levels than bins 3 and 4 EECs, even though bin 2 EECs still likely provided an overestimate. Where adjusted bin 2 EECs would not lead us to determine there would be toxic effects, we had greater confidence that bin 3 and 4 EECs would also not be driving effects for those uses. Therefore, to take this into account and more accurately reflect the level of risk from exposure in our analysis from EECs in bins 3 and 4, we adjusted the level of risk accordingly as well:

If the aquatic species (primarily fish and mussels) inhabits only large waterbodies, including larger rivers and streams assigned to bins 3 and 4, but not bin 2 (small flowing waterbodies), we changed the risk level in the final Opinion to 'low'. This is based on our assumption that the new EEC levels are below the level where we would expect toxic effects to the species, if exposed. This same approach applies if the species inhabits larger static waterbodies (i.e., bins 6 and 7) in addition to larger flowing waterbodies, provided the species does not occur in smaller habitats (i.e., bin 2 or bin 5).

If the aquatic species (primarily fish and mussels) inhabits bins 3 and 4 waterbodies, and also smaller flowing or static waterbodies assigned to bin 2 or 5 (which have higher EECs), respectively, we adjusted the risk level from either 'high' to 'medium' or 'medium' to 'low' in the final Opinion. Thus, we no longer anticipate toxic effects to the species based on exposure to malathion in bins 3 and 4, however, exposure to malathion in bins 2 or 5 habitats would be at levels where we anticipate toxic effects to the listed species or other species on which it depends.

Open Space Developed EECs

The Open Space Developed EEC category includes developed areas (with a low percentage of impervious surfaces), such as campgrounds, parks, and recreational areas. EPA developed scenarios for treatments in these areas; however, they were never linked to a stand-alone Open Space Developed category scenario. They are linked to the Developed EEC category scenario instead. As a result of this modeling, the Open Space Developed category is not shown in the aquatic EECs and, therefore, is not displayed on the R-Plot. However, the Open Space Developed EECs are accounted for within the Developed use category PWC scenario. The Developed EECs are displayed on the R-plots. Together, the Developed and Open Space Developed EECs are ultimately included in the overall risk for final calculations contained in a species exposure analysis (see Integration and Synthesis Summary tables).

Pine Seed Orchard EECs

Similarly to the Open Space Developed EECs as discussed above, the pine seed orchard EEC category is not displayed on the R-Plot aquatic EECs. It is accounted for within another PWC scenario, the nursery category. The R-plot tool does not calculate the pine seed orchard scenario separately and, therefore, it will not be displayed on the aquatic species the R-plots. The EECs, however, are accounted for within the nursery EECs which are displayed on the R-plots. Together, the pine seed orchard and nursery EECs are included in the overall risk for the final calculations contained in a species exposure analysis (see I& S Summary tables).

Rice EECs

Rice is modeled using a different surface modeling approach because it involves a flooded field scenario (Pesticides in Flood Applications Model [PFAM]) (Young, 2013). The model considers the environmental fate properties of pesticides and allows for the specifications of common management practices that are associated with flooded agriculture, such as scheduled water releases and refills.

Thus, there are no resulting EECs used in the R-Plots to determine exposure to aquatic species; however, there is overlap information generated for this UDL and that information is then considered for the overall impacts to aquatic species.

Fish

Fish were grouped by order or family and all species within the group were analyzed using the R-Plot tool. Outputs were recorded in the Integration and Synthesis summary tables (Appendix K). R-Plot Tool results indicate the percent overlap tracks closely with the percent mortality in small flowing waters/streams (bin 2) and small and medium static water bodies (i.e., small, medium ponds/lakes, bins 5,6). For malathion, percent mortality in medium and large streams/rivers (bins 3, 4) is more variable.

We evaluated each use to determine whether the anticipated effect of exposure would cause mortality, indirect, or sublethal effects based on the EECs for each bin and the toxicity information. The following rules were applied:

Mortality

- A “low” rank is indicated when the 4-day averaging period 50th percentile EEC is below the magnitude of mortality scale 1% level for the HC_{05} LC_{50}.
- A “medium” is indicated when the 4-day averaging period 50th percentile EEC falls between the lowest effect level (1%) and the HC_{05} LC_{50} effect level.
- A “high” is indicated when the 4-day averaging period 50th percentile EEC exceeds the HC_{05} LC_{50} level.

Sub-lethal

We evaluated each use to determine whether the anticipated effect of exposure would cause an effect based on any of the sub-lethal endpoints. Rankings used for sub-lethal effects are the following (See also *General Effects to Aquatic Species*):

Growth and Reproduction

- Risk is indicated when the 21-day averaging period 50th percentile EEC greater than the lowest LOAEC effect level

- High risk is indicated when the 21-day averaging period 50th percentile EEC exceeds the geometric mean of the LOAECs

Behavior

- Risk is indicated when the 1-day averaging period 50th percentile EEC is greater than the NOAEC effect level

- High risk is indicated when the 1-day averaging period 50th percentile EEC is greater than the LOAEC effect level

Prey-item Mortality

For aquatic invertebrate prey:

- A “low” rank is achieved when the 4-day averaging period 50th percentile EEC is below the magnitude of mortality scale 1% level for the All Aquatic Invertebrate HC_{10} LC_{50}

- A “medium” rank is achieved when the 4-day averaging period 50th percentile EEC falls between the lowest effects level (1%) and the All Aquatic Invertebrate HC_{10} LC_{50}

- A “high” is achieved when the 4-day averaging period 50th percentile EEC exceeds the All Aquatic Invertebrate HC_{10} LC_{50}

For aquatic vertebrate prey (if species consumes other fish species):

- A “low” rank is achieved when the 4-day averaging period 50th percentile EEC is below the magnitude of mortality scale 1% level for the All Aquatic Vertebrate HC_{10} LC_{50}

- A “medium” rank is achieved when the 4-day averaging period 50th percentile EEC falls between the lowest effects level (1%) and the All Aquatic Invertebrate HC_{10} LC_{50}

- A “high” is achieved when the 4-day averaging period 50th percentile EEC exceeds the All Aquatic Vertebrate HC_{10} LC_{50}

Enzyme

The enzyme dose-response curve appears on all fish R-plots and refers to the toxicity data available for fishes for effects to AChe activity. Inhibition of AChE interferes with proper neurotransmission in cholinergic synapses and neuromuscular junctions. This can lead to sublethal effects (e.g., increased respiration, lethargy) and mortality. This mechanism of action is highly conserved among animal taxonomic groups (i.e., fish, mammals, birds, amphibians, reptiles, and invertebrates all possess AChE and are subject to the effects of malathion). These data however were not considered in the lines of evidence for effects analyses for fishes. Rather, this information is to provide context in relation to the other sub-lethal effects response curves to demonstrate there are data to show the potential of effects. However, to what extent this could impact listed species at the population level is unknown at this time.

We used the same approach for evaluating mortality and sub-lethal effects to aquatic-phase amphibians (see Table 25 for R-Plot inputs) that we used for fish.

Aquatic Invertebrates

We analyzed effects to aquatic invertebrates (i.e., aquatic insects, crustaceans, aquatic snails, and mussels) using the following methods. We evaluated each use to determine whether the anticipated exposure would result in mortality based on the EECs for each bin and the toxicity information. We use the following rules:

<u>Mortality</u>

A “low” rank is indicated when 4-day averaging period 50th percentile EECs are below the lowest effect level identified in the magnitude of mortality scale (1%) used for a given taxa group; All Aquatic Invertebrate HC_{05} LC_{50} for aquatic insects and crustaceans, All Aquatic Invertebrate HC_{50} LC_{50} for aquatic snails; LC_{50} for *Lamspilis* spp. for mussels (See *General Effects to Aquatic Species*)

- A “medium” is indicated when the 4-day averaging period 50th percentile EECs falls between the lowest effect level identified for the taxa group (1%); and 50% effect level for the taxa group
- A “high” is indicated when the 4-day averaging period 50th percentile EEC exceeds the 50% effect level for a given toxicity range

<u>Fish Hosts</u>

Fish host for mussel glochidia – fish magnitude of mortality scale

- A “low” rank is indicated when the 4-day averaging period 50th percentile EEC is below the magnitude of mortality scale 1% level for the HC_{05} LC_{50}
- A “medium” is indicated when the 4-day averaging period 50th percentile EEC falls between the lowest effect level (1%) and the HC_{05} LC_{50} effect level
- A “high” is indicated when the 4-day averaging period 50th percentile EEC exceeds the HC_{05} LC_{50} level

All species within a taxa group were run, and the following information from each R-Plot was recorded:

- The high, medium, and low effect levels for each use for each bin
- The acreage and percentages for each use and their corresponding usage
- Totals for acreage and percentages

We determined effects for each use and compared them to the magnitude of response scale on the R-Plots (see *Aquatic Species Approach to the Effects Analysis*; Example R-Plot above) within a bin for a given species at the 4-day peak. The effect was noted (High, Medium, or Low; see *Aquatic Species Approach to the Effects Analysis* above), along with the percent overlap for a given use. This information was then integrated into a vulnerability assessment table (as described further in the *Integration and Synthesis* section later in this Opinion).

Output for Aquatic Species

We analyzed effects to aquatic species (fishes, aquatic-phase amphibians, aquatic insects, aquatic snails, crustaceans, and mussels) and provided the output as summaries in an Integration and Synthesis table (see *Integration and Synthesis* section and Appendix K).

Individual R-Plots per species are in the R-Plot appendices (Appendices M). The summary includes effects levels for pesticide uses (interpreted from the R-Plots) and the overlap of those uses in the species range.

Summary Tables: See Effects appendices for fish, aquatic amphibian, aquatic insect, aquatic snail, mussels, and crustacean summary tables.

<u>Approach for Plants</u>

The general methodology of how the toxicity of malathion would impact listed plant species was done using an R-plot tool specifically designed for plants. The Plant R-plot was designed to display a variety of outputs to determine the specific uses that could overlap with the species range and cause exceedances of the direct effects to a plant or indirect effects to a pollinator. Other information displayed is the percent of that acreage in the overlap, the PCT applied to that overlap amount, and the impacts (magnitude of mortality) to potential pollinators due to spray drift.

The flowering plants, conifers and cycads, ferns and allies, and lichens taxonomic groups were designated in the BE and species within each of these groups was assigned a specific assessment group for purposes of this Opinion (for details on how this was accomplished, see “Analysis for Plants” in the *Integration and Synthesis* section). Given the wide breadth of taxonomic groupings within each assessment group category, assumptions were made based on the known effects of the Action based on toxicity data for effects to dicot v monocot species (discussed in more detail in *General Effects to Plants*) to parameterize the R-plots for plants.

Direct Effects

Data for plants are provided as application rates (pounds of active ingredient per acre) based on the toxicity tests that are performed for plants. Therefore, the Plant R-Plot tool uses this information to determine exceedances directly to the plant. For example, each malathion use has a labeled application rate (for all taxa groups, we used the maximum application rate for this Opinion). The Plant R-plot tool then aggregates the application rates for all of the uses that may be found within a plant species range, then compares that to the toxicity value chosen for a given plant assessment group (see *General Effects to Plants*). If that aggregated rate exceeds the threshold for what is observed from the toxicity data to impact dicot plants (a 12% reduction in growth, see toxicity data in *General Effects to Plants* section), then we can determine the direct effects to that plant will likely be a 12% reduction in growth. This information will also be in concert with other lines of evidence as explained below.

Toxicity values (see *General Effects to Plants*) are provided for each plant assessment group within the Plant R-plot tool. The user enters the species identifier (Entity ID) into the R-plot tool program to obtain the results. Whether or not the direct threshold to plants is exceeded for a given species (based on whether it is a monocot or dicot) will appear in the Plant R-plot display at the bottom of each R-Plot. Other relevant information provided in the Plant R-plot tool when an entity id is entered is shown in Table 40.

Table 40. Plant R-Plot Tool Output Layout and Information

<table>
<tr><th>Plant R-plot display item</th><th>Information provided on Plant R-plot output</th><th>Behind the scenes info that will dictate the final display on the Plant R-plot</th></tr>
<tr><td>Entity ID</td><td>information here will tell the user what plant is being called up for analysis</td><td rowspan="4">Information pulled from general plant information spreadsheet</td></tr>
<tr><td>Scientific Name</td><td>Information here will identify the species by scientific name</td></tr>
<tr><td>Common Name</td><td>Information here will identify the species by common name</td></tr>
<tr><td>Pollinator</td><td>Information here will show insect/ bird / mammal / none</td></tr>
<tr><td>Monocot, Dicot, Fern and Allies, Conifer</td><td>Information here will indicate what type of</td><td></td></tr>
</table>

Plant R-plot display item	Information provided on Plant R-plot output	Behind the scenes info that will dictate the final display on the Plant R-plot	
Lichen, Non-flowering?	plant is being assessed which will in turn determine how the threshold value was used		
Direct Effects threshold exceeded?	Information here will indicate if the direct effects to plants threshold value is exceeded. See columns to the right for the distinctions for effects for different assessment groups	If monocot, then direct effects threshold exceeded = NO	If dicot, fern and allies, conifer, lichen, then direct effects threshold exceeded = YES
Assessment Group	Information here will indicate to what assessment group a given species belongs and whether or not the threshold is exceeded based on the toxicity data to monocots, dicots or other (see section *General Effects to Plants)*	Information pulled from general plant information spreadsheet	

The designation of "Aquatic/Wetland" was provided by EPA (and brought forth into the Opinion analyses in the Plant R-plot Tool) based on habitat designations for plants from the BE but does not necessarily dictate an assessment grouping for a listed species in the Opinion. This designation is simply to allow the user of the R-plot Plant Tool to determine that although aquatic, these species will be most likely exposed to malathion via terrestrial routes such as spray drift.

The Plant R-plot Tool does not have the ability to look at effects to plants considered to have an aquatic habitat and are therefore not assessed using aquatic plant toxicity data (for this Opinion). Aquatic plant toxicity data are not utilized in this Opinion due to the inability of these data to be compared to application rates (aquatic plant data are in units for concentration such as mg a.i/L;

see BE section on Aquatic Plant Toxicity). While these species do require an aquatic habitat, their flowering takes place above water and therefore would be most susceptible to the impacts of malathion from a terrestrial exposure directly or due to spray drift. Therefore, an aquatic exposure (run off to the aquatic environment) was not considered for the analysis in this Opinion (see *General Effects to Plants*). Therefore, all plants with an aquatic lifestyle were assessed using terrestrial plant data. Spray drift for aquatic plants will be determined similarly to how terrestrial plants spray drift is determined.

Indirect Effects

Data for pollinators are provided based on the toxicity values for all species that can be potential pollinators/seed dispersers for plants; terrestrial invertebrates, birds, and mammals. The Plant R-plot tool then uses this information in concert with the overlap of the different uses within the plant species' range to determine the magnitude of the indirect effects to the pollinator. Therefore, for each species with a biotic pollinator (insect, bird, mammal) the Plant R-plot Tool will display the malathion uses with which the plant species overlaps and will display on a scale (top of the R-plot), where the direct overlap and spray drift will influence the magnitude of mortality for a given pollinator species. To obtain this value, the Plant R-plot Tool aggregates the EECs for a given dietary item (nectar/pollen) based on the pollinator species for those uses that may be found within the plant species' range, then displays that toxicity value on the Plant R-plot (round symbols on the R-plot). The user then looks at that value in relation to the magnitude of mortality scale (also displayed on the Plant R-plot tool) calculated for a given pollinator (see *General Effects to Plants*).

Toxicity values (see *General Effects to Plants*) are provided for each plant assessment group and each chemical analysis within the Plant R-plot Tool. The user need only enter the species identifier (Entity ID), and the pollinator dietary items to determine spray drift pollinator mortality to obtain the results. Whether or not the direct threshold to plants is exceeded for a given species (based on whether it is a monocot or dicot) will appear in the Plant R-plot Tool display at the bottom of each R-plot.

The Plant R-plot Tool output will provide the uses where the application rate is exceeded and will aggregate these uses by year. This output page will also show the distance (in feet) off-field where spray drift will occur, and the effects to the pollinator from spray drift.

Spray Mortality

Effects of spray mortality to pollinators is provided by the specific uses that overlap within the species' range for a given chemical. The distance to which effects will be observed will vary based on the uses for a given chemical that will overlap with a species range and are designated by lines on the plot. So, for example, a given species will have displayed on the R-plot Tool the distance at which spray drift is impacting the plant (between 30 and 300 m), and the lines are read in relation to the pollinator magnitude of mortality to determine the impact to the pollinator.

R-Plot Tool

The R-Plot Tool for plants was developed for use in the National pesticide consultations and used to help characterize risk for listed plant species. The R-Plots overlay use and usage information for the plant as well as toxicity data, i.e., values at which adverse effects are detected, with exposure information (i.e., EECs for dietary items; nectar/pollen) for the plant pollinator.

The R-Plot summarizes several types of information used to inform the *Plant Risk Characterization* section. An R-Plot displays pesticide exposure output (EECs for dietary items; nectar/pollen) and toxicity data (Figure 13). The exposure output and the toxicity data are taken from EPA's BE. We use the R-Plots to determine the magnitude of effects to particular pollinators of each plant species for each use that overlaps with the plant species' range which fed into our risk indicator ranking for that species. We also use R-Plots to aid in evaluating the likelihood of exposure by incorporating the usage information (percent and acreage) from the R-plot into the effects determination. The sample R-Plot above shows data for the Leafy prairie-clover.

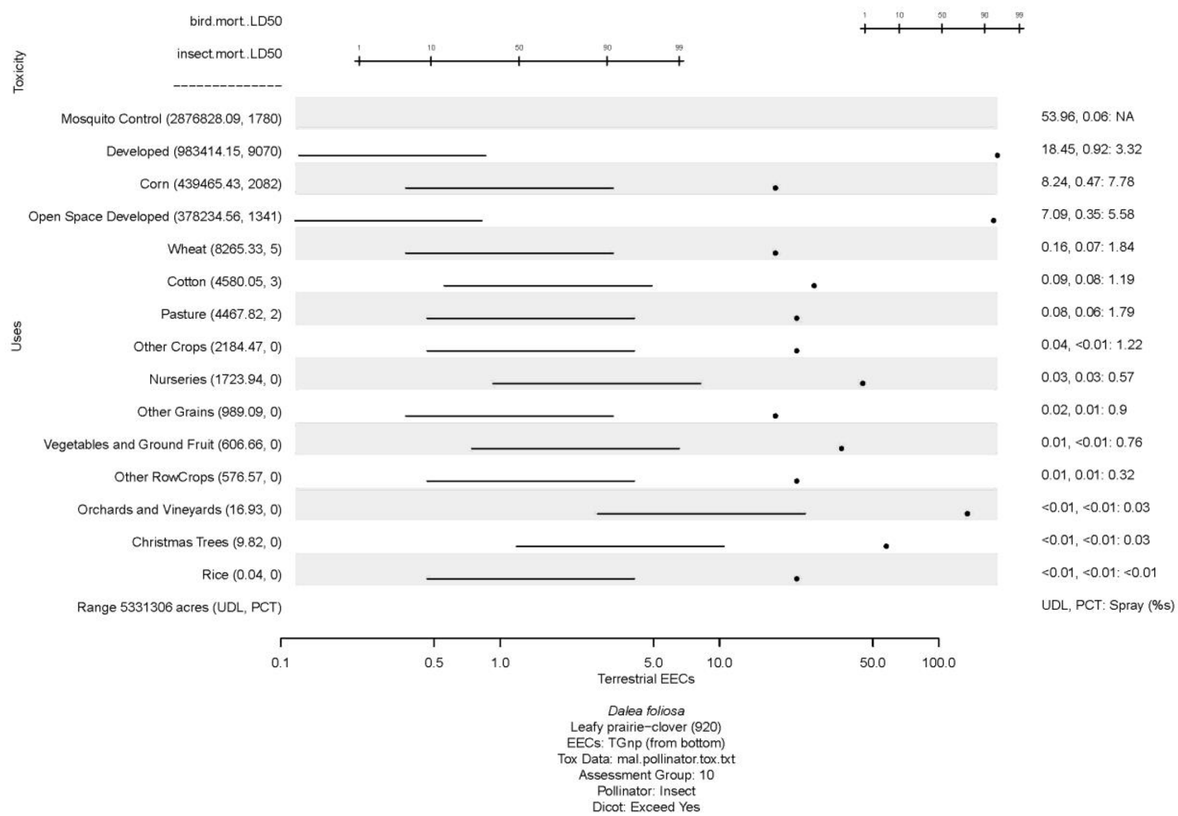


Figure 13. Example output from the Plant R-Plot Tool for the Leafy prairie-clover, Entity ID 920.

An R-Plot graphic is read by (1) selecting an EEC for a use from the center of the plot; (2) corresponding that information with a toxicity row associated with an endpoint for the pollinator, e.g., mortality, to determine the level of effect predicted from the EEC; and (3) looking on the right side of the plot to identify the percentage of area that overlaps with the species range; (4) looking on the right side of the plot second value to determine the usage associated with that EEC; and (5) looking at the third value on the right side of the plot to determine the spray mortality impacts to the pollinator species as well.

The bottom four lines of the R-Plot indicate the following:

- The first line shows the species scientific name selected
- The second line shows the species common name and Entity ID number.
- The third line shows the EPA generated EECs for each dietary item for the pollinator denoted by a shorthand code based on how the dietary items are arranged in the EEC file the R code is pulling from. The dietary item can be chosen by the user to display the correct spray mortality associated with a dietary item a pollinator species might consume and are shown on

the plot itself in bottom to top order (for the species listed in the R-plot below, the EEC dietary item for the pollinator (insect) is TGnp or Tall grass, nectar, pollen).

- The bottom line contains the toxicity data shown on the plot to show the magnitude of mortality.

The remainder of the plot is organized into several components:

- The upper portion of the plot presents the toxicity data based on the mortality to the pollinator. The bar indicates concentrations that produce the specified effect levels (e.g., 90% mortality) based on the dose-response relationship applied). See discussion below and in *General Effects to Terrestrial Species – Effects to Birds* and *Effects to Terrestrial Invertebrates*) to see how the terrestrial invert toxicity data and the pollinator toxicity data dose-response curves were generated, respectively.

- The center of the plot shows EECs grouped by use, dietary item, and spray drift mortality distance (i.e., 30-300 m at 30-meter increments). Each dietary item EEC is depicted as a closed circle and read from bottom to top corresponding to the dietary item listed at the bottom of the plot on third line. Each horizontal line corresponds to the spray drift distance associated with the effect of the dietary item.

- The acreages for the uses and the PCTs are listed on the lower left Y-axis. The numbers display the 6 year mean value of the total acres for the particular use or acres for the usage across the 6 years of Cropland Data Layer (CDL)[46] data; shown in the parentheses.

- The lower right portion of the Y-axis displays, the mean percent of the total acres of the use for each of the 6 years, the mean for the PCT for each use for each of the 6 years, and the percent mortality associated with the spray drift for each use.

R-Plot Effects Analysis

We completed R-Plot and effects summaries for plant species to provide detailed information utilized and displayed in each Plant Assessment Group Integration and Synthesis summary.

All CONUS species were reviewed based on their respective assessment groups and the following information from the R-plot was considered for the analyses:

- the percent overlap

- the percent usage

- the percent mortality to the pollinator (risk)

[46] National Agricultural Statistics Service GIS data layers on cropland for all the lower forty-eight conterminous states.

- pollinator or seed disperser type (insect, bird, mammal)

Sums of the mean overlaps for uses within a range were compiled for each species. Using the R-Plots as a guide, effects were determined for each use and the percent overlap for a given use. For several invertebrate taxa, because the EECs are so high in relation to concentrations that cause mortality to these taxa groups, the resulting overlap percentage for the use site is equivalent to the expected mortality for that species. This is not unexpected, as invertebrates are the target species of malathion, and is designed to be used in a manner that results in their mortality. Therefore, we use the total overlap percentages for each use for the plant as the total mortality or risk to the terrestrial invertebrate pollinator. For bird pollinators, the calculation that involves the overlap percentages with the dose-response curve, is done all together to provide a final mortality/overlap combined percentage. The overlap percentage is also scaled based on the dose-response of the species in relation to the dietary item(s) consumed and the size of the species to determine the extent of mortality based on this route of exposure. The percent overlap will dictate the extent of the mortality to the population, but it may not cause mortality to 100% of the population and the percent overlap may not always be equal to the percent mortality.

The information for use, usage, and risk was then integrated into a risk indicator, summarized for each assessment group in the *Integration and Synthesis* section of this Opinion.

Caribbean and Pacific Island Plants

As mentioned previously, the effects analysis for Island plants was more qualitative due to a lack of data for these species.   In short, we assessed exposure by categorizing plant species into groups based on their preferred habitat. A detailed description of our methods can be found in the *Approach for of Pacific and Caribbean Island Species* section.

Output for Plants

The analysis for plants is incorporated into the conclusions documents for each of the assessment groups for the contiguous United States and Island species (Island species are analyzed qualitatively outside of R-plot Tool outputs but retain their respective assessment group categories). The final outputs from the Plant R-plot Tool are incorporated directly into the Integration and Synthesis summary tables for each of the plant assessment groups (see Plant Integration and Synthesis Summaries in Appendix K).

Influence of Conservation Measures on Exposure and Effects

Below we describe the general and species-specific conservation measures and discuss the anticipated change in exposure or effects of each to species and their habitats. As noted previously, these measures were developed after the issuance of the draft Opinion to address effects predicted from that analysis. Because of the limitations to quantitatively describe and assess the influence of these measures on effects to species and their critical habitats, we continue to report the magnitude of effects as predicted from the Action as originally proposed and analyzed in the draft Opinion for each species and their critical habitats, as determined by the MagTool, R-Plots, and other means as described above. We then consider how these measures reduce the effects of malathion that were predicted prior to their inclusion in the *Description of the Action*.

There are several factors that limit our ability to quantify the effects of these measures. Some conservation measures are expected to reduce exposure to malathion by limiting the opportunity for exposure, such as restricting applications when crops are blooming, limiting mosquito control applications to dawn and dusk, and restricting usage during certain times of the year. Other measures are expected to result in reductions of EECs on or near species habitats. EECs in EPA's BE were modeled to capture a broad range of habitat conditions, application practices, and on-field conditions. Conservation measures are expected to result in a range in reduction of these EECs based on factors such as site-specific landscape conditions and application methods that will vary for each species. For example, as described in greater detail below, EPA's examination of restricting applications when rain is predicted within 48 hours varied considerably, with reductions from 9-69% dependent on application scenarios and environmental conditions.

As such, we consider the effect of conservation measures qualitatively, but specific to each species. We consider which measures are applicable based on overlap with crop types, habitat features, and which species or element of its habitat will be exposed. We evaluate the effects of those measures with a level of specificity that is not captured by EPA's quantitative modeling, considering factors such as weather, soil properties, density of vegetation, proximity to use sites, and behavior, as appropriate for each species. This species-specific evaluation of the conservation measures more accurately reflects the effects on species than would modification to the more generalized modeling that was performed for the BE analysis.

Where we can quantitatively describe reductions in environmental concentrations for specific measures in a general sense, we have provided that information below. We also acknowledge that results may vary not only across landscapes, but by each exposure event. In some instances, conservation measures may not result in the full reduction of exposure anticipated. For example, wind speed or direction may change unexpectedly, individuals of a species may behave in an atypical manner, and exposure may otherwise occur when we otherwise considered it to be unlikely. However, we expect that these conservation measures will result in an overall, substantial reduction in exposure and effects. For many species considered in this Opinion, several conservation measures will be applicable, and we consider their combined effect in our individual analyses of these species and their critical habitats. Overall, in light of these conservation measures, we have determined that species/population-level effects have been avoided or reduced, and the Action, therefore, is not likely to appreciably diminish the survival and recovery of any of the species analyzed in this Opinion. Likewise, with the implementation of these conservation measures, we have determined that the Action is not likely to appreciably diminish the conservation value of critical habitat as a whole.

Conservation measures are divided into "general" and "species-specific" measures. General measures are those that will appear on all malathion labels within a use type category (e.g., agriculture, residential, mosquito control) and apply to any use of malathion authorized by those labels, regardless of whether a listed species or critical habitat is likely to be found near the area of use. These conservation measures are likely to reduce the amount of malathion entering non-target habitats and lower the amount of malathion in the environment overall. We expect these measures to reduce malathion exposure to many listed species and their critical habitats, depending on their proximity to various use sites.

Species-specific conservation measures are those that are confined to a geographic area within or near a species' range or critical habitat. All malathion labels for agriculture or mosquito control will contain a statement instructing users to access EPA's *Bulletins Live! Two* website to determine if additional measures apply within their area of application. Conservation measures for residential labels were sufficient to reduce risk to listed species and their critical habitats, and, therefore, no species-specific measures exist for these uses. Below we describe these measures generally, with more specific descriptions of each within the Integration and Synthesis summaries for applicable listed species and critical habitats.

Changes to Agricultural Labels

Rain restrictions: All agricultural labels will be changed to instruct users not to apply when soil is saturated, or when a storm event likely to produce runoff from the treated area is forecasted to occur within 48 hours following application. After assessing the measure's efficacy across the variety of aquatic habitats, we have determined that a 48-hour rain restriction on agricultural usage would substantially reduce runoff and estimated environmental concentrations of malathion in aquatic habitats, subsequently reducing the risk malathion poses to aquatic species and their critical habitats.

Given the relatively short half-life of malathion and rapid degradation via hydrolysis and other processes, persistence of malathion in storm run-off into most aquatic habitats is not anticipated to last longer than 48 hours under typical pH values, (i.e., 6.5-8.5) and water temperatures corresponding to growing season. EPA conducted a sensitivity analysis to characterize how a 24-hour rain restriction might affect exposure from surface runoff into aquatic habitats. This analysis showed that a one-day difference in application day to static water bodies (bins 5, 6, and 7) results in concentrations that vary considerably, with reductions from 9-69% dependent on application scenarios and environmental conditions. Increasing the period of analysis from 24- to 48-hours resulted in an increase in the reduction of malathion in runoff into waterbodies, though the increase was considered to be minor.

For low flow habitats (i.e., bin 2), EPA's sensitivity analysis demonstrated negligible changes to estimated concentrations over the duration of one year, as determined by examination of 1-day average concentrations. However, rainfall events can generate highly variable concentration peaks of short durations that are of ecological concern to aquatic organisms (Holvoet, Seuntjens, Mannaerts, De Schepper, & Vanrolleghem, 2007) (Lefrancq, Jadas-Hecart, La Jeunesse, Landry, & Payraudeau, 2017). A 48-hour rain restriction for agricultural uses is anticipated to reduce the extent and magnitude of instantaneous peaks, providing an effective mitigation measure for species and critical habitat areas that occur in these low flow habitats as well.

Aquatic habitat buffers: New language on agricultural use labels stipulates minimum distances from water bodies (such as, but not limited to, lakes, reservoirs, rivers, streams, marshes, ponds, estuaries, and commercial fishponds) where malathion cannot be applied. Ground application buffers will be established at 25 feet from aquatic habitats and existing buffers for aerial applications will be extended to 50 feet for non-ultra-low volume aerial applications and 100 feet for ultra-low volume aerial applications.

The establishment of no-spray buffers from sensitive areas is a common measure used to reduce exposure of listed species and their critical habitats to pesticides that can drift off use sites into adjacent water bodies. The degree of spray drift entering adjacent bodies of water is dependent on numerous factors including the application method used to apply the pesticide. Thus, the appropriate buffer distance required to sufficiently protect non-target areas are dependent on application type. We used spray drift calculations modeled using AgDRIFT 2.1.1 to determine the reductions in drift-based aquatic exposure that would be achieved by increasing aquatic habitat buffers for each of the six bins that EPA evaluated in their final BE for malathion. Results indicate that a 25-foot ground application buffer would be expected to reduce spray drift deposition by 62-91%, a 50-foot aerial non-ULV application buffer would be expected to reduce spray drift by 40-66%, and a 100-foot aerial ULV buffer would be expected to reduce spray drift deposition by 58-81%. For each application method, spray drift reduction was highest for low flow and low volume bins, as these aquatic habitats had the greatest spray drift accumulation based on their physical characteristics.

To evaluate the efficacy of these aquatic habitat buffers, we adjusted the estimated environmental concentrations from EPA's final BE by the amount predicted for each bin and application method for a variety of aquatic listed species that represent a wide range of taxa and sensitivities to malathion. We re-evaluated the predicted level of toxic effects using adjusted estimated environmental concentrations and qualitatively assessed the expected reduction in toxic effect that would be associated with implementing these new buffers. In addition, we also qualitatively considered other factors that could result in lower concentrations than modeled in the BE. EPA's modeling represents the most conservative assumptions that produce worst case scenarios, which may not reflect common or best practices. Variations in factors such as weather conditions (e.g., wind speed, wind direction, turbulence) and application method (e.g., droplet size, application rate) would be expected to further reduce spray drift deposition into off target aquatic habitats. Modeled concentrations are also based on the assumptions that pesticide spray moves through the environment unhindered, with no interception by surrounding vegetation, although we do not anticipate this would always be the case.

For most species, the new aquatic habitat buffers would lower the probability of effects to listed species, their habitats, and other species on which they depend, with even greater reductions with consideration of other factors related to spray drift. Only the most sensitive taxa (e.g., arthropods) showed little benefit from these measures. For species and critical habitats that were not sufficiently protected by these general buffers, species-specific measures were proposed, and are described later in this section.

Blooming crops restriction: New restrictions on crops within the orchards and vineyard, pasture, and other crops UDLs prohibit application within 3 days prior to bloom, during bloom, or until petal fall is complete. These restrictions are anticipated to protect pollinators from malathion exposure, given that most pollinating insects vulnerable to malathion are likely to be attracted to crops in bloom and thus more likely to be present in agricultural areas during these times.

Avoiding applications during blooming periods are commonly recommended practices to protect honeybee hives by reducing exposure and resultant mortality and should be similarly protective of listed insect pollinator species, insect pollinators of listed plants, and, to a lesser extent, the broader insect community that enters these use areas during blooming periods. This measure may also reduce exposure to those seed dispersers that are attracted to blooming crops, or that are found in or around these crops during bloom.

Reduction in application rates, number of applications and retreatment interval changes: For agricultural uses, application rates and number of applications impact both the frequency and magnitude of concentrations on use sites, as well as the amount of malathion that can run-off into adjacent water bodies or drift into adjacent habitats. Based on feedback from growers and usage patterns for malathion on a variety of crops, the registrant has committed to revising label language to lower maximum allowable application rates and/or number of applications where feasible (see Appendix A-B for letters of commitment). This change to the *Description of the Action* will result in reductions of one or more of these parameters for many crops. We did not attempt to quantify the effect on environmental concentrations of these various changes but consider that species and critical habitats near these crops will generally be, subject to lower concentrations on use sites and in adjacent habitats, and will have a lower possibility of an exposure event. These changes will also allow for a substantial reduction in the potential for malathion to drift or run-off into adjacent waterways and habitats thus reducing the effects to species, prey host fish, and pollinators/seed dispersers, and their habitats.

The reduction of the maximum application rate for citrus (4.5 lbs/acre reduced to 1.5 lbs/acre outside of California), in particular, is expected to greatly lower the risk of effects to species and critical habitats from that which was modeled in the BE. The reduction in application rate is expected to result in a corresponding reduction in EECs to one-third of modeled values. These lowered environmental concentrations are expected to reduce sublethal effects and mortality to species such as birds that are particularly vulnerable to higher application rates of malathion, and reduce exposure to all species and habitats near citrus groves by decreasing the amount of malathion in and near these use sites. Because of the relatively high usage of malathion in Florida citrus and its proximity to listed species, this conservation measure is likely to have the greatest impact on species and critical habitats in this geographic area.

For some malathion agricultural applications (e.g., grass/hay/forage) a minimum retreatment interval (i.e., the time in between applications) of 14 days will also allow any initial concentrations to degrade in the environment prior to another application, since malathion has a half-life of approximately 0.3-7 days (under typical pH values and variety of soil types and moisture conditions). We expect these measures to largely avoid malathion concentrations in the environment that exceed values expected from a single application, further reducing effects to listed species and their critical habitats.

Changes to mosquito control labels

Daylight restriction: New additions to mosquito control use labels will prohibit the application of malathion as a mosquito adulticide during most daylight hours (from two hours after dawn until two hours before sunset), with the exception of spraying that must occur during daylight hours to address a public health threat. (We anticipate this exception will represent a small percentage of total adulticide spraying with malathion.) The new restriction period coincides with the active period of diurnal insects, thus reducing their exposure to malathion and resultant mortality, as insects are more likely to be exposed to malathion when they are flying and foraging during the day, and less likely to be exposed at night when they hide from predators by seeking cover. The location where diurnal insects will take cover at night varies widely by species. Generally speaking, in the case of bees they typically rest and hide in a hive, ground nest, or other cavity, and in the case of butterflies in dense evergreen or broadleaved shrubs or trees, brush piles, rock crevasses, etc. While malathion has a relatively short half-life, we recognize that residues from dawn or dusk applications will likely remain to some degree on foliage and other surfaces, leading to some level of exposure to listed species. However, this low level of surface residual malathion still represents a substantial decrease relative to active spraying during daylight hours, decreasing the risk of exposure. For listed plant species that can rely on a variety of pollinators species (that are themselves not listed species) and occur within mosquito adulticide use sites, this conservation measure is an effective means to protect the pollinators, and to some extent, seed dispersers, and reduce impacts to flowering plants. For listed insect species and critical habitats that overlap with mosquito adulticide use sites, this conservation measure will act as a tool among a suite of other measures to help reduce exposure and decrease risk of adverse effects.

Changes to Residential Label Language

Malathion use on developed and open space developed use sites was of concern for many species due to high levels of overlap with these areas. These UDLs also contain other areas that may be suitable habitat for species, such as parks or other types of lands with lower degrees of development. We analyzed malathion exposure and effects on these sites using label parameters and usage data for residential areas, which encompass the majority of malathion applications expected. However, not all lands in these use sites are labeled for malathion use and several changes to the general malathion labels to clarify and restrict how malathion can be applied allow us to refine our assessment of malathion exposure and effects in these UDLs. When taken together, these measures reduce our concern regarding the probability of exposure and effects from these uses to the extent that we determined species-specific measures were not needed.

Limitation to spot treatments: New label language ensures that malathion usage in non-agricultural areas, such as residential and similar developed/open space developed areas, will be limited to spot treatments and not broadcast over lawns or other expansive areas. Specific label changes that reduce our uncertainty in delineating areas of treatment include limiting application equipment to hand-pump sprayers, hose-end sprayers, and sprinkler cans, and by explicitly stating “spot treatment only” on labels. Instructions also forbid application to impervious horizontal surfaces such as sidewalks, driveways, and patios except as a spot or crack-and-crevice treatment.

These limitations on how malathion can be applied in these areas allows us to reduce the extent of the overlap between species ranges and critical habitats and treatment areas in the developed and open space developed UDLs. For quantitative analysis of overlap in the BE, MagTool, and R-Plots, we considered that malathion application could occur in the full extent of the overlap for these UDLs. However, unlike agricultural UDLs where entire fields can be treated, application of malathion is allowable only in certain areas of developed and developed open space use sites.

In EPA's BE, a "Percent Use Area" was calculated within residential lots for use in aquatic modeling to account for the extent to which areas within these use sites could be treated. This calculation considers that certain areas within the lot, such as houses and driveways, cannot be treated with malathion and that there would be no use in those portions of the lot that would contribute to aquatic loading. The Percent Use Area attributes the estimated area within a standard lot that can be treated to gardens, the house perimeter, patios, garbage cans, under porches, shrubbery, firewood piles, ornamentals, and treatment areas along fences. Taken together, these areas account for an estimated 29.7% of a lot that can be treated with malathion. Most of these areas were considered pervious surfaces (28.1%) with 1.6% attributed to use over impervious surfaces. (Because terrestrial EECs are calculated based on concentrations at the site of exposure, this metric was not used in calculating terrestrial exposure.)

We applied the same analysis to consideration of overlap, accounting for the changes provided by the new general label language. While the BE calculates that about 29.7% can be considered treatment area, label changes reduce that estimate by eliminating broadcast applications, limiting perimeter treatment to a 2-foot swath around structures, limiting use on impervious surfaces to spot and crack treatment, and limiting use of application equipment, which would hamper larger areas of treatment, such as entire hedgerows. In addition, these application methods render the possibility of spray drift off use sites or beyond the immediate application area unlikely. We consider these factors qualitatively, estimating that the extent of area which can be treated in developed and open space developed areas is reduced 75% or more from that which was estimated by the overlap analysis. This is likely a conservative estimate in that it extrapolates homeowner use of malathion on a 1000 foot^2 lot to the entire UDL, which also consists of other developed areas that contain greater amounts of impervious surfaces such as roadways, commercial centers, and parking lots, as well as areas such as parks or golf courses that consist or areas where treatment is prohibited (e.g., lawns and grassy areas) or less likely (e.g., natural areas).

Limitations to frequency of application: Residential labels considered in the BE instruct applicators to "repeat as necessary". New label changes will limit the number of application to two for most uses within developed and open space developed UDLs (i.e., ornamental plants, vines, shrubs, ornamental/shade trees, and residential fruit tree and vegetable gardens,) or four for household/domestic dwelling perimeter applications. We expect this limitation to reduce the possibility of an exposure event for any species that could still be exposed from spot treatment on use sites. In addition, retreatment intervals of 7-10 days between applications are expected to reduce environmental concentrations by allowing any initial residues to degrade prior to the next application.

Runoff minimization measures: Like agricultural labels, residential labels now contain language instructing applicators to avoid treating 25 feet from water or when a storm event likely to produce runoff from the treated area is forecasted to occur within 24 hours following application. We anticipate that these measures will limit residues that enter waterways by creating buffers from these habitats and allowing malathion to degrade before runoff into aquatic habitats can occur. (See more detailed discussion of these measures for agricultural uses above.)

Species-Specific Measures

The following types of mitigations are components of species-specific conservation measures to be included in EPA's *Bulletins Live! Two.* For specific measures related to species, see Appendix A-D of this Opinion.

Avoidance areas: For some species, conservation measures limit malathion applications in specific areas of the species range, critical habitat, key habitat types/areas, or other important features to reduce the risk of exposure and adverse effects. For each species requiring specific or refined avoidance areas, we qualitatively assessed which areas were either the most vulnerable to malathion use or most important to preserve for the conservation and recovery of the listed species and their critical habitats. Examples of refined areas that require specific avoidance areas include springs, sinkholes, or other low flow and low volume aquatic habitats, which can aggregate malathion residues from a broad drainage area and other habitat features that are important for breeding, nesting, or reintroductions.

- *Alternatives for mosquito adulticide*: Given the important role that mosquito control districts play in protecting human and public health, conservation measures for this use include alternative measures to allow for greater flexibility when malathion is needed for this purpose.

  - First, for species and critical habitats where malathion use as a mosquito control agent was of concern in our analysis in the draft biological opinion, avoidance areas have been identified that coincide with the ranges or critical habitat of those species, or, in some cases, a selected portion of the range where exposure is expected to occur. Where applicators are able to avoid these areas, our concern from this use is alleviated.

  - In times or places where avoidance is not feasible or impairs the ability of the mosquito control district or agency to protect the public's health and welfare, applicators are required to coordinate with the local Service Ecological Services field offices to determine alternative measures to determine appropriate measures to ensure the proposed application is likely to have no more than minor effects on listed species. Discussions at the local level may allow for greater flexibility and in many cases less restrictive measures based on site- or species-specific considerations, such as specific timing, species life history, and geographic or habitat factors. According to discussions with the American Mosquito Control Association and anecdotal reports from Service field offices, this type of coordination is likely already occurring to varying degrees for mosquito control applications in general. The addition of this label requirement for certain species and critical habitats where malathion use was initially of particular concern in preliminary stages of our analysis will ensure that these interactions take place and that mosquito control operators maintain records documenting coordination and describing any alternate measures implemented.

Limitations on restrictions based on timing: For some species, conservation measures limit restrictions on malathion use to specific times of the year that coincide with periods when species are likely to have the greatest exposure to malathion or are expected to be most vulnerable to that exposure. This timing will be specific to each listed species and may be related to factors such as the presence/absence of individuals, life cycle (e.g. spawning or breeding), or periods of the year when species are known to be most active. Given the relatively short half-life of malathion, we do not anticipate that malathion residues will persist in these environments into restricted time periods but recognize that some concentrations may still be detectable under certain environmental conditions. However, we anticipate that any effects of these malathion concentrations to listed species or their habitats would be minor.

Habitat buffers for terrestrial species: The establishment of no-spray buffers in proximity to sensitive areas is a common measure used to reduce exposure of listed species and their critical habitats to pesticides that can drift off use sites into adjacent areas. Pesticide concentrations from this drift are anticipated to be greatest in areas closest to use sites and drop as distance from the sites increases. We used spray drift concentrations calculated from agricultural applications reported in EPA's MagTool to evaluate the effectiveness of buffer sizes in reducing exposure and effects to listed species. At distances of 30 and 60 meters from use sites (approximately equivalent to 100 and 200 foot buffers), concentrations are expected to be about 82% and 90% lower, respectively, than concentrations on the field, resulting in a substantial reduction in exposure for listed species. Specific EECs will vary with application rate and in some cases may still exceed concentrations associated with mortality for the most sensitive invertebrates. However, it is important to note that spray drift EECs reported in the MagTool are calculated using the combination of factors that produces the maximum deposition that could occur under allowable label parameters. Factors that can affect magnitude and occurrence of spray drift include:

- Weather conditions (e.g., wind speed, wind direction, air turbulence)
- Application method (e.g., aerial, ground, or spot treatment, droplet size, application rate, use of drift reduction technology)
- Habitat considerations (e.g., interception by vegetation, use of cover)

It is reasonable to assume that a portion of applications will occur when winds are blowing away from the habitat, when wind speed is below the maximum permitted (10 or 15 mph, depending on boom length), when air is turbulent, or using other application equipment or methods that will result in less drift. In our analysis of the effects of drift, we also consider the extent to which drifting pesticide residues will result in exposure to non-target organisms, considering interception by habitat/plant canopy, the presence or absence of individuals in the spray path, and species-specific behavior that may reduce the probability of exposure (e.g., burrowing, secretive, use of cover). These considerations, in combination with reductions in exposure expected from buffering applications from species ranges or habitats per the new label restrictions, are expected to considerably reduce exposure to spray drift to species and critical habitat. Where concentrations of malathion enter habitats despite these measures, very small number of individuals of listed species or aspects of their habitat will be exposed, and will experience mortality, sublethal effects to growth, survival or reproduction, or small reductions in fitness, as described in the *Integration and Synthesis* and species accounts (Appendix K).

Restrictions to application related to wind direction: Pesticide spray drift is the movement of pesticide dust or droplets through the air at the time of application or soon after, to any site other than the area intended. Pesticide drift during application is caused by wind carrying pesticide particles off the site of application. Checking wind direction and ensuring that wind is blowing away from sensitive sites and habitats is a common practice used in integrated pest management to reduce exposure to these areas. As such, limiting malathion applications to when winds are blowing away from habitats used by listed species is an effective way to reduce exposure to malathion. When effectively applied, we expect this use limitation will likely prevent nearly all exposure to malathion from spray drift. We recognize that wind direction can change suddenly, even after application has begun. When this occurs, some malathion may drift into habitats of listed species, depending on the new wind direction, distance from the habitat, application method, droplet size, wind speed, and other factors that influence drift. In these cases, very small number of individuals of listed species or aspects of their habitat will be exposed, and, depending on the species, will experience mortality, sublethal effects to growth, survival or reproduction, or small reductions in fitness, as described in the Integration and Synthesis and species accounts (Appendix K). However, we anticipate that the overall effectiveness of this measure will greatly reduce exposure of species from off-site movement of malathion.

Assumptions and Uncertainties for All Species in this Consultation

There are many uncertainties and assumptions that accompany an analysis of this size and scope. The manner in which chemicals can move through the environment and interact with other biotic and non-biotic stressors is highly complex and necessitates that we focus our analysis on those factors that are identifiable, reasonably predictable, likely to influence whether species are affected, and for which we have data to characterize those effects. As such, we have made assumptions about certain elements of the analysis for which we are limited in our abilities to address directly due to lack of relevant data or appropriate models. Below we identify several assumptions and uncertainties we have considered in our analysis for the overall approach as well as specific to the effects analysis. In some instances, we are aware that certain assumptions, when taken alone, may under-predict effects to listed species. However, by using conservative assumptions in other areas that may overestimate effects in some instances, we expect that we are capturing the overall breadth of effects to species and critical habitat in evaluating whether EPA's action is likely to jeopardize listed species or adversely modify critical habitat. For example, we lack data to quantitatively assess the effects of malathion to individual species in combination with other stressors in the environment (e.g., temperature, other chemicals; #6 Exposure to multiple stressors, below). However, by making conservative assumptions about exposure to malathion at maximum environmental concentrations and looking at the full extent of lethal and sublethal effects, we expect that we are capturing the breadth of effects to species, including those that may manifest at sub-maximal concentrations, but in combination with other environmental stressors. In some cases, we are unable to predict whether individual assumptions will under- or over-predict effects to listed species and critical habitats. Overall, we expect that when taken together, the assumptions we have made are based upon the best scientific and commercial data available, capture the magnitude and extent of the effects of the action, and are otherwise consistent with the ESA and its implementing regulations.

Surrogate Data

In the *General Effects by Taxa* section, we briefly discuss how we used toxicity data to analyze effects to listed species. Very few listed species have toxicity data specifically addressing effects from malathion. We therefore discuss toxicity data that are available for the taxa groups and the decision process we employed to arrive at the toxicity values we used for our effects analyses. Where toxicity data are lacking, such as for reptiles and amphibians, we discuss the use of toxicity data from other taxonomic groups in the *General Effects for Reptiles* and *General Effects for Amphibians* sections. More specifically, we used fish and bird data for amphibians and bird data for reptiles. For amphibians and reptiles, data are also lacking to convert doses and dose-based endpoints across individuals, as discussed above. For aquatic plants, toxicity data are reported as mg a.i./L, which are differing units from how terrestrial plant toxicity data are provided (lbs a.i./acre). Aquatic plant toxicity data are most often based on studies on non-vascular algae which may or may not be applicable to listed aquatic vascular plants to assess effects. For many plants, often the only correlation between tested species and the listed species is that they share a seed growth mechanism, such as if both the listed and test species are dicots. However, there are several listed ferns and other allies, conifers/cycads, and some lichens that would not be comparable to any tested species, and we use available toxicity data from dicot species for these non-flowering plants.

In addition, there are several data gaps for basic biology for plant and animal species covered under this consultation that add additional complexity to this analysis. For example, there is often little to no available data regarding different types of effects (sub-lethal, effects to prey base, effects to pollinators, direct impacts to flowering plants) of pesticides on species that are rare, highly specialized, and occur in specialized habitats. The toxicity data we have chosen to use, and have discussed in depth in the general effects to taxa sections, is the best available information we have regarding the impacts of this pesticide to listed species. These data often represent one or more species within a taxa group that are applied to all species within that taxa (e.g., honey bee toxicity data to address effects to all insects) or a taxa group for wish data are lacking (e.g., fish toxicity data to address effects to aquatic-phase amphibians). We also explain why certain data were used for certain species (e.g., *Lampsilis* data for mussel species) in the general effects to taxa sections as well.

Estimated Environmental Concentrations

For this analysis of the effects of malathion to different taxonomic groups in this Biological Opinion, we assume that individuals will be exposed to modeled annual maximum pesticide concentrations, although we acknowledge this assumption may overestimate exposure to listed species. In addition, exposures are based on pesticide scenarios that generate the highest EECs, which also may overestimate effects. For aquatic species, distribution within aquatic habitat bins is assessed differently (bins 2, 5, 6, 7 versus bins 3 and 4; see above) that may over- or underestimate exposures to listed fishes, crustaceans, aquatic insects, aquatic snails, and mussels. However, effects are limited to a single exposure of malathion, when, in reality, individuals may be exposed more than one time to concentrations that could cause effects; thus, this assumption may also underestimate effects.

This Opinion operates on the assumption that all use sites will be treated at the same time, and all individual members of a listed species within the use overlap will be exposed to peak applications, once a year. In reality, we do not expect all use sites will be treated at the same time, resulting in every individual member of a species that overlaps the area being exposed to peak applications and, therefore, we acknowledge this approach will overestimate exposure. On the other hand, some areas may have additional peak events occurring in a year, and, therefore, the above assumption may underestimate exposure. The assumption that use area represents where a given pesticide will be applied, for a small ranging species, may over- or underestimate the exposure. The assumption that the use scenario generating the highest combined application rates should represent exposures resulting from a given CDL use layer (e.g., vegetables and ground fruit) may overestimate effects. More specifically, multiple applications for spray drift values are not considered in this analysis, and may, therefore, underestimate exposures. These assumptions vary in whether or not they over or underestimate exposures depending on the analysis being done. However, overall, our analysis in this Opinion contains reasonable assumptions in determining whether the Action is likely to jeopardize species or adversely modify critical habitat.

Species-specific Information

Where more life history information was available for a species, it allowed us to make fewer assumptions about how the species may be exposed to malathion. Specifically, knowledge of the types of habitats used by individuals of a species and their tendency to be found near and within use sites allowed us to better predict whether individuals would be exposed to malathion and, if so, the magnitude of that exposure. However, the extent of this information, and our ability to project the likelihood of exposure in this manner varied across species. This lack of information could result in an overestimation or underestimation.

An individual is assumed to occur at a single fed location and cannot be exposed to pesticides at other locations or at other times. Exceptions to this include migratory birds, migratory fish, or migratory mammals where additional exposure could be realized along a migratory path (e.g., whooping crane, Gulf sturgeon, some bat species). This may overestimate exposure for mobile species that may not be present during application or underestimate exposure for mobile species that forage on more than one treated field or are exposed during different stages of migration.

Effects to Critical Habitat

For aquatic and terrestrial animal species that have critical habitat, where physical and biological features (PBF, or other features as defined in Critical Habitat Approach to the Assessment) are discussed, our analyses assume that if a pesticide will impact these features now or preclude their development in the future (i.e., prey items, water quality, pollinators, etc.), then the critical habitat would be negatively affected. If no specific PBFs that would be likely to be affected by exposure to pesticides have been identified in the critical habitat rule, then the critical habitat would not be impacted (e.g., if PBFs pertain to features that are not susceptible to pesticides, such as geological features such as talus slopes, sandy areas in pine rockland, moist, well-drained moss mats growing on rocks and boulders, or plant structures such as nesting trees, etc.).

Species Range Maps

One of the main uncertainties within the analysis for this consultation is the reliance on current ranges for each species that may not accurately reflect the species' actual distribution within those mapped ranges. Often these ranges are defined as entire counties or smaller subunits (e.g., quads, HUCs) within which the species is known to occur but do not identify actual areas of suitable habitat where the species is likely to be found. During the collection of current range maps for these consultations, we requested that Service Field Offices provide refined current range maps if available. Additionally, through internal Service efforts to refine species ranges, and in some cases with the assistance of FIFRA Endangered Species Task Force biologists, we were able to refine and improve many of the existing current range maps, either by reducing the number of overall counties or by mapping at a sub-county level (e.g., by habitat associations for Hawaii plants), based on the best scientific and commercial data available at the time.

Without detailed information on where a species can be found, our assumption for this assessment is that each species analyzed is uniformly distributed within its range. This may overestimate or underestimate our understanding of where a species is found. Exceptions to this assumption were for species where information is known based on specific data from Service Recovery Plans or 5-Year Reviews (e.g., Moapa Dace). Some species will have information where specific segments of the range have been identified for recovery, for critical habitat, or for other specified uses, and the locations of populations of the species are known within these areas.

Use sites

For terrestrial and aquatic species, we assume the GIS information we have for all malathion use sites is accurately represented within the species' range because this is the best information available to us. This may over or underestimate the presence of use sites.

Pesticide Usage Information

Pesticide usage data is derived from a variety of sources that inherently vary with respect to the reliability, accuracy, and specificity of the data being reported. We assume these data may over- or underestimate the actual pesticide usage based on the source. Kynetec agricultural data may over- or underestimate actual usage due to the methodology behind how these data are collected, how they are applied within a given state where a crop may be grown, and how they are statistically analyzed. The California pesticide use reporting data from California's pesticide use reporting (PUR) program is a very comprehensive pesticide usage database (CDPR, 2020). Under the program, all agricultural pesticide use must be reported monthly and all agricultural uses can be evaluated on a scale as precise as a county-township range section (a section being a land unit which constitutes one square mile or 2.6 square kilometers, containing 640 acres) and as broad as the county level. These data are generally very reliable, but uncertainties in the reporting do exist. Other non-agricultural uses under the California PUR program such as mosquito control usage are reported only at the county scale. This may over- or underestimate the actual usage of pesticides in California. There are some uses for which usage information may overestimate impacts to species due to the application rates chosen. These are discussed elsewhere in the *Approach to the Usage Analysis* section on application rate.

Spray Drift Effects

Spray drift is a primary route of offsite transport of pesticides when applied to use areas. For all species, spray drift will increase the area of overlap with the species range, and is particularly important for species that are not anticipated to enter use sites (i.e., plants), as it may represent the only exposure to malathion that is likely to occur. However, it is important to note that spray drift areas and areas for different uses can overlap with one another, depending on their proximity on the landscape. For this reason, combining areas from different uses where spray drift exposure could occur without accounting for this proximity is likely to overestimate the total overlap with the species range.

An additional set of spray drift EECs was developed, which is unique to the terrestrial exposure analysis because the aquatic analysis aggregates the contribution of all inputs into waters when generating aquatic EECs. For terrestrial vertebrates, EECs and overlap values for exposure via spray drift were generated by EPA in 30-m increments from use sites (up to 300 m from the site). Overlap values with species ranges are based on the aggregated six years of CDL data (as in the BE), as opposed to the 50th percentile or mean values used to assess effects on use sites, as described previously. For these reasons, the extent of overlap and effects associated with spray drift may be more conservative for these species than that associated with exposure on use sites. Estimation of mortality for these species was based on a single generic maximum application rate for malathion, as was calculated for the BE, and thus may over- or underestimate the actual spray drift dose depending on the maximum application rates contributing to the spray drift. At each 30-m interval, the magnitude of mortality was multiplied by the spray drift overlap for that interval, summed, and then adjusted to account for the fact that the wind generally only blows in a single direction (see Appendix D). A generic 0.5 adjustment factor was used for all calculations, as the maximum number of allowable applications, on average, was two (see Appendix D for further discussion of how spray drift calculations were adjusted).

Other Considerations for Plants

For plants, we used the best available data to determine if there are any species that have obligate pollinators or seed dispersers, and we attempted to determine what general taxonomic group those pollinators or seed dispersers occur within. However, we note that for many plant species, there is little to no information regarding the specific pollinators and dispersers that frequent a species' flowers and fruits. Additionally, there is little specific information regarding the movement distances and patterns for many pollinators and seed dispersers. While there are often general month ranges available for floral periods for each species (e.g., flowers present from May to June), there is little to no information available for floral duration and reproductive periods within the floral period for many plant species. This is an important consideration, as the loss of pollinators during peak blooms periods can lead to reduced plant reproduction and dispersal.

Impacts to soil microbial communities and mycorrhizae have been noted for pesticides. However, there is little to no information available regarding the degree of impact to the soil microbial community or mycorrhizae after pesticides are applied. Additionally, for many species where we may know or assume there is a mycorrhizal associate (i.e., orchids), the identity and basic biology of that associate species is often unknown.

Summary

We acknowledge that many of the assumptions we have made in this analysis have the potential to under- or overestimate the extent of effects to listed resources. However, we have provided an explanation of why we made the assumptions and addressed uncertainties and have endeavored to clarify and frame our assumptions to adequately support our understanding of the effects of the action. Table 41 below provides a summary of our main assumptions and uncertainties, including whether there is an underestimate, overestimate, or an unknown risk of overestimating or underestimating effects to the species associated with each.

Table 41. Assumptions for the effects analysis.

Table 41 -
Assumptions_Effects

Risk Characterization

In general, where exposure occurs, we expect most species to experience mortality; sublethal effects; or loss of forage, prey base, insect pollinators (and in some cases, seed dispersers), or host fish following exposure to malathion. The degree the species will be affected is highly influenced by the toxicity of malathion to the taxonomic group (e.g., highly toxic to invertebrates, less toxic to mammals) and the overlap with the use sites. Due to the toxicity of malathion, most species are expected to experience impacts indirectly via dietary items, fish hosts, or pollinators where exposure occurs. Conservation measures are anticipated to reduce these predicted effects.

Terrestrial Vertebrates

Birds, Reptiles, and Terrestrial-phase Amphibians

Because effects to birds, reptiles, and terrestrial-phase amphibians are based on the same avian toxicity values, results were similar across these taxa.

One of the main factors that influenced the likelihood of exposure to malathion, and consequently its effects to birds, reptiles, and terrestrial-phase amphibians, was whether the species was expected to utilize malathion use sites. Following application, concentrations on use sites can be as much as one to two orders of magnitude higher than the concentrations expected from spray drift on areas adjacent to use sites. When available information indicated a reduced probability of individuals being exposed on use sites, the effects anticipated for these species were lowered. For example, based on information from species experts, we determined that species such as the Cape Sable seaside sparrow, dusky gopher frog, and northern Mexican garter snake were unlikely to enter and forage in most use sites and therefore limited the effects analysis to a small number of use sites. Spray drift was not expected to reach levels of concern for most birds, reptiles, and terrestrial-phase amphibians.

Because there are few limits on when malathion can be used, all listed terrestrial vertebrates had the potential for exposure to malathion, including those which hibernate, estivate, or migrate outside of the action area for part of the year. While these species will have less total opportunity for exposure, the majority may have exposure during breeding so may be exposed to malathion during especially vulnerable periods when adults may be courting, females are reproductive, young can be exposed, and adults are more confined to a specific nesting area or territory. For migratory birds, few listed species breed outside of the U.S. (e.g., red knot, whooping crane - Aransas-Wood Buffalo National Park population). However, for all species, migration increases the area in which individuals can be exposed, and often tends to overlap with periods of pest pressure. For example, birds that travel through more of the action area to their breeding sites (e.g., Piping plover: Great Lakes to southern East Coast and Gulf Coast) may be more vulnerable than birds that travel shorter distances through the action area (e.g., Golden-cheeked warbler: central and southern Texas to Mexico).

For birds, reptiles, and terrestrial-phase amphibians that forage in or adjacent to pesticide use sites, risk of mortality was dependent on the diet and body weight of individuals. Species that forage on aquatic dietary items (e.g., benthic invertebrates, fish) tended to have the least predicted mortality. This is not unexpected as, in many cases, terrestrial prey are expected to have higher concentrations of malathion due to more direct exposure (e.g., terrestrial invertebrates may have pesticide residues directly deposited on the surface of their bodies, as opposed to aquatic invertebrates that bioconcentrate pesticide residues that are diluted in water). Additionally, larger species generally have less risk than smaller species eating the same dietary items. In summary:

1. For birds, body weight was the largest influence, with mortality for larger birds only predicted on use sites with the highest allowable application rates. Birds that prey upon mammals or other birds had the greatest risk of mortality, followed by birds that prey on arthropods, grass and leaves. We predicted little to no mortality for many species of birds, with small birds that may enter use sites most susceptible.

2. Few reptiles had predicted mortality from malathion uses, and those with predicted mortality were limited to small species that consume terrestrial vertebrates (e.g., bluetail mole skink, Coachella Valley fringe-toed lizard). We did not anticipate other species to die from malathion exposure based on their larger size, difference in dietary items, and tendency not to enter malathion use sites.

3. As most amphibians have a similar diet (terrestrial invertebrates), body weight was the largest influence, with mortality for larger amphibians influenced by the maximum

> allowable application rate on use sites. We predicted little to no mortality for many species of amphibians, with small amphibians that may enter use sites most susceptible.

Uses with the highest application rates, and thus the highest malathion concentrations in prey or other dietary items were orchards and vineyards, developed, and open space developed. Of these, listed birds, reptiles, and terrestrial-phase amphibians frequently overlapped with developed and open space developed areas, and were often expected to utilize these areas to some degree.

For most birds, reptiles, and terrestrial-phase amphibian species, we predicted individuals to experience effects to growth, reproduction, and behavior in lieu of, or in addition to those individuals predicted to experience mortality. However, there were a number of species for which we predicted no mortality or sublethal effects, especially amongst the reptiles. We predicted some species to experience effects to growth and reproduction, but not behavior, though this is likely an artifact of the limited data available on behavioral effects in these species rather than a true indication of the toxic effects of malathion. While we would generally expect exposure to a pesticide to result in sublethal effects to individuals at lower concentrations than would result in mortality, in some cases, mortality was triggered in a greater percentage of the population than sublethal effects. This is likely a function of the available data. While lethality data exist for numerous avian species (used as surrogate for amphibians and reptiles), studies on growth, reproduction, and behavior are fewer. Thus, the lethality data is more likely than other data to capture concentrations where sensitive species could be affected. For reptiles and amphibians in particular, mortality is more highly influenced by body size due to conversions for dose-based endpoints. In general, it is anticipated that birds, reptiles, and terrestrial-phase amphibians will generally experience sublethal effects typical of exposure to cholinesterase-inhibiting pesticides (e.g., lethargy, neuromuscular effects) prior to death; however, adequate data did not exist to allow us to consistently assess the concentration of malathion at which those effects may occur.

We anticipate loss of forage and prey resources for terrestrial vertebrates that consume most dietary items. We anticipate mortality for all terrestrial and aquatic invertebrates exposed to malathion on use sites. Thus, mortality of these prey items is equivalent to the percent of the species range that overlaps with malathion use sites (considering the likelihood of a species to enter a use site, as discussed above). Plants are anticipated to experience decreased biomass on only those uses with the highest application rates (about 5 out of 15 uses overall). Mammalian prey, an important food source to species such as owls and pine snakes, were not generally anticipated to experience mortality. Loss of other dietary items varies across use sites. Note that mortality of terrestrial vertebrates as dietary items does not always correlate with mortality of the listed species being assessed. This is because mortality of dietary items was based on a representative prey species for each taxa. For example, we calculated effects to birds and mammals as prey species using a small insect-eating bird and a small grass-eating mammal. Birds and mammal species that consume other dietary items or are larger or smaller may experience different effects following exposure to malathion.

We anticipate that some species of birds, reptiles and terrestrial-phase amphibians will experience mortality from dermal absorption of malathion if exposed from either direct spray or from contact with foliage or other contaminated media. The possibility and extent of mortality is highly influenced by body size, with the largest species of all three groups not anticipated to experience any mortality, and the smallest species expected to experience 100% mortality if exposed. For species where a high level of mortality is also predicted from dietary exposure, we state that dermal exposure may contribute to that mortality. For some species, life history characteristics preclude most opportunities for dermal exposure. For example, we do not expect marbled murrelets to have contact with direct spray or contaminated foliage while traveling to and from offshore feeding locations. Salamanders and sand skinks generally live underground or under leaf litter. The chance of encountering malathion from direct spray or from contact with contaminated media was an important consideration and varied by species. Dermal exposure was an especially important consideration for species where effects from dietary exposure were not anticipated, or species that may travel through, but not forage in, malathion use sites, such as dispersing juveniles or migrating individuals.

For mosquito adulticide, loss of prey or forage items was a concern for insectivorous species, depending on the extent of overlap as we anticipate mortality for terrestrial and aquatic invertebrates. However, we did not anticipate effects to plant biomass from this use. Mortality and sublethal effects following a mosquito adulticide application were generally less likely than for other uses, driven by the comparatively lower application rate for this use (about an order of magnitude lower than other uses). We did not expect any reptiles, and only a few amphibian species, to experience mortality or sublethal effects. As with other uses, body size and dietary items influenced which species we anticipated to experience effects. We did not expect concentrations from mosquito adulticide use to be high enough to cause adverse effects following dermal absorption from direct spray or contact with contaminated media for birds or reptiles, but expect these concentrations could affect some amphibians.

The effects described above for terrestrial vertebrates were considered in the development of conservation measures that apply either broadly to malathion use across the landscape, or within the range of specific listed birds, reptiles, and amphibians or their critical habitats. We anticipate that these conservation measures will reduce exposure, and thus predicted effects described above to listed birds, reptiles, and terrestrial-phase amphibians.

Mammals

Malathion is considerably less toxic to mammals than other terrestrial vertebrates. There were many species of listed mammals for which we anticipated no mortality or sublethal effects. Generally, we only anticipated mortality and sublethal effects to mammals for species in the use sites with the highest allowable application rates of malathion (i.e., orchards and vineyards, developed, and open space developed use sites). However, there was often no, or low, overlap with these uses within the range of listed mammals. Listed mammals more often overlapped with other use areas where maximum application rates are lower.

Similar to the summary of effects to forage and prey to birds, reptiles, and amphibians above, effects in the form of loss of food resources are the most anticipated effects for mammals consuming most dietary items. We anticipate mortality for all terrestrial and aquatic invertebrates exposed to malathion on use sites. Thus, mortality of these prey items is equivalent to the percent of the species range that overlaps with malathion use sites (considering the likelihood of a species to enter a use site, as discussed above). We anticipate decreased biomass of plants on only those uses with the highest application rates (about 5 out of 15 uses overall). We generally do not expect mammalian prey, an important food source to species such as foxes, kit foxes, and wolves, to experience mortality. Loss of other dietary items varies across use sites.

The effects described above for mammals were considered in the development of conservation measures that apply either broadly to malathion use across the landscape, or within the range of specific listed mammals or their critical habitats. We anticipate that these conservation measures will reduce exposure, and thus predicted effects described above to listed mammals.

Terrestrial Invertebrates

As malathion is designed to kill terrestrial invertebrates (specifically insects), we anticipate mortality to these taxonomic groups. We also observed high overlaps with use sites for most of these species. Some uses for malathion were consistently high regardless of species and location, such as corn, pasture, developed, and open space developed. For mosquito control, overlap varied, depending on where in the continental U.S. the species range was located; however, the overlaps for this use were generally very high and contributed to high risk estimates where there was overlap and usage.

Spray drift compounded the risk to the species and increased the mortality that would be observed with exposure. We acknowledge the spray drift mortality may be an overestimate of effects from this exposure pathway; however, estimated effects contributed to high risk for many species.

The effects described above for terrestrial invertebrates were considered in the development of conservation measures that apply either broadly to malathion use across the landscape, or within the range of specific listed terrestrial insects, terrestrial cave insects, and arachnids or their critical habitats. We anticipate that these conservation measures will reduce exposure, and thus predicted effects described above to listed terrestrial invertebrates.

<u>Terrestrial Insects</u>

Indirect effects (via dietary items) for terrestrial insects were analyzed similarly to the analysis for the species itself. Where risks were high, we assumed there would be impacts if individuals of a species consumed food resources such as nectar/pollen, broad leaf plants, short grass, etc. However, if a terrestrial insect consumed other terrestrial invertebrate prey item (e.g., certain beetles), or if a species was reliant on another taxonomic group of invertebrate for survival that would also experience similar mortality (e.g., lepidopterans that rely on ants to protect their larvae from predators), this information was provided in the discussion for the species, and a similar effect was noted for that dietary item or obligate relationship. We were not able to directly assess the impacts to other food resources (e.g., detritus) where there were no specific EECs identified for the food item. In these cases, species that are reliant on these food items (e.g., certain beetles) were assigned closely related EECs as substitutes when possible; these values were then designated as the input for the EEC dietary item in the R code to produce the R-

Plot. For example, a detritivore, or a species that consumed plant or tree roots, had soil as the closely related dietary item EEC input for the R-Plot.

Terrestrial Cave Insects

Agricultural and non-agricultural uses in areas near where listed cave insects are found that had the highest overlaps were other grains, developed, and open space developed. These species are mostly restricted to a few caves in two counties in Texas. While we do not anticipate direct application or drift would be likely pathways for cave species when they are in subterranean habitats, we do anticipate all cave species may be exposed to malathion via a variety of other pathways. With the large overlap of areas often directly above these species and documented studies providing information that these caves are porous, allowing for malathion or other pollutants to reach subsurface areas, we observed high risk to all cave species from exposure to malathion via applications above ground in areas that overlap with the caves where these species are found. In particular, these areas have very high overlap with mosquito control (> 90%), and we anticipate risk of mortality from this use of malathion in addition to the other non-agricultural and agricultural uses.

Terrestrial Snails

Malathion is not expected to kill any exposed snail, and thus we do not anticipate mortality to listed terrestrial snail species from malathion. We based our conclusion of relatively low toxic effects to terrestrial snails by using aquatic snail toxicity data as a surrogate[47]. While results indicate high mortality to snails from estimated environmental concentrations of malathion as calculated using the most sensitive terrestrial invertebrate (*Apis mellifera*) as a surrogate, data in the primary literature for aquatic snails indicate this taxa group tends to be relatively tolerant to malathion. While terrestrial species may not be exposed to malathion via the same exposure route as aquatic snails (i.e., in water), we consider aquatic snails to be a more suitable surrogate than a honeybee, and assume terrestrial snails would be expected to exhibit similar tolerances as aquatic snails to malathion from contact exposure. Because toxicity data for aquatic snails are based on concentrations in water and we do not have applicable data to perform a quantitative analysis on estimated concentrations in the terrestrial environment, we apply the assumption of malathion tolerance to terrestrial snails in a qualitative manner.

Some species of terrestrial snails may also be considered lower risk due to their life history traits, such the Virginia fringed mountain snail. The Virginia fringed mountain snail is fossorial (i.e., buried in soils along 6 miles of river bluffs), and we do not expect exposure to occur. For other terrestrial snail species considered (e.g., Stock Island tree snail, Iowa Pleistocene snail, Flat-spired three-toothed snail, painted snake coiled forest snail, noonday globe, Morro shoulderband snail, Chittenango ovate ambersnail, and the Kanab ambersnail), their life histories do not

[47] This is a change from our April 2021 draft biological opinion, where we used a less related and likely more sensitive invertebrate surrogate *A. mellifera* (a honeybee) for terrestrial snails, in the absence of terrestrial snail toxicity data. For our revised analysis in this Opinion, we reconsidered the snail toxicity data and determined that adequate data were available to draw conclusions about the sensitivity of aquatic snails to malathion. These data were used to assess sensitivity to terrestrial snails, as a more closely related taxonomic group is more likely a suitable surrogate for these species.

include aspects that would preclude exposure; however, based on the aquatic snail toxicity data, malathion uses described in the effects analysis are not expected to result in the mortality of individuals of these species should exposure occur.

We estimated that malathion uses would vary from between 1-28% for total overlap within the range of all listed terrestrial snail species. The uses with the highest overlaps were pasture, developed, open space developed, and corn. Due to this overlap, listed snails are likely to experience high exposures from direct contact, except where exposure would not be expected due to a specific life history strategy, as described above. For mosquito adulticide, overlap with the range for these species is anticipated to be high (0.1% – 93%); however, effects from this use and usage, where information was available within the range of listed snails, suggests low risk of mortality.

Indirect effects (dietary items) for terrestrial snails were analyzed similarly to the species itself As with terrestrial insects above, we were not able to directly assess the impacts to other food resources, such as detritus, where there were no specific EECs available, so therefore species that are reliant on these food items were also provided closely related EECs as substitutes where possible. These values were then designated as the input for the EEC dietary item in the R code to inform the R-Plot. For example, a detritivore or a species that consumed plant or tree roots had soil evaluated as the dietary item EEC input for the R-Plot. Similarly, species that consumed lichen or algae from rocks had broad leaf plants as the dietary item EEC input for the R-Plot.

Generally, we anticipate a low risk of mortality to terrestrial snails based on the discussion above, either due to life history strategy (i.e., Virginia fringed mountain snail due to the low exposure anticipated in view of its burrowing life history) or the assumption of tolerance based on available toxicity data for aquatic snails (all terrestrial snail species).

<u>Arachnids</u>

Most listed arachnids are subterranean and will be discussed below. The spruce-fir moss spider, the only non-subterranean listed arachnid, would likely experience a high risk of mortality from exposure to malathion in its environment. We anticipate that any individual, if exposed, would be killed based on the high toxicity of this pesticide to invertebrate species. Agricultural applications at lower elevations within close proximity to this species' range in the southern Appalachians may carry malathion via droplets in wind or precipitation to where this spider is found. Overlaps for this region varied for malathion uses (ranged from <1% for most uses to 1% for developed or 4% for open space developed).

All but one of the cave arachnids are located within one or two counties in Texas, with the remaining cave spider found in lava tubes in Hawaiʻi (the Hawaiian cave spider risk assessment is discussed in the *Pacific and Caribbean Islands* section). Agricultural and non-agricultural uses in areas where listed cave arachnids are found that had the highest overlaps were other grains, developed, and open space developed. While we do not anticipate that direct application would be likely pathways for cave arachnids when they are in subterranean habitats, we do anticipate all arachnid cave species could be exposed to malathion from run-off or spray drift that infiltrates through the substrate to the species' habitat. These exposure pathways are not direct exposures per se for these cave arachnids. Due to the large overlap of areas directly above where these species are located, and the documented studies providing information demonstrating that these caves are porous, absent effective conservation measures (which have now been incorporated into the Action), we would anticipate high risk of mortality to all cave species from exposure to malathion.

For mosquito adulticide, overlap totals were also very high for the cave arachnid species (37%, 38% and 94%), and mortality risk from this use within the range of the cave arachnids was also determined to be high. However, we anticipate the conservation measures that now being incorporated into the Action in the form of label changes will substantially reduce exposure to these species and thus substantially lower their risk of mortality. For example, the label language regarding rain restrictions will substantially reduce runoff and estimated environmental concentrations of malathion into aquatic habitats, subsequently reducing the risk from run-off or spray drift that infiltrates through the porous karst substrates, sink holes, and lava tube substrates where the cave arachnids reside. In addition, the aquatic buffer protections describing application buffers 25, 50 and 100 feet from aquatic habitats for ground, aerial and ultra-low volume aerial applications, respectively, are also designed to create no-spray buffers from sensitive aquatic areas. These application restrictions will also reduce exposure from pesticides that can drift off use sites that may subsequently enter into these porous karst and lava tube habitats as well.

Species-specific measures for the Kauai wolf spider (pe‘e pe‘e maka‘ole) regarding restricting irrigation of fields to a minimum of 24 hours after malathion application and scheduling irrigations to allow at least 24 hours between malathion applications and irrigation maximize the interval of time to allow malathion to naturally degrade in the environment. This label language is also designed to minimize the potential for run-off into the fissures, openings, and voids in young lava tubes and consolidated calcium carbonite deposits scattered throughout the Koloa District where this arachnid is found.

We analyzed indirect effects (i.e., dietary items) for arachnids. Where risk of mortality was high for dietary items (e.g., other arthropods), we assumed there would be impacts to species based on effects to the prey base. The conservation measures described above are also expected to reduce exposure to the dietary items for these arachnid species.

Fish and Aquatic-Phase Amphibians

Risks to aquatic vertebrates posed by labeled uses of malathion across their range were most influenced by the amount of agricultural and non-agricultural activity in the range (overlap), the type of uses, and the waterbodies inhabited by the species (bins). Three quarters of all listed fish species spend part or all of their life cycle in small streams, bin 2, and nearly a third live in small ponds, bin 5. Most amphibians with aquatic phases inhabit small streams and small ponds, particularly during early life stages. Malathion use near these habitats can pose high risk of mortality and variable risk (low to high depending on the species) of sub-lethal effects to species. Agricultural uses are particularly hazardous as EECs resulting from those use types are frequently estimated to cause high direct mortality, sublethal effects among survivors, and indirect effects on prey. The use types that most often occur in Fish species ranges (with ≥ 1% overlap) are Corn, Other Crops, Wheat, and Pasture and those in aquatic-phase amphibian species ranges are Corn, Other grains, Wheat, and Cotton. Alternatively, there are non-agricultural uses, specifically Developed, that are much less hazardous to fish and aquatic-phase amphibians because of the low EECs associated with that use type. Depending on the uses in the range, the species may be more or less likely to be at risk of mortality.

The other important factor in determining risk is the amount of agricultural and non-agricultural activity (overlap) in the species range. Overall, approximately a third of fish species had total overlap (all uses except mosquito control) > 5% and about a third had total overlap < 1%. For aquatic-phase amphibians, total overlaps ranged from 1.46 to 25%. For those species in bins 2 and/or 5 that had higher overlap of range with predominantly agricultural uses, risk of mortality would be high. If Developed was the predominant use in the range, risk of mortality would be lower. If the overlap was in the lower end of the range, <1%, risk of mortality would be lower regardless of the uses in the range.

Species that inhabit medium sized lakes/ponds (bin 6) and larger lakes (bin 7) have EECs (associated with the different agricultural and non-agricultural uses) that are lower compared to bins 2 and 5. For species in bin 6, the EECs for agricultural uses fall in the range where mostly high levels of mortality would be expected. Whereas EECs in bin 7 were most often aligned with medium levels of mortality, EECs and expected effects (mortality and sublethal) from the Developed use tended to be low for both bins 6 and 7. Species that primarily inhabit larger lakes would generally be at lower risk of mortality especially in areas where there is low overlap or Developed is the main use type in the range.

Whereas bins 2, 5, 6, and 7 were modeled at the field scale, EPA modeled bins 3 and 4 (the medium- and high- flow flowing waters) at the watershed (HUC12) scale. Consideration of bins 3 and 4 were problematic, as these larger rivers and streams receive water from numerous use sites and will have EECs that aggregated the uses across the entire range of the species, overestimating environmental concentrations of malathion. We previously used bin 2 EECs as an upper bound of bin 3 and 4 EECs, but in conversations with EPA since the issuance of the draft Biological Opinion, this was determined to still be an overly conservative approach. Subsequent additional analyses from EPA indicated that EECs from bin 2 may be scaled down proportionately by an order of magnitude to generate an approximate bin 3 or 4 EEC values that now more accurately reflect anticipated environmental concentrations. We considered risks from mosquito adulticide separately as the overlap and usage information was considered separately. The modeling scenario for mosquito adulticide use generated EECs that were relatively high, and, thus, direct lethal effects were often high for species inhabiting bin 2 and bin 5, medium in bin 6, and low in bin 7. In all modeled aquatic habitats, high lethal effects are anticipated for aquatic invertebrates, thereby reducing food availability for invertivores. Effects on prey fish were estimated to be high in bins 2/5 and low in bins 6/7. For some species, mosquito control had the most influence on risk of mortality as overlaps were as high as 100% and greater than 20% for many species.

Because malathion has high acute lethal toxicity to these taxa, the predominant type of effect for fish and aquatic phase amphibians from the R-Plot analysis tended to be mortality. . In most cases where mortality was expected, sublethal effects to surviving individuals were also likely to occur. Individuals experiencing behavioral effects such as reduced swimming performance may be less capable of surviving, particularly during earlier life stages, such as larvae and juveniles. Reduced growth may also have fitness consequences that could affect survival as well as reproduction. For some fish species, larger females tend to produce more eggs. In most cases where exposures were low enough such that direct effects were not anticipated, there was still risk from indirect effects, because of high mortality to aquatic invertebrate prey.

We considered the effects described above for fish and aquatic phase amphibians in the development of conservation measures that apply either broadly to malathion use across the landscape, or within the range of specific listed fish and amphibians or their critical habitats. We anticipate that these conservation measures will reduce exposure, and thus predicted effects to listed fish or amphibians.

Aquatic Invertebrates

Aquatic Insects and Crustaceans

High risk to aquatic insects and crustaceans was observed across all use types for malathion. High overlaps (0-74%) associated with the ranges for most of these species were also observed and high effects were observed for all aquatic bins. Uses that had the highest overlap for these species were Developed, mosquito control, and pasture. For most uses and bin combinations in which aquatic insects and crustaceans would be found (bins 2, 3, 4, 5, 6, and 7), effects observed were high for malathion, regardless of location of a given species' range.

Indirect effects were not analyzed for aquatic insects and crustaceans, based on the assumption that most indirect effects items considered for an aquatic invertebrate would involve dietary items that would also experience similar mortality (other aquatic invertebrates as dietary items) and the aquatic R plot tool does not provide a quantitative assessment to food resources (algae).

For mosquito adulticide, effects from this use within the range of the aquatic insects and crustaceans also estimated high risk of mortality (overlaps varied from <1 – 98%).

Generally, aquatic insects and crustaceans are considered to have very limited range and are endemic to specific habitat locales (e.g., vernal pools, certain cave species, freshwater springs) and thus were found to be more at risk from malathion exposure. These species tended to have higher overlap with use sites such as pasture, developed, and orchards and vineyards (vernal pool species tended to have the highest overlaps with these uses) and occur in bins (2,3,5,6) which tend to concentrate the pesticide more than larger waters or higher flowing waters. Overall, aquatic insects and crustaceans are generally limited in range and are not found in multiple or different locations or habitat types. Therefore, the combined high hazard (i.e., toxicity) of malathion to these taxa and high exposure of malathion to listed aquatic insects and crustaceans resulted in a high risk of mortality to these species.

We considered the effects described above for aquatic insects and crustaceans in the development of conservation measures that apply either broadly to malathion use across the landscape, or within the range of specific listed aquatic invertebrates and crustaceans, or their critical habitats. We anticipate that these conservation measures will reduce exposure, and thus predicted effects to listed aquatic invertebrates and crustaceans.

Mussels

Exposure varied among the species based on the bins in which they are found from low to medium to high. However, effects to the 23 representative listed mussel species indicated no direct mortality would occur due to the high LC_{50} value for *Lampsilis*. Contrary to direct effects to the mussel, high indirect effects to fish hosts, which are sufficiently sensitive, were observed to cause mortality. The loss of the fish host predicted for all listed mussel species is particularly relevant as the continued survival of any listed mussel species is directly reliant on a fish host for glochidia to attach and derive nutrients as it grows and matures.

For most uses and bin combinations in which mussels would be found (bins 2, 3, 4, 5, 6, and 7), the observed effects were high risk of mortality to the host fish , regardless of location of a given species' range. Effects in bin 2, however demonstrated lower effects (mortality) for all species, mostly from Developed and mosquito control uses. Effects in other bins varied depending on the use and the overlap of that use with a species' range.

For all uses, total overlap in the different species ranges varied from <1% - 64% and uses with the most overlap were mosquito control, developed, and corn.

Freshwater mussels in the families Unionidae and Margaritiferidae (to which these listed species belong) are long lived (10 to 20 years in general, with other species living more than 100 years) and have unique and complex life cycles. With long life comes the potential to accumulate a greater body burden of environmental contaminants, making these aquatic invertebrates particularly vulnerable to effects of certain chemicals, although we do not expect this vulnerability to apply to malathion due to the low toxicity this pesticide has on these species. Due to these species reliance on host fish to complete their life cycle, and where recruitment is absent or occurs only at low levels, freshwater mussels, while present, could become functionally extinct in the absence of effective conservation measures, listed mussel species are greatly at risk due to reduced reproductive success or, in some cases, local extirpations due to the often high overlaps of malathion use in their range and the subsequent effects of malathion to their fish hosts.

We considered the effects described above during coordination with EPA and the registrant as we advised them during the development of conservation measures that apply either broadly to malathion use across the landscape, or within the range of specific listed mussels, or their critical habitats. We anticipate that these conservation measures will substantially reduce exposure by limiting the amount of malathion that reaches the aquatic habitats in which listed mussels and their host fish reside.

Aquatic Snails

The endangered and threatened freshwater snails live in springs or flowing waters such as streams and rivers and require very pristine water quality with specific levels of temperature, rates of water flow, oxygenation, and pH in order to thrive. For all uses, total overlap for the different species ranges varied from <1% to 59%, and uses with the most overlap were Developed, corn, and pasture. Overlap for mosquito adulticide, ranged from < 1% to 86%. However, because of the relative tolerance of aquatic snails to malathion, a low risk of mortality from malathion use is anticipated for these species.

Indirect effects were not analyzed for aquatic snails, based on the assumption that most indirect effects for items considered for aquatic snails would involve dietary items that prove difficult to assess for malathion residues in an aquatic environment and that we can assume would acquire the malathion concentrations that are already in the water column, thereby directly exposing the aquatic species within the water body where the species resides; bins 2-7). In addition, the aquatic R plot tool does not provide a quantitative assessment for food resources such as algae.

Plants

Plants were divided into 11 assessment groups to represent plants occurring in CONUS and Alaska and 11 corresponding assessment groups containing plants occurring in Hawaiʻi, American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, the U.S. Virgin Islands and Puerto Rico. Of these 11 assessment groups, overlap with malathion uses for CONUS species was assessed by determining effects to species based on the reproduction strategy for that species. The 11 plant assessment groups are discussed in more detail in the *General Effects to Plants* section. Spray drift of the pesticide off the site of a specific use was also analyzed. The approach for how listed plant species were analyzed is described in more detail in the plant approach to the assessment but briefly, the magnitude of effects directly to plants and indirectly to pollinators or seed dispersers was analyzed using the Plant R-Plot tool for CONUS species (see also *Approach to the Effects Analysis for Plants* for more information on the Plant R-Plot tool). Effects to pollinators and seeds dispersers for island plants were also assessed in the context of the 11 groups, but it was done more qualitatively given the lack of overlap and usage data available for these species. Details can be found in the *Analysis for Pacific and Caribbean Island Species* section of this Opinion.

Life history traits for plant species were also considered for both CONUS and island species in determining the impacts of malathion to plants; annual or perennial flowering strategies, pollination by an obligate insect, utilization of agricultural areas, seed dispersal mechanisms, and pollinator strategy. Mortality to pollinators/seed dispersers was also highly influenced by overlap with malathion use sites for CONUS species, though the percent affected differed depending on the type of pollinator (insect, bird or mammal). For island species, pollinator mortality was considered qualitatively based on the type of pollination/seed dispersal vector used and the likelihood of exposure to malathion given the species preferred habitat and overall anticipated usage throughout the islands. In addition to mortality on use sites, some pollinators may be lost in adjacent areas due to spray drift.

<u>Pollination Strategy</u>

Plants have two general categories of pollination vectors (how pollen is transferred between individuals); biotic and abiotic. Biotic pollination vectors include insects, birds, and mammals, among others. Abiotic pollination vectors are typically wind or water. Successful pollination leads to seed production and is a critical step in successful reproduction for many plant species. In addition, transfer of pollen between individual plants or populations of plants allows species to reproduce sexually, thereby recombining genes and allowing gene flow to occur. Gene flow is especially important in small, fragmented, or isolated populations where pollinating animals may provide the only connection among populations. We observed that most listed plant species with abiotic pollination vectors would be less impacted by the effects of malathion and thus would experience lower risk. We anticipate high risk for listed plant species with biotic pollination vectors due to the high risk observed for one or more pollinators (insect, or bird, depending on the plant species and the use due to the application rate; see discussion on effects to pollinators and seed dispersers; *General Effects to Plants*).

<u>Annual Versus Perennial Plants</u>

We expect there to be differential responses to malathion based on differences in plant life history. Plant life history strategies can vary from annual, biennial, or perennial life cycles. Plant species can be either monocarpic, with one reproductive event per life cycle, or polycarpic, with many reproductive events per life cycle. The risk to plant species based on life history is linked to the number of flowering opportunities available and the need for recruitment from any one years' seed set. Annual species have only one opportunity to grow, flower, and reproduce during their life cycle while perennial species typically have many opportunities. We considered life history strategy where available, though as described earlier in this Opinion, there is lack of specificity on information regarding the timing of malathion application and how that application may or may not coincide with a plant’s flowering and fruiting season. Therefore, we assumed that regardless of a plant’s flowering/fruiting season or duration, it is reasonable to expect that malathion would be applied during these critical periods. This assumption could over – or underestimate exposure depending on the species under consideration. Regardless, we anticipate the conservation measures to be implemented will reduce pollinator exposure during these critical times in the life history of the listed plants, and therefore reduce reproductive effects to low or negligible levels.

<u>Seed Dispersal Mechanisms</u>

Successful seed dispersal is often a critical mechanism for the long-term persistence of many plant species. Dispersal enables plants to colonize additional suitable locations, thereby increasing the size of a population, or establishing new populations. Larger populations as well as well-developed meta-population dynamics among populations can maintain genetic diversity in these already rare plant species and prevent inbreeding depression among isolated populations. Declines in dispersal distance or ability may prevent these plant species from finding additional suitable sites to colonize and limit successful reproduction.

Plants utilize a variety of seed dispersal mechanisms. We do not anticipate negative effects from malathion on abiotic seed dispersal mechanisms such as wind, water, and gravity, among others, as there is no reasonable, functional tie between malathion use and these physical mechanisms of seed dispersion. However, many plant species rely upon biotic seed dispersal mechanisms;

mainly internal or external transport by animal species. Typical taxa groups involved in seed dispersal include insects, birds, and mammals.

We anticipate that malathion impacts to seed dispersal bird species consuming nectar on use sites with higher allowable application rates (e.g., developed, open space developed, nurseries, orchards and vineyards) could experience similar rates of mortality from consumption of nectar as compared to arthropods. Those consuming nectar on agricultural crops with lower allowable application rates (e.g., pasture, corn, wheat, pine seed orchards, other crops) are not expected to experience significant mortality. We also note that we anticipate negative impacts to insects that are seed dispersers and resultant limitations on the successful reproduction of applicable plant species. We specifically note that we expect the effects of malathion to be less prevalent for plant species with abiotic and non-insect seed dispersal mechanisms.

Pollination or Seed Dispersal by an Obligate or Specific Species

Plants that depend upon an obligate pollinator may see a disproportionately greater negative effect from the action since these species of plants cannot utilize another insect species for pollination if the specific pollinator they rely upon has been reduced or temporarily extirpated from the area due to pesticide use (See discussion; *General Effects to Plants*).

Utilization of Agricultural Areas

While we expect to see plants growing in such use sites as pasture, developed, and open space developed areas, we are less confident of their presence in agricultural areas. However, information we gathered from Service Field Offices indicated some species of plants utilized agricultural areas for all or a portion of their life cycle. These species could see greater negative effects of the action as they may experience higher exposures than plants which reside outside of agricultural areas. In addition, we assume pollinator and seed dispersers will experience effects in all use areas equally due to their mobility across use sites, and ability to forage in all use sites.

Summary

For direct effects, we observed that the uses with the highest application rates, nurseries, orchards and vineyards, developed, and open space developed would result in exceedances of the threshold for reductions in biomass for the dicot plants. Subsequent impacts to listed plants with insect pollinator or seed disperser species were also observed with high risk of mortality, compounding the effect to the plant itself.

Indirect effects varied widely depending on the plants' reproductive methods, which determined their relative risk to malathion exposure and dictated their assignment to a particular assessment group.

Risk was generally low for plants in Assessment Groups 1 – 4 and 8 where pollination and seed dispersal is not part of the life cycle of the species (Group 1, lichens and Group 2, ferns and allies), or abiotic pollination vectors are used (Group 3, conifers and cycads; Group 4, monocots; Group 8, dicots).

For Assessment Group 5, medium risk was observed to these monocot species due to reliance on biotic pollination vectors and outcrossing for successful reproduction. Risk for Assessment Group 6 varied from low to medium, again based on the capability to self-fertilize or asexual / clonal reproduction in addition to relying on biotic pollination. Risk for Assessment Group 7 similarly remained low to medium. Low to medium risk was observed for all of these monocot groups where impacts to pollinators or seed dispersers depended on the whether or not that species maintained a reserve strategy to compensate for loss of a pollinator or seed disperser if that pollinator loss could occur due to malathion exposure.

We assessed these next groups (9-11) based on direct impacts to dicot plants from the toxicity data discussed above (exceedances of application rate will reduce biomass of the plant) and indirect effects to different pollination vectors. Assessment groups 9 and 10, those listed dicots with biotic pollination vectors that require outcrossing for successful reproduction or are capable of self-fertilization or asexual / clonal reproduction, respectively, had a few species with low risk but mostly species with medium to high risk of reproductive effects due to loss of pollinators and/or seed dispersers.

The dicot angiosperms in Assessment Group 11 utilize biotic vectors to accomplish pollination, but other aspects of their reproductive mechanism are unknown. We observed the range of risk to be from low, medium, and high for these species that is related to overlap in the range for CONUS species (uses with the higher application rates or higher usage having larger overlaps with the species' range may see higher risk versus less percent overlap with uses and lower usage information for sites with lower application rates). Risk for island species, as mentioned, was determined qualitatively based on pollination vector type, potential exposure based on preferred habitat type and overall usage of malathion within the islands as a whole.

The outputs from the Plant R-Plot tool for CONUS species (see Appendix M) also described mortality to biotic seed dispersers and pollinators from overlap that ranged from 0%-84% and additional mortality to insect pollinators/seed dispersers was observed from spray drift that ranged from 0%-100%. This spray drift value was calculated as the distance off the field (up to 300 m) where residues of malathion were expected to remain great enough to cause mortality to invertebrate pollinators or seed dispersers. Effects to pollinating / seed dispersing birds and mammals were not expected from exposure to spray drift. In cases where we determined additional mortality to insect vectors from spray drift could be significant, this was discussed in the conclusion section for the applicable species.

For the malathion applications of mosquito adulticide for CONUS species, overlap was determined for all species. For islands species, mosquito adulticide usage was determined to be very low, see section *Analysis for Pacific and Caribbean Island Species* in the Opinion. We did not anticipate effects to plant biomass from this use due to the lower application rate (about an order of magnitude lower than other uses). We assume that risk to insect pollinators and seed dispersers within the species' ranges would be high and directly related to the overlap value as there are no EECs for mosquito control to determine effects to pollinators / seed dispersers from consumption of dietary items that were exposed from this use. Similarly, for bird or mammal pollinators and seed dispersers, risk from exposure to malathion applied for mosquito adulticide was low, we did not expect concentrations from mosquito adulticide use to be high enough to cause adverse effects following dermal absorption from direct spray or contact with contaminated media for birds.

We considered the effects described above for plant species in the development of conservation measures that apply either broadly to malathion use across the landscape, or within the range of specific listed plants or their critical habitats. We anticipate that these conservation measures will reduce exposure and thus predicted effects to listed plants.

Critical Habitat Approach to the Assessment

Critical Habitat Effects Analyses

We assessed whether the registration of malathion is likely to reduce the conservation value of designated or proposed critical habitat. Critical habitat designation rules have included a variety of terms, such as “physical or biological features” (PBFs), “primary constituent elements” (PCEs), or “essential features” to characterize the key components of critical habitat essential for the conservation of the listed species. The 2016 critical habitat regulations (81 FR 7413) discontinue use of the terms PCEs and essential features, and rely exclusively on the term PBFs originally used in the ESA 1986 amended regulations (50 CFR §402.02). However, the shift in terminology does not change the approach used in conducting a “destruction or adverse modification” analysis, which is the same regardless of whether the original critical habitat designation identified PCEs, PBFs or essential features. For those reasons, in this Opinion, we broadly use the term PBFs when referring to the key components of critical habitat that are described as essential for the conservation of the listed species in critical habitat designations as a standardized way to cover all features described by these terms.

When designating critical habitat, we assess whether the areas within the geographical area occupied by the species at the time of listing contain the PBFs that are essential to the conservation of the species, and which may require special management considerations or protection. Specific areas outside the geographical area occupied by the species at the time it is listed may also be designated if determined to be essential for the conservation of the species. General PBFs include, but are not limited to: (1) space for individual and population growth and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, or rearing (or development) of offspring; and (5) habitats that are protected from disturbance or are representative of the historical, geographic, and ecological distributions of a species. Specific PBFs are also often included in critical habitat rules to describe habitat elements that are essential for the species based on the best scientific data available about the species’ habitat, ecology, and life history. A feature may be a single habitat characteristic, or a more complex combination of habitat characteristics and functions.

For purposes of assessing whether or not a destruction or adverse modification determination is appropriate, the effects of the Action, together with the status of critical habitat, the environmental baseline, and any cumulative effects, are evaluated to determine if the critical habitat range-wide would remain functional or retain the current ability for the PBFs to be functionally re-established in areas of currently unsuitable but restorable habitat, to serve its intended conservation and recovery role for the species. Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the PBFs essential to the conservation of a species. We analyze effects to critical habitat separately from effects to the species. The effects to PBFs are related to but are not always the same as effects to the species, and the species does not have to be present for adverse effects to the critical habitat to occur.

To facilitate our analysis of the large number of critical habitat proposals and designations in this Opinion, we identified the types of PBFs that we anticipate may be negatively affected by the Action. The pertinent elements of PBFs we identified that would be susceptible to effects from malathion fell into four categories that may apply to the critical habitats of various taxa: (1) water quality for aquatic or water-dependent species, or conditions related to pollution-levels for terrestrial habitats to function for the species (i.e., habitat function); (2) arthropods as prey (e.g., for insectivorous species); (3) non-arthropods, including as prey for omnivorous or carnivorous animal species, as pollinators/seed dispersers for plants, and as host fish for mussels; and (4) insect pollinators/seed dispersers for plants. For example, a common PBF for many listed species' critical habitat designations is a sufficient prey base to provide for population viability or growth of the listed species. Where the prey base primarily consists of insects and other arthropods, the use of insecticides may negatively affect the availability of food for those insectivorous listed species. A substantial decrease in food availability would affect the listed species' ability to grow, reproduce, or survive, and thus, the loss of an important prey base could adversely affect the conservation value of the critical habitat for the species.

The Service assessed the likely impacts of the Action on the PBFs of proposed and designated critical habitat to determine if the Action would appreciably diminish the value of the critical habitat. We based the analyses for our adverse modification determinations on the specific PBFs identified for the critical habitat that are susceptible to effects from malathion, the overlap of critical habitat with labeled uses, the anticipated malathion usage in critical habitat areas over the duration of the Action, and our assessment of the impacts to the critical habitat as a whole for the conservation of the species. While we consider effects to critical habitat separately from effects to the species, we often use our understanding about certain types of effects to listed species, such as importance of prey base, to make assumptions about the degree of effect to related PBFs. The following sections describe the exposure and expected response of critical habitats to the Action through impacts to their PBFs.

Exposure of Critical Habitat to Malathion

The registration of malathion is nationwide in scope according to the labeled uses. 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 movement and 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 of EPA's BE for malathion.

The EPA made “may affect” determinations for all 744 proposed and designated critical habitats under Service jurisdiction in their BE, pursuant to Step 1 of the agreed-upon consultation process and the NAS report (see *Introduction*). EPA then conducted an overlap analysis using the results from Step 1 to calculate the percent overlap of critical habitat affected by potential applications on each use site (i.e., potential use sites plus the off-site transport area). The EPA assumed any potential for effects to a listed species, based on the lines of evidence, are also important to determine the effects to that species’ critical habitat, regardless of whether the species currently inhabits the critical habitat. For a more thorough description of how EPA determined exposure of critical habitat to pesticide use, see Chapter 3 of the BE.

For this Opinion, we reviewed all of the currently proposed and designated critical habitats, which varies somewhat from the list of those considered in the BE due to more recent rulemakings involving proposed critical habitat, final critical habitat designations, and species delistings. For the purposes of our analysis, we initially considered using the estimation of geographic overlap between proposed and designated critical habitat and malathion use per the BE, which was estimated to be 100% for all proposed and designated critical habitats. While the degree of overlap with other uses varies, malathion use as a mosquito adulticide is allowed per the labels across all potential landscapes and, therefore, would have 100% overlaps with all proposed and designated critical habitat. However, we do not anticipate the maximum extent, frequency and rates of usage (i.e., wherever and as many times as the labels allow) are reasonably certain to occur. To better assess the extent and types of usage that are reasonably certain to occur within the overlapping areas over the duration of the Action, we considered additional information about use sites and past usage which refined and reduced areas of overlap and anticipated affected acreages (see *Approach to the Usage Analysis* for a more detailed discussion).

Response of Critical Habitat

Most of EPA’s critical habitat determinations were derived from weight of evidence analyses. As described previously for listed species, EPA considered direct effects to listed animals, including effects on mortality, growth, reproduction, behavior and sensory function of individuals of a species. Their analysis of indirect effects considered impacts to prey, other dietary items, habitat and obligate organisms. For their analysis of effects to critical habitats, any potential for effects to a listed species, based on the lines of evidence, were also considered for the effects determination to the critical habitat, regardless of whether the listed species is present within and/or currently inhabits the designated or proposed critical habitat. As such, stressors that are capable of reducing the viability of individuals or their populations through direct mortality or by decreasing reproductive success will at least temporarily affect the suitability of critical habitat for those species, regardless of whether the critical habitat designation specifically identifies pesticides as a threat. The persistence of malathion in the environment is limited, with a typical half-life between 0.3 to 7 days in soil (Connell, 2005), and 0.5 to 6 days in water under most natural conditions, although it can persist longer under uncommon conditions such as in waters that are highly acidic (see Chapter 3 of EPA’s BE for malathion for a more detailed discussion). While impacts to habitat suitability may be temporary after an application, habitat impairments and species exposures could continue or reoccur due to repeated applications in the same areas.

Rules designating critical habitat often provide PBFs that are specific to the species, but may be described either very specifically or generally. For example, water quality parameters may be indicated for specific chemicals or conditions, or a general underlying requirement may be described, such as that water quality must be sufficient to support the species. When identified, the details of species-specific PBFs for critical habitats can be located in the proposed and final rules. Table 42 lists general PBFs and identifies some of the typical components that may be specified in critical habitat rules for plants and animals considered in this Opinion.

Table 42. General Physical and Biological Features with examples of the types of elements that may be specified for plants and animals.

PBF	Plant	Animal
Space for individual and population growth and for normal behavior	Sufficient space and soil for root growth, recruitment and adequate numbers of individuals for viable populations	Foraging areas, breeding areas, overwintering sites, home ranges and movement corridors
Food, water, air, light, minerals, or other nutritional or physiological requirements	Sufficient precipitation or groundwater to support tissue growth, soil nutrients and minerals, adequate light to support photosynthesis, and adequate climate to support plant survival and reproduction	Sufficient prey base or forage material, sufficient quantity and quality of water, air of sufficient quality to support species survival, and climate conditions that support survival and growth of individuals and populations
Cover or shelter	Vegetative canopy, riparian habitat, forest habitat	Vegetation, canopy cover, geologic formations, cavity trees, burrows, moisture, riparian habitat, woody debris, stream geomorphological features
Sites for breeding, reproduction, or rearing (or development) of offspring	Locations that support pollinator communities, soil seed banks, sufficient habitat space and structure to support reproduction	Vegetative communities, food resources, geologic formations, cavity trees, temporary or permanent water sources, substrate, habitat structure, elevation, aspect
Habitats that are protected from disturbance or are representative of the historical, geographic, and ecological distributions of a species	Natural fire or flooding regimes, dispersal pathways, lack of human disturbance	Natural fire or flooding regimes, hydrology, migration corridors, habitat connections, natural vegetative communities, lack of human disturbance

When malathion is applied within critical habitat, we consider whether these pesticide applications would impact any of the aforementioned PBFs. These effects could be the reduction of suitable habitat due to reduced food resources or increased toxicity of land and water to such an extent that the exposed area no longer provides the PBFs that make the habitat suitable for use by the species. The label allows applications across a wide variety of habitats and geographic areas. Single applications could affect some PBFs for a limited duration, although effects to other

PBFs may take longer to recover or may have more lasting consequences. Frequent or repeated applications of malathion could negatively affect critical habitat over a longer time period by repeatedly exposing the PBFs to this chemical.

Critical Habitat Features Susceptible to Malathion Applications

Not all PBFs are susceptible to pesticides, and some PBFs may be susceptible to some types of pesticides, such as herbicides, but not others. The effects of malathion applications on critical habitat PBFs that have been determined to be important for our analysis are expected to primarily be in the form of: (1) negative effects to water quality parameters and terrestrial habitat functions; (2) impacts to arthropod prey; (3) impacts to non-arthropod prey, pollinators/seed dispersers, and host fish; and (4) impacts to insect plant pollinators/seed dispersers of plants. The relevant types of PBFs are described in more detail below.

Water Quality and Terrestrial Habitat Function

In the discussion below, we describe the full range of effects to water quality and terrestrial habitat function that we expect would be likely to occur from exposure to malathion. While malathion usage could potentially impact the water quality and habitat function PBFs of many critical habitats, as discussed below, the implementation of general and species-specific conservation measures is expected to reduce the likelihood malathion entering critical habitat and affecting water quality and terrestrial habitat function PBFs.

Malathion usage is expected to cause temporary negative effects to water quality parameters and terrestrial habitat functions that are essential PBFs of some of the proposed and designated critical habitats. For example, malathion usage in the vicinity of critical habitat may impact a water quality or terrestrial habitat function PBF by introducing contaminants into the habitat for a listed or proposed species. If that listed or proposed species is sensitive to malathion, the concentrations of malathion entering critical habitat could decrease the water quality or terrestrial habitat function to a level where the critical habitat may no longer be suitable for the species. The conservation value of the critical habitat can be decreased whether or not the habitat is currently occupied by the species. In most cases, we would expect these PBFs would return to a suitable condition for the species following the pesticide exposure. While the amount of time malathion requires to degrade is influenced by numerous environmental factors, we expect the water quality and terrestrial habitat function PBFs would typically be restored within a few weeks after a malathion application, as observed in field studies.

There could be cases where regular or repeated application of malathion may not allow enough time for the water quality or terrestrial habitat function to be restored to levels that would not be harmful for the species. For example, prior to the adoption of the label changes that are now included as part of the Action, there were no restrictions on the number of applications or the interval between each application for residential uses. In the absence of restrictions, regular or repeated use could preclude the presence, establishment, or function of a water quality- or terrestrial habitat-related PBF, thereby inhibiting the critical habitat from being suitable for occupation. In most cases, we found that the implementation of general conservation measures would change application patterns such that water quality and habitat function PBFs would be maintained, or the likelihood of frequent exposures that would impact critical habitat would be reduced enough to result in only low-level impacts and provide time for water quality and terrestrial habitat function PBFs to restore after malathion usage. For example, implementation of general conservation measures for residential uses, such as limiting uses to spot treatments only, reducing the extent of developed and open-spaced developed areas that are treatable, and changing application frequency from “as needed” to a maximum of 2 applications per year, is expected to limit impacts to and facilitate the restoration of water quality and terrestrial habitat function PBFs between applications.

However, there were cases where malathion usage, even with the implementation of the general conservation measures, would still have subjected some critical habitats to higher levels of adverse effects. In these remaining cases, species-specific conservation measures such as avoidance areas, timing restrictions, and wind and rain restrictions, were incorporated into the Action to address use patterns in or near the critical habitats in order to reduce impacts to the PBFs. With the general and species-specific conservation measures that are in place as part of the Action, we do not anticipate impacts to water quality or terrestrial habitat function will occur to an extent and magnitude that would be likely to appreciably diminish the value of critical habitat as a whole for the conservation of the species for any of the proposed or designated critical habitats in this Opinion.

Arthropods as Prey

In the discussion below, we describe the full range of effects to arthropods as prey where identified as PBFs of proposed or designated critical habitats for listed species. The implementation of general and species-specific conservation measures is expected to reduce the likelihood malathion entering critical habitat and affecting arthropod prey species, as described further below.

When and where malathion is applied, we anticipate negative effects to exposed terrestrial and aquatic arthropods that are prey items of listed animals, as arthropods are generally sensitive to the effects of this pesticide. For example, for listed species that are strictly or primarily insectivorous, a decrease in insect populations from insecticide usage may reduce food availability to such an extent that the affected critical habitat areas are impacted and may no longer support the survival, growth, or reproduction of individuals or the population in the exposed area. Thus, any arthropod prey base PBFs for the species may be adversely affected, and may affect the conservation value of the exposed critical habitat area.

Malathion is generally expected to only temporarily affect arthropod prey species. Recovery or recolonization of the area by new prey organisms would generally be expected to occur relatively quickly since malathion is only expected to remain in the environment from days to weeks (the exact time for arthropod community recovery will vary depending on the application frequency as well as the prey community and environmental conditions). Under most circumstances, we would expect prey populations to recover shortly after malathion degrades or is diluted to non-toxic concentrations in the environment, although some may take longer to return to baseline levels than others. In cases where malathion usage could have been frequent or at high application rates that prevent arthropod community recovery, we anticipate conservation measures involving changes to many of malathion's labeled uses, such as reducing the maximum allowable number of applications a year, specifying buffer distances from waterbodies, or implementing application restrictions when crops are in bloom, will substantially reduce the likelihood of exposure to arthropod prey species within critical habitat. All of these measures would effectively reduce exposures and allow arthropod prey populations to recover over a short period of time after applications, as observed by many field studies of both aquatic and terrestrial invertebrate communities.

While a temporary loss or decline in suitable prey could still have long-term impacts on the conservation value of the critical habitat for the species if alternate food resources are not available as needed, species- and critical habitat-specific measures, such as avoidance areas, wind direction restrictions, and timing restrictions, have been developed where needed to further reduce exposure where high impacts would otherwise be anticipated. Thus, with consideration of both general and species-specific conservation measures, we do not anticipate impacts to the arthropod prey base PBF will occur to such an extent and magnitude that would be likely to appreciably diminish the value of critical habitat as a whole for the conservation of listed species for any of the proposed or designated critical habitats in this Opinion.

Non-arthropods as Prey, Pollinators/Seed Dispersers and Host Fish

In the discussion below, we describe the full range of effects to non-arthropod prey species, pollinators/seed dispersers, and host fish for listed species. The implementation of general and species-specific conservation measures is expected to reduce the consequences of malathion entering critical habitat and affecting arthropod species that serve as elements of the critical habitat PBFs.

Applications of malathion are anticipated to result in impacts to non-arthropod species that are prey, pollinators/seed dispersers, or host fish for listed species. For example, for critical habitat of listed species that are strictly or primarily carnivorous, a decrease in prey population abundance from malathion applications could reduce food availability, resulting in adverse effects to the role of the PBF in providing conservation value for the species. In some cases, reductions may occur to such an extent that the habitat no longer supports the survival, growth, or reproduction of listed individuals or the population in exposed areas. Similarly, listed species that have obligate relationships with non-arthropod animals may experience reduced reproduction and recruitment due to direct effects to their necessary pollinators/seed dispersers or host animals. The Service does not generally expect non-arthropod populations to be impacted to the same extent as arthropod populations due to differences in the susceptibility of these taxa to malathion. However, some non-arthropod taxa are known to be sensitive to malathion (such as fish hosts for freshwater mussels or birds that serve as pollinators). We analyzed MagTool toxicity outputs for the associated types of non-arthropod species to determine likely effects to the related PBFs considering differences in taxa group sensitivity. For non-anthropod taxa that are known to be sensitive to malathion, we anticipate higher adverse effects to critical habitat would occur in areas with with malathion usage than taxa that are less sensitive, especially in the absence of effective measures to avoid, reduce, or minimize exposure and effects to the PBFs.

In the absence of the conservation measures incorporated into the Action, malathion effects would likely result in: 1) a decreased ability of the PBF to support growth, reproduction, or survival due to a lack of nutritional energy or requirements, through increased toxicity of food items to such an extent that the exposed area is no longer suitable for feeding by the species; 2) reduced capacity for pollination or seed dispersal; or 3) a loss or reduction in host fish availability for mussel glochidia distribution and metamorphosis. However, in most cases where malathion usage would have a high impact on essential non-arthropod species, we anticipate conservation measures involving changes to many of malathion's labeled uses, such as reducing the maximum allowable number of applications a year or specifying buffer distances from waterbodies, will substantially reduce the likelihood of exposure to and effects on essential non-arthropod species within critical habitat.

For those critical habitats where a temporary loss or decline in essential non-arthropod species could still have had long-term impacts on conservation value of the critical habitat for the listed species, species- and critical habitat-specific measures, such as extended buffer areas, restrictions on certain crop types, and reductions to the number of allowable applications for a variety of crops, were incorporated into the Action to further reduce impacts to sensitive non-arthropods and protect the PBF. While a temporary loss or decline in suitable prey, pollinators/seed dispersers, or host fish could leave long-term impacts on the species if alternate resources are not available, the general and species-specific conservation measures are anticipated to be sufficiently protective to minimize effects. We do not anticipate impacts to the non-arthropod PBF will occur to such an extent and magnitude that would be likely to appreciably diminish the value of critical habitat as a whole for the conservation of listed species for any of the proposed or designated critical habitats addressed in this Opinion.

Insect Pollinators or Seed dispersers

In the discussion below, we describe the full range of effects to insect pollinators or seed dispersers that have been identified as PBFs for some critical habitats. The implementation of general and species-specific conservation measures is expected to reduce the likelihood of malathion entering critical habitat and affecting these species and their functional roles as PBFs of the critical habitats.

Many listed plant species rely on insect pollinators and/or seed dispersers, and pollinators or seed dispersers are frequently included in plant critical habitat PBFs. Additionally, pollinators may be identified as a factor in sustaining specific plant species that are PBFs of some animal critical habitats, such as host plant species for listed insects. We reviewed critical habitat rules for explicit connections to pollinators and seed dispersers as elements of the PBFs. Applications of malathion are expected to adversely affect insect pollinator-related PBFs similarly to arthropods as prey species, in some cases, reducing the ability of listed or key plant species to survive, reproduce, and expand their range in the critical habitat (see *General Effects - Plants*). Plant species that rely on insects for pollination or seed dispersal are more susceptible to pesticide application than those that have other modes of pollination such as wind or water (Refer to *Plant Integration and Synthesis Assessment Group Summaries* in *Appendix K* for species-specific pollination methods), and we anticipate similar considerations are important for evaluating effects to PBFs for these species' critical habitats. However, as demonstrated by field studies, malathion application is not expected to have community-level effects on pollinators/seed dispersers such that the conservation value of critical habitat as a whole would be impacted. In addition, there are many species that are able to rely on multiple species of pollinators and seed dispersers, which make them more resilient to malathion exposure than those that may be reliant on a single or few species.

Since malathion is expected to remain on the landscape for a short period of time after an application, effects to insect pollinator communities are expected to occur during and immediately after the application and may extend for a period of time (generally a few weeks) after pesticide application. Under most circumstances, we would expect previously healthy insect communities to recover after malathion degrades or is diluted to non-toxic concentrations in the environment, typically within a few weeks of time, as demonstrated in field studies. Repeated and long-term applications of malathion within critical habitat, regardless of occupancy, could extend the period during which the PBF would be impacted (i.e., habitat would not be capable of supporting ESA-listed species). However, general conservation measures that have been incorporated into the Action, such as reductions in the maximum allowable number of applications per year for a variety of crops and restrictions on applications during periods when crops are blooming, are expected to reduce the risk of exposure to the pollinator and seed disperser communities, reducing the risk of negative impacts to this category of PBFs.

Critical habitats for listed plants and animals (e.g., those that rely on host plants) that rely on the pollinator and/or seed disperser PBF to provide conservation value for the species can be adversely affected due to the loss of pollinators, especially where pesticide applications occur over large portions of the critical habitat, when usage is particularly high, or if general conservation measures otherwise do not address effects to pollinators/seed dispersers from the specific malathion uses that occur in the area. In limited cases, general conservation measures would not have been sufficiently protective, and species-specific measures were incorporated into the action to change application patterns (e.g., avoidance areas, timing restrictions, wind and rain restrictions) to decrease the environmental concentrations of malathion entering critical habitat. With the general and species-specific conservation measures in place, we do not anticipate impacts to the arthropod PBF will occur to such an extent and magnitude that would be likely to appreciably diminish the value of critical habitat as a whole for the conservation of listed species for any of the proposed or designated critical habitats addressed in this Opinion.

Summary of Assumptions for Effects to Critical Habitat Features

We reviewed each critical habitat rule to determine if water quality, habitat function (associated with pollutant levels), arthropods as prey, non-arthropods (as prey, pollinators/seed dispersers or host fish), and/or insect pollinators/seed dispersers are explicitly identified or could be clearly and simply linked to proposed and designated critical habitat PBFs. In some cases, these factors are identified in descriptions of the “Special Management Considerations and Protection” required for the PBFs, activities that may result in the destruction or adverse modification of critical habitat as described in the “Effects of Critical Habitat Designation,” or are discussed in relation to the application of the “Adverse Modification Standard" described in the rules. If specific PBFs sensitive to pesticides are not identified in the critical habitat rule, or if explicitly listed PBFs or related factors associated with the critical habitat designation have no clear and direct link to water quality parameters, habitat function associated with pollutant levels, impacts to non-arthropods, prey populations, host fish or plant pollinators/seed dispersers, we considered the likelihood of adverse effects from malathion exposure to be low, and, therefore, unlikely to result in effects to the critical habitat.

As a general convention, those critical habitats that have one or more of the PBFs identified above and that overlap with malathion use sites where usage is anticipated are expected to be negatively affected. In cases where critical habitat overlaps with use sites, but no PBFs or factors related to the critical habitat designation have been specified that are particularly susceptible to malathon usage as described above, we do not expect negative effects to critical habitat because malathion would not affect elements of the critical habitat identified as being essential for the conservation of the species. For critical habitats that have no overlap with pesticide use sites, regardless of the PBFs identified, we generally do not anticipate pesticide use would result in adverse effects that are likely to rise to the level of destruction or adverse modification. Additional qualitative review was conducted to confirm whether critical habitats with no overlap with use sites were at low risk for exposure. For critical habitats that overlap with pesticide use sites (or were qualitatively determined to be at risk of being exposed to malathion) and have PBFs specified that are susceptible to pesticide usage, the vulnerability of the PBF, as well as expected usage levels and numerous other factors, were evaluated to assess the consequences of adverse effects on the critical habitat. General conservation measures were evaluated to assess whether they would sufficiently reduce the risk of diminishing the value of the critical habitat as a whole for the conservation of the listed species, as needed. In cases where general conservation measures would not likely be sufficient, species- or critical habitat-specific measures were incorporated into the action to protect critical habitat and avoid destruction or adverse modification.

Description of Critical Habitat Analysis

For our analyses, we reviewed critical habitat rules to determine if there were any specific PBFs or general habitat characteristics constituting PBFs that may be affected by malathion, as described above. We then grouped the critical habitats into three categories: (1) those with generalized, non-specific PBFs (Category 1); (2) those with specific PBFs, but none that would be affected by malathion (Category 2); and (3) those with PBFs that would be affected by malathion (Category 3).

For critical habitats in Category 1, if we were unable to identify any habitat elements as PBFs that would be affected by malathion, we did not undertake further analysis as we do not anticipate any effects from malathion to the PBFs. Similarly, we did not undertake any further analysis of critical habitat in Category 2, as none of the PBFs would be affected by malathion. For critical habitats in Category 3, as well as a subset of those in Category 1 for which we were able to identify habitat elements constituting PBFs that could be affected by malathion, we conducted additional analyses to determine the effects of the action.

Using a dichotomous key (see Appendix L-C) to facilitate our assessment of effects, we considered numerous factors to determine preliminary levels of concern, including use overlap, individual PBF sensitivity to malathion, usage data, and other ecologically relevant information for each species. We started by determining whether critical habitats overlap with malathion use sites[48]. While use site locations may change over the project duration, and thus future overlapping areas may change, we understand the most recent available land use data is a reasonable indicator of land uses over the next few years or decades (see *Overall Considerations for the Opinion*). Given that use overlap is a conservative metric for potential exposure (as we do not expect malathion to be used everywhere it is authorized, or at the maximum rates or application frequencies allowed), we determined that critical habitats with no overlap were not likely to be at risk of destruction or adverse modification. However, critical habitats with no overlaps were checked and qualitatively assessed when there was concern regarding adjacent malathion use areas or when no overlap was found to be inaccurate given gaps in use data (such as for island species).

For critical habitats that overlap with malathion use sites, we determined which critical habitats primarily occur on Federal lands (i.e., >95%). These critical habitats were assigned a low concern ranking as we anticipate only low usage on Federal land over the duration of the Action. Additionally, applications on Federal lands generally employ avoidance and minimization measures for listed species and critical habitats that may be affected (see the *Effects of the Action* section of the Opinion). Further, we individually assessed information in each critical habitat rule to determine if it would be likely for the small portion of critical habitat on non-Federal lands to contain habitat features that would make these areas disproportionately more vital for the conservation and recovery of the species than areas on Federal lands. The purpose was to assess whether unmitigated usage on the non-Federal portion could affect the value of the critical habitat as a whole for the conservation of the associated species. We did not find evidence of this and confirmed that critical habitats that were primarily located on Federal lands warranted only low concern.

Remaining critical habitats that had overlap with malathion use sites and did not primarily occur on Federal lands were then further analyzed for anticipated effects to each PBF that would be susceptible to the effects of malathion. PBFs were broken down into individual features related to the specific habitat requirements for the listed species. These features were reviewed to assess whether they had a high or low vulnerability to the effects of malathion exposure (e.g., based on anticipated environmental concentrations of malathion in aquatic habitats considering flow rates or water volume, or sensitivity of species needed for the PBF based on taxa group). PBFs that consisted of only low vulnerability features were given a low concern ranking. PBFs consisting of at least one vulnerable feature were given a high concern ranking. All critical habitats were further analyzed with usage data. A preliminary low concern ranking was assigned to vulnerable PBFs if usage was 5% or less and a preliminary high concern ranking was assigned when usage was greater than 5%. Any critical habitat that had at least one PBF assigned a high concern

[48] Critical habitat overlap information provided by EPA in the BE was used, as available. Some critical habitats included in the Opinion had not been proposed or designated at the time the BE was produced. For those critical habitats that were not included in the BE, an overlap analysis was not available, and species range use overlap was used as an approximation for our analyses, as described below. Critical habitats are generally contained within species ranges, with few exceptions. Thus, we expect malathion uses in species ranges would be similar to those found in critical habitats.

ranking was presumed to be at higher risk of destruction or adverse modification than those with only low concern PBFs.

After we completed the initial assessment using the dichotomous key, as described above, all critical habitats were further assessed to confirm if the concern level was assigned appropriately. For critical habitats that had overlap with use sites and were not primarily on Federal lands, we considered additional species-specific information, such as prey and habitat preferences, whether the species had obligate or generalist relationships with host fish or pollinators, the timing of important life history events, and other relevant information that might modify the vulnerability of the PBFs or consequences of anticipated effects. We conducted additional review of specific cases where usage data was near the high/low concern cutoff to confirm if concern was appropriately assigned. We changed the concern level to increase or decrease concern as appropriate considering this additional information and review (e.g., increased concern for critical habitats reliant on groundwater features originating from areas outside of critical habitat).

To make the final determinations for critical habitats that overlap with malathion use sites and are not primarily located on Federal lands, we evaluated applicable general conservation measures that have been incorporated into the Action and the degree to which the measures would sufficiently reduce the risk of effects to the PBFs and avoid destruction or adverse modification. In most cases where the concern was low, we expect that the general conservation measures would reduce the environmental concentrations of malathion to a level that would only result in minimal effects to the PBFs, even in cases where there might be especially vital or vulnerable areas of critical habitat that overlap with malathion use sites. In some cases where the concern was high and general conservation measures did not sufficiently reduce the risk of effects to the PBFs, we developed species-specific measures to address the additional need for protection, which were incorporated into the Action.

Our effects analysis considered the overlap of malathion use sites with critical habitats, anticipated usage, overlap with Federal land, and the level of risk to the critical habitat based on anticipated effects to the PBFs that could be affected by malathion (or general habitat elements constituting PBFs that could be affected by malathion). Critical habitat use site overlap information provided by EPA in the BE was used, as available. Where use site overlaps with critical habitat were not available in the BE (such as for critical habitats that were proposed or designated after the BE was finalized), overlaps with species ranges were used as an approximation, although we also reviewed critical habitat areas outside of the species range, as described below. Critical habitat overlaps with mosquito adulticide use sites and Federal lands were not included in the overlap data provided by EPA and were calculated separately.

Anticipated usage overlap for critical habitats was not available due to difficulties with conducting spatial overlap analyses with incompatible shape files for critical habitat. The boundaries of many proposed and designated critical habitats consisted of complex geometries that resulted in erroneous overlap calculations. These errors tended to overinflate the overlap measurements and the calculations were deemed unsuitable for use in our analysis. The removal of Federal lands from critical habitat geospatial data further exacerbated this issue. Thus, our decision was to use the species range usage information for calculating anticipated usage in the critical habitat analysis. Uses that did not overlap with critical habitat were not included in the critical habitat analysis, even if there was overlap with those use sites in the species' range. Since usage data occurs at relatively coarse resolutions, with mosquito adulticide usage data given at the county-level and non-mosquito adulticide usage data given at the state level, species range usage would be expected to be similar to critical habitat usage given that we would not expect usage overlap values to change over a broad spatial scale. Since critical habitats are typically proposed or designated within (or outside but near, in some instances) the species' range, we expect that usage information from the species range is generally an appropriate approximation for usage information on critical habitat, and for use overlaps for critical habitats where this information was not available in the BE. In cases where areas of critical habitat are designated in areas outside of the range or in areas where we expect different levels of usage (e.g., critical habitat located in different counties or states outside of the species' range), we conducted qualitative examinations of these areas to determine if usage in these parts of the critical habitat are of concern; where relevant, we documented these findings in our analysis. Usage data from the species' range was not a determinative factor in our effects analyses for critical habitat. Rather, it was considered alongside numerous other factors, including species-specific information that influence the vulnerability and risk of critical habitats.

As described above and in our analysis of effects to listed species, we found that use of malathion on Federal lands has been relatively limited in the past. It has likely resulted only in low levels of adverse effects to critical habitat PBFs where critical habitat overlaps with Federal lands. We anticipate that limited usage on Federal lands is likely to continue in the future. Thus, Federal lands were not included in our overlap analysis results prior to applying usage information to refine our estimates of exposure and effects, and we considered use and usage on Federal lands qualitatively. See the *Federal Lands* section under *Approach to the Usage Analysis* in this Opinion for further details and our qualitative assumptions related to the limited use on Federal lands.

Our specific conclusions and rationales for each proposed and designated critical habitat are included in Appendix L-A for animal critical habitats and in Appendix L-B for plant critical habitats, and are discussed generally in the *Integration and Synthesis* section below.

Cumulative Effects

Cumulative effects are defined in ESA section 7 implementing regulations as "those effects of future State or private activities, not involving Federal activities, which are reasonably certain to occur within the action area of the Federal action subject to consultation." (50 CFR 402.02). Cumulative effects are considered broadly in this Opinion, due to the national scope of the action. More refined species-specific information on cumulative effects are also found in the species accounts of the Integration and Synthesis summaries in Appendix K of this Opinion. Future Federal actions that are unrelated to the Action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Declines in the abundance or range of many threatened, endangered, and other special status species are attributable to various human activities on state or private lands. We anticipate human population expansion and associated infrastructure, commercial, and private development will occur in the action area via various State private actions. Such activities will likely include, but are not limited to:

- water use and withdrawals (e.g., water retention, diversion, or dewatering of springs, wetlands, natural and artificial impoundments, and streams);

- land and water development including excavation, dredging, construction of roads, housing, and commercial and industrial activities;

- mining and mineral extraction activities;

- recreational activities;

    - expansion, or changes in land use for agricultural or grazing activities, and other land uses including alteration or clearing of native habitats for domestic animals or crops; and

    - inadvertent introductions of non-native plant, wildlife, or fish or other aquatic species, which can alter native habitats or out-compete or prey upon native species.

All manner of development and competing use projects and activities (as above) are likely to continue in many areas, resulting in clearing, addition of impervious surfaces, and introductions of non-native species. Similarly, the incremental effects of climate change from such activities are anticipated to continue and intensify over the course of the Action. Some examples of such effects include, but are not limited to, more extensive and severe droughts that reduce the extent or quality of aquatic habitats, more extensive and severe wildfires that impact habitat more intensely, alterations of local temperature regimes that alter vegetation and water availability and composition. These activities are expected to result in various impacts to water quality (degradation, as with increased pollutants), habitat quality (loss or degradation), and other negative effects to listed species and their critical habitats. In some cases, increased pesticide use, including those in addition to malathion, may occur to address new or emerging pest pressure (e.g., mosquitoes and other pests) in agricultural and nonagricultural settings. We anticipate some use of pesticides, including those in addition to malathion, may be used to directly or indirectly benefit listed species or their critical habitat. For example, future pesticide use is anticipated to be used to eliminate or reduce competing or predatory species within a species' habitat. While we are not aware of any such proposed projects at this time that would use malathion to specifically benefit listed species, we do anticipate that malathion or other pesticides will be used in the action area for this purpose over the life of the Action. Where implemented with appropriate avoidance and minimization measures to reduce the potential for lethal, sub-lethal, and indirect effects to listed species and their critical habitats, such projects could improve habitat conditions, thereby benefitting the species. However, in the absence of specific information for such activities, or for sufficient avoidance and minimization measures for other pesticides, we anticipate listed species will continue to be impacted as described previously in the *Environmental Baseline* section of this Opinion.

We also anticipate that conservation actions, such as habitat enhancement and restoration activities, will be undertaken in accordance with regional plans, recovery plans, and other planned or ongoing efforts. Where implementation is undertaken and successful, these activities are likely to benefit certain listed species and their habitats, food base, hosts, pollinators and other related species to varying degrees.

Given the broad geographic extent of the action area, many of the activities mentioned in the paragraphs above are expected within the ranges of various Federally listed wildlife, fish, and plant species, and could contribute to cumulative adverse, and in some cases beneficial, consequences to the species within the action area. We anticipate that species with small population sizes, high degrees of endemism or limited distributions, or slow reproductive rates will generally be more susceptible to cumulative effects than species with greater resilience and redundancy to stochastic events (i.e., via multiple stable or increasing populations). For example, narrow endemics confined to specific habitat locations may experience habitat degradation that in turn results in reductions in individuals or even localized extirpations. Where such a species is unable to recolonize or repopulate the habitat, species-level declines would be expected. Species with single or small numbers of populations may struggle to maintain sufficient numbers of individuals to persist where cumulative effects result in loss of individuals or habitat degradation. Designated and proposed critical habitats with essential physical and biological features that are affected by these activities may also experience varying levels of degradation or improvement from these activities.

INTEGRATION AND SYNTHESIS

In this section of the Opinion, we consider whether the Action is likely to jeopardize any of the proposed, candidate, or listed species considered in this consultation. We also consider whether the Action is likely to destroy or adversely modify critical habitat as a whole for the conservation of a listed or proposed species. This *Integration and Synthesis* section considers the effects of the Action in the context of the status of the species and critical habitats (as appropriate), the environmental baseline and cumulative effects. The first section below is a review of the overall considerations for the Opinion. The next section provides a brief summary overview of the *Environmental Baseline*, *Status of the Species and Critical Habitat*, *Cumulative Effects* (together "Background Information") and *Effects of the Action*. The final sections provide an overview of our approach to the integration and synthesis along with determinations and rationales for our Opinion for each plant and animal species and critical habitat, presented by taxa group and habitat group and further discussed in Appendix K (for each species) and Appendix L (for each critical habitat designation), as applicable.

Overall Considerations for the Opinion

The Action is the registration of malathion, which authorizes all the uses of the pesticide per the products labels. The authorized uses of malathion are relatively broad and include both agricultural and non-agricultural uses. As the Action is the approval of labels containing the active ingredient malathion, once approved, these labels become the law. The proposed registration of the pesticide authorizes use of the pesticide on any of the crops or land categories described previously, with labels specifying one or more uses and associated restrictions and guidance for that use. Labels with guidance generally use terminology that can be considered subjective and do not serve as enforceable restrictions. Some labels also include recommendations for tank mixtures. Tank mix recommendations may specify other ingredients that can be added to increase efficacy, such as surfactants, emulsifiers, oil, or salts, or may include another product with a different active ingredient. Species (as well as other species and habitats on which they depend) and their critical habitats exposed to pesticide mixtures may be at greater risk of adverse effects than when exposed to single pesticides, as described in the *Effects of the Action* section of this Opinion.

Early in the consultation period, the Agencies observed there are often general trends and patterns related to agriculture, forestry, and other land uses throughout the action area. We understand the most recent available land use data is a reasonably good indicator of present land use or land uses over the next few years or decades. While this information may suggest where pesticides such as malathion may be applied in the future, we also recognize that land uses and pesticide usage may change over time due to a variety of often unforeseeable factors, such as future market forces, pest pressures, individual grower preferences and decisions, development and other land use changes, as well as changes in environmental conditions such as drought, floods, and maximum/minimum seasonal temperatures (e.g., unanticipated heat waves or freeze/frost events). We have incorporated these considerations by using a refined overlap analyses that considers use sites (by land use type) with labeled uses specific to malathion, and by calculating estimates of anticipated malathion usage, as described previously in the *Effects of the Action* section of this Opinion. We find most pesticide usage datasets are collected for very different purposes than addressing the limits of overlap of malathion usage and listed species and their critical habitats in the action area. However, we were able to use this information, with its inherent uncertainties and our assumptions, in order to better identify malathion use sites and gage anticipated usage that is reasonably certain to occur for all use categories throughout the action area over the 15-year duration of the proposed registration of malathion. We anticipate this information is also likely to have some value in determining appropriate avoidance and minimization measures in localized areas where adverse effects to listed species would be anticipated.

We recognize that growers will ultimately choose when and where crops and other commodities will be grown, and that growers, various local jurisdictions, and other property owners will likely determine where pesticide applications are needed. The broad label language, as currently written, is thus likely considered an asset for stakeholders to allow for greatest flexibility of use. However, we do not anticipate that malathion will be used in all the areas it is authorized to be applied under the label over the duration of the Action. As we must also consider what effects are reasonably certain to occur, we considered the best available scientific and commercial data available for usage data to better predict the consequences from the Action.

For some uses, overlap of pesticide use sites with species ranges is extremely low (i.e., <1%). When considered in context, however, we emphasize that even where the overlap is extremely low, the very small degree of overlap may nonetheless lead to effects to the species, and if usage occurs in an area that is an important site for the species it may even have a disproportionate effect on the species. For example, certain areas may support important foraging, migrating, overwintering, or breeding habitat for a species. Where such habitat may be limited or of lower quality elsewhere within the range, pesticide applications in this area where the species is congregating or is otherwise dependent on the area could lead to species-level effects. Alternatively, the area of overlap may be an area that is rarely used by the species in its range, either at all or during the time in which applications would occur. Thus, where overlap with species ranges and critical habitat appeared extremely low, we would still consider the value of that area to the species or critical habitat using geospatial data and species information. It was only when we had information that indicated there was no true overlap that these areas were not considered further in our analyses, based on a closer look at the geospatial data and species information. However, for many species, our analysis included an assessment of small areas of overlap with malathion use when we could not refine and/or exclude these areas based on additional information. These small overlaps were still part of the analysis because no additional information was available to exclude them and exposure in these areas are still a concern for a species. Such an approach is appropriate when even extremely low levels of overlap may still be of concern for species.

Summary of Status of the Species and Critical Habitat, Environmental Baseline, Cumulative Effects, and Effects of the Action

In the *Status of the Species* and *Critical Habitat, Environmental Baseline,* and *Cumulative Effects* sections of the Opinion, we established the effects of past and ongoing activities in the overall action area would maintain the existing degraded habitat conditions that are prevalent, although restoration activities and other conservation efforts may address some of the habitat conditions for some of the species, at least in part. We considered the status of the species and critical habitat through species-specific accounts (i.e., detailed in Appendix C). The *Environmental Baseline* and *Cumulative Effects* sections in the body of this Opinion were broadly summarized and provided a generalized overview of the effects of previous and ongoing actions in the larger action area for the Action. Brief species-specific environmental baseline and cumulative effects considerations are included for species and habitat groups in their respective integration and syntheses summaries for each taxa group (Appendix K) and to varying degrees in the *Status of the Species* and *Critical Habitat* (Appendix C).

Numerous activities across the landscape have impacted the habitats and ecological communities on which listed species depend. A variety of land uses associated with human activities, such as agriculture and grazing, residential and commercial development, and forestry, have altered habitat over the long-term. Changes in land use such as development, land clearing, diking, and other activities have affected terrestrial and aquatic habitats. Water diversions and storage, replacement of pervious soils and surface with impervious materials, impacts to riparian buffers, loss of wetlands, stream channelization, and other activities have affected the water quality and quantity for many aquatic habitats. Discharges and runoff from many land uses also result in the degradation of water quality due to contaminants, such as excess nutrients, fertilizers, pesticides, and other chemicals. Several pesticides have been detected in various waterbodies throughout the country. In many habitats, pesticides and other pollutants are present in the environment at detectable levels, although these levels cannot generally be tied to specific application events or all of the sources that may be contributing to accumulative concentrations. As noted in the *Effects of the Action* section, we have high confidence from past monitoring efforts that applicators are likely to apply tank mixtures throughout the action area, whether these include multiple active ingredients, surfactants, or other substances intended to increase efficacy. Additionally, monitoring data from state and Federal agencies described in the BE and other sources have indicated that multiple pesticides often co-occur in aquatic habitats located throughout the action area.

It is reasonable to assume that as some ecological communities are affected by extreme stresses or changing conditions over the short- or long-term future, pest pressures may increase. As discussed earlier with forests, activities such as timber harvest, grazing, fire suppression, road construction, and management practices, together with other influences (e.g., introduction of invasive species, climatic conditions) have resulted in increases in disease and pests. Although pests and disease have always been present in habitats, an increase in both native species viewed as pests, as well as introduced non-native pest species, may be of increasing concern in the future. Some pest species may impact various agricultural and non-agricultural actions related to the use categories, resulting in the use of various pesticides in the future that are not considered part of the Action. We also recognize pesticides may, in some cases, also be used to benefit listed species or their critical habitats by reducing or eliminating competing, predatory or otherwise harmful species as part of a suite of activities to enhance or restore species habitats and support survival and recovery of the species.

Stressors that have influenced the environmental baseline and/or continue into the future as cumulative effects may often combine to result in an increased threat to sensitive species, where a single threat may have been less of a concern to a given species, its food base, habitat or other species (such as pollinators or hosts) on which it relies. The introduction of invasive species, together with other stressors, such as habitat impacts, pollution, harvest, and many other threats, is a major factor associated with species endangerment and loss of biodiversity across the action area. Combined with more frequent extreme weather events and other stressors on the landscape, including but not limited to increased frequency of drought or precipitation events, damaging storms, more or less frequent fire regimes, these stressors often exacerbate conditions that threaten a species' ability to persist. In coastal areas, sea level rise and ocean acidification are also expected to impact persistence of sensitive species that live in littoral, estuarine, or marine habitats.

In summary, we expect that numerous activities and resultant effects have occurred over the years and will continue into the future, and in many cases, will further degrade habitat conditions. We anticipate that, in some areas, restoration and recovery actions have and will continue to be undertaken to benefit listed resources to reduce impacts from these activities but are not necessarily anticipated to completely mitigate these impacts.

Recovery Considerations

We also generally considered threats and factors associated with the needs of listed species in order to support their potential for recovery in addition to their continued survival in our analysis. Recovery is achieved when the status of a listed species is improved to the point at which protection of the ESA is no longer needed based on the criteria in section 4(a)(1) of the ESA. When determining whether an Action will likely result in jeopardy of a species or adverse modification of critical habitat, we evaluate whether the species will persist into the future and if it will have sufficient resilience to allow for the potential recovery from endangerment, in accordance with section 7(a)(2).

We reviewed the available recovery plans, 5-year status reviews, and other Service information for each species to gather information about the status of the species, habitats areas and environmental elements essential for species' survival and recovery, as well as threats to the species and actions needed for recovery. The recovery goals, objectives, and reclassification and delisting criteria identified in recovery plans were reviewed to help us understand and assess threats to each species in order to understand the effects of the Action on the recovery potential for the species. Reclassification and delisting actions result from successful recovery efforts. Achieving recovery so that species can be delisted is the ultimate goal of the ESA. Information related to the species' recovery is included in the Status of the Species and Critical Habitat (Appendix C).

Summary of the Effects of the Action

Malathion is an organophosphate insecticide used to kill insects systemically and on contact. Organophosphate toxicity is based on the inhibition of the enzyme AChE, which cleaves the neurotransmitter acetylcholine. Inhibition of AChE interferes with proper neurotransmission in cholinergic synapses and neuromuscular junctions. This can lead to sublethal effects (e.g., increased respiration, lethargy) and mortality.

The persistence of malathion in the environment is limited, with a typical half-life between 0.3 to 7 days in soil, and 0.5 to 6 days in water under most natural conditions, although it can persist longer under uncommon conditions such as in waters that are highly acidic. Malathion is considered moderately mobile. Malathion has been detected in air and rainwater indicating that volatilization can occur.

We anticipate the most significant effects to many of the candidate, proposed and listed species from the Action are likely to result from direct contact or ingestion, such as consumption of contaminated prey or food resources and direct contact with the chemical. The Action will also result in other types of effects to many species as well, such as via their prey or hosts. Pesticides are inherently toxic and applied at levels to kill or affect growth of target organisms. The pesticide is designed to result in toxic effects to target organisms, but its mode of action is not species-specific; if a non-target species that is also sensitive to the effects of the chemical is exposed, it is also reasonable to assume it would experience the same mortality. For some species, we anticipate that exposure at even the lowest considered application rates would result in death of the individual or adverse sublethal effects or effects to prey, pollinators, or other resources on which the species depends. This exposure could occur if an individual is present at an application site or exposed via drift in adjacent or nearby habitats.

For our analyses, we used different approaches for plants, terrestrial vertebrates, terrestrial invertebrates, and aquatic animals based on the suitability two different tools, the MagTool and the R-Plot Tool. As described in the *Effects of the Action* section, we evaluated terrestrial vertebrates using the MagTool and terrestrial invertebrates, plants, and aquatic animals, using R-Plots. Both of these tools compare EECs with toxicity endpoints for individual species. We have concluded that both of these tools allow us to predict effects to species in a comparable manner, and they are appropriate for the given taxonomic groups selected. Where effects were predicted to listed, proposed, or candidate species or the critical habitats from these analyses, we considered how conservation measures are anticipated to reduce exposure to malathion, and subsequently, predicted effects.

Overview of Integration and Synthesis Analyses

We considered the consequences to candidate, proposed and listed species from the Action in the context of the species background information (i.e., *Status of the Species* and *Critical Habitat*, where applicable, *Environmental Baseline*, and *Cumulative Effects*). Plant species were grouped by life history categories, while animal species were evaluated individually or by sub-groups. While we recognize the species in this Opinion have variable life histories, distributions, recovery needs, and responses to the Action, as we reviewed the background information about the species and the anticipated consequences of the Action, we observed patterns in both species considerations and pesticide exposure that helped us sub-group terrestrial and aquatic animal species for the initial stages of our analysis. Additionally, where relevant taxonomic groupings exist (e.g., terrestrial vs. aquatic snails, families of mussels, sea turtles or marine mammals), or habitat groups (e.g., cave systems), we considered them simultaneously in the integration and synthesis analysis to ensure better consistency across species. The information described above for each species, or group of species (e.g., in the case of plants), was briefly considered to determine how and to what extent the consequences of the Action would affect the listed resources, per the language of the labels and consideration of anticipated usage within the species range. We found that taxa, habitat, or other assessment groupings were helpful in both organization and in conducting or describing parts of our analyses and associated rationales for our conclusions. However, we also included information specific to each species or critical habitat in our analysis. Thus, while species are frequently presented and discussed as part of groups, this Opinion provides conclusions for each species and critical habitat.

The rationale for our conference opinion[49] for proposed and candidate species and proposed critical habitat designations are included in this section and its appendices. Due to the complexity of the jeopardy analysis needed for most species, proposed and candidate species were evaluated in the same manner as listed species. Similarly, proposed critical habitat designations were considered in the same manner as designated critical habitat. We integrate and summarize our analysis and conference opinion together with listed species in the following subsections.

Some listed, proposed and candidate species and designated and proposed critical habitats have EPA determinations listed as “Not in BE” or “NA” in the tables in the *Integration and Synthesis* sections below, but include Service conclusions. These species and critical habitats are included in this Opinion due to their status and occurrence in the action area at the time this Opinion was under development. Additionally, since the time the BE was submitted, there have been a number of species status changes, including reclassifications and delistings for listed species, and listing decisions for proposed and candidate species. As described previously in the *Concurrence* section, we removed listed species that were in the BE from this consultation that have been delisted, along with proposed or candidate species for which listing was determined to be not warranted, and updated the status for other species, where appropriate. We also added recently proposed, listed and candidate species and proposed and designated critical habitats that were not addressed in the BE.

Analysis for Animal Species

For the majority of the animal species considered in this Opinion, we organized our analysis and associated conclusions according to broad taxa groupings (listed alphabetically): amphibians, arachnids, birds, bivalves (i.e., mussels, clams), crustaceans, fishes, insects, mammals, reptiles and snails. We sub-grouped species in some taxa groups for analysis based on the commonalities of anticipated effects (e.g., sea turtles within the *Reptiles* section, and marine mammals within the *Mammals* section) or by the risk assessment tool used (i.e., R-Plots for aquatic species, plants, and terrestrial invertebrates, and the MagTool for terrestrial vertebrate species). Additionally, while we considered most species according to their taxa group throughout the action area, we found it necessary to consider two geographic areas separately due to differences in the available information for those areas, with species within these areas addressed in separate subsections: (1) the Caribbean territories and (2) Hawaii and the Pacific Islands. The analyses for these species, as well as the larger taxa groupings mentioned above, are described below. As we

[49] All species and critical habitat included as proposed or candidate in EPA’s BE are included in this Opinion or in the *Concurrence* section preceding the Opinion in this document, except species under review (e.g., candidate species) that were ultimately not listed, species that were delisted, and proposed critical habitats that were not designated (see Table 3 in Appendix B). For species that have been listed or critical habitat that has been designated since the final BE was submitted, the listing status has been updated in this Opinion.

considered the life histories, status, background information and effects analysis for the different taxa and geographic groups, we began to see various patterns in preliminary analysis of exposure, effect, magnitude of response based on the outputs from the MagTool or the R-Plot analyses (as applicable), and species information.

Due to the nature of the Action itself, the exact timing, location, and extent of usage is not precisely known. Nonetheless, we undertook the jeopardy analysis using the best information available, while applying reasonable assumptions based upon our professional judgment. Our approach to the jeopardy analysis first considers the following three factors:

(1) Vulnerability: species were ranked according to their status, environmental baseline and cumulative effects;

(2) Risk: the level of risk to the species from the Action was ranked based on the integration of exposure and effects across its range, per the MagTool and R-Plots analyses (definition in *Probabilistic Exposure Modeling and Exposure Estimates* section);

(3) Usage: the amount of anticipated usage within the species range was ranked, based on the degree of overlap of the species range (refined where feasible) with the most likely use sites (based on use category and sites) and associated usage data.

An Integration and Synthesis Worksheet (see Appendix J) was developed with ranking indicators used to categorize these factors as high, medium and low, as shown in our Integration and Synthesis summaries. Overall rankings for each factor were used as a starting point for determining the consequences of the Action to the species addressed in this Opinion. Each of these factors is described further below.

Vulnerability Factors and Ranking

We considered several factors for each animal in order to summarize the status and vulnerability of that species, focusing largely on factors in regard to the following: (1) the species listing status and recent 5-year status review recommendation (if available), (2) distribution, (3) number of populations, (4) species population trends, (5) if pesticides have been noted as a threat, and (6) impacts from activities associated with environmental baseline and cumulative effects. Sources for this information were listing rules, recovery plans, 5-year status reviews and Species Status Assessments. This effort allowed us to consider whether species were moving toward recovery or further decline, and identify which species were most (and least) at risk to additional stressors in general, where this information could be surmised from species listing and recovery documents or other sources as cited. When insufficient information was available to adequately rank a vulnerability ranking factor, we noted the factor as “unknown” and considered them to be neutral factors that did not move the overall vulnerability ranking toward a “high” or “low” indicator. This vulnerability exercise provides a snapshot of the overall status of the species together with the environmental baseline and cumulative effects.

We compiled and summarized information about the listing status, 5-year status review recommendations, environmental baseline and cumulative effects and several vulnerability factors. Vulnerability factors related to distribution, number of populations, and species population trends are described further below. As we reviewed species information in listing rules and recovery documents to generate the vulnerability factors, we also noted when pesticides were identified as a threat to the species in these documents and included this as an indicator in the Integration and Synthesis Worksheet. However, pesticide threats were not always mentioned or consistently evaluated for a species in listing rules or recovery documents, and such an omission does not necessarily mean the species would not be vulnerable to that factor. As such, where pesticides were not noted as a threat in the listing or recovery documents, we treated this consideration as a neutral factor in the indicator tool.

Distribution

We considered the distribution of a species as a vulnerability factor with the general view that the smaller or more confined the range, the more susceptible the species may be to a disturbance or stochastic event. If a species was a narrow endemic, or otherwise limited to small, isolated, or fragmented habitats or habitat patches, we assigned a “high vulnerability” ranking to this factor. Where species were wide-ranging and/or able to easily recolonize new or existing habitats, we assigned a low vulnerability ranking to this factor. A “medium vulnerability” ranking was assigned to species that did not clearly fall into either the constrained or widespread categories.

Species that migrate can be considered to be inherently wide-ranging based on the extent of their ranges, especially for those that are long-distance migrants. However, parts of a species range that the species relies on seasonally, such as for breeding or overwintering, may be fragmented and constrained. The assignment of vulnerability rankings takes into consideration how vulnerable the species may be across its range as well as in seasonally used portions of its range within the U.S. In some cases, even though a “low vulnerability” ranking generally applies to wide-ranging species, a “high vulnerability” or “medium vulnerability” ranking for this factor may be assigned to migratory species to more accurately reflect how vulnerable the species may be in light of seasonal habitat requirements.

Numbers of Populations

For numbers of populations, we considered whether a species was limited to a single population, few populations, or many populations. The use of “few” versus “many” was necessarily subjective, as it is related to the species’ distribution, redundancy, and resiliency to the effects of stochastic events that could result in extirpations of populations or subpopulations. Generally speaking, “few” is less than 10 populations, and for some species, may be limited to only two populations (or sub-populations, depending on the available species information). We assigned vulnerability ranking factors of: “high vulnerability” to species with a single population (or in some cases a single, small metapopulation, as appropriate); “medium vulnerability” to species with “few” populations, which allow for at least a limited level of redundancy to protect against stochastic events or localized extirpations; and “low vulnerability” to species with numerous populations, which may provide a greater level of redundancy.

<u>Species Population Trends</u>

For species population trends, we considered whether populations are declining, stable or increasing, based on the most recent information from listing rules, recovery plans, 5-year status reviews and other Service sources for the species (e.g., Service species experts). We assigned vulnerability factors of "high vulnerability" to species with one or more declining populations; "medium vulnerability" to species with all stable populations where none are known to be increasing or decreasing, or unknown population trends, and "low vulnerability" for species with increasing population(s) trends. This factor indicates whether the species is moving towards extinction or recovery as part of the species status and baseline.

We acknowledge that for species population trend information, various life history considerations or the species status can complicate an observation of its trend. For example, a species that appears "stable" according to this ranking factor (i.e., neither increasing nor decreasing) may actually have a very small population size(s), which in some cases may not be sufficiently robust to maintain the population over the long term even though numbers may appear stable. While we recognize this is a potential shortcoming in this ranking factor, by evaluating this factor in combination with species distribution, population size, and the other considerations described above, we are less likely to assign the factor undue weight in determining the vulnerability of the species in such a scenario.

Risk Factors and Ranking

The risk factors considered the level of risk to the species from the Action based on anticipated species exposure and response (effects to the species) from labeled uses across the range. The overall risk factor is based on (1) direct effects, which include mortality and sublethal effects (e.g., effects associated with growth, reproduction, behavior, sensory, and enzyme) and (2) indirect effects (e.g., effects to prey or other forage items or host species) as calculated by the MagTool and R-Plots. A risk modifier was included to adjust high, medium and low rankings based on additional information that was not fully captured in the MagTool and R-Plot outputs (e.g., pesticide information specific to the species; species range limited to protected areas where exposure would not be expected to occur based on site-specific considerations, etc.).

We derived the ranges of high, medium and low based on anticipated risks that generally fit the applicable categories, considering degrees of effects that would most likely occur from low to high to indicate effects that would be less to more likely to result in species-level effects across species and taxa (based on best professional judgment). We weighted mortality and sublethal effects more heavily than effects to food items or host species. Where mortality or sublethal effects occur, the effect may be more immediate, resulting in death, injury, or behavioral changes that result in death or injury, such as an inability to escape a predator or find sufficient food resources. Effects to other species or habitat features the species relies upon may also be important, as individuals of the species may have secondary exposure to the pesticides through these pathways, or experience reductions in resources they need to survive and reproduce. For prey or forage base, or in the case of host species, we also consider whether other resources are available to individuals of the species (e.g., other prey items), and this consideration factors into our ranking as well.

Usage Factors and Ranking

While past usage does not necessarily predict all usage in the future, it is relevant in informing our estimate of future usage. The usage factors primarily aid us as we consider the total estimated percent of the species range where usage that will have effects to the species is anticipated to occur. We base the calculation for this percentage on all use sites that overlap with the species range, information about whether or not the species is likely to occur in the use site, and past usage data for each use category considering variances in use site geographies to the extent possible. We derive ranges of high, medium, and low based anticipated usage that generally fit the applicable categories considering the degrees of effects that would result in species-level effects across species and taxa. We also indicate the source of the usage data as either "standard data" or "CalPUR data." CalPUR data is selected when at least 75 percent of the range falls within California. Because we have a higher level of confidence in usage data available in California (see *Approach to the Usage Analysis* in the *Effects of the Action* section) we note this for consideration in the next step in the jeopardy analysis.

Conservation Measures

As part of our analysis, we also consider the influence of the additional general and species-specific conservation measures on the effects of malathion uses on species and critical habitats. Since these measures were incorporated into the Action later in the consultation process to address anticipated effects and exposure that had been described in the BE and our draft BO, we discuss the additional measures in the context of how we anticipate they would avoid, minimize, or reduce exposure and effects. For each species, we identify in our analysis those conservation measures that are likely to reduce exposure and effects based on use and usage patterns relevant to the species and their critical habitats, and describe the nature of the reduction. The measures have been added as a new section within the *Integration and Synthesis* summaries in Appendix K to clarify the relevant general and species-specific label restrictions that apply to each taxa (animals) and assessment group (plants), and are addressed in the rationales for our conclusions. We identify and discuss any relevant label restrictions associated with these measures within the rationales for critical habitats in Appendix L.

Rationales and Conclusions

Once the overall categories for each factor are determined for each species using the Integration and Synthesis Worksheet and the new conservation measures are identified, we continue the jeopardy analysis by considering the combination of the overall vulnerability, risk, and usage factors described above, how the conservation measures relevant to each species are anticipated to avoid, minimize, or reduce any identified effects, and any additional information relevant to the consequences of the Action that may reduce the species reproduction, numbers and distribution. We then develop our conclusion, and the rationale on which it is based, for each species. Our conclusions and rationales are organized by taxa group, assessment group, or in some cases, grouped by sub-taxa or geographies as discussed above.

Overlap of the Species Range with Anticipated Use Sites

As described previously, malathion applications would occur on a site-specific basis for the duration of the Action. Although some degree of change in land uses or crop selection is expected over time, we expect large acreages within specific geographic regions in the action area to remain relatively static over time in terms of land use. These include, but are not limited to, specific crops and crop rotation patterns, lands used to grow other products, rangeland, developed areas, and other land uses. However, even in these areas, we anticipate changes at a small scale as land uses are not static over time. For example, new plant nurseries, and similar facilities associated with applications of malathion may be established in a variety of locations within the action area. Specific locations where such facilities may be sited or where land changes will occur, cannot be predicted in many geographic locations with any degree of certainty or geographical precision, except perhaps in extremely remote geographic areas that are currently uninhabited or with specific types of land management (e.g., certain private or public lands with on-going land uses that are not expected to change over the project duration). Alternatively, certain types of crops or products may predominate in a given geographic area, although market forces, environmental conditions (e.g., drought, flooding, extreme temperature events, pest pressure, etc.), and grower decisions may result in changes in land uses over time. Some crops or land uses in which malathion could be used may be limited to certain climatic conditions, elevations, or other environmental factors. Even within geographic areas with relatively continuous crop types. However, we expect other crop types may be grown in these areas as well.

Nevertheless, we performed our analysis on areas and land use types where we expect malathion to be used, over the 15-year duration of the Action, as described above. While we can generalize about the anticipated use of pesticides in these use areas for the foreseeable future, we also acknowledge these generalizations do not address all current or future uses within an area where malathion would be used. Therefore, we based our conclusions on a quantification of those areas most likely to support uses where the pesticide can be applied, according to the labels as currently written, and we considered the extent of overlap of these areas with species ranges and critical habits as well as available usage data to assess the extent and magnitude of the anticipated effects (as described in the *Approach to the Usage Analysis* section).

For each general category of uses, we considered both percent overlap with likely use sites and application rates per the BE in our evaluation of species exposure, effects, and magnitude of response. Some uses had high degrees of overlap, but relatively low application rates (e.g., pasture). For other uses, percent overlap may have been relatively low, but application rate was higher (e.g., orchards and vineyards). These differences were considered in both effects to the species via mortality and sublethal effects as well as through effects to hosts, pollinators, seed dispersers, habitat, prey items, or other food base components. For each species, we considered which uses were driving the analysis of adverse effects to the survival and recovery of the species by evaluating effects to essential breeding, feeding, and sheltering behaviors.

Species Background Information

In an effort to simultaneously capture important species-specific considerations in the integration and synthesis and to streamline the analysis for each of the listed resources considered in this Opinion, we use a method to briefly summarize the relevant issues and effects for each species in the integration and synthesis. Using this method, we refer to background information in the Status of the Species and the most recent listing documents, recovery plans, and 5-year status reviews for the species. For this Opinion, we consider these documents on a species-by-species basis for animal species. The listing and recovery documents are located on the Service's Environmental Conservation Online System (ECOS[50]), with endangered, threatened, proposed, and candidate species accounts. We also include relevant information from these documents in the Status of the Species and Critical Habitat (Appendix C) and in the Integration and Synthesis summaries (see Appendix K).

Additional Considerations for Animal Species

While the best scientific and commercial data available for the toxicological analysis relies on a relatively short list of surrogate species for testing, we sometimes found it challenging to apply this information to many of the listed, proposed, and candidate species under consideration in this Opinion. These species exhibit different and unique characteristics and behaviors that enable them to survive in their environments. Some species are habitat or foraging generalists, using a wide variety of habitat types or food source, while others may rely solely (or heavily) on a single or small number of specific habitats or prey resources to survive. Some species require other species to complete their life cycle, such as freshwater mussels that require host fish for the survival, development, and distribution of glochidia (juvenile life stage); plant species that require animal pollinators; and certain lycaenid butterflies that rely on ants to tend their larvae ("myrmecophilic").

Other relevant life history characteristics that affect the analysis and conclusion include life span, sensitivity to stochastic events, migration and other movements between habitats, reproductive capacity, and behaviors associated with reproduction. The offspring of species require varying degrees of parental care, such as altricial (i.e., heavily dependent on parental care) versus precocial young (i.e., more independent ability to survive at birth). For example, among avian fauna, many raptors and passerine young require significant parental care and feeding, while shorebirds such as western snowy plovers produce chicks that can move and forage largely on their own a few hours after hatching. Some species require no parental care once young are born or eggs hatch (e.g., turtles, insects, salmonids). Many insects, small mammals, and other short-lived species may produce multiple generations or numerous offspring in a relatively short period of time, while longer-lived species may require longer maturation times before reproducing (e.g., sturgeon), or may produce relatively small numbers of young at a time or over their lifetime. For some species, such as certain fish, fecundity may increase over time, with larger females often producing greater numbers of young during a given reproductive event (e.g., salmonids). These factors can influence the survival and recovery of species when subjected to threats and stressors on the landscape. For example, a short-term stressor that results in the loss

[50] https://ecos.fws.gov/ecp/

of a single brood for a species that has multiple broods per year would generally be expected to have less of an effect on the survival and recovery of the species than the loss of mature adults (and often especially females) that reproduce only occasionally. Similarly, stressors may result in low to no juvenile recruitment for a long-lived but aging population of species, ultimately affecting the survival and recovery of the species when those remaining adults eventually die.

Some species are limited to small areas or habitat patches; they are either unable to move due to obstacles or unlikely to move very far from a territory due to the barriers created by unsuitable habitat. For example, pupfishes and poolfishes may be limited to one or a few small spring-fed pools or streams, with permanent or ephemeral barriers to recolonization. While certain species, such as tiger beetles and smaller, non-migratory butterflies, have the ability to fly short distances, they may be relegated to a few small habitat patches too far from one another to assist in natural recolonization if a population or subpopulation is extirpated after a devastating stochastic event. Many species move frequently within their habitats, with some travelling great distances within a watershed or territory. Some even move between continents, such as migratory birds. Even species within taxa groups that are relatively sessile, such as mussels, are nonetheless known to make small movements as adults or larger movements as juvenile glochidia attached to the gills of highly mobile fish hosts. Some species may employ different life history strategies either among individuals of a population or even from year to year for a given individual. For example, bull trout may be migratory, travelling short or long distances within a given year, or resident, remaining in their natal or nearby streams; some reside in lakes, or, in coastal areas of the species range, may enter estuarine or marine waters to forage. In some cases, an individual may exhibit different life history strategies from year to year.

Additionally, several species considered in this Opinion live in subterranean habitats, such as caves or lava tubes. Some of these species, such as cave fish and many cave invertebrates, spend their entire lives in subterranean environments ("trogblobites"). Other species, such as certain species of bats, may use both caves (e.g., for roosting) and terrestrial environments (e.g., for foraging, migration and other movements) ("troglophiles"). For both troglobites and troglophiles, exposure in subterranean habitats to pesticides is derived from outside sources such as leaf litter and other detritus that falls or is washed or seeps into the habitat, or from troglophiles that die in caves after exposure from terrestrial sources and subsequently become a food source for other cave inhabitants. Thus, there are several pathways where cave organisms may be exposed to pesticides.

For most species, natural and anthropogenic stressors can affect a species' ability to persist or recover by affecting survival, growth, or reproduction of individuals or during sensitive life history phases such as feeding, breeding, sheltering or reproduction. Such stressors may affect survival of juveniles to adulthood, number of offspring produced, availability and quality of food resources, habitat quality, and other requirements of species. When multiple stressors act together on a species, its habitat and/or prey, the effects of an additional stressor (such as the Action) on individuals, populations, or the species as a whole can be exacerbated.

Effects of the Action on Animals

In the Integration and Synthesis summaries (Appendix K), we evaluate the results from the tools that were available for each taxa group (as described in the *Effects of the Action* section of this Opinion). For species, type of effects, and pathways of exposure that could be evaluated with the MagTool, we report the range of results for each species (see MagTool Summary appendices). For mussels, snails, other aquatic invertebrates, and many of the fishes or the species which could not be addressed by the MagTool (cave invertebrates), we used R-Plots as described above (see Effects of the Action and R-Plot Appendices). While we may consider the effects of individual use types or categories, the combined effect of all of the overlapping uses are of concern and may also contribute to species-level effects.

Generally speaking, we found relatively high levels of mortality are anticipated for both aquatic and terrestrial invertebrates where exposure occurs. For other taxa groups, we anticipate variable levels of mortality, sublethal, and indirect effects based on their life history, food base, and other considerations. We summarize these results and related conclusion rationales for the species in the sections below.

For each animal species, we considered all of the information described above, any reduction in exposure and effects to the species from the implementation of conservation measures, and developed a rationale for the conclusion. Within each taxa group, we documented our determinations for each endangered and threatened species. Proposed species and critical habitat, as well as candidate species, are included in the taxa group tables, although determinations for these species are provided as part of our conference biological opinion. Our analyses for these species and critical habitats are provided in Appendices K (species). Each taxa group and associated assumptions and narratives are included in the sections below. The first set of narratives and tables are comprised primarily of species in the continental United States. Pacific Island and Puerto Rico/Caribbean species are described in separate tables and narratives in this section. Where rationales for conclusions could be written broadly enough to apply to multiple species within a taxa or geographic group (e.g., sea turtles, mussels), we streamlined reporting within the table or narrative for clarity and to avoid redundancy.

Amphibians

This taxa group includes species from the orders Anura and Caudata, including frogs, salamanders and toads. All amphibians are ectothermic and have skin that is permeable to air and water. Frogs and toads share many similar life history characteristics.

Both frogs (family Ranidae) and toads (family Bufonidae) generally have both an aquatic and terrestrial phase; although adults of some species may spend more time on land (e.g., Yosemite toad, California red-legged frog), others may spend most of their time in their aquatic environment (e.g., mountain yellow-legged frog), only moving onto land to occasionally forage along the water's edge. Both frog and toad families lay eggs in an aquatic environment, which develop into tadpoles and eventually metamorphose into adults. Metamorphosis may occur within a single breeding season or over one to three breeding seasons depending on environmental conditions. One family of frogs (Eleutherodactylidae) includes species that lay eggs that hatch directly into small frogs (e.g., Guajon) and a species that is ovoviviparous, giving birth to live young (golden coqui).

Salamanders exhibit a diverse array of life history characteristics. For instance, the family Plethodontidae (lungless salamanders) includes fully terrestrial species (e.g., Jemez Mountains salamander) which breathe entirely through their skin, lay eggs in a underground burrow, and have hatchlings that resemble small adults compared to fully aquatic species (e.g., Georgetown salamanders) that retain their gills throughout adulthood. Mole salamanders (family Ambystomatidae) have adults that are fully terrestrial, have fully developed lungs, and spend most of their time in underground burrows, but return to their natal breeding habitat to lay eggs in which tadpoles have gills until undergoing metamorphosis. The vast majority of amphibians that have an aquatic phase tend to spawn large numbers of eggs with limited or no parental care after laying (e.g., Oregon spotted frog). Terrestrial salamanders spawn far fewer eggs (typically under 20) in which the parent often guards the eggs until hatching (e.g., Shenandoah salamander). Both aquatic and terrestrial amphibians typically remain within or very close to their natal habitat (e.g., Texas blind salamander, Shenandoah salamander), while amphibians that have both an aquatic and terrestrial phase may remain close to their natal breeding habitat (e.g., Wyoming toad) or may travel several miles in search of suitable upland habitat or even new breeding habitats (e.g., California red-legged frog, Houston toad).

We used the MagTool to quantitatively assess all terrestrial amphibians and those amphibians that have a terrestrial life phase. We used R-plots to qualitatively assess the risk to the aquatic and aquatic-phase amphibians (see Appendix M). Because some amphibians can have both a terrestrial and aquatic phase, both the MagTool and R-Plots were necessary to assess these species. The MagTool uses calculations to determine the magnitude of effects from expected environmental concentrations (EECs) via diet for a terrestrial-based exposure. R-plots are used for these species to determine the magnitude of effects from EECs associated with the bin type (static or flowing waters) where the species is found for an aquatic-based exposure. We note these methods are comparable and both methods provide a similar estimate of risk (see Appendix I). For each species, we also consider how the conservation measures would reduce any effects predicted by these tools.

Use areas for malathion overlap with and occur adjacent to habitats used within the ranges of all of the listed amphibian species in this consultation. Exposure to this pesticide can result in direct mortality, mortality due to the consumption of contaminated food resources, sub-lethal effects affecting growth, reproduction, behavior and sensory functions for individuals that survive exposure, and the loss of important food resources that can lead to starvation, reproductive failure, site abandonment or other detrimental effects. The effects can vary greatly by species depending on the degree of overlap between pesticide uses and the species range, the species' preferred habitats, and the diet of the species in light of how their food resources may be affected. Amphibian tadpoles generally feed on algae and detritus, while adults eat aquatic and terrestrial invertebrates, and in the case of larger frogs and toads, small terrestrial vertebrates. These food resources are susceptible to contamination by pesticides that can then be passed on to amphibians that consume them, as well as direct adverse effects that can in turn reduce the food supply available to amphibians. The anticipated exposures and pesticide effects on amphibians and their food resources, as well as the status of the species and factors related to their vulnerabilities, were considered when evaluating the effects of the Action on each amphibian species.

For the analysis, mosquito adulticide was separated out from all other uses (e.g., agricultural sites, developed areas), since this use has no geographic restrictions to its application. Mosquito adulticide exposure (as well as all other uses) is likely to result in a range of effects (from sub-lethal to mortality) in amphibians that are wholly aquatic or have an aquatic phase, though lower or no mortality is likely for wholly terrestrial amphibians for some uses. Malathion exposure elicits some level of sub-lethal effect to most, but not all amphibians, and is anticipated to cause a range of reductions in available prey resources. The anticipated pesticide exposures and effects on amphibians and their food resources, as well as the status of the species and factors related to their vulnerabilities and risk, were considered when evaluating the effects of the Action on each amphibian species. Collectively, all amphibian species are expected to experience varying levels of effects and reductions in available food resources if exposed to malathion over the duration of the Action.

We expect that conservation measures will reduce exposure to malathion, and subsequently, effects to individuals and their prey items. For example, for the California red-legged frog, which breeds in ponds and spends most of its life history in moist sheltered areas in or around its various aquatic habitats (e.g., ponds, springs, streams, marshes), we anticipate the addition of conservation measures, including rain restrictions, aquatic habitat buffers, residential use label changes, and reduced numbers of applications and application rates will further reduce the likelihood of exposure of the species, their prey, and their habitat. As with most amphibians, the rain restriction is anticipated to reduce the likelihood of exposure (directly or in runoff) to the California red-legged frog when the animals are most active (e.g., following a precipitation event). Similarly, the aquatic buffers, reduction in the number of applications and reduction in applications rates are anticipated to reduce the likelihood of exposure by reducing or eliminating the pesticide from aquatic habitats proximate to agricultural applications. Lastly, residential use label changes are expected to reduce environmental concentrations as initial residues degrade prior to the next application, reduce the likelihood of and the environmental concentration of exposure by establishing buffers from waterways (specified on the label a distance from water bodies where pesticides are not to be applied), and restrictions to application during periods where rain is not forecasted within 24 hours or when the soil is not saturated.

Species-specific measures were developed for two species (i.e., Wyoming toad, Houston toad) to further lower the amount of malathion entering their habitats and reduce exposure where the species are expected to be found (see also Table 5 for a list of the species-specific measures and Appendix K for discussion of the species-specific conservation measures for the Wyoming toad and Houston toad and for individual species discussions related to the general label changes).

As described in each of the species accounts for this taxon, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild,. Integration and Synthesis summaries for species in the CONUS amphibian taxa group can be found in Appendix K. The amphibian species included in this group and our conclusions for each are presented in Table 43.

Table 43. Listed, proposed, and candidate CONUS Amphibian species addressed in this Opinion.[51]

Table 43. Amphibians.xlsx

Arachnids

The arachnid's taxa group is comprised of species of the following orders: Opiliones (harvestmen and kin), Araneae (spiders), and Pseudoscorpiones (pseudoscorpions). The spruce-fir moss spider lives in spruce fir forests while the remaining listed arachnids are subterranean, living in caves or mesocaverns.

The spruce-fir moss spider's typical habitat appears to be associated with moist, well-drained moss mats growing on rocks and boulders in well-shaded situations in mature high-elevation conifer forests dominated by Fraser fir, *Abies fraseri*, often with scattered red spruce, *Picea rubens*. Most recently, the species has been found among pure red spruce (Service 5-year status review). The Spruce-fir moss spider is vulnerable to threats due to its isolated and fragmented distribution, which is limited to just four mountain peaks in the spruce-fir forest in western North Carolina and one mountain peak in the spruce-fir forest in eastern Tennessee. Additional information for this species is found in the Status of the Species and in the integration and synthesis summary (Appendix C and Appendix K).

Cave species are restricted to the subterranean environment and typically exhibit morphological adaptations to that environment, such as elongated appendages and loss or reduction of eyes and pigment. Troglobitic habitat includes caves and mesocavernous avoids in karst limestone (a terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by solution of bedrock). Karst areas commonly have few surface streams; most water moves through cavities underground. Troglobites typically inhabit the dark zone of the cave where temperature and humidity are relatively constant. Within their habitats, species may depend on high humidity, stable temperatures, and nutrients derived from the surface. Examples of nutrient sources include leaf litter fallen or washed in, animal droppings, and animal carcasses. The species are most likely predators and are found in relatively small numbers. Each species may have a different preferred microhabitat and may depend on certain prey species for survival. Troglobites tend to be rare and limited in distribution. Four of the species (Bee Creek Cave harvestman, Bone Cave harvestman, Tooth Cave pseudoscorpion, and Tooth Cave spider) are found in Travis and Williamson County, Texas caves. Six species (Madla Cave meshweaver, Braken Bat Cave meshweaver, Government Canyon Bat Cave meshweaver, Robber Baron Cave

[51] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = "May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

meshweaver, Cokendolpher cave harvestman, and Government Canyon Bat Cave spider) occur in cave habitats in Bexar County, Texas.

Threats to the cave species include destruction and/or deterioration of habitat by numerous stressors, which vary across geographic areas. Examples include impacts from construction and development; collapse or filling of caves and karst features; loss of impermeable cover; alteration of drainage patterns; alteration of surface plant and animal communities (including predation by and competition with invasive red fire ants, where present); contamination from septic effluent, sewer leaks, run-off, pesticides, and other sources; and vandalism. Many of these species still face the same threats they did when they were listed. Their limited distributions combined with low reproductive rates, ecological specialization, and other factors, make troglobites especially vulnerable to habitat destruction, fire ant infestations (where present), pollution, and other factors.

Effects to the Arachnid Species

Where individuals of any of the species are exposed to malathion, we anticipate mortality would occur based on the hazard assessment. However, the overlap of use sites does not lead us to conclude that all individuals would be exposed to malathion over the duration of the Action. For the spruce-fir moss spider, we anticipate exposure of the species and its prey to applications and spray drift would occasionally occur over the 15-year period in response to unexpected pest pressure. We do not anticipate that direct application or drift would be likely pathways for cave arachnids, such as most of the arachnids, when they are in subterranean habitats. Nonetheless, we anticipate all arachnid cave species could be exposed to malathion in a variety of pathways. Several studies cite that nutrients in cave ecosystems are derived from exterior sources (Poulson & White, 1969; Howarth, 1983; Culver, 1986) and in particular directly from organic material washed in or brought in by animals. Bats are usually the major source of these nutrients in cave habitats as well as the major source of contaminants via the transport mechanisms mentioned above (Kunz, 1982), although bats would not necessarily be found in subterranean habitat for all the listed cave arachnids. Detritus within caves from decaying plant and animal matter (e.g., leaf litter fallen or washed in, animal droppings, and animal carcasses) is an additional exposure pathway to pesticides for cave species.

Terrestrial applications have been known to result in accumulation of pesticides in the detritus via agricultural practices, residential applications, and other activities over or near lava tubes, sinkholes, or other porous features near the surface of cave habitats. In addition, terrestrial application of pesticides above karst caves allow for contaminated water to flow into the caves due to the permeable, porous substrates that comprise these unique habitats. Terrestrial organisms within caves that have accumulated the pesticide from outside the cave and comprise the detritus will also be exposed. Aquatic cave species can also be exposed via similar routes, particularly in the absence of effective measures to avoid, minimize or reduce such exposure. Pesticide may accumulate in cave waters and place aquatic species at risk as well due to low or no flow of these waters. Food resources for these species may also be reduced or eliminated due to pesticide use. For example, some terrestrial cave organisms consume invertebrates and other prey. Pesticide use may affect availability of food resources for these species, resulting in effects to growth and survival of individuals. Reduced food availability could result in substantial effects on individuals and populations of a species, particularly in habitats where food resources may already be relatively scarce.

We expect that conservation measures will reduce exposure to malathion, and subsequently, effects to individuals and their prey items. For example, the label language regarding rain restrictions will substantially reduce runoff and estimated environmental concentrations of malathion into aquatic habitats, thereby reducing the risk from run-off or spray drift that infiltrates through the porous karst or lava substrates where the cave arachnids reside. In addition, the aquatic buffer protections describing application buffers of 25, 50, and 100 feet from aquatic habitats for ground, aerial and ultra-low volume aerial applications, respectively are also designed to create no-spray buffers from sensitive aquatic areas. These application restrictions will also reduce exposure from pesticides that can drift off use sites that may consequently enter into these porous karst and lava tube habitats as well. The area surrounding these cave arachnids are also heavily developed. The residential label use changes will also help to reduce the amount of malathion that may reach these porous systems. New label changes will limit the number of application to two for most uses within developed and open space developed UDLs. Residential labels also now contain language instructing applicators to avoid treating 25 feet from water or when a storm event likely to produce runoff from the treated area is forecasted to occur within 24 hours following application. New label language ensures that malathion usage in residential areas will be limited to spot treatments and not broadcast over lawns or other expansive areas. Instructions also forbid application to impervious horizontal surfaces such as sidewalks, driveways, and patios except as a spot or crack-and-crevice treatment. Together these label changes will lower concentrations on use sites and in adjacent habitats, and also allow for a reduction in the potential for malathion to drift or run-off into adjacent waterways and into these porous underground systems, thus reducing the effects to species, their prey, and their habitat.

Species-specific measures were developed for several species and/or their critical habitats and for use in conjunction with general label changes for most species to further lower the amount of malathion entering habitats and reduce exposure where the species are expected to be found. For example, critical habitat-specific measures for the Kauai wolf spider (pe‘e pe‘e maka‘ole) regarding restricting irrigation of fields to a minimum of 24 hours after malathion application and scheduling irrigations to allow at least 24 hours between malathion applications and irrigation maximizes the interval of time to allow malathion to naturally degrade in the environment. This label language is also designed to minimize the run-off potential into the fissures, openings, and voids in young lava tubes and consolidated calcium carbonite deposits scattered throughout the Koloa District where this arachnid is found. As another example, the karst cave arachnids within Bexar County, Texas also have measures for protection of their critical habitat. The measure describes avoidance of the application of malathion near the critical habitat by 100 feet. This conservation measure will not only ensure protection of the critical habitat for these cave arachnids but will also function to protect these species directly as well.

As detailed in each of the species accounts for this taxon, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild. Additional information for these species is found in the *Status of the Species* and *Critical Habitat* (Appendix C) and the *Effects of the Action* sections. Integration and Synthesis summaries are provided for each species (Appendix K). The arachnid species included in this group and our conclusions for each are presented in Table 44. Island arachnids are discussed in the *Hawaii and the Pacific Islands Integration and Synthesis* section of the Opinion.

Table 44. Listed, proposed, and candidate CONUS Arachnid species addressed in this Opinion.[52]

Table 44. Arachnids.xlsx

Bivalves (Mussels/Clams)

The bivalve species in this taxa group includes individuals from the families Margaritiferidae and Unionidae. Of the approximately 100 species in this taxa, only the Alabama pearlshell and the spectaclecase occur in the family Margaritiferidae; the rest occurring in the family Unionidae. In general, threats to these species are associated with habitat alteration and degradation (e.g., sedimentation, river channelization, river impoundment, drought, nutrient enrichment, chemical contamination) and introductions of non-native species (Master, 1993; Neves, Bogan, Willliams, Ahlstedt, & Hartfield, 1997; Neves, 1999; Havlik & Marking, 1987; Schloesser & Nalepa, 1995; Schloesser, Nalepa, & Mackie, 1996; Stewart & Swinford, 1995). Impacts from past and ongoing threats have left many species in these taxa with one or few remaining populations that are typically fragmented and isolated from one another. Population status is generally characterized as declining or unknown.

All bivalve species in this analysis use a fish host to complete their reproduction cycle. Both Unionidae and Margaritiferidae mussels vary in their host specificity. Some mussel species can use a variety of fish species as hosts, but they are usually limited to one or two families of fishes. A small number of mussels appear to be limited to a single fish host (obligate host); for example, the scaleshell appears to utilize the freshwater drum (*Aplodinotus grunniens*) exclusively as a host for its larvae. The reproductive life cycle involving the fish host begins when glochidia (parasitic larvae) are released from the female mussel and attach to the appropriate fish host and the fish host's epithelial cells form a cyst around the glochidia. The glochidia have a parasitic relationship with the host, deriving all their nutrients from the host for several weeks or months as they transform into juvenile mussels. After transformation, the juvenile mussel drops from the host fish and buries into the sediment.

We do not anticipate the Action would result in adverse effects to the green blossom (pearlymussel), tubercled blossom (pearlymussel), turgid blossom (pearlymussel), yellow blossom (pearlymussel), flat pigtoe, stirrupshell, southern acornshell, or upland combshell.

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[52] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = "May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

While these species are currently listed under the ESA, all eight of these species have been recommended for delisting due to extinction in their most recent 5-year status reviews. For these species, we anticipate that exposure is unlikely to occur, and that species-level effects are not anticipated. Therefore, we do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild.

For the remaining mussel species, we divided them into two subgroups. In Subset 1, we included a detailed presentation of our analysis of risk related to overlap and usage. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we present results from the R-Plot analysis (see Appendix M for R-Plots), use and usage data, and our determination as to whether the proposed action is likely to jeopardize the continued existence of 35 species within this taxon. For Subset 2, we used a summarized analysis of risk related to overlap and usage (without including information in the tables for these species *Integration and Synthesis* sections, as we did for Subset 1). Due to the similarities between Subset 1 and Subset 2, we believe that the methods used accurately represent anticipated risk between the subsets. All species in Subset 2 are anticipated to have low usage (<5%) and are presented in a streamlined, abbreviated manner for this Opinion. For Subset 2, we included a group conclusion and an abbreviated Integration and Synthesis summary. For the low usage species, we completed a group conclusion, but only included a list of species names and corresponding aquatic habitat bins for the species and their host fish. More detail on the approach for the two subsets of species and usage categories is provided in the mussels *Integration and Synthesis* summary (Appendix K).

For all use types, we do not anticipate direct effects (mortality or sublethal effects) to the mussels themselves. However, we do anticipate use of this pesticide as allowed by the labels would kill many individuals of host fish directly exposed to malathion either through exposure to runoff or spray drift as a result of applications. This exposure may vary depending on waterbody type and use type as described previously in the *Effects of the Action* section. For example, for host fish with some or all life stages in small flowing or static waterbodies, mortality effects are generally likely to be higher than those in larger static water bodies, i.e., larger lakes and ponds. Effects are somewhat more variable for larger flowing waterbodies as exposures in large streams and rivers may be influenced by applications throughout the watershed. Given the information we have for host fish, we anticipate variable degrees of effects, although most uses, particularly near smaller waterbodies, are likely to result in high levels of mortality where exposure occurs. Because malathion has such high acute lethal toxicity, mortality is the predominant effect driving risk, although some host fish' survivors may be at risk of sublethal effects. For host fish species that prey on invertebrates or fish, we anticipate contamination of or reduction in their forage base as well, reducing the suitability and availability of food items. Reduced food availability could result in substantial effects on individual host fish or their populations, particularly in habitats where food resources may already be relatively scarce. Where localized effects to reductions in prey occur as a result of applications of malathion, we anticipate these to be relatively short-term, whereas additional food resources from upstream sources would quickly recolonize or host fish would seek out other areas of available prey, where sufficient habitat is present to do so. However, where unaffected areas are limited due to fragmented habitat, and during the time in which prey resources have adequately re-established to provide a sufficient prey base, we anticipate reduced ability of host fish to forage and mortality or reduced body condition for these fish. Such effects would result in lower survival and reproduction of affected host fish. In addition, we anticipate high levels of mortality to the mussel prey resources (zooplankton/plankton) in areas of malathion applications, however, we anticipate that additional food resources from upstream sources would quickly recolonize affected areas. Mussels also generally consume phytoplankton and detritus, which is not anticipated to be impacted by malathion applications. Conservation measures on both general malathion labels as well as species-specific bulletins are anticipated to reduce exposure and effects identified for these species, their host fish, and their habitats.

As we considered the effects of the Action on the species, we recognized the pesticide would not be used on every application/use area, and would not be used at the same time, during the same year, or at the maximum labeled uses for every application. However, the broad label language allows for such applications, including re-applications. It is thus reasonable to assume some of these applications will occur on multiple sites on consecutive days or weeks or during the same year. Where individual host fish are lost, or a large proportion of a population(s) of host fish are lost, individual mussels would eventually be lost to natural mortality over time without the ability to successfully breed. Since many adult mussel numbers are already low in many populations, and their habitats are isolated and fragmented, currently populated areas may be lost and not recolonized in the absence of measures to reduce exposure and effects. We expect general label conversation measures (rain restrictions, aquatic habitat buffers, residential use label restrictions, and reduced application rates and numbers of applications) and species-specific measures will reduce exposure to malathion, and subsequently, effects to individuals, their host fish, and prey resources. Conservation measures are aimed at reducing the amount of malathion runoff and spray drift that enter into sensitive habitats (e.g., species habitat, aquatic environments). For example, by placing a 48-hour rain restriction on agricultural applications, malathion has the ability to degrade after application (e.g., by hydrolysis, other processes) prior to any rain/runoff events, thus minimizing malathion runoff into aquatic habitats and decreasing exposure to listed species. Increasing application buffers reduces the amount of malathion that drifts off target and subsequently into non-target environments. In addition, changes to residential labels limits applications to spot treatments and reduces the number of applications per year (2-4), significantly decreasing the overall amounts of malathion used in residential areas and resulting amounts of runoff and drift. Additional reductions in the number of applications and rates allowed for certain crops (e.g., corn, vegetables and ground fruit) further reduces the amount of malathion used in agricultural settings, thereby decreasing potential exposure the species. Considered together, these conservation measures and species-specific conservation measures (e.g., application avoidance areas or coordination with Service field offices) substantially reduce exposure to these species, their host fish, and host fish prey resources and therefore minimizes overall risk and adverse effects to the species.

As described in each of the species accounts for this taxon, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild. The bivalve species included in this group and our conclusions for each are presented in Table 45. Integration and Synthesis summaries for species in the CONUS bivalve taxa group can be found in Appendix K.

Table 45. Listed, proposed, and candidate bivalve (mussel/clam) species addressed in this Opinion.[53]

Table 45. Clams (Bivalves, Mussels).xls

Birds

Birds are a diverse group in the class Aves, which is divided into 23 taxonomic orders based on the similarity of their characteristics: Ducks, Geese, and Swans (Anseriformes); Grouse, Quail, and Allies (Galliformes); Grebes (Podicipediformes); Pigeons and Doves (Columbiformes); Cuckoos (Cuculiformes); Nightjars (Caprimulgiformes); Swifts and Hummingbirds (Apodiformes); Cranes and Rails (Gruiformes); Plovers, Sandpipers, and Allies (Charadriiformes); Loons (Gaviiformes); Tubenoses (Procellariiformes); Storks (Ciconiiformes); Frigatebirds, Boobies, Cormorants, Darters, and Allies (Suliformes); Pelicans, Herons, Ibises, and Allies (Pelecaniformes); New World Vultures (Cathartiformes); Hawks, Kites, Eagles, and Allies (Accipitriformes); Owls (Strigiformes); Trogons and Quetzals (Trogoniformes); Kingfishers and Allies (Coraciiformes); Woodpeckers (Piciformes); Caracaras and Falcons (Falconiformes); Parrots (Psittaciformes); and Perching Birds (Passeriformes).

Birds are ubiquitous throughout the landscape, as they can be found using virtually every type of habitat and land use across the full spectrum of terrestrial and aquatic environments. Each species of bird generally occurs only within certain types of habitat within a specific geographical area or areas, although ranges for many bird species can be expansive, especially for species that migrate. Resident species stay in the same area year-round, although they may make seasonal movements between local habitat areas. Migratory birds tend to have complex and often extensive habitat needs, requiring networks of appropriate habitats in key locations across large geographical areas that support the full gamut of land uses. They require suitable habitats in different places for breeding and overwintering, as well as flyways and stopover sites for travelling, resting and refueling during migration. As a whole, birds face numerous threats and environmental problems. Reductions in habitat quantity and quality, the primary causes of negative population trends in many species, are often exacerbated by the direct loss of bird life from an array of external environmental hazards. Clean air, clean water, and abundant, diverse and healthy habitats are essential for listed bird species to survive and recover.

Use areas for malathion overlap with and/or occur adjacent to habitats used within the ranges of nearly all of the listed bird species in this consultation. Exposure to this pesticide can result in direct mortality, mortality due to the consumption of contaminated food resources, sublethal effects affecting growth, reproduction and behavior for individuals that survive exposures, and

[53] For calls and conclusions: LAA = "may affect, likely to adversely affect;" NLAA = "may affect, not likely to adversely affect;" NE = "no effect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species); PE = Presumed Extinct.

the loss of important food resources that can lead to starvation, reproductive failure, site abandonment or other detrimental effects. The effects can vary greatly by species depending on the degree of overlap between pesticide uses and the species range, usage patterns, the species' preferred habitats, and the diet of the species in light of how their food resources may be affected. Birds eat many types of foods, including plant components, terrestrial and aquatic invertebrates, small terrestrial vertebrates, fish, carrion and more. These food resources are susceptible to contamination by pesticides that can then be passed on to birds that consume them, as well as lead to losses of prey that can in turn reduce the food supply available to birds.

While the above-mentioned effects would be anticipated to occur based on the Action as described in the BE and at the time the draft Opinion, conservation measures were developed after the issuance of the draft Opinion that are now evaluated as part of EPA's Action. These measures include general conservation measures (rain restrictions, aquatic habitat buffers, residential use label restrictions, and reduced application rates and numbers of applications) and species-specific measures that will reduce exposure to malathion, and subsequently, effects to individuals and their prey resources. Conservation measures are aimed at reducing the amount of malathion runoff and spray drift that enter into sensitive habitats (e.g., species habitat, aquatic environments). For example, by placing a 48-hour rain restriction on agricultural applications, malathion has the ability to degrade after application (e.g., by hydrolysis, other processes) prior to any rain/runoff events, thus minimizing malathion runoff into aquatic and other non-target habitats and decreasing exposure to listed species. Increasing application buffers reduces the amount of malathion that drifts off target and subsequently into non-target environments. In addition, changes to residential labels limits applications to spot treatments and reduces the number of applications per year (2-4), significantly decreasing the overall amounts of malathion used in residential areas and resulting amounts of runoff and drift. Additional reductions in the number of applications and rates allowed for certain crops (e.g., corn, vegetables and ground fruit) further reduces the amount of malathion used in agricultural settings, thereby decreasing potential exposure the species. Species-specific measures further reduce exposure from agricultural uses and mosquito control for two species (i.e., Attwater's greater prairie chicken and the Florida grasshopper sparrow) through the use of application avoidance areas, coordination with Service field offices, seasonal use limitations, and wind and buffer requirements (see Table 5 for the species-specific measures). Considered together, the general and species-specific conservation measures substantially reduce exposure to these species and their prey resources, therefore minimizing the overall risk and adverse effects to the species (see Appendix K for discussions of the conservation measures in the effects analyses for individual species).

All of the species included in the CONUS bird group and our conclusions for each are presented in Table 46. Island birds are discussed in the *Hawaii and the Pacific Islands Integration and Synthesis* section of the Opinion. Integration and Synthesis summaries for species in the CONUS bird taxa group can be found in Appendix K, with the exception of the species that we addressed qualitatively below. As described in each of the species accounts for this taxon, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild. While we anticipated the Action would likely jeopardize the Florida grasshopper sparrow, Audubon's crested caracara and Attwater's greater prairie-chicken in our draft Opinion, conservation measures since incorporated into the Action are expected to substantially reduce exposure of individuals and their prey items such that we no longer anticipate species-level effects for any of these species. While we also anticipated in the draft Opinion that the Everglade snail kite would be jeopardized due to impacts to prey items (primarily aquatic apple snails), a review of additional data available from toxicity tests for aquatic snails indicate that these species have relatively higher tolerance to malathion and have a low risk of mortality at estimated environmental concentrations, and therefore, we only anticipate low-level impacts that would not result in species-level effects. For the Mississippi sandhill crane, the primary driver for effects to the species was anticipated to be from usage associated with mosquito control. However, we no longer anticipate that usage for mosquito control will occur in the species range based on data specific to a recently refined species range, and thus only low-level effects that are not likely to result in species-level effects are anticipated.

Select Bird Species - Qualitative Assessment

In the Service's 2019 5-year status review[54] for the ivory-billed woodpecker, we recommended delisting the species due to extinction; we published a proposed rule to delist the species on September 30, 2021 (86 FR 54298 54338). Because the available information does not indicate the species is extant in the wild, and there are no captive individuals, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of the species.

Based on the life histories of the marbled murrelet, short-tailed albatross, Steller's eider or spectacled eider and two Roseate tern populations, the risk of exposure of these species is extremely low. For example, marbled murrelets nest high in the canopy of late successional and old growth forest habitats where we do not expect that they will come into contact with malathion. Additionally, the seabird species forage offshore in marine waters where we do not anticipate measurable effects to the species or their marine prey base. As far as the risk of exposure as individuals may be traveling over or through use sites to forage or during migration, we do not anticipate these species will come into contact with direct spray or spray drift from use sites. Therefore, we do not anticipate that the Action would be likely to adversely affect these species due to the likelihood of exposure being so remote as to be discountable[55].

[54] Available on-line at: https://ecos.fws.gov/docs/five_year_review/doc6021.pdf

[55] If EPA elects to change its determination for these species to "may affect, not likely to adversely affect," prior to finalization of this Opinion, we would not object. In either case, we do not anticipate that the Action is likely to jeopardize the continued existence of these species.

Table 46. Listed, proposed, and candidate CONUS and Alaska bird species in this Opinion.[56]

Table 46. Birds.xlsx

Crustaceans

The crustaceans taxa group includes the following orders: Amphipoda (amphipods); Anastroca (fairy shrimp), Decapoda (shrimp, crayfish), Isopoda (isopods), and Notostraca (fairy shrimp, tadpole shrimp). Most are aquatic and dwell in streams, vernal pools, or subterranean habitats. Alternatively, the Kauai cave isopod does not occupy waterbodies, but lives in moist subterranean environments, and is thus dependent to some degree on aquatic habitats. Several partially terrestrial species live in ephemeral habitats (i.e., vernal pools), and are adapted to survive periodic dry conditions (e.g., cyst phase of fairy shrimp and tadpole shrimp).

We anticipate all crustacean species will be affected either directly or indirectly, through dietary exposure. As we do not generally expect survivors where individuals are exposed, sublethal effects are not anticipated for crustaceans. For species in streams, wetlands and non-subterraneous aquatic habitats, we anticipate that drift or runoff from nearby applications may reach the species habitat as described in the *Effects of the Action* section. Effects to invertebrate prey or invertebrate constituents of detritus in the forage base were not considered in the R-Plot analysis, although it is reasonable to assume additional indirect effects may occur to these species via temporary reductions in prey resources after applications.

We anticipate that many of the crustaceans considered in this Opinion will experience high levels of mortality (up to 100%) from malathion uses where exposure occurs. For many narrow endemics, any mortality could result in species-level effects due to isolation and low population numbers. We also anticipate mortality will also be lower (i.e., up to approximately 10% of the species) for most of the cave species (i.e., Madison Cave isopod, Peck's cave amphipod, Kentucky cave shrimp, Lee County cave isopod, Hell Creek cave crayfish, Benton County cave crayfish) and a few others (i.e., Big Sandy crayfish, Pecos amphipod, diminutive amphipod). However, we expect that conservation measures incorporated in the Action will reduce exposure to malathion, and subsequently, effects to individuals and their prey items. Species-specific measures were developed for some species (e.g., Illinois cave amphipod), and for use in conjunction with general label changes for most species to further lower the amount of malathion entering habitats and reduce exposure where the species are expected to be found (see also Table 5 for a list of the species-specific measures and Appendix K for discussion of the species-

[56] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

specific conservation measures for the Illinois cave amphipod and for individual species discussions related to the general label changes)..

For cave-dwelling crustaceans, we do not anticipate that direct application or drift are likely pathways of exposure. Nonetheless, we anticipate all cave species could be exposed to pesticides via a variety of other pathways, in the absence of measures to avoid, minimize, or reduce exposure. Several studies cite that nutrients in cave ecosystems are derived from exterior sources (Poulson & White, 1969; Howarth, 1983; Culver, 1986) and, in particular, directly from organic material washed in or brought in by animals. Bats are usually the major source of these nutrients as well as the major source of contaminants via the transport mechanisms mentioned above (Kunz, 1982), although bats would not necessarily be found in subterranean habitat for all the listed cave crustaceans. Detritus within caves from decaying plant and animal matter (e.g., leaf litter fallen or washed in, animal droppings, and animal carcasses) serves as an additional source of contaminants (i.e., pesticides) for cave species. Terrestrial applications have been known to result in accumulation of pesticides in the detritus via agricultural practices, residential applications, and other activities over or near lava tubes, sinkholes, or other porous features near the surface of cave habitats. For example, the Kauai cave species have been reported to be particularly susceptible to pesticides because of their tendency to seek water sources (Howarth, 1983). In the absence of the conservation measures incorporated in EPA’s Action that will be implemented to avoid or reduce exposure and, thereby, minimize effects to these species, both terrestrial and aquatic cave species would have been anticipated to be exposed via groundwater contamination and/or accumulation from detritus or other sources. Pesticides may accumulate in cave waters and place aquatic species at risk (e.g., Alabama cave shrimp, Benton County cave crayfish, Kentucky cave shrimp, Peck’s cave amphipod, Madison cave isopod, Illinois cave amphipod) due to low or no flow of these waters. Food resources for these species (i.e., roots, other plant parts, invertebrates, other prey) may be reduced or eliminated due to pesticide use, resulting in effects to growth and survival of individuals and to populations of the species if food resources are already relatively scarce. However, we anticipate that exposure of malathion to these cave species will be reduced by implementation of conservation measures that are now incorporated into EPA’s Action. Thus, we do not expect that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild, as described in each of the species accounts for this taxon (see *Integration and Synthesis* summaries in Appendix K). The species included in this group and our conclusions for each are presented in Table 47. Additional information for these species is found in the *Status of the Species and Critical Habitat* (Appendix C) and the *Effects of the Action* sections. Island crustaceans are discussed in the *Hawaii and the Pacific Islands Integration and Synthesis* section of the Opinion.

Table 47. Listed, proposed, and candidate CONUS Crustacean species addressed in this Opinion.[57]

Table 47.
Crustaceans.xlsx

Fish

The fish species in this taxa group include a wide variety of families: sturgeon (Acipenseridae), cavefish (Amblyopsidae), a silverside (Atherinidae), suckers (Catostomidae), sunfish (Centrarchidae), sculpins (Cottidae), dace, minnows, and other cyprinids (Cyprinidae), goby (Gobidae), madtoms (Ictaluridae), smelt (Osmeridae), darters and logperch (Percidae), mosquitofish and topminnows (Poeciliidae), and salmonids (Salmonidae). Most are freshwater species, with a few species of sturgeon, salmonids, and smelt using freshwater, estuarine, and/or marine waters at different stages in their life cycles.

We do not anticipate the Action would result in adverse effects to the Scioto madtom, San Marco gambusia, or Maryland darter. While these species are currently listed under the ESA, they were recommended for delisting due to extinction in the Service's latest 5-Year Status Reviews (2014, 2018, and 2021, respectively). Because it is not likely that these species are extant in the wild, and there are no captive individuals, we do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of the species.

For the remaining species, as described previously, we used R-Plots to assess the risk to the species in this taxa group (see *Effects of the Action* section and the R-Plots in Appendix M). Additionally, as with bivalve (mussel) species above, we divided the species into two subgroups for analysis (Appendix K). In Subset 1, we included a detailed presentation of our analysis of risk related to overlap and usage. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we present results from the R-Plot analysis (see Appendix M for R-Plots), use and usage data, and our determination as to whether the proposed action is likely to jeopardize the continued existence of 38 species within this taxon.. For Subset 2, we considered generalized risk to the species based on the risk to species in Subset 1 and the assumptions related to aquatic habitat bins (as described in more detail in Appendix K). All species in Subset 2 are anticipated to have low usage (<5% usage within the range per year; usage indicating how the pesticide has been applied in the past to the use sites based on available data sources) and are presented in a streamlined, abbreviated manner for this Opinion. For Subset 2, we completed a group conclusion, but only included a list of species names and corresponding aquatic habitat bins for

[57] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

the species. More detail on the approach for the two subsets of species and usage categories is provided in the Fish Integration and Synthesis summaries (Appendix K).

For all use types, we anticipate, in the absence of implementation of conservation measures incorporated in EPA's Action that would reduce exposure and, thereby, minimize effects, that use of this pesticide as allowed by the labels would kill many individuals of most species directly exposed per application, although this varies by waterbody type and use type as described previously in the *Effects of the Action* section. For example, for species with some or all life stages in small flowing or static waterbodies, mortality effects are generally likely to be higher than those in larger static water bodies, i.e., larger lakes and ponds. Effects are somewhat more variable for larger flowing waterbodies as exposures in large streams and rivers may be influenced by applications throughout the watershed. Given the information we have for this taxa group, we anticipate variable degrees of effects, although most uses, particularly near smaller waterbodies, are likely to result in high levels of mortality where exposure occurs. Because malathion has such high acute lethal toxicity to fish, we expect mortality to be the predominant effect, although sublethal effects may occur in surviving individuals. For species that prey on invertebrates or fish, we anticipate contamination of or reduction in their forage base as well, reducing the suitability and availability of food items. Reduced food availability could result in substantial effects on individuals and populations of a species, particularly in habitats where food resources may already be relatively scarce. However, based on uses overlap with the species range, and consideration of usage data (as described in the *Effects of the Action* section), in many cases, the likelihood of exposure is very low. Where exposure was predicted to be greater, we find that the conservation measures incorporated in EPA's Action and identified in the analysis for each species, will reduce exposure and effects to these species.

We expect general label conversation measures (rain restrictions, aquatic habitat buffers, residential use label restrictions, and reduced application rates and numbers of applications) and species-specific measures will reduce exposure to malathion, and subsequently, effects to individuals and their prey resources. Conservation measures are aimed at reducing the amount of malathion runoff and spray drift that enter into sensitive habitats (e.g., species habitat, aquatic environments). For example, by placing a 48-hour rain restriction on agricultural applications, malathion has the ability to degrade after application (e.g., by hydrolysis, other processes) prior to any rain/runoff events, thus minimizing malathion runoff into aquatic habitats and decreasing exposure to listed species. Increasing application buffers reduces the amount of malathion that drifts off target and subsequently into non-target environments. In addition, changes to residential labels limits applications to spot treatments and reduces the number of applications per year (2-4), significantly decreasing the overall amounts of malathion used in residential areas and resulting amounts of runoff and drift. Additional reductions in the number of applications and rates allowed for certain crops (e.g., corn, vegetables and ground fruit) further reduces the amount of malathion used in agricultural settings, thereby decreasing potential exposure the species. Considered together, these conservation measures and species-specific conservation measures (e.g., application avoidance areas or coordination with Service field offices) substantially reduce exposure to these species and their prey resources and therefore minimizes overall risk and adverse effects to the species.

For species that inhabit springs, streams, vernal pools and other wetlands, we anticipate exposure from both application and drift. A few species in this taxa group live in caves or other subterranean environments. As with other cave species described in previous sections, we do not expect that direct application or drift are likely pathways for cave fish when they are in subterranean habitats. However, these pathways would be expected to result in runoff to waterbodies that enter caves or infiltrate through porous substrates into subterranean habitats. Overall, we anticipate cave fish species could be exposed to pesticides via a variety of pathways, both directly via exposure to the pesticide and through effects to their prey base, as described previously (for cave species and in Appendix K). Conservation measures designed to reduce malathion entering waterways are anticipated to lower exposure to these species, and thus subsequent effects.

We do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild, as described in each of the species accounts for this taxon. Additional information for these species is found in the *Status of the Species and Critical Habitat* (Appendix C) and the *Effects of the Action* sections. *Integration and Synthesis* summaries are provided for each species (Appendix K). The species included in this group and our conclusions for each are presented in Table 48.

Table 48. Listed, proposed, and candidate FISH species addressed in this Opinion.[58]

Table 48. Fish.xlsx

Insects

This taxa group includes several different orders of insects, including Colepterans (beetles), Dipterans (flies), Hemipterans (true bugs), Hymenopterans (bees), Leopidopterans (butterflies and moths), Odenates (dragonflies and damselflies), and Orthopterans (grasshoppers). These species exhibit a variety of life history characteristics. All are generally short-lived, although some may live multiple years (e.g., at a larval stage). Some adult life stages may be very short and can be as brief as a few weeks. A majority of the insect species considered in this Opinion are terrestrial. As a group, they inhabit numerous habitat types within the action area, depending on the species' life history requirements. The terrestrial species are generally capable of flight, at least in adult life stages, although some adults are not able or naturally expected to move large distances and are restricted to small habitat patches separated by unsuitable habitat.

A few listed insect species have aquatic life stages. Some aquatic insects are fully aquatic, such as riffle beetles. Others have both aquatic and terrestrial life stages, including dragonflies,

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damselflies, stoneflies and similar species. For these species, juvenile and subadult (i.e., eggs, larvae, pupae) individuals generally live in aquatic habitats, while the adult life stage either exclusively or primarily occupies terrestrial habitats, depending on the species.

As described previously, we used R-Plots to assess the risks to the species in this taxa group (see *Effects of the Action* section and R-Plots in Appendix M). For all malathion uses, we anticipate usage of this pesticide as allowed by the labels would kill large proportions of individuals of most terrestrial and aquatic species directly exposed per application. For fully aquatic insect species (e.g., Ash Meadows naucorid) or for terrestrial insect species with aquatic life stages (e.g., dragonflies, stoneflies), this can vary by waterbody type and use type as described previously in the *Effects of the Action* section. For example, for species with some or all life stages in small flowing or static waterbodies, mortality effects are generally likely to be higher than those in medium or large flowing water bodies because smaller flowing or static water bodies concentrate malathion and malathion can reach levels where adverse effects will be observed. Effects are somewhat more variable for larger static waterbodies, and they are provided at a species-specific level in the integration and synthesis for each species.

Given the information we have for this taxa group, we anticipate variable degrees of effects, although all uses are likely to result in high levels of mortality where exposure occurs, particularly in the absence of effective measures to avoid, minimize, or reduce such exposure, because malathion is an insecticide developed specifically to kill insects. As all or large numbers of individuals exposed to the pesticide will die across most uses and habitat types, we do not generally anticipate there will be surviving individuals to experience sublethal effects. For mosquito adulticide use, however, mortality effects range from low to high based on R-Plots results, and where there are survivors, sublethal effects to growth, reproduction, behavior and sensory function are more likely. For species that prey on other invertebrates, we anticipate contamination of or reduction in their forage base as well, reducing the availability of food items. Reduced food availability could result in substantial effects on individuals and populations of a species, particularly in habitats where food resources may already be relatively scarce.

For species that inhabit springs, streams, vernal pools and other wetlands, we anticipate exposure from both applications on use sites and spray drift. A few beetles in this group live at least partially in subterranean habitats, and many of the considerations related to cave arachnids and other subterranean species described above apply to these species (ground beetles (Carabidae), mold beetles (Pselaphidae), a dryopid beetle (Dryopidae), and a riffle beetle (Elmidae)) as well. As with the cave species described in previous sections, we do not anticipate that direct application or drift would be likely pathways for insects when they are in subterranean habitats. However, we anticipate pathways for exposure from runoff into waterbodies that enter caves or infiltration through porous substrates into subterranean habitats. Overall, we anticipate cave and other subterranean insect species will be affected by pesticides through a variety of pathways, both directly from exposure to the pesticide and from effects to their prey base, as described previously.

For all insect species, however, we expect that conservation measures will reduce exposure to malathion, and subsequently, effects to individuals. Where general label changes were not adequate to reduce exposure, species-specific measures were developed to lower the amount of malathion entering habitats where species are expected to be found. For example, the Miami tiger beetle occurs in small patches of pine rockland habitat south of Miami, Florida. General conservation measures that will reduce exposure to this species include residential use label changes, as the species can occur in proximity to developed areas. This measure restricts the method and frequency of application, by limiting use to spot treatments only and reducing the extent of area which can be treated by as much as 75% or more from modeled values. In addition, to reduce exposure further from agricultural and mosquito control uses, species-specific conservation measures were developed. Applicators of mosquito control products, where feasible, cannot apply malathion within the species range plus 200 feet, to prevent spray drift from adjacent applicators from entering the range. Agricultural applicators within the species range plus 200 feet must follow one of two measures to decrease exposure to this species: 1) apply malathion only when wind is blowing away from pine rockland habitat or 2) use specific buffers from pine rockland habitat based on the application rate being used (for complete discussion of measures for this species and other insects, see the *Insects Integration and Synthesis* summary in Appendix K). Thus, we do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild, as described in each of the species accounts for this taxon.

Additional information for these species is found in the *Status of the Species and Critical Habitat* (Appendix C) and the *Effects of the Action* sections. *Integration and Synthesis* summaries are provided for each species (Appendix K). The species included in this group and our conclusions for each are presented in Table 49. Island insects are discussed in the *Hawaii and the Pacific Islands Integration and Synthesis* section of the Opinion.

Table 49. Listed, proposed, and candidate CONUS Insect species addressed in this Opinion.[59]

Table 49. Insects.xlsx

Mammals

All mammals are vertebrate endotherms distinguished from other animal taxa by possessing hair or fur and mammary glands for milk production in females. The mammals covered in this Opinion fall into two general categories, terrestrial and marine. The species included in this group and our conclusions for each are presented in Table 51.

[59] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = (May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

Terrestrial Mammals

Terrestrial mammals include species from the orders Carnivora (carnivores), Chiroptera (bats), Eulipotyphla (shrews), Lagomorpha (rabbits), and Rodentia (rodents). Mammal species exhibit a variety of life history characteristics. Some species hibernate, such as the Virginia big-eared bat, while others like the northern long-eared bat migrate. Some species live in underground burrows, such as kangaroo rats and beach mice, while others spend most of the day up in trees, like the ocelot. Species ranges vary from only one location (e.g., riparian brush rabbit) to only a few locations (e.g., Southeastern beach mouse), but many states for others (e.g., the gray bat). Diet varies greatly as well. Some species are carnivores like the ocelot; the Buena Vista Lake ornate shrew and many bats are insectivores; pocket gophers and the Columbia Basin pygmy rabbit are herbivores; and other species, like beach mice, consume insects and vegetation.

Effects to mammals from malathion uses vary depending on the amount of overlap with malathion uses, anticipated usage in the species' range, specific life history traits, and dietary items consumed. In general, we anticipate most effects will be from loss of food or prey items and sublethal effects from consumption of contaminated dietary items. We expect the use of malathion as a mosquito adulticide will have the biggest impact on mice species due to the large reduction in food resources (i.e., terrestrial invertebrates) on use sites. Loss of significant food resources can lead to high mortality from starvation or a reduction in growth and reproduction. Sublethal effects to growth, reproduction, and behavior can result in population declines as well. However, we anticipate recently developed conservation measures that have been incorporated as part of EPA's Action will likely reduce exposure to malathion, and subsequently, effects to individuals of species and prey items that are susceptible to the effects of malathion. Species-specific measures were developed for several species (e.g., Alabama beach mouse) and for use in conjunction with general label changes for most species to further lower the amount of malathion entering habitats and reduce exposure where the species are expected to be found (see also **Error! Reference source not found.** for a list of the species-specific measures and Appendix K f or discussion of the species-specific conservation measures for the several of the beach mice and Preble's meadow jumping mouse and for individual species discussions related to the general label changes).

As described in each of the species accounts for this taxon, we do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild. Additional information for these species is found in the *Status of the Species and Critical Habitat* (Appendix C) and the *Effects of the Action* sections. *Integration and Synthesis* summaries are provided for each species (Appendix K), with the exception of the species discussed further below. The CONUS and Alaska species and marine mammals included in this group and our conclusions for each are presented in the table at the end of the mammal section below. Island mammals are discussed in the *Hawaii and the Pacific Islands Integration and Synthesis* section of the Opinion.

Select Mammal Species – MagTool/Qualitative Assessment

Terrestrial MagTool outputs and our assessment of mosquito adulticide use derived using the UDLs provided in the BE indicated that there would be low effects to the CONUS mammal species listed in Table 50 based on all labeled malathion uses across the species ranges. We did not find it necessary to continue with additional refinements to the overlap and UDLs (e.g., Federal land, pasture, pine seed orchards) and usage data, as described in the *Exposure* section. We would expect continuing with refinements to our assessment for these species would find effects that are the same or lower than those in our initial assessment of use authorized under the label (i.e., maximum allowable use). A summary of anticipated effects to each of these species is provided in Table 50.

No mortality is anticipated for any of these mammals, except for the Canada lynx, red wolf, Sonoran pronghorn, Peninsular bighorn sheep and silver rice rat, which could each experience mortality of less than 1% from dietary exposure by consuming contaminated vertebrate prey (Canada lynx, red wolf and silver rice rat), or leaves and grass (Sonoran pronghorn and Peninsular bighorn sheep). About 2% of Canada lynx and 1% of silver rice rats could experience sublethal effects from eating birds, and 4% of Mexican long-nosed bats could experience sublethal effects from dermal exposure. It is possible, but unlikely, that some of the other mammal species would experience sublethal effects. These levels of mortality and sublethal effects are based on labeled uses across the species ranges. We do not anticipate malathion will be used everywhere and to the degree the labels allow, and the percentages of mortality and sublethal effects would be the same or lower with MagTool outputs and our assessment of mosquito adulticide based on refined UDLs, thus actual effects are anticipated to be lower than the percentages discussed herein and summarized in Table 50.

All of these mammals could experience some loss of food items, as summarized in Table 50. However, due to the varied diets and food preferences of these species, we anticipate only low levels of adverse effects to these species from effects to dietary items due to the availability of alternate and, for some species, more preferable food resources. For example, the Canada lynx predominantly preys upon the snowshoe hare, but also eats grouse and a variety of other small mammals and fish. The small reduction in birds, which is not the primary food source of the lynx, is not likely to result in appreciable effects to the Canada lynx. Many of the mammal species eat terrestrial invertebrates, which are anticipated to experience mortality when exposed to malathion.

There are no restrictions on where malathion can be used for mosquito adulticide, so the effects shown in Table 50 reflect 100% overlap with species ranges, and thus 100% loss of terrestrial invertebrate prey for species that consume them. However, we do not anticipate malathion will be used everywhere, and we expect alternative food resources will remain available for all of these mammals. Primary food items tend to be vertebrates or plants for most of these species rather than invertebrates, which are the most susceptible to mortality from malathion exposure. Losses of vertebrate prey are anticipated to be at low levels, and we only anticipate low level effects to plants from reduced growth. Some mammal species, such as the Mexican long-nosed bat, primarily forage on plants. The bat feeds on nectar and pollen at night from at least 49 species (primarily Agave spp.), while supplementing their diet to some degree with insects (USFWS, 2018). There may be a slight decrease in growth of night-blooming plants and loss of insects across a portion of their range where usage occurs, but we would not expect a reduction in foraging opportunities for the bats due to the low effects on plants and high mobility of the bats that would allow them to access alternate foraging sites for insects if needed. In summary, we do not anticipate that the limited reduction in prey and plant growth from exposure to malathion will lead to adverse effects to foraging behavior or insufficient food resources that would appreciably reduce the likelihood of both the survival and recovery of any of these species.

After considering the current status of the species, the environmental baseline for the action area, the effects of the Action (based on our initial assessment), and the cumulative effects, we concluded that any changes to reproduction, numbers or distribution of the affected listed species are not likely to reduce appreciably the likelihood of both the survival and recovery of the species listed in Table 50. Therefore, it is the Service's biological opinion that the species listed in Table 50 are not likely to be jeopardized by the Action.

Table 50. Summary of effects from the Terrestrial MagTool and assessment of mosquito adulticide using original UDLs for mammal species with low anticipated risks.

Table 50. Summary of Effects MagTool.xls

Wood Bison

The wood bison occurs in Wood Buffalo National Park and in other areas of Alaska through the establishment of several herds. The foraging habitats most favored by wood bison are grass and sedge meadows, typically interspersed among tracts of coniferous forest, stands of poplar or aspen, bogs, fens, and shrublands. Meadows typically represent 5 to 20 percent of the landscape occupied by wood bison. Wood bison travel between favored foraging habitats along direct routes including established trails, roads, river corridors, and transmission lines (Reynolds et al. 1978, p. 587; Mitchell 2002, p. 50 as cited in 77 FR 26191, 2012). While malathion use sites overlap with portions of the species range, the habitats used by this species are not typically agricultural or non-agricultural sites where a high degree of malathion usage would be anticipated. The risk to the wood bison from malathion is anticipated to be low. Based on MagTool outputs and our assessments for similar large mammals, mortality is not anticipated and sublethal effects are possible, but unlikely. This species is an herbivore. While some reduction in plant growth could occur, the effects would be small and we would not expect changes in foraging behavior or available food as the species is large and wide-ranging (i.e., we anticipate only localized reductions in plant growth, which would minimally affect a large, mobile species like the wood bison).

In conclusion, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of the wood bison at the scale of the species. Therefore, after reviewing the current status of the species, the environmental baseline for the action area, the effects of the Action, and the cumulative effects, it is the Service 's biological opinion that the registration of malathion, as proposed, is not likely to jeopardize the continued existence of the wood bison.

Marine Mammals

All species of marine mammals are protected under the Marine Mammal Protection Act (MMPA), and some are also protected under the ESA and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The Service and NMFS share Federal jurisdiction for marine mammals, with NMFS having lead responsibility over whales, dolphins, porpoises, seals and sea lions, and the Service having lead responsibility over the remaining marine mammals. The marine mammals under Service jurisdiction that would be affected by the Action were discussed qualitatively in the BE (See Chapter 4 of the BE). While several mammals were addressed in the *Concurrence* section preceding this Opinion, two species, the West Indian manatee (*Trichechus manatus*) and Southern sea otter (*Enhydra lutris nereis*), are considered in this Opinion and discussed below. For information on the status, vulnerability, environmental baseline and cumulative effects for these species, see Appendix K.

Manatees are aquatic herbivores that consume algae and aquatic plants in fresh and marine water. West Indian manatees (*Trichechus manatus*) can be found throughout the southeastern United States. The sea otter (*Enhydra lutris*) is the largest member of the family Mustelidae and the smallest species of marine mammal in North America. Sea otters are also primarily aquatic but spend some time in terrestrial habitats. They consume invertebrates and fish. In the estuarine and marine waters where these species occur, we would anticipate routes of exposure to include runoff from treated areas into aquatic habitat and impacts via their forage base. When Southern sea otters (*Enhydra lutris nereis*) occupy terrestrial habitats, exposure routes may include inhalation and dermal interception of spray droplets at time of application. That said, we anticipate effects to West Indian manatees and Southern sea otters from the Action are mostly like to occur from secondary exposure to malathion via their diet (aquatic plants, invertebrates, or fish) while they are in estuaries and near shore and off-shore habitats, rather than mortality or sublethal effects from direct exposure to malathion.

According to the qualitative analyses in the BE, there is a great deal of uncertainty surrounding the EECs for listed mustelids (such as sea otters) and manatees. Thus, additional dilution (resulting in decreased toxicity), uncertainty from mixing, or the likely insufficient physical size or representativeness of surrogate modeled aquatic habitat bins contribute to our uncertainty in the effects outcomes from aquatic dietary sources. EECs for water bodies located near treated fields are most likely to exceed sublethal and mortality thresholds for prey items, but again, these are not anticipated to occur near intertidal or subtidal estuarine or marine environments. For more information see the marine mammal qualitative effects analyses in the BE (Chapter 4).

In summary, we agree with the assessment in the BE and do not anticipate that direct effects from exposure to malathion would be likely in estuarine areas, as malathion is generally not expected to accumulate in prey or forage items, and because mammals, even when exposed, typically metabolize malathion readily. Sublethal effects anticipated are primarily behavioral responses to AChE inhibition, as described in EPA's BE. We do not anticipate exposure resulting in mortality to either manatees or Southern sea otters.

We anticipate sublethal effects over the duration of the Action, particularly in the absence of adequate conservation measures, but do not expect that these effects will affect significant numbers of individuals. In conclusion, based on analyses in the BE, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of the West Indian manatee or the Southern sea otter at the scale of the species.

Therefore, after reviewing the current status of the species, the environmental baseline for the action area, the effects of the Action, and the cumulative effects, it is the Service 's biological opinion that the registration of malathion, as proposed, is not likely to jeopardize the continued existence of the West Indian manatee or the Southern sea otter.

Table 51. Listed, proposed, and candidate CONUS, Alaska and Marine Mammal species addressed in this Opinion.[60]

Table 51.
Mammals.xlsx

Reptiles

We have separated this section into two subsections: (1) terrestrial and freshwater/estuarine reptiles, and (2) sea turtles. The first subsection includes a brief narrative on terrestrial and freshwater/estuarine reptiles followed by a summary of conclusions table (Table 52) for this subsection. The sea turtle subsection follows.

Reptiles (Terrestrial and Freshwater/Estuarine)

The reptile taxa group includes species from the orders Crocodilia (crocodiles), Squamata (lizards and snakes), and Testudines (turtles). Reptiles are tetrapod vertebrates, creatures that either have four limbs or, like snakes, are descended from four-limbed ancestors. Reptiles are ectothermic, relying on external heat sources (e.g., sunlight, warm surfaces) to regulate their body temperatures. Most reptiles are oviparous (egg layers; e.g., Alameda whipsnake, American crocodile, Plymouth redbelly turtle), although several species of squamates are viviparous (give live birth; e.g., giant garter snake). Reptiles do not have an aquatic larval stage. For those species that are oviparous, eggs usually have a soft leathery shell, although some eggs may have a hard shell. Eggs are usually laid on land in a nest covered with a layer of soil or vegetative debris or laid in some form of burrow. Most reptiles do not care for eggs once they have been deposited. However, American crocodiles for example, will guard their nests until the eggs hatch.

Reptiles can be found in a variety of habitats; from sea level to mountainous terrain. Terrestrial and freshwater/estuarine reptiles can be found living along coastlines in mangrove swamps (e.g., American crocodile), in freshwater streams (e.g., yellow-blotched map turtle) and ponds or

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wetlands (e.g., bog turtles), to forests (e.g., Louisiana pine snake) and to drier environments including creosote bush scrub (e.g., Mojave Desert tortoise) and wind-blown sandy environments (e.g. Coachella Valley fringe-toed lizards). Most listed reptiles have relatively small current ranges and are limited to one to a few counties within a single state (e.g., blue-tailed mole skink), while a few tend to have larger ranges (e.g., gopher tortoise). As a whole, reptiles face numerous threats including habitat destruction, fragmentation, land-use changes, changes in habitat suitability (e.g., timber practices, invasive species), disease, predation, loss of natural processes (e.g., fire suppression), and climate change. In addition, chemicals and pollution can alter the suitability of a species environment (e.g., water quality), and can affect the species itself by reducing its survival and reproduction. Clean air and clean water, and abundant, diverse and healthy habitats are essential for listed reptile species to survive and recover in the wild.

Use areas for malathion overlap with and/or occur adjacent to habitats used within the ranges of nearly all of the listed reptile species in this consultation. Exposure to this pesticide can result in direct mortality, mortality due to the consumption of contaminated food resources, sublethal effects affecting growth, reproduction and behavior for individuals that survive exposures, and the loss of important food resources that can lead to starvation, reproductive failure, site abandonment or other detrimental effects. The effects can vary greatly by species depending on the degree of overlap between pesticide uses and the species range, usage patterns, the species' preferred habitats, and the diet of the species in light of how their food resources may be affected. Reptiles have a highly varied diet, from those species that are generally herbivorous (e.g., desert tortoise) to those species that eat primarily aquatic and terrestrial invertebrates, fish, and/or small mammals. Crocodiles are opportunistic feeders and will eat whatever they can catch, including snakes, fish, crabs, small mammals, turtles, and birds. These food resources are susceptible to contamination by pesticides that can then be passed on to reptiles that consume them, as well as direct adverse effects that can in turn reduce the food supply available to reptiles. The anticipated exposures and pesticide effects on reptiles and their food resources, as well as the status of the species and factors related to their vulnerabilities, were considered when evaluating the effects of the Action on each reptile species.

As described previously in the *Analysis for Animal Species* section above, we analyzed the species vulnerability, the risk to the species (exposure and response) and the amount of anticipated usage within the species range for the terrestrial and freshwater/estuarine reptiles. For the reptiles, the risk analysis was based primarily on MagTool outputs. The majority of reptiles have high vulnerabilities due to small and isolated populations; they are limited to one or a few populations, one or more populations are declining, and they face continuing threats such as habitat loss and exposure to environmental contaminants. Anticipated effects from labeled uses varied from low effects (e.g., low mortality, sublethal effects) to high (e.g., high mortality to prey resources) across the species range, which includes direct effects and indirect effects (in risk assessment terminology, as described previously). Such effects can result from direct contact with the chemical or from consuming contaminated food resources which would lead to mortality or sublethal effects. Additionally, effects that affect the species food resources would result in reduced food availability. We anticipate impacts to reptile species via a reduction in their food resources will also vary from low to high levels. Usage data also varies, from extremely low levels (<1%) to high levels (19%); however, we anticipate most reptile species will have either low or medium amounts of usage that overlap with their ranges. Where effects were anticipated to reptiles based on use and usage information, conservation measures are expected to reduce exposure to malathion, and subsequently, effects to individuals.

We expect general label conversation measures (rain restrictions, aquatic habitat buffers, residential use label restrictions, and reduced application rates and numbers of applications) and species-specific measures will reduce exposure to malathion, and subsequently, effects to individuals and their prey resources. Conservation measures are aimed at reducing the amount of malathion runoff and spray drift that enter into sensitive habitats (e.g., species habitat, aquatic environments). For example, by placing a 48-hour rain restriction on agricultural applications, malathion has the ability to degrade after application (e.g., by hydrolysis, other processes) prior to any rain/runoff events, thus minimizing malathion runoff into aquatic habitats and decreasing exposure to listed species. Increasing application buffers reduces the amount of malathion that drifts off target and subsequently into non-target environments. In addition, changes to residential labels limits applications to spot treatments and reduces the number of applications per year (2-4), significantly decreasing the overall amounts of malathion used in residential areas and resulting amounts of runoff and drift. Additional reductions in the number of applications and rates allowed for certain crops (e.g., corn, vegetables and ground fruit) further reduces the amount of malathion used in agricultural settings, thereby decreasing potential exposure the species. Considered together, these conservation measures and species-specific conservation measures (e.g., application avoidance areas or coordination with Service field offices) substantially reduce exposure to these species and their prey resources and therefore minimizes overall risk and adverse effects to the species.

As described in each of the species accounts for this taxon, we do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild,. Additional information for these species is found in the Status of the Species and Critical Habitat (Appendix C) and the *Effects of the Action* sections. *Integration and Synthesis* summaries for species in the CONUS reptile taxa group can be found in Appendix K. The reptile species included in this group and our conclusions for each are presented in Table 52.

Select Reptile Species – Qualitative Analysis

We do not anticipate mortality or sublethal effects to the Alabama red-bellied turtle, Plymouth redbelly turtle, or the giant garter snake for any malathion use as described on labels. Effects to plants and prey resources are not anticipated for the Alabama red-bellied turtle or the giant garter snake. While Plymouth red-bellied turtles may see a decline in available aquatic invertebrates as a food source, aquatic invertebrates are not the primary food source of the turtle and therefore, loss of this alternative food source would not lead to a reduction of survival or reproduction for the species in the wild. For these three species, we do not anticipate any adverse effects that would arise to the level of appreciably reducing the likelihood of survival and recovery of these species in the wild.

<u>Sea Turtles</u>

The Service shares Federal jurisdiction for sea turtles, with the Service having lead responsibility on the nesting beaches and NMFS on the marine environment. Therefore, the following conclusions are only for sea turtles while in terrestrial habitats (i.e., on beaches). The species we consider in this section include:

- Green Sea Turtle, Central North Pacific DPS (*Chelonia mydas*)
- Green Sea Turtle, Central South Pacific DPS (*Chelonia mydas*)
- Green Sea Turtle, Central West Pacific DPS (*Chelonia mydas*)
- Green Sea Turtle, East Pacific DPS (*Chelonia mydas*)
- Green Sea Turtle, North Atlantic DPS (*Chelonia mydas*)
- Green Sea Turtle, South Atlantic DPS (*Chelonia mydas*)
- Hawksbill Sea Turtle (*Eretmochelys imbricata*)
- Kemp's Ridley Sea Turtle (*Lepidochelys kempii*)
- Leatherback Sea Turtle (*Dermochelys coriacea*)
- Loggerhead Sea Turtle, North Pacific Ocean DPS (*Caretta caretta*)
- Loggerhead Sea Turtle, Northwest Atlantic Ocean DPS (*Caretta caretta*)

All sea turtles use beaches to lay their eggs and at least one species (green sea turtles in Hawaii) uses beaches to bask. As a result, eggs, hatchlings, and adults may be exposed to this pesticide from spray drift transport from treatment sites that are adjacent to nesting or basking sites. Exposure routes of concern include inhalation and dermal interception of spray droplets on the period of the application. Since sea turtles do not forage while on land, dietary exposure while in terrestrial habitats is not expected. For more information, see the sea turtle qualitative effects analyses in the BE (Chapter 4).

Dermal exposure could occur to adult females while laying eggs, to adults while basking, to eggs while in the nest, or to hatchlings as they leave the nest and move to nearby open water. If exposed to formulated products and tank mixtures containing this pesticide, sea turtles may experience toxicity effects. However, the risk of dermal exposure occurring to adults and hatchlings is low due to the short time these species are on land, with the exception of Hawaiian green sea turtles, which are known to bask on beaches for less than an hour to upwards of 8 hours per day (Whittow & Balazs, 1982). Such behavior was originally thought to be limited to the northwest Hawaiian Islands where the risk of exposure would be negligible. However, observations are now frequently made of basking green sea turtles on both Oahu and Hawaii. Similarly, arribadas, or nesting aggregations, of Kemp's ridley sea turtles may last for several days, but an individual female sea turtle is typically on the beach for just a few hours and for one to three nesting events per year once she reaches sexual maturity at around twelve years of age. Unlike other species of sea turtles that nest at night, Kemp's ridley sea turtle nest primarily during the day, which would incrementally increase their likelihood of exposure to daytime treatments, but limit nighttime exposures when few pesticide applications would be anticipated. One exception to this assumption would be for mosquito adulticide applications, which may occur between dusk and dawn, or at other times, depending on the mosquito species being targeted. However, we anticipate the risk of dermal and inhalation exposure to adult sea turtles in any of these cases would remain low given the general remoteness of field applications of pesticides versus sea turtle nesting (or basking beaches in the case of Hawaiian green sea turtles) and the brief duration of terrestrial exposure for all species of nesting sea turtles (i.e., less than a day per nesting event and for 1 to 10 events per year) (USEPA, 2017).

Similarly, hatchlings crawl immediately to the water to avoid predators and swim to offshore areas where they reside for several years and would be subject to a low risk for dermal and other forms of exposure (e.g., inhalation) while they are on land. Most nesting adults and hatchlings move during the night when the risk of dermal or inhalation exposure from spray drift is the lowest because most pesticides are applied during the day with the exception of mosquito adulticide applications, as noted above.

Sea turtle eggs have very porous shells to allow the exchange of oxygen and carbon dioxide. Pesticides have been documented to travel through the permeable sand which covers nests and into eggs. For example, organochlorine pesticides, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons have been found in loggerhead sea turtle eggs (Alam & Brim, 2000). Therefore, the greatest risk to sea turtles in terrestrial habitats from the Action appears to be exposure of eggs to malathion. Sea turtle eggs are vulnerable to exposure during their incubation period, which is up to two months.

In summary, we understand that malathion will not be used on all use sites and at the maximum rates allowed by the label in any given year; however, we do anticipate that sea turtles will be exposed to the chemical over the course of the 15-year registration period. We anticipate the effects to adult sea turtles exposed to malathion will be minimal based upon general toxicological information on effects to reptiles and the life history characteristics of the turtles. In general, mortality to adult turtles is not anticipated unless there is an incidence of direct spray on use sites; however, we do not anticipate that adult sea turtles would utilize these areas since they are only found on sandy beaches and for limited amounts of time. While mosquito adulticide applications could occur within these habitats, direct spray or drift from these applications is not anticipated to cause mortality to adult turtles. Additionally, since sea turtles do not forage on land, we do not anticipate sublethal effects or effects to their prey resources. As above, effects to juveniles (sub-adults) is not within our scope as these are entirely marine. While hatchlings could be exposed to the chemical, the limited amount of time that hatchlings spend moving from nest to ocean is very short in duration and thus would minimize any exposure. We anticipate there is a low risk for sea turtle eggs to be exposed to malathion. While we have no specific data on malathion presence in sea turtle eggs, a combination of proximity to use sites, spray drift from agricultural or non-agricultural uses, mosquito adulticide applications, and timing (i.e. occurring during egg incubation) could result in exposure to buried sea turtle eggs, as other pesticides have been documented in sea turtle eggs. In general, malathion has less residual time, degrades more rapidly in the environment, and does not accumulate in tissues as organochlorines or PCBs do. Since sea turtles utilize sandy beaches exclusively for nesting, and in the case of green sea turtles in Hawaii, for basking, actual exposure is likely limited to spray drift from agricultural and non-agricultural use sites and mosquito adulticide applications. Contamination of nesting/basking beaches from spray drift or mosquito adulticide applications would be lower in concentration than exposure from actual use sites. Due to the lower concentrations (spray drift) and low application rates (ultra-low volume mosquito adulticide applications), degradation rates and limited absorption into the buried nest, we anticipate that the amount of chemical that would actually reach the sea turtle eggs would be low. Therefore, while there may be some low level of exposure of small numbers of individual sea turtles (e.g., small numbers of hatchlings exposed to spray drift in developed areas for mosquito adulticide) over the duration of the Action, we expect that such low levels of exposure would not likely result in mortality or effects to growth and reproduction. We do not anticipate species-levels effects will occur.

In conclusion, based on the life histories of the above-listed sea turtles and our analysis described above, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of the above-listed sea turtles. After reviewing the current status of the species, the environmental baseline for the action area, the effects of the proposed registration of malathion, and the cumulative effects, it is the Service's biological opinion that the registration of malathion, as proposed, is not likely to jeopardize the continued existence of any of the above-listed sea turtles.

Table 52. Listed, proposed, and candidate Sea Turtle and CONUS Reptile species addressed in this Opinion.[61]

Table 52. Reptiles.xlsx

Snails

This taxa group is divided into two subsections: terrestrial and aquatic snails. Snail species found only in the Pacific Islands are in *Pacific Island* section below (following the animal species taxa group subsections).

<u>Effects to Terrestrial Snails</u>

We reviewed seven listed species of terrestrial snails that occur within the contiguous United States. The life history and distribution information vary substantially by species. Terrestrial snails inhabit a range of habitat types, including coastal dunes, talus outcrops and cliff faces, and trees of hardwood hammocks. Diets vary but include lichens, fungal mycelia, fallen leaves, and other detritus. For additional information, see the *Status of the Species* for these species and *Environmental Baseline*. Relevant life history traits are discussed below for a general understanding of ecology of each species. We used R-Plots to determine the effect of malathion for each species (see *Effects of the Action* – R-Plots).

In general, we do not anticipate effects to terrestrial snails as a result of exposure to malathion[62]. Data available from toxicity tests for aquatic snails indicate that these species have relatively

[61] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

[62] This is a change from our April 2021 draft biological opinion, where we used a less related and likely more sensitive invertebrate as a surrogate for terrestrial snails. For our revised analysis in this Opinion, we reconsidered the snail toxicity data and determined that adequate data were available to draw conclusions about the sensitivity of

higher tolerance to malathion and have a low risk of mortality at estimated environmental concentrations.

Thus, we do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild, as described in each of the species accounts for this taxon. Additional information for terrestrial and aquatic snails is found in the *Status of the Species and Critical Habitat* (Appendix C) and the *Effects of the Action* sections. *Integration and Synthesis* summaries are provided for each species (Appendix K). The species included in this group and our conclusions for each are presented in Table 53.

<u>Effects to Aquatic Snails</u>

We reviewed listed, proposed and candidate species of freshwater aquatic snails that occur within the contiguous United States. The life history and distribution information vary substantially by species. Freshwater snails inhabit a range of water bodies, from cave pools, springs, and small tributaries, up to large rivers. A threat common among many of the listed aquatic snails are the effects posed by dams (e.g., reduced ability to expand range and exchange genetic information between populations, and alternation of flow and water quality). Very little information on diets of aquatic snails is available. For additional information, see the *Status of the Species* for these species and *Environmental Baseline*. Relevant life history traits are discussed below for a general understanding of ecology of each species. We used R-Plots to determine the effect of malathion for each species (see *Effects of the Action* – R-Plots).

In general, we expect that aquatic snails will have a low risk of mortality as a result of exposure to malathion. Data available from toxicity tests for these species indicate that snails have relatively higher tolerance to malathion and will not experience effects at estimated environmental concentrations[63].

Thus, we do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild, as described in each of the species accounts for this taxon. Additional information for terrestrial and aquatic snails is found in the *Status of the Species and Critical Habitat* (Appendix C) and the *Effects of the Action* sections. *Integration and Synthesis* summaries are provided for each species (Appendix K). The species included in this group and our conclusions for each are presented in Table 53.

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aquatic snails to malathion. These data were used to assess sensitivity to terrestrial snails as more suitable surrogates for these species.

[63] This is a change from our April 2021 draft biological opinion, where we used a less related and likely more sensitive invertebrate as a surrogate for aquatic snails. For our revised analysis in this Opinion, we reconsidered the snail toxicity data and determined that adequate data were available to draw conclusions about the sensitivity of aquatic snails to malathion. These data were used to assess sensitivity to aquatic snails as more suitable surrogates for these species.

Table 53. Listed, proposed, and candidate CONUS Snail species addressed in this Opinion.[64]

Table 53. Snails.xlsx

[64] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = (May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

Analysis for Plant Species

This consultation covers over 900 listed, proposed, and candidate plant and lichen species. In order to facilitate the efficient and timely analysis of such a large number of species, we have incorporated a strategy for grouping plant species into this Opinion; lichen species did not require such grouping strategies and we discuss these species further in a separate section. Our grouping strategy for plants began with large taxonomic groupings; we then proceeded to divide these into successively smaller groups based on reproductive mechanism. The end result was 11 main plant assessment groups, or collections of species sharing characteristics similar enough that a broad starting-point for the rationale could be written to cover all of the species within the group. We chose the selected life history characteristics based on their relevance in defining the relative risk of reproductive effects by the group of plant species to malathion exposure (see the *Life History Characteristics Used to Define Assessment Groups* section below for more details). In order to define the relative risk of the plant species across assessment groups, we identified additional life history characteristics beyond those used for a particular assessment group (see the *Additional Life History and Other Information Used in Effects Analyses* section below).

We assumed that plants within an assessment group would have the same general response characteristics, unless the information and data collected on individual species indicated otherwise. As such, we considered species-specific information, including species' status and effects analysis output for all species within each assessment group, to make a final determination for each individual species.

We arrived at preliminary determination indicators for plant species by using the same risk indicator system followed for animal species, though we made several adjustments to the methodology based on characteristics and aspects of our analysis that are unique to plants (see *Analysis for Animal Species* section for complete discussion). Differences with the animal methodology are described below, and, as with animal species, we use a worksheet tool to evaluate the ranking for each factor (see Appendix J for worksheet examples).

Vulnerability Factors and Ranking

Since we are concerned with the anticipated adverse effects of malathion exposure on pollinator species, especially insects, we included a factor to indicate if a given plant species has pollinator loss or decline identified as a threat in a recent SERVICE document. In addition, we did not include a ranking factor for cumulative effects as we were unable to perform an extensive and detailed review of cumulative effects for each plant species (see discussion in *Environmental Baseline* and *Cumulative Effects* section, below).

Risk Factors and Ranking

Direct exposure to malathion in plants does not cause adverse effects in monocots but may cause sub-lethal effects to post-emergent dicots. The level of sub-lethal effects to dicots are not expected to be above a 12% reduction in dry weight and there is considerable uncertainty regarding what the reduction in biomass of an agricultural test species may indicate to the continuing survival of a listed plant species. As such, we did not include a high category for the direct effects factor. Plants were either assigned a ‘medium’ ranking if effects were expected (dicots and non-flowering plants) or ‘low’ if no effects from direct exposure were expected (monocots).

For the Indirect effects risk factor, we categorized anticipated effects to each plant’s pollinators. Effects to pollinators were a sum of anticipated effects from malathion exposure on agricultural and non-agricultural use areas, spray drift from these sites and mosquito control applications. The percentages used to define the high, medium, and low rankings were adjusted upward from those used for animal species, given the fact we combined mortality from several different malathion use types. In addition, spray drift areas from different uses can overlap with one another or with use sites themselves, depending on their proximity on the landscape, thus over-estimating spray drift mortality.

We added three risk modifiers for plants, method of reproduction, seed dispersal vector, and obligate/specific pollinator, as these life history characteristics can modify the response of a plant to malathion exposure. More discussion of these characteristics can be found below in the *Life History Characteristics Used to Define Assessment Groups* and *Additional Life History and Other Information Used in Effects Analyses* sections. There were no adjustments to the usage indicator section for plants.

Conservation Measures

For each plant assessment group, we identify those conservation measures that are likely to reduce exposure and effects based on use and usage patterns relevant to the species, and describe the nature of the reduction. Many listed plants require a healthy population of pollinators in or near their range in order to reproduce successfully, as pollinators transport pollen containing genetic material from one individual plant to another to accomplish sexual reproduction and fruit and seed production. Pollen transfer also allows gene flow throughout the population, thus ensuring adequate genetic diversity of the species. Many of the conservation measures for plants were designed to reduce exposure to the pollinators essential for the reproduction of the listed plant species under consultation. For example, one general conservation measure to be added to the label for mosquito control use will prohibit application of malathion as a mosquito adulticide during most daylight hours. The restriction period coincides with the active period of many diurnal pollinators, thus reducing their exposure to malathion and resultant mortality, as pollinators are more likely to be exposed to malathion when they are flying and foraging during the day, and less likely to be exposed at night when they hide from predators by seeking cover. Furthermore, some plant species required species-specific conservation measures to be used in conjunction with the general conservation measures as these species were particularly vulnerable to the effects of malathion because of their current status, reproductive strategy, and/or high anticipated pollinator mortality from high usage within their range. An example is the measure for Avon Park harebells and other Lake Wales Ridge species in Florida. This measure directs agricultural applicators in the vicinity of suitable habitat for these species to choose one of three options when applying malathion. They can either apply malathion before dawn or after dusk, thus avoiding the active period of pollinators, or apply malathion only when wind is blowing away from suitable habitat, or they can use specific buffers around suitable habitat when applying.

For additional general and species-specific conservation measures applicable to particular plant assessment groups and discussion of individual species' rationales, please see the plant *Integration and Synthesis* summaries in Appendix K.

Rationales and Conclusions

The information and data used for each of the three risk indictor ranks (vulnerability, risk and usage) are summarized in the tables provided for assessment groups in the *Integration and Synthesis* section of this Opinion. Our rationales for the plant assessment groups and the species within them can be found in each assessment group summary after the risk indicator tables.

In the following sections, we describe in greater detail the information and data we considered in making determinations for plant species for each of the Assessment Groups (see also Appendices C and K for *Status of the Species and Critical Habitat* and *Integration and Synthesis* summaries).

Assessment Groups

1. Lichens
2. Ferns and Allies
3. Conifers and Cycads
4. Monocot flowering plants using abiotic pollinating vectors
5. Monocot flowering plants using biotic pollinating vectors and requiring outcrossing for optimum reproduction
6. Monocot flowering plants using biotic pollinating vectors and capable of sustaining the population using self-pollination or asexual methods
7. Monocot flowering plants using biotic pollinating vectors, other aspects of reproductive strategy unknown
8. Dicot flowering plants using abiotic pollinating vectors
9. Dicot flowering plants using biotic pollinating vectors and requiring outcrossing for optimum reproduction
10. Dicot flowering plants using biotic pollinating vectors and capable of sustaining the population using self-pollination or asexual methods
11. Dicot flowering plants using biotic pollinating vectors, other aspects of reproductive strategy unknown

Of the plant and lichen species covered under this consultation, over 450 of them are found outside of the continental United States (CONUS). Of those outside CONUS, most are found in the Hawaiian Islands and the Caribbean. Analyses for species occurring outside CONUS can be found in the Islands sub-section of the *Integration and Synthesis* section of this Opinion.

Species Assessment

In our analysis, we determined whether the Action would appreciably diminish the likelihood of both the survival and recovery of the plant and lichen species. We analyzed the environmental baseline, status of the species, cumulative effects, and effects of the Action. The following sections discuss how we gathered, assessed, and ultimately synthesized these four categories of information.

Status of the Species and Species Vulnerability

We identified data and information within each SOS (Appendix C) that was of particular biological importance to the species and used that information in our analysis. The metrics that most comprehensively represent the overall status and vulnerability of each species to additional stressors (including those from the Action considered in this consultation) are a species' resiliency, redundancy and representation (together known as the "3Rs"). When combined, these metrics give an overall picture of species' health. These metrics integrate aspects of the species' population size, growth rate, distribution, and diversity, among other factors. The 3Rs are now used routinely by the Service in Species Status Assessments (SSAs), which are summaries of a species' status used to inform decisions made under the ESA (USFWS, 2016). In general, representation describes the ability of a species to adapt to changing environmental conditions, which is related to distribution within the species' ecological settings. Resiliency describes the ability of the species to withstand stochastic disturbance events, which is associated with population size, growth rate, and habitat quality. Redundancy describes the ability of a species to withstand catastrophic events, which is related to the number, distribution, and resilience of populations (USFWS, 2016).

However, almost all the plant species covered under this consultation do not currently have a finalized SSA or otherwise have the 3Rs defined for them. For the few plant species with finalized SSAs or defined 3Rs, we used the 3Rs in our analysis, but for the vast majority of listed plant species, we chose metrics and information available in the SOS accounts that most closely approximated the 3Rs[65]. These metrics include species' distribution pattern, number of populations, overall number of individuals, and population trends. Secondary factors we considered included reproductive capacity and sensitivity to stochastic events.

Assessed together, the 3Rs or alternate metrics described above outline the current health of the species and can indicate the vulnerability of the species to additional stressors in the environment in the absence of effects from the Action under consultation. For example, if a species has a declining trend, a small population size and only one population, it is more likely to be vulnerable to additional stressors (including those from the effects of the Action under consultation) in the environment. On the other end of the scale, if a species has an increasing

[65] These metrics and information were identified to assist with this consultation in the absence of finalized SSAs and should not be considered final 3R metrics or for any use beyond this consultation. Future SSAs would presumably identify appropriate 3Rs for the species, and this effort does not constrain those products.

trend, a healthy population size and a number of populations well distributed across the landscape, it is less likely to be vulnerable to additional stressors in the environment. We used these metrics to determine the vulnerability indicator ranking as described in the *Analysis for Animal Species* section of this Opinion. Vulnerability rankings for plants are summarized in Table 1 of each of the Plants Integration and Synthesis Summaries in Appendix K.

Effects of the Action on Plants

General Effects to Plants (refer to General Effects section of this Opinion for complete information)

Mortality and Sub-lethal Effects[66]:

We used the studies and data provided in EPA's BE (2016), that measured effects to plants from exposure to malathion either during pre-emergent or post-emergent time frames and applied these data to all plants and lichens under consultation, as there are no data on the effects of malathion to listed plant or lichen species (details available in General Effects – Plants). No effects to terrestrial plants (monocot or dicot) are reported from studies of pre-emergent exposure to malathion. Furthermore, no effects are reported to terrestrial monocot flowering plants from studies of post-emergent exposure.

Studies involving dicot plant species found sub-lethal effects following malathion exposure for the following uses: orchards and vineyards, developed, nurseries, open space developed, and Christmas trees. For this consultation, we used the most sensitive dicot species (cabbage), which showed a 12% decrease in dry weight when exposed to malathion, as a surrogate for direct effects to all terrestrial dicot plants. There are also no studies evaluating the effects of malathion exposure to non-flowering plants or lichens. To be sufficiently protective in addressing this uncertainty, we assumed listed species in these groups would experience the same direct effects as terrestrial dicot plants.

Plant mortality following malathion exposure has been documented in one study on two species of carnivorous plants in the Droseraceae family (Jennings, Congelosi, & Rohr, 2012). While there are no listed plant species in this family under consultation, there are three listed species of carnivorous pitcher plant (the green pitcher, Alabama canebrake pitcher plant and the mountain sweet pitcher plant) belonging to a separate family (Sarraceniaceae). In their 2012 study, Jennings et al. (2012) postulated the main cause of mortality in the species studied was increased uptake of pesticide through digestive glands on plant leaf surfaces. Some species of pitcher plants have an area of tissue within their pitchers that contains digestive glands (Thornhill, Harper, & Hallam, 2008), and it is possible the three pitcher plant species in this consultation do as well. Assuming they possess these glands, these species could experience effects from direct exposure to malathion beyond what is anticipated for other dicots (12% reduction in biomass, as discussed in the *General Effects to Plants* section). These effects were considered in our analyses

[66] Mortality and sub-lethal effects correspond to risk assessment terminology of "direct effects."

for these plants species. Rationales can be found in the *Integration and Synthesis* summaries for plant Assessment Groups 9 and 10 in Appendix K.

Effects to Pollinators and Seed Dispersers[67]

The vast majority of plant species covered in this consultation are pollinated by insects or a combination of insects and other animals. As described in detail in the *General Effects – Plants* sections, impacts to insect pollinators and seed dispersers for listed plants can be significant because malathion is designed to kill insects. The pesticide will also kill non-target insect pollinators and/or seed dispersers of listed, proposed, and candidate plant species.

In contrast, we do not anticipate any appreciable reductions in the availability of mammalian pollinators or seed dispersers (such as bats) from malathion exposure, either on use sites or from spray drift (see *General Effects to Plants* section). Similarly, we do not anticipate appreciable reductions in available avian pollinators or seed dispersers from exposure to spray drift. However, birds consuming nectar on use sites with higher allowable application rates (e.g., developed, open space developed, nurseries, orchards and vineyards) could experience similar rates of mortality from consumption of nectar as compared to arthropods; therefore, we anticipate plants using birds as pollinators/seed dispersers may experience some level of effects from loss of pollinating services from birds species within their range. Alternatively, birds consuming nectar on agricultural crops with lower allowable application rates (e.g., pasture, corn, wheat, pine seed orchards, other crops) are not expected to experience significant mortality that would result in appreciable reductions of available pollinators.

R-Plots for Plants and their Pollinators

We used R-Plots for plants to determine the magnitude of mortality (on use sites and by spray drift) for a plant's pollinators, as applicable. Pollinator mortality was analyzed by use site categories in order to deduce the relative contribution of each use. Complete details and an example R-Plot for plants can be found in the *Approach to the Effects Analysis* section of this Opinion. We did not take conservation measures into account in the development of R-Plots, but instead considered how relevant measures would reduce effects predicted for individual species or assessment groups.

Life History Characteristics Used to Define Assessment Groups

Certain life history characteristics of plant species may increase or decrease their response to the effects of the Action. As described earlier, plants and lichens were sorted into assessment groups based on life history characteristics, as represented through taxonomic groupings: lichens were placed in one Group and plants in another in the initial sorting effort. We assumed that lichens, as members of a different kingdom than plants, would share more characteristics among themselves than with plants, and should therefore be assessed as a separate Group (Assessment Group 1).

[67] Effects to pollinators and seed dispersers correspond to risk assessment terminology of "indirect effects."

We divided plants into two large groups: flowering plants and non-flowering plants. We used taxonomy to divide the non-flowering plants into two smaller assessment groups: ferns and allies (Assessment Group 2) and conifers and cycads (Assessment Group 3 respectively). As with lichens, we assumed that the plants within these smaller assessment groups would have enough life history characteristics in common (such as wind pollination in the conifers, and ferns' use of spores and gametophytes) that a broad starting-point for our analysis and rationale could be used to cover all of the species within these groups.

We divided the flowering plants by class into monocots and dicots, based on the differences in mortality and sublethal effects seen in the literature between these two classes of flowering plants (see *General Effects – Plants*). The monocots and dicots were each subdivided into four assessment groups based on two main categories of reproductive characteristics (Assessment Groups 4-11, as shown above in the bulleted list): 1) use of biotic or abiotic pollinating agents, and 2) whether the species required outcrossing for successful reproduction or could reproduce using self-pollination or asexual mechanisms.

We defined abiotic pollinating agents as wind or water, and biotic pollinating agents as insects, birds, or mammals (in a few cases, there were other pollinator taxa used by the plant species; these are discussed in individual species rationales as applicable). There were a number of species with limited or no information on pollinating agent(s); these species were classified as having an 'unknown' pollinator. Pollinator determinations were initially based on categories in EPA's BE (2016). However, these categories were reviewed and updated with the most recent Service documents available. Pollinator category assignments for the species are identified in each of the Integration and Synthesis summaries for the taxa groups (Appendix K).

In order to reproduce successfully, outcrossing plants require pollen to be transferred from the flower of one plant to a flower on a separate plant. Some plant species are obligate outcrossers, meaning in order to reproduce, individual plants must be pollinated with pollen from a separate individual plant. Many plants are not obligate outcrossers, but they need to outcross at least partially in order to maintain a viable population over time. Outcrossing is achieved by either biotic or abiotic pollinating agents. If a plant uses biotic pollinating agents for outcrossing, there must be a population of pollinators of sufficient size to ensure successful reproduction of the plant population (Spira, 2001; Potts, et al., 2010; Lennartson, 2002).

Generally speaking, we do not anticipate that most monocots and dicots in Assessment Groups 4 and 8 (i.e., species that use abiotic pollinating agents) would experience impacts from malathion applications via their pollinators, as the pesticide would not affect abiotic pollination. However, we do anticipate effects to some of these species via their biotic seed dispersers for species that use both abiotic and biotic seed dispersers.

Alternatively, we anticipate that monocots and dicots using biotic pollinating agents would experience effects to their pollinators and/or seed disperser via mortality or sub-lethal effects to these organisms from exposure to malathion in or near the range of the listed plant species. We expect plant species that require outcrossing, and especially those that are obligate outcrossers, to experience greater effects via impacts to their pollinators because they must have healthy pollinator populations available near their habitat in order to reproduce successfully (Assessment Groups 5 and 9) (Potts, et al., 2010; Biesmeijer, et al., 2006).

In contrast, we anticipate that plant species capable of maintaining viable populations by reproducing through self-pollination (i.e., where pollination can occur without a pollination agent) or asexual mechanisms (such as vegetative reproduction) would experience fewer indirect effects as they do not rely exclusively on animal pollinators for their reproduction and survival (Assessment Groups 6 and 10) (Potts, et al., 2010; Biesmeijer, et al., 2006). Finally, as noted above, there were numerous monocot and dicot species that did not have sufficient information to determine whether the species was reliant on outcrossing or could depend on self-fertilization or asexual means of reproduction. These species were placed in Assessment Groups 7 and 11.

To make Assessment Group placement decisions for species, we used the most recent Service documents available (mainly SOS accounts, Recovery plans, 5-year status reviews, listing decisions and SSAs) and our best scientific judgement based on the known life history of the species.

Additional Life History and Other Information Used in Effects Analyses

As described in the previous section, plant species were sorted into 11 assessment groups based on taxonomy and certain shared life history characteristics. This process resulted in several very large assessment groups (for example, Group 9 contained 249 species and Group 11 contained 436 species). In order to proceed through the effects and jeopardy analyses for these assessment groups in the most efficient and effective way possible, we identified additional life history characteristics within these larger groups that could refine the relative risk of response to malathion for the species that possess one or more of the identified characteristics.

The characteristics considered include the following:

- Obligate or need for specific insect pollinator(s): These listed plant species are reliant on an obligate or a few specific pollinators for successful reproduction and survival. They cannot be pollinated by other available pollinators if the population of specific pollinators they require is reduced in size by malathion application(s). As a result, possession of this trait was assumed to increase the relative risk of the species to malathion (Potts, et al., 2010; Wicock & Neiland, 2002).

- Type of biotic pollination vector: use of an insect pollinator was assumed to increase the relative risk of the species to malathion, while use of an avian or mammalian pollinator would decrease the relative risk.

- Type of seed dispersal vector: use of an insect seed disperser was assumed to increase the relative risk of the species to malathion, while use of an abiotic, avian or mammalian seed disperser would decrease the relative risk.

<u>Synthesis of Information and Determinations</u>

As described above, we streamlined our analysis wherever feasible, and for many plant species, we were able to write conclusions and supporting rationales by assessment group.

Group 1: Lichens:

Lichens are composite organisms formed from algae and fungi living in a mutualistic relationship. Lichens do not produce flowers or seeds and therefore do not rely on pollinators or seed dispersers for reproduction. The primary means of reproduction of the lichens in this Group is asexual, with colonies or organisms spreading clonally through vegetative reproduction. Both species have highly specific habitat requirements: Florida perforate cladonia live in open patches in rosemary scrub and rock gnome lichen are found on vertical rock faces in areas of high humidity on cliffs or gorges. We expect the lichens will experience minimal effects from direct malathion exposure, but will not experience adverse reproductive effects due to pollinator or seed disperser mortality from malathion exposure given these species do not rely on such vectors for reproduction.

Table 54. Listed, proposed, and candidate CONUS plant species addressed in this Opinion (Assessment Group 1).[68]

Assessment Group	Species Scientific Name	Common Name	Status	Entity ID	EPA Species Determinations	Service Species Conclusions	EPA Critical Habitat Determinations	Service Critical Habitat Conclusion
1	Cladonia perforata	Florida perforate cladonia	Endangered	1219	LAA	NJ	NA	NA
1	Gymnoderma lineare	Rock gnome lichen	Endangered	1220	LAA	NJ	NA	NA

Group 2: Ferns and Allies:

Ferns and their allies (such as the Louisiana quillwort) do not have flowers or seeds, but reproduce sexually via spores that are dispersed by wind. Ferns and their allies can also reproduce asexually, through vegetative reproduction in the form of bulbets or rhizomes. During sexual reproduction, ferns produce two free-living generations, a diploid sporophyte (i.e. a fern plant) and a haploid gametophyte. The gametophytes are typically very small (around ½ inch), fragile, and have very specific requirements for growth, such as damp soil conditions and high humidity. We expect the ferns and their allies will experience some effects from direct malathion exposure, but will not experience adverse reproductive effects due to pollinator or seed disperser

[68] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NJ = "No Jeopardy;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

mortality from malathion exposure given these species do not rely on animal vectors for reproduction.

Table 55. Listed, proposed, and candidate CONUS plant species addressed in this Opinion (Assessment Group 2).[69]

Assessment Group	Species Scientific Name	Common Name	Status	Entity ID	EPA Species Determination	Service Species Conclusion	EPA Critical Habitat Determination	Service Critical Habitat Conclusion
2	*Asplenium scolopendrium var. americanum*	American hart's-tongue fern	Threatened	1195	LAA	NJ	NA	NA
2	*Isoetes louisianensis*	Louisiana quillwort	Endangered	1199	LAA	NJ	NA	NA
2	*Isoetes melanospora*	Black spored quillwort	Endangered	1203	LAA	NJ	NA	NA
2	*Isoetes tegetiformans*	Mat-forming quillwort	Endangered	1204	LAA	NJ	NA	NA
2	*Polystichum aleuticum*	Aleutian shield fern	Endangered	1201	LAA	NJ	NA	NA
2	*Thelypteris pilosa var. alabamensis*	Alabama streak-sorus fern	Threatened	1209	LAA	NJ	NA	NA
2	*Trichomanes punctatum ssp. floridanum*	Florida bristle fern	Endangered	9721	LAA	NJ	NA	NA

Group 3: Conifers and Cycads:

Conifers and cycads are gymnosperms; vascular plants, usually trees or shrubs, that reproduce by means of an exposed seed, or ovule. Gymnosperms do not produce flowers and their pollen is dispersed by wind. With the exception of whitebark pine, all species have very restricted ranges and limited dispersal capabilities. Santa Cruz cypress and Florida torreya rely on squirrels for seed dispersal and whitebark pine on the Clark's nutcracker (*Nucifraga columbiana*). The

[69] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = "May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

whitebark pine's cones will not open on their own and are completely dependent upon the nutcracker to break apart their cones and disperse the seeds. We expect the conifers in this group will experience some effects from direct malathion exposure, but will not experience adverse reproductive effects due to pollinator mortality given these species do not rely on animal vectors for reproduction. The seed dispersers for these conifers are mammals or birds. No mortality or sublethal effects are expected for mammalian seed dispersers from malathion exposure either on use sites or from spray drift, thus we do not anticipate reproductive effects to the species utilizing mammalian vectors, such as Santa Cruz cypress. The Clark's nutcracker, used by the whitebark pine for seed dispersal, may experience some effects (mortality and sub-lethal) on certain use sites. However, we do not anticipate the loss of small numbers of birds from the low anticipated usage of malathion within the species range would measurably reduce reproduction for the whitebark pine.

Table 56. Listed, proposed, and candidate CONUS plant species addressed in this Opinion (Assessment Group 3).[70]

Assessment Group	Species Scientific Name	Common Name	Status	Entity ID	EPA Species Determination	Service Species Conclusion	EPA Critical Habitat Determination	Service Critical Habitat Conclusion
3	*Cupressus goveniana ssp. goveniana*	Gowen cypress	Threatened	1192	LAA	NJ	NA	NA
3	*Hesperocyparis abramsiana (=Cupressus abramsiana)*	Santa Cruz cypress	Threatened	1190	LAA	NJ	NA	NA
3	*Pinus albicaulis*	Whitebark pine	Proposed Threatened	1935	LAA	Conference - NJ	NA	NA
3	*Torreya taxifolia*	Florida torreya	Endangered	1191	LAA	NJ	NA	NA

Groups 4-7: Monocot flowering plants (for list of species and conclusions, see Table 57):

All species in these assessment groups are monocots, a class of angiosperm flowering plant defined by having one cotyledon (embryonic seed leaves). There are a large variety of monocot

[70] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = "May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

species, though typical monocot plants include grasses, lilies and palms. Monocots are not expected to experience effects to growth or survival from direct exposure to malathion.

Monocots use a variety of pollination vectors in order to accomplish pollen and gene transfer between individual plants and among populations. Likewise, they use a variety of seed dispersal vectors to ensure movement and transport of seeds away from parent plants and ensure the germination and survival of some of the seeds to adults. In addition, pollination and seed dispersal can ensure genetic diversity among populations and seed dispersal can lead to colonization of new sites within the range of the plant.

Species with abiotic pollination vectors will not experience reproductive effects from malathion exposure to pollinator populations in their range. Species using biotic pollination vectors will experience varied levels of effect from mortality of their pollinating species based on the specific taxa group involved in pollination, particularly in the absence of effective measures to avoid, minimize, or reduce pollinator exposure. Magnitude off effects to insect and bird pollinating species are displayed in individual R-Plots for each plant species. Similarly, as plants in these groups rely on a variety of seed dispersal vectors, the magnitude of effects of seed disperser loss on the particular plant from malathion exposure will depend on the specific taxa group of animals involved in seed dispersal. Mortality is expected for insect pollinators and seed dispersers exposed to malathion on use sites or via spray drift. Some bird pollinators and seed dispersers exposed to malathion on use sites may experience mortality or sublethal effects, depending on the site of exposure and size of the bird. Smaller birds exposed on use sites with higher allowable use rates (e.g., developed, open space developed, orchards and vineyards) have a greater chance of being affected. Exposure to spray drift is not expected to result in effects to bird seed dispersers. No mortality or sublethal effects are expected for mammalian pollinators or seed dispersers from malathion exposure either on use sites or from spray drift.

Group 4 species, such as northeastern bulrush and California Orcutt grass, use abiotic pollination vectors and a variety of seed dispersal vectors. None of the species in this group are expected to experience effects from pollinator loss on their reproductive capacity.

Group 5 species, such as the Eastern prairie fringed orchid and persistent trillium, use a variety of biotic pollinating vectors, and require outcrossing, the transfer of pollen between individuals, at least partially, in order to reproduce successfully and maintain their populations over time. For successful outcrossing, individual plants need to be close enough spatially that their pollinators will be able to travel easily between plants of varying genetic composition. These species are expected to experience limited effects to their reproduction from pollinator loss due to very low usage of malathion within their ranges. Several species in this group use wind as their primary seed dispersal vector and therefore will not experience reproductive effects from loss of seed dispersers. The other species rely on a variety of abiotic and biotic methods and given their ability to rely on a number of different vectors, are not expected to experience significant negative reproductive effects due to seed disperser loss from malathion applications.

Group 6 species, such as the Pitkin marsh lily and Munz’s onion, use a variety of biotic pollinating vectors to transfer pollen between individuals, but can also reproduce, at least partially, by self-pollination (pollen transfer within the same individual) or asexually (typically vegetative or clonal reproduction). As a result, they are less reliant on the pollinators within their range for successful reproduction and can withstand some loss of those pollinator populations. Most species in this group, including relict trillium and bunched arrowhead, have very low usage of malathion across their range and combined with their ability to reproduce without pollinators are not expected to experience significant negative reproductive effects.

Group 7 species, including the purple amole and Harper's beauty, also use a variety of biotic pollinating vectors to transfer pollen between individuals, and a variety of seed dispersal vectors, but other aspects of their reproductive mechanisms are unknown. All species had very low malathion usage with their ranges, and therefore were not expected to experience significant negative reproductive effects from pollinator mortality.

Table 57. Listed, proposed, and candidate CONUS plant species addressed in this Opinion (Assessment Groups 4-7).[71]

Table 57. Plants (Groups 4-7).xlsx

Groups 8-11: Dicot flowering plants (for list of species and conclusions see Table 58)

All species in these assessment groups are dicots, a class of angiosperm flowering plant defined by having two cotyledons (embryonic seed leaves). Dicots are a hugely diverse class of flowering plants, with tens of thousands of species. Familiar dicots include plants such as daisies, roses and oak trees. The individual plants in this assessment group are estimated to experience up to a 12% decrease in dry weight if exposed to malathion on the following use sites, based on labeled application rates: orchards and vineyards, developed, nurseries, open space developed and Christmas trees. No effects are expected on other use sites.

Dicots also use a variety of pollination vectors in order to accomplish pollen and gene transfer between individual plants and among populations. Likewise, they use a variety of seed dispersal vectors to ensure movement and transport of seeds away from parent plants and ensure the germination and survival of some of the seeds to adults. In addition, pollination and seed dispersal can ensure genetic diversity among populations and seed dispersal can lead to colonization of new sites within the range of the plant.

Species with abiotic pollination vectors will not experience reproductive effects from malathion exposure to pollinator populations in their range. Species using biotic pollination vectors will experience varied levels of effect from mortality of their pollinating species based on the specific taxa group involved in pollination, particularly in the absence of effective measures to avoid,

[71] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = "May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

minimize, or reduce pollinator exposure. Magnitude of effects to insect and bird pollinating species are displayed in individual R-Plots for each plant species. Similarly, as plants in these groups rely on a variety of seed dispersal vectors, the magnitude of effects of seed disperser loss on the particular plant from malathion exposure will depend on the specific taxa group of animals involved in seed dispersal. Mortality is expected for insect pollinators and seed dispersers exposed to malathion on use sites or via spray drift. Some bird pollinators and seed dispersers exposed to malathion on use sites may experience mortality or sublethal effects, depending on the site of exposure and size of the bird. Smaller birds exposed on use sites with higher allowable use rates (e.g., developed, open space developed, orchards and vineyards) have a greater chance of being affected. Exposure to spray drift is not expected to result in effects to bird seed dispersers. No mortality or sublethal effects are expected for mammalian pollinators or seed dispersers from malathion exposure either on use sites or from spray drift.

We expect the general conservation measures will reduce exposure of pollinators to malathion, thus reducing resultant reproductive effects to the listed plants. For example, the new daylight restriction to mosquito control use labels will prohibit application of malathion as a mosquito adulticide during most daylight hours. The restriction period coincides with the active period of many diurnal pollinators, thus reducing their exposure to malathion and resultant mortality, as pollinators are more likely to be exposed to malathion when they are flying and foraging during the day, and less likely to be exposed at night when they hide from predators by seeking cover. For additional general conservation measures applicable to particular plant assessment groups, please see the plant *Integration and Synthesis* summaries in Appendix K.

Species-specific measures were developed for several plant species for use in conjunction with the general label changes, such as the daylight restriction, to further lower the amount of malathion entering habitats where pollinators and seed dispersers are expected to be found. Examples of these measures can be found below with the corresponding plant assessment group.

Group 8, such as the Hinkley oak and California seablite, use abiotic pollination vectors and a variety of seed dispersal vectors. None of the species in this Group are expected to experience effects from pollinator loss on their reproductive capacity.

Group 9 encompasses over 180 species, including the Otay tarplant, Monterey clover, Tobusch fishhook cactus and many others. Species in this Group use a variety of biotic pollinating vectors and require outcrossing, the transfer of pollen between individuals, at least partially, in order to reproduce successfully and maintain their populations over time. For successful outcrossing, individual plants need to be close enough spatially that their pollinators will be able to travel easily between plants of varying genetic composition. A variety of seed dispersal vectors are used by the species in this Group. A number of species within this assessment group occur in the Lake Wales Ridge region of Florida, a narrow ridge of ancient sand dunes that runs down the central peninsula of the state and harbors a rich diversity of endemic plants and animals. All are threatened by continuing loss of habitat from development and lack of proper fire regimes, resulting in small, highly fragmented populations. Species-specific conservation measures will be implemented for six of the Ridge species, such as scrub lupine and Avon Park harebells, to further reduce their exposure to malathion from agricultural uses. The measures direct agricultural applicators in the vicinity of suitable habitat for these species to choose one of three options when applying malathion. They can either apply malathion before dawn or after dusk, thus avoiding the active period of pollinators, or apply malathion only when wind is blowing away from suitable habitat, or they can use specific buffers around suitable habitat when applying. For further details, see the *Integration and Synthesis* summary for Assessment Group 9 in Appendix K. All species-specific conservation measures have been incorporated into the Action and will be implemented through *BulletinsLive! Two*.

Group 10 includes more than 90 species, such as Tiburon jewelflower and marsh sandwort. Species in this Group use a variety of biotic pollinating vectors to transfer pollen between individuals, but can also reproduce, at least partially, by self-pollination (pollen transfer within the same individual) or asexually (typically vegetative or clonal reproduction). As a result, they are less reliant on the pollinators within their range for successful reproduction and can withstand some loss of those pollinator populations. A few species in this Group, including Garrett's mint and Florida ziziphus, required species-specific conservation measures in conjunction with the general label changes given their high vulnerability and high anticipated exposure to malathion (for complete discussion, see the *Integration and Synthesis* summary for Assessment Group 10 in Appendix K). The measure is the same as for Group 9, above, and directs agricultural applicators in the vicinity of suitable habitat for these species to choose one of three options when applying malathion.

Group 11 species contains approximately 100 species, including the Vail Lake ceanothus, autumn buttercup and tiny polygala. Species in this Group use a variety of biotic pollinating vectors to transfer pollen between individuals, and a variety of seed dispersal vectors, but other aspects of their reproductive mechanisms are unknown. As for Group 10, a few species in Group 11, including highlands scrub hypericum and acrub mint, required species-specific conservation measures in conjunction with the general label changes given their high vulnerability and high anticipated exposure to malathion (for complete discussion, see the *Integration and Synthesis* summary for Assessment Group 11 in Appendix K). The measure is the same as for Group 9, above, and directs agricultural applicators in the vicinity of suitable habitat for these species to choose one of three options when applying malathion.

For all plant and lichen species in this Opinion, we do not anticipate that the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild, as described for each species in each of the plant assessment groups referenced above. *Integration and Synthesis* summaries for species in the CONUS and island plant taxa groups can be found in Appendix K. The list of plants by assessment group are not included here due to the large number of species, but are included for each assessment group in Appendix K.

Table 58. Listed, proposed, and candidate CONUS plant species addressed in this Opinion (Assessment Groups 8-11).[72]

Table 58. Plants (Groups 8-11).xlsx

Analysis for Pacific and Caribbean Island Species

The risk of malathion use to Pacific and Caribbean Island species is generally determined by estimating exposure and effects as described previously in the Biological Opinion (see *General Effects*). However, we are less reliant on the mapped overlap of the species range with malathion use sites to understand exposure due to greater uncertainty associated with:

- Landcover data
- Usage data
- Species range maps

We discuss each of these factors and the related uncertainty below. We consider qualitatively the likelihood that species will be exposed to malathion on or near a use site, based on available information regarding habitat types used and species life history information, where available. We also describe below any additional considerations in assessing listed species in the Pacific or Caribbean Islands.

Landcover data for Pacific and Caribbean Islands

We derived the landcover categories representing malathion use sites in Pacific and Caribbean islands to determine overlap with species' ranges from the 1980 Agricultural Land Use Map (ALUM). These categories include agriculture (all uses), pasture, developed, open spaced developed, and nurseries. Because agricultural uses are combined into a single landcover, we cannot associate specific crops and their application rates and methods with areas of overlap within the species range. The category of pasture is also broader than represented for CONUS species (i.e., contains landcovers in addition to alfalfa).

In addition to the above landcover data, the State of Hawai'i Department of Agriculture maintains a 2015 Statewide Agricultural Land Use report that was prepared by the University of

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Hawai'i at Hilo's Spatial Data Analysis and Visualization Lab (SDAV; http://hdoa.hawaii.gov/salub/). While they represent just a single year of landcover data (2015), these layers and accompanying report demonstrate the change in land use and the continuing diversification and decentralization of crop use Hawai'i has experienced over the past 40 years since the derivation of the 1980 ALUM data. The report indicates that in 1980, Hawai'i had 350,830 acres in cropland and another 1.1 million acres in pasture use. In 2015, active cropland area fell to more than half of that acreage, to 151,830 acres; similarly, pasture fell by about one-third to 751,430 acres. The report also states that Hawai'i is moving to increase the supply of fresh, local foods to minimize import, leading to the greater diversification at the local level. The central agricultural areas on the island of Oahu have become the primary location for the diversified crop farms, with Oahu having the most crop acres (9,860 acres) compared to any of the other islands combined (7,000 acres). With this agricultural shift in focus to a very diverse base group of crops, we anticipate there will most likely be a representative shift in pesticide use and usage across the state. While we cannot necessarily predict how this shift will change malathion usage, it lowers the likelihood that the ALUM landcover layers can solely be relied upon to predict where agriculture crops occur at present.

Based on our inability to differentiate effects across agricultural crops, and the change in landcover data since the time of the ALUM mapping, we employed a more qualitative approach to the analysis of Pacific Island species. We can also surmise from the 2015 Statewide Agricultural Land Use report that overlap values for crops and pasture are likely to be over-estimated for the region, though we cannot assess the degree for any particular species.

In Puerto Rico, new crops such as cacao are slowly on the rise in areas previously abandoned by agriculture, which may change the agricultural profile and use of pesticide products in an area (though malathion is not registered for use on cacao, in particular). The locations and extent of area on each island that could become occupied by commercial nurseries are also not restricted. Therefore, while we do not expect the pesticide to be used everywhere within the range of the species, the labeled uses could occur on many areas of the landscape.

Given the number of years since the ALUM landcover layer was created, our inability to differentiate effects across agricultural crops, and our knowledge of the changes in landcover data since the time of the ALUM mapping, we employed a more qualitative approach to the analysis of Pacific and Caribbean Island species. Where we felt use of any of the landcover layers would aid in our analysis, we describe our approach within the analysis for particular species.

Usage data for Pacific and Caribbean Islands

We describe our approach to estimate past usage in the Pacific and Caribbean islands in greater detail in the *Approach to the Usage Analysis* section. In short, no data are available to estimate past usage of specific pesticides on use sites in these geographic areas, and so we must instead consider usage data related to categories of pesticides. For agriculture, we consider the total amount of cropland treated with insecticides in Hawaii, American Samoa, and Puerto Rico (as data were only available for these areas) to estimate upper limits of expected use for the individual insecticide, malathion. For islands where even this information is lacking, we extrapolate from either Hawaii or Puerto Rico. While these values generally implied low usage on agricultural sites across the islands (~5 to 11% of cropland treated with insecticides), we lack information on where the applications have taken place and whether they tended to be spread uniformly across malathion use areas, or clustered in specific areas due to factors relating to specific environmental conditions or target pests. Thus, without further information, we cannot generally assume low usage within or near the range of all species as we know some applications do occur. In addition, due to the large temporal difference in when the landcover data was mapped (1980) and when the usage data was collected (2007 to 2017), and our knowledge of changing agricultural land use in these islands, we cannot reliably combine these data to determine the number of acres treated. Finally, these values were from a single year of survey data, and we are unsure whether this data represents typical usage. For non-agricultural uses, we apply usage values derived from information in the lower 48 states. It is unknown if doing so over-estimates or under-estimates actual usage. Thus, we consider quantitative usage data broadly.

Considering the limitations above, exposure from malathion usage in the Pacific and Caribbean Islands is better assessed qualitatively by considering life history factors or habitat preference that can provide evidence of a species' proximity to malathion usage. Thus, we consider the likelihood that species will occur in the areas where insecticide usage is anticipated to occur. We make assumptions that there will be low usage in places where malathion is not registered for use, such as forests, or where malathion use sites are unlikely to occur, such as cliffs which are not typical malathion use sites. On the other hand, we assumed usage would be medium or high in the ranges of species that are known to exist within or near areas such as agriculture, pasture, or developed sites, or for species that are likely to travel to across different habitat types where usage could occur.

Mosquito Adulticide in the Pacific Islands

Because mosquitoes are not known to occur in subalpine and alpine zones above the fog belt, use of malathion as a mosquito adulticide would not be expected in these high areas. For other areas, as of May 2020, available sources indicated that malathion is not currently being used in Hawaii and the Pacific Islands (Commonwealth of the Northern Mariana Islands, American Samoa, and Guam, as a mosquito adulticide. We acknowledge the possibility remains that this pesticide may be considered an option should mosquito resistance occur to other currently used mosquito adulticides. However, we do not anticipate that its use would increase significantly in this event based on the following assumptions:

- At this time, mosquito adulticide spraying occurs in Hawaii with non-malathion products during a human disease response. The Hawaii Department of Health (HDOH), Honolulu, Hawaii indicated that malathion is not being used in vector control for public health reasons in Hawaii in any capacity (Lincoln Wells, Public Health Entomology Specialist, HDOH, pers. comm., 2019). DOH pesticide applications are generally in response to disease threat (e.g., imported case of an arboviral disease) or following specific complaints (such as large mosquito populations found at a school or government properties). In response to a disease threat, the amount of area that is covered with non-malathion products is usually the number of properties they are allowed access within a

200-m radius from the property of the suspected case. Thus, since mosquito adulticide usage is not generally widespread, but localized and in response to threats, there would be a low chance of resistance happening in Hawaii to necessitate the need for malathion in the future. Within the state, the main adulticide and insect growth regulator products that are used include Suspend SC (deltamethrin), Talstar P Professional/Talstar One (bifenthrin), and Altosid products (methoprene). The products used between islands do not typically vary. However, the frequency of applications does vary with the island of Hawaii carrying out the most applications and other islands significantly less.

- The Pacific Island Health Officers Association on Guam communicated that little mosquito control is currently taking place in the Commonwealth of the Northern Mariana Islands, American Samoa and Guam. When controlling adult mosquitos, they mainly use pyrethoids, with bifentrhrin, sumethrin, and Suspend being the most popular. Malathion does not seem to be used at this time for vector control. Unfortunately, no documentation on past usage is available.

Mosquito Adulticide in Caribbean Islands

Pesticide use has a long history in Puerto Rico, both for agricultural purposes and as a disease vector control. From World War II until it was banned in the early 1970s, DDT was regularly sprayed widely in Puerto Rico by the military, the public health department and local farmers. As DDT was banned, other pesticides came into use. Mosquito control has been a major use of pesticides in Puerto Rico and over application has resulted in resistance to DDT, malathion, and other pesticides by island mosquitos (Flynn, Schoof, Morlan, & Porter, 1964; CDC, 2017).

In 2016, the Center for Disease Control (CDC) began a bioassay study in Puerto Rico to examine the resistance of the mosquito *Aedes aegypti* to several of the most commonly used EPA-approved insecticides for mosquito control. *Aedes aegypti* is responsible for transmitting Zika, chikungunya and dengue and as such, this species is the primary target of vector control efforts in Puerto Rico and U.S. Virgin Islands. Figure 14 below depicts where test results indicated mosquito resistance to malathion (red indicates resistance, yellow indicates partial resistance, green indicates susceptibility to malathion). While resistance is apparent in significant portions of Puerto Rico and control of *Aedes aegypti* is an important public health objective, there are approximately 30 species of mosquito known to inhabit the island and we have little additional information about the threat these species pose or control methods. However, it is reasonable to conclude that for *Aedes aegypti*, as the primary target for mosquito control in Puerto Rico and the U.S. Virgin Islands, malathion would not be the pesticide of choice and that several other pesticides would be more likely to be used, given the documented resistance to malathion.

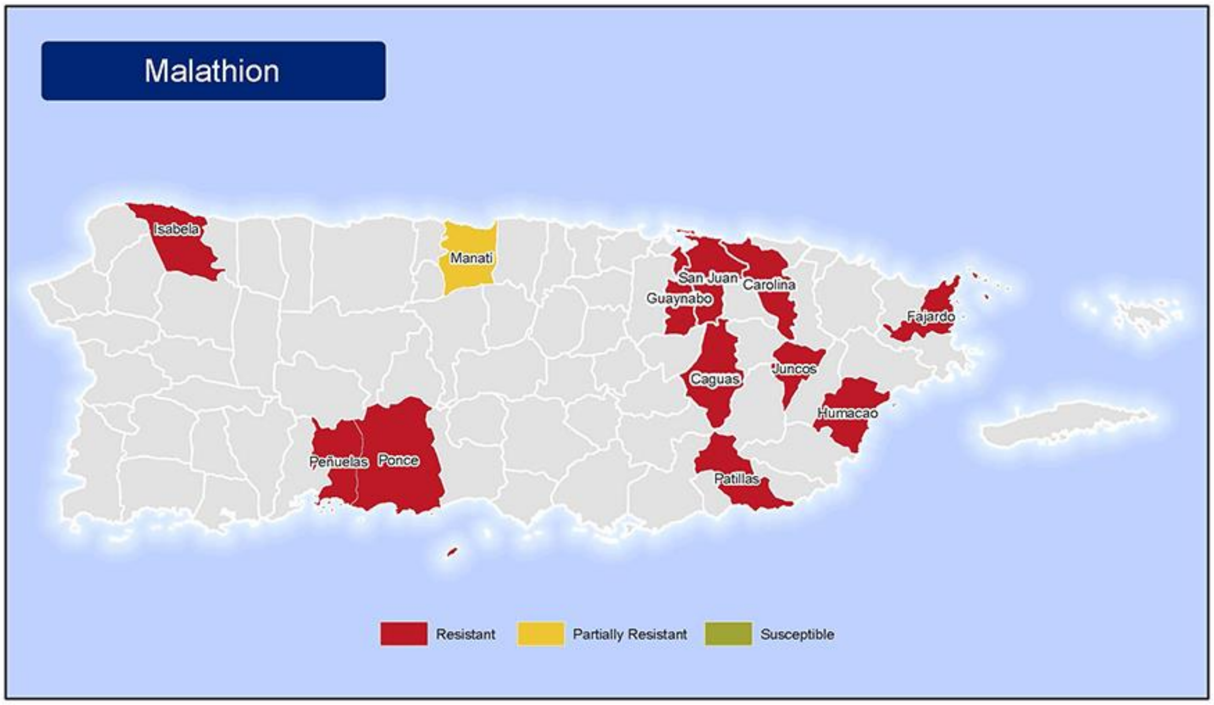

Figure 14. CDC bioassay study of malathion resistance in *Aedes aegypti*. Source: **https://www.cdc.gov/zika/vector/testing-puertorico.html**

Species range maps

For some Pacific and Caribbean Island species, the ranges as mapped encompass the entire island or islands where the species can be found. Thus, exposure is better assessed by the degree to which these species are likely to be within or adjacent to malathion use sites. For some groups of species in the Pacific, where the current range was at a sub-island level, a visual comparison of the 2015 Hawaii Statewide Agricultural Land Use Baseline and current aerial photography was used to determine overlap with the species current range.

Other considerations for Pacific and Caribbean Islands

Another route of exposure for listed species in the Pacific and Caribbean Islands is the occurrence of environmental conditions that may lead to volatilization.

Topographical and atmospheric conditions on the Main Hawaiian Islands are likely to result in montane deposition of the volatilized pesticide residues as fog or rainfall in the 500 to 2,225-meter elevation fog and cloud zone on flanking mountains of the Hawaiian Islands. Fugitive dust, which may transport pesticide residues, is likely to further increase pesticide movement in the central and leeward dry areas of the Hawaiian Islands. Prevailing northeasterly trade winds blow more than eighty percent of the time in the Hawaiian Islands (Cao, Giambelluca, Stevens, & Schroeder, 2007). A cloud and fog zone occurs when moisture-laden air rises to the high-elevation areas of the islands of Kauai, Oahu, Molokai, Maui, Lanai, and the Island of Hawai’i.

In addition, fog development and rainfall on the leeward sides of islands is also caused by orographic lifting (i.e., the rise of air as it ascends a mountain side, cools, then creates precipitation) and convection caused by thermal land heating of the west- and south-facing slopes of the mountainous Hawaiian Islands, which cause onshore/upslope south and west winds at ground level on the southern and leeward sides of the Hawaiian Islands (Van Nguyen & Chen, 2010). Fog is an important source of water in forests between 500 meters and 2,000 meters (Juvik & Ekern, 1978; Scholl, Giambelluca, Gingerich, Nullet, & Loope, 2007; Zhang, Wang, Lauer, Hamilton, & Xie, 2012). Cloud vertical development is capped at the bottom of a trade wind inversion (Leopold, 1949), which results in very dry climates at the highest elevation areas on east Maui and the Island of Hawai'i. On most days, fog and clouds occur between approximately 500 and 2,110 to 2,225 meters elevation in the mountains of the main Hawaiian Islands (Zhang, Wang, Lauer, Hamilton, & Xie, 2012). Orographic cloud water may account for 37% of total precipitation at windward and 46% at leeward sites (Scholl, Giambelluca, Gingerich, Nullet, & Loope, 2007).

In the Caribbean Islands, environmental conditions may lead to volatilization from application sites to the cloud and fog zone (500 – 1,340 meters) in the form of condensation, fog drip, and rainfall. Pesticides can be carried in dry air and in fog and adhere to plants. Interior mountainous region of Puerto Rico (e.g., Luquillo Mountains of northeast Puerto Rico) including lower montane rain forests (or dwarf forests) are subject to cloud forest volatilization effects. No deposition of malathion volatilized at low elevation agricultural and nursery areas would be expected to occur above the fog belt.

Although we would expect species within high-level elevation areas to be exposed to malathion via volatilization, we conclude, based on the best information available, that species in high elevations would not be exposed to concentration levels that would affect them (see *General Effects* for further information on volatilization).

Analysis for Pacific and Caribbean Islands Animals

Based on the above considerations for exposure and effects, the approach used to analyze animal species in the Pacific islands was identical to that used for CONUS species with a few notable exceptions. These exceptions are discussed below, and also refer to the *Analysis for Animal Species* section of this Opinion for a complete discussion. Changes were made to the ranking indicator systems used to arrive at preliminary determination indicators for each species. While the vulnerability factors and ranking remained the same, we adjusted the Risk and Usage factors by accounting for the unique aspects of data available for island species. The template for determining preliminary indicators is included below for reference.

<u>Risk factors and ranking</u>

As explained above, there is a high degree of uncertainty for landcover data for Pacific and Caribbean Island species, and thus, we did not rely on this information to make conclusions regarding the magnitude of anticipated effects to species from malathion exposure. Instead, we ranked a species' direct and indirect effects based on information provided in the "Risk to Individuals if exposed" and the "Risk to the species from labelled uses" across the range sections. This allowed for the assessment of the direct and indirect effects to species and their food items.

Usage factors and ranking

As discussed above, there is a high degree of uncertainty for quantitative usage data for Pacific and Caribbean Islands. As such, we did not include this data in our ranking indicator system. Instead, in order to differentiate the anticipated magnitude of exposure for a large number of animal species without having reliable overlap or usage data, we categorized the animal species into groups based on their preferred habitat. Animals living in pasture, agricultural, cultivated or other disturbed areas were assumed to have ‘high’ exposure to malathion, as these habitat types are more likely to experience malathion use. Animals occurring in forests, on cliffs or sand dunes and in bogs were assumed to have ‘low’ for malathion exposure. malathion is not registered for use in forests and we assumed there would also be low likelihood of spray drift within a forest given its physical structure and ability to block drift. Cliffs, sand dunes and bogs on the islands tend to be isolated physically from other land use areas; thus, we assumed there would be a low likelihood of malathion exposure from direct use and spray drift. Animals found in shrubland or grassland and those animals without habitat descriptors that provided indication of exposure were assigned a ‘medium’ exposure.

The Usage factors and ranking used for CONUS animals gave us a reasonable approximation of the amount of usage, and thus exposure, that could occur within a species range. We used habitat types as a proxy for usage as they were able to give us an approximation of exposure, though coarse, that a species may experience within its range. While we did not include the available usage data figure directly in our indicator ranking system, we still considered it when making draft determinations for individual species where applicable. Vulnerability, Risk and Usage indicators were combined to arrive at a preliminary ranking indicator using the same method as for CONUS animals.

Conservation Measures

For each species or group of species, we identify those conservation measures that are likely to avoid, minimize and reduce exposure and effects based on use and usage patterns relevant to the species, and describe the nature of the reduction. Species-specific measures were developed and incorporated into the Action for several species (e.g., *Drosophila heteroneura*) and also for use in conjunction with general label changes for most species to further lower the amount of malathion entering habitats and reduce exposure where the species are expected to be found (see also Table 5 for a list of the species-specific measures and Appendix K for discussion of the species-specific conservation measures, as applicable, and for individual species discussions related to the general label changes). For example, for the Llanero coqui, which is an obligate wetland species, spending its life history in moist sheltered areas in its only known habitat (e.g., a freshwater wetland in Puerto Rico), we anticipate the addition of conservation measures, including rain restrictions, aquatic habitat buffers, residential use label changes, and reduced numbers of applications and application rates will further reduce the likelihood of exposure of the species, its prey, and its habitat. As with most amphibians, the rain restriction is anticipated to reduce the likelihood of exposure (directly or in runoff) to the Llanero coqui when the animals are most active (e.g., following a precipitation event). Similarly, the aquatic buffers, reduction in the number of applications and reduction in applications rates are anticipated to reduce the likelihood of exposure by reducing or eliminating the pesticide from aquatic habitats proximate to agricultural applications. Lastly, residential use label changes are expected to reduce environmental concentrations as initial residues degrade prior to the next application, reduce the likelihood of and the environmental concentration of exposure by establishing buffers from waterways (specified on the label a distance from water bodies where pesticides are not to be applied), and restrictions to application during periods where rain is not forecasted within 24 hours or when the soil is not saturated.

Approach for Pacific and Caribbean Islands Plants

Based on the above considerations for exposure and effects, the approach used to analyze plant species in the Pacific and Caribbean islands was identical to that used for CONUS species with a few notable exceptions. Those exceptions are discussed below; refer to the *Analysis for Plant Species* section of this Opinion for a complete discussion of the plants analysis. The template used to determine preliminary indicators can be found in Appendix J.

Risk Factors and Ranking:

As explained above, there is a high degree of uncertainty for landcover data for Pacific and Caribbean Islands species, and thus we did not rely on this information to make conclusions regarding the magnitude of effects to pollinators from malathion exposure. Instead, we ranked a species indirect effects based on their level of reliance on particular pollination vectors. Species solely reliant on insects for pollination are expected to experience 'high' indirect effects, while those using abiotic pollination vectors are expected to experience 'low' indirect effects. Species with avian pollinators or a mix of pollinators are expected to experience 'medium' indirect effects.

Usage Factors and Ranking

As discussed above, there is a high degree of uncertainty for quantitative usage data for the Pacific and Caribbean Islands. For species with a portion of their range on Federal lands, we did not quantitatively evaluate use or usage on in these areas, but we assume only low levels of usage, per the rationale described in the Approach to Usage Analysis. For the non-Federal lands portion of the species ranges, we have limited past malathion usage in the Pacific and Caribbean Islands, and thus our estimation of usage and exposure on non-Federal lands contains a large degree of uncertainty. Briefly, we anticipate that usage in non-agricultural areas will be low (up to 5% of overlap in any given area). We anticipate that the available agricultural usage data, which is from a single year and does not distinguish between use categories, likely provides an upper bound of malathion usage for our analysis, particularly as it includes all insecticides. This usage is also anticipated to be low (~5% of agricultural lands treated across the islands as an upper bound for malathion for the Pacific Islands and ~11% of agricultural lands treated across the islands as an upper bound for malathion for the Caribbean islands), though we cannot predict the degree of usage in proximity to particular species' ranges. However, given that 89 to 95% of agricultural fields are not anticipated to be treated with insecticides, we assume a low probability that any individual plant will be in proximity to agricultural usage of malathion. In addition, the immobility of plants can serve to both limit that likelihood and help to anticipate the likelihood of exposure, as opposed to an animal such as a bird that may travel through and within various habitat types for activities such as foraging, dispersal, or migration. We anticipate these assumptions are reasonable for characterizing risk of exposure for most or all of these species. In the rare cases where exposure for an individual plant or species would occur, we anticipate the greatest effects of exposure would be to its pollinators. However, we anticipate the pollinator base will generally be able to withstand a higher level of disturbance from exposure before impacts to the listed entity would occur.

To differentiate the anticipated magnitude of exposure for hundreds of plant species without having reliable overlap or usage data, we categorized the plant species into groups based on their preferred habitat. Plants living in pasture, agricultural, cultivated or other disturbed areas were assumed to have ‘high’ anticipated exposure to malathion, as these habitat types are more likely to experience malathion use. Plants occurring in forests, on cliffs or sand dunes and in bogs were assumed to have ‘low’ anticipated exposure to malathion. Malathion is not registered for use in forests and we assumed there would also be low likelihood for spray drift within a forest given its physical structure and ability to block drift. Cliffs, sand dunes and bogs on the islands tend to be isolated physically from other land use areas, thus we assumed there would be a low likelihood for malathion exposure from direct use and spray drift. Plants found in shrubland or grassland and those plants without habitat descriptors that provided indication of exposure were assigned a ‘medium’ exposure.

The usage factors and ranking used for CONUS plants and animals gave us a reasonable approximation of the amount of anticipated usage, and thus exposure that could occur within a species range. We used habitat types as a proxy for usage as they were able to give us an approximation of exposure, though coarse, that a species may experience within its range. While we did not include the available usage data figure directly in our indicator ranking system, we still considered it when making draft determinations for individual species. See Integration and Synthesis Worksheet for island species in Appendix J.

Conservation Measures

We expect the general and species-specific conservation measures will reduce exposure of pollinators to malathion, thus reducing resultant reproductive effects to the listed plants. For example, portions of the range of *Catesbaea melanocarpa,* a spiny shrub endemic to Puerto Rico and St. Croix in the U.S. Virgin Islands, occurs adjacent to agricultural areas. In order to minimize exposure of the insect pollinators of this species, which are essential to the plant’s reproductive success, a species –specific conservation measure will be implemented that does not allow malathion application within the range of the species, plus 100 feet beyond the range to account for potential spray drift from applicators adjacent to the range. In conjunction with the general conservation measures applicable to this species, such as the new label restrictions on the method and frequency of residential use applications, these measures are anticipated to substantially reduce the pollinator exposure and thus mortality from malathion application within and immediately surrounding the range of this species, substantially reducing reproductive effects.

In the Integration and Synthesis summaries for each species or group of species (Appendix K), we identify those conservation measures that are likely to avoid, minimize, or reduce exposure and effects based on use and usage patterns relevant to the species, and describe the nature of the reduction. All conservation measures are being incorporated into the Action and species-specific measures will be implemented through EPA's *BulletinsLive! Two*.

Pacific and Caribbean Island Species, Summary of Findings

Species in these island groups are diverse and consist of plants and animals within various taxonomic groups: birds, mammals, amphibians, reptiles, terrestrial invertebrates, aquatic invertebrates, ferns, and flowering plants.

Each species generally occurs only within certain habitat types, though for species that are more mobile or migrate, such as birds, habitat use can be broader and include many types. Plants and resident species stay in the same area year-round, although some animals may make seasonal movements between local habitat areas. Migratory species may have more complex habitat needs, and a greater likelihood to encounter numerous habitat types. As a whole, species in these islands face numerous threats and environmental problems. Reductions in habitat quantity and quality, the primary causes of negative population trends in many species, are often exacerbated by the direct loss of life from an array of external environmental hazards. Clean air, clean water, and abundant, diverse and healthy habitats are essential for most species to survive and recover.

Individual species that occur on Pacific and Caribbean islands live in a broad variety of habitat types that may influence their exposure to malathion. Some species occur in forests or remote locations, or feed in the ocean where malathion exposure is not expected based on its labeled uses. Other species may be found on or near agricultural or developed sites, especially as development has reduced native habitat on some islands. Furthermore, species that live at elevation or within the fog zone of islands may be subject to exposure to pesticides through environmental factors including volatilization, though we anticipate exposure would involve low concentration levels that would not result in effects to these species.

Exposure to malathion can result in a range of effects including direct mortality, mortality due to the consumption of contaminated food resources, sublethal effects affecting growth, reproduction and behavior for individuals that survive exposure, loss of important food resources that can lead to starvation, reproductive failure, site abandonment or other detrimental effects, and loss of pollinators vital to reproduction. The effects can vary greatly by species depending on the likelihood that a given species occurs within or adjacent to malathion use sites, the pattern of malathion usage, the diet of the species in light of how their food resources may be affected, and reliance on other species to complete their reproductive cycle. Food resources are susceptible to contamination by pesticides that can then be passed on to individuals that consume them, as well as lead to losses of prey that can in turn reduce the available food supply. The anticipated pesticide exposures and consequences to species, their food resources, or pollinators, the expected reduction in these effects as a result of conservation measures, and the status of the species and factors related to their vulnerabilities and life histories, were all considered when evaluating the effects of the Action on each species of the Pacific and Caribbean Islands.

As described for each species in each of the taxa and assessment groups, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of the Pacific and Caribbean Island species in this Opinion the Pacific and Caribbean islands species addressed in this Opinion in the wild.

Pacific Species

Integration and Synthesis summaries for species in the Pacific Animal and Plant groups can be found in Appendix K. All of the species included in the Pacific Animal and Plant groups and our conclusions for each are presented in **sections.**

Table 59 - 62. Additional information for these species is found in the Status of the Species and Critical Habitat (Appendix C) and the *Effects of the Action* sections.

Table 59. PACIFIC ANIMALS. Listed, proposed, and candidate species addressed in this Opinion.[73]

Table 59. Pacific Animals.xlsx

Pacific Islands Plants

Groups 2 and 3: Ferns and Allies and Conifers and Cycads

Ferns and their allies do not have flowers or seeds, but reproduce sexually via spores that are dispersed by wind. Ferns and their allies can also reproduce asexually, through vegetative reproduction in the form of bulbets or rhizomes. During sexual reproduction, ferns produce two free-living generations, a diploid sporophyte (i.e., a fern plant) and a haploid gametophyte. The gametophytes are typically very small (around ½ inch), fragile, and have very specific requirements for growth, such as damp soil conditions and high humidity. We expect the ferns and their allies will experience some effects from direct malathion exposure, but will not experience adverse reproductive effects due to pollinator or seed disperser mortality from malathion exposure given these species do not rely on animal vectors for reproduction. There is one cycad species in the Pacific islands, the Fadang, Cycas micronesica. Cycads are gymnosperms, vascular plants, usually trees or shrubs that reproduce by means of an exposed seed, or ovule. Gymnosperms do not produce flowers and their pollen is dispersed by wind. We expect the cycad in this group will experience some effects from direct malathion exposure, but they will not experience adverse reproductive effects due to pollinator mortality given these species do not rely on animal vectors for pollen transfer.

[73] For determinations and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = "May affect, not likely to adversely affect;" NE = "no effect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

Table 60. PACIFIC PLANTS Groups 2 and 3. Listed, proposed, and candidate species addressed in this Opinion.[74]

Table 60. Pacific
Plants (Groups 2 - 3).x

Groups 4-7: Monocot flowering plants (for list of species and conclusions see Table 61)

All species in these assessment groups are monocots, a class of angiosperm flowering plant defined by having one cotyledon (embryonic seed leaves). There are a large variety of monocot species, though typical monocot plants include grasses, lilies and palms. Monocots are not expected to experience effects to growth or survival from direct exposure to malathion.

Monocots use a variety of pollination vectors in order to accomplish pollen and gene transfer between individual plants and among populations. Likewise, they use a variety of seed dispersal vectors to ensure movement and transport of seeds away from parent plants and ensure the germination and survival of some of the seeds to adults. In addition, pollination and seed dispersal can ensure genetic diversity among populations and seed dispersal can lead to colonization of new sites within the range of the plant.

Species with abiotic pollination vectors will not experience reproductive effects from malathion exposure to pollinator populations in their range (Group 4). Species using biotic pollination vectors will experience varied levels of effect from mortality of their pollinating species based on the specific taxa group involved in pollination (Groups 5-7). Magnitude of effects to insect and bird pollinating species were assessed qualitatively based on pollinating taxa group and likelihood of exposure given the plant’s preferred habitat. Similarly, as plants in these groups rely on a variety of seed dispersal vectors, the magnitude of effects of seed disperser loss on the particular plant from malathion exposure will depend on the specific taxa group of animals involved in seed dispersal. Mortality is expected for insect pollinators and seed dispersers exposed to malathion on use sites or via spray drift. Some bird pollinators and seed dispersers exposed to malathion on use sites may experience mortality or sublethal effects, depending on the site of exposure and size of the bird. Smaller birds exposed on use sites with higher allowable use rates (e.g., developed, open space developed, orchards and vineyards) have a greater chance of being affected. Exposure to spray drift is not expected to result in effects to avian seed dispersers. No mortality or sublethal effects are expected for mammalian pollinators or seed dispersers from malathion exposure either on use sites or from spray drift.

For these species, we anticipate their high vulnerabilities and medium to high levels of risk to individuals or species is offset by low levels of usage of malathion, as described below. For

[74] For determinations and conclusions: LAA = “may affect, likely to adversely affect;” NLAA = “may affect, not likely to adversely affect;” NE = “no effect;” No J = “No Jeopardy;” No Ad Mod = “No destruction or adverse modification;” NA = Not Applicable (e.g., critical habitat has not been designated for a species).

species with a portion of their range on Federal lands, we did not quantitatively evaluate use or usage on in these areas, but we assume only low levels of usage, per the rationale described in the Biological Opinion. For the non-Federal lands portion of the species ranges, we have limited information on past malathion usage in the Pacific Islands, and thus our estimation of usage and exposure on non-Federal lands contains a large degree of uncertainty. Briefly, we anticipate that usage in non-agricultural areas will be low (up to 5% of overlap with species range in any given area). We anticipate that the available agricultural usage data, which is from a single year and does not distinguish between use categories, likely provides an upper bound of malathion usage for our analysis, particularly as it includes all insecticides. For the Pacific Islands as a whole, this usage is also anticipated to be low (~5% of agricultural lands treated across the islands as an upper bound for malathion), though we cannot predict the degree of usage in proximity to particular species' ranges with exact precision. However, given that 95% of agricultural fields are not anticipated to be treated with insecticides, we assume a low probability that any individual plant will be in proximity to agricultural usage of malathion. We further discuss our assumptions and analysis of usage data on Federal lands and in the Pacific Islands in the *Approach to the Usage Analysis* section of this Opinion.

Table 61. PACIFIC PLANTS Groups 4 - 7. Listed, proposed, and candidate species addressed in this Opinion.[75]

Table 61. Pacific
Plants (Groups 4-7).xl

Groups 8-11: Dicot flowering plants (for list of species and conclusions see Table 62)

All species in these assessment groups are dicots, a class of angiosperm flowering plant defined by having two cotyledons (embryonic seed leaves). Dicots are a hugely diverse class of flowering plants, with tens of thousands of species. Familiar dicots include plants such as daisies, roses and oak trees. The individual plants in these assessment groups are estimated to experience up to a 12% decrease in dry weight if exposed to malathion on the following use sites, based on labeled application rates: orchards and vineyards, developed, nurseries, open space developed and Christmas trees. No effects are expected on other use sites.

Dicots also use a variety of pollination vectors in order to accomplish pollen and gene transfer between individual plants and among populations. Likewise, they use a variety of seed dispersal vectors to ensure movement and transport of seeds away from parent plants and ensure the germination and survival of some of the seeds to adults. In addition, pollination and seed

[75] For determinations and conclusions: LAA = "may affect, likely to adversely affect;" NLAA = "may affect, not likely to adversely affect;" NE = "no effect;" No J = "No Jeopardy;" No Ad Mod = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

dispersal can ensure genetic diversity among populations and seed dispersal can lead to colonization of new sites within the range of the plant.

Species with abiotic pollination vectors (Group 8) will not experience reproductive effects from malathion exposure to pollinator populations in their range. Species using biotic pollination vectors (Groups 9-11) will experience varied levels of effect from mortality of their pollinating species based on the specific taxa group involved in pollination. Magnitude of effects to insect and bird pollinating species were assessed qualitatively based on pollinating taxa group and likelihood of exposure given the plant's preferred habitat. Similarly, as plants in these groups rely on a variety of seed dispersal vectors, the magnitude of effects of seed disperser loss on the particular plant from malathion exposure will depend on the specific taxa group of animals involved in seed dispersal. Mortality is expected for insect pollinators and seed dispersers exposed to malathion on use sites or via spray drift. Some bird pollinators and seed dispersers exposed to malathion on use sites may experience mortality or sublethal effects, depending on the site of exposure and size of the bird. Smaller birds exposed on use sites with higher allowable use rates (e.g., developed, open space developed, orchards and vineyards) have a greater chance of being affected. Exposure to spray drift is not expected to result in effects to bird seed dispersers. No mortality or sublethal effects are expected for mammalian pollinators or seed dispersers from malathion exposure either on use sites or from spray drift.

For these species, with only a few exceptions, we anticipate their high vulnerabilities and medium to high levels of risk to individuals or species is offset by low levels of usage of malathion, as described below. For species with a portion of their range on Federal lands, we did not quantitatively evaluate use or usage in these areas, but we assume only low levels of usage, per the rationale described in the Biological Opinion. For the non-Federal lands portion of the species ranges, we have limited historical malathion usage data in the Pacific Islands, and thus our estimation of usage and exposure on non-Federal lands contains a large degree of uncertainty. Briefly, we anticipate that usage in non-agricultural areas will be low (up to 5% of overlap in any given area). The available agricultural usage data, which is from a single year and does not distinguish between use categories, likely provides an upper bound of malathion usage for our analysis, as the data includes all insecticides. For the Pacific Islands as a whole, this usage is also anticipated to be low (~5% of agricultural lands treated across the islands as an upper bound for malathion), though we cannot predict the degree of usage in proximity to particular species' ranges with exact precision. However, given that 95% of agricultural fields are not anticipated to be treated with insecticides, we assume a low probability that any individual plant will be in proximity to agricultural usage of malathion. We further discuss our assumptions and analysis of usage data on Federal lands and in the Pacific Islands in the *Approach to Usage Analysis* section of this Opinion.

Table 62. PACIFIC PLANTS Groups 8 - 11. Listed, proposed, and candidate species addressed in this Opinion.[76]

Table 62. Pacific Plants (Groups 8-11).›

Caribbean Species

Integration and Synthesis summaries for species in the Caribbean Animal and Plant groups can be found in Appendix K. All of the species included in the Caribbean Animal and Plant groups and our conclusions for each are presented in Table 63 and Table 64. CARIBBEAN PLANTS. Listed, proposed, and candidate species addressed in this Opinion., respectively. Additional information for these species is found in the *Status of the Species and Critical Habitat* (Appendix C) and the *Effects of the Action* sections.

Table 63. CARIBBEAN ANIMALS. Listed, proposed, and candidate species addressed in this Opinion.[77]

Table 63. Caribbean Animals.xlsx

Caribbean Plants

For these species, except in a few cases, we anticipate their medium to high vulnerabilities and medium to high levels of risk (as applicable) to individuals or species is offset by low levels of usage of malathion in most cases, as described below. For species with a portion of their range on Federal lands, we did not quantitatively evaluate use or usage in these areas, but we assume only low levels of usage, per the rationale described in the Biological Opinion. For the non-Federal lands portion of the species ranges, we have limited historic malathion usage data in the Caribbean Islands, and thus our estimation of usage and exposure on non-Federal lands contains a large degree of uncertainty. Briefly, we anticipate that usage in non-agricultural areas will be low (up to 5% overlap with species range in any given area).The available agricultural usage data, which is from a single year and does not distinguish between use categories, likely provides an upper bound of malathion usage for our analysis, particularly as it includes all insecticides.

[76] For determinations and conclusions: LAA = "may affect, likely to adversely affect;" NLAA = "may affect, not likely to adversely affect;" NE = "no effect;" No J = "No Jeopardy;" No Ad Mod = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).
[77] For determinations and conclusions: LAA = "may affect, likely to adversely affect;" NLAA = "may affect, not likely to adversely affect;" NE = "no effect;" No J = "No Jeopardy;" No Ad Mod = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

For the Caribbean Islands as a whole, this usage is also anticipated to be low (~11% of agricultural lands treated across the islands as an upper bound for malathion), though we cannot predict with exact precision the degree of usage in proximity to particular species' ranges. However, given that 89% of agricultural fields are not anticipated to be treated with insecticides, we assume a low probability that any individual plant will be in proximity to agricultural usage of malathion. We further discuss our assumptions and analysis of usage data on Federal lands and in the Caribbean Islands in the *Approach to the Usage Analysis* section of this Opinion.

Table 64. CARIBBEAN PLANTS. Listed, proposed, and candidate species addressed in this Opinion.[78]

Table 64. Caribbean Plants.xlsx

Critical Habitat

The effects of malathion on critical habitat are anticipated to be in the form of impacts to PBFs involving (1) water quality and habitat function, (2) arthropods as prey, (3) essential non-arthropods that function as prey species, pollinators/seed dispersers, and host fish, and (4) insect pollinators/seed dispersers, as described in the *Critical Habitat Approach to the Assessment* section of this Opinion. Critical habitat that includes PBFs related to the elements listed above are susceptible to effects from pesticide exposure.

As described in the *Critical Habitat Approach to the Assessment* section, we reviewed each critical habitat rule to determine if PBFs related to those listed above were explicitly identified or could be clearly and simply linked to the proposal or designation of the critical habitat. For all critical habitats that overlap with pesticide use sites (or were qualitatively determined to be at risk of being exposed to malathion) and have PBFs specified that are susceptible to pesticide usage, we evaluated the vulnerability of the PBF, expected usage levels, and numerous other factors (such as overlap with Federal lands and other species- and critical habitat-specific information), to analyze effects to the critical habitat. General conservation measures were assessed to determine whether they would sufficiently reduce risks to the PBFs, as needed to maintain the conservation value of the critical habitat as a whole for the species. In cases where general conservation measures would not likely be sufficient, critical habitat- or species-specific measures were incorporated into the Action to further reduce adverse effects.

For all designated and proposed critical habitats in this Opinion, we do not anticipate that the Action would appreciably diminish the value of these critical habitats as a whole for the conservation of their respective species. Thus, we do not expect the Action would destroy or

[78] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = "May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

adversely modify critical habitat for these species. Our analysis of the effects of the Action on proposed and designated critical habitats, our conclusions, and the dichotomous key used to facilitate our assessment are included in Appendix L.

CONCLUSION

The proposed registration of malathion is not likely to jeopardize the continued existence of any of the species analyzed in this Opinion. The Opinion considers 1,598 species (see individual taxa/group tables in the *Integration and Synthesis* section of this Opinion). Of these, 30 species are included as part of conference opinions (23 are proposed and 7 are candidate species). All of these species have vulnerabilities ranging from low to high, represented by a single population or few to many populations, with populations that may be declining, stable or increasing. While most listed species have isolated and fragmented populations, some of these species are less vulnerable to overall threats. Varying degrees of sublethal effects or mortality are anticipated, depending on the species, ranging from a few to many individuals of some species being impacted, while losses of prey resources, host fish (for mussels) and pollinators or seed dispersers (for plants) is likely to have consequences such as reduced fitness, recruitment and dispersal of some individuals and populations. In some cases, individuals may experience multiple effects concurrently (e.g., sublethal effects and loss of food resources) within a given application area. These effects are generally anticipated to be lower in magnitude for species with ranges that have lower overlaps with use sites and lower levels of malathion usage. For many species, new label restrictions with general or species-specific conservation measures (or both) are expected to substantially reduce the likelihood or frequency of exposure. While we anticipate that a number of individuals for some species are likely to be lost to mortality, be subjected to sublethal effects (e.g., effects to behavior, reproduction and growth), and/or experience reductions in food resources, hosts, or pollinators/seed dispersers, we do not anticipate the Action would appreciably reduce the likelihood of both the survival and recovery of these species in the wild and, therefore, we do not anticipate that the registration of malathion is likely to jeopardize the continued existence of the species analyzed in this Opinion.

Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species. Through this consultation, we determined pertinent elements of the PBFs of proposed and designated critical habitats that are susceptible to effects from malathion. These elements fall within the following categories: (1) water quality for aquatic or water-dependent species, or conditions related to pollution-levels for terrestrial habitats to function for the species (habitat function), (2) arthropods as prey (e.g., for insectivorous species), (3) non-arthropods as prey for omnivorous or carnivorous animal species, pollinators/seed dispersers for plants, and host fish for mussels, and (4) insect pollinators and seed dispersers for plants. The degree to which these PBFs would be affected by malathion and the consequences for each critical habitat was evaluated, and our assessments and conclusions are included in Appendix L.

The Opinion covers critical habitats for 778 species (see individual taxa/group tables in the *Integration and Synthesis* section of this Opinion). Of these, 28 are analyzed in conference opinions as proposed critical habitats. Based on the critical habitat analysis described above and presented in Appendix L, adverse effects are anticipated for some critical habitats. However, we do not anticipate that those adverse effects would rise to the level where they are likely to appreciably diminish the value of the critical habitat as a whole for the conservation of the listed species. Therefore, it is the Opinion of the Service that the Action is not likely to result in the destruction or adverse modification of critical habitat.

INCIDENTAL TAKE STATEMENT

Challenges in Estimating Incidental Take

In view of the specific characteristics of many of the species analyzed in this Opinion and the very nature of this large-scale Action, even the best scientific and commercial data available are not sufficient to enable the Service to estimate the specific quantity of individuals anticipated to be incidentally taken for each affected species. Thus, in this Opinion, we describe the types of incidental take reasonably certain to occur in a generalized manner and the relative levels of incidental take anticipated for each species. In addition, although we cannot precisely quantify the number of individuals anticipated to be taken as a result of this Action, we have provided a measurable value for each species by which the relative levels of incidental take associated with the usage data that we analyzed in this Opinion can be re-evaluated. As explained in more detail below, if the specific value pertaining to usage is exceeded during the course of this Action, EPA and the Service will coordinate to determine if additional incidental take is occurring and whether the consultation should be re-initiated pursuant to ESA section 7 implementing regulations at 50 C.F.R. 402.16 (a).

Partially due to the characteristics of many of the species analyzed in this Opinion, the express number of individuals taken incidental to the Action cannot be provided. Incidental take will often be difficult to detect, particularly where the species is small or cryptic (e.g., insects, arachnids, amphibians), wide-ranging (e.g., certain birds, reptiles, mammals, and fish), or inhabits areas that are difficult to monitor or access (e.g., caves, aquifers). In many cases, finding a dead or impaired specimen is unlikely; this is particularly true when sublethal effects to growth, reproduction, behavior, or fitness are anticipated as a result of direct exposure and impacts on prey and other resources upon which the listed species depends. In addition, losses of individuals may be masked by seasonal fluctuations in numbers or other causes (e.g., oxygen depletions for aquatic species, drought, or other stochastic events). In fact, entire taxa groups, such as insects, arachnids and bivalves, and species of amphibians, birds and fish have the characteristics described above that render precise quantification of individual losses impossible.

In addition to species' characteristics, the very nature of the Action evaluated in this Opinion makes it difficult to detect and measure incidental take. The Action involves the registration of a chemical that is used in a variety of ways across the entire country. Due to the paucity in data, we cannot predict the exact timing and location of incidental take. Furthermore, gaps in our knowledge concerning various species' toxicity levels and estimated environmental concentrations also compound the difficulty in detecting and measuring incidental take.

Amount or Extent of Take Anticipated

In this Opinion, we generally describe the types of anticipated incidental take in the *Integration and Synthesis* section, its appendices, and our *Conclusion* section above. Overall, we anticipate the Action will result in the loss of individuals and/or sublethal effects (such as impacts to growth, reproduction, or survival), or reductions in fitness or changes in behavior that lead to mortality or sublethal effects, to individuals of the species addressed in this Opinion, the numbers of which will vary by species. Some listed species will also experience impacts to their prey or forage base, or to other species or habitat upon which they depend, which will indirectly impact listed species' growth, reproduction, fitness and/or survival. As with mortality and sublethal effects associated with direct exposure, the numbers of individuals affected by impacts to their prey or forage base and the anticipated degree of such effects will also vary by species.

We list the anticipated incidental take that is reasonably certain to occur for each animal species over the duration of the Action (Appendix K-E), as described in the Integration and Synthesis summaries (Appendix K). This anticipated take is based on reviewing the risk to individuals of listed species, to listed species' food resources, and to any other species on which listed species rely that we expect will be exposed to malathion in light of: (1) the best available scientific and commercial data (e.g., usage, sales) that applied to each species; and (2) any other considerations that are relevant, such as general or species-specific conservation measures described in the Integration and Synthesis summary for each species. Despite the conservation measures incorporated in the Action that will avoid the likelihood of jeopardy and adverse modification by reducing exposure to malathion, we anticipate that low levels of incidental take will still occur for certain species.

For those species in which incidental take is reasonably certain to occur, we provide a brief description of expected take in each Integration and Synthesis summary (Appendix K). In Tables 1-11 (Appendix K-E) we indicate that low levels of individuals would experience mortality, sublethal effects (e.g., survival, growth, or reproduction), or impacts to fitness (e.g., expressed as impacts to prey or forage base, etc.) over the duration of the Action. For example, for bivalves, we do not anticipate mortality or sublethal effects to individuals of the species, but for some mussel species that occur in smaller-sized flowing or static waterbodies (bin 2 or bin 5), we anticipate minor impacts to the reproduction of small numbers of individual mussels due to a small reduction in host fish. Similarly, for listed fish species, we anticipate small numbers of individuals of some listed fish species will be killed or experience sublethal effects in smaller waterbodies (bin 2 or 5); we also anticipate that small numbers of individuals of many (but not all) listed fish species in a variety of types of waterbodies will also experience minor reductions to their growth or fitness through a small reduction in prey or forage base. For still other species, such as certain birds, amphibians, and reptiles, we anticipate small numbers of individuals will be killed or experience sublethal impacts to growth or reproduction from exposure to malathion, and in many cases, small reductions in fitness due to losses of prey or other food resources.

Usage Data Used for Extent of Take

Due to the nature of the Action and characteristics of many of the species analyzed in this Opinion, we are unable to estimate the amount of incidental take anticipated in terms of the numbers of individuals expected to be lost. For the same reasons, we are unable to express the extent of incidental take relative to impacts on habitat or on other species that can serve as surrogates for individual losses or other impacts experienced by listed species. Instead, usage information that we evaluated in this Opinion, as described for each species or species group in its Integration and Synthesis summary (Appendix K), can be used to detect trends or changes in usage patterns over the duration of the Action. Because the expected level of incidental take for each species is linked, in part, to the level of usage that we anticipated for each species in this consultation, certain measures of usage (e.g., the percentage of crops treated [PCT] for agricultural uses, volume of mosquito control products sold to counties) can be appropriately used in helping inform whether re-initiation of consultation is warranted for exceeding the extent of take specified in this incidental take statement, pursuant to 50 CFR 402.16(a). Although changes in usage patterns do not necessarily correlate to an exceedance of incidental take, regular monitoring for changes in usage will help indicate when additional evaluation is needed to assess whether the incidental take described in this statement is being exceeded. In some cases, however, changes in certain types of usage data (e.g., PCTs, sales data) will not likely be of concern. For example, where general or species-specific conservation measures would effectively minimize exposure to listed species, their food resources or hosts, increases in the usage measures that we anticipated in this Opinion (i.e., exceedances) will not necessarily change the incidental take levels described in this statement. Similarly, where changes in usage patterns or levels would only affect uses that are not of significant concern to a species, we would not likely anticipate exceedances of incidental take. In contrast, in some cases, after further investigation of changes in usage or usage patterns, we may determine the anticipated levels of incidental take are likely to, or have been, exceeded.

To further illustrate, given the anticipated toxicity to the host fish of species of freshwater mussels in the example used above, we expect small numbers of host fish will be killed each year resulting in incrementally minor levels of take for some species of mussels. Should subsequent information reveal an increase in malathion usage over time, this information would be a basis for EPA and the Service to evaluate if the increase in usage was resulting in an increase in host fish mortality, and consequently, a decrease in reproduction of the listed mussel. Likewise, if subsequent years of malathion usage information reveals a general downward trend, we would generally not anticipate the need for re-assessment unless additional factors (e.g., change in species status, localized increase in usage affecting discrete areas important to the species, its prey or its habitat, new information about the toxicity to species, etc.) become apparent. Thus, the trigger for evaluating any exceedances of incidental take (as well as the need for re-initiation of consultation) will be a two-part assessment of both the risk to the species based on our understanding of the toxicity of malathion and the level of exposure based upon the usage of malathion in the habitat of the species.

As usage data is acquired in monitoring implementation of the Action, periodic review of these data will be needed to ensure assumptions in the BE and the Opinion remain valid. The ability to detect important changes in usage data, ecological incident data, water quality monitoring data, and other information that the BE and the Opinion relied upon will also be important to consider over the duration of the Action. The reasonable and prudent measures (RPMs) and the Terms and Conditions described below include measures that address the acquisition and analysis of usage data. Thus, for species in which incidental take is reasonably certain to occur, we anticipate that trend data and exceedances of our conservative assumptions herein, over multiple years, and reported at intervals described below in the Terms and Conditions to carry out the RPMs will determine when further discussions with the Service are needed, and, where appropriate, re-initiation of consultation is required.

The use of malathion usage data to help monitor levels of incidental take also allows us to monitor and test our overarching assumptions in this Opinion, including assumptions on usage. We recognize that there are significant gaps and a paucity of usage data. For example, usage data are not uniform across the action area, and the data are not available for each use on the same time frame. In addition, usage data are reported at varying spatial scales. However, the usage data represents a portion of the best scientific and commercial data available, was an important component of our analysis in this Opinion, and will continue to provide a valuable means to measure the intensity of adverse effects across a broad array of species and their extensive geographies.

In coordination with EPA (as referenced in the Terms and Conditions below), we intend to examine subsequent/future usage data for values that exceed our usage estimates based on state-level agricultural data, section-level CalPUR data, and/or county-level mosquito adulticide sales data (described in the *Effects of the Action* section of this Opinion and for each species in Appendix K-A). As detailed in the *Approach to the Usage Analysis* section above, for each state within most species' range[79] , we estimated agricultural usage for each UDL overlapping the range considering maximum PCT values over the 5-year reporting period in EPA's SUUM (Appendix G). These percentages were translated to the number of acres treated within a state, and compared to the number of acres in the species range to determine what percentage of the range could have been treated. For species that reside wholly or partially within California, we were able to apply more geographically-specific (section-level) agricultural usage data from CalPUR regarding malathion applied within each species' range. For mosquito control, we applied sales and reporting information to determine acres treated within the ranges of species in a manner similar to state-level agricultural data, but at a county level. We found that information derived from sales data largely encompassed the data for mosquito control for the few states from which it was available (e.g., California, New Jersey, Vermont). For both agricultural and mosquito control usage, we can assess whether we expect a change from the number of acres we estimated to be treated with malathion in the range of each species by monitoring the base information we used to make this estimate (i.e., PCT for state-level agricultural data, acres treated for California agricultural data, and sales data within a county for mosquito control). This information will be considered in light of species range information to assess whether or not that exceedance is meaningful for the applicable species. Put another way, a value that exceeds a value within the species' Integration and Synthesis Summaries[80] in Appendix K will alert us to the possibility of levels of take exceeding those anticipated in this Opinion, but additional coordination between EPA and the Service (as referenced in the Terms and Conditions listed below) will be needed to determine whether the exceedance actually indicates that re-initiation of

[79] Refer to *Approach to Usage Analysis* above for exceptions, such as Caribbean and Pacific Islands species. Still, the basic concept of periodically acquiring and evaluating updated data (e.g., USDA Census of Agriculture) for changes in how malathion is used will apply.
[80] In the case of subset 2 fishes and bivalves, the applicable values are listed in Appendix K-A4-1 (bivalves) and Appendix K-A6-1 (fish)

consultation is warranted (e.g., the data indicates the amount or extent of taking specified in this incidental take statement is exceeded).

As previously mentioned, we note that the usage data utilized in this Opinion are not uniform. For example, the California data (CalPUR) on usage are more geographically refined and at resolution that can be more useful in understanding exposure to species that often occur in small geographic areas. Thus, changes in the CalPUR data, as opposed to changes in aggregated usage data at the state level, may be more likely to reflect an exceedance in incidental take. Alternately, the non-agricultural crop data (e.g., Nurseries and Christmas trees, pine seed orchards, developed and open-space developed) generally represent usage data with lower confidence levels, and we are confident that these uses are not likely drivers for effects to species. For these uses, we do not believe incidental take is reasonably certain to occur, and as such, monitoring is not needed. EPA will provide us state-level and CalPUR agricultural data and as outlined in our Terms and Conditions below. We believe that by examining state-level PCT values and acres treated within California, we will be able to identify potential exceedances. Lastly, mosquito adulticide use will also necessitate ongoing monitoring. While we cannot divulge sales information for mosquito control usage (it is Confidential Business Information), EPA has access to this information and will continue to provide it to the Service at appropriate intervals (as referenced in our Terms and Conditions below). We believe that by examining malathion sales information for mosquito control, particularly with respect to (1) new counties in which malathion is being sold and (2) increases in the volume of product sold, we will be able to identify potential exceedances.

As discussed in the Integration and Synthesis Summaries, prior to finalizing this Opinion, we discovered that the overlap of malathion use sites with the species range was calculated based on an inaccurate range map for 13 species (California tiger salamander (Sonoma DPS), Yosemite toad, Oregon spotted frog, Arroyo toad, Buena Vista Lake ornate shrew, purple cat’s paw, tan riffleshell, spectaclecase mussel, sheepnose, Presidio clarkia, American chaffseed, Leedy’s roseroot, and Kenwood Marsh checkermallow)[81]. When determining potential exceedances, we will generally use the same approach for these species (i.e., evaluating state-level agricultural data, section-level CalPUR data, and/or county-level mosquito adulticide sales data). However, if for instance, subsequent data indicates an increase in malathion usage on vineyards within the range of one of the Sonoma DPS of the California tiger salamander, we will first rerun the overlaps using the correct range map for the CalPUR data used in this opinion. This will allow us to better determine whether anticipated take levels have been exceeded or the Action is affecting the species to an extent not previously considered.

Reasonable and Prudent Measures

“Reasonable and prudent measures” (“RPM”) are those actions the Service believes necessary or appropriate to minimize the impacts, *i.e.*, amount or extent, of incidental take. (50 CFR 402.02).

[81] We determined incidental take was reasonably certain to occur for six of these species: California tiger salamander (Sonoma DPS), Yosemite toad, Oregon spotted frog, Arroyo toad, Buena Vista Lake ornate shrew, and spectaclecase mussel.

The Service believes the following reasonable and prudent measures will minimize the impact of incidental take of listed species from the proposed Action.

1. EPA shall use its authorities under FIFRA to minimize impacts of incidental take to the listed species addressed in this Incidental Take Statement.

TERMS AND CONDITIONS

To be exempt from the prohibitions of section 9 and section 4(d) of the ESA, the EPA must comply with the following terms and conditions, which implement the reasonable and prudent measures described above.

As part of the RPM and Terms and Conditions described below, we anticipate monitoring and reporting will be needed to confirm our assumptions in our Opinion, as well as the assumptions outlined in EPA's BE. We anticipate that data collection will continue to occur over the duration of the action on variable time schedules and that we will gain information on an annual basis (e.g., incident data, status of label changes during the first two years), while other data set updates or collection will be available after longer intervals[82]. For the initial annual reporting, the Service expects that the first report will be transmitted no later than March 1, 2023, as described below.

To implement RPM #1, EPA shall:

1) Provide annual reports to the FWS summarizing all information collected and analyzed as a result of monitoring and reporting required under the Terms and Conditions described below.
    a) The first annual report shall be submitted no later than March 1, 2023.
    b) Each annual report will include, at a minimum: (1) water quality monitoring data and (2) ecological incident data. Beginning with the March 1, 2025, annual report, in addition to water quality monitoring and ecological incident data, EPA shall also provide usage data for agriculture (state-level values for percent crop treated("PCT")) and mosquito control (county-level sales data), with an analysis of trends of this usage data. These data and associated timelines are discussed below in Terms and Conditions 3 and 4.
    c) EPA shall set up annual meetings with the FWS to review annual report findings and species and critical habitat status updates relevant to this Opinion. Annual meetings can be organized to cover the needs of multiple FIFRA consultations over time, as appropriate and mutually agreeable.

2) Ensure that label changes (described in the revised *Description of the Action*) are implemented in a timely manner according to the timeline outlined below, and provide

[82] We also anticipate that, over time, annual meetings and/or reports may include information relevant to multiple pesticides that have undergone consultation, such as incident data, use data layer updates or supplementary information, etc.

confirmation on the status of that implementation to the Service. These label changes that are part of the Action include both general measures described in the Letters of Commitment from the technical registrants, as well as species-specific measures that will be incorporated as Endangered Species Protection Bulletins that contain relevant instructions per amended labels and the associated Letters of Commitment from the registrants. Both the general measures and the species-specific measures that are incorporated in Endangered Species Protection Bulletins and Letters of Commitment are included in Appendices A-B, A-C and A-D of this Opinion.

a) EPA will ensure these activities occur within the following timeline:
    i) Within 60 days of receipt of this Opinion, EPA shall notify the registrants of label language changes incorporated as part of the Action and the requirement for registrants to submit amended labels per the registrant commitment letters (and EPA's revised Action), as described in Appendix A-B, within 60 days of EPA's notification.
    ii) Within 18 months of the issuance date of this Opinion, EPA shall review and act on the registrants' amended labels.
    iii) Within 18 months of the issuance date of this Opinion, EPA shall develop Endangered Species Protection Bulletins per registrant commitment letters (and EPA's revised Action), as described in Appendix A-B and amended labels.
b) EPA shall provide confirmation to the Service that all label changes have been completed and Endangered Species Protection Bulletins have been posted no later than 18 months after the date of this Opinion. EPA will provide status and confirmation as part of any annual reports and meetings.

3) Compile and evaluate available data to detect changes in estimations of malathion exposure to ESA listed species and critical habitat designations described in this Opinion related to a) water quality monitoring data (i.e., malathion concentration in the environment); b) ecological incidents; c) malathion use; and d, e) malathion usage.
    a) Water quality monitoring data: EPA shall evaluate available water quality monitoring data for exceedances of values reported in the Biological Evaluation and for trends that indicate malathion concentrations in waterways are either increasing or decreasing.
        i) No later than 12 months following the release of the Opinion, EPA shall perform a trend analysis in the initial annual report to include water quality monitoring data from all years since those provided in the BE. EPA will include a summary of any such information, including any relevant information that either supports or amends the validity of the assumptions in the Opinion. Results will be included in the first annual report (March 1, 2023). Following this initial report, EPA will perform this trend analysis again in five years, and then every five years thereafter.
        ii) EPA shall coordinate with the Service to identify sources that provide water quality monitoring data and will use sources that are mutually deemed relevant by EPA or the Service.

b) Ecological incidents: EPA shall compile and evaluate available ecological incident data to determine if those data suggest that labeled uses of malathion have caused unforeseen ecological impacts.
    i) EPA shall include this information in its annual reports to the Service, and specify any information related to malathion-specific incidents for any species. This includes any information regarding:
        (1) Any ecological incidents reported as a result of non-compliance with labels or other factors.
        (2) All minor and major ecological incidents attributable to the application of products containing malathion.
        (3) Where no reports were submitted, EPA shall document this in the annual report referenced in Paragraph 1.
    i) EPA will work with the registrants to include the following statement in the beginning of the "Directions for Use" and "Environmental Hazard" sections of the label: *Reporting Ecological Incidents: To report ecological incidents, including mortality, injury, or harm to plants and animals, call [insert registrant name and phone number]*.
c) For use data:
    i) No later than 12 months following the release of USDA NASS Census of Agriculture updates (which are conducted every 5 years), EPA shall evaluate whether there are meaningful changes that affect the assumptions on geographic extent of use, with any applicable thresholds evidencing change to be determined jointly by EPA and the Service. For example, an evaluation of the change in CDL layers, census information, or other spatial data over time may be used to confirm whether the assumptions in the BE and BO on potential use locations/geographic areas remain valid. Findings shall be included in annual reports to the Service in years when NASS updates of this data triggers this analysis. In the event the analysis reveals that no meaningful changes have occurred, this result shall also be acknowledged in the annual report.
    ii) EPA will work with registrants and other stakeholders to better understand the geographic extent of use where recent or use-specific landcover data is lacking (e.g., Pacific Islands, Caribbean). Additional information received shall be provided in annual reports to FWS.
d) Usage data (mosquito control): For mosquito adulticide usage data, EPA shall work with registrants, other stakeholders and the Service to improve monitoring and reporting of mosquito adulticide usage as follows:
    i) Work with malathion registrants to obtain mosquito adulticide sales data for malathion adulticide products to include the amount of product sold (EPA Reg No. and volume), where the product was shipped (zip code), and where it was intended for use (e.g., mosquito control/abatement district), if known.
        (1) No later than 12 months after the release of the Opinion, EPA shall work with malathion registrants to obtain mosquito adulticide sales data for all years available beginning in 2019, including

identification of any counties not listed in information previously provided to the Service as having purchased mosquito adulticide products.

(2) EPA shall provide the mosquito adulticide sales data and analysis described above in annual reports.

ii) Work with registrants and other stakeholders to obtain information on malathion use in public mosquito/vector control/abatement programs, such as EPA reg. nos. of malathion product used, application volumes, application method, and location (e.g., US National Grid 10k) of adulticide applications. EPA shall provide this usage data in yearly reports.

iii) Work with registrants and other stakeholders to obtain available information on the results of coordination between public mosquito/vector control/abatement programs and FWS field office contacts, such as a brief summary of the technical assistance received and subsequent measures implemented during control and abatement efforts. EPA will incorporate information regarding the results of mosquito control applicators coordination with FWS field offices, as outlined above, into their annual reports to the Service.

e) Usage data (other than for mosquito control):

i) No later than 3 years after the release of the Opinion, EPA shall provide an analysis of agricultural and non-agricultural usage data available since the August 2013 malathion National and State Use and Usage Summary (SUUM), using similar data sources. EPA shall report overall usage trends in this data every 5 years after the initial report. At a minimum, EPA shall report any exceedances of maximum Percent Crop Treated (PCT) values since the previous report.

ii) No later than 3 years after the release of the Opinion, EPA shall provide CalPUR usage data for registered uses of malathion within the State of California, beginning with data from 2019. This data shall be provided to the Service at 5-year intervals thereafter.

iii) EPA will work with registrants and other stakeholders to better understand usage where malathion-specific usage information is not currently available for a geographic region (e.g., Pacific Islands, Caribbean, states without refined usage data) or for a particular use (e.g., residential). Additional information received shall be provided in annual reports to FWS.

4) Provide training and education to pesticide users and applicators.

a) EPA will work with the Service to develop a voluntary, generic pesticides/listed species training module for its website. Within this training, EPA will highlight new malathion requirements for listed species, with a particular focus on novel mitigations for pesticide applicators (e.g., identifying sensitive habitats). EPA will provide a link to this voluntary training/educational material within the specific malathion Bulletins.

b) EPA will review the training modules and work to update them to improve understanding of ESA issues and compliance with ESA requirements for malathion labels 5 years after the release of the BO.
c) EPA will seek and implement ways to increase use of ESA training modules by licensed applicators over the duration of the action, such as providing optional training modules to states for adoption into their training and licensing programs as they deem appropriate.

CONFERENCE REPORT

Conferencing On Proposed and Candidate Species and Proposed Critical Habitat

Formal consultation was undertaken for most endangered and threatened species and designated critical habitat, and these listed resources are addressed in this Opinion. The Act requires a Federal agency to conference if their action is likely to jeopardize a species proposed for listing or that is likely to destroy or adversely modify critical habitats proposed for designation (ESA 7(a)(4)). Recommendations resulting from that conference are advisory (i.e., they are not required) because the species or critical habitat is the subject of a proposed rule and the prohibition against jeopardy and adverse modification under ESA section 7(a)(2) only applies to listed species and critical habitat designations. Conferencing can be conducted informally, or can follow the format of a formal consultation under 7(a)(2).

In this case, because the duration of the Action is 15 years, the Agencies agreed it would be prudent to use this opportunity for EPA to conference with the Service on the effects to species that are proposed for listing and critical habitats proposed for designation. In addition, although not required, the Agencies agreed to evaluate candidate species that may be proposed in the near future in this Conference. By conferencing now, any future consultation required under 7(a)(2) when a species listing or critical habitat designation is finalized may be streamlined, and in some cases, conferences can satisfy the consultation requirements under 7(a)(2). Using this approach, in this conference, we found the Action is not likely to jeopardize any proposed or candidate species or result in the destruction or adverse modification of any proposed critical habitat designations.

Upon completion of this conference, EPA may elect to adopt any of the recommendations provided by the Service, including any of the reasonable and prudent measures to minimize incidental take for the proposed and candidate species and proposed critical habitat. In the future, upon listing of the species or designation of critical habitat, the EPA can request the Service adopt the conference opinion as a biological opinion to satisfy the EPA's 7(a)(2) requirement.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of an Action on ESA-listed species or critical habitat, to help implement recovery plans, or develop information (50 C.F.R. §402.02).

EPA's implementation of the following conservation recommendations would provide information and support for future consultations involving upcoming FIFRA registrations authorizing use of pesticide active ingredients that may affect ESA-listed species and critical habitats:

1. Improve reporting by initiating an interagency committee to work with stakeholders and other interested parties to devise a methodology(s) or programs to better understand and more comprehensively track usage of chemicals in the field. Implementation of methodologies or programs for tracking usage may include various tasks. For example, one option may include setting up or overseeing a volunteer data collection program regarding agricultural and non-agricultural pesticide usage.

2. Develop a conservation program for endangered and threatened species in collaboration with stakeholders and Agencies that specifically addresses threats to listed species and how implementation of FIFRA programs and collaboration with pesticide registrants and other stakeholders can help to ameliorate those threats.

3. Develop a conservation banking, in-lieu fee, and/or environmental market-based initiative, through a cooperative effort with pesticide registrants and stakeholders, designed to voluntarily offset impacts to listed species and designated critical habitats from multiple pesticides that may pose similar threats.

4. Work with other appropriate Federal, state, and local partners to study the efficacy of conservation practices in reducing pesticide loading to streams, lakes, wetlands, sinkholes, and other terrestrial and aquatic habitats from off-site transport. Topics may include the width, structure and complexity of buffer strips, swales, riparian areas, other vegetation types, use of in field native vegetation buffers and cover crops, precision agriculture technologies and other strategies that have the potential to reduce adverse impacts to listed species.

5. Develop methods and models that better describe and quantify pesticide persistence and fate and transport to assist in analyses for future pesticide consultations. For example, models may be used to better quantify pesticide persistence in freshwater and terrestrial environments that correlate to mortality or sublethal effects. Similarly, improving capabilities to model pesticide fate and transport at the watershed scale would help to inform future analyses.

6. Develop methods to better understand and quantify pesticide exposure from non-agricultural uses.

7. Develop criteria that address when pesticide-contaminated sediment is an important route of exposure to aquatic or terrestrial organisms.

8. Sponsor additional research to support new technological devices or procedures to further reduce effects to ESA-listed resources.

9. Work with stakeholders and growers to develop conservation guidelines.

10. Facilitate outreach to large growers so they are educated about the issues and work with the agencies to minimize impacts to listed species and critical habitat.

REINITIATION NOTICE

Issuance of a final biological opinion will conclude formal consultation on the Action outlined in the request. As provided in 50 CFR 402.16, reinitiation of formal consultation is required and shall be requested by the Federal agency or by the Service, where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of taking specified in the incidental take statement is exceeded; (2) If new information reveals that effects of the action may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action.

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