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

Photo credit: Tessenderlo-Kerley, Inc.

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March 31, 2025

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INTRODUCTION

This document represents the U.S. Fish and Wildlife Service's (Service) Biological and Conference Opinion (Opinion) based on our review of the Environmental Protection Agency's (EPA) proposed national registration of carbaryl and its effects on endangered and threatened species and designated critical habitat in accordance with section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). On March 31, 2021, EPA submitted the necessary information and a request to initiate formal section 7 consultation.

We based this Opinion on information in the final Biological Evaluation (BE) for carbaryl, many interagency meetings, workshops and conference calls, and other sources of information as described herein. The methods employed in EPA's BE follow the Revised Method for National Level Listed Species Biological Evaluations of Conventional Pesticides (referred to as the "Revised Method")[1]. In March 2020, EPA released the Revised Method for National Level Listed Species Biological Evaluations of Conventional Pesticides. EPA used the Revised Method to conduct the draft BE for carbaryl. The Revised Method incorporates recommendations from the National Research Council (NRC) of the National Academies of Science (NAS) for the process EPA developed with the Service and National Marine Fisheries Service (NMFS) for determining effects from the action to listed species and critical habitats. A preliminary approach developed in 2015 is referred to as the Interim Method, which was applied to the first three national-level pilot BEs (for chlorpyrifos, diazinon and malathion; discussed in more detail below in the Consultation Background section). EPA's "lessons learned" during the three pilot BEs provided the starting point for development of the Revised Method via public comments provided through stakeholder meetings, through the docket on the draft BEs for chlorpyrifos, diazinon and malathion, and through the docket on the proposed Revised Method; comments received during consultation with federally recognized tribes; and comments provided by the Service, NMFS, and the U.S. Department of Agriculture (USDA). On March 17, 2020, EPA released the draft BE for carbaryl for public comment. EPA received public comments on the proposed Revised Method and the carbaryl BE through July 2, 2020, which included a 45-day extension of the original public comment period. Updates to the Revised Method and updates that were specific to carbaryl were incorporated into the final BE. 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 proposed 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 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

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

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 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 (CBD) 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 CBD 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 CBD 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 CBD 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 CBD, 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 CBD 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.

In a recent case filed by CBD, in March of 2025, FWS was found to be unreasonably delayed in completing ESA Section 7 consultations on chlorpyrifos, diazinon, carbaryl, atrazine, and simazine, in violation of Section 555(b) of the APA, (*CBD v. FWS, et al.*, 4:22-cv-00090-JCH [D. Ariz.]). Having already completed the consultation for methomyl in December 2024, the Court ordered FWS to complete the 5 remaining consultations by the estimated dates previously provided by the agency: carbaryl (March 31, 2025); atrazine and simazine (March 31, 2026); and chlorpyrifos and diazinon (September 30, 2028).

NAS Report and Path Forward

In September 2010, the Agencies, NMFS, and the 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[2]. 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

[2] 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.

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. We review EPA's no effect determinations for species and designated critical habitats and adopt their determinations unless otherwise noted in the *Supporting Information for the Concurrence Section of the Consultation* (Appendix A).

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.

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 review of carbaryl. While many of the events related to the NAS report and subsequent activities discussed in the paragraphs above form the consultation history for this Opinion, the listing below is focused on the more recent activities.

Early Coordination on EPA's Biological Evaluation:

September - October 2016	EPA and the Services begin to discuss the approach for the BEs for the next two carbamate pesticides outlined in the Pesticide Litigation Summary above, carbaryl and methomyl.
December 5, 2017	Presentation to the Service on California's Prescribe and California Pesticide Use Reporting (CalPUR) 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 EPA and how to utilize them to assess effects on threatened and endangered species. Participants: staff, management, solicitors, and senior leadership from Department of Interior (DOI), EPA, NMFS, and USDA, and Council on Environmental Quality (CEQ).
December 10, 2018	Briefing on Agricultural Usage Data - Meeting held to update interagency management on progress defining the agricultural portion of the proposed action area incorporating usage data.
October 2018-November 2019	The Service participated in various stakeholder meetings on several topics pertaining to a path forward for pesticide consultations.
July 2019	Meeting with EPA to discuss the application of the usage data available for Hawaiʻi, Alaska, Puerto Rico, and other territories.
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.
February 11, 2020	The Generic Endangered Species Task Force (GESTF) submits a petition to EPA to change the parameterization of the Pesticide in Water Calculator (PWC) modeling tool

March 2020	EPA provides the Service with the draft BE for methomyl and carbaryl
March 31, 2021	EPA provides the Service with the final BEs for carbaryl and methomyl.
June 29, 2021	The Service received the consent of EPA and the 3 technical registrants (who are "applicants" to the consultation), Bayer, Drexel Chemical Company (Drexel), and Tessenderlo Kerley, Inc. (TKI), to extend the timeframe for completing the carbaryl consultation, pursuant to ESA Section 7(b).
August 18, 2021	The Service and EPA meet to discuss questions on the "No Effect" (NE) and "Not Likely to Adversely Affect" (NLAA) determinations in the BE.
January 2022	EPA and carbaryl applicants agree to proposed mitigations from Proposed Interim Registration Review Decision (PID)
June 1, 2022	Inter-agency workshop between EPA, the Service, NMFS, and USDA to discuss aligning methodologies for usage data, including California Department of Pesticide Registration data.
January 29, 2024 – November 2024	EPA and the Service meet regularly to discuss carbaryl where topics include: • Progress on Carbaryl Registration Review and Listed Species Assessments • Updates on carbaryl since the BE • Species/critical habitat analysis approach • Differences between methomyl and carbaryl approach • Deliverables • Timelines • EPA NLAA/LAA/NE determinations and lists

December 26, 2024	The Service submits the draft Opinion for carbaryl to EPA for review. EPA publishes the draft Opinion for public comment.
January – March 2025	Discussions with EPA, USDA, TKI, Drexel, and Loveland (a registrant for non-agricultural uses of carbaryl) to address mitigations, incorporate label changes or restrictions, and integrate newly listed species into the analysis.
March 31, 2025	The Service transmits the final Opinion for carbaryl to EPA.[3]

CONCURRENCE

In their BE for carbaryl, EPA provided determinations of "no effect (NE)" that we adopted for 417 proposed or listed species and 377 proposed or designated critical habitats (see Appendix A, Table 1). Similarly, EPA made "may affect, not likely to adversely affect (NLAA)" determinations for 66 listed species and 20 proposed or designated critical habitats under Service jurisdiction. Our discussion of these species and critical habitats is provided in Appendix A.

[3] Pursuant to an ESA Section 7(b) extension agreement, FWS, EPA, and the registrants for carbaryl previously agreed to complete consultation and issue a final biological opinion on EPA's FIFRA registration of carbaryl by March 31, 2025. FWS completed this final opinion within the agreed-upon timeframe, notwithstanding a recent court order from March 12, 2025, which required FWS to issue a final biological opinion for carbaryl by March 31, 2025. *Ctr. for Biological Diversity v. FWS, et al.*, 4:22-cv-00090-JCH (D. Ariz. Mar. 12, 2025). FWS was on track to complete consultation by this mutually agreed upon date well before the Court issued its order a few weeks ago.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

The proposed federal action addressed in this Opinion (hereafter, the proposed action) is the registration review of carbaryl under FIFRA. Pursuant to FIFRA, before a pesticide product may be sold or distributed in the United States, 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 is categorized as FIFRA section 3 (new product registrations), section 18 (emergency use), or 24(c) Special Local Needs. FIFRA requires chemicals registered under section 3 and section 24(c) to have their registrations reviewed periodically. As EPA has adopted a 15-year timeframe to review pesticides, the Service considers the duration of the proposed action to be 15 years. The following chemical-specific descriptions are taken largely from EPA's BE for carbaryl.

For this pesticide, the proposed action includes registration review of the uses, as described by product labels, of all pesticide products containing carbaryl as the active ingredient. Three major degradates (i.e., 1-naphthol, 1, 4 napthoquinone, and CO_2) were detected in various environmental fate studies, but these degradates do not contain a N-methylcarbamate functional group and thus do not inhibit cholinesterase therefore 1-naphthol, 1, 4 napthoquinone, and CO_2 are considered to be less toxic than the parent compound. Additionally, 1-naphthol can also be generated by a variety of natural and anthropogenic processes, including the breakdown of the polycyclic aromatic hydrocarbon (PAH) naphthalene, its presence in the environment is not necessarily indicative of carbaryl use and data from the published literature (Lamberton & Claeys, 1970) show, in graphical form, approximately a 20% loss of 1-naphthol over a period of ~20 days, from combined hydrolysis and photolysis in sterile seawater. Furthermore, based on previous Quantitative Structure-Activity Relationship (QSAR) analyses, the degradates 1, 4 napthoquinone, and CO_2 are estimated to be less toxic than the parent. Thus, we agree with EPA's assessment that the carbaryl degradates1-naphthol, 1, 4 napthoquinone, and CO_2 are of no toxicological concern. We discuss some studies in more detail of 1-naphthol in the *Toxicological Effects* and *Exposure Effects* Section of this Opinion further demonstrating the low toxicity of 1-naphthol compared to the parent carbaryl compound. The proposed 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).

In their BE, EPA considered the likely use types of the chemical over the duration of the proposed action, although the Agencies recognized that future uses are difficult to predict with either accuracy or precision, particularly as more time passes. However, the best available information on future uses have been estimated and assessed 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 proposed action, as noted in the BE, is used for pest control on food and feed crops, to thin fruit in orchards to enhance fruit size and repeat bloom, to control mud and ghost shrimp in commercial shrimp ponds in Texas, as well as in turf management, ornamental production, rangeland, and residential settings that, under FIFRA, 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 in the Problem Formulation of the BE. The following sections describe the proposed action in greater detail and are taken largely from the BE for carbaryl.

Labeled Uses

Use data are based on registered product labels and include pesticide application information relevant to a treatment site *(e.g.,* an orchard). EPA determined the uses based on registered labels and define crop or non-crop sites to which a pesticide may be applied. Use data also describe the maximum application rates, method (*e.g.,* aerial or ground spray), re-treatment intervals and number of applications that may occur according to registered product labels.

Carbaryl is used on a wide variety of terrestrial food and feed crops, as well as uses in turf management, ornamental production, rangeland, and residential settings. Additionally, carbaryl is used to thin fruit in orchards to enhance fruit size and enhance repeat bloom. Carbaryl is also used to control mud and ghost shrimp and in commercial shrimp ponds in Texas. There are currently two active technical registrants of carbaryl: Drexel and TKI, with 61 active product registrations (60 Section 3s and 1 Special Local Need registration or SLNs; a SLN is a registration under FIFRA section 24(c) which authorizes state lead agencies to register additional uses of federal registered pesticides. SLN permits distribution and use only within the registering state), which include formulated products (see Appendix 1-1 of the BE). Bayer was previously identified as a technical registrant but has cancelled all its carbaryl products since. Carbaryl can be applied in liquid (i.e., flowable concentrate, emulsifiable concentrate, wettable powder, water soluble powder), bait, granular, or dust forms. Aerial and ground application methods are allowed, as are pressure sprayers, dust applicators, spreaders and shank applicators, and baits.

Table 1. List of Current Carbaryl Registrations[4]

Final Table 1
Carbaryl Registratio

Uses

The EPA developed a list of all current registered uses for carbaryl (Table 2 and Appendix 1-2 of the BE), which reflects all currently registered labels. In general, the single maximum carbaryl

[4] To view the spreadsheet in MS Excel from the MS Word Opinion, double click on the Excel icon. To view the spreadsheet in MS Excel from the portable document format (pdf) Opinion, open the Opinion in the desktop version of Adobe Acrobat or Reader and open the embedded attachment corresponding to the numbered table.

application rates do not exceed 9 lb a.i./A nationwide for granular formulations and 8.33 lbs a.i./A for flowable formulations. The maximum single application rate is 12 lbs a.i./A for a flowable formulation applied to citrus in California. The maximum annual rate of carbaryl that may be applied to a crop site is 15 lb a.i./A for olives, tree nuts, and pome fruit. The maximum annual rate that may be applied to a non-crop site is 16 lbs a.i./A/year for golf courses, sod farms, and lawns. Table 3 provides a summary of the application rates and use patterns that result in the highest estimated environmental exposures EPA used in their BE.

Table 2. Detailed Master Use Summary[5]

Final Table 2
Carbaryl Uses (Detai

Agricultural Uses

Carbaryl is currently registered on a variety of agricultural use sites (see Appendix 1-2 of the BE) and to treat some specific pests. Agricultural uses include: alfalfa, apple, asparagus, beans, beans (dried type), beets (greens), beets (root), blackberry, blueberry, boysenberry, Brassica (Head and stem) vegetables, broccoli, brussels sprouts, bushberry subgroup 13-07B, cabbage, caneberry subgroup 13-07A, carrot, cauliflower, cherry, citrus crop group 10, clover, collards, cranberry, cucumber, cucurbit crop group 9, dandelion, dewberry, dried shelled pea and bean subgroup 6C, edible-podded legume vegetables subgroup 6A, eggplant, endive, fallow land, field corn, flax, forage crops, fruiting vegetables, grapes, grass forage, grasses grown for seed, hay, horseradish, kale, kohlrabi, leaf petioles subgroup 4B, leafy greens, legume vegetables crop group 7, lettuce, loganberry, melons, nectarine, okra, olive, parsley, peach, peanuts, pear, peas, pepper, pistachio, plum, popcorn, pome fruit crop group 11, potato, prickly pear cactus pads, prune, pumpkin, radish, raspberry, root and tuber vegetables, rutabaga, salsify, small fruits, sorghum, soybeans, spinach, squash, sweet corn, stone fruit crop group 12, strawberry, sugar beet, sunflower, sweet potato, tree nut crop group 14, tobacco, trefoil, turnip greens, and walnut.

Table 3. Condensed summary of application rates and use patterns for each use that results in the highest estimated environmental exposures[4]

[5] To view the spreadsheet in MS Excel from the MS Word Opinion, double click on the Excel icon. To view the spreadsheet in MS Excel from the portable document format (pdf) Opinion, open the Opinion in the desktop version of Adobe Acrobat or Reader and open the embedded attachment corresponding to the numbered table.

Final Table 3
Condensed Carbaryl

Non-agricultural and Pest Uses

Non-agricultural uses include outdoor household domestic premises, outdoor buildings and structures, perimeter treatments, ornamentals, paths and patios, non-agricultural uncultivated areas, rights of way, fencerows, hedgerows, ornamental lawns and turf, residential lawns, recreational areas, cemeteries, camp sites, golf courses, noncropland, conservation reserve areas, forested areas and rangeland trees, pastures, rangeland, sod farms, and commercial fisheries.[6]

Pest uses include grasshoppers, imported fire ants, nuisance pests, ticks, and Mormon crickets.

Consideration of Usage Data

Usage data describe how the pesticide has been applied to multiple use sites within a state, region, or the United States. In development of its BE, EPA reviewed usage data that documents the actual (field) applications of a pesticide, including information such as actual application rates and timing, and spatial distribution of applications across multiple sites (usually based on survey data). The difference between use and usage is that use refers to the authorized application under the label while usage refers to how it is actually applied on the landscape.

This Opinion considers the proposed action, specifically the registration review of carbaryl 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 proposed 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 review. While we agree carbaryl 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), we also recognize that carbaryl can be used anywhere the label allows and at the highest rates and frequencies specified for a given use. Similarly, we also recognize that, while knowledge of past usage patterns and locations may be helpful in providing

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[6] EPA registration number TX020007 allows for use of carbaryl to control mud and ghost shrimp in commercial shrimp ponds. The label requires that water in the treated ponds must be held for two weeks post-application to allow carbaryl degradation, and the pond must then be drained and dried before restocking. EPA, therefore, assumed minimal exposure for this use pattern as the representative model input aerobic aquatic metabolism half-life values range from 2.0 to 18.2 days and carbaryl is expected to degrade before the water is drained; however, some uncertainty with this assumption as degradation may be pH dependent.

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 carbaryl was 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 proposed action ensures against the likelihood of jeopardy of species or destruction and adverse modification of critical habitat. 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

This Opinion includes consideration of several conservation measures in the proposed action (e.g., the registration) to address effects to listed species identified herein. Based on a letter submitted to EPA in January 2022, TKI and Drexel agreed to the proposed changes in the PID and most of these changes were incorporated into the aquatic modeling for carbaryl in the BE which we carried forward into our analysis in this Opinion. The only change that was not incorporated into the modeling in the BE was the rain restriction measure, which we consider in our analyses in this Opinion.

These conservation measures include the following:

Run-off Mitigation:

Ground Application

- Do not apply within 25 feet of aquatic habitats (such as, but not limited to, lakes, reservoirs, rivers, permanent streams or ephemeral streams when water is present, wetlands or natural ponds, estuaries, and commercial fish farm ponds)

Aerial Application

- Do not apply within 150 feet of aquatic habitats (such as, but not limited to, lakes, reservoirs, rivers, permanent streams or ephemeral streams when water is present, wetlands or natural ponds, estuaries, and commercial fish farm ponds).

Rain restriction:

Do not apply during rain. Do not apply when soil in the area to be treated is saturated (if there is standing water on the field or if water can be squeezed from soil) or if NOAA/National Weather Service predicts a total rainfall of 1 inch or greater over the 48 hours following the day of application, only considering a 48-hour period when, at any point during the 48-hour period, the precipitation potential is 50% or greater. Detailed National Weather Service forecasts for local weather conditions should be obtained on-line at: www.weather.gov or by contacting your local National Weather Service Forecasting Office.

General Changes to Carbaryl Use

- Carbaryl may not be applied in Hawaiʻi for agricultural uses; only broadcast use for turfgrass is allowed.
- Remove aerial application method from all uses except rangeland
- Ground boom applications must be made with the release height recommended by the manufacturer, but no more than 2 feet above the crop canopy.
- Ground boom applications must be made using nozzle and pressure that deliver medium or coarser droplets in accordance with American Society of Agricultural and Biological Engineers Standard 572 (ASABE S572).
- Maximum application rate = 12 lbs a.i./acre
- No consumer use in California

Specific changes for specific crops:

Asparagus

- Maximum Annual Number of Applications: 4 (currently 5)
- Minimum Reapplication Interval: 7 days (currently 3 days)

Sweet Corn

- Maximum Annual Amount: 8 lbs. ai / acre (currently 16 lbs. ai / acre)
- Maximum Annual Number of Applications: 4 (currently 8)

Cucurbit Vegetables

- Maximum Annual Amount: 4 lbs. ai / acre (currently 6 lbs. ai / acre)
- Maximum Annual Number of Applications: 4 (currently 6)

Fruiting Vegetables

- Maximum Annual Number of Applications: 4 (currently 7)

Leafy Vegetables

- Maximum Annual Number of Applications: 4 (currently 5)

Peanuts

- Maximum Annual Number of Applications: 4 (currently 5)

Prickly Pear Cactus

- Maximum Annual Number of Applications: 4 (currently not specified)

Sweet Potatoes

- Maximum Annual Amount: 4 lbs. ai / acre (currently 8 lbs. ai / acre)
- Maximum Annual Number of Applications: 4 (currently 8)

Small Fruits and Berries (Including Grapes)

- Maximum Annual Amount: 8 lbs. ai / acre (currently 10 lbs. ai / acre)
- Maximum Annual Number of Applications: 4 (currently 5)

Citrus Fruits (all sites including CA and FL)

- Maximum Annual Number of Applications: 4 (currently 8)

Olives

- Maximum Annual Amount: 10 lbs. ai / acre (currently 15 lbs. ai / acre)
- Maximum Application Rate: 5 lbs. ai / acre (currently 7.5 lbs. ai / acre)

Pome Fruits

- Maximum Annual Amount: 12 lbs. ai / acre (currently 15 lbs. ai / acre)
- Maximum Annual Number of Applications: 4 (currently 8)

Ornamental Trees and Plants

- Maximum Annual Amount: 4 lbs. ai / acre (currently 6 lbs. ai / acre)
- Maximum Annual Number of Applications: 4 (currently 6)

Turfgrass (Golf Turf, Sports Fields, Sod Farms, Domestic and Commercial Lawns, Cemeteries, Parks, Campsites, Recreational Areas)

- Maximum Annual Amount: 10 lbs. ai / acre (currently 16 lbs. ai / acre)
- Maximum Application Rate: 5 lbs. ai / acre (currently 8 lbs. ai / acre)

All the conservation measures described in this section were considered in our analyses as described in this Opinion. The Service, EPA and the technical registrants continue to discuss proposals that may be included as conservation measures to the proposed action prior to release of the final Opinion.

General Conservation Measures developed after the draft Biological Opinion

Because of the effects identified in our draft Biological Opinion, EPA and the applicant agreed to revise existing bloom restrictions found on product labels to be more protective and enforceable. For terrestrial species that are anticipated to be adversely affected from exposure on use sites, measures to reduce exposure were included that restricted application of carbaryl to pollinatorattractive crops during bloom, limited application to certain times of the day, and/or restricted use of carbaryl on certain crops or areas within the species range or critical habitat or at certain application rates. We expect these limitations on application during bloom to broadly reduce carbaryl exposure to pollinators on both agricultural and non-agricultural use sites anywhere carbaryl can be used.

Species- and Critical Habitat-Specific Measures and EPA Draft Insecticide Strategy

After the draft Biological Opinion was released for public comment, EPA and the registrants agreed to implement additional mitigations beyond those outlined above to protect listed species and critical habitats that had significant residual effects from carbaryl exposure, including measures for both agricultural and non-agricultural uses. Species-specific mitigations to minimize spray drift and runoff exposure were developed by EPA using methodologies and mitigation measures described in their Draft Insecticide Strategy. If species had significant effects resulting from exposure on use sites instead of or in addition to offsite exposure, we developed additional measures to reduce the likelihood of exposure and subsequent effects. Additional species-specific mitigations to decrease exposure from spray drift and runoff and on-site exposure will apply within pesticide use limitation areas (PULAs; described further below) specific to these species or critical habitats. EPA will communicate these additional measures through their online *Bulletins Live! Two* system.

Taken together, we found these measures to be sufficiently protective of species and critical habitat, such that when applied, we do not anticipate that the proposed action is likely to jeopardize any species or destroy or adversely modify critical habitat. These measures are described in detail for each species in Appendix A-1 and in the individual Integration and Synthesis summaries in Appendix C.

Measures to reduce spray drift exposure to species and critical habitat PBFs generally require the use of buffers from non-target habitats when applying carbaryl in order to minimize drift into these habitats. EPA determined the distance for these buffers on a species-specific basis, based on the anticipated toxicity to species and/or their pollinators, host fish, prey, or other food resources, or critical habitat elements, and the distance needed to reduce concentrations in the environment to adequately minimize adverse effects. EPA's Draft Insecticide Strategy provides applicators with options to reduce the distance of these buffers by using other spray drift reduction strategies that we anticipate will result in an equivalent reduction in spray drift entering non-target habitats as stated buffers. As such, we adopt these measures as well. Each of these measures and the degree to which applicators can reduce buffers by employing them are described in EPA's Draft Insecticide Strategy and EPA's Ecological Mitigation Support Document to Support Endangered Species Strategies. These documents are provided in Appendix A-1.

Measures to reduce runoff to species and critical habitat PBFs are required when applying carbaryl to minimize off-site transport to non-target habitats. These measures include in-field measures (such as cover crops), field-adjacent measures (such as vegetative filter strips), and systems that capture runoff and discharge (such as water retention systems). EPA employed the methods of the Draft Insecticide Strategy to determine the extent of mitigation required on a species-specific basis, based on the anticipated toxicity to species or and/or their pollinators, host fish, prey, or other food resources, or critical habitat elements, and the resultant number of mitigation points, as described in their Draft Strategy. We expect the use of these mitigation measures to significantly reduce concentrations in species' habitats. EPA's Draft Insecticide Strategy provides applicators with different options to reduce runoff, and as such, acquire mitigation points which are strategies to reduce the impact of exposure for listed species. We considered these various measures and agreed with EPA's evaluation of their efficacy in reducing runoff. Each of these runoff reduction measures and the number of points associated with them are described in EPA's Draft Insecticide Strategy and EPA's Ecological Mitigation Support Document to Support Endangered Species Strategies. Briefly, these runoff reduction measures and mitigation points are different tactics that growers may incorporate into their management practices to functionally reduce exposures to listed species. These strategies count toward a number of points that are needed to reduce exposures. These strategies can be something the applicator does such as use of different buffers such as vegetative filter strips, hedgerows or wind breaks, or different tilling methods for soil preparation, or something inherent in the nature of the landscape such the slope (lower sloped land has less run off) or soil type (soils with a sand, loamy sand, or sandy loam soil texture have a low runoff potential). This results in reduced runoff and erosion from these soil types as compared to others). All of these mitigations are discussed in more detail in the documents provided in Appendix A-1.

EPA is currently considering public comments received on the Draft Insecticide Strategy. If additional mitigation options become available during finalization of the Insecticide Strategy or in the future, EPA will provide documentation as to whether these measures provide equivalent conservation for listed species and critical habitat, including reductions in off-site transport. If EPA determines that the final version of the measures provide equivalent conservation, and the Service agrees with that determination, then the Service will update the list of acceptable mitigations for end users of carbaryl in this biological opinion to reflect those changes made to the Final Insecticide Strategy. However, if EPA or the Service determines that incorporating these changes from the Final Insecticide Strategy into the proposed action would result in effects to listed species or critical habitat that were not previously considered in the Biological Opinion or written concurrence (i.e., the measures do not provide equivalent conservation), then the agencies would reinitiate consultation to evaluate any effects of the action that were not previously considered.

Pesticide Use Limitation Area Development

We have evaluated species- and critical habitat-specific conservation measures as part of our assessments in this Opinion, as described above and in each individual Integration and Synthesis Summary in Appendix C. As discussed above; to determine the extent of spray drift and/or runoff mitigation required on a species- or critical habitat-basis, EPA employed the methods of the Draft Insecticide Strategy. If additional mitigation options become available during finalization of the Insecticide Strategy or in the future, this might warrant re-initiation to incorporate those measures into the action. In that case, EPA will provide documentation that these measures provide equivalent conservation for listed species, including reduction in off-site transport. Upon confirmation by the Service, those options will be added to the acceptable mitigations listed for end users of carbaryl.

The locations where those mitigations will apply are called Pesticide Use Limitations Areas (PULAs). For each species, the PULA represents the area within the range where mitigations are needed to reduce exposure and effects to listed species. During implementation of the Opinion, EPA and the Service will jointly develop PULAs for each species and critical habitat with a geographically specific measure identified. The standardized process for developing PULAs is described in detail in EPA's "Process EPA Uses to Develop Core Maps for Draft Pesticide Use Limitation Areas for Species Listed by the U.S. Fish & Wildlife Service (FWS) and their Designated Critical Habitats" (Appendix A-1). Briefly, EPA or other stakeholders use information typically obtained from the Service, including a species' designated critical habitat, its range, or biological information (such as occurrence data, habitat information, or other biological information that can be mapped), to identify and map geographic areas that need to be conserved for listed species and/or critical habitats. For listed species, the resultant map is typically a subset of the range, but in some cases, where the species range represents a refined area, the PULA may encompass the entire range. EPA reviews all maps developed internally or by external stakeholders for quality control and assurance, makes any revisions necessary to adhere to the standardized process, and adjusts the maps to add adjacent areas to account for pesticide-specific transport (via spray drift and runoff/erosion) and/or exposure to taxa the species depends on such as pollinators or prey, as applicable. EPA then submits the maps to the Service for review to ensure that all relevant areas where pesticide mitigations are essential to the conservation of species and critical habitats are captured within the PULA. PULAs are not considered final until reviewed and approved by the Service.

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 carbaryl, we evaluated the physical, chemical, and biotic effects of the proposed action on the environment that would not occur but for the proposed action and that are reasonably certain to occur. For the reasons mentioned below, the action area for this consultation is delineated by these effects to the environment and consists of the labeled uses within the entire United States and its territories.

Carbaryl is a widely used chemical with multiple registered uses and formulations. To lawfully use carbaryl, individuals are required to adhere to EPA's registered uses described on the label of products containing carbaryl. 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 carbaryl products registered under FIFRA may be lawfully used and registered carbaryl products may be legally used only in the manner specified on EPA's label, any effects on the landscape from carbaryl application would not occur but for EPA's registration review.

From EPA's BE, the action area was derived in ArcGIS 10.8 by combining the data layers representative of carbaryl potential uses plus off-site transport. The currently registered uses (summarized in Section 4 and Appendix 1-2 of the BE) include agricultural, non-agricultural, and forest areas.

All species' range or critical habitats that overlap with use sites and off-site transport areas , or species that are dependent upon a prey base which overlaps with use sites and off-site transport areas (Chapter 4 of the BE) are assessed. EPA's analysis used spatial data of species' ranges and critical habitat designations from the Service. In the conterminous United States (CONUS), agricultural potential use sites are represented using the USDA Crop Data Layer (CDL)[7] from 2013-2017 (Appendix 1-5 of the BE). CDL use data layers (UDLs) used for carbaryl include alfalfa, corn, soybeans, forest trees, wheat, vegetables and ground fruit, other grains, other row crops, other crops, grapes, citrus, developed, open space developed, nurseries, rights-of-way, and other orchards. Other data sources are used to represent agricultural areas in United States territories outside of CONUS (referred at as NL48), for which the CDL is not available (Appendix 1-6 of the BE). For carbaryl use on ornamental and/or shade trees, reliable data were not available to map the locations of the potential use sites. However, EPA determined that these uses were limited in geographic scope and adequately represented by uses within the Developed and Open Spaced Developed UDLs. EPA assessed species whose ranges, resources (e.g., prey species), or critical habitats overlap use sites or off-site transport areas were analyzed in the MAGTool to make species and critical habitat effects determinations. For EPA's final BE, several UDLs were updated, including parsing out alfalfa and other agricultural grasses (non-grazing area) from the pasture/rangeland (grazing areas).

The product labels for carbaryl 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[8], and due to the variety of allowable agricultural uses for the chemical, the combination of uses on the label covers broad expanses and portions of every state and territory of the United States. Furthermore, the method(s) of application (e.g., by aircraft, ground, irrigation/chemigation.) is expected to result in varying amounts of drift/transport of carbaryl 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, the likelihood of transport from application sites, broad expanses of agricultural use sites (where allowable), and indeterminant location of non-agricultural use sites, it is reasonable to assume one or more labeled uses could legally occur in any area of the United States throughout the duration of the proposed 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, in considering usage information and commonly assumed use areas in our effects analyses, we assume, based upon

[7] USDA National Agricultural Statistics Service Cropland Data Layer. 2013-2017. Published crop-specific data layer [Online]. Available at https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php (accessed 3/2018; verified 02/2021). USDA-NASS, Washington, DC.

[8] We recognize that the various carbaryl formulations are unlikely to be used evenly or consistently throughout the Action area as defined. However, the labels describe all 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").

our professional judgment and the extent of the label, that the action area will consist of the United States.

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. However, as explained in more detail in our analysis of species exposure and effects of the action, we identified some areas in which certain species are extremely unlikely to be exposed to generalized environmental effects arising from a specific registered carbaryl use (i.e., the effect is discountable to the species), or alternatively, exposure would occur, but in such low levels that the effects to species from exposure are likely to be insignificant.

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, the National Park Service, Bureau of Land Management, and U.S. Forest Service. A specific review of previous carbaryl use on Service lands (e.g., National Wildlife Refuges (NWRs)) revealed some carbaryl usage (729 total lbs a.i. applied for all NWRs) for the 10-year period of 2013 to 2023 (PUP Report 2023). Likewise, a review of past and recent consultations under section 7 of the ESA indicated that there has been some use of carbaryl on other federal lands (concurrence on use of carbaryl in the San Bernardino National Forest to control goldspotted oak borer 2022; Palm Springs FWO; concurrence on use of carbaryl for the USDA-APHIS grasshopper and Mormon cricket suppression program; (USFWS, 2024)). However, while informative, the queries of Service database information may not be definitive for other federal land management agencies (e.g., the Department of Defense). 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 carbaryl within their jurisdictions. For this reason, and because the labels allow use on federal lands, we determined it would be inappropriate to remove federal lands from the action area. Previous consultations involving carbaryl use on federal lands are considered to be part of the environmental baseline.

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 carbaryl products, the absence of other geographic restrictions on the labeland available data on past and present use and usage, we conclude that generalized environmental effects are reasonably certain to occur and would not occur but for the registration in 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 and would not occur in these areas but for the FIFRA registration.

Carbaryl will initially enter the environment via direct application (e.g., as liquid sprays, dusts, and granular formulations) to use sites (e.g., soil and foliage). It may move off-site via spray drift, dissolved in runoff, and/or as residue sorbed to eroded sediment. Major routes of carbaryl transformation in the environment include alkaline hydrolysis, photolysis in water, and soil and aerobic aquatic metabolism. Carbaryl has a vapor pressure of 1.3×10^{-7} torr and a Henry's Law constant of 1.28×10^{-8} atm-m^3/mol, which indicate that it has a low potential to volatilize and long-range transport is not expected to be a significant exposure pathway of concern.

Degradation kinetic calculations were updated in 2020 to be consistent with the most recent guidance (USEPA, 2015). The hydrolysis of carbaryl is pH dependent. At acidic pH (5), the compound is hydrolytically stable, while under neutral (pH 7) and alkaline (pH 9) conditions, carbaryl hydrolyzes with half-lives of 12 days and 0.13 days, respectively. Carbaryl photodegrades in water with an observed half-life (at pH 5) of 21 days, adjusted to reflect a 12:12 hourly light-dark cycle. Carbaryl was stable to photolysis in soil.

Degradation rates of carbaryl in studied aerobic soils range from slow to fairly rapid (half-lives of 4-253 days). Based on carbaryl's aerobic soil metabolism and aerobic and anaerobic aquatic metabolism data, carbaryl is not considered persistent[9] in the environment. The data described above regarding hydrolysis in water, photodegradation, and degradation in soils also indicate that carbaryl is not likely to persist in the water, in terrestrial habitats, or within soils where listed species are found. Degradation rates for carbaryl have been shown to be relatively slow (half-life: 68.9 days) under anaerobic aquatic conditions. Metabolism in the aerobic aquatic environment is more rapid, with representative half-life values ranging from 2.0 to 18.2 days which is most relevant to habitats where listed species occur.

Linear sorption coefficients are calculated and utilized in this assessment to be consistent with current modeling input guidance (USEPA, 2009a). Carbaryl is moderately mobile in soils, according to the FAO mobility classification system. Based on batch equilibrium studies, the compound has soil-water distribution coefficients ranging from 1.33 to 2.43 L/kg. Soil sorption of carbaryl is partly a function of soil organic matter content, and increases with increasing organic carbon content, with a mean K_{oc} of 153 mL/g_{oc}. Terrestrial field dissipation data (MRID 00155759) show dissipation half-lives of 62 to 116 days for carbaryl in the upper 30 cm of the soil profile.

Because of its low octanol/water partition coefficient (log K_{ow} of 2.4)), carbaryl is not expected to bioconcentrate to a significant extent. Bioconcentration data confirm this expectation, with a bioconcentration factor of 45 L/kg-wet weight measured in whole tissues of bluegill sunfish (MRID 00159342). These sorption coefficient data indicate carbaryl is subject to run-off from fields and thus enter into receiving waterbodies nearby. The octanol / water coefficient data indicate that carbaryl is not anticipated to accumulate in organisms, which means that it is not expected to become increasingly toxic as organisms consume other organisms exposed to carbaryl.

Overlap with Species Ranges and Critical Habitats

It is difficult to determine with precision where all labeled uses might occur over the duration of the proposed 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 allow for one or more uses among many land types in the United States and its territories. Thus, we are unable to eliminate

[9] Based on the Toxic Release Inventory classification system where half-lives greater than 60 days in water, soil, and sediment are considered persistent and half-life greater than 6 months are considered very persistent (USEPA, 2012).

overlap of any listed species[10] or designated or proposed critical habitats that occur within the action area, with the following exceptions[11]:

(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 proposed action; or

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

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 whether the effects of the action, in the context of environmental baseline, status of the species, and cumulative effects, would be expected to appreciably reduce the survival and the recovery of the listed species. Thus, our analysis relies on four components: (1) the *Status of the Species*, which describes the condition of the species in its entirety, 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 reasonably certain to occur and would not occur but for 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 proposed action and cumulative effects, (4) adds the effects of the

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[10] This Opinion does not consider foreign listed species, due to the extent of the action area as described in EPA's BE.

[11] 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 proposed action.

proposed action and cumulative effects to the environmental baseline, and, in light of the status of the species, determines if the proposed 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 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 as a whole 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 reasonably certain to occur and would not occur but for 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 designated 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 by appreciably diminishing the ability of critical habitat as a whole to provide for the conservation of the species.

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 proposed action. Species addressed in this Opinion are listed in Table 4 (animal species), Table 5 (plant species), and Table 6 (experimental populations). Species that were included in the BE but have been removed from this Opinion because the species are not currently listed may be included in Appendix B of this Opinion. The detailed status of each listed and proposed[12] species and their proposed or designated critical habitat is provided in Appendix B.

[12] At the time of the final Opinion, listing determinations were made for all candidate species that had been included in the consultation, so no candidate species are included in the final Opinion.

Table 4. Listed and proposed animal species and proposed and designated critical habitats addressed in this Opinion included in the BE for carbaryl.[13 14]

Final Table 4 animals (BE).xlsx

Table 5. Listed and proposed plant species and proposed and designated critical habitats addressed in this Opinion included in the BE for carbaryl.[12]

Final Table 5 plants (BE).xlsx

Table 6. Listed entities with experimental populations (EXPN; all are non-essential populations). [12]

Final Table 6. Experimental popul

The listed entities in Table 6 are designated non-essential experimental populations (EXPN). They were included in EPA's BE, with all populations except one given a "likely to adversely affect" determination by EPA. The California condor EXPN was given a "not likely to adversely affect" determination by EPA, and we concurred with this determination. Experimental 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. They 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 proposed action was likely to jeopardize the species. Thus, while EPA was not required to confer on non-essential experimental populations, they provided determinations for them in their BE.

[13] For determinations and conclusions in Tables 4 and 5: 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).

[14] To view the spreadsheet in MS Excel from the MS Word Opinion, double click on the Excel icon. To view the spreadsheet in MS Excel from the portable document format (pdf) Opinion, open the Opinion in the desktop version of Adobe Acrobat or Reader and open the embedded attachment corresponding to the numbered table.

Table 7. Listed and proposed species and proposed critical habitat included in this Opinion that were added to the consultation after the BE was submitted.[15]

Final Table 7
species and CH sinc

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 critical habitat caused by the 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 impacts to listed species or designated critical habitat from Federal agency activities or existing Federal agency facilities that are not within the agency’s discretion to modify are part of the environmental baseline” (50 CFR § 402.02, as revised May 6, 2024).

Because this consultation addresses a large geographic area and the distribution of species within the action area is widespread, this Opinion will consider the environmental baseline at a broad scale. Many of the ESA-listed species and their critical habitats are exposed to multiple stressors comprising the past and present impacts of actions and activities that are described below. The environmental baseline in this Opinion focuses primarily on the status and trends of the ecosystems in which these species and their critical habitats occur in the United States and the factors that contribute to the current status for ESA-listed species and their resources. We first explore factors that affected listing decisions over the last several decades, then describe factors that affect the environmental baseline for listed species and designated critical habitats, including pesticide use, land use change, invasive species, pollution, harvesting, water-related issues, climate change, and several others.

In Table 8 (column 2), we present threats that contributed to listings 877 ESA-listed species identified through Federal Register documents up to August 1994 (Czech, Krausman, & Devers, 2000). In Table 8 (column 3), we also present the factors associated with 143 ESA listing decisions (threatened or endangered) from February 2011 to October 2014 (Smith-Hicks & Morrison, 2021). In both assessments, the most frequently referenced threats were: non-native species, urbanization/roads, agriculture, and loss of genetic viability/small population sizes. Before 1994, some species were listed due to threats that were not referenced in the 2011-2014

[15] To view the spreadsheet in MS Excel from the MS Word Opinion, double click on the Excel icon. To view the spreadsheet in MS Excel from the portable document format (pdf) Opinion, open the Opinion in the desktop version of Adobe Acrobat or Reader and open the embedded attachment corresponding to the numbered table.

rules (e.g., aquifer depletion/wetland filling, native species competition, and vandalism). In the 2011-2014 rules, several new threats were presented (i.e., commercial fishing, climate change, and pesticides/herbicides). Some species may be affected by multiple stressors at the same time. Of particular interest is that several factors (e.g., pesticides, agriculture, fire suppression and related activities, urbanization, and water diversions) were influential to species' listings across both time periods (before 1994 and between 2011-2014).

Table 8. Threats identified for ESA-listed species from rules before 1994 (column 2) and between February 2011-October 2014 (column 3). Modified from (Czech, Krausman, & Devers, 2000) and (Smith-Hicks & Morrison, 2021).

Threat	Number (%) of Species Listed by Threat (Czech, Krausman, & Devers, 2000)	Number (%) of Species Listed by Threat (Smith-Hicks & Morrison, 2021)
Non-native species	305 (35)	76 (53)
Urbanization	275 (31)	77 (54) (combined with Roads in "Land conversion")
Agriculture	224 (26)	55 (38)
Recreation	186 (21)	38 (27) (combined with Industry/Military in "Competing uses")
Ranching	182 (21)	49 (34) (combined with Fire suppression in "Modified disturbance regimes")
Reservoir and water diversions	161 (18)	52 (36)
Fire suppression	144 (16)	49 (34) (combined with Ranching in "Modified disturbance regimes")

Threat	**Number (%) of Species Listed by Threat** **(Czech, Krausman, & Devers, 2000)**	**Number (%) of Species Listed by Threat** **(Smith-Hicks & Morrison, 2021)**
Pollution	144 (16)	30 (21)
Mining/Oil & gas	140 (16)	47 (33) (combined with Logging in "Resource use")
Industry/military activities	131 (15)	38 (27) (combined with Recreation in "Competing uses")
Harvest	120 (14)	18 (13)
Logging	109 (12)	47 (33) (combined with Mining/Oil and gas in "Resource use")
Roads	94 (11)	77 (54) (combined with Urbanization in "Land conversion")
Loss of genetic viability	92 (10)	97 (68)
Aquifer depletion/wetland filling	77 (9)	N/A
Native species competition	77 (9)	N/A
Disease	19 (2)	31 (22)

Threat	Number (%) of Species Listed by Threat (Czech, Krausman, & Devers, 2000)	Number (%) of Species Listed by Threat (Smith-Hicks & Morrison, 2021)
Vandalism	12 (1)	N/A
Commercial fishing	N/A	3 (2)
Climate change	N/A	56 (39)
Pesticides/Herbicides	N/A	22 (15)
Unknown or Other	N/A	8 (6)

Land Use and Land Cover Change

A primary factor negatively affecting imperiled species are changes to their habitat. Many habitat modifications have occurred in the United States throughout human history, the earliest of which 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 being used for agriculture, forestry, urban and industrial development, and mining. Each of these land uses affect species and habitats differently. The land use categories that most affect species and habitat long-term are agriculture and urban/industrial development.

Over the last 300 years, forests in the eastern United States were reduced by at least half due to land use change for agriculture, urbanization, and infrastructure development. Intensive, large-scale land use changes began during European settlement and continued rapidly as settlers moved west, exploiting the land for tobacco and lumber for export (Keeney & Kemp, 2002). The United States Congress gave away land in the West to encourage settlement through the Homestead Act, and development further increased as transportation across the country became easier with the invention and expansion of railroads after the 1830s. Many prairie habitats (tall, mixed, and short grass) were nearly eliminated by agricultural expansion. Between 1938 and 1992, urban areas expanded by 140%, wetlands decreased, and agricultural land uses (e.g., cropland and hay) decreased nationwide by 18% with higher decreases in the east. Forestland and grassland increased, primarily due to agricultural abandonment (Sohl, et al., 2016). Between the early 1900s and early 2000s, the area of forest cover in the United States was relatively stable (Masek, et al., 2011), though reforested areas may not provide the same quality of habitat as unharvested, old-growth forests do for ESA-listed species (Sutherland, Gergel, & Bennett, 2016). For example, marbled murrelets use old-growth forests that take 100-200 years to recover with necessary nesting habitat structures (USFWS, 1997), and if these forests are removed, they may not recover into the same forest structure as was present before deforestation took place. In many cases, abandoned areas succeed into different communities from the ones that occurred before the land was converted to agriculture.

Agriculture

Agriculture (e.g., croplands and animal operations) is a principal industry in the United States, accounting for over 50% of the country's land uses (cropland, pasture and range, forested grazelands). As of 2021, there were over 2 million crop and livestock farms (a decrease of nearly 7,000 from 2020) across approximately 895,300,000 acres of land in the United States (NASS, 2022). Most grasslands in the United States are plowed and planted for crops for human consumption, livestock grazing, and more recently, biofuel production (Mitchell, Wallace, Wilhelm, Varvel, & Wienhold, 2010). Crop production is concentrated in the Midwest and California (Figure 1), but it occurs across the country in every state (USDA, 2017).

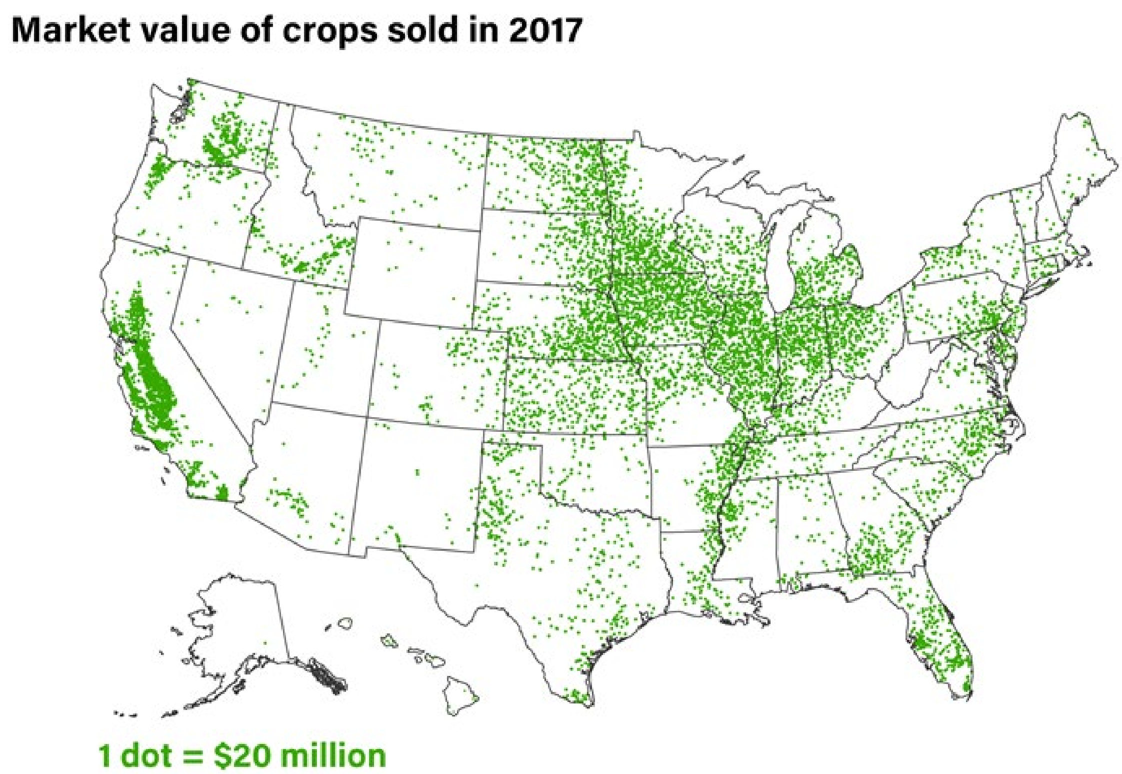

Figure 1. Market value of United States crops sold in 2017; data and figure from (USDA, 2017).

Between 2008-2016, croplands expanded by over 10 million acres across the continental United States, with over 1 million acres converted per year. Simultaneously, 3.52 million acres of cropland were converted to non-cropland uses, including abandonment (Lark, Spawn, Bougie, & Biggs, 2020) (Figure 2). Land use change is non-linear and when one area is converted from a natural area to agriculture, another may be allowed to succeed into a novel natural area after abandonment.

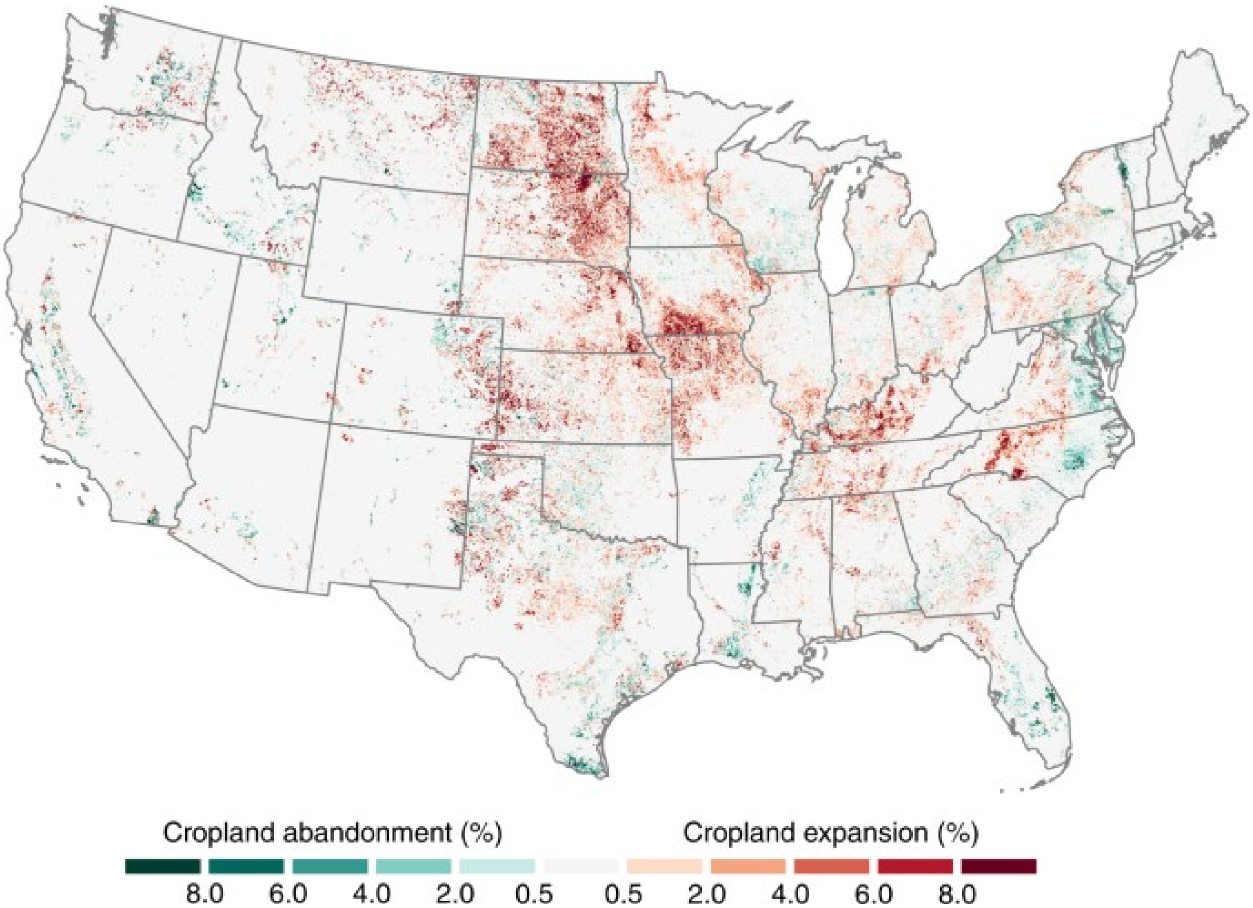

Figure 2. Cropland conversions between 2008-2016 in the continental United States, including abandonment and expansion (Figure 1 from (Lark, Spawn, Bougie, & Biggs, 2020)).

Crop production can lead to pesticides leaching into groundwater and entering streams from surface water runoff (Spence, Lomnicky, Hughes, & Novitzki, 1996; Rao & Hornsby, 2001). Several pesticides were 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 documented that large quantities of herbicides and their degradate products were flushed into streams during post-application run-off (Scribner, Battaglin, Goolsby, & Thurman, 2003). For more information about effects of pesticides, please see the *Use of Pesticides* section below.

Large animal husbandry operations are common in the Midwest and throughout the eastern United States. (Figure 3). In 2019, the cattle inventory in the United States was approximately 95 million head. Texas has the most cattle (13%) in the United States, followed by Nebraska and Kansas. Thirty-one states have more than 1 million head of cattle, fourteen have more than 2 million, and nine have more than 3 million head of cattle (based on USDA NASS data as cited in (Cook, 2019)). Other smaller operations raise horses, pigs, sheep, geese and ducks, dairy goats, rabbits, and exotic animals (e.g., llamas, emus, alpacas, ostriches). Many animal operations require grasslands for grazing and/or pasture farming (i.e., rangelands, pasturelands, and others), which occur in a large portion of the United States. Rangelands are managed as a natural ecosystem with mostly native grassy vegetation, while pasturelands are grazing lands used to permanently produce forage species, primarily for grazing animals (USDA, 1997). In the east, grasslands are mostly seeded pasturelands and, in the west, grasslands are mostly rangelands. Seeded pasturelands often receive more fertilizer and herbicides to control unwanted species than rangelands (Mitchell, Wallace, Wilhelm, Varvel, & Wienhold, 2010). As of 2018, some rangelands in the west were in relatively good condition (i.e., Great Plains) and others were in concerning conditions (i.e., Intermountain, Southwest Regions) from invasion of weedy plants, shrubs, and non-natives (i.e., bromes, mesquite); erosion; and aridity and drought (NRCS, 2018). As of 2018, 6% of non-federal lands are pastureland, most of which is in the South Central, Midwest, and Southeast regions of the United States (NRCS, 2018).

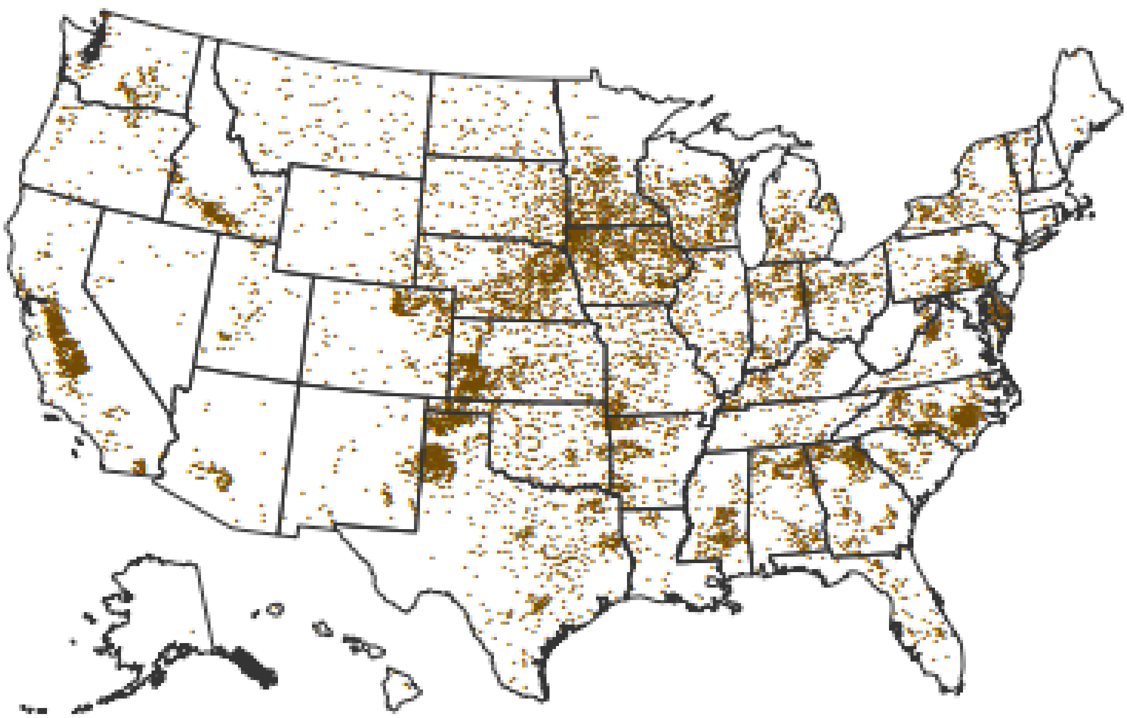

Figure 3. Market value of United States livestock, dairy, poultry, and their products sold in 2017; data and figure from (USDA, 2017).

Livestock grazing has been important to the United States agriculture system for centuries. In some areas, intense grazing resulted in a general decline in range conditions; conflicts among livestock owners due to limited resource availability; removal of highly flammable fuels and reduction in ground fires that limited tree seedling establishment; uncontrolled fires caused by purposeful fire setting by livestock owners; 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 cattle grazing pressure allowed recovery of some rangeland, including forests (Oliver, Irwin, & Knapp, 1994). By the 1960s and 1970s, legislation allowed for monitoring, improvements, and better stewardship of rangeland (including those in National Forests). Despite these efforts, over 70% of federal land (e.g., Bureau of Land Management, U.S. Forest Service) was grazed by cattle and sheep in the western Unites States by 1970 (CAST, 1974).

Agricultural grasslands, including rangelands and pasturelands, provide many ecosystem services to wildlife. For example, agricultural lands have less impervious land cover than urban or industrial lands (Nowak & Greenfield, 2010). Low-intensity agricultural lands provide food resources, shelter, and environmental heterogeneity that help some species to thrive. In contrast, agriculture is the leading cause of deforestation (Benayas & Bullock, 2012) and is responsible for 10% of anthropic greenhouse gas emissions in the United States (USEPA, 2021a). Agriculture has contributed to the loss of side-channel areas, loss of native and riparian vegetation, degradation of water quality, and introduction of contaminants (Hamilton & Helsel, 1995). Effects from livestock grazing can be considerable if management practices are not sufficient to protect habitat functions (Wissmar, et al., 1994; Belsky, Matzke, & Uselman, 1999). In overgrazed areas, native understory grasses are eliminated, tree seeds establish and are not consumed by grazers, and dense tree seedling areas further succeed in the absence of fire (Madany & West, 1983; Franklin, Hemstrom, Van Pelt, Buchanan, & Hull, 2008), changing the vegetation composition of the habitat over time. Livestock trampling damages fragile moss and lichen layers (i.e., biocrust) that provide nutrients to the soil, protect the soil against erosion, support native grasses, and limit colonization by non-native invasive vegetation (e.g., cheatgrass) (Finger-Higgins, Duniway, Fick, & Belnap, 2022).

Agriculture is the leading cause of water quality concerns in the United States (Keeney & Kemp, 2002). Water quality can be affected by increases in temperature and sediment from clearing shaded riparian areas along waterways and solar heating of water flowing across fields. Irrigation systems often result in warmer water temperatures in canals and streams also. In addition to effects on or adjacent to agricultural lands, effects to water quality may extend far downstream of agriculture activities through runoff. For example, livestock production often degrades water quality through the addition of excess nutrients from animal manures and agricultural fertilizer, which can contribute to excessive growth of aquatic plants, harmful algal blooms, reduced levels of dissolved oxygen, and adverse effects to fish (Embrey & Inkpen, 1998; USEPA, 2006) and other aquatic organisms. Additional impacts to water quality may result from improper spreading of manure and increased surface runoff from overgrazed pasture and/or other areas in which large numbers of animals are confined (Rau, 2015).

Other impacts result from the maintenance of grazing lands. Fencing can provide environmental benefits such as keeping cattle out of sensitive areas, but 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 and interspersed metal posts, wooden posts, or live trees. On flat terrain, power equipment may be used to auger holes and construct fencing. On steep terrain, hand tools and chain saws become more common. Rock cribs are often used when crossing areas of bedrock. Each of these activities can affect sensitive species and habitats through noise, human disturbance soil compaction, among others.

Attempts have been made to begin correcting some of the past impacts on the country's ecosystems from agricultural operations. In 1970, the EPA took over implementation of FIFRA to regulate the registration and use of chemical pesticides, although some authors note challenges associated with its implementation. Additionally, State and federal programs were organized to aid landowners in voluntarily managing their properties to improve water and habitat quality (Edge, 2001). The 2002 farm bill drastically increased funds for conservation and created the voluntary Conservation Security Program (Keeney & Kemp, 2002), which provided funds to producers for conservation actions. Though revised a few times since its establishment, the Conservation Stewardship Program (formerly, Conservation Security Program) has been reauthorized with each new farm bill (Stubbs, 2023).

Forestry Activities

At the beginning of European settlement in 1630, an estimated 423 million hectares (46%) of what would become the United States was forest lands. Many forest lands were converted to other uses such as agricultural and urban uses over the next several hundred years. From 1850 to 1997, forest land remained relatively stable across the country and by 2012, forests comprised 309 million hectares (USDA, 2014). Reserved forest land, State and federal parks and wilderness areas, has doubled since 1953 and now stands at 7% of all forest land in the United States (not including 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). 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.

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.

<u>Timber Harvest</u>

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. Following World War II, truck road systems replaced railroads, but smaller streams continued to be used as transportation corridors. 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. 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.

Timber harvest changes the forest composition and can change forest ecosystem functions. Before timber harvest began, forest composition included many age classes, diverse species, and various canopy levels. Timber harvest initially focused on large-diameter trees and, secondarily, small-diameter trees, ultimately reducing the number of large-diameter trees in forests and slowing recruitment (Sedell, Leone, & Duval, 1991; USFS, 2003). In particular, old-growth forests have declined on federal and non-federal lands across the United States, and they take 150+ years to grow. Once old-growth forests are disturbed, they may not succeed or recover with the same characteristics that they had before the disturbance (i.e., they may have a different species composition) (Spies, 2004). Many species rely on characteristics of old-growth forests that are not found or are less common in other habitat types (i.e., tree snags). In addition to providing unique habitat, temperate coastal rainforests collect moisture from fog, which helps provide water to these ecosystems without rainfall. Significant reductions in large trees may result in less moisture retention, affecting future runoff and/or precipitation patterns (Dawson, 1998).

In addition to forest effects, 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 runoff patterns. Runoff timing and magnitude can change to deliver more water to streams in a shorter period, which causes increased stream energy and scouring and decreased base flows during summer months. Stream temperatures may rise with decreases in the forest canopy and riparian zone shading. Loss of large trees also increases erosion and simplifies stream channels (Quigley & Arbelbide, 1997).

Improvements in forestry methodologies have reduced some effects from these practices. 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 from forest fires resulted in a mosaic of diverse habitats. Before European settlement in the United States, both natural and human-initiated fires are believed to have affected forests. Fire is a necessary phenomenon for many ecosystems; many species rely on fire, like jack pines whose cones only open when heated during a fire and Douglas fir seedlings rely on openings in the canopy made by forest fires to grow (Cooper, 1961). In addition to facilitating germination of some pine species and making room for others to grow into the canopy of a forest, fires release nutrients back into the soil, maintain grassland and other early successional habitats that are otherwise overtaken by forests, and diversify landscapes more broadly (Knapp, Estes, & Skinner, 2009). In some lowland areas, 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.

Starting in the late 1880s, fire suppression was used to protect human-dominated areas and it became a priority of the U.S. Forest Service to suppress all fires in 1905. Forest control and suppression since the early 1900s changed the composition of many forests across the United States. Historically, burned areas were maintained as early successional vegetation through grazing or were left to develop into dense stands with different compositions than was previously present. Many fire-dependent pine species were outcompeted by hardwoods (e.g., oaks, maples, yellow poplar) that do not need fire to reproduce and are otherwise restricted to wetter environments (Keane, et al., 2008). The environmental integrity of forests changed and denser forest stands may be more susceptible to disease and pests (Oliver, Irwin, & Knapp, 1994). Fire suppression led to a buildup of forest fuels, which increased the likelihood of large, intense forest fires in some areas. Large fires can cause longer-lasting damage than small fires because their heat effects run deeper into the soil and they can create larger burn areas (Keane, et al., 2008).

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. In the 1960s, the National Park Service recognized that fire was an important natural process and began letting naturally ignited fires run their course under prescribed conditions. The Forest Service began allowing natural fires to burn in wilderness areas in 1974. Other land management agencies (e.g., U.S. Fish and Wildlife Service, Bureau of Land Management, Bureau of Indian Affairs) began implementing fire management, as opposed to fire control, in the 1990s and 2000s (van Wagtendonk, 2007).The use of prescribed fire in certain environments was encouraged, with certain precautionary measures. Although scientists 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 liability. There are other constraints upon prescribed burning including short-term expenses and air-quality regulations.

Forest Diseases and Pests

Forest diseases and pests were present in forests before European settlement, including fungal pathogens, defoliating insects, among others. Many diseases and pests were transported unintentionally to the United States as world travel became more common. Invasive insects and plant pathogens can change forest composition and structure if they only damage a subset of the plants in the habitat (Poland, et al., 2021). By the mid-1900s, several defoliating insects were documented across the United States (e.g., tussock moths, pine butterflies, bark beetles, pine beetles) that kill trees, reduce their growth, and increase their susceptibility to other damage from insects or disease (Kulman, 1971). Starting in the 1930s, surveys and control were used to combat pests. Pest control included selective harvesting or salvage harvest to remove infested trees, pesticide use (e.g., ethylene dibromide, dichlorodiphenyltrichloroethane (DDT), and other insecticides), and removal of host plants (e.g., currant [*Ribes* spp.], host of white pine blister rust). Between 1860-2006, about 2.5 new non-native forest insects were detected in the continental United States each year. By 2010, there were an estimated 450 non-native insects and 16 new pathogens in our forests and urban trees, and at least 14% of them caused notable tree damage (Aukema, et al., 2010). In addition, fungal pathogens, oomycetes, and parasitic plants can devastate forests and change their structure and composition (Cobb & Metz, 2017). Forests that have been affected by defoliating insects and/or pathogens are more susceptible to other threats like drought, fire, and effects of climate change (Kliejunas, et al., 2008).

Since the 1960s, integrated pest management has been used to control insect outbreaks. With integrated pest management, several 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 integrated pest management 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).

Urbanization

In general, urban land acreage quadrupled from 1945 to 2007 with an estimated 61 million acres in 2007 (Nickerson, Ebel, Borchers, & Carriazo, 2011). By 2012, USDA estimated that 70 million acres of the United States (3% of total land area) were urbanized. Urban land area increased at more than double the human population growth rate between 1945 and 2012, and between 1982 and 2012, the increase in developed land acreage was primarily driven by conversion of forest and cropland (Bigelow & Borchers, 2017). Between 2001 and 2016, the most persistent and permanent land use change in the continental United States was development (5.6 of the total land area), most of which occurred between 2001-2006 (Homer, et al., 2020). Figure 4 depicts the 2020 human population density by county in the United States and serves as a coarse representation of urbanization. Between 2010-2020, the United States human population grew by over 22 million people, with a total population in the 2020 Census of 331,449,281 people (USCB, 2021). In general, urbanization (including impervious land cover, manufacturing and waste, housing densities, and contributions to greenhouse gas emissions) concentrates effects of water, land, and mineral use; increases the pollutant load in water 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.

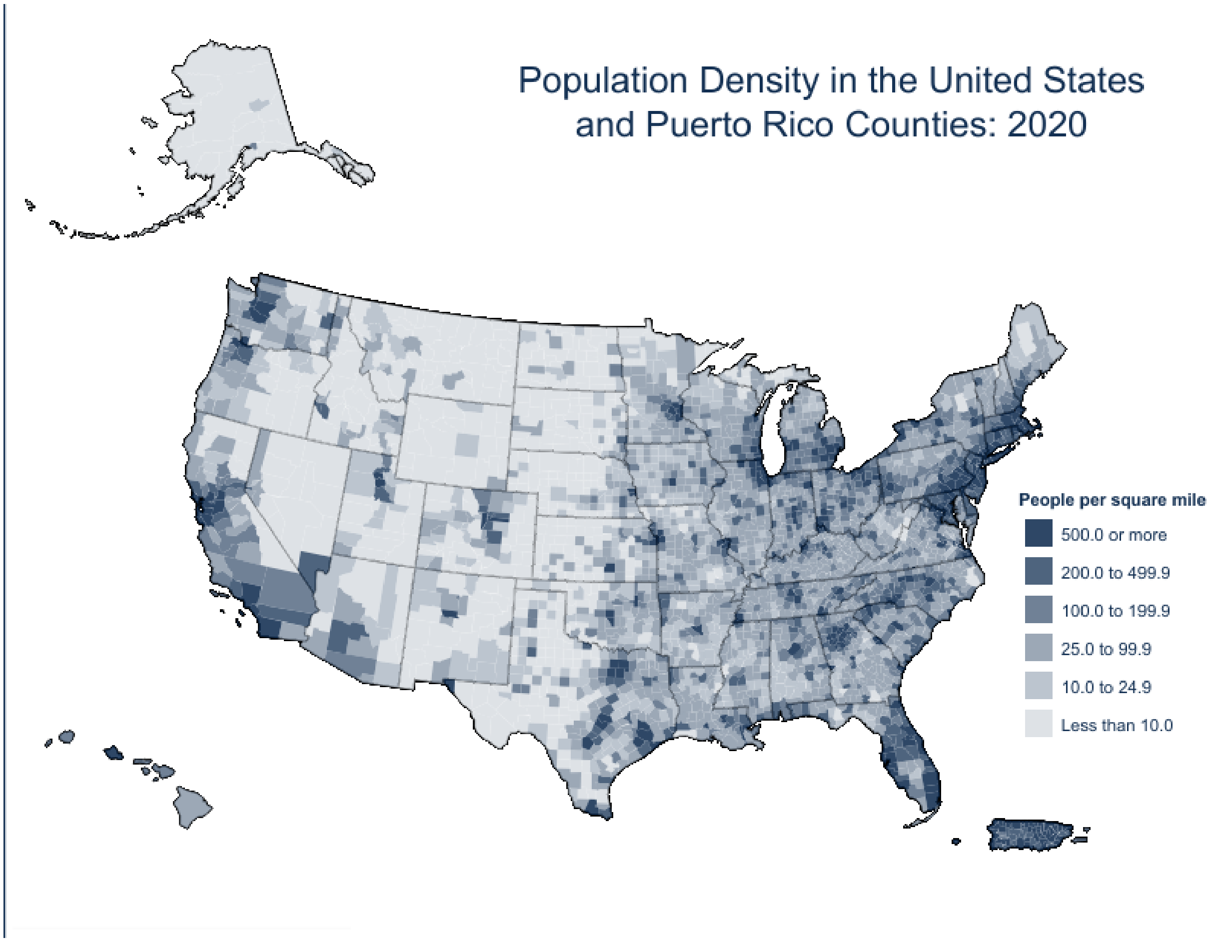

Figure 4. United States population density by county (USCB, 2021).

Land uses in urban and suburban areas 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). Urban and suburban development often includes construction of roads, railroads, associated rights-of-way (ROWs) and associated clearing of vegetation and other habitat features. These activities, as well as installation of below grade utility lines, pipelines, transmission lines and other infrastructure, can change terrestrial and riparian habitats and simplify and channelize streams, thereby reducing connectivity of surface water and groundwater. Historically, stream materials (e.g., sand, gravel and cobbles) were often used as fill, and excess excavation materials were pushed over the road bank, where they 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 United States, road and ROW siting, construction, and maintenance practices have not changed significantly through time and thus continue to contribute to the decline of ecosystem function for fish, wildlife, and plants. Constriction of floodplains resulted in increased flooding (Palmisano, Ellis, & Kaczynski, 2003), which continues today in some areas. Construction, maintenance, and use of urban and suburban areas can also result in loss or degradation of riparian and wetland areas, degradation and fragmentation of terrestrial plant and animal habitats, sedimentation, erosion and slope hazards, reduction of species' passage, dispersal, or migration , and increased strike hazards to many classes of animals. Activities that involve land disturbance increase the risk of erosion and, therefore have the potential to affect the quantity of sediment that reaches waterways. Excessive sediment reduces stream depth, leads to increases in water temperatures and reductions in dissolved oxygen content (Ringler & Hall, 1975; Henley, Patterson, Neves, & Lemly, 2000).

Most land areas covered by natural vegetation are highly porous and have limited sheet flow; precipitation falling on these landscapes infiltrates the soil, is transpired by the vegetative cover, or evaporates. The transformation of land into a mosaic of urban and suburban land uses has increased the area of impervious surfaces (e.g., roads, rooftops, parking lots, driveways, sidewalks). Precipitation that would normally infiltrate soils in forests, grasslands and wetlands falls on and flows over impervious surfaces and runs off the land. Runoff is channeled into storm sewers and released directly into surface waters (e.g., rivers and streams), which changes the magnitude and variability of water velocity and volume in those receiving waters. Runoff also can transport pollutants into waterways and across landscapes.

Impervious surfaces associated with residential and urban development create one of the most lasting impacts to stream systems. The amount of new impervious surfaces increased significantly in recent history, and this trend will likely continue in the future. There is a strong relationship between the amount of forest cover, level of impervious and compacted surfaces, and degradation of aquatic systems (Klein, 1979; Booth, Hartley, & Jackson, 2002). Intensive development leads to losses of forest cover, increases in impervious surfaces, and changes to hydrology (e.g., increased peak flows, increased flow duration, reduced base flows, decreased evapotranspiration and groundwater infiltration) and these environmental changes can be detected when impervious surface in the watershed is as low as 5 to 10% (Booth, Hartley, & Jackson, 2002; May, Horner, Karr, Mar, & Welch, 1997). Some environmental changes, like increased peak flows and flow duration, often require engineering channels to address flooding, erosion, and sediment-transport concerns. Impervious surfaces also increase stormwater runoff, which causes many contaminant and pollution concerns (see the *Use of Pesticides* and *Pollution* sections below).

Additional water-quality concerns related to urban and suburban development include stormwater runoff, adequate sewage treatment and disposal, transport of contaminants to streams by storm runoff, and preservation of stream corridors. Human-dominated landscapes influence water availability, which 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 (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. For more information about impervious surfaces, water quantity, or pollutants, please see the *Impervious Surfaces*, *Water Quantity and Use*, and *Pollution* sections below.

To avoid or minimize negative environmental effects of impervious surfaces, developers and decision makers can implement actions to counter effects of impervious surfaces and stormwater runoff on natural resources. Narrower roads can be used in some cases to reduce the amount of impervious surface, and swales and rain gardens can be installed to reduce the amount of runoff. Land use planning, zoning, addition of parks, and natural area acquisitions are used in many communities to incorporate green infrastructure into developed landscapes that can help maintain functional floodplains, stream flows, water quality, fish and wildlife habitat, and other ecosystem functions and public benefits. Permeable pavement has been used to reduce stormwater runoff and pollution transport (Brattebo & Booth, 2003; Drake, Bradford, & Marsalek, 2013), among other negative effects of impervious surfaces. Some states and localities have laws intended to control erosion and sedimentation (USEPA, 2024b; Fairfax County, 2024; State of Virginia, 2024).

Mining and Mineral Extraction

The United States has a history of mining that dates to the early 17th century when iron, lead, silver, copper, and coal were discovered and mined by early colonial settlers of New England and the Mid-Atlantic states. Today, all states and Puerto Rico produce mined materials or extract minerals from below the Earth's surface. Mined materials include fuels (e.g., coal, oil, and gas) and building materials (e.g., sand, gravel, and clay). Extracted minerals include rare Earth minerals, aluminum, and copper. There are no readily available summary data to illustrate the extent 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 were disturbed or adversely impacted by surface coal mining (USACE, 1979).

Environmental effects from mining and mineral extraction including habitat loss, reduction in surface and ground water quality, reduction in air quality, and pollution from mining waste disposal. Mining activities can affect downstream water chemistry, which may in turn affect species, their habitat, and other resources on which they depend. Studies have shown that mining-impacted waterways often contain elevated levels of arsenic, selenium, iron, aluminum, manganese, and sulfate. These waters typically have lower alkalinity concentrations and lower pH, while specific conductivity and total suspended solids are typically higher compared to streams unimpacted by mining (Skogerboe, Lavallee, Miller, & Dick, 1979; Wangsness, Miller, Bailey, & Crawford, 1981; Zuehls, Fitzgerald, & Peters, 1984; Herlihy, Kaufmann, Mitch, & Brown, 1990; Bryant, McPhilliamy, & Childers, 2002; Petty, et al., 2010; USEPA, 2011; Presser, 2013). These environmental impacts have caused decreases in macroinvertebrate communities (Hartman, Kaller, Howell, & Sweka, 2005; Pond, Passmore, Borsuk, Reynolds, & Rose, 2008) and fish (Hopkins & Roush, 2013; Giam, Olden, & Simberloff, 2018; Sergeant, et al., 2022) downstream of mining activities. For some sites, even after years of reclamation and restoration efforts, the sites continue to show low levels of forest productivity compared to nearby native forests (Groninger, Fillmore, & Rathfon, 2006).

In 1977, the United States passed the Surface Mining Control and Reclamation Act (SMCRA), "the primary federal law that regulates the environmental effects of coal mining in the United States" (OSMRE, 2024). SMCRA required minimum standards for coal mining to be used nationwide with an aim to protect the environment. SMCRA also allowed states to enact stricter regulations. Mining activities that occurred after SMCRA were required to return the mined lands to pre-mining conditions as much as possible, including successful revegetation. Acid-producing pyritic (FeS_2) materials now need to be isolated below the final surface of the revegetated area. Post-SMCRA mine soils (i.e., 2002) had a higher pH than the finer-textured mine soils from mines sampled in 1980. In addition to the implementation of SMCRA, many technology improvements have occurred over the last several decades and more recent mining activities have bored deeper into unweathered rock as opposed to weathered rock closer to the surface (Daniels, Haering, & Galbraith, 2004).

Water Quantity and Use

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.

Freshwater withdrawals increased from 1950 until the 1980s, after which surface water use appeared to decrease even with population increases. In 2015, water use across the United States was estimated to be 322 billion gallons per day, which is the lowest overall withdrawal since 1970 and was 9% less than the 2010 estimate. Freshwater withdrawals accounted for 87% of the total and saline-water withdrawals accounted for 13%. Between 2010-2015, fresh surface-water withdrawals decreased by 14%, fresh groundwater withdrawals increased by 8%, and saline surface-water withdrawals decreased by 14%. Overall, the largest water uses in 2015 were thermoelectric power (decreased by 18%) and irrigation of agricultural lands (increased by 2%). Other water uses decreased in by 2015: public supply (7%), self-supplied domestic (8%), Self-supplied industrial (9%), and aquaculture (16%). Mining reported a 1% increase in withdrawals and livestock withdrawals remained essentially the same (Dieter, et al., 2018).

Thermoelectric power plants use water to cool steam used to drive thermoelectric generators. Nearly all (100%) water used in thermoelectric power plants is surface water, and 72% was from freshwater sources. Thermoelectric power withdrawals were greatest in TX, and when combined with IL, MI, AL, and NC, these five states accounted for 40% of freshwater withdrawals for thermoelectric power. Saline surface withdrawals were primarily used in FL, NY, and MD (53% of total saline withdrawals for thermoelectric power) and 90% of saline groundwater withdrawals occurred among NV, CA, FL, and HI (Dieter, et al., 2018).

Irrigation is used to grow plants for agriculture and horticulture (i.e., forest nurseries, seed orchards, other crops), to maintain green spaces (i.e., golf courses, parks, turf farms, cemeteries, and other landscaping), and for other water-related processes (i.e., frost protection, chemical application, weed control, harvesting, dust suppression, and leaching salts from the root zone). In 2015, irrigation accounted for 42% of total freshwater withdrawals. Most irrigation withdrawals (81%) were used in the western United States (i.e., ND south to TX and west to the Pacific Ocean). Groundwater was the primary source of irrigation water in CA, NE, TX, KS, SD, and OK and surface water was the primary source elsewhere in the west (Dieter, et al., 2018).

Effects associated with water withdrawals include lower water volumes in rivers, streams, lakes, and aquifers; modification of natural flow regimes; water shortages downstream and during drought periods; reduced water quality; and degradation of wildlife habitat (Wissmar, et al., 1994; Saha & Quinn, 2020). Irrigation also includes effects from water storage and drainage, increased water temperatures (which can become thermal barriers for salmonids and other aquatic species), introduction of pollutants (such as runoff containing pesticides and fertilizers), and increased sediment levels (Wissmar, et al., 1994; Krupka, 2005).

There have been several attempts to reduce impacts from water withdrawal and water-diversion activities. Some efforts to minimize effects to anadromous fish were undertaken relatively early (Palmisano, Ellis, & Kaczynski, 2003), such as screening of irrigation diversions in the 1930s, although the screens did not protect all life stages, nor were they adequately maintained. More recently, the EPA published a handbook for developing watershed plans to restore and protect United States waters (USEPA, 2008), in which they outline information needed for a watershed plan to meet water quality standards and protect water resources; many states have similar guides also. Some projects were 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. Many similar projects exist across the country (NOAA, 2023; WDOE, 2023; Yuba Water Agency, 2023) (WDOE, 2023) (Yuba Water Agency, 2023).

Pollution, Contaminants, and Pesticides

Pollution is the introduction of harmful materials into the environment. Pollutants can include a wide variety of chemicals such as excess nutrients, heavy metals (e.g., mercury, lead), persistent organic pollutants like polycyclic aromatic hydrocarbons (PAHs), poly-bromated diphenyl ethers (PBDEs), hazardous waste, microplastics, and others. The types and concentrations of pollutants in the environment vary depending on the pollutant's chemical characteristics and sources and can be influenced by environmental factors, habitat type, and region. Altogether, pollutants represent a complex network of environmental stressors that contribute to habitat degradation, cause toxic effects in listed species, and impair ecosystems around the world. Given the wide diversity of pollutants that currently contaminate the habitat of listed species, we are not able to fully address the breadth of impacts that pollutants have on the environmental baseline of listed species. Here, we provide a general survey of different types of pollutants, a summary of their impacts on the environment, and description of how they contribute to the environmental baseline of listed species.

Chemicals associated with land use practices, like pesticides and fertilizers, are used on agricultural and developed lands and can enter the environment through stormwater runoff and spray drift (see *Use of Pesticides* section below for further discussion of the impact of pesticides on the environmental baseline). The EPA estimated that 50% of the nation's streams (approximately 300,000 miles) and 45% of the nation's lakes (approximately seven million acres) were in fair to poor condition because of nutrients commonly found in fertilizers, like nitrogen or phosphorus, relative to reference condition waters (USEPA, 2013). Pesticides and excess nutrients can impair water quality, adversely affecting aquatic species inhabiting polluted streams and terrestrial species that rely on contaminated water sources. Additionally, excess nutrients can trigger harmful algal blooms, which result in broad ecosystem effects like depleted dissolved oxygen resources for aquatic species, altered pH, reduced light availability, and increased turbidity (USEPA, 2024c). Some harmful algal blooms produce potent toxins and cause a number of illnesses in wildlife and humans, such as paralytic shellfish poisoning. Harmful algal blooms commonly result in major environmental impacts, such as large-scale fish kills and hypoxic dead zones (Hallegraeff, Anderson, & Cembella, 1995).

Inorganic pollutants, including heavy metals like lead, mercury, and arsenic, occur naturally in the environment, but can accumulate as pollutants as a result of human activities. Heavy metals are widely used in industrial, domestic, agricultural, medical, and technological applications. These pollutants can enter the environment through hazardous material spills, industrial emissions, vehicle emissions, stormwater runoff, and through common products like discarded batteries, paints, and dyes. Given their wide use, heavy metal contamination is a world-wide phenomenon. Heavy metals can be highly toxic, causing a wide range of effects like disruption of organ systems and metabolic function, developmental effects, neurological disorders, or other illnesses in wildlife and humans (Timothy & Williams, 2019). Heavy metals do not degrade and thus can persist in the environment indefinitely without any remediation efforts.

Similarly, organic pollutants cover an incredibly wide array of chemical types. Many organic pollutants, such as PBDEs, polychlorinated biphenyls (PCBs), and chlorinated compounds (including dioxins), are (or previously were) components of manufactured goods and their widespread use facilitates environmental contamination on a global scale. Some organic pollutants, such as PAHs, dioxins, and microplastics, are byproducts of industrial processes like combustion or leaching, or form during waste disposal and are unintentionally released into the environment. Regardless of their origin, organic pollutants are widespread and persistent in the environment. Their chemical characteristics (e.g., low water solubility, high volatility, slow degradation) make them long-lasting environmental contaminants as they permeate soils, are transported long distances by air, and accumulate in animal tissues, even long after removal of original sources.

Organic pollutants can have a variety of toxic effects, ranging from acute toxicity of various organ systems to long-term chronic effects like altered reproduction, endocrine disruption, and carcinogenesis. In the 2007 National Lakes Assessment, EPA found that only 56% of the nation’s lakes were in good biological condition and several contaminants, including mercury, PCBs, dioxins, furans, and DDT (an insecticide), were widely distributed across surveyed lakes. Of particular concern is that some of these harmful pollutants (e.g., PCBs and DDT) remained detectable 30+ years after they were banned for use in the United States because of their effects on humans and the environment (USEPA, 2009b). As suggested by the EPA results, some chemicals and their breakdown products persisted 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, multiple substances are present in the habitat and/or biota and little is known about their synergistic effects.

Other sources of toxic contaminants (including inorganic and organic pollutants mentioned previously) include solid waste and leaching from landfills, discharges of municipal and industrial wastewater, improper disposal of hazardous waste (e.g., printing, dry cleaning, auto repair shops), and channel dredging, which can result in resuspension of contaminated sediments. Discharges from wastewater treatment plants may be treated prior to discharge into receiving waters, but some persistent, bio-accumulative, endocrine-disrupting, or toxic compounds often remain in the water (Bennie, 1999; CSTEE, 1999; Daughton & Ternes, 1999; Servos, 1999). Stormwater runoff is another significant contributor of non-point source water pollution and can contain complex mixtures of multiple chemical and biological contaminants, which can have devastating effects on fish, like salmonids (KCDNR and WSCC, 2000; Chow, et al., 2019), reefs, seagrass beds, and other aquatic life. The presence of roads and other impervious surfaces increase the distance pollutants can travel throughout runoff because they prevent water absorption into the ground, greatly exacerbating the environmental impact of many types of pollutants.

Even if contaminated areas are relatively small, their effects can be far-reaching and long lasting. Many pollutants, particularly those that have low solubility like organic pollutants, are taken up by living organisms through a variety of routes of exposures, such as inhalation, dermal contact, or ingestion. Many pollutants can biomagnify within an ecosystem, where body burdens disproportionately increase with increasing trophic levels. Consequently, predators can have very high contaminant levels, even if they have spent little or no time in contaminated areas.

Due primarily to risks to human health, much attention was given to hazardous dump sites and other areas of high pollution in the 1970s. In 1980, Congress established the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), which allows the EPA to clean up contaminated sites, or "Superfund" sites. CERCLA also forces responsible parties to either clean up their pollutants or reimburse the EPA for their efforts. CERCLA authorizes short-term removals and long-term remedial responses, depending on the nature of the contaminated site and the urgency of human and environmental health risks (USEPA, 2024d). Many Superfund sites exist across the country, and success stories include Otis Air National Guard Base/Joint Base Cape Cod in MA, Brick Township landfill in NJ, Tobyhanna Army Dept in PA, Kerr-McGee Chemical Corp in MS, Celotex Corporation in IL, the USDOE Pantex Plant in TX, Kansas City Structural Steel, Libby Asbestos in MT, and Black Butte Mine in OR (USEPA, 2024e).

Use of Pesticides

Pesticide use is a common practice to kill or manage unwanted plants, animals, and other pests (e.g., fungi, microbes). Many classes of pesticides are used for targeted pests: herbicides (i.e., plants), insecticides, rodenticides, fungicides, among others. In general, pesticides are beneficial to foresters and residential developers through control of unwanted or invasive non-native plants and aid in restoration of native habitat. They are beneficial to agriculture through control of pests that destroy crops, outcompete crops, degrade soils or water, and affect livestock. Pesticides can increase food production, increase profits for farmers, and prevent spread of diseases. Pesticides also benefit human health by killing pests such as mosquitos that that carry and transmit diseases (e.g., malaria, West Nile virus, and Zika).

When pesticides are applied to land, plants, or animals, they can enter air, water, and soil across the environment. How long pesticides remain in the environment varies with the chemical itself (i.e., how easily it degrades) and environmental conditions (i.e., soil water content) when its applied and after application (Arias-Estévez, et al., 2008). During a 10-year study by the U.S. Geological Survey (1992-2001), they detected pesticides in more than 90% of stream water samples, 80% of fish samples, and 50% of bed-sediment samples collected across the country (n=186). Pesticides were detected at concentrations above benchmarks for the protection of aquatic life in 50% of streams tested nationwide, 83% of streams in urbanized areas, and 94% of streambed sediments (Gilliom, et al., 2006). They were common throughout the year in streams of developed watersheds dominated by agriculture, urban, and mixed land uses. Fish and sediment in streams were contaminated with organochlorines like DDT, many of which have not been in use for years due to known environmental impacts. Other similar studies showed that pesticides were frequently detected in groundwater samples and while concentrations were often below human-health benchmarks, they did not assess wildlife or other environmental benchmarks (Toccalino, Lindsey, & Rupert, 2014; Bexfield, Belitz, Lindsey, Toccalino, & Nowell, 2021).

Pesticide use as part of past federal and non-federal actions has resulted in impacts to listed species, their habitats, and other species on which listed species depend. Pesticides affect taxa groups differently. For example, insecticides are targeted for insect pests, so they typically have greater effects on listed insects and potentially predators of insects than on other taxa groups. In general, pesticides have been documented to affect bird eggshell thickness, fish behavior and reproduction, insect behavior and survival, and many unintended indirect effects (Pimentel D. , 1971) (Köhler & Triebskorn, 2013).

Some federal actions have undergone section 7 consultations related to pesticide use. For example, the USDA Animal and Plant Health Inspection Service (APHIS) Pest Program uses pesticides to achieve its mission and has consulted with the Service on multiple occasions. APHIS's implementation of these activities is generally supported by a well-established program infrastructure that includes environmental compliance, training, monitoring, and reporting, as well as species-specific conservation measures designed to avoid and minimize adverse effects (e.g., their use of pesticides for the Grasshopper and Mormon cricket suppression program has included conservation measures that led to Service concurrence on NLAA determinations for many species). Most APHIS activities have occurred on non-federal lands.

Aquatic Habitats

Wetlands

Wetlands perform functions that contribute to the health of ecosystems used by many species. There are many kinds of wetlands including tidal salt marshes, mangroves, freshwater marshes, swamps, riparian forests, and peatlands (Mitsch W. J., Gosselink, Anderson, & Zhang, 2009). Wetlands store atmospheric carbon, protect clean water, maintain cool water temperatures, retain sediments, store and desynchronize flood flows, maintain base water flows, mitigate storm damage to coastal areas, and provide food and cover for many species of fish, birds, aquatic organisms, and other wildlife (Mitsch & Gosselink, 1993; Beechie, Beamer, & Wasserman, 1994; Mitsch W. J., Gosselink, Anderson, & Zhang, 2009). Wetlands also 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. Between the 1780s and the 1980s, 118 million acres of wetlands were lost after human interference. Wetlands were often excavated or filled to create upland for real estate development or converted to agriculture (Duke & Krucynski, 1992). Arkansas, California, Connecticut, Illinois, Indiana, Iowa, Kentucky, Maryland, Missouri, and Ohio lost 70% or more of their original wetland acreage. California lost an estimated 91% and Florida lost 46% of its 1780s total (Dahl, 1990). Between 2006 and 2009, approximately 13,800 acres of wetlands were lost per year (Dahl, 2011). In 2019, wetlands occurred on approximately 116.4 million acres of the conterminous United States and most of them (95%) are freshwater (Lang, Ingebritsen, & Griffin, 2024). Most wetlands were vegetated (i.e., 92% freshwater and 80% saltwater), primarily freshwater emergent or scrub-shrub wetlands and salt marsh. Net wetland loss between 2009-2019 increased by over 50% compared to 2004-2009, most of which was loss of vegetated wetlands (Figure 5, Figure 6). The authors believe some loss of saltwater wetland vegetated indicates a future loss of wetland to sea level rise and coastal storm impacts. Many remaining wetlands have been degraded and have reduced functionality compared to the 1780s. Lang et al. (2024) also documented an increase in non-vegetated wetlands, a shift which reduces the prosperity, health, and safety of wetland and nearby communities compared to vegetated wetlands.

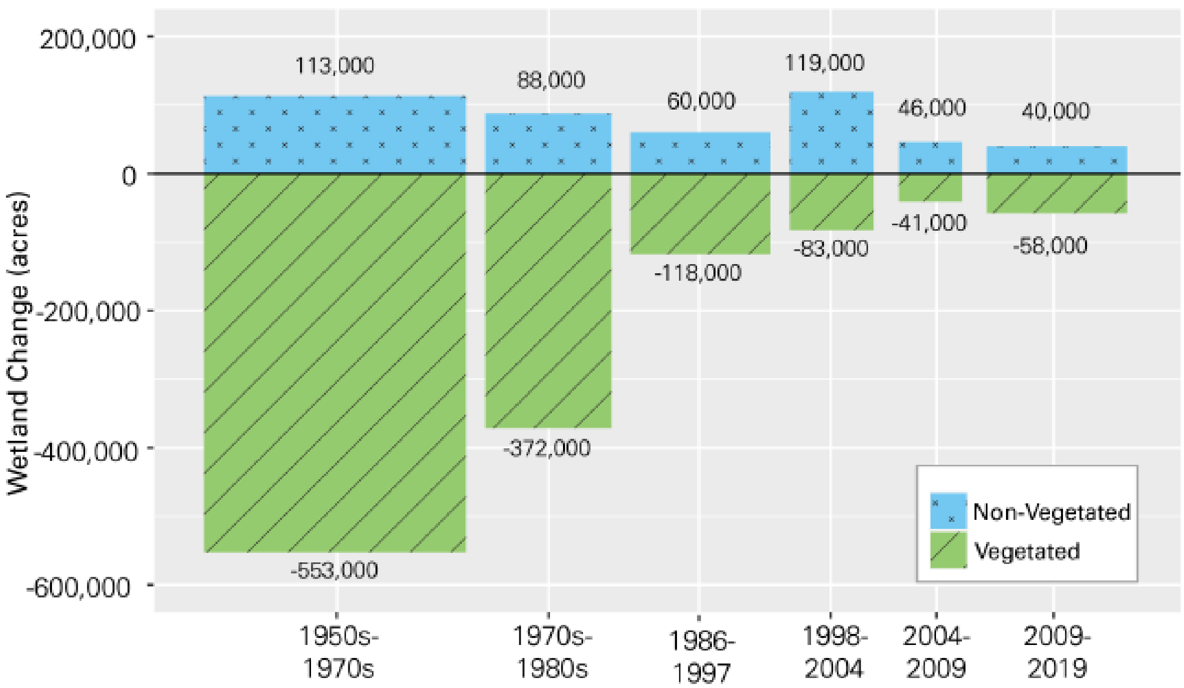

Figure 5. Average net annual non-vegetated and vegetated freshwater wetland acreage change estimates for the conterminous United States from the 1950s-2019. Figure on page 21 of (Lang, Ingebritsen, & Griffin, 2024).

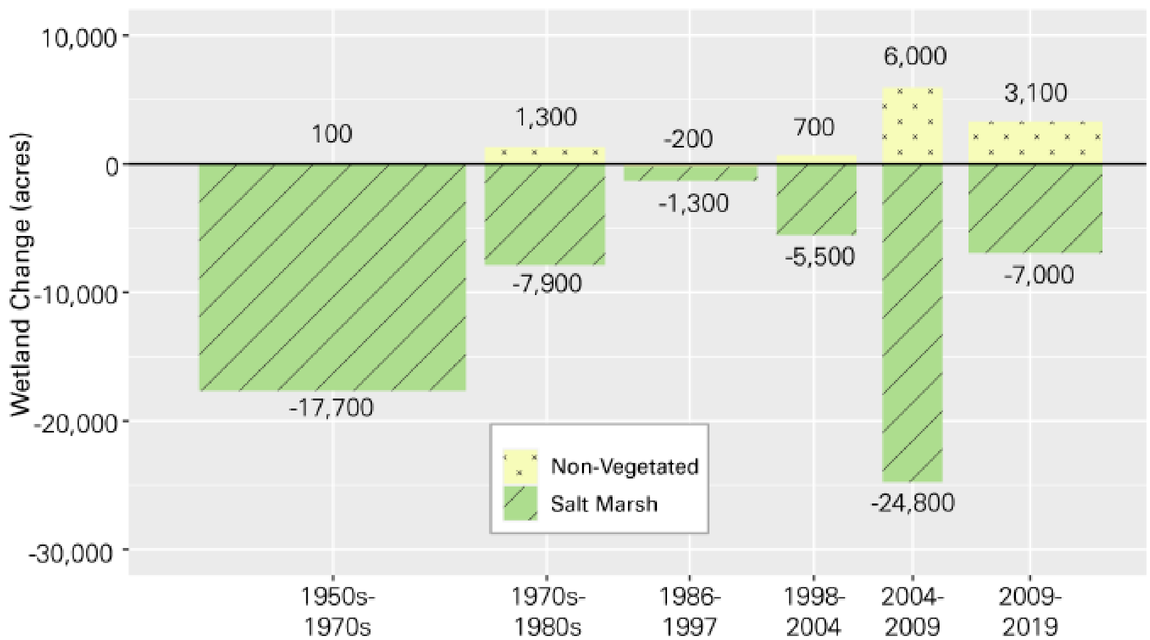

Figure 6. Average net annual salt marsh and non-vegetated saltwater wetland acreage change estimates for the conterminous United States from the 1950s-2019. Figure on page 21 of (Lang, Ingebritsen, & Griffin, 2024).

Various factors have contributed to wetland loss and degradation including agricultural development, urbanization, timber harvest, road construction, and other land-management activities. These activities affect wetlands and are responsible for much of the loss of riparian buffers (70% of the original area of riparian ecosystems) in the United States (Swift, 1984). Riparian areas, the transitional zone between streams and uplands, protect the stream from excess sediments, sequester pollutants, contribute to the reduction in peak stream flows during floods, and act as holding areas for water that is released back into the stream during times of low flow. They create habitat features essential for wildlife, like pools, riffles, slack areas, and off-channel habitats. Riparian areas are affected by development, logging, recreation, grazing, mining, and water diversions. Though efforts to create and restore wetlands and riparian buffers have dramatically reduced the rate of destruction or degradation, many wetland habitats continue to be lost. Different riparian widths provide various ecological functions depending on the characteristics of a particular riparian zone. 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).

All waterbodies in the United States have been affected by anthropogenic stressors, which often lead to long-term environmental degradation, lower biodiversity, reduced primary and secondary production, and a lower capacity or resiliency of the ecosystem to recover to its original state in response to natural perturbations (Rapport & Whitford, 1999). Freshwater habitats are among the most threatened ecosystems in the world (Leidy & Moyle, 1997). Reviews of aquatic species' conservation statuses for 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).

Rivers and Streams

Free-flowing rivers regularly flood and recede, collecting and depositing sediment materials both laterally and downstream. Rivers carry sediment and nutrients down river, eventually depositing it in the deltas and estuaries where freshwater enters saltwater. Natural rivers typically are narrower, have more riparian and bank cover, more habitat diversity, and higher pool volume than rivers that have been managed for transportation or other purposes. Past land use can leave legacy effects on streams and rivers and restored riparian zones may not serve the same ecosystem function as the original habitat (Wohl & Merritts, 2007).

Many streams have been channelized, diverted, and confined through the construction of dikes, levees, berms, revetments, embankments, and other structures. Channelization (and often its associated bank armoring) is used 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 wildlife. Channelization results in simplification of the stream and has resulted in changes in flow, velocity, temperature, and movement of water (Tarplee, Louder, & Weber, 1971; Bolton & Shellberg, 2001). Channelization also degrades and fragments migratory corridors, eliminates historical foraging, migration, and overwintering habitats (Bolton & Shellberg, 2001), and changes songbird and small mammal communities (Possardt & Dodge, 1978).

<u>Barriers to Fish Movement</u>

Water management structures (i.e., dams, dikes, levees) are often used for flood control, conversion of wetlands to agriculture, bank protection, water supply needs, power generation, recreation, or other/urban development and can reduce connectivity among and within watersheds. By 2024, 600,000 miles of river in the United States (conservatively, 17%) have been modified by over 75,000 large dams (IWSRCC, 2024). Dams serve as a barrier to fish passage (Limburg & Waldman, 2009) and delay or block passage of anadromous fish to upstream reaches. The ability of anadromous fish to access areas above man-made barriers is important for the survival of individuals and populations of the species and for the integrity of the ecosystems they support (Cederholm, et al., 2000). Fish movement is also extremely important to the survival of many freshwater mussel species who rely on fish hosts for their reproductive strategy (Haag, 2012). Barriers to fish passage also contribute to fragmented mussel populations. Staging and spawning adult fish are prey for upstream aquatic and terrestrial predators. 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 (Doughty, Roman, Faurby, & and Svenning, 2015; Mattocks, Hall, & and Jordaan, 2017).

Controlled flow from a dam often slows river movement 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 affects water quality, temperature, and material transport (e.g., sediments, nutrients, and large woody debris). Reservoirs fill with sediment and less sediment reaches downstream deltas and estuaries. For example, in a press release about the Iron Gate Dam drawdown, the Klamath River Renewal Corporation mentioned that 17-20 million cubic yards of sediment has been trapped behind three dams slated for removal (Brownell, 2024).

Many projects aimed to mitigate or minimize effects of past or present dams or reservoirs on downstream habitats exist across the country (USFWS, 2022; NRCS, 2023; NOAA, 2023). Fish ladders were added to some waterways to aid in fish passage, but some life stages of fish still cannot get through. Over 1,200 dams were removed across the United States by 2017, according to Bellmore, et al. (2017). Few studies have assessed changes to habitat or ecosystem biodiversity after dam removal (Bellmore, et al., 2017), but some non-native species (i.e., Asian carp (Cyprinidae) and lampreys (Petromyzontidae)) benefit from dam removal and use of fish ladders. Fish ladders also encourage congregation, which facilitates disease spread and resource competition. In some locations, dams are being used intentionally to limit movement of an unwanted or invasive fish species from affecting target species, like trout, chubs, and salmon (McLaughlin, et al., 2013). In addition, when dams are removed, trapped sediment (often millions of cubic yards of sediment) runs downstream (Brownell, 2024) and can change waterflow and cause turbidity.

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

Estuaries

Estuaries are some of the most productive ecosystems in the world (Correll, 1978) and they include salt marshes, mangrove forests, mud flats, tidal streams, rocky intertidal shores, reefs, and barrier beaches. Estuaries are home to thousands of species of birds, mammals, fish, and other wildlife in the United States. Salt marshes filter pollutants that flow through it and trap nutrients, which explains why salt marshes serve as nursery and breeding grounds for many wildlife species. Estuaries and associated wetlands also stabilize shorelines and protect nearby coastal and inland areas from flooding and other storm damage (NOAA, 2024). Many animals, including most commercially important fish (e.g., salmon, sturgeon), sea turtles, and waterbirds, depend on estuaries for nursery, rearing, foraging, or migration habitat.

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 reduced the tidal prism, reduced freshwater inflows, change sediment flows, and eliminated emergent and forested wetlands and floodplain habitats. Dikes may have marked effects on tidal channel biota, specifically on the seaward side of the structure, and their construction may result in decreased sinuosity and complexity, fpreventing energy dissipation during flood events in some places (Hood, 2004). 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. Diking, filling, and dredging has: 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 estuarine areas to stochastic events (e.g., hurricanes) (Johnston, 1981; Nightingale & Simenstad, 2001).

The Estuary Restoration Act of 2000 was developed to address wetland loss and damage from human activities, and the U.S. Army Corps of Engineers (USACE) received funding for project implementation across the country. For example, Florida has had two large restoration projects underway to address environmental problems caused by dikes. The first is the Kissimmee River Restoration Program authorized by Congress and initiated in 1992. In July 2021, the South Florida Water Management District and USACE Jacksonville District completed the project's construction. Overall, they restored >40 mi^2 of the river floodplain, 20,000 ac of wetlands, and 44 mi of historic river channels (SFWMD, 2021). The second is the Comprehensive Everglades Restoration Plan, which was authorized by Congress in 2000 to "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). 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 America 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 is ongoing (NPS, 2022). Mitigation of losses of estuarine marsh in the mid-Atlantic and Gulf of America 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).

In Washington, restoration efforts 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). Other similar restoration work has occurred across the country (USACE, 2013).

Shorelines

Significant shoreline development and urbanization has occurred throughout the action area. Habitats at risk from shoreline alteration include riparian buffers, freshwater habitats (e.g., streams, lakes), and shallow subtidal, intertidal, and shoreline habitats known collectively as the "marine nearshore." Submerged aquatic vegetation (i.e., seagrass beds) on the Pacific and

Atlantic coasts grow in the intertidal zone and in mud and sand in the shallow sub-tidal zone. Turtle grass, shoal grass, manatee grass, and wigeon grass occupy similar ecological niches in the northern estuaries of the Gulf of America. Many of these areas house migratory shorebirds and waterbirds, spawning and rearing salmonids, shellfish reefs, and other sensitive wildlife (Duke & Krucynski, 1992).

Portions of nearshore and shoreline habitats 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 (i.e., docks, harbors) for vessels (BMSL et al. , 2001; Prosser, et al., 2017). Depending on placement and other shoreline characteristics, shoreline armoring can interrupt the natural inputs of sand from landward bluffs and result in sediment deficits within the landscape (Prosser, et al., 2017). Docks, bulkheads, and other shoreline developments likely contribute to the reduction in submerged aquatic vegetation and other spawning and rearing areas for forage fish. For example, losses of sensitive and highly productive submerged aquatic vegetation habitats were estimated between 20-100% in northern estuaries of the Gulf of America (Handley, Altsman, & Demay, 2007). In many cases, submerged aquatic vegetation serves as an indicator of lake or shoreline health and die offs result from decreases in water quality or contamination (Moorman, Augspurger, Stanton, & Smith, 2017) from development on or near the shoreline.

Clean Water Act

Several laws and regulations have been put in place to help improve the state of our aquatic resources, the principal one being the Clean Water Act (CWA). The original 1948 statute was re-written in 1972 and defined its current purpose: "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Federal Water Pollution Control Act, Public Law 92–500). Congress made substantial amendments to the CWA in the Water Quality Act of 1987 (P.L. 100-4) in response to significant and persistent water quality problems.

To achieve its objectives, the CWA generally prohibits all point source discharges into waters of the United States (as defined in 40 CFR 120.2[16]), unless otherwise authorized under the CWA. One of the main ways that point source discharges are regulated is through permits issued under the National Pollutant Discharge Elimination System (NPDES) authorized under the CWA. For example, the NPDES program regulates discharges of pollutants like bacteria, oxygen-consuming materials, and toxic pollutants like heavy metals, pesticides, and other organic chemicals. EPA has also promulgated regulations setting effluent limitations guidelines and standards under CWA sections 301, 304, and 306 for more than 50 industries [40 CFR Parts 405 through 471]. These effluent limitations guidelines and standards for categories of industrial dischargers are based on pollutants of concern discharged by industry; the degree of control that can be attained using pollution control technology; consideration of various economic tests appropriate to each level of control; and other factors identified in sections 304 and 306 of the CWA (such as non-water quality environmental impacts including energy impacts) (76 FR 22174-22288). These effluent limitations have been credited for helping reduce the amount of

[16] See https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-120/section-120.2.

pollutants like toxic metals entering the aquatic environment (Smail, Webb, Franks, Bruland, & Sañudo-Wilhelmy, 2012). While provisions of the CWA have helped significantly improve the quality of aquatic ecosystems, nonpoint sources of water pollution, which are believed to be responsible for most of modern water quality problems in the United States, are not subject to CWA permits or regulatory requirements. Instead, nonpoint sources of pollution are regulated by programs overseen by the states.

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 increased over the past several decades 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, 2005). Invasive species are considered a contributing factor in the decline of half 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 of invasive species is even greater.

An estimated 50,000 or more non-native terrestrial and aquatic species are believed to have been introduced into the United States across its history. Non-native mammals include dogs, cats, horses, sheep, pigs, goats, deer, and rodents. About half of these species are plants, 5,000 of which were introduced to the United States as food or ornamental plants and have since escaped and established on their own. In some cases, non-native plants are capable of completely dominating new habitats, forming dense monocultures, and completely excluding other native plants (Pimentel, Zuniga, & Morrison, 2005). In addition, invasive plants can accelerate carbon cycling, alter hydrologic cycles, reduce sunlight penetration in aquatic habitats, and change nutrient cycles (Poland, et al., 2021). Approximately 97 non-native birds exist in the United States with self-sustaining populations, 56% of which are considered pest species. Many non-native birds compete with or displace native birds, and they are vectors for avian diseases. Some invasive birds were released intentionally as biocontrol agents (e.g., common myna [*Acridotheres tristis*] to control cutworms and armyworms in sugarcane in HI and house sparrows [*Passer domesticus*] to control canker worms). About half (35/69) of the non-native birds introduced to HI between 1850-1984 remain on the islands. As of 2005, 138 non-native fish were introduced into the United States and at least 44 native fish species are threatened or endangered because of invasive fish. Approximately 53 species of reptiles and amphibians have been introduced to the United States and they often prey upon native species. More than 4,600 non-native invertebrate species are found in the United States, some of which are well known for vast ecological impacts (e.g., balsam woolly adelgid [*Adelges piceae*], red imported fire ant [*Solenopsis invicta*], and European green crab [*Carcinus maenas*]), including the decline or extirpation of native species (Pimentel, Zuniga, & Morrison, 2005).

Once an invasive species is established, management strategies available include prevention of further spread, early detection, eradication, control, and adaptation. Prevention includes actions like ship inspections and eradication at entry ports before it is brought into the location. If a species is missed during prevention efforts, it can be detected early and potentially eradicated, particularly if there are only a few individuals or a small population. Control includes efforts to limit the growth and spread of an established species or population (e.g., physical barriers). Adaptation can include use of pesticides on the invasive species or harvest of the species. The optimal choice for managing invasive species varies with the species of concern, environment affected, and policy and fiscal considerations (Marbuah, Gren, & McKie, 2014; Espanchin-Niell, 2017). The Lacey Act of 1900 is a tool used to limit transportation of "injurious" wildlife. In 1996, the United States amended the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 to include the National Invasive Species Act of 1996, which aims to prevent introductions and spread of invasive aquatic species in the Great Lakes through ballast water.

Collection and Harvesting

Some ESA-listed species, such as salmonids and freshwater mussels, are economically important species that are harvested as food. Harvesting and exploitation, often associated with the pearl industry, is identified as a contributing factor to 18% 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 because harvest requires a permit issued by the Service, and permits are 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 harvest is still likely occur to some degree, it rarely affects species substantially now, and it is not expected to greatly affect currently listed species in the action area in the future.

Climate Change

All species discussed in this Opinion are or may be threatened by the effects of global climate change. The Intergovernmental Panel on Climate Change (IPCC) estimated 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 between 0.3-0.7 degrees Celsius during the next 20 years. The IPCC observed global mean surface temperature for the decade 2006-2015 was 0.87 °C higher (likely between 0.75°C and 0.99°C) than the average between 1850-1900 (IPCC, 2018). This temperature increase is greater than what would be expected by natural climate variability alone, considering recorded temperatures over the past 1,000 years (Crowley & Berner, 2001). Increasing atmospheric temperatures have contributed to changes in the quality of freshwater, coastal, and marine ecosystems and the decline of populations of endangered and threatened species (Mantua, Hare, Zhang, Wallace, & Francis, 1997; Karl, Melillo, & Peterson, 2009; Littell, Elsner, Whitely-Binder, & Snover, 2009).

Climate change is also anticipated to impact the timing and intensity of seasonal stream flows (Staudinger, et al., 2012). Warmer atmospheric temperatures are expected to reduce snow accumulation, increase winter stream flows, cause spring snowmelt to occur earlier in the year, and reduce 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). Changes in stream flow due to use changes in 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 temperatures may also increase water use for agriculture, both for existing fields and the establishment of new ones in once unprofitable areas (ISAB, 2007). If agriculture requires more water, streams, rivers, and lakes will experience additional water withdrawals and potentially higher contaminant loads from returning effluent.

Warmer global air temperatures are causing rapid melting of sea ice and global sea level rise. Between 1880 and the 2010s, global mean sea level increased between 21-24 cm, the fastest rate of sea level rise over the last 2,800 years. Higher sea levels worsen effects of coastal storms, storm surge, tidal flooding, and waves. Climate change is also anticipated to increase storm frequency and intensity, which would exacerbate these concerns. Wave action, beach inundation, marsh flooding, and general sea level rise affect coastal habitats and wildlife, including geomorphology and sediment cycling, and modify the future flood risk profile of communities and ecosystems (Sweet, et al., 2017).

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 United States (Harley, 2011) and shifts in migration timing of pink salmon (*Oncorhynchus gorbuscha*), which may lead to high pre-spawning mortality (Taylor J. A., 2008). In Yellowstone National Park, climate warming resulted in wetland desiccation and declines in four amphibian species (McMenamin, Hadly, & Wright, 2008). Warmer water also stimulates biological processes that 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). Effects of aquatic nuisance species invasions are also likely to increase as ecosystems become less resilient to disturbances (USEPA, 2008). Invasive species that are better adapted to warmer water temperatures could outcompete native species that are physiologically adapted to lower water temperatures; such a situation already occurs along central and northern California (Lockwood & Somero, 2011).

Other effects of climate change include decreases in sea ice, changes in sea surface temperatures, alterations in precipitation patterns, rises in sea level, and increased success of non-native, invasive, and pathogenic species. Biota may be forced to respond to climate-induced changes in their environment like 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; McElwee, et al., 2023).

The EPA has several programs and standards in place to help combat greenhouse gas emissions, and thereby combat climate change. In 2005, EPA created the Renewable Fuel Standard, which requires all fuels sold in the United States to contain a certain amount of renewable fuels to offset petroleum-based fossil fuels and reduce greenhouse gas emissions (USEPA, 2023). EPA implements a carbon dioxide emission standard for commercial and large business aviation and a greenhouse gas emissions standard for passenger cars and light trucks for model years 2023-

2026. The passenger standards are estimated to save over 3 billion tons of greenhouse gases up to 2050 (USEPA, 2024f).

Change of Ecosystem Function and Biodiversity Loss

The environmental and habitat changes discussed in the previous sections affect ecosystem function and biodiversity. Biodiversity, the variety of life in a community often measured in number of species and equity of those species (i.e., richness and evenness, respectively), has been declining globally and in the United States for decades. Many aspects of biodiversity and its effects on ecosystem function that are unknown, but evidence supports that communities with higher biodiversity in terrestrial, aquatic, and marine ecosystems are more productive than monocultures in the same environments. Productivity comes from optimal use of limited resources, lower incidence of disease and herbivory, and higher nutrient stores and more nutrient-cycling feedbacks. Communities with higher biodiversity are more resistant to non-native species invasions because few resources are unconsumed and available for invaders. Highly diverse communities have a greater bacteria diversity, which makes them more resistant to some pathogens (Tilman, Isbell, & Cowles, 2014). Climate change and drivers of climate change exacerbate biodiversity loss across taxa and regions (McElwee, et al., 2023).

Insect Pollinator Decline

Of particular concern to national pesticide consultations is the documented insect pollinator decline that has occurred over the last several decades. Insects have been experiencing a worldwide decline in biomass, abundance, and diversity with potentially negative implications for plant pollination. 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). Consequences of insect declines could impact ecosystems by reducing services like pollination and seed dispersal (Dornelas & Daskalova, 2020). By 2010, there were already 54 studies covering 89 plant species that showed the most frequent proximate cause of reproductive impairment of wild plant populations in fragmented habitats was pollination limitation (Potts S. G., et al., 2010). The scope of global and national pollinator decline has been evaluated in numerous studies and we summarized a few here. Over the last 10-30 years, many pollinators are at risk of extinction, and they have shifted or contracted their ranges due to several factors, including habitat loss, environmental changes, competition with invasive or non-native species, and potentially other reasons (McElwee, et al., 2023).

In Illinois, Burkle (2013) used historic data sets to determine the degree of change over 120 years in a temperate forest understory community. 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. More specialist pollinators were lost then generalists, even though their host plants were still present. Bees that were specialists, parasites, cavity-nesters, and those that participated in weak historic interactions were more likely to be extirpated. Bee species richness visiting forb *C. virginica* did not change between 1891 and 1971, but it declined by over half in the following 40 years, likely due to changes in forested habitat during that time (Burkle, 2013). Also in Illinois, Marlin & LaBerge (2001) found 140 bee species in 1970–1972, implying a 32% reduction in biodiversity compared to historical records from the same location 75 years earlier. Only 59 of the 73 prairie-inhabiting bees and 15 of the 27 forest-dwelling bees were found (Marlin & LaBerge, 2001). Another study evaluated changes in the distribution of six bumblebee species by comparing historical records with intensive surveys across 382 locations in the United States. 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, only 5 of the 10 species of bumblebees that were present in 1949 were found in 2013 after extensive surveys across 21 counties. Additionally, the species *B. variabilis* was presumed extinct (Figueroa & Bergey, 2015).

In southern Ontario, bumblebee community composition was compared between 2004–2006 and 1971–1973 at the same sites and this formerly bumblebee diverse region of eastern North America underwent declines in bumblebee species richness, diversity, and relative abundance between these two time periods. Between 1971–1973, 14 bumblebee species were found and between 2004–2006, 11 species were found. Fourteen species found between 1971–1973 were either absent or decreasing in relative abundance between 2004-2006. For example, the rusty patched bumblebee (*B. affinis*) was previously widespread and common but underwent drastic decline and has likely been extirpated throughout much of its range. It was not found during the 2004–2006 surveys. No new species were identified (Colla & Packer, 2008).

GENERAL EFFECTS

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 but that are not part of the 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 review of carbaryl on listed resources under the Service's purview is presented first by discussing the effects of carbaryl to different taxa groups in the *General Effects* section. The *General Effects* section of this Opinion is divided into several sections and subsections. First, we briefly summarize the anticipated toxicological effects related to the proposed action, including the anticipated general pathways of exposure to listed species taxa groups and their designated critical habitat. Next, in the *Exposure* and *Usage Analysis* sections, we describe specific aspects of carbaryl (e.g., chemical properties, applications rates, routes of exposure), its use and usage on the landscape, and how it will impact species and critical habitats based on these properties. We describe those factors that influence exposure and effects 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 carbaryl use. We included taxa-specific information that brought meaningful information to the analysis wherever possible.

Toxicological Effects

As described in the BE, carbaryl is an N-methylcarbamate insecticide. N-methylcarbamate insecticides act by inhibiting acetylcholinesterase, thereby reducing the degradation of the cholinergic neurotransmitter acetylcholine. As a result, inter-synaptic concentrations of acetylcholine increase as the neurotransmitter accumulates, leading to increased firing of the postsynaptic neurons. This may ultimately lead to convulsions, paralysis, and death of an organism exposed to the chemical. Acetylcholinesterase inhibition is rapidly reversed once exposure to an N-methylcarbamate insecticide has ended. Carbaryl is also used as a plant growth regulator to thin blossoms in orchards. Carbaryl's activity in the abscission of flower buds may be related to its structural similarity to plant auxins, such as α-naphthalene acetic acid. Carbamate 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 (i.e., how a substance produces an effect in an organism) is generally present in animal taxonomic groups (i.e., fish, mammals, birds, amphibians, reptiles, and invertebrates all possess AChE and are subject to the effects of carbaryl). Plants also have AChE; however, its mechanism of action is not clearly understood. Figure 7 depicts the Adverse Outcome Pathway for animals exposed to both organophosphates and carbamates as the metabolic pathway is highly conserved for both chemical families.

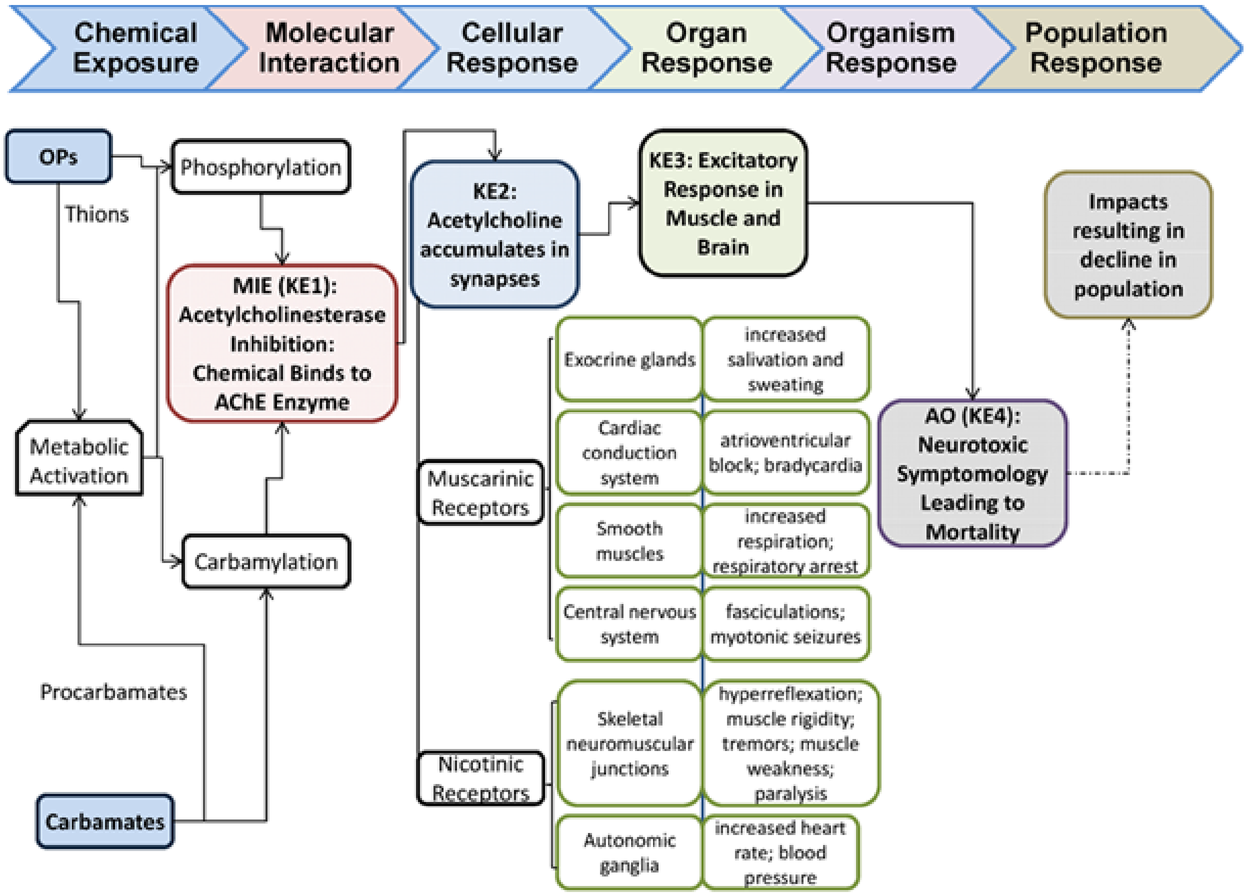

Figure 7. Adverse Outcome Pathway for Acetylcholinesterase Inhibition (the figure is from (Russom, LaLone, Villeneuve, & Ankley, 2014)).

Effects by Taxa

The effects of carbaryl have been studied extensively in many taxa, particularly in fish, birds, 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 carbaryl. 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 most other metabolites of carbaryl is not warranted because they are not believed to be of toxicological concern (i.e., 1-naphthol, 1, 4 napthoquinone, and CO_2). Available toxicity data for the primary metabolite of carbaryl, 1-naphthol, was reviewed and compared to toxicity data for the parent compound. Available acute and chronic fish data for 1-naphthol is within the range of known EC_{50}/LC_{50} and NOEC values for carbaryl and fish. The same also holds true when comparing available aquatic invertebrate data for carbaryl and 1-naphthol. In studies where comparisons were made between technical carbaryl and 1-naphthol, the metabolite appears to be slightly more toxic but still within the same order of magnitude. (Rao, Murty, & Swarup, 1984) reported that the 96-hour LC_{50} for technical grade carbaryl was 5.9 mg/L while the comparative value for 1-naphthol was 1.46 when using the fish *Cirrhinus mrigala*. (Tilak, Rao, Devi, & Murty, 1981) demonstrated that the acute fish toxicity of formulated carbaryl was less toxic than the metabolite 1-naphthol. Calculated 96-hr LC_{50} values of carbaryl for *Catla catla*, *Anabas testudinens*, *Mystus casius,* and *M. vittatus* were 6.4, 6.6, 4.6, and 2.4 mg/L, respectively, compared to 1-naphthol toxicity values which were 4.3, 3, 0.33 and 1.0 mg/L, respectively. (Shea & Berry, 1983) also reported higher comparative toxicity of 1-napthol to technical grade carbaryl; however, no toxicity values were reported. In addition, 1-napthol does not inhibit acetylcholinesterase and its toxic mode of action for animals is thought to be narcosis (Russom, Bradbury, Broderius, Hammermeister, & Drummond, 1997). In aquatic organisms, narcosis is a reversible anesthetic effect that is caused by chemicals partitioning into cell membranes and nervous tissue that result in disruption of cell functions including central nervous system function (Barron, Hansen, & Lipton, 2001).

Laboratory tests are extrapolated to responses expected to occur in organisms exposed in the field, with the recognition that these types of studies are limited in their ability to recreate natural settings and exposure routes. 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 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 those which have been identified in lab studies and that may be attributable to the presence of other stressors (e.g., increased or decreased predation).

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 in this Opinion were divided into ten taxonomic group (i.e., mammals, birds, fish, reptiles, amphibians, aquatic insects, crustaceans, mollusks, terrestrial insects, and plants), which are somewhat similar to those groups 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[17], including mortality, growth, and reproduction) at predicted exposures. Where these analyses have already been performed in the BE, they have been directly carried over.

For each taxonomic group, we selected endpoints for mortality and their accompanying slopes to ensure we captured the sensitivity of the species being assessed. Mortality endpoints include the median lethal dose (LD_{50}) (lethal dose that causes 50% mortality of test subjects), median lethal concentration (LC_{50}) (lethal concentration that causes 50% mortality of test subjects), and hazardous concentration (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, hazardous concentration 5th percentile (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 we 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.

For all taxonomic groups, we generally assessed 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 data do not exist to show that listed species are generally 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 impacts. 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.

We conducted a similar process for each sublethal response endpoint (i.e., growth, behavior, reproduction). 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 response endpoints,

[17] 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.

and the entire data array presented in the BE was used to determine the ultimate response endpoint used for that taxa group for the Opinion. For other taxonomic groups, few studies were available to describe effects for one or more response endpoint, and the magnitude of response was wholly based on those data. In other cases, no data were available to describe a response endpoint line of evidence. In these cases, effects were either extrapolated from data from another taxonomic group, or that response was not carried forward in the analysis, 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 Master Record Identifier (MRID) are studies submitted by registrants, and those that begin with "E" are from EPA's ecotoxicology database (ECOTOX). Full citations for these references can be found in EPA's BE.

General Effects to Terrestrial Vertebrates

Terrestrial species may be exposed to pesticides such as carbaryl through one or more routes of exposure, including ingestion, dermal absorption, or inhalation. We extrapolate results of laboratory studies to predict the likely effects of each type of exposure to listed species. However, the difficulty in recreating natural settings and exposure routes in the laboratory limits the relevance of these studies when assessing effects 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, most laboratory studies measure effects of toxicity from the ingestion route of exposure. Researchers provide test subjects with contaminated food (concentration based, for derivation of LC_{50} values) or administer a single dose through oral gavage or injection (dose-based, for derivation of LD_{50} values). Generally, only orally administered routes are considered to be environmentally relevant and directly comparable to estimated environmental concentrations, 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 the type of exposure route selected for toxicity testing (for derivation of LD_{50} values) to avoid potential regurgitation of the administered dose in certain cases (Lukas, Brindle, & Greengard, 1971). Both dietary endpoints (LC_{50} values) and dose-based endpoints (e.g., LD_{50} values) 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. 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. Highly mobile species 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 has not been fully digested nor on the surface of prey, but remains 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.

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 in assessing 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, we often have greater uncertainty in predicting effects than other taxonomic groups as there is no testing requirement under FIFRA for these taxa, data from the open literature are often lacking, and taxa-specific conversion factors are generally derived from a smaller breadth of species than for birds and mammals. Where taxa-specific data are lacking to predict effects to these species, we use toxicity data from birds to predict effects, as we consider amphibians and reptiles to be more closely related to birds than other broad taxa groups (such as mammals, arthropods, etc.). While there is notable uncertainty in this approach, we rely on the conservative nature of endpoint selection (e.g., most sensitive species, lowest endpoint, use of dose-based studies) to adequately capture the sensitivity of these taxa.

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. For these types of studies, we consider the nature and magnitude of effects at test concentrations as well as in the No Observed Adverse Effect Concentration (NOAEC). In some cases, effects may be observed at the concentration identified as the NOAEC, but they are not statistically different from controls due to test design and sensitivity. While we cannot assign these effects to the test substance in these cases, we can consider these observations in the larger context of the study. In all cases, it is important to consider effects that could occur in the span of concentrations between the NOAEC and the Lowest Observed Adverse Effect Concentration (LOAEC), especially when there are high effects at the LOAEC.

Effects to Birds

The data set for mortality to birds includes 5 references representing 23 endpoints and 9 species (canary, northern bobwhite quail, Japanese quail, California quail, ring-necked pheasant, mallard duck, sharp-tailed grouse, Canada goose, and chukar).

Mortality: Dose-based oral exposure

Available dose-based mortality data (LD_{50}, LOAEL and NR-LETH) are available for 8 species of birds (mallard duck, ring-necked pheasant, sharp-tailed grouse, Canada goose, chukar, Japanese quail, rock dove and California quail) with a reported mortality effect range (LD_{50}) from 707 to 3000 mg/kg-bw (Table 9**.** Given the small number of species studied, the EPA was not able to calculate a species sensitivity distribution.

EPA selected the LD_{50} reported from the Japanese quail (LD_{50} = 2290 mg/kg-bw) data as the acute oral toxicity threshold because of the study's relatively large sample size (n=24) and its use of 85% TGAI. Also, the confidence interval for the Japanese quail LD_{50} (1740 to 3020 mg/kg-bw) overlapped with the LD_{50} values for other species that had a lower reported LD_{50} value, but also had study deficiencies such as low numbers of tested birds and low percent AI. Based on the Japanese quail LD_{50} value, carbaryl is considered practically non-toxic (*i.e.,* $LD_{50} > 2000$ mg/kg-bw) to birds on a dose-based acute oral basis.

The endpoints considered for mortality are included in the tables below.

Table 9. Available Dose-Based Toxicity Data (oral) for Birds Exposed to Carbaryl.

Scientific Name	Common Name	LD_{50} or other endpoint (mg/kg-bw)	Duration (days)	MRID/ECOTOX ref #
Mortality				
Banta canadensis	Canada Goose	1790 CI: 1480 – 2180	14	E50386 (Hudson et al 1984)
Anas platyrhynchos	Mallard Duck	>2564	14	E50386
Tympanuchus phasianellus	Sharp-Tailed Grouse	<1000	14	E50386
Callipepla californica	California quail	>2000	14	E50386
Anas platyrhynchos	Mallard Duck	>2000	14	MRID 45820601
Alectoris chukar	Chukar	1888	14	E50386
Coturnix japonica	Japanese Quail	2290 CI: 1740 – 3020	14	E50386
Phasianus colchicus	Ring-Necked Pheasant	>2000	14	E50386
Phasianus colchicus	Ring-Necked Pheasant	707	14	E50386
Columba livia	Rock Dove	1000-3000	14	E50386
Other endpoints (mg/kg-bw)				
Anas platyrhynchos	Mallard Duck	LOAEL = 27.3	30	E50386
Phasianus colchicus	Ring-Necked Pheasant	LOAEL = 91.6	30	E50386
Phasianus colchicus	Ring-Necked Pheasant	NR-LETH= 261.7	14	E50386

NR = Not reported; NR-LETH = 100% mortality or 0% survival; no statistically derived endpoint reported.

Mortality: Dietary-based oral exposure

Available dietary based LC_{50} studies cover four species from two orders of birds (Galliformes and Anseriformes) (Table 10). Reported LC_{50} values range from >5,000-10,000 mg/kg-bw. The study reporting the most sensitive LC_{50} tested several avian species via dietary exposure in food at four dietary concentrations over eight days. Tests indicate that dietary-based LC_{50} values ranged from >5,000 to 10,000 mg/kg diet. Based on the lowest LC_{50} values, carbaryl is considered practically nontoxic to birds on a subacute dietary basis.

Based on the available mortality data, the acute LC_{50} for carbaryl is >5000 mg/kg diet for four species of birds (northern bobwhite quail, Japanese quail, ring-necked pheasant, and mallard) cited in two reports (E35243 and E35214). The birds were exposed to carbaryl in food at four dietary concentrations over 8 days (E35243 and E35214).

Table 10. Available Dietary-Based Mortality Data for Birds Exposed to Carbaryl.

Scientific Name	Common Name	LC_{50} (mg/kg-diet)	Duration (days)	MRID/ECOTOX ref #
Colinus virginianus	Northern Bobwhite Quail	> 5,000	8	E35243/E35214
Coturnix japnica	Japanese Quail	> 5,000	8	E35243/E35214
Phasianus colchicus	Ring-Necked Pheasant	> 5,000	8	E35243/E35214
Anas platyrhynchos	Mallard	> 5,000	8	E35243/E35214
Coturnix japonica	Japanese Quail	> 10,000	5	E50181

Growth

The data set for growth effects in birds has a range of reported growth effects from 243.8 to 1023 mg ai/kg diet. Based on a review of reliable studies, the most reliable endpoint is a NOAEL and LOAEL of 343 and 1023 mg/kg diet, respectively, based on a dose responsive 73% reduction in adult female weight gain, 8% reduction in 14-day old survivor body weight, and 7% reduction in hatchling weight; other reproductive effects were also noted (MRID 49312801). The calculated MATC is 592 mg/kg diet. There were no dose-based growth endpoints for carbaryl in avian species.

Newly submitted avian toxicity data are available for the passerine canary (*Serinus canaria*) exposed to technical grade active ingredient (99.2% ai) in which the LD_{50} was 783 mg ai/kg-bw and a NOAEL of 250 mg ai/kg-bw (MRID 49254901) was established. Partial regurgitation occurred in 20% of tested birds at the LOAEL of 500 mg ai/kg-bw. Since regurgitation was observed in the study, the LD_{50} is not considered an appropriate acute toxicity measurement endpoint; therefore, the NOAEL of 250 mg ai/kg-bw is used as the toxicity endpoint. Because regurgitation is linked to growth and mortality by limiting organism's nutrient intake, we use that endpoint was to derive carbaryl's sublethal threshold for growth.

<u>Reproduction</u>

The data set for avian reproductive effects includes 2 references representing 4 endpoints and 2 species. In the first (MRID 49312801) of the two studies, based upon treatment-related effects on various adult and reproductive endpoints at 1023 mg/kg diet, the overall NOAEC and LOAEC were 343 and 1023 mg a.i./kg diet, respectively. Specifically, at 1023 mg/kg diet, necropsy results indicated a treatment-related increase in the incidence of regressed ovaries, a 37% reduction ($p < 0.05$) in the number of eggs laid per hen, and a 6% reduction (not significant) in eggshell thickness. In the second study (E35124) there were no dose-based reproductive endpoints for carbaryl in avian species; the study appeared to be oral-based because the results were reported in ppm, but the type of dosing was not entirely clear.

Drinking water and Inhalation

No studies involving avian exposure via drinking water or inhalation were identified in registrant studies or the ECOTOX database.

Dermal

In one study, male and female Japanese quail were exposed to dusting at 160 mg/kg and 140 mg/kg, respectively (E50180, (Hill E. F., 1979)). No overt signs of toxicity were observed, but plasma cholinesterase activity was significantly reduced at both test levels.

<u>Incident Reports</u>

There are currently (as of March 22, 2017) 6 bird incident reports in the IDS with a certainty index of 'possible', 'probable' or 'highly probable'. Of these incidents, 1 is from a registered use, 1 is from a misuse (intentional), and in 4 of the incidents, the legality of use was undetermined (see Table 11 below and Attachment 2-2 in the BE for details). All of the bird incidents occurred in the United States. The following discussion only includes those incident reports with a certainty index of 'possible', 'probable' or 'highly probable' and a legality classification of 'registered' and 'undetermined' (the incident that was caused by a misuse is not reported further). For more information on incidents see Attachment 2-2 in the BE.

The dates of the incident reports range from 1991 to 2001 (Table 11). The bird incident reports involve a variety of different kinds of birds (*e.g.*, songbirds, doves, and ducks). In four of the known incidents, the use site is not reported or is unknown. Three incidents do report the following use sites: shrubbery (1); residential turf (1); and garden (1). The carbaryl product involved in the incidents is not reported in 5 of the incidents; the product is reported as 'Liquid Seven,' a liquid product, in one incident (I000799-003). However, carbaryl was not identified by residue analysis of tissue and six other active ingredients were reported as used recently in the environment, therefore, it is unlikely that carbaryl was responsible for the event. Since carbaryl was reported as recently used in the area it is possible that it contributed in some way to the observed mortalities. Another incident (I018734-001) where the product was reported as 'Bug-Geta Plus,' a granular product, also involved metaldehyde; carbaryl poisoning was claimed to be the cause of death, but no diagnostic report was provided. In one incident (I020380-001), carbofuran was also present and was considered the primary cause of the incident because of its high toxicity to birds. Another incident (I004375-004) involved diazinon and lindane as well as carbaryl; diazinon was present at the highest concentration in the birds and the latter two were found in minor amounts. Incident I007720-020 involved both carbaryl and bendiocarb in unspecified concentrations, with both chemicals likely responsible for the mortalities. In two of the seven incident reports (I002048-001 and I012817-001), carbaryl was the only pesticide noted in the report (Table 11).

Table 11. Summary of reported bird incidents involving carbaryl provided by the EPA.

<table>
<tr><th>Incident Number</th><th>Year</th><th>State</th><th>Product</th><th>Legality</th><th>Certainty Index</th><th>Use Site</th><th>Species</th><th>Distance</th><th># Affected</th><th>Magnitude</th></tr>
<tr><td rowspan="4">I000799-003</td><td rowspan="4">1991</td><td rowspan="4">NC</td><td rowspan="4">Liquid Seven</td><td rowspan="4">U</td><td rowspan="4">Possible</td><td rowspan="4">Shrubbery</td><td rowspan="4">Duck
Turkey
Cardinal
Blackbird</td><td>VICINITY</td><td>NR</td><td>HUNDREDS</td></tr>
<tr><td>VICINITY</td><td>NR</td><td>UNKNOWN</td></tr>
<tr><td>VICINITY</td><td>NR</td><td>UNKNOWN</td></tr>
<tr><td>VICINITY</td><td>NR</td><td>UNKNOWN</td></tr>
<tr><td rowspan="2">I002048-001</td><td rowspan="2">1995</td><td rowspan="2">VA</td><td rowspan="2">NR</td><td rowspan="2">U</td><td rowspan="2">Possible</td><td rowspan="2">NR</td><td>Grackle</td><td>NR</td><td>1</td><td>NR</td></tr>
<tr><td>Starling</td><td>NR</td><td>5</td><td>NR</td></tr>
<tr><td rowspan="2">I007720-020</td><td rowspan="2">1997</td><td rowspan="2">NJ</td><td rowspan="2">NR</td><td rowspan="2">U</td><td rowspan="2">Probable</td><td rowspan="2">Turf, residential</td><td>Mallard</td><td>VICINITY</td><td>10</td><td>NR</td></tr>
<tr><td>Duck</td><td>VICINITY</td><td>10</td><td>NR</td></tr>
<tr><td>I012817-001</td><td>2001</td><td>NY</td><td>NR</td><td>U</td><td>Highly Probable</td><td>NR</td><td>Mourning Dove</td><td>NR</td><td>1</td><td>NR</td></tr>
<tr><td>I018734-001</td><td>1999</td><td>FL</td><td>Bug-Geta Plus</td><td>R</td><td>Probable</td><td>Garden</td><td>Ringneck Dove</td><td>Vicinity</td><td>7</td><td>NR</td></tr>
</table>

NR = Not reported; U = undetermined; R = registered use

In addition to the terrestrial incident reports available in IDS, there have also been a total of 18 aggregate wildlife incidents reported to EPA (see Table 12).

Table 12. Aggregate Wildlife Incidents for Carbaryl.

PC Code	Ingredient Name	Sum	WB	ONT
056801	Carbaryl	51	16	9
056801	Carbaryl	154	2	3

WB = Wildlife - minor; PB = Plant damage – minor; ONT = Other nontarget

Since 1998, incidents that are allowed to be reported aggregately by registrants [under FIFRA 6(a)(2)] include those that are associated with an alleged effect to wildlife (birds, mammals, or fish) without differentiation between species or terrestrial and aquatic environments. Typically, the only information available for aggregate incidents is the date (*i.e*., the quarter) that the incident(s) occurred, the number of aggregate incidents that occurred in the quarter, and the PC code of the pesticide and the registration number of the product involved in the incident. Because of the limited amount of data available on aggregate incidents it is not possible to assign certainty indices or legality of use classifications to the specific incidents. Therefore, the incidents associated with currently registered products are assumed to be from registered uses unless additional information becomes available to support a change in that assumption.

Effects to Reptiles

No toxicity data are available for reptiles exposed to carbaryl. The available toxicity data and thresholds for birds are used as a surrogate for reptiles. There is notable uncertainty in using birds as surrogates for reptiles as it is assumed that they will have similar responses to carbaryl.

Effects to Terrestrial Amphibians

There are limited toxicity data available for terrestrial-phase amphibians exposed to carbaryl. There is only one endpoint available for terrestrial amphibians in a relevant exposure unit, namely an LD_{50} of >4,000 mg/kg (oral exposure) for bullfrogs (*Rana catesbeiana*; E50386); only three bullfrogs were tested in the study and a 50% purity product was used as the test item. Therefore, we instead used the available toxicity data and thresholds for birds as a surrogate for amphibians. There is notable uncertainty in using birds as surrogates for amphibians, but it is assumed that they will have similar responses to carbaryl.

Effects to Mammals

The effects of carbaryl on mammals have been studied extensively. The EPA excluded mammalian studies if they were considered invalid or not associated with an environmentally relevant exposure route. Acute toxicity data were only available for two species within the order Rodentia, thereby preventing calculation of a species sensitivity distribution. As such, thresholds are based on the most sensitive lethal and sublethal effects identified among registrant-submitted studies and open literature in the ECOTOX database.

Mortality: Dose-based oral exposure

Based on the available data for mortality studies, the most sensitive LD_{50} for carbaryl is 104.3 mg ai/kg-bw (as tested body weight, females; slope 7.7) in the CD-1 strain of European house mouse (*Mus musculus*), which translates to 112.1 mg /kg-bw when scaled to a 15g mammal (Table 13). Mice were exposed to 99.9% carbaryl in distilled water at 25, 50, 75 and 100 mg/kg-bw (E64571). This endpoint is used to derive the thresholds for mammals.

Table 13. Available carbaryl mortality data in mammals.

Scientific Name	Common Name	LD_{50} (mg a.i./kg-bw)	Duration (days)	Reference
Mus musculus	European house mouse	112.1 (scaled to 15 g mammal)	7	E64571
Rattus norvegicus and Cavia porcellus	Brown rat	NA	25	E39323
Mus musculus	European house mouse		10	E87557
Rattus norvegicus and Cavia porcellus	Brown rat and Guinea pig	100 (rat)/300 (Guinea pig)	243	E39322
Rattus norvegicus and Meriones unguiculatus	*Brown rat and gerbil*	NR	21	E35102

NA = not applicable; NR = not reported

Growth

Endpoints range from 4 mg/kg-bw (NOAEL based on body weight reductions) to 21,978 mg/kg-bw (NOAEL based on decrease in total weight). Two developmental studies with rats (exposed Day 6 through Day 20; MRID 44732901) and rabbits (exposed Day 6 through Day 29; MRID 44904202) were submitted by the registrants, yielding NOAEL values of 4 and 50 mg/kg/day, respectively, on the basis of body weight reductions. The reported growth endpoints are displayed in Table 14.

Table 14. Selected data on sublethal effects to growth from carbaryl in mammals.

Scientific Name	Common Name	NOAEL (mg/kg-bw)	LOAEL (mg/kg-bw)	Observed Effect	Duration (days)	Reference
Rattus norvegicus and Meriones unguiculatus	*Brown rat and gerbil*	NR (rat) and 2,000 (gerbil)	2,000 (rat) and 6,000 (gerbil)	Decrease in litter size in rat and gerbil. In rats, effects seen in all generations at 5,000 ppm and in 2 of the generations at 10,000 ppm. For gerbils: decreases in weaning index at 10,000 ppm and some evidence at 6,000 ppm	21	E35102
Rattus norvegicus	Brown rat	4	30	7-8% decrease in fetal body weight, 7% decrease in maternal body weight	6-20	MRID 44732901
Oryctolagus cuniculus	New Zealand white rabbit	50	NR	decrease in total weight	6-29	MRID 44904202

NR = not reported

Reproduction

Reproduction endpoints range from a NOAEL of 75 ppm based on decreased pup survival, reduced body weights and feeding consumption in F_0 parents, to a NOAEL of 2000 mg /kg-bw in a multi-generation reproduction study (highest dose tested, fertility measures in second generation). Registrant submitted data includes a rat reproduction study with decreased survival of F_2 pups, leading to a NOAEL of 75 ppm (MRID 45448101). All reported reproductive effects endpoints are displayed in Table 15.

Table 15. Selected data on sublethal effects to reproduction from carbaryl in mammals.

Scientific Name	Common Name	NOAEL	LOAEL	Observed Effect	Duration (days)	Reference
Rattus norvegicus	Brown rat	75, 300, ≥ 1500 ppm	1500, -, 300 ppm	F_0: decreased body weight gain and feed consumption. F_0, F_1, F_2: no reproductive toxicity observed F_1 and F_2: reduced pup survival, reduced body weights, sexual maturation delayed (F_1)	**70**	MRID 45448101
Rattus norvegicus *Cavia porcellus*	Brown rat Guinea pig	NR	NR	Brown rat: Reduced litter size, reduced survival of offspring, pup abnormalities, Guinea pig: reduced body weight gain, fetal abnormalities,	330	E39322
Mus musculus	Swiss albino mice	NR	150 mg/kg-bw	Reduced weight gain in dams, increased mortality in dams, reduced litter size, resorbed fetuses	18	E87868
Oryctolagus cuniculus *Mus musculus*	New Zealand white rabbit European house mouse	NR NR	200 mg/kg/day 150 mg/kg/day	Rabbits: offspring abnormalities, decrease in fetal body weight Mice: maternal mortality, decreased maternal body weight gain,	18 18	E87557

Scientific Name	Common Name	NOAEL	LOAEL	Observed Effect	Duration (days)	Reference
Rattus norvegicus *Meriones unguiculatus*	Brown rat gerbil	NR (rat) 2,000 (gerbil)	2,000 (rat) 6,000 (gerbil)	Decrease in litter size in rat and gerbil. In rats, effects seen in all generations at 5,000 ppm and in 2 of the generations at 10,000 ppm. For gerbils: decreases in weaning index at 10,000 ppm and some evidence at 6,000 ppm	21	E35102

NR = not reported

Drinking water

No studies involving mammalian exposure via drinking water were identified in the ECOTOX database or in review of registrant submitted studies.

Dermal

A 4-week dermal toxicity rat study with a NOAEL of 20 mg/kg/day was submitted by the registrants. The LOAEL of 50 mg/kg/day was based on significant decreases in RBC cholinesterase in males and females and brain cholinesterase in males. The long-term dermal (months to a lifetime) scenario relied on a chronic dog study that did not establish a NOAEL; the LOAEL of 3.1 mg/kg/day was based on plasma and brain cholinesterase inhibition in females.

Inhalation

There are two studies involving mammalian exposure via the inhalation route for carbaryl (Table 16). Together these studies indicate that the rat inhalation LC_{50} is between 3.4 and 5.3 mg/L.

Table 16. Mammalian Inhalation Studies for Carbaryl

Exposure Scenario	Dose (mg/kg/day)	Endpoint	Study
Acute inhalation-rat test model	LC_{50}>3.4 mg/L	Mortality	MRID 00148502
Acute inhalation-rat test model	2.1 mg/L<LC_{50}<5.3 mg/L	Mortality	MRID 41056804

Incident Reports

A review of the incident databases showed a total of 4 reported ecological incidents involving mammals associated with the use of carbaryl (Table 17). Carbaryl has been reported as the 'probable' or 'highly probable' causative agent for 2 terrestrial incidents involving mammals, one of which included a co-exposure with metaldehyde. All the incidents involved the use of carbaryl bait materials.

Table 17. Summary of reported mammal incidents involving carbaryl provided by the EPA.

Number	Chemical(s) Involved	Certainty Index	Use Site	Species	Distance	Effect/ Magnitude	Product
B0000501-88	Carbaryl	Highly Probable	Not reported	Mole	Not reported	1	Slug Bait
I018734-001	Carbaryl Metaldehyde	Probable	Garden	Squirrel Rat	Not reported	42	Slug Bait
I021276-014	Carbaryl	Possible	Home exterior	Cat	Not reported	1	Slug Bait
I024855-001	Carbaryl Metaldehyde	Possible	Residential	Dog	Not reported	2	Slug Bait

Effects to Terrestrial Invertebrates

The terrestrial invertebrates taxonomic group was designated in the BE and described as all invertebrates with a terrestrial lifecycle. The Service further divides the terrestrial invertebrates as a taxonomic group to be addressed in this Opinion based on available toxicity data into terrestrial insects and arachnids, a group which includes: all insects with a terrestrial or partial terrestrial lifecycle, spiders and their relatives. The other groups is the terrestrial snails. We more narrowly apply the terrestrial invertebrate data from the BE based on insect toxicity data to terrestrial insects and discuss toxicity data to terrestrial snails below using data specifically for terrestrial snails.

Carbaryl is an insecticide that acts through inhibition of acetylcholinesterase and is used to kill a broad range of insects and mites. As an insecticide, carbaryl's effects on terrestrial invertebrates have been well documented in the literature. Most available studies have focused on mortality endpoints, but there are also data available describing sublethal effects, including those related to growth, behavior, and reproduction. We did not pursue the sublethal effects studies for this Opinion at this time as endpoints were in units not easily comparable to concentrations listed species would encounter in the environment or mortality would be observed prior to any sublethal effects.

Mortality - Insects and Arachnids

Mortality is the most sensitive endpoint available for the different environmentally relevant exposure units for terrestrial invertebrates. 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 (mg/kg bw), microgram per organism (e.g., µg/bee or µg/larvae), milligram per kilogram soil (mg/kg soil), or microgram per gram dry food (µg/g diet).

Considering the wide breadth of taxonomic Orders within the terrestrial insect and arachnid category, assumptions were made 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 only terrestrial or partially terrestrial insects, and spiders and their relatives 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} (discussed in more detail below) to describe direct effects to terrestrial insects and arachnids.

Given that terrestrial insects are the target organism for the effects of carbaryl, species in this taxonomic group 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 available. The mortality toxicity data we used to assess the effects of carbaryl are provided below, along with a discussion of the available incident reports for carbaryl and terrestrial invertebrates as also described in the BE.

Mortality data associated with the exposure unit of mg/kg-bw are available for 9 orders (*i.e*., Coleoptera, Dictyoptera, Diptera, Hemiptera, Heteroptera, Hymenoptera, Lepidoptera, Neuroptera, and Orthoptera), represented by 45 families, 68 genera, and 71 species. Based on the available data, carbaryl is associated with mortality of terrestrial invertebrates at concentrations ranging from 0.11 to >10,000 mg/kg-bw.

For the exposure unit 'mg/kg-bw' the most sensitive endpoint available for terrestrial invertebrates is an LD_{50} value of 0.11 mg/kg-bw for skeletonizing leaf beetles (*Trirhabda adela*) (E157787). As part of a larger study to evaluate the function of mixed function oxidases in insect response to xenobiotics, including pesticides, the author exposed ~60 species of terrestrial invertebrates to carbaryl residues using a 24-hour contact exposure. Residues were applied to the dorsum of the thorax (mg/kg-bw endpoints) or to substrate (lbs/acre endpoints). Three to four treatment rates were used for each experiment to determine a variety of regression-based mortality endpoints, including LD_{50} values.

Mortality - Terrestrial Snails

For the toxicological analysis for terrestrial snails, we find the open literature data available on carbaryl exposure in terrestrial snails more appropriate to address the effects of carbaryl on terrestrial snails than the contact exposure study described above for the skeletonizing leaf beetle (*Trirhabda adela*). The exposure routes (contact and dietary) described in these studies are also a more appropriate means by which terrestrial snails could be exposed to carbaryl.

Several open literature studies for carbaryl assess exposure to terrestrial snails and slugs (Schuytema, Nebeker, & Griffis, 1994; Leomanni, et al., 2015; Judge, 1969; Ghamry, Kokab, & Willson, 1994). These data had various units of measurements for the endpoints studied (µM, mg/kg-bw, % bait, etc.). Despite the various endpoints, terrestrial snails were relatively tolerant of carbaryl exposure across these studies. While there are few studies to use for the terrestrial snail toxicity endpoint, we posit it is more appropriate than using carbaryl or related carbamate data from aquatic snails (we use carbamate data for aquatic snails; see discussion in the *Effects to Aquatic Invertebrates* section below). The route of exposure would be different for terrestrial snails (dietary for terrestrial snails) than for aquatic snails (contact) and the value used for aquatic snails is based on an SSD using all aquatic snail data combined with other aquatic mollusks. We also believe this endpoint is appropriate for terrestrial snails as it verifies that snails in general are not sensitive to carbaryl exposure and the endpoints for both terrestial and aquatic snails are within the same order of magnitude. We use the most sensitive 14-d LC_{50} value of >10 ppm from a study by (Schuytema, Nebeker, & Griffis, 1994) using the terrestrial brown garden snail species *Helix aspersa* exposed to a carbaryl amended diet.

Using this more appropriate surrogate species, we do not expect any mortality to occur, as even the highest estimated environmental concentrations are much lower than the LC_{50} reported in available studies for terrestrial snails. Effects to the food base (e.g., algae, plant leaves or roots, lichen, detritus) are likely to be minimal and impacts to the food base will not have a discernable effect at the species level.

Incident Reports

There are currently (as of December 23, 2019) 471 terrestrial invertebrate incident reports (non-aggregate) from North America in the Incident Data System (IDS). All incidents explicitly involve honey bees (*Apis mellifera*) or are assumed to involve honey bees because no other bee species was implicated. Most of the incidents (55) occurred between 1992 and 2000 (see Table 18), and for two of the incidents no year was reported. Most of the incident reports (52) come from Washington state, but there are also four each from Minnesota and North Carolina, and two each from California, Mississippi and Vermont. In most cases (57), the product involved in the incident is not reported; of the remaining 14 incidents in which the product is reported, 'Sevin' or 'Sevin XLR Plus' are listed. In most cases (60), the legality of the use involved in the incident is undetermined; five of the incidents are considered misuses (including one reported as an intentional misuse); and in six incidents the legality of use is reported as a registered use. In 46 of the reports, the certainty that the incident was due to carbaryl is 'possible', while in 19 of the incidents and six of the incidents, the certainty is listed as 'probable' and 'highly probable', respectively. In 25 of the incidents, the use site is listed as an unspecified orchard; while two are associated with apple orchards (misuse), seven involved agricultural areas, two involved use on a garden, three each involved use on asparagus or in forests, and one involved a direct application to an apiary (intentional misuse); in 23 of the incidents the use site was not reported.

Table 18. Summary of reported terrestrial invertebrate incidents involving carbaryl provided by the EPA.

Incident Number	Year	State	Product	Legality	Certainty Index	Use Site	Magnitude
B0000300-03	N/R	SD	SEVIN	Misuse (accidental)	Probable	Alfalfa	N/R
I001611-002	1994	WA	SEVIN XLR Plus	Registered Use	Highly Probable	Asparagus	N/R
I003826-021	1994	NC	SEVIN	Undetermined	Highly Probable	Agricultural Area	Unknown
I005855-001	1997	CA	SEVIN	Undetermined	Highly Probable	N/R	Thousands
I013587-012	1999	WA	N/R	Undetermined	Possible	Alfalfa	150 colonies exposed
I013587-032	1999	WA	N/R	Misuse	Probable	Apple	50 hives
I013587-033	1999	WA	N/R	Undetermined	Probable	Orchard (unspecified)	4 bee hives
I013587-034	1999	WA	N/R	Undetermined	Probable	Orchard (unspecified)	12 hives
I013883-031	1997	WA	N/R	Registered Use	Highly Probable	Orchard (unspecified)	84 bee hives
I014202-001	1999	MN	SEVIN XLR Plus	Registered Use	Probable	Forest	Unknown
I014202-015	2001	MN	SEVIN XLR Plus	Registered Use	Possible	Forest	Not given
I014202-019	N/R	MN	SEVIN XLR Plus	Registered Use	Probable	Forest	Not given
I014341-002	1996	WA	N/R	Undetermined	Possible	N/R	76 hives
I014341-003	1996	WA	N/R	Undetermined	Possible	Orchard (unspecified)	430 hives

Incident Number	Year	State	Product	Legality	Certainty Index	Use Site	Magnitude
I014341-004	1996	WA	N/R	Undetermined	Possible	Orchard (unspecified)	120 hives
I014341-027	1999	WA	N/R	Undetermined	Possible	N/R	46 hives
I014341-028	1999	WA	N/R	Undetermined	Possible	N/R	110-120 hives
I014341-029	1999	WA	N/R	Undetermined	Possible	N/R	>50 hives
I014341-030	1999	WA	N/R	Undetermined	Possible	Orchard (unspecified)	150 hives
I014341-038	1999	WA	N/R	Undetermined	Possible	Orchard (unspecified)	192 hives
I014341-039	1999	WA	N/R	Undetermined	Possible	N/R	131 hives
I014341-040	1999	WA	N/R	Undetermined	Possible	Orchard (unspecified)	Unknown
I014341-041	2000	WA	N/R	Undetermined	Highly Probable	N/R	3000-4000
I014341-042	2000	WA	N/R	Undetermined	Probable	N/R	Unknown
I014341-046	1992	WA	N/R	Undetermined	Possible	Orchard (unspecified)	90 hives
I014341-047	1992	WA	N/R	Undetermined	Possible	Orchard (unspecified)	300 hives
I014341-048	1992	WA	N/R	Undetermined	Possible	Orchard (unspecified)	186 hives
I014341-049	1992	WA	N/R	Undetermined	Possible	N/R	36 hives
I014341-050	1993	WA	N/R	Undetermined	Possible	N/R	262 hives

Incident Number	Year	State	Product	Legality	Certainty Index	Use Site	Magnitude
I014341-051	1993	WA	N/R	Undetermined	Possible	N/R	168 hives
I014341-052	1993	WA	N/R	Undetermined	Possible	N/R	250 hives
I014341-053	1993	WA	N/R	Undetermined	Possible	N/R	274 hives
I014341-054	1993	WA	N/R	Undetermined	Possible	N/R	130 hives
I014341-055	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	228 hives
I014341-056	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	250 hives
I014341-057	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	Unknown
I014341-058	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	76 hives
I014341-059	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	70 hives
I014341-060	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	1,000 hives
I014341-061	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	1,000 hives
I014341-062	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	120 hives
I014341-063	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	76 hives

Incident Number	Year	State	Product	Legality	Certainty Index	Use Site	Magnitude
I014341-064	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	100 hives
I014341-065	1994	WA	N/R	Undetermined	Possible	Orchard (unspecified)	100 hives
I014341-066	1994	WA	N/R	Undetermined	Possible	Asparagus	400 hives
I014341-067	1994	VT	N/R	Undetermined	Possible	N/R	100 hives
I014341-068	1994	WA	N/R	Undetermined	Possible	N/R	30 hives
I014341-069	1994	WA	N/R	Undetermined	Possible	N/R	unknown
I014341-070	1995	VT	N/R	Undetermined	Possible	Orchard (unspecified)	108 hives
I014341-071	1995	WA	N/R	Undetermined	Possible	Orchard (unspecified)	16 hives
I014341-072	1995	WA	N/R	Undetermined	Possible	Orchard (unspecified)	Unknown
I014405-031	1996	WA	N/R	Undetermined	Probable	N/R	N/R
I014407-009	1994	WA	N/R	Undetermined	Probable	N/R	228 colonies
I014407-015	1994	WA	N/R	Undetermined	Probable	N/R	250 colonies
I014407-023	1994	WA	N/R	Undetermined	Probable	N/R	120 colonies
I014407-025	1994	WA	N/R	Undetermined	Probable	N/R	76 colonies
I014407-032	1994	WA	N/R	Undetermined	Probable	N/R	1000 colonies
I015994-001	1999	MN	Sevin	Registered Use	Probable	Agricultural area	unknown

Incident Number	Year	State	Product	Legality	Certainty Index	Use Site	Magnitude
I017893-028	2006	CA	Sevin	Misuse (intentional)	Probable	Apiary	$375,000
I020998-024	2002	WA	N/R		Misuse	Probable	Apple orchard
I021587-001	2009	UT	N/R	Undetermined	Probable	Agricultural area	320 Hives
I022741-001	2010	MS	Sevin	Undetermined	Possible	Garden	1 hive
I022741-001	2010	MS	Sevin	Undetermined	Possible	Garden	30 hives
I025169-001	2012	NC	Bonide Fruit Tree Spray	Undetermined	Probable	Residential	50,000 bees
I026798-00014	2012	Alberta, Canada	N/R	Undetermined	Possible	Agricultural area	24 hives
I028254-00005	2015	NC	N/R	Undetermined	Possible	N/R	1 hive
I029512-00007	2016	NC	N/R	Undetermined	Possible	N/R	6 bee colonies
I029808-00001	2017	AL	CARBARYL	Undetermined	Probable	Agricultural area	30-40,000 bees
I030063-00001	2017	WA	N/R	Undetermined	Possible	Agricultural area	Hundreds
I030063-00001	2017	WA	N/R	Undetermined	Possible	Agricultural area	>1000
I031697-00001	2018	MI	CARBARYL 4L	Misuse (accidental)	Highly Probable	Asparagus	40 hives affected

General Effects to Aquatic Species

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 studied for regulatory purposes (i.e., fish, aquatic insects, and aquatic crustaceans), compared to less well-studied taxa, such as mollusks (including mussels and aquatic 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., two orders of magnitude difference between the highest and lowest fish acute mortality data or LC_{50} values), it is important that we take this uncertainty into account when assessing risks to listed species.

Listed aquatic species that may be affected by carbaryl 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 carbaryl 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 carbaryl 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. Our approach to applying the acute mortality data (LC_{50} values) for assessing lethal effects to listed species relies on the SSDs developed in the BE (Appendix 2-5 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}. 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). 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 carbaryl.

Effects to Fish and Aquatic-Phase Amphibians

We rely on toxicity data carried forward from the BE for our effects analysis to fish and aquatic phase amphibians. Overall, there was sufficient data on acute lethality to fish to create an SSD and there are several studies that address effects on growth. There were three studies on reproduction.

Mortality data for fish and aquatic-phase amphibians are available for carbaryl. The mortality acute toxicity estimates (96-hour LC_{50}) for carbaryl for fish varied by four orders of magnitude. Mortality values for aquatic-phase amphibians ranged from 0.005 mg/L (NOAEC; E71723) to 500 mg/L (LOAEC; E99684).

The acute mortality studies conducted with technical grade carbaryl were used to derive an SSD, including toxicity data for all fish and all amphibians exposed to carbaryl. Five distributions were tested, and a variety of methods were used. The triangular distribution and maximum likelihood (ML) method were ultimately chosen to represent the HC_{05} through HC_{95} values for freshwater and estuarine/marine fish.

We generally use the fish toxicity endpoints as surrogates for aquatic and aquatic-phase amphibians where there are few data for amphibians and discuss both taxa groups together in this section. The toxicity data used to assess the effects of carbaryl are provided below and in Table 19. Incident reports are discussed at the end of this section. All data referenced in the following sections are from the Effects Characterization (Chapter 2) of the BE.

<u>Mortality</u>

Fish

In Appendix 2-3 of their BE, EPA provides a list of studies that they evaluated when selecting the most sensitive endpoints for their ESA risk assessment for fish (Table 19). Atheriniformes, Salmoniformes, and Acipenseriformes, in general, appear to be the most sensitive to carbaryl. Acute toxicity estimates (96-hour LC_{50}) for carbaryl range from 0.14 mg/L (E5722) -1188 mg/L (E13614) and span four orders of magnitude, indicating a wide range of sensitivity to carbaryl among fish. The lowest LC_{50} for carbaryl is for TGAI (Technical Grade Active Ingredient) tested on *Ictalurus punctatus* (LC_{50} = 0.14 mg/L; E5722). Toxicity data for carbaryl when tested as a formulated product are also available (Appendix 2-5 on the BE). The most sensitive endpoint for the formulated product was an LC_{50} value of 0.44 mg/L (Rainbow trout; E112236). The fish mortality HC_{05} is 1,055.4 ug a.i./L.

Aquatic and aquatic-phase amphibians

For aquatic-phase amphibians, there are studies on mortality for 18 amphibian species identified in the ECOTOX database (BE Appendix 2-5). The values range from 0.58 to 150 mg/L and span more than two orders of magnitude. The lowest LC_{50} value of 0.58 mg/L is for the listed amphibian, the foothill yellow-legged frog *(Rana boylii*) (Derby, 2006; E118706).

<u>Sublethal effects</u>

Growth

For fish, growth endpoints range from 0.25 to 9.99 mg/L carbaryl. There are two studies that reported low growth-related endpoint values for carbaryl. In the first study, a NOAEC value of 0.25 mg/L was reported based on dry weight (LOAEC of 0.50 mg/L) reductions in 4-day old fathead minnow larvae (*Pimephales promelas*) exposed to 99.8% pure carbaryl for 7 days (E16510). In the other study, an IC_{25} of 0.25 mg/L from a 7-day study was based on the reduction of biomass (using an inhibition concentration methodology)[18] for bonytail freshwater fish following exposure to 99.7% TGAI (E93091). However, both studies contained limitations (including limited information on methodology, nonstandard endpoint analysis, and lack of raw data), and therefore were not considered as the growth endpoint threshold for freshwater fish. The least sensitive growth-related endpoint (NOAEL of 9.99 mg/L) was for general developmental changes in freshwater zebrafish exposed for 4 days to 99.9% TGAI (E109343). In these studies, the tested species belonged to the same fish order (*i.e.*, Cypriniformes), suggesting that fish species within the same order could potentially display different sensitivities to carbaryl TGAI with regards to growth-related effects.

There was another study that evaluated growth effects of carbaryl to freshwater fish (Carlson, 1972, MRID 40644801, E5073), which was classified as acceptable for quantitative use. This was a study in which chronic exposure of fathead minnows to carbaryl for 9 months resulted in no effects on growth, but rather reduced survival (27.5% reduction) and fecundity (98.5% reduction in eggs/mature female; 92.4% reduction in eggs/spawning) at 0.68 mg/L.

Aquatic and aquatic-phase amphibians

For aquatic-phase amphibians, the growth endpoints in the dataset range from 0.0005 to 20.1 mg/L (Figure 2-6 in the BE). A review of the available aquatic-phase amphibian studies indicated that there was insufficient information reported to allow for an independent evaluation of the data; therefore, the freshwater fish growth data were used as a surrogate for aquatic-phase amphibians.

Reproduction

Fish

Three studies evaluating reproductive effects to fish were available for carbaryl. The study with the lowest reproductive endpoint was the same study as discussed above for growth effects. In this study, chronic exposure of fathead minnows (*Pimephales promelas*) to carbaryl resulted in reduced reproductive effects (NOAEC = 0.21 mg a.i./L; LOAEC 0.68 mg a.i./L; and the calculated MATC was 0.378 mg a.i./L.) including reduced number of eggs per female and reduced number of eggs spawned (MRID 40644801 as reported in (Carlson A. R., 1972). In the other two studies, decreases in hatching were reported at 1.7 mg/L (E162695), whereas, in this study, no effects in fecundity or fertility were observed up to 0.82 mg/L (MRID 48669601).

Aquatic and aquatic-phase amphibians

While there were two open literature studies for aquatic-phase amphibians evaluating reproduction, both studies reported no effects at the concentrations tested (up to 7 mg/L). Thus, the fish data are used as a surrogate.

[18] The inhibition concentration (IC) is determined for each test using a linear interpolation methods (Norberg-King, 1993).

Table 19. Toxicity values for carbaryl for Fish and Aquatic-phase Amphibians (Table 2-8 from the BE).

Taxa	Threshold Type	Effect (endpoint)	Value (µg a.i./L)	Duration of exposure/Species	Source
Freshwater and Estuarine/Marine Fish	Mortality	HC_{05}	1,055.4	4 days	5th percentile LC_{50} from freshwater and estuarine/marine SSD (slope: 4.5)
Freshwater and Estuarine/Marine Fish and aquatic-phase amphibians	Sublethal (reproduction)	LOAEC based on effects on spawning (92.4% decrease), larval mortality within 30 days of hatching (56.5% decrease), eggs per mature female (98.5% reduction), and eggs per spawning event (92.4% reduction)	680 (LOAEC) 210 (NOAEC) 378 (MATC)	9-months exposure (1-5 day old to 30 days post-hatch) Fathead minnow (*Pimephales promelas*)	MRID 40644801
Aquatic-phase amphibians	Mortality	HC_{05}	HC_{05} = 2,331.8 (Amphibians) from SSD[1]	4 days	5th percentile LC_{50} from aquatic-phase amphibian SSD (slope: 4.5)

Effects to Dietary Items

Additionally, we consider impacts to fish and aquatic-phase amphibian dietary items as part of our effects analysis. These include effects to fish, aquatic invertebrates, aquatic vegetation, phytoplankton, and zooplankton. While carbaryl can cause adverse effects to vascular and non-vascular aquatic plant growth, we anticipate impacts will be minor at estimated environmental concentrations and result in minimal indirect adverse effects to fish and aquatic-phase amphibians. See the *General Effects to Plants* section below for a more detailed description of anticipated effects to aquatic plants.

Incident Reports

A review of the aggregate ecological incidents involving carbaryl was completed on December 23, 2019 (Table 20). The Aggregate Incident Report database contains information on 18 "minor" wildlife incidents. The database also includes 12 incidents associated with carbaryl for "other non-target" species (unspecified) that are also classified as "minor." For more information on incidents see Attachment 2-2 in the BE.

With respect to ecological incidents involving fish reported in the Incident Database System (IDS), a total of six fish-kill incidents were reported for carbaryl. Only one of those incidents, report #B0000-501-92, could be credibly associated with a specific carbaryl use, *i.e.*, to control gypsy moth in New Jersey in 1980. No data on residues were provided.

In an incident (I000910-001) in Louisiana, a fish kill was reported to have occurred in early June 1992. A number of pesticides (carbaryl, MSMA, atrazine, iprodione, dimethylamine, dicamba with 2,4-D, and chlorpyrifos) had been applied to area lawns and golf courses prior to the incident, which followed a high rain event. No chemical residues were reported; however, carbaryl had not been applied in the area since late April, while chlorpyrifos (bluegill LC_{50} = 0.0018 mg/L) and iprodione (Channel catfish LC_{50} = 3.1 mg/L) had been applied less than a week before the incident. It is unlikely that carbaryl residues would have been sufficiently high to result in a fish kill if the chemical had been applied two months prior. Both chlorpyrifos and iprodione are more likely candidates for being responsible for this fish kill.

A number of pesticides (toxaphene, carbaryl, endrin, methyl parathion and DDT) were associated with a fish kill in Oklahoma where approximately 22,000 catfish died (B0000-246-01). No residue data were provided; however, given that toxaphene and endrin are both classified as very highly toxic to catfish with LC_{50} values of 0.0027 mg/L and 0.013 mg/L (NIH, 2019), respectively, it is likely that they are more credible candidates for having caused the fish kill than carbaryl.

In 2001, a large incident (several thousand fish) occurred in the San Joaquin River in California (I013436-001). The fish were primarily threadfin shad and small catfish (< 3 in). A variety of pesticides were found in the river water and in discharges to the river, including demeton-S, diazinon, naled (dibrom), disulfoton and azinphos methyl. Dioxathion, carbaryl, carbofuran, fenuron, methomyl, and monuron were found in the gill tissue of the fish. Carbaryl was found only in the fish tissue at 1.75 mg/kg. Azinphos methyl was found at 0.016 mg/L in water from an agricultural drain entering the river, and 0.002-0.008 mg/L in the San Joaquin River itself. It is possible that azinphos methyl was the cause of the fish kill rather than carbaryl.

For two other incidents in Texas in 1994 (I001297-011) and 2004 (I015419-664), insufficient information was provided in the report to allow any evaluation of a cause and effect relationship with carbaryl.

Table 20. Incident reports for fish involving carbaryl.

INCIDENT NUMBER	YEAR	CHEMICAL(S) INVOLVED	CERTAINTY INDEX (for carbaryl)	STATE	LEGALITY (for carbaryl)	USE SITE	SPECIES AFFECTED	DISTANCE	EFFECT/ MAGNITUDE	PRODUCT
B0000-501-92	1980	Carbaryl	Probable	NJ	-	-	-	-	-	-
I013436-001	2001	Ammonia demeton-S diazinon naled (dibrom) disulfoton azinphos methy dioxathion carbaryl carbofuran fenuron methomyl monuron	Possible	CA	Undetermined	Unknown (the fish kill was in the San Joaquin River near the town of Lathrop)	29 fish species from 9 families including threadfin shad (*Dorosoma petenense*) and catfish (*Ictalurus* sp.)	Pesticide use in the watershed adjacent to the incident site in the San Joaquin River was not determined; evidence of pesticides use was from fish gill tissue samples.	Several thousand fish killed	Not reported. Upon further review of the incident, it was acknowledged by California Fish and Game that un-ionized ammonia was the primary cause of the fish kill. Analyses of composited gill samples found the presence of several pesticides (dioxathion = 121.1 ppm; carbaryl = 1.75 ppm; carbofuran = 4.51 ppm; fenurin = 0.78 ppm; methomyl = 5.08 ppm; monuron = 5.83 ppm). However, these pesticides were not detected in the water samples. Carbaryl was found only in the fish tissue at 1.75 mg/kg. Azinphos methyl was found at 0.016 mg/L in water from an agricultural drain entering the river, and 0.002-0.008 mg/L in the San Joaquin River itself. It is possible that azinphos methyl was the

INCIDENT NUMBER	YEAR	CHEMICAL(S) INVOLVED	CERTAINTY INDEX (for carbaryl)	STATE	LEGALITY (for carbaryl)	USE SITE	SPECIES AFFECTED	DISTANCE	EFFECT/ MAGNITUDE	PRODUCT
										cause of the fish kill rather than carbaryl.
B0000-246-01	-	Toxaphene Carbaryl Endrin methyl parathion DDT	-	OK	-	-	catfish	-	22,000 catfish died	No residue data were provided; however, given that toxaphene and endrin are both classified as very highly toxic to catfish with LC_{50} values of 0.0027 mg/L and 0.013 mg/L (NIH, 2019), respectively, it is likely that they are more credible candidates for having caused the fish kill than carbaryl.
I000910-001	1992	carbaryl MSMA atrazine iprodione dimethylamine dicamba with 2,4-D chlorpyrifos	-	LA	-	Area lawns and golf courses	Bluegill Channel catfish	-	-	while chlorpyrifos (bluegill LC_{50} = 0.0018 mg/L) and iprodione (Channel catfish LC_{50} = 3.1 mg/L) had been applied less than a week before the incident. It is unlikely that carbaryl residues would have been sufficiently high to result in a fish kill if the chemical had been applied two months prior. Both chlorpyrifos and iprodione are more likely candidates for being responsible for this fish kill.

INCIDENT NUMBER	YEAR	CHEMICAL(S) INVOLVED	CERTAINTY INDEX (for carbaryl)	STATE	LEGALITY (for carbaryl)	USE SITE	SPECIES AFFECTED	DISTANCE	EFFECT/ MAGNITUDE	PRODUCT

- = no information provided.

Effects to Aquatic Invertebrates

The effects of carbaryl on aquatic invertebrate species have been studied extensively and have been well-documented in the literature including studies on both freshwater and estuarine/marine invertebrates. Registrant-submitted studies involving aquatic invertebrates were also considered in EPA's BE in order to assess effects to this grouping of species, including acute and chronic laboratory studies with either technical or formulated carbaryl. As designated in the BE, the aquatic invertebrates taxonomic group includes 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 aquatic crustaceans, such as crayfish, isopods, and amphipods.

EPA generated SSDs for mollusk and non-mollusk aquatic invertebrates separately, with freshwater and estuarine/marine species pooled together in both groups. SSDs are based on acute 48 and 96-hr LC_{50} values from studies using TGAI only (LC_{50} values from formulation/mixture testing were not included).

We made certain assumptions on the known effects of carbaryl 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 either effects to non-mollusk aquatic invertebrate or aquatic mollusks. The reasons for using this approach include the range of the available data for the different aquatic invertebrate species; and a wide range of within-Order variability across a number of studies.

The mollusk and non-mollusk mortality thresholds are based on the HC_{05} value from the pooled freshwater and estuarine/marine SSD for the taxon. Sublethal effects were not pursued for the non-mollusk aquatic invertebrate analysis at this time due to the response threshold values being of similar magnitude for both mortality and sublethal endpoints (see Table 21 in this Opinion or Table 2-10 from the BE). For mollusks, we consider the sublethal effects and note the response concentration is similar for both growth and reproduction. We provide the values below in Table 21for reference. The relatively high estimated environmental concentration(s) (EEC)s aquatic invertebrates are likely to experience based on the waterbodies in which they are found (see Table 3-5 of the BE) will elicit mortality prior to any sublethal effects as well. Therefore, the mortality toxicity data used to assess the effects of carbaryl are provided below, along with a discussion of the available incident reports for carbaryl and aquatic invertebrates.

Table 21. Effects endpoints used to derive mortality and sublethal thresholds for determining effects to listed aquatic invertebrates exposed to carbaryl (adapted from Table 2-10 from the BE).

Taxa	Threshold Type	Effect (endpoint)	Value (µg a.i./L)	Duration of Exposure	Source
Aquatic Invertebrates (non-mollusks)	Mortality	HC_{05}	1.6	48 or 96 hours	5th percentile LC_{50} from pooled non-mollusk aquatic invertebrate SSD (slope = 4.5)
Aquatic Invertebrates (non-mollusks)	Sublethal (growth)	12% decrease in length at the LOAEC	0.2/0.4 (NOAEC/LOAEC) 0.28 (MATC)	21 days (*D. magna*)	TGAI; E171508 (Burga-Perex, Ferard, & Toumi, 2016)
Aquatic Invertebrates (non-mollusks)	Sublethal (reproduction)	14% decrease in number of neonates per surviving adult	0.2/0.4 (NOAEC/LOAEC) 0.28 (MATC)	21 days (*D. magna*)	TGAI; E171508 (Burga-Perex, Ferard, & Toumi, 2016)
Aquatic Invertebrates (mollusks)	Mortality	HC_{05}	6,600	48 or 96 hours	5th percentile LC_{50} from pooled mollusk aquatic invertebrate SSD (slope = 4.5)
Aquatic Invertebrates (mollusks)	Sublethal (growth)	95% reduction in growth rate	LOAEC = 1,000	Eastern oyster (*Crassostrea virginica*)	(Butler, Wilson Jr., & Rick, 1960); E3708
Aquatic Invertebrates (mollusks)	Sublethal (reproduction)	Decreased fecundity (e.g., 45% decrease in number of eggs laid)	LOAEC = 1,000	Freshwater snail *(Lymnaea acuminata)*	(Tripathi & Singh, 2003); E71686

Mortality

Aquatic Insects and Crustaceans:

Mortality data were available (submitted by registrants or available in ECOTOX database) for several different orders of aquatic invertebrates. There were 25 orders and 53 species of non-mollusk invertebrates and an SSD is used to establish a dose-response relationship for aquatic invertebrate non-mollusks. Acute mortality data (48- and 96-hour EC/LC_{50}s) are available for these 53 species of aquatic non-mollusk invertebrates; a 48- or 96-hour test duration is common for acute mortality toxicity testing. These types of studies are generally conducted using juvenile stages of invertebrates. The cumulative distribution function for the SSD for all non-mollusk invertebrates are presented in the carbaryl BE Figures 2-10 and 2-11. The SSD report for aquatic invertebrates is in the BE Appendix 2-6 and includes the details of how the SSD was derived. We bring forward the toxicity endpoint provided in the BE (Table 21) to assess effects to aquatic insects and crustaceans from the aquatic invertebrate SSD as 1.6 µg/L.

Mollusks (mussels and aquatic snails):

For mollusks, acute LC_{50} values range from 3.08 to 67.01 mg/L (exceeding solubility). Acute mortality data (48-and 96-hour EC/LC_{50}s) are available for 15 different species of mollusks (BE Appendix 2-6) and an SSD is used to establish the dose-response relationship for mollusks. The cumulative distribution function for the SSD for all mollusks are presented in Figures 2-10 and 2-11 in the carbaryl BE. The SSD report for the all-mollusk SSD is in Appendix 2-6 of the BE and includes the details of how this SSD was derived. Data from BE (USEPA, 2021b) (and Table 21) indicate that the HC_{05} from the SSD for mortality for mollusks is 6,600 ppb based on toxicity data from among five orders and 15 species (Table 21). The SSD pooled data from both estuarine/marine and freshwater species.

Sublethal

Aquatic Insects and Crustaceans:

For non-mollusks, the most sensitive toxicity value suitable for establishing a sublethal threshold is a *Daphnia magna* life-cycle reproduction study (E171508). Sublethal effects were not pursued for the non-mollusk aquatic invertebrate analysis at this time due to the response threshold values being of similar magnitude for both mortality and sublethal endpoints (see Table 21 in this Opinion or Table 2-10 from the BE) and mortality will be observed before observation of sublethal effects. The endpoints used to derive these sublethal (*i.e.*, growth and reproduction) thresholds for direct and indirect effects for aquatic invertebrates are also in the BE, Table 2-10. Appendix 2-3 in the BE also provides the open literature reviews for studies with endpoints used to derive threshold values.

Mollusks (mussels and aquatic snails):

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. We used the carbaryl mollusk SSD data as described above to assess direct effects to listed mussels using the carbaryl mollusk HC_{05} of 6.6 ppm as the analysis showed there were no differences among the estuarine/marine and freshwater mollusks in their response to exposure to carbaryl (Appendix 2-6 of the BE).

There are approximately100 listed species of freshwater mussels that are considered in this consultation that generally belong to two families, Unionidae and Margaritiferidae, several species that are members of which are included in the SSD analyses.

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 (1,055.4 μg a.i./L) was used.

For mollusks, the sublethal threshold is based on the reduction in fecundity and number of eggs in a study with the freshwater snail *Lymnaea acuminata* (E71686). There was a reduction in reproductive output of the snails as a result of the exposure to carbaryl pesticides. Carbaryl significantly reduced fecundity and survival rates of the embryos of the snails. Fecundity was low at higher doses of carbaryl. Some egg masses were laid without eggs at higher doses of carbaryl. No significant difference was found in the duration of hatching between the control and carbaryl-treated snails. The number of eggs after 96 hours (84±3.4) and the number of eggs hatched (65±1.7) were 55% and 43% of control values at the LOAEC which as 1.0 mg/L test concentration level (Table 21).

<u>Incident Reports for Aquatic Invertebrates</u>

No incidents specific for effects to aquatic invertebrates were available. The Aggregate Incident Reports database identified 18 incidents linked to carbaryl use as aggregated counts of minor wildlife incidents (W-B) and 12 reported for other non-target (ONT) species. Because limited details about these incidents were reported, no information was available on the use site, the certainty level, or on the types of organisms that were involved. For more information on incidents see BE Attachment 2-2.

General Effects to Plants

Carbaryl exposure to plants occurs through contact exposure, either from direct spray or dissolved in runoff. Toxicity data provided by the EPA (USEPA, 2021b) are primarily from greenhouse experiments or fields studies using planted crops, which are conducted under conditions that mimic those occurring on agricultural fields. These studies use spray application designed to expose plants to predetermined concentrations of active ingredients and are carried out for a set duration (e.g., 21 days) with a desired endpoint in mind (e.g., plant height, plant weight, seedling emergence, or survival).

Effects to Aquatic Plants

Most of the available toxicity studies with aquatic plants have focused on growth, mortality, physiological effects, and population effects. All but three of the available toxicity endpoints for aquatic plants involve non-vascular species. All the threshold values for aquatic plants are based on effects to yield. Because of the variability in study designs and endpoints, it was not possible to derive an SSD with the available aquatic plant data. Endpoints are provided for multiple groupings including aquatic plants, non-vascular aquatic plants, and vascular aquatic plants.

Endpoints related to growth, physiology (specifically effects to photosynthesis), and population size (most of which are related to yield and abundance) are considered as 'growth' effects for aquatic plants. For non-vascular aquatic plants, effects to growth are seen at carbaryl concentrations ranging from 0.11/0.26 (NOAEC/LOAEC, initial measured concentration; MRID 49101001) to 336.23 mg/L (IC50; E68365). The IC_{50} values for growth range from 0.34 (MRID 49101001) to 336.23 mg/L (E68365).

For vascular aquatic plants, the only endpoint available for growth is an IC_{50} of 23.9 mg/L (E117719). This 96-hour study was conducted under renewal conditions with technical grade carbaryl (98.0% a.i.) in duckweed (*Lemna minor*). At a lower concentration of 3.3 mg a/L, a 17.3% reduction in frond count was observed. At the highest exposure concentration of 45.2 mg/L, a 64.5% reduction in frond count was observed (Table 22).

Based on the available data for aquatic plants (including vascular and non-vascular and freshwater and estuarine/marine species), the most sensitive EC_{50}/IC_{50} for carbaryl (TGAI) is 0.34 mg/L for reduced yield in the saltwater diatom *Skeletonema costatum* (MRID 49101001). The lowest NOAEC/LOAEC threshold values for carbaryl (TGAI) and aquatic plants is from the same study based on reduced yield where the NOAEC was 0.045 mg/L, the LOAEC was 0.11 mg/L, and the IC_{50} was 0.34 mg/L. (MRID 49101001). This 96-hour acute toxicity study was conducted under static conditions and was classified as acceptable.

The only growth IC_{50} endpoint available for vascular aquatic plants is an IC_{50} of 23.9 mg/L for reduced abundance of duckweed, *Lemna minor,* from the same study mentioned above (Brooke, 1993; E117719). This study was conducted under 96-hour renewal conditions with technical grade carbaryl at 98.0% purity. Frond counts were measured at varying exposure concentrations. Effects were seen at all concentrations tested in this study. At the lowest concentration tested (3.3 mg/L), a 17.3% reduction in frond count was observed. At the highest exposure concentration of 44.3 mg/L, a 64.5% reduction in frond count was observed. Therefore, the NOAEC is <3.3 mg/L and the LOAEC = 3.3 mg/L. We use these data as the endpoint to address effects to aquatic plants from carbaryl exposure. Effects to *L. minor* are more relevant to aquatic plants and dietary or habitat resources which other listed species rely on such as listed snails, amphibians, fishes, and crustaceans rather than a marine diatom which few if any of Service species rely on or are related to, and thus we used that study as relevant toxicity data for effects.

Table 22. Summary of aquatic plant toxicity data.

Taxon	Threshold	Endpoint (mg a.i./L)	Effect(s)	Species	Study ID	Comments
All Aquatic Plants	NOAEC/LOAEC/MATC	0.045/0.11/0.07	Reduced yield	*Skeletonema costatum* (marine diatom)	MRID 49101001	This study was conducted under static conditions.
	IC_{50}	0.34				
Non-Vascular Aquatic Plants	NOAEC/LOAEC/MATC	0.045/0.11/0.07				
	IC_{50}	0.34				
Vascular Aquatic Plants	LOAEC[1]	3.3	Reduced frond abundance	*Lemna minor* (duckweed)	E117719	This study was conducted under 96-hour renewal conditions.

Taxon	Threshold	Endpoint (mg a.i./L)	Effect(s)	Species	Study ID	Comments
						The LOAEC was based on 17.3% reduction in frond count.

Effects to Terrestrial Plants

Most available toxicity studies with plants have focused on growth endpoints. Endpoint values and effects data arrays in this assessment are based on endpoints expressed in, or readily converted to, environmentally relevant concentrations (i.e., lbs a.i./acre). Because of the variability in study designs and endpoints, it was not possible to derive a species sensitivity distribution with the available plant data. Therefore, the endpoints used to derive terrestrial plant thresholds are based on the lowest toxicity values available for the taxa (see Table 23, and the discussion below). Threshold values are provided in exposure units of lbs a.i./acre and most of the threshold values are based on effects to growth (i.e., weight and/or height). Values are provided for all terrestrial plants, as well as for monocots and dicots separately.

From the breadth of carbaryl data for terrestrial plants, the IC_{25} values for decreases in growth (reduced weight) occur at application rates between 0.45 lbs a.i./acre to 13.8 lbs a.i./acre which includes results from both dicots and monocots. Changes in growth (weight and/or height) are reported between 0.45 and 13.8 lbs a.i./acre (based on the available NOAEC and LOAEC values) for monocots. Based on NOAEC/LOAEC values, the available IC_{25} values for dicots, based on growth, occur at concentrations of ~0.73 and 8.8 lbs a.i./acre. Population-level effects (*i.e.*, biomass) to terrestrial plants from carbaryl exposure, occur at application rates of 0.125 lbs a.i./acre.

While direct exposure to carbaryl at these application rates can cause direct adverse effects, we do not anticipate exposures to listed plants will occur at levels synonymous to application rates as listed plant species are not likely to occur on use sites and will only be directly exposed through spray drift. Given the rapid deposition rates of spray drift residues (with the vast majority of residues depositing within a few meters of application sites), we have high confidence that listed plant species will be exposed at levels lower than the LOAEC and IC_{25} levels where they actually occur in the wild.

NOAEC/LOAEC values

Based on the available data for terrestrial plants, the most sensitive NOAEC and LOAEC values for carbaryl are 2.0 lbs a.i./acre and 5.5 lbs/acre, respectively, based on reduced weight (dry weight) in winter barley (*Hordeum vulgare*) (MRID 49142501), which was the most sensitive monocot tested.

In this Tier II seedling emergence study, the effect of Carbaryl SC240 (Sevin RP2; 22.2% a.i.) on four monocots [corn (*Zea mays*), onion (*Allium cepa*), ryegrass (*Lolium perenne*), and winter barley (*Hordeum vulgare*)] and six dicot species [cabbage (*Brassica oleracea*), cucumber (*Cucumis sativus*), soybean (*Glycine max*), sugar beet (*Beta vulgaris*), sunflower (*Helianthus annuus*), and tomato (*Lycopersicon esculentum*)] was studied at nominal concentrations of 0 (negative control), 0.27, 0.73, 2.0, 5.5, and 14.9 lbs/acre. The highest application rate was the only one which was analytically-determined; the mean-measured concentration at the nominal 14.9 lbs a.i./acre treatment level was 13.8 lbs/acre. On day 21 post application, the surviving plants per pot were recorded, and plant height and weight were measured. There was no difference in percentage emergence from control at any concentration tested and there were no effects to height or weight for cucumber, sugar beet, or sunflower. For winter barley, a 12.7% reduction in dry weight was statistically significant compared to the control at the 5.5 lbs a.i./acre treatment level.

The most sensitive dicot tested was tomato with NOAEC and LOAEC values of 5.5 and 14.9 lbs a.i./acre (analytically measured LOAEC was 13.8 lbs a.i./acre), respectively, based on a statistically significant 47.4% reduction in survival at 14.9 lbs a.i./acre (analytically determined to be 13.8 lbs a.i./acre) treatment level. There were also statistically significant reductions in cabbage weight (inhibitions from 22 – 40%) at the four highest tested concentrations (0.73, 2, 5.5, and 13.8 lbs a.i./acre). However, there was no dose dependent relationship to these inhibitions, therefore, they were not considered biologically meaningful. There was no difference in % emergence from control at any concentration tested and there were no effects to height or weight for cucumber, sugar beet, or sunflower. Thus, overall the NOAEC and LOAEC values for all terrestrial plants (pre-emergent exposure) were used from this study, at 2.0 lbs a.i./acre and 5.5 lbs a.i./acre, respectively.

EC_{25}/IC_{25} values

Based on the available data for terrestrial plants, the most sensitive EC_{25}/IC_{25} for carbaryl is 7.83 lbs a.i./acre based on reduced dry weight in winter barley (*Hordeum vulgare*) from the same study discussed above to describe the NOAEC and LOAEC values used (MRID 49142501). IC_{25} values were determined for two of the four monocots tested; IC_{25} values could not be determined for onion or corn. The IC_{25} for ryegrass emergence was determined to be 11.8 lbs a.i./acre and the IC_{25} for ryegrass survival was determined to be 7.9 lbs a.i./acre. For winter barley, the IC_{25} for dry weight was determined to be 7.83 lbs a.i./acre, making winter barley the most sensitive monocot tested with NOAEC and IC_{25} values of 2.0 and 7.83 lbs a.i./acre, respectively.

IC_{25} values were determined for two of the six dicots tested, IC_{25} values could not be determined for cucumber, soybean, sugar beet, or sunflower. For tomato, the IC_{25} for survival was 8.79 lbs a.i./acre. For cabbage, the IC_{25} for dry weight could not be determined. Inhibition in cabbage ranged from 13-40%, relative to the negative control, but given the variable response pattern, a reliable IC_x value could not be determined. Therefore, the most sensitive IC_{25} available for dicots is 8.79 lbs a.i./acre based on tomato survival.

Table 23. Summary of terrestrial plant toxicity data (Table 2-25 in the BE).

Taxon	Threshold	Exposure	Endpoint	Effect(s)	Study Species	Study ID	Comments
All terrestrial plants	NOAEC/LOAEC	Pre-emergence	NOAEC – 2.0 lbs a.i./acre LOAEC – 5.5 lbs a.i./acre MATC – 3.3 lbs a.i./acre	12.7% reduction in dry weight	Winter barley (*Hordeum vulgare*)	MRID 49142501	monocot study species
All terrestrial plants	IC_{25}	Pre-emergence	7.83 lbs a.i./acre	Reduced weight	Winter barley (*Hordeum vulgare*)	MRID 49142501	monocot study species
All dicots	NOAEC/LOAEC	Pre-emergence	NOAEC - 5.5 lbs a.i./acre LOAEC – 13.8 lbs a.i./acre MATC – 8.71 lbs a.i./acre	47.4% reduction in survival	Tomato (*Lycopersicon esculentum*)	MRID 49142501	dicot study species
All dicots	IC_{25}	Pre-emergence	8.79 lbs a.i./acre	Reduced survival	Tomato (*Lycopersicon esculentum*)	MRID 49142501	
All monocots	NOAEC/LOAEC	Pre-emergence	NOAEC – 2.0 LOAEC – 5.5 lbs a.i./acre	12.7% reduction in dry weight	Winter barley (*Hordeum vulgare*)	MRID 49142501	

Taxon	Threshold	Exposure	Endpoint	Effect(s)	Study Species	Study ID	Comments
All monocots	IC_{25}	Pre-emergence	7.83 lbs a.i./acre	Reduced weight	Winter barley (*Hordeum vulgare*)	MRID 49142501	

Fruit thinning use of carbaryl effects to plants and pollinators

Carbaryl is also used to thin fruit in orchards, and its activity in the abscission of flower buds may be related to its structural similarity to plant auxins, such as α-naphthalene acetic acid. Several carbaryl labels are registered for fruit thinning (Carbaryl 4L, Sevin® 4F, Sevin® SC, and Sevin® XLR Plus) to increase the quality of fruit output. Many cooperative extension services recommend or direct users on how best to apply carbaryl for this use (University of Illinois, Washington State University, Pennsylvania State University, University of Massachusetts, Amherst, etc.), and direct users to follow the label with care due to carbaryl's properties as an insecticide which may harm bees.

(Byers, Carbaugh, Presley, & Wolf, 2008) found that when carbaryl was applied on the first day of artificially shaded trees, more thinning occurred than if trees were not shaded. Applying carbaryl during lower light conditions and specific temperatures can increase the efficacy of carbaryl as a fruit thinner. This information coincides with label protections for bees indicating that the best timing of application for fruit thinning is protective of bees as it is recommended to do so when bees are not active based on time of day (in low light) and lower temperatures. (Matta & Ouma, 2007) determined carbaryl to be an effective fruit thinner resulting in an increase in yield, sugar content, and apple color for certain cultivars without compromising fruit size.

The cooperative extensions and the carbaryl labels for these formulations indicate that applying carbaryl once or twice in the four weeks following bloom is an effective way to thin apple fruit, but avoid spraying when trees are in bloom or bees are present in the orchard. Based on information from the extension services indicating this use is primarily used for apple thinning and less recommended for other tree fruits as it is not effective (peaches or plums), we find that this application of carbaryl is not likely a widespread usage of carbaryl as it would be restricted to only where apples are grown. In addition, application rates and number of applications are far less for fruit thinning than other crop application rates. This application of carbaryl is not likely to impact listed flowering plants adjacent to apple orchards as insect pollinators such as bees that are active during daylight conditions or higher temperatures would not be impacted when recommended conditions favor applying carbaryl as a fruit thinner (as stated above such as low light and low temperatures).

While registered fruit thinning uses and available toxicity data indicate that listed plants can experience adverse effects from carbaryl exposure, we do not anticipate exposures to listed plants will occur at levels that will cause direct adverse effects, as listed plant species are not likely to occur on use sites and will only be directly exposed through spray drift. Given the rapid deposition rates of spray drift residues (with the vast majority of residues depositing within a few meters of application sites), we have high confidence that listed plant species will be exposed at levels lower than these LOAEC and IC_{25} thresholds where they actually occur in the wild.

Incident Reports

As of December 23, 2019, there were 14 terrestrial plant incident reports in the IDS with a certainty index of 'possible,' 'probable,' or 'highly probable.' Of these 14 incidents, 10 are from a registered use, one is from a misuse (either accidental or intentional), and in three of the incidents, the legality of use was undetermined (see Table 2-6 and Attachment 2-2 in the BE for details). The following discussion only includes those incident reports with a certainty index of 'possible,' 'probable,' or 'highly probable,' and a legality classification of 'registered use' or 'undetermined.'

The dates of the incident reports range from 1994 to 2013. Most of the terrestrial plant incident reports involve damage to the crop treated (*i.e.*, from direct application). In most of the incidents, carbaryl was the only pesticide noted in the report; however, four incidents involved other pesticides (Table 24). Therefore, in four of the incidents the specific effects to plants from carbaryl use are unclear. Registration numbers are rarely provided in the IDS database; however, based on the product names in the reports, it appears that at least a few of the incidents involve products that are no longer registered (*e.g.*, I009262-128, I010017-016, I023832-017, I024179-368).

Table 24. Summary of Incident Reports for Terrestrial Plants.

Incident Number	Year	Chemical(s) Involved (PC Code)	Certainty Index	State	Legality	Use Site	Species Affected	Distance	Effect/ Magnitude	Product
I008034-002	1998	Carbaryl	Possible	CA	Registered	Quince	Quince	Direct application	Fruit spotting/ 8 acres	Carbaryl wettable powder in tankmix containing five (unspecified) products
I008034-003	1998	Carbaryl	Possible	CA	Registered	Quince	Quince	Direct application	Fruit spotting/ 9 acres	Carbaryl tankmix (unspecified)
I008034-004	1998	Carbaryl	Possible	CA	Registered	Quince	Quince	Direct application	Fruit spotting/ 43 acres	Sevin 50W, Sevin 80 WSP + tankmix (unspecified)
I009262-128	1999	Carbaryl	Possible	NY	Registered	Home garden	Cucumber, pumpkin, squash, and tomato	Direct application	Plant browning, death/NR	Bug-B-Gon Multi-Purp Gard Dust
I009305-001	1999	Carbaryl	Probable	PA	Registered	Home garden and field	Broccoli, cabbage, potato, & tomato	Direct application	Plant damage/NR	GardenTech Ready-To-Use Sevin Bug Killer

Incident Number	Year	Chemical(s) Involved (PC Code)	Certainty Index	State	Legality	Use Site	Species Affected	Distance	Effect/ Magnitude	Product
I009412-001	1999	Carbaryl	Possible	NC	Registered	Orchard	Orchard	Direct application	Plant damage/NR	Sevin XLR Plus
I010017-016	2000	Carbaryl	Probable	FL	Registered	Tomato	Tomato	Direct application	Mortality/ two tomato plants	Bug-B-Gon Multi-Pur Gard Dust
I012089-008	2001	Carbaryl	Possible	MN	Registered	Cucumber	Cucumber	Direct application	Plant damage/15 acres	Sevin XLR Plus
I017865-034	2006	Carbaryl	Probable	CA	Registered	Apples	Apples	Direct application	Fruit damage / 10 ACRES	Sevin XLR Plus
I022392-023	2010	Carbaryl	Possible	KY	Undetermined	Tree	Trees	Direct application	Mortality/47 trees	Not specified
I023832-017	2012	Carbaryl/ Metaldehyde (053001)	Possible	FL	Undetermined	Impatients	Impatients	Direct application	Plant damage/ > 45% damage	Bug-GeTe Plus Snail & Slug Killer
I024179-368	2012	Carbaryl	Possible	SC	Undetermined	Residential ornamental	Ornament-al	Direct application	Plant damage/ > 45% damage	Bug-GeTe Plus Snail & Slug Killer
I025475-001	2013	Lambda cyhalothrin (128897) Flubendiamide (027602)	Possible	NY	Registered	Apples	Apples	Direct application	Burning and speckling of	Fontelis (a.i. penthiopyrad) with was applied in a large mixture

Incident Number	Year	Chemical(s) Involved (PC Code)	Certainty Index	State	Legality	Use Site	Species Affected	Distance	Effect/ Magnitude	Product
		Zinc oxide (088502) Abamectin (122804) Prohexadione calcium (112600) Carbaryl Thiomethoxam (060109) Sodium 1-naphthaleneacetate (056007) N6-Benzyladenine (116901) Captan (081301) Streptomycin sesquisulfate (006310)							leaves and fruit thinning/ NR	of other products, including thinners, adjuvants, and plant growth regulators.

In addition to the terrestrial plant incident reports available in IDS, there have also been a total of 175 aggregate plant incidents reported to the Agency (Table 25). Of these 175, 21 are associated with active registrations (154 involve products no longer registered) (see Table 2-27 in the BE). Also, of the 175 aggregate plant incidents, 4 were attributed simply to "carbaryl" without a specific product registration reference, and another 4 were attributed to "Bug B Gon Carbaryl" without reference to which of the two specific product formulations (*i.e.*, granules or dust) resulted in the incidents.

Since 1998, plant incidents that are allowed to be reported aggregately by registrants [under FIFRA 6(a)(2)] include those that are associated with an alleged effect to plants that involves less than 45 percent of the acreage exposed to the pesticide. Typically, the only information available for aggregate incidents is the date (*i.e.*, the quarter) that the incident(s) occurred, the number of aggregate incidents that occurred in the quarter, and the PC code of the pesticide and the registration number of the product involved in the incident. Because of the limited amount of data available on aggregate incidents it is not possible to assign certainty indices or legality of use classifications to the specific incidents. Therefore, the incidents associated with currently registered products are assumed to be from registered uses unless additional information becomes available to support a change in that assumption.

Table 25. Aggregate Plant Incidents for Carbaryl Involving Currently Registered Products.

Product Registration Number	Product Name	Number of Aggregate Plant Incidents	Year(s)
000239-01349	ORTHO SEVIN 5 DUST	11	1995, 1996, 1997, 2007, 2008
000239-01513	ORTHO SEVIN 10 DUST	1	1995
000239-02181	ORTHO SEVIN GARDEN DUST	16	1996, 1997, 1998, 2000, 2001, 2004, 2005
000239-02314	ORTHO BUG-GETA GRANULES	1	1997
000239-02356	ORTHO LIQUID SEVIN	14	1995, 1996, 1997, 1998, 1999
000239-02514	GET-A-BUG SNAIL, SLUG & INSECT KILLER	52	1995, 2009

Product Registration Number	Product Name	Number of Aggregate Plant Incidents	Year(s)
000239-02628	ORTHO SEVIN LIQUID BRAND CARBARYL INSECTICIDE FORMULA II	21	1998, 2001, 2003, 2007, 2009, 2011
000264-00333	SEVIN BRAND XLR CARBARYL INSECTICIDE	1	1998
000264-00334	SEVIN BRAND RP2 CARBARYL INSECTICIDE	2	1996
000264-00334-000239	ORTHO SEVIN(R) LIQUID BRAND CARBARYL INSECTICIDE	27	1996, 1997, 1998, 2000
000264-00349	SEVIN 4F	1	2004
000264-00428-000524	GREENSWEEP LAWN INSECTICIDE	1	2005
000432-01227	SEVIN SL CARBARYL INSECTICIDE	1	2015
000524-00444	GREENSWEEP LAWN INSECTICIDE WITH SEVIN SPRAY-ON LIQUID	1	1997
028293-00233-000239	BUG B GON GRANULES/LAWN & SOIL LAWN INSECT KILLER	16	2002, 2003, 2004, 2005, 2006

Exposure

Carbaryl will initially enter the environment via direct application (*e.g.*, as liquid sprays, dusts, and granular formulations) to use sites (*e.g.*, soil, foliage). It may move off-site via spray drift, dissolved in runoff, and/or as residue sorbed to eroded sediment. Carbaryl can break down in the environment in a variety of ways, the primary routes including alkaline hydrolysis, photolysis in water, and soil and aerobic aquatic metabolism. These processes are important because they occur naturally and will cause the carbaryl structure to change into metabolites and breakdown products that are less toxic in the environment.

Based on vapor pressure, carbaryl is classified as non-volatile under field conditions (USEPA, 2010a). Carbaryl has a half-life in air of 1 to 4 months. The low vapor pressure and Henry's law constant of carbaryl makes it unlikely that there will be significant volatilization from soil, water, or treated surfaces (Dobroski, O'Neill, Donahue, & Curley, 1985). While transport in air and precipitation is not a major transport pathway, carbaryl has been detected in precipitation at up to 0.756 µg/L in rain and 4 µg/L in fog (Foreman, Majewski, Goolsby, Wiebe, & Coupe, 2000), (Mast, Foreman, & Skaates, 2007); (Sanusi, Millet, Mirabel, & Worthman, 2000); (Vogel, Majewski, & Capel, 2008); (Waite, et al., 1995). Once in air carbaryl is expected to degrade in hours. Carbaryl may be found in the atmosphere associated with air-borne particulates or as spray drift and can react with hydroxyl radicals in the ambient atmosphere (Kao, 1994).

Potential transport mechanisms of carbaryl in air include spray drift and as with all chemicals applied by aerial or ground spray, spray drift can cause exposure to non-target organisms downwind. (Bunce, Liu, Zhu, & Lane, 1997); (Kawasaki, 1980); (Pitter, 1976); (Rogers, Li, & Felice, 2002); (USEPA, 2018).

Carbaryl's degradation in aerobic soil varies as a consequence of the variability in pH among the tested soils. Overall, carbaryl is not persistent in soil due to multiple degradation pathways including hydrolysis, photolysis, and microbial metabolism.

The major degradate of carbaryl is 1-naphthol, with minor degradant compounds of 1,4-naphthoquinone, 5-hydroxy-1-naphthyl methylcarbamate and 1-naphthyl-(hydroxymethyl) carbamate. These are discussed in more detail in the *Description of the Proposed Action* Section of this Opinion.

Hydrolysis is the primary degradation pathway for carbaryl at pH 7 and above. The hydrolysis of carbaryl is pH dependent with half-lives of 3.2 hours at pH 9, 12 days at pH 7, and no evidence of degradation at pH 5. Carbaryl is assumed to be hydrolytically stable at a pH of 5 (USEPA 2003c). Carbaryl photodegrades in water with an observed half-life (at pH 5) of 21 days, adjusted to reflect a 12:12 hourly light-dark cycle.

In natural water, carbaryl is expected to degrade faster due to the presence of microorganisms. The half-lives of carbaryl in streams, rivers, and brooks, as a result of forest spraying, are 25, 28, and 23 hours, respectively (Stanley & Trial, 1980). A study by Bonderenko et. al. reported aqueous half-lives of carbaryl in natural waters from California and Washington State ranging from 0.3 to 4.7 days (Bonderenko, Gan, Haver, & Kabashima, 2004). Carbaryl is moderately soluble in water with a reported solubility range of 23 to 120 mg/L (USEPA, 2003a; USDA Forest Service, 2008).

Carbaryl is moderately mobile in soils, according to the FAO mobility classification system. Based on batch equilibrium studies, the compound has soil-water distribution coefficients ranging from 1.33 to 2.43 L/kg or K_{oc} values of 100 to 1,054 (Jana & Das, 1997), (USDA Forest Service, 2008), (USEPA, 2003b) indicating carbaryl moderately binds to soil. Soil sorption of carbaryl is partly a function of soil organic matter content, and increases with increasing organic carbon content, with a mean K_{oc} of 153 mL/g_{oc} (K_{oc} is the organic carbon-water adsorption coefficient). This value measures the amount of the chemical to sorb to organic carbon per amount of water. A higher number means it will sorb more readily to organic soils than to water). Carbaryl sorption to soil has been shown to increase with increasing percent organic carbon (Ćwieląg-Piasecka, 2023; Shareef & Shaw, 2008). Terrestrial field dissipation data (MRID 00155759) also show dissipation half-lives of 62 to 116 days for carbaryl in the upper 30 cm of the soil profile.

Because of its low octanol/water partition coefficient (log K_{ow} of 2.4) (Windholz, Budavari, Blumetti, & Otterbein, 1976), carbaryl is not expected to bioconcentrate to a significant extent. Carbaryl is not subject to significant bioaccumulation due to its moderate water solubility and low octanol-water partition coefficient (Dobroski, O'Neill, Donahue, & Curley, 1985; USEPA, 2003b). Uptake of carbaryl in fish has been detected, with 95% excreted within 8 hours (Tompkins, 1966). Bioconcentration factors (BCF) in fish and invertebrates are low with values less than 15 (USDA Forest Service, 2008). Typically values greater than 1,000 represent chemicals that would be expected to bioconcentrate while BCF values below 200 are considered to have a low potential.

Carbaryl bait, due to its application method, will exhibit reduced soil effects when compared to spray applications (USDA APHIS 1987). Very little transport of carbaryl through runoff or leaching to groundwater is expected due to the combination of moderate water solubility, moderate sorption, and rapid degradation in soils. There are no reports of carbaryl detection in groundwater, and less than 1% of carbaryl applied to a sloping plot was detected in runoff (Caro, Freeman, & Turner, 1974).

Carbaryl has a short residual half-life on plant surfaces: insecticidal properties are retained for 3 to 10 days (USEPA, 1985). This potentially has the most implications for pollinating insects that preferentially visit certain crops in bloom and may pollinate listed plant species near agricultural areas. Although carbaryl is a polar compound, bioconcentration in plants is not of concern due to limited plant uptake related to its water solubility and rapid degradation (Nash, 1974). The half-life of carbaryl for foliar degradation is 3.71 days, and the foliar washoff rate is 0.91 cm-1 (USEPA, 2010b). Based on forestry field dissipation studies, foliar half-lives of 21 days have been reported with a leaf litter half-life of 75 days (USEPA, 2003b).

Rate, Frequency, and Number of Applications

Estimated environmental concentrations (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. Generally, EPA modeled EECs using the highest allowable application rate and minimum re-entry interval for each labeled use. We recognize that carbaryl 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 it is reasonable to assume that carbaryl is used in a manner to produce such concentrations.

In selecting application dates for aquatic modeling, EPA considers a number of factors including label directions, timing of pest pressure, meteorological conditions, and pre-harvest restriction intervals. Agronomic information was consulted to determine the timing of crop emergence, pest pressure and seasons for different crops. General sources of information include crop profiles, agricultural extension bulletins, and/or available state-specific use information.

Carbaryl may be applied during different seasons, and the directions for use indicate the timing of application, such as, at plant, dormant season, or foliar (e.g. when foliage is on the plant), etc. For most carbaryl uses, the Pesticide in Water Calculator (PWC) model inputs for the application dates were chosen based on these timings, the crop emergence and harvest timings specified in the PWC scenario, and precipitation data for the associated meteorological station. Application dates were selected to represent conservative and reasonable estimates. If applicable, dormant seasons were assumed to occur between November and February, the predominant period throughout the country when crops are dormant. Foliar applications were assumed to occur when the crop was on the field in the PWC scenario. Pre-harvest intervals (the minimum time between an application and harvest) were also considered. Applications would not occur closer to harvest than allowed by the pre-harvest interval.

Determining Percent of the Population That Could Be Exposed to Carbaryl

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, carbaryl use sites were binned (i.e., categorized) by the general land cover class that best represents the use pattern (e.g., peaches are categorized with other orchards while cole crops – e.g., cabbage, broccoli, Brussels sprouts, and kale – are binned with vegetables and ground fruit; see Table 26). 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 and Table 2). To map use sites on the landscape, EPA used the 2017 National Agricultural Statistics Service (NASS) Census of Agriculture (CoA) crop acreage reports and the 2017 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. We use the NOAA C-CAP[19] data from 2010-2012 to address agricultural uses in these areas.

[19] National Oceanic and Atmospheric Administration, Coastal Services Center. 1995-present. The Coastal Change Analysis Program (C-CAP) Regional Land Cover. Charleston, SC: NOAA Coastal Services Center. Accessed at https://coast.noaa.gov/digitalcoast/data/ccapregional.html.

Table 26. Composition of Use Data Layers (UDLs) for carbaryl.

Use Data Layers for Carbaryl
Citrus: Oranges, Grapefruit
Corn: Field Corn, Seed Corn
Developed
Forestry
Grapes
Nurseries
Open Space Developed
Other Crops: Clover/Wildflowers, Sod/Grass Seed, Fallow/Idle Cropland, Aquaculture
Other Grains: Sorghum, Barley, Other Small Grains, Rye, Oat, Millet, Speltz, Canola, Flaxseed, Safflower, Rapeseed, Camelina, Buckwheat, Sugarcane, Triticale
Other Orchards: Almonds, Apples, Apricots, Cherries, Pecans, Peaches, Pears, Pomegranates, Pistachios, Nectarines, Walnuts, Prunes, Olives, Plums
Other Row Crops: Sunflower, Peanuts, Tobacco, Sugarbeets, Hops
Pasture: Alfalfa, Agricultural grasses, Switchgrass, Vetch
Rangeland
Rights of Way
Soybean
Vegetables and Ground Fruit: Asparagus, Beans (dry and succulent), Blueberries, Broccoli, Brussels sprouts, Caneberries, Cantaloupe, Cabbage, Carrots, Cauliflower, Celery, Chick peas, Cucumbers, Collards, Cranberries, Eggplant, Endive (Escarole), Garlic, Gourds, Herbs, Honeydew melons, Horseradish, Leafy Green Vegetables (beet tops, dandelion greens, kale, kohlrabi, mustard greens, parsley, Swiss chard, and turnip greens), Lentils, Lettuce (head and leaf), Melons, Mint (peppermint and spearmint), Mustard, Okra, Onions (green and dry bulb), Parsnip, Peas, Peppers, Pop Corn, Potatoes, Pumpkins, Radishes, Raspberries, Rutabaga, Salsify, Strawberries, Summer squash, Sweet Corn, Sweet Potatoes, Tomatoes, Watermelons

The "percent overlap" for each use site is generally divided between on-field overlap, off-field overlap, and total overlap. On-field overlap refers solely to the footprint of the use site itself.

Off-field overlap is comprised of the 30-m offsite transport area outside of use sites. This is the distance at which EPA determined there is an attenuation of the spray drift and the maximum distance at which they expect impacts to terrestrial invertebrates (i.e., the most sensitive taxa). The total overlap combines these two metrics. 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 carbaryl use areas, we made the following refinements and deviations from the methods described in EPA's BE:

- Based on discussions with carbaryl's primary registrant, TKI[20], we concluded, that for landcovers among the pasture category as defined in the BE, carbaryl 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, EPA mapped this category with only the alfalfa layer of the CDL.

<u>Distribution of individuals within the range:</u>

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 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. Conversely, vulnerability may increase for species with few individuals that overlap use site and are not widely distributed outside of these sites. Our approach took into account this scenario as well. However, the availability of 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.

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

Seasonal exposure:

Species may be precluded from exposure to a pesticide due to life history factors such as migration, estivation, or hibernation. Where species may avoid exposure to a pesticide 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 United States (they only winter and migrate within the United States) 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 and vapor pressure ($1.28\text{x } 10^{-8}$ atm-m^3/mol $1.3\text{x}10^{-7}$ torr, respectively) and moderate soil/water partitioning, carbaryl has low volatilization potential from soil. This is discussed in more detail in the *Action Area* Section of this Opinion. Carbaryl has been detected in precipitation at up to 0.756 µg/L in rain and 4 µg/L in fog (Foreman, Majewski, Goolsby, Wiebe, & Coupe, 2000; Mast, Foreman, & Skaates, 2007; Sanusi, Millet, Mirabel, & Worthman, 2000; Vogel, Majewski, & Capel, 2008; Waite, et al., 1995) Based on these data, it is possible that carbaryl can be deposited on land and into waterbodies via precipitation. However, transport in the air and precipitation via volatilization is not expected to be a significant exposure pathway.

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).

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 BE 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 exposed to a range of 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.

For each application of carbaryl, 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; as explained below, use of peak EECs is a rational approach for analyzing species response. Accordingly, 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 carbaryl 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. However, the above approach is a rational and balanced one for several reasons. As previously explained, our analysis evaluates effects from a single exposure event, but it is also possible that carbaryl may not be applied in areas of overlap, or if applied and the species is exposed, it may be the case that exposure is at concentrations that would not illicit an adverse response from the subject species. By using peak EECs, the Service is evaluating the full breadth of species response. For example, 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 multiple applications in 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 carbaryl to affect individuals based on a single peak EEC value.

Contact exposure – direct spray or contact with contaminated media

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 involving cholinesterase-inhibiting pesticides, particularly organophosphates, have shown this can be a significant route of pesticide exposure for terrestrial vertebrates, especially for birds (Henderson, Yamamoto, Fry, Seiber, & Wilson, 1994; Vyas, et al., 2006; Schafer, Brunton, Lockyer, & De Grazio, 1973; Hudson, Haegele, & Tucker, 1979). For carbaryl, while data are lacking for contact toxicity of carbaryl in other terrestrial vertebrates, acute studies in mammals described in the BE showed dermal exposure to be a much less sensitive route of exposure than oral toxicity, with no mortalities at concentrations that were orders of magnitude greater than the mammalian oral acute LD_{50}. As such, we base our analysis on dietary toxicity as the primary route of exposure and effects to terrestrial vertebrates. While we acknowledge dermal contact can be an additional route of exposure that may increase the total amount of carbaryl that terrestrial vertebrates may be exposed to, we do not anticipate this type of exposure will result in additional measurable impacts to individuals that are not already accounted for given the conservative nature of the dietary assessment (i.e., diets consisting of only forage/prey items exposed at maximum concentrations) and the comparative data between the two routes of exposure.

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.

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. We considered data regarding dermal toxicity and found this route to be a less sensitive endpoint than dietary exposure. However, the absence of an assessment from preening or grooming adds additional uncertainty to our analysis.

Inhalation

Exposure via inhalation can occur from spray droplets at the time of the application and volatilized residues under the crop's canopy. There are two studies involving mammalian exposure via the inhalation route for carbaryl (Table 16). Together these studies indicate that the rat inhalation LC_{50} is between 3.4 and 5.3 mg/L.

For this analysis, estimated doses for inhalation were one to three orders of magnitude lower than mean avian dietary doses (there were no mammalian dietary studies for comparison) and two to three orders of magnitude lower than dermal doses for both avian and mammalian studies (sections 6.3.4 and 9.3.4 in the BE). 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 from dietary exposures based on the concentrations where effects are observed.

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 from dietary exposures based on the concentrations where effects are observed.

Estimated Environmental Concentrations (EECs) on Use Sites and from Offsite transport

For the overlap with species range, the BE considers the aggregate of the six years (2013-2017) of available Cropland Data Layers (CDL) data for pesticide use categories to ensure the full footprint is captured for each use. For the Opinion, we bring forward the same analysis as is used in the BE. Terrestrial exposure concentrations are uniquely calculated for each species depending on relevant use overlap with the species range, application rates associated with these relevant uses and the dietary items, habitat and obligate relationships for that species. To provide a bounding of potential terrestrial EECs used in the effects determinations, EECs were calculated for the range of application rates for carbaryl (a minimum application rate of 0.45 lb a.i./A with 1 application per year and a maximum single application rate of 12.24 lb a.i./A) and are provided in the BE in Table 3-16. The BE summarizes the mean and upper bound dietary-based EECs and the associated base model that is used. However, EECs could be slightly higher with mid-range application rates applied multiple times. All uses for carbaryl and associated application rates are provided in the BE Appendix 1-3.

Terrestrial EECs and overlap values for exposure via spray drift at two distances: 0 meters (representing concentrations directly on use sites) and at 30 meters from the application site, as this the distance at which EPA determined there is an attenuation of the spray drift and the maximum distance at which they expect impacts to terrestrial invertebrates (i.e., the most sensitive taxa) based on available toxicity data. 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 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 carbaryl 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. We account for this overlap in use site treatment footprint by combining all use site and spray drift overlaps in our exposure analyses, which we discuss in more detail in the *Exposure* sub-section in the *Integration and Synthesis* section of this Opinion.

Mixtures

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. Formulated products containing carbaryl have been identified as part of this action and are shown in Table 1 (current registered products are the only formulated products available for carbaryl). 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 United States. 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.

While carbaryl may be tank mixed with other pesticides, there is no information available on the use of tank mixtures (e.g., what the composition of each tank mixture is, where tank mixtures are being used, how often they are used). Given the lack of available use and usage data on tank mixtures as well as the lack of tank mixture toxicity data, we limit our analysis to consider only the effects of carbaryl alone. However, available data on pesticide mixtures indicate that effects from exposure to one or more pesticide will result in an additive effect; that is, we do not expect that any toxic interactions will occur. In light of this, the National Academy of Sciences recommended in its 2013 *Report Assessing Risks to Endangered and Threatened and Species to Pesticides* that in the absence of data showing a synergistic (i.e., more than additive) response between a pesticide active ingredient and another mixture component, the analysis of effects should proceed on the assumption of additivity. Therefore, we consider that mixtures of pesticides with carbaryl, including tank mixes, will exert independent effects on species. Thus, given the lack of information to predict tank mixtures and our expectation that other pesticides will not enhance the effects of carbaryl, we do not further consider these mixtures in our analysis.

Factors to Determine Percent of the Population Exposed – Terrestrial Species

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 because concentrations of pesticides are known to attenuate further from the point of application on a use site. 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. 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, exposure was considered both on the use site and as a result of spray drift off site. If a species is only likely to travel through a use site and not forage within use sites. we primarily focused our analysis on dietary exposure from spray drift or other off-site transport. If a species was deemed unlikely to enter a use site, we did not consider effects from on-field exposure. Where data were lacking on whether 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 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 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.

Determining Percent of the Population Exposed – Aquatic Species

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. In addition, concentrations of carbaryl are not expected to accumulate in prey or other food resources, and as such, we do not expect significant exposure through this route. As such, 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 depend 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, EPA modeled different aquatic habitats. Aquatic exposures are quantitatively estimated for nine of the ten generic habitat types (Table 27), nine of which are aquatic, and one of which is a semi-aquatic habitat (or aquatic-associated terrestrial habitat).

Aquatic exposures (surface water and benthic sediment pore water) were quantitatively estimated for representative carbaryl uses included in the master use summary document by HUC 2 Regions (Figure 8) and by aquatic habitat using the Pesticide Root Zone Model (PRZM5) coupled to the Variable Volume Water Model (VVWM)[21] in the Pesticides in Water Calculator (PWC). The master use summary document for carbaryl includes over 700 use/formulation/application-type combinations. In order to limit simulations to a manageable number, grouping of uses into general categories was performed where possible (see BE Appendix 1-3). Within these use groups, as well as within non-grouped uses (*e.g*., golf courses), formulations and application methods were selected that were expected to generate maximum Estimated Environmental Concentrations (EECs). Thus, use/formulation/application methods that had the highest application rates and/or lowest retreatment intervals were generally chosen. Because even at a given application rate, spray drift and runoff loadings differ between aerial spray, ground spray, and dust applications, both ground and aerial spray (or dust) applications were also modeled, where applicable, for each use/formulation/application method combination. The maximum resulting EECs for each use/bin/HUC combination were then selected (*e.g*., for aerial vs. ground spray), and are assumed to represent exposures for all uses in the grouped category (*e.g*., both aerial and ground spray) for the relevant aquatic habitat/HUC combination. Ornamental direct applications to trees and spot treatments were not simulated.

For carbaryl, when using PWC, the EPA has relied on two standard waterbodies which they have traditionally used to estimate EECs for the various aquatic habitats. The standard farm pond was used to develop EECs for the medium and large static waterbodies and the index reservoir for the medium and large flowing waterbodies. For the smallest flowing and static bins, EPA derived Edge-of-Field estimates from the PRZM daily runoff file (See Section *Aquatic Habitats* of this Opinion).

The Service identified the representative aquatic habitats utilized by each listed species. A single species may occur in a range of habitats represented by multiple aquatic habitats. Aquatic habitat characteristics were defined by the Service to facilitate the estimation of pesticides in surface water for comparison to relevant toxicity endpoints for listed species assigned to the appropriate habitat, based on habitat requirements. Each habitat described below varies in depth, volume, and flow; Table 27 summarizes the characteristics of each habitat type. It should be noted that the same waterbody used in PWC may be used as a surrogate to represent multiple habitat types defined by the Service (e.g., the Edge-of-Field model to represent both low flow and low volume waterbodies).

- Aquatic habitat 1 is intended to represent riparian habitats or other land-based habitats adjacent to waterbodies that may occasionally be inundated with surface water (such as

[21] The exposure models can be found at: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment

wetlands) and provide habitat or influence the water quality for aquatic and semi aquatic organisms.

- Aquatic habitat 2, the low flow habitat, is intended to represent habitats with flow rates occurring of 0.001-1 meters^3/second.

- Aquatic habitat 3, the medium flow water body, is representative of small to large streams (1-100 meters^3/second).

- Aquatic habitat 4 and 7, the highest flow and highest volume aquatic habitats. Habitat 4 represents larger volumes and flow rates exceeding 100 meters^3/second) correspond with larger riverine habitats. Habitat 7 represents larger ponds or small lakes 100 x 100 meters

- Aquatic habitats 5 and 6 are relatively static, where flow is less likely to substantially influence the rate of pesticide dissipation are characterized by examples of low volume habitats (volumes <100 meters^3) such as vernal pools, small ponds, floodplain habitats that are cut off from main channel flows, and seasonal wetlands. Aquatic habitats with lower volumes correspond with many ponds, vernal pools, wetlands, and small shallow lakes and the high volume static aquatic habitat represents larger volume habitats such as lakes, impoundments, and reservoirs.

- Aquatic habitats 8 – 10, The aquatic habitats represented by intertidal near shore, sub tidal near shore, and offshore marine (as described in Table 27) 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 habitats as appropriate.

EPA and the Service[22] have assigned surrogate freshwater flowing or static systems to evaluate exposure for these estuary and marine bins. The aquatic habitat used as surrogate for pesticide exposure to species in tidal pools is aquatic habitat 8; aquatic habitats to represent exposure to species at low and high tide are habitats 8 and 9, and exposure to marine species that occasionally inhabit offshore areas are represented by habitat 10.

Table 27. Generic aquatic habitats.

Generic habitat	Width (meters)	Length (meters)	Depth (meters)	Flow (m3/second)	Waterbody used for Modeling
1 *(wetland)*	64	157	0.15	variable[23]	Custom

[22] This "standard farm pond" scenario assumes that rainfall onto a treated 10-hectare agricultural field causes pesticide-laden runoff into a one hectare water body which is 2-meters deep (total volume: 20,000 cubic meters).

[23] The depth and flow-rate in this waterbody are variable, depending on rainfall

Generic habitat	Width (meters)	Length (meters)	Depth (meters)	Flow (m3/second)	Waterbody used for Modeling
2 – *Low-flowing waterbody*	2	Field[24]	0.1	0.001	Edge-of-Field
3 – *Medium-flowing waterbody*	8	Field[21]	1	1	Farm Pond
4 – *High-flowing waterbody*	40	Field[21]	2	100	Farm Pond
5 – *Low-volume, static waterbody*	1	1	0.1	NA	Edge-of Field
6 – *Medium-volume, static waterbody*	10	10	1	NA	Farm Pond
7 – *High-volume, static waterbody*	100	100	2	NA	Farm Pond
8 – *Intertidal nearshore*	50	Field[21]	0.5	NA	Edge-of-Field
9 – *Subtidal nearshore*	200	Field[21]	5	NA	Farm Pond
10 – *Offshore marine*	300	Field[21]	200	NA	NA

NA = not applicable

Aquatic Exposure Modeling

The EPA relies on two standard conceptual model waterbodies which have been traditionally used to estimate pesticide concentrations in water using PWC. The standard farm pond is used to develop EECs for the medium and large static aquatic habitats (*e.g.*, habitats 6 and 7; Table 27) and the medium and large flowing habitats (*e.g.*, habitats 3 and 4; Table 27). For the smallest flowing and static bins (aquatic habitats 2 and 5; Table 27), EPA derived edge-of-field estimates from the PRZM5 daily runoff file (*i.e.*, the .tzts file) to be protective of concentrations in a headwater stream or a standing puddle that receives runoff at the edge of a treated field.

The U.S. Geological Survey (USGS) delineated watersheds in the United States based on surface hydrologic features classified by hydrologic unit. Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to twelve digits based on the level of classification

[24] The habitat being evaluated is the reach or segment that abuts or is immediately adjacent to the treated field. This habitat is assumed to run the entire length of the treated area.

in the hydrologic unit system (these levels range from region to subwatershed). The HUC-02 is the first level of classification and represents specific hydrologic regions distributed across 21 HUC-02 regions of the United States, eighteen of which are within the conterminous 48 states (CONUS; Figure 8). The EPA conducted surface water aquatic modeling with the HUC-2 regional Pesticide in Water Calculator (PWC) scenarios matching the registered uses. The PWC uses soil, hydrology, land cover/land use, weather, and waterbody properties to simulate environmental conditions. This is described in more detail in the Exposure Section of the BE.

The EPA grouped non-commodity (*i.e.*, crops other than corn, wheat, soybeans, sugarcane, and cotton) crops based on agronomic practices to reduce the level of uncertainty in the spatial footprint for individual minor crops. The EPA selected a single 90th percentile scenario for each crop/group of crops within each hydroregion or subregion where the crop is present, based on CDL data, for a total of up to 21 scenarios to represent each group of crops on a national scale. Since pesticides with different soil organic carbon normalized sorption coefficient (K_{OC}) values will behave differently in the different scenarios and what is vulnerable for one set of chemicals may be different for another, EPA selected separate sets of 90th percentile scenarios to represent chemicals based on three ranges of K_{OC} values. The scenarios were developed, analyzed, and ranked using an automated methodology to identify the 90th percentile vulnerability scenario within each National Hydrography Dataset Hydroregion (NHDPlus HR)[25]

Beyond 30 meters, EPA assumes the runoff becomes concentrated (channelized) into rivulets, gullies, etc., which are represented by the wetland plant exposure zone (WPEZ). The WPEZ is intended to represent a non-target wetland or aquatic plant community that is exposed to pesticide via overland flow and spray drift. The wetland can be immediately adjacent to the treated field or some unspecified distance away. The WPEZ is intended to represent any plant community that can exist in a saturated to flooded environment (e.g., a depression or shallow wetland that would collect and hold runoff from an upland area) and would receive all the runoff from an adjacent treated field.

In addition to the TPEZ and WPEZ analyses that are specific to PAT, PWC calculates exposure estimates in the aquatic plant exposure zone (APEZ) using the standard farm pond assumptions (i.e., runoff and spray drift from a 10-hectare field into a 2 meter deep 1-hectare pond) to represent exposure concentrations in aquatic environments that could receive runoff and spray drift from the treated field.

For the carbaryl cranberry uses, the EPA used the Pesticides in Flooded Applications Model (PFAM, version 2.0). PFAM was developed specifically to estimate exposure to pesticides used in flooded agriculture, such as rice paddies and cranberry bogs. The model simulates two linked compartments when the field is flooded: a water column and a sediment zone (benthos). The model accounts for hydrolysis, photolysis, and metabolism in water, sediment, and soil (when no water is present), sorption, and volatilization. The model considers the environmental fate

[25] The NHDPlus HR is a national, geospatial model of the flow of water across the landscape and through the stream network. The NHDPlus HR is built using the National Hydrography Dataset High Resolution data at 1:24,000 scale or better, the 1/3 arc-second (10 meter ground spacing) 3D Elevation Program data, and the nationally complete Watershed Boundary Dataset (https://www.usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution#WhatIsIt).

properties of pesticides and allows for the specification of common management practices associated with flooded agriculture, such as scheduled flooding and water releases. Water, sediment, and pesticide may flow out of the flooded field, particularly upon deliberate water release. Changes in water body conditions (temperature, water levels, wind speed, etc.) and resulting changes in degradation rates are simulated on a daily time step. Pesticide application and flooding sequences are mapped onto the time series in 1-year cycles for the duration of a 30-year simulation.

Cranberries may be grown in bogs that are temporarily, deliberately flooded to control pests, prevent freezing, and/or to facilitate harvest. After flooding, water may be held on site, recirculated to other cranberry growing areas, or released to adjacent waterbodies (rivers, streams, lakes, etc.). For cranberries, a 12-inch flood was modeled on October 1, followed by draining of the bog on October 4th. A winter flood was also simulated. The modeled flood date was selected as a plausible date of harvest.

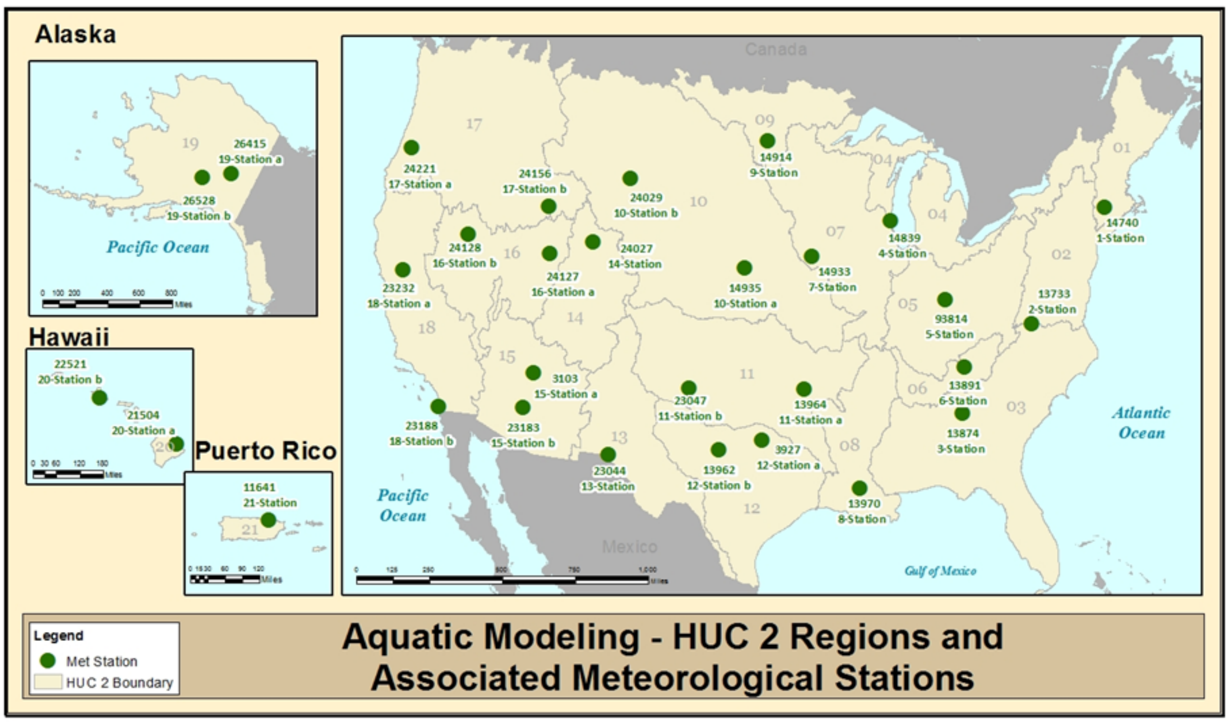

Figure 8. Hydrologic Unit Code (HUC) 2-digit Regions and Associated Metrological Data.

Estimated Environmental Concentrations (EECs) for Aquatic Habitats

We delineated aquatic species ranges by HUC12s (subwatershed) and based exposure of aquatic species to carbaryl on the overlap of carbaryl use sites with the HUC12(s) that comprised their ranges. For the static-water habitats and the smallest flowing-water habitats within HUC12s, EECs are calculated for each overlapping use site (e.g., corn, vegetables, and groundfruit). We modeled each use as if the water body was immediately adjacent to the site (i.e., edge of field). However, the medium and large streams/rivers) were modeled at the subwatershed/HUC12 scale (USEPA, 2017a). The EECs derived from the PWC modeling based on maximum labeled rates included in the master use summary document are summarized for the various aquatic habitats in Table 3-5 and Table 3-6, for water column, respectively in the BE. The complete set of modeling inputs and results are available in Appendix 3-1 of the BE.

Proximity to Pesticide Use Sites

The likelihood that individuals will be exposed to carbaryl 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), and we considered this information qualitatively. Where this information was not available, 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 of low flow and volume or large volume, 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 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 aquatic habitats were modeled at the subwatershed scale.

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 of 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.

Aquatic Exposure Assessment

As mentioned above, we carried forward EECs generated for the BE into the Opinion. The 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 from the 30-year annual time series (1-day time step) generated for each pesticide use/scenario/HUC2/aquatic habitat combination. The 1-in-15-year exposure concentrations are estimated using the daily time series of estimated concentrations from 30-year PRZM5/VVWM simulations, to be consistent with the length of the action (15 years), based on the registration review cycle. In this manner, the generation of the EECs is based on probabilistic methods. We incorporate a maximum from these scenario values to establish an upper bound for EECs within the aquatic habitat a species may be found in within its range.

Plant-specific Exposure Factors

Based on our review of the possible effects of the action to plant species covered under this consultation, we assume 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 carbaryl to potential insect pollinators and the dependence of many plants on insect pollinators for successful reproduction.

<u>Routes of Exposure for Pollinators</u>

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 carbaryl 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).

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

Listed cave-dwelling organisms consist of terrestrial invertebrate species (cave arachnids and beetles), crustaceans (cave amphipods), and fish. These species may be exposed to pesticides in water from over land flow or leaching from soil from agricultural practices over or near lava tubes, sinkholes, karst systems, or other porous features near the surface of cave habitats. However, the environmental fate, transport, and physicochemical properties of carbaryl are such that it is not mobile enough in soil matrices or water, or persistent enough in the environment where it would be able to remain at levels toxic enough from run-off of fields after application and to impact cave species or contaminate their dietary items outside of caves. This is due to the time scale of recharge of karst cave systems, or the process of aboveground water reaching the groundwater supply. This will often take several days to weeks to months, at which point we expect carbaryl to be degraded and no longer present in the water that enters the cave.

Carbaryl may enter the environment via spray and spray drift as well as run-off onto soil, foliage, and/or water. Carbaryl is moderately soluble in water with a reported solubility range of 23 to 120 mg/L (USEPA, 2003a; USDA Forest Service, 2008) and we know that its presence in run-off water has been detected from field application monitoring studies (Walters, et al., 2003) measured residues of carbaryl in surface water after application of carbaryl to trees, shrubs, and herbaceous plants in residential areas to control the glassy-winged sharpshooter (*Homaladosica coagulata*) in Porterverille, Fresno, Rancho Cordova, Brentwood, and Chico, California. Applications of carbaryl were made with a truck mounted sprayer following rates recommended on labels to areas ranging from 24 to 2,300 hectares. Surface water samples were collected from various waters near applications or adjacent to treated areas. No detections of carbaryl were observed in pretreatment samples collected from the same sites. Carbaryl was detected at 0.125 µg/L in a water treatment basin, at 6.94 µg/L in a goldfish pond, and 1,737 µg/L in a rain runoff sample collected from a drain adjacent to a sprayed site.

Aerobic soil metabolism and aerobic and anaerobic aquatic metabolism data indicate carbaryl is not considered persistent, with half-lives 4 to 253 days depending on soil and water conditions. Carbaryl degrades more slowly in anaerobic aquatic soil, with an estimated half-life of 72 days (USEPA, 2017b). Half-lives of carbaryl exhibit a monotonic decrease with increasing pH that is consistent with study results showing the chemical to be susceptible to hydrolysis under alkaline, but not acidic, conditions. The wide range in observed aerobic soil half-lives is a consequence of the variability in pH among the tested soils. Under anaerobic soil conditions, carbaryl has a half-life of 72 days. Overall, carbaryl is not persistent in soil due to multiple degradation pathways including hydrolysis, photolysis, and microbial metabolism. Microbes play a significant role in the degradation of carbaryl in soil (Xu, 2003). In addition, little transport of carbaryl through runoff or leaching to groundwater is expected due to the combination of moderate water solubility, moderate sorption, and rapid degradation in soils. There are no reports of carbaryl detection in groundwater, and less than 1% of carbaryl applied to a sloping plot was detected in runoff (Caro, Freeman, & Turner, 1974).

Karst systems are known to have enhanced porosity and permeability and are therefore susceptible to pesticide contamination that could be present in run-off water (Vesper, Loop, & White, 2000). While run-off water is likely to contain carbaryl from field applications of carbaryl, it is not likely to reach karst systems from the surface waters and enter the subterranean habitats where many listed cave species reside (cave arachnids, cave crustaceans, and cave fish) because carbaryl is not likely to persist very long (as mentioned above) after it has traveled from the surface and into karst cave reaches.

Lava tubes are a different type of cave system formed from lava flow and present in Hawai‘i where there are two listed cave invertebrates (Kaua‘i cave spider and Kaua‘i cave amphipod). The water table in lava tubes generally lies much deeper and below the lava layer (Kiernan & Middleton, 2005) and therefore is not likely to retain carbaryl from surface flow. The main energy sources in Hawaiian lava tubes are plant roots, especially Ohia-lehua, slimes deposited by percolating ground water, and animals that die and get washed in or fall in (Howarth, 1983). Plants are not adversely impacted by exposure to carbaryl and surface-derived nutrients from carcasses are also not likely to accumulate or be adversely impacted by carbaryl.

Carbaryl is predominantly present in the water column and to a lesser extent, bound to sediments based on measured octanol-water partition coefficient (log $K_{ow} = 2.4$) and K_{oc} (153). These values indicate exposure to sediment-dwelling organisms is likely to occur but to a lesser extent as compared to organisms in the water column. The low octanol/water partition coefficient also suggests that the chemical will have a low tendency to accumulate in aquatic and terrestrial organisms and is further supported by bioconcentration studies with results indicating these values are low with values less than 15 (USDA Forest Service, 2008) and thus does not occur in fish and invertebrates (Howard, 1991). Other evidence indicates carbaryl does not accumulate in plants either (Nash, 1974). Thus, we do not anticipate water entering cave systems will contain carbaryl because it will degrade before it enters the cave depths, nor will it accumulate in organisms that cave species may utilize as prey inside cave systems. In addition, it will not accumulate in terrestrial organisms that may be external food sources for cave species.

Cave dwelling organisms may also feed on dietary items near the cave entrance. 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; Howarth, 1983) 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. However, we do not anticipate that cave-dwelling organisms that forage on guano will be exposed to as it does not bioconcentrate or bioaccumulate.

Terrestrial field dissipation studies were conducted at two locations, one in California and one in North Carolina as cited in: (IPCS, 1994). Data showed that most residues remain in the first 0-0.15 m of soil, with only one finding in the layer of 0.3-0.45 m. The dissipation half-lives of carbaryl were estimated to be from 0.76 to 10.9 days. Other terrestrial field dissipation data show carbaryl dissipation half-lives of 62 to 116 days in the upper 30 cm of the soil profile (USEPA, 2017b). In a forestry dissipation study, half-lives ranged from 21 days on foliage, 65 days on soil, to 75 days in leaf litter (USDA Forest Service, 2008). Thus, providing further evidence that carbaryl is likely to dissipate before it reaches cave depths regardless of the cave type (karst or lava tube) and is dependent on the soil moisture content.

In summary, we do not anticipate that direct application or drift from carbaryl would be likely pathways for cave species when they are in subterranean habitats. Nor do we anticipate cave species would be exposed to carbaryl from contaminated food sources entering the cave or leaching through porous substrate, such as karst or lava tubes.

Usage Analysis

The overlap information above describes the footprint of the carbaryl use based on the product label and any off-site transport. We apply usage data to describe how the pesticide has been applied in the past to use sites based on available data sources. The key difference between use and usage is that use data extends to all carbaryl uses authorized by EPA, whereas usage refers to how carbaryl has been actually applied on the landscape. To determine effects to listed species, we employ usage data to refine the scope of analysis from any area where carbaryl is authorized to be applied, to those areas where carbaryl applications are reasonably certain to occur. While we recognize that past usage data may not fully predict future usage, we believe this information better informs where we would expect usage to occur in the future and provides more context for our assumptions related to uncertainty.

As part of its BE and supplemental submissions, EPA provided the following usage information:

- National and State Use and Usage Summary for Carbaryl
- USDA Census of Agriculture (CoA) data for CONUS species
- USDA Census of Agriculture data for Puerto Rico
- California Department of Pesticide Regulation Pesticide Use Reporting data

We briefly describe each data source and how it was applied in our analysis below.

EPA's Carbaryl National and State Summary Use and Usage Matrix (SUUM; Appendix 1-4 in the BE)

Data provided in EPA's Use and Usage Summary for agricultural crops are obtained by EPA from USDA, the state of California, and a commercial source (Kynetec), as described in more detail in the BE. Analysis of this data by EPA indicated there has been an overall decreasing trend in agricultural usage of carbaryl between 1999 – 2017, with pounds applied and total acres down by approximately 70% during that period. Most of the data provided for states outside of California describing past agricultural usage of carbaryl 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. The Kynetec data are provided at the state level and indicate how many acres of a crop has been treated with carbaryl over a 5-year period (2013 – 2017). 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 carbaryl is registered, and do not address every state in which surveyed crops are grown. In addition, 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. However, in a previous analysis of usage data, we did not find other data sources that would broadly inform our understanding of agricultural usage of pesticides on a nationwide scale (USFWS 2022). As such, we consider these data as our primary source of agricultural usage data for all CONUS states except for California, as described further below. We employed the conclusions from our 2022 analysis to inform our application of these data to our analysis of carbaryl usage in these states. In short, our analysis of various data usage sources led us to adopt a conservative approach when applying this survey data to better ensure that we capture the extent of usage occurring within states. Specifically, we consider the percent of a species' range treated with carbaryl using EPA's "upper maximum" scenario, which compares the total number of acres treated within a state to the total number of acres in the range of the species (see BE Appendix 1-7). In addition to using the maximum yearly usage across 5 years, this method assumes a 2.5% PCT for crops that were surveyed and no usage was reported to buffer against the uncertainty associated with these surveys and low usage estimates. Carbaryl usage data are not available for Pacific and Caribbean islands, Hawai'i and Puerto Rico. We discuss our methods for estimating usage on these islands below. USDA's Census of Agriculture (CONUS species) USDA's Census of Agriculture (CoA) is a complete count of United States farms and ranches that includes any plot of land, whether rural or urban, if $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year. The Census of Agriculture is conducted once every five years, looks at land use and ownership, producer characteristics, production practices, income, and expenditures. Response to Census of Agriculture is required by federal law and is therefore considering mandatory reporting data. As part of the data requested from operators, respondents report the number of acres treated with insecticides that year. In summarizing the data collected, USDA analyzes and reports results at the national, state, and county level. In its analysis of CONUS species, EPA used the 2017 CoA data to estimate the number of acres treated with insecticides within counties that overlapped with the ranges of listed species, and then compared that with the total number of acres in the species' range. EPA did not provide estimates of the percent of the range treated for every CONUS species, rather they reported when the number of total acres treated within the range of the species was <5% of its range. As this percentage reflects usage of all insecticides, and not just carbaryl, we consider this as an additional line of evidence, when appropriate, as an upper bound for carbaryl usage.

USDA's Census of Agriculture for Pacific and Caribbean Islands

Since carbaryl is not registered for agricultural use in the Pacific Islands, no usage analysis was performed. For Caribbean islands (including Puerto Rico and the U.S. Virgin Islands), we reviewed available usage data and concluded that there are no comprehensive, chemical-specific usage data that are suitable for incorporating quantitatively. In the absence of carbaryl specific usage data, we consider CoA data provided by EPA for Puerto Rico to define the proportion of agricultural areas where insecticides may be applied. For Puerto Rico, data are reported at the municipality level (municipio) from the 2018 CoA report and range from 20-70% of crops treated with insecticides across 60 municipalities. We use these data broadly as confirmation that insecticide usage occurs on these islands, with carbaryl presumably among these insecticides. In all cases, which we consider these values to be an upper bound for carbaryl usage.

California Department of Pesticide Regulation Pesticide Use Reporting (CalPUR)

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. Information is publicly available and can be downloaded from their website[26]Because of the robust nature of this data set, we exclusively apply CalPUR data to estimate agricultural usage for species wholly within California, based on information provided by EPA (USEPA, 2024a). For these species, EPA used a three-tiered approach to characterize potential exposure of Service listed species to carbaryl, calculating the extent that each species' range overlapped with any pesticide usage, any insecticide usage, or carbaryl only usage for the years 2013 - 2022. We used the maximum yearly value to estimate future usage for these species, as described further in (USEPA, 2024a). In general, we considered the carbaryl-only overlap in our species-specific analyses. This value represents high maximum single year overlap of treated areas with the species' range over the 10-year period. However, in instances where the sample size is very small (there are few pesticide reporters within the range), this value will have greater uncertainty and we may consider one of the higher tier values reported by EPA, such as usage of all insecticide with the range. This value is considered a more protective estimate as it is likely to account for the possibility that users may switch their insecticide choice to carbaryl within the time frame of the registration review. The overlap metric that considers any pesticide usage within the range is the most conservative value provided by EPA and will likely overestimate carbaryl usage as it includes usage from other pesticide classes such as herbicides and fungicides.

Federal Lands

Federal lands cover about 640 million acres, which equates to 28% of land in the United States. Of these federal lands, 65% are managed by DOI agencies, 30% by the U.S. Forest Service, 2% by the Department of Defense, and 3% by other federal agencies (Congressional Research

[26] http://www.cdpr.ca.gov/docs/pur/purmain.htm

Service, 2020). DOI land management agencies (the Service, National Park Service, and Bureau of Land Management) and the U.S. Forest Service 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 coordinates the exchange of information on all matters related to pest management throughout the Department of Defense (AFPMB, 2020).

We expect pesticide use on federal lands for a variety of reasons, including invasives control and the protection of human health. Carbaryl is registered for use on both agricultural crops and non-agricultural uses. While we recognize that some federally managed lands may contain agriculture, we expect these areas to account for a small percentage of these areas and that carbaryl usage will be limited. For instance, cooperative agriculture is a long-standing practice on National Wildlife Refuges (NWRs) in which the Service partners with farmers to meet wildlife management objectives. A search of the Service's Pesticide Use Proposal System (PUPS) database indicated that carbaryl usage or subsequent applications of carbaryl have occurred between the years 2013-2023 (Table 28). While a subset of these applications occurred on cropland within NWRs, many applications were performed for conservation purposes, using carbaryl as a tool in listed species protection and recovery to control invasive and/or disease-carrying pests such as fire ants, ticks, and fleas. Table 28 below indicates the year of usage of carbaryl, the specific carbaryl product and the context of application on the NWRs indicated. Several years had several NWRs where carbaryl was applied thus totals for that year are indicated. The different NWR locations where applications were made are also included.

Table 28. Pesticide Use Proposal System Query for Carbaryl Use on National Wildlife Refuges from 2013 – 2023.

Field Station	***Year***	***Trade Name***	***Trade Name lbs Applied (total for the year)***	***Acres Treated (total for the year)***
SOUTHWEST LOUISIANA REFUGES COMPLEX CENTRAL LOUISIANA REFUGES COMPLEX CLARKS RIVER NATIONAL WILDLIFE REFUGE NORTH MISSISSIPPI REFUGES WHEELER NATIONAL WILDLIFE REFUGE CHOCTAW NATIONAL WILDLIFE REFUGE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE MADISON WETLAND MANAGEMENT DISTRICT KLAMATH MARSH NATIONAL WILDLIFE REFUGE MINGO NATIONAL WILDLIFE REFUGE ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE PEE DEE NATIONAL WILDLIFE REFUGE	**2013**	Sevin XLR Plus Carbaryl 4L Hi-Yield 5% Carbaryl Garden & Pet Dust Sevin-5 Ready-To-Use 5% Dust Bug Killer Eco Bran Ultra 5% Carbaryl 5% Bait	**10**	**2.6**
WHEELER NATIONAL WILDLIFE REFUGE CLARKS RIVER NATIONAL WILDLIFE REFUGE PEE DEE NATIONAL WILDLIFE REFUGE SOUTHWEST LOUISIANA REFUGES COMPLEX ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE CHOCTAW NATIONAL WILDLIFE REFUGE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE MADISON WETLAND MANAGEMENT DISTRICT MINGO NATIONAL WILDLIFE REFUGE KLAMATH MARSH NATIONAL WILDLIFE REFUGE NORTH MISSISSIPPI REFUGES	**2014**	Sevin XLR Plus Carbaryl 4L Hi-Yield 5% Carbaryl Garden & Pet Dust Sevin-5 Ready-To-Use 5% Dust Bug Killer Eco Bran Ultra 5% Carbaryl 5% Bait	**233.2**	**3,934.2**
ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE CHOCTAW NATIONAL WILDLIFE REFUGE CLARKS RIVER NATIONAL WILDLIFE REFUGE KLAMATH MARSH NATIONAL WILDLIFE REFUGE SOUTHWEST LOUISIANA REFUGES COMPLEX WHEELER NATIONAL WILDLIFE REFUGE	**2015**	Sevin XLR Plus Sevin-5 Ready-To-Use 5% Dust Bug Killer Carbaryl 5% Bait Hi-Yield 5% Carbaryl Garden & Pet Dust	**16.1**	**16.5**
ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE CHOCTAW NATIONAL WILDLIFE REFUGE KLAMATH MARSH NATIONAL WILDLIFE REFUGE PEE DEE NATIONAL WILDLIFE REFUGE SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE TALLAHATCHIE NATIONAL WILDLIFE REFUGE WHEELER NATIONAL WILDLIFE REFUGE	**2016**	Sevin XLR Plus Sevin-5 Ready-To-Use 5% Dust Bug Killer Carbaryl 5% Bait Hi-Yield 5% Carbaryl Garden & Pet Dust Sevin Concentrate	**32.8**	**35.8**

Field Station	*Year*	*Trade Name*	*Trade Name lbs Applied (total for the year)*	*Acres Treated (total for the year)*
		Carbaryl 4L		
ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE CHOCTAW NATIONAL WILDLIFE REFUGE MINGO NATIONAL WILDLIFE REFUGE PEE DEE NATIONAL WILDLIFE REFUGE PIEDMONT NATIONAL WILDLIFE REFUGE SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE WHEELER NATIONAL WILDLIFE REFUGE	**2017**	Sevin XLR Plus Sevin-5 Ready-To-Use 5% Dust Bug Killer Carbaryl 5% Bait Hi-Yield 5% Carbaryl Garden & Pet Dust Carbaryl 4L	**70.3**	**34.2**
ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE CHOCTAW NATIONAL WILDLIFE REFUGE MINGO NATIONAL WILDLIFE REFUGE PEE DEE NATIONAL WILDLIFE REFUGE SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE WHEELER NATIONAL WILDLIFE REFUGE	**2018**	Sevin XLR Plus Sevin-5 Ready-To-Use 5% Dust Bug Killer Carbaryl 4L	**12.1**	**15.3**
ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE CHOCTAW NATIONAL WILDLIFE REFUGE GUAM NATIONAL WILDLIFE REFUGE MINGO NATIONAL WILDLIFE REFUGE NORTH MISSISSIPPI NATIONAL WILDLIFE REFUGES SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE WHEELER NATIONAL WILDLIFE REFUGE	**2019**	Sevin XLR Plus Sevin-5 Ready-To-Use 5% Dust Bug Killer Hi-Yield 5% Carbaryl Garden & Pet Dust Carbaryl 4L	**11.4**	**16,523.5**
ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE CHOCTAW NATIONAL WILDLIFE REFUGE GUAM NATIONAL WILDLIFE REFUGE MINGO NATIONAL WILDLIFE REFUGE SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE WHEELER NATIONAL WILDLIFE REFUGE	**2020**	Sevin XLR Plus Sevin-5 Ready-To-Use 5% Dust Bug Killer Carbaryl 5% Bait Hi-Yield 5% Carbaryl Garden & Pet Dust Carbaryl 4L	**6.2**	**8.5**
ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE GUAM NATIONAL WILDLIFE REFUGE MINGO NATIONAL WILDLIFE REFUGE POCOSIN LAKES NATIONAL WILDLIFE REFUGES SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE WHEELER NATIONAL WILDLIFE REFUGE	**2021**	Sevin-Ready-To-Use Spray Hi-Yield 5% Carbaryl Garden & Pet Dust Sevin XLR Plus Carbaryl 4L	**61**	**3,634.7**

Field Station	Year	Trade Name	Trade Name lbs Applied (total for the year)	Acres Treated (total for the year)
ATTWATER PRAIRIE CHICKEN NATIONAL WILDLIFE REFUGE GUAM NATIONAL WILDLIFE REFUGE POCOSIN LAKES NATIONAL WILDLIFE REFUGES SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE WHEELER NATIONAL WILDLIFE REFUGE	**2022**	Sevin-Ready-To-Use Spray Hi-Yield 5% Carbaryl Garden & Pet Dust Sevin XLR Plus Carbaryl 4L Sevin-5 Ready-To-Use 5% Dust Bug Killer	**128.5**	**99**
BOSQUE DEL APACHE NATIONAL WILDLIFE REFUGE GUAM NATIONAL WILDLIFE REFUGE NORTH CAROLINA COASTAL PLAIN REFUGE COMPLEX SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE WHEELER NATIONAL WILDLIFE REFUGE	**2023**	Sevin-Ready-To-Use Spray Sevin XLR Plus Carbaryl 4L Sevin-5 Ready-To- Use 5% Dust Bug Killer	**90.3**	**60.6**

As such, we anticipate carbaryl usage in these areas will continue to be low, as we do not have any information suggesting that future usage is expected to increase. Where information suggests that agriculture may be present in other federally managed lands within a species range, we consider this on a case-by-case basis. Where no information indicates that agriculture represents a significant influence in these areas, we assume that use of carbaryl on federal lands will be low over the duration of the proposed action, and only occur in very localized areas as needed.

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 is 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 proposed 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 proposed 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 carbaryl, may occur to address new or emerging pest pressure (e.g., mosquitoes and other pests) in agricultural and non-agricultural settings. We anticipate some use of pesticides, including those in addition to carbaryl, may be used directly or indirectly to benefit listed species or their critical habitats. For example, future pesticide use is anticipated 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 carbaryl to specifically benefit listed species, we anticipate that carbaryl or other pesticides may be used in the action area for this purpose over the life of the proposed action. Where implemented with appropriate avoidance and minimization measures to reduce the potential for lethal, sublethal, 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 bases, 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 proposed action is likely to jeopardize any of the proposed, candidate, or listed species considered in this consultation. We also consider whether the proposed action is likely to destroy or adversely modify designated and proposed critical habitat. In the *Integration and Synthesis* section, we consider the effects of the proposed 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 of the *Environmental Baseline*, *Status of the Species and Critical Habitat*, *Cumulative Effects* (together "Background Information"), and *Effects of the Action* sections. 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 C (for each species) and Appendix D (for each critical habitat designation), as applicable.

Overall Considerations for the Opinion

The proposed action is the registration review of carbaryl, which authorizes all the uses of the pesticide per the products labels. None of the registered formulated products are restricted use products, meaning these products may be purchased and used by anyone; no training or licensing is required. As the proposed action is the approval of labels containing the active ingredient carbaryl, once approved, these labels become the law and are legally enforceable. The proposed registration review 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, associated restrictions, and guidance for that use. Proposed registration review labels have guidance that generally use terminology that is considered advisory or recommended, and these proposed registration review labels do not serve as enforceable restrictions until the technical registrants have committed to implementing them. 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. Listed 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.

Agricultural Uses

We and EPA are aware that there are often general trends and patterns related to agriculture, 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 carbaryl 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 analysis that considers use sites (by land use type) with labeled uses specific to carbaryl, and by calculating estimates of anticipated carbaryl usage, as described previously in the *General Effects* section of this Opinion. We find pesticide usage datasets are collected for very different purposes than addressing the limits of overlap of carbaryl 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, to better identify carbaryl use sites and gauge 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 carbaryl. 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 carbaryl will be used in all the areas it is authorized to be applied under the label over the duration of the proposed action. As we must also consider what effects are reasonably certain to occur, we considered the best available scientific and commercial data for usage to better predict the consequences from the proposed 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 adverse 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 adverse 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 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 carbaryl 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 is 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.

Non-Agricultural Uses

Carbaryl has several registered non-agricultural uses, including use sites within developed, open space developed, nurseries, rangeland, managed forests, and rights of way UDLs. UDLs for non-agricultural uses tend to be less defined than those for agricultural UDLs and may not accurately represent the actual footprint of these use sites on the landscape. As such, we assess exposure of species to non-agricultural uses of carbaryl in a qualitative manner by considering the life history of species, methods of application, available past usage data, and any existing conservation measures to reduce drift and runoff or otherwise limit exposure to species. When available, we incorporate additional past usage data for specific use patterns to further contextualize the level of usage we expect is reasonably certain to occur over the duration of the proposed action.

Developed, Open Space Developed, and Nurseries UDLs: Carbaryl is registered for a number of uses that fall in the developed, open space developed, and nurseries UDLs, such as residential buildings, lawns, turf, and ornamental plants. Given the expansive presence of human development across the national landscape, we anticipate most listed species' ranges contain at least some developed or open space developed use sites. Available usage data indicate that there is generally a low level of past usage within these use sites, with conservative estimates of 0.21-3.1% of all treatable areas likely to be treated with carbaryl annually. While this is a low level of usage, this may still represent a large treatment area for a listed species depending on how prevalent developed, open spaced developed, or nursery use sites are within its range. In addition to the general low level of expected usage, there are a number of existing conservation measures that are likely to influence a listed species' likelihood for exposure to this use category. As a result of the 2022 FIFRA Proposed Interim Decision and the 2024 NMFS Biological Opinion for carbaryl, most residential and developed area uses of carbaryl are limited to spot and crack treatments (defined as a 2 ft^2 area), crack-and-crevice treatment, or narrow perimeter bands around urban structures (from 1 inch to 6 feet) using hand-held equipment. This limitation in application restriction greatly reduces the extent of area that can be treated in the developed and nurseries UDLs and renders off-site spray drift unlikely, reducing the likelihood of exposure to species that occur near developed areas. In contrast, species that are specifically attracted to residential areas (e.g., pollinators attracted to ornamental plant species) or species occurring on open space developed areas (like lawns, turf areas, golf courses) may still experience high levels of exposure.

We assess each listed species' life history traits, known locations, habitat preferences, and known behaviors to determine whether a species is likely to occur in or near developed, open space developed, or nursery use sites. In cases where a listed species is likely to occur in these use sites, we qualitatively assess the level of anticipated exposure based on available information on the species and possible usage trends in the areas relevant to the species.

Managed Forests: Carbaryl is registered for use in managed forests. Available data on past usage from the USFS indicate that very little of the total treatable area has been treated with carbaryl in the past. From 2016-2020, USFS has treated 322 acres of forests in California for gold spotted oak borer control and 557 acres of forests spread across 10 western states (in parts of North Dakota, Montana, South Dakota, Idaho, Kansas, Nebraska, Colorado, Wyoming, Utah, and Nevada) for bark beetle control. We anticipate listed species that use forested habitat that do not occur in these states are not likely to be exposed to carbaryl through this use pattern. In cases where a listed species' range occurs within the states where USFS has recently applied carbaryl, we qualitatively assess the level of exposure anticipated to occur to the species based on available information on treatment areas and application methods.

In general, forestry uses of carbaryl represent only a small treatment footprint. USFS treatments in California are limited to small oak woodlands using ground-based sprayers targeting tree trunks and low branches. Treatments made for bark beetle control are typically less than one acre in size and are made using hand-held equipment in highly visible areas of USFS properties (such as parks, recreation areas, campgrounds, and visitor's centers) where listed species are not expected to occur. While these applications may result in off-site transport, we anticipate the inherent physical features of the forests where applications are made would reduce the level of off-site transport. For example, we anticipate spray drift from hand-held equipment and ground sprayers will not travel very far from application sites with the majority of residues depositing within a few meters of the application site. We expect that the trees within a forest setting act as natural wind breaks, providing a high level of interception of any remaining carbaryl residues suspended in air, and further reducing transport and exposure of listed species habitat adjacent to treatment sites. Similarly, we anticipate that the inherent topography, soil characteristics, and root structure of forested areas would reduce the amount of runoff likely to occur in forested areas.

Rangeland: Carbaryl uses in rangelands are currently registered for use. Available usage data from the U.S. Department of Agriculture's Animal and Plant Health Inspection Service's (USDA APHIS) Mormon cricket and grasshopper suppression program indicate that, from 2019-2023, carbaryl has only used to control for rangeland pest species in select states (including Arizona, Idaho, Montana, Nevada, Utah, Washington, and Wyoming). We anticipate listed species that use rangeland habitat that do not occur in these states are not likely to be exposed to carbaryl through this use pattern. In cases where a listed species' range occurs within the states where USDA APHIS has recently treated rangeland habitat with carbaryl, we qualitatively assess the level of exposure anticipated to occur to the species based on available information on treatment areas and application methods.

With the exception of one application made in Johnson County, Wyoming, in 2020, all of USDA APHIS's applications of carbaryl have been in the form of formulated bait. We do not anticipate bait applications are likely to result in spray drift or significant levels of runoff, suggesting that off-site transport and off-target exposure is not likely to occur at significant levels. Additionally, there are a number of existing conservation measures regarding USDA APHIS's use of carbaryl as part of the Mormon cricket and grasshopper suppression program (USFWS 2024). Examples of measures included a reduced agent area treatment strategy that minimizes the amount of pesticide applied within a treatment block, allowance of only one application per year, reduced application rates, minimized treatment area size within 500 feet and 1,000 feet from listed species ranges for ground and aerial applications, respectively, and extended application buffers when applications are made near the listed species' habitat (e.g., up to 750 feet for some ground applications and up to a mile for some aerial applications). We incorporate these conservation measures as appropriate when assessing the potential for this use pattern to exposing listed species.

Rights of Way: Carbaryl use in rights of ways is currently a registered use. Many listed species are known to occur in rights of ways areas, including along roadsides, maintenance routes, and other transition areas. Available data on past usage for this use type is sparse as insecticide usage in many types of rights of way is so low that non-agricultural market research data do not include surveys for insecticide usage in certain types of rights of way at all (such as for rail and electrical rights of way). Available data on carbaryl usage in other types of rights of way (i.e., roadways) indicate that less than 500 lbs of carbaryl are applied nationwide each year, which EPA conservatively estimates can treat up to 2,000 acres/year (less than 0.000018% of all treatable roadway right of way acres) (USEPA 2021). While this level of usage may result in a large treatment footprint if all rights of way usage were concentrated in one location or within one species' range, we expect this is highly unlikely to occur and rather expect that usage in rights of way is likely to be sporadic across the national landscape, with only small amounts of carbaryl will be used within a single species' range. In cases where a listed species is known to frequent or occur in rights of ways areas, we qualitatively assess the anticipated level of exposure from this specific use pattern using available knowledge of the species' distribution, habitat preferences, life history traits, and any other relevant information that may inform a species' use of these areas or the likelihood of specific rights of way use sites to be treated with carbaryl.

Overview of Integration and Synthesis Analyses

We considered the consequences to candidate, proposed, and listed species from the proposed action in the context of the species background information (i.e., *Status of the Species*, *Environmental Baseline*, *Cumulative Effects*, and when applicable, *Designated Critical Habitat*). 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 proposed action, as we reviewed the background information about the species and the anticipated consequences of the proposed action, we observed patterns in both species considerations (e.g., life history traits, habitat preferences, feeding behaviors, etc.) 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 (e.g., terrestrial vs. aquatic snails, families of mussels, sea turtles or marine mammals) or habitat groups (e.g., cave systems) exist, we considered them simultaneously in the integration and synthesis analysis to streamline our discussion by avoiding repeating our findings when species are affected similarly. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species, including those species in the grouped analyses, and are presented in full in Appendices B and E. We discuss this approach in greater detail in the *Species Grouping* subsection further below in this Opinion.

The rationale for our conference opinion[27] for proposed species and proposed critical habitat designations are included in this section and its appendices. We applied the same approach used for listed species and designated critical habitats for proposed species and proposed critical habitats. 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.

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[27] Our assessments and conference opinions for all species and critical habitat included as proposed or candidate in EPA's BE are included in this Opinion or in the concurrence section and Appendix A of the Opinion, 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 Appendix D). 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.

Some listed and proposed species and designated and proposed critical habitats that were not considered in EPA's BE were later added to the consultation and conference, and the tables in the *Integration and Synthesis* sections below. These entities and critical habitats were 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 in the *Supporting Information for the Concurrence Section of the Consultation* (Appendix A), 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.

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- and critical habitat-specific accounts (i.e., detailed in Appendix C). The *Environmental Baseline* and *Cumulative Effects* sections in the body of this Opinion were broadly summarized in the generalized overview of the effects of previous and present and future ongoing activities in the action area for the proposed action. 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 C) and in the *Status of the Species* and *Critical Habitat* (Appendix B).

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. Numerous 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. Additionally, as noted in the *Effects of the Action* section, 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 habitat 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 adverse 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 jeopardize the continued existence of a listed species, we evaluate whether the action is reasonably 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, in accordance with the ESA section 7 implementing regulations at 50 C.F.R. 402.02.

We reviewed the available recovery plans, 5-Year 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 and also to understand the effects of the proposed 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 B).

Approach to the Effects Analysis

Where the BE indicated an individual of a listed species is likely to be adversely affected, we carried forward with a population level assessment. We assessed the following responses for each listed species, where applicable, by considering all lethal and sublethal effects observed in toxicity studies, including:

1. Mortality to portions of the population(s) of a listed species from direct, acute exposure from the use of carbaryl according to registered labels;

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

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

4. Indirect effects to species, including declines 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, pollinators/seed dispersers for plant species, symbiotic organisms) and impacts to suitability and/or quality of habitat on which the listed species depends.

As part of our assessment, we use qualitative rankings of high, medium, or low for a listed species' vulnerability, exposure, and toxicity. Each of these factors considers several pieces of information to inform the assignment of organizational descriptions for each species. We used these descriptions of high, medium, or low to organize our review certain species, based on common, specific factors (e.g., species that may have high levels of exposure and have high toxicity, species that have high levels of exposure and are highly vulnerable). The rankings, however, are not necessarily indicative that a species is likely to be jeopardized. For example, we may find that a species with high exposure, high toxicity ratings, and high vulnerability rankings are not likely to be jeopardized because, for instance, the species' life history indicates that it would spend very little time in use sites or other areas of high concentration of carbaryl.

For plants, before the qualitative rankings for vulnerability, exposure, and toxicity were determined for each species, we grouped species by reproductive strategy, given that species that require insects to transport their pollen for successful reproduction are inherently more susceptible to the effects of an insecticide such as carbaryl, than those plants that do not use pollinators (e.g., ferns); those that may use pollinators but can also use other reproductive methods (e.g., self-fertilization, vegetative reproduction); and those that use wind or water for pollination. This upfront grouping allowed us to better understand the general level of concern for larger groups of plant species before determining individual species' rankings. A detailed description of these plant groupings, called Assessment Groups, are found in the *Toxicity* section of this Opinion.

Vulnerability

We considered several factors to summarize the current status and vulnerability of a listed species to additional stressors. This effort allows us to consider whether a species' current condition is moving toward recovery or further decline. In general, we expect the species' vulnerability to additional stressors to be higher if they are moving toward further decline than if their condition is improving. We also identify which species are most (and least) susceptible to additional stressors in general based on information that could be surmised from species listing and recovery documents, or other sources as cited and considered in the *Status* section of this Opinion.

Our assessment of vulnerability focuses on six factors: (1) the species listing status and recent 5-Year 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. We obtained the information to create the vulnerability summary from the *Status of the Species* accounts (Appendix B), the overarching *Environmental Baseline* section of this Opinion, 5-Year Reviews, species recovery plans, species status assessments, and other sources containing the best available scientific information for the species.

Vulnerability factors related to distribution, number of populations, and species population trends are described further below.

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 United States. 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 in instances where information on the species' seasonal habitat requirements indicates increased vulnerability.

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, we consider "few" to be fewer than 10 populations, though for some species, we may consider "few" to be 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.

Species Population Trends

For species population trends, we considered whether populations are declining, stable or increasing, based on the best available scientific information, including the most recent information from listing rules, recovery plans, 5-Year 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.

Pesticides Listed as a Threat

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 our overall assessment of species' vulnerability. 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 our overall vulnerability ranking.

Vulnerability Ranking

We scored each of the six vulnerability components with high, medium, or low scores. We assigned a high vulnerability ranking to a species if all vulnerability components were scored as medium or high. We assigned a medium vulnerability ranking if a species' scores were a mix of high, medium, and low (though exceptions were allowed for species that have a low status score or have an uplisting recommendation). We assigned a low vulnerability ranking to species with only low scores. Considerations regarding specific aspects of the species' vulnerability or beyond what was included in the vulnerability ranking were applicable for some species depending on unique aspects of their life history. This information is reflected in the rationales for the jeopardy determination for each listed or proposed species and for the destruction or adverse modification determination for each designated or proposed critical habitat.

Exposure

As described previously, we expect carbaryl applications to occur on a site-specific basis for the duration of the proposed action. Our analyses include a quantification of areas where the pesticide can be applied according to the labels as currently written. We characterize the expected level of exposure using the extent of overlap between these carbaryl use sites and the species' range, past carbaryl usage data, and any species-specific considerations such as life history information (e.g., habitat preferences, dispersal behavior), and existing protections or conservation actions.

Agricultural Overlap

Overlap data refers to the extent that carbaryl use sites (i.e., on-field areas) and adjacent areas likely to be exposed through off-site transport (i.e., off-field areas) occur within a listed species' range and is reported by the EPA as a percentage for each relevant use type. Given that agricultural uses of carbaryl are limited to ground application methods, we extend our off-field analysis to 30 meters from the edge of application sites as EPA determined this was the maximum distance at which effects are likely to occur to listed species. Our default approach is to assume that individuals of listed species are uniformly distributed throughout their range (see *Assumptions and Uncertainties for all species, Species Range Maps* section of this Opinion). We use this percent overlap to represent the proportion of individuals that may be exposed throughout the duration of the proposed action. We address species where available information indicate that a uniform distribution assumption is not appropriate on a case-by-case basis (see the *Additional Exposure Considerations* section below for more details).

We determine the total overlap between the species' range and the action area by summing the on- and off-field area overlaps with the species' range for each relevant use type (except for listed aquatic species, which we address below). We aggregate the overlaps across all non-highly redundant crop groups. Non-highly redundant crop groups refer to those crops that are not likely to be grown using the same fields (for example, crops that are not rotated out or replaced within the same field location such as other orchards and vegetables and groundfruit). The 'other orchards' use category consists of berries and fruit trees which need to be established over several years or growing seasons before they can bear fruit and thus are not rotated out after only a few growing seasons. In contrast, row crops (such as those in the 'vegetables and groundfruits' use category) may be rotated out over growing seasons for various reasons such as replenishing soil nutrients or availability or demand for certain crops. Redundancy in relation to use type refers to the fact that mapped use sites are not exclusive of one crop type over time. As such, for highly redundant crops such as corn and soybean, or citrus and other orchards, we use the higher overlap between the two redundant crop use sites in our total overlap calculations.

Based on the value of a listed species' total overlap, each species' overlap is given a score. Species with greater than 10% overlap are assigned a high overlap score, species with 5-10% overlap are assigned a medium overlap score, and species with less than 5% total overlap are assigned a low overlap score. This assignment of high, medium, or low rankings to these specific percentages of overlap are used for purposes of organizing our analyses along assumptions that generally apply with all the species evaluated in this Opinion. For example, the Service has generally found that the greater the extent of overlap between species range and use and spray drift sites can be indicative of increased exposure of individuals to carbaryl. However, available information may indicate that general assumption does not apply to certain species. For example, even if the range of a species has a high overlap with carbaryl use and spray drift sites, the Service may have information indicating that individuals would not be present in certain areas of overlap.

We modified our approach for characterizing overlap for the following groups of species: aquatic listed species and species occurring in Pacific and Caribbean U.S. territories. We go into the specific overlap characterization process for these species below.

<u>Aquatic species overlaps</u>

We anticipate listed aquatic species will primarily be exposed to carbaryl through contact with contaminated water in their habitats. We do not expect these species will occur on-field, and thus expect exposure will only result from off-field transport via spray drift or runoff into their aquatic habitats. Given that the ranges for listed aquatic species are generally delineated using the relevant U.S. Geologic Survey (USGS) Hydrologic Unit Code 12 (HUC 12) watersheds, we anticipate that all residues that leave use sites will be collected in the waterbodies within the species range where individuals occur regardless of how residues leave treated sites or where in the range they are deposited. As such, on-field overlap represents the total extent of agricultural activity within the species' ranges, and we do not extend overlap metrics off-field as this would not functionally change the expected exposures that listed aquatic species are likely to experience. Carbaryl degrades quickly (i.e., within a few days to weeks) in aerobic aquatic habitats and as such is not likely to persist in water bodies for long periods of time, be transported long distances in surface waters, or occur in groundwater sources.

<u>Pacific and Caribbean Island species overlap</u>

Spatial data for specific carbaryl use sites are not available for U.S. territories in the Pacific and Caribbean regions, including American Sāmoa, the Commonwealth of the Northern Mariana Islands, Guam, the U.S. Virgin Islands, and Puerto Rico. The EPA uses data from the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program (C-CAP), which is a nationally standardized, raster-based inventory of land cover for the coastal areas of the U.S. Data are derived from the analysis of multiple dates of remotely sensed imagery. The EPA uses this data to characterize cultivated land use in the island territories. We are not able to isolate areas where carbaryl is registered for use and expect these metrics are likely to overestimate the extent of exposure to species.

Agricultural Usage

Usage data refers to the maximum annual percent of a crop that has been treated with carbaryl in the past. EPA uses past usage data, as summarized by the State Summary and Usage Matric (SUUM) in the BE, to calculate the percent of a species' range or critical habitat that is likely to be treated annually. Briefly, EPA calculates a percent crop treated at a state level, which they use to calculate the number of acres of a crop within a state that is treated within a year. Since the data do not indicate where within the state past usage has occurred, we conservatively assume that all treated acres of a crop occur within a listed species' range to determine the percent range treated annually. Similar to overlap, we assume that individuals of a listed species are uniformly distributed throughout their range, and that the percent range treated represents the likely proportion of individuals that will be exposed annually.

Similar to overlap, we determine the maximum percent of each species' range likely to be treated annually with carbaryl by aggregating the percent range treated of all non-highly redundant crop groups. For most species, we do not expect all areas of a specific crop use site will be treated with carbaryl each year. As such, total usage is typically smaller than overlap.

We score total usage based on the total percent area that is likely to be treated with carbaryl annually. Species that data indicate will have a large portion of their range (>10%) treated with carbaryl each year are assigned a high usage score. Species that will have a medium portion of their range (5-10%) treated with carbaryl each year are assigned a medium usage score, and species for which data indicate will have a low portion of their range (<5%) treated with carbaryl each year are assigned a low usage score. In the sections below, we outline cases where available data results in a slightly different approach to assessing usage, including for species occurring entirely in the state of California, species occurring in Hawaiʻi, and species occurring in the Pacific and Caribbean Island territories.

<u>California Pesticide Use Report</u>

The California Department of Pesticide Regulations' California Pesticide Use Report (CalPUR) provides spatially specific information regarding pesticide usage in the state of California. The state of California mandates pesticide usage reporting for all agricultural applicators and a subset of nonagricultural applicators. The EPA summarizes these data in terms of the percent of a species' range that has been reported to be treated with any pesticide, treated with any insecticide, and treated with carbaryl over a 10-year period (2013-2022). The EPA also provides estimates of the average number of growers/applicators that report pesticide usage within the species' range in that same 10-year period, which we use as a surrogate metric for the potential variability in pesticide usage over time (e.g., a large number of growers reporting pesticide usage within a species' range indicates less variability in the total area treated each year as changes in pesticide usage of a few growers is not likely to affect the proportion of the range treated). Given that this state level data is spatially specific to the species' ranges and is this reporting is mandated by the state, we have a high confidence that these data more accurately represent likely exposure than other sources of usage data. As such, we replace the usage data provided in EPA's SUUM with CalPUR data for species and critical habitats that occur entirely or largely within the state of California.

Pacific and Caribbean Island Usage Data

We omit this score for our analysis of listed species that occur in these areas. Carbaryl specific usage data is not available for Caribbean or Pacific islands (including Puerto Rico, the U.S. Virgin Islands, the Commonwealth of the Northern Mariana Islands, Guam, and America Sāmoa). As such, for most species that reside in these areas, we omit the usage score for our analysis of exposure and rely solely on the overlap with the action area. In general, we consider that the Census of Agriculture insecticide data provided by EPA for Puerto Rico confirms that insecticide usage occurs on these islands, with carbaryl presumably among these insecticides.

Additional Exposure Considerations

When information on a specific species indicates that exposure assumptions are not likely true (e.g., species are known to avoid agricultural areas, species that are only found in protected areas with no agricultural pesticide use), we qualitatively incorporate that information into our exposure rankings. Some examples of relevant information include knowledge of species' distribution on protected lands that are less likely to be treated with carbaryl (e.g., national parks and some national wildlife refuges), life history information that indicates a low likelihood of exposure (e.g., avoidance of agricultural areas, fossorial life history strategy), or additional sources of usage data, such as USDA's Census of Agriculture.

Life History Traits

Listed species often exhibit different and unique characteristics and behaviors that enable them to survive in their environments. For instance, species that occupy habitats that naturally accumulate lower levels of pesticides (e.g., aquatic habitats with high flow rates, terrestrial habitats located in remote areas far from agriculture) are not likely to experience high levels of exposure compared to species that live in areas surrounded by cultivated land or habitats that are likely to accumulate high levels of pesticides. Behavioral traits such as how and where individuals forage, and their tendency to use particular habitats can also be highly influential in their susceptibility to pesticide exposure. We qualitatively incorporate relevant life history traits that are expected to modify the level of expected exposure relative to our baseline assumptions where relevant species information is available.

U.S. Department of Agriculture's Census of Agriculture Data

The USDA's Census of Agriculture is reported at a county level and includes information on pesticide usage summarized by pesticide class (i.e., all insecticide usage). The EPA provides information in cases where there are low levels of general insecticide usage within the counties that a listed species' range occurs in. Given that these data are more spatially specific than carbaryl-specific usage data available (with the exception of California, where data are available at a sub-county level) and covers all insecticides used (not just carbaryl), we consider instances where the CoA reports low levels of usage for all insecticide within a species' range as strong evidence that carbaryl usage is unlikely to exceed low levels of usage throughout the course of the action.

Non-Agricultural Exposure

As discussed above in the *Overall Considerations for the Opinion* section, we differentiate our evaluations of potential exposure to agricultural and non-agricultural uses of carbaryl. In contrast to agricultural UDLs, UDLs for non-agricultural uses tend to be less defined, use maps that only generally approximate use site locations, likely to incorporate large areas that will not be treated with carbaryl, and are not likely accurate representations of the actual footprint of non-agricultural use sites on the landscape. As such, we assess exposure of species to non-agricultural uses of carbaryl in a qualitative manner by considering the life history of species, methods of application, available past usage data, and any existing conservation measures to reduce drift and runoff or otherwise limit exposure to listed species.

Hawaiian species

In February 2024, the technical registrants committed to amending carbaryl registrations to prohibit agricultural uses in Hawaiʻi. After this change in the registration, only non-agricultural uses in developed and open space developed use sites remain in Hawaiʻi. As such, we rely on a qualitative approach to determine the expected level of exposure to listed Hawaiian species. Our evaluation of exposure for each Hawaiian species considered in this Biological Opinion included an assessment of suitable habitat, current known locations of the species, visual inspection of species ranges using satellite imagery to determine general proximity to potential use sites, and any other relevant information available in Service documents.

Exposure Ranking

We determine the overall exposure ranking by qualitatively considering both the total overlap and total usage (when available), as well as any additional exposure considerations that might modify the level of exposure likely to occur. When overlap and usage scores are the same, we assign the overall exposure ranking the same score (e.g., if both overlap and usage is high, the overall exposure ranking is high). In cases where overlap is high and usage is medium or when overlap is medium and usage is low, we use the overlap score as the overall exposure ranking to maintain conservative exposure assumptions, as usage is a subset of overlap and so the overlap score will always be greater than the usage score. In cases where overlap is high but usage is low, we anticipate a moderate portion of the range may be treated over the duration of the proposed action even if only a small portion of the range is treated in any given year (particularly if the areas treated occur in different locations each year). Thus, species with high overlap but low usage have an overall exposure ranking of medium. In cases where no usage data is available, in the absence of any additional exposure considerations for these species, our ranking is based on total overlap of carbaryl use sites for species that occur in these areas. For all species, where there are additional exposure considerations, we adjust the overall exposure ranking to reflect this additional information, as appropriate.

Toxicity

We characterize the expected toxic effect to species based on the anticipated level of direct and indirect adverse effects to individuals. Our analysis of toxicity assumes individuals are exposed to carbaryl at levels estimated by EPA's environmental exposure modeling and is focused on determining the level of adverse effect expected to occur once exposure has taken place. Direct effects are based on the anticipated level of mortality and sublethal effects (e.g., reduced growth) likely to occur in exposed individuals. Indirect effects are based on the impact a listed species is likely to experience when the organisms they rely on, such as those that act as food or habitat resources, are exposed to carbaryl and experience adverse effects.

Direct adverse effects refer to adverse physiological impacts resulting from exposure to carbaryl (whether it is through contact, inhalation, or ingestion). We use available toxicity data in surrogate species as reference points to estimate the level of mortality or sublethal effects (e.g., growth or reproduction) to listed species. We also use available toxicity data in surrogate species for taxa groups where toxicity data is not available for a given taxonomic group (e.g., avian data to address endpoints for reptiles). Given that mortality is the most adverse of direct effects to an individual of a species, we assign the most weight to direct adverse effects resulting in mortality when determining the toxicity ranking. Species that are likely to experience more than 10% mortality in exposed individuals are given a high direct effects score. Species that are likely to experience between 5-10% mortality of exposed individuals are given a medium direct effects score. Species that are likely to experience less than 5% mortality of exposed individuals and are not likely to experience sublethal effects are given a low direct effects score. Species that are likely to experience less than 5% mortality but are likely to experience sublethal impacts are given a medium direct effects score.

Indirect adverse effects refer to adverse impacts resulting from carbaryl exposure to other organisms that the subject species relies on (e.g., prey species that are exposed to carbaryl). These impacts may result even if an individual is not exposed to any carbaryl itself (e.g., loss of pollinators upon which the species depends or loss of prey species). We qualitatively score the expected level of indirect adverse effects a listed species will experience based on the dietary items the species relies on or the effects to another species with which the listed species shares an obligate/symbiotic relationship with (e.g., host fish for mussels, ant species for myrmecophilous butterflies). Species that are particularly reliant on species that are sensitive to carbaryl at estimated environmental concentrations (e.g., insects) are assigned a high indirect effect score while species that use a variety of prey species with a range of sensitivities to carbaryl and species that use food resources that are not affected by carbaryl are assigned a medium or low indirect effects score, respectively.

To characterize the toxic effect of carbaryl to listed species, we first select an appropriate reference point from the available toxicity data (e.g., lowest reported LD_{50} or LC_{50}, the HC_{05} from a species sensitivity distribution, lowest reported LOAEC for sublethal effects). We then compare estimated environmental concentrations that EPA provides for each species to the appropriate toxicity reference point to determine the general magnitude of adverse effect likely to occur. The reference data used to characterize the magnitude of direct and indirect adverse effects will vary by taxa and is dependent on the breadth and depth of information available. We summarize the different toxicity considerations taken for the different taxa groups in the sections below.

Toxicity Ranking

We determine the overall toxicity ranking for listed species by considering the expected levels of direct adverse effects (i.e., mortality and sublethal effects) and indirect effects (i.e., prey or habitat loss). Given the immediate impact of mortality on the continued existence of a species, we weight the mortality score highest. Similarly, we weight sublethal effects higher than indirect effects score. As such, species with high or medium level of mortality are given an overall toxicity ranking of high or medium, respectively. Species with a low level of mortality but are likely to experience sublethal effects are given an overall toxicity ranking of medium as we anticipate a mix of mortality and reduced fitness (via reduced growth or reproduction) are likely. Species with a low level of mortality and a low level of sublethal effects and a high or medium level of prey or habitat loss are given an overall toxicity ranking of high or medium, respectively. Species with low levels of mortality, low levels of sublethal effects, and low levels of indirect effects are given an overall toxicity ranking of low.

Invertebrates

We expect contact exposure is the primary route of exposure for listed invertebrate species. We separate our invertebrate analyses into arthropods and mollusks/snails as available toxicity data indicate that insects and crustaceans are highly sensitive to carbaryl exposure while mollusks are not likely to experience adverse effects from carbaryl at environmentally relevant exposure levels. We compare estimated environmental concentrations resulting from the aerially applied product to the lowest terrestrial arthropod reference LD_{50} to determine the level of mortality listed terrestrial arthropod species are likely to experience. We compare estimated environmental concentrations in water to the aquatic invertebrate HC_{05} to determine the level of mortality listed aquatic arthropod species are likely to experience. We compare estimated environmental concentrations in water to the lowest mollusk LC_{50} to determine the level of mortality listed snails and bivalves are likely to experience.

Given that arthropods are likely to experience high levels of mortality, we do not estimate levels of sublethal effects to listed arthropod species as we anticipate exposed individuals are likely to die before any sublethal effects can occur. For carbaryl sublethal effects may occur in listed mollusk species as available toxicity data indicate adverse effects to reproduction are likely to occur at some environmentally relevant exposures but are more likely to occur in lower flow or lower volume aquatic habitats.

For listed invertebrate species that rely on other invertebrates (e.g., predatory insects, butterflies with symbiotic relationships with ants), we use the lowest insect LD_{50} or the aquatic invertebrate HC_{05} to estimate the loss of prey or symbionts in terrestrial and aquatic environments, respectively. For species that rely on vertebrates (e.g., listed bivalves that use fish host species for reproduction), we estimate the level of vertebrate mortality expected to occur at estimated environmental concentrations predicted to occur within the species' range. We do so by using a generic fish mortality dose-response curve that uses the HC_{05} from the fish mortality species sensitivity distribution EPA generated in the carbaryl BE and a default slope of 4.5.

Terrestrial Vertebrates

We expect dietary exposure is the primary route of exposure for terrestrial vertebrates. The EPA provided dietary dosage estimates for listed terrestrial vertebrate species based on body weight, diet, metabolic rate, assimilation efficiency, mass of food consumed per day, and carbaryl concentration on food for each dietary item a species consumes on-field and off-field. We used a dose-response curve with an LD_{50} (mass adjusted) and default slope of 4.5 to calculate the level of mortality expected to occur to a listed terrestrial vertebrate species consuming exclusively one dietary item. We compared estimated dietary dosages to the lowest NOAEC or LOAEC available for terrestrial vertebrates, as appropriate, to determine whether sublethal effects are likely to occur. While pesticide exposure can result in a broad scope of sublethal effects, our analysis is confined to the data submitted by registrants or available in the open literature, which for carbaryl, was limited to growth and reproduction. Given that there is not sufficient toxicity data for amphibians or reptiles to create a separate analysis for these taxa, we used available bird toxicity data as a surrogate for terrestrial-phase amphibians and reptiles. We qualitatively adjusted the level of direct adverse effect based on available knowledge of whether a listed species is likely to exclusively consume one dietary item, whether individuals are likely to forage on-field or forage on prey that have recently foraged on-field, whether foraging is likely to occur soon after carbaryl application, and other relevant life history features (e.g., foraging distance, home range size, specificity of diet).

We expect terrestrial vertebrates that consume other animals are likely to experience some indirect effects in the form of reduced availability of prey. For terrestrial vertebrate species that consume insect prey, we assumed that insects exposed on-field or within the 30-m offsite transport zone were likely to die. For terrestrial vertebrates that consume other terrestrial vertebrates, we estimated the level of indirect effect by generating toxicity analyses for generic prey species. We determined the level of mortality a generic small mammal (weighing 15 grams that consumes grass), a generic small bird (weighing 20 grams that consumes grass), a generic large mammal (weighing 1000 grams that consumes grass), and a generic large bird (weighing 1000 grams that consumes invertebrates) are likely to experience from feeding on use sites that have recently been treated with carbaryl and from feeding off-field in areas exposed through runoff or spray drift. Similar to estimates of direct effects to terrestrial-phase amphibians and reptiles, we use estimates of toxicity to the generic small bird and generic large bird to represent the anticipated impact to amphibian and reptile prey. We qualitatively adjust the anticipated level of indirect effects based on any relevant life history traits, including information regarding prey preferences, ability to use multiple food resources, relevant foraging behavior, changes in diet across life stages, etc.

Aquatic Vertebrates

We expect contact with contaminated water is the primary route of exposure for aquatic vertebrates. The EPA provided estimated environmental concentrations (EECs) of carbaryl for different types of aquatic habitats (e.g., low flow/shallow habitats, high flow/large volume habitats) within the each USGS hydrologic unit code level 2 (HUC2) watershed. We compare maximum EECs corresponding to the UDLs with the greatest overlaps with the species' range to the HC_{05} reported in EPA's BE to determine the general level of mortality likely to occur. We consider the HC_{05} a conservative threshold for qualitatively estimating anticipated mortality to listed fish as data representing a wide diversity of fish species are used to generate HC_{05} estimates. If maximum EECs are below the HC_{05} (i.e., below the level where we anticipate 95% of fish species will not experience high levels of mortality), then we have high confidence that mortality is likely low for a listed aquatic vertebrate species. We compare EECs to the lowest reported NOAEC or LOAEC, as appropriate, to determine whether sublethal adverse effects are likely to occur. We qualitatively modified the expected level of direct and indirect effect based on any available information on general preference for specific types of habitats, if species use certain habitats at certain life stages or time of year, etc. Given that there is not sufficient data on amphibians to create a separate analysis for this taxon, we use these lethal and sublethal endpoints for fish as a surrogate for aquatic-phase amphibians.

We use the aquatic invertebrate HC_{05} to estimate the level of invertebrate prey loss that is likely to occur at estimated environmental concentrations of carbaryl. We use the fish $HC_{05}$to estimate the level of fish prey loss that is likely to occur at environmental concentrations of carbaryl to listed piscivorous species. We qualitatively adjust the likely level of prey loss based on available information on life history traits (such as known prey preference, ability to use multiple food resources, habitat use, changes in dietary requirements across life stages, etc.).

Plants

We assessed the plant taxa group, consisting of more than 900 individual species, based on 11 groupings categorized by taxonomy and reproductive strategy. While exposure to carbaryl at high application rates can cause direct adverse effects, given that listed plant species are unlikely to grow within use sites and will only be exposed directly through spray drift or runoff (at levels much lower than what the application rates were), we anticipate listed plant species will not likely be exposed at concentrations that will cause adverse effects. As such, the focus of our analysis on listed plant species is on impacts to pollinators and seed dispersers, particularly insect pollinators and insect 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 S. G., et al., 2010; Thomas, et al., 2004; Biesmeijer, et al., 2006). To estimate the level of indirect effects to listed plants, we compare predicted EECs to occur in the habitat of listed plant species to the lowest insect LD_{50}. We qualitatively adjust the level of indirect adverse effects to species based on available information regarding a listed plant species' relationship with pollinators (e.g., can a species be pollinated by non-insect vectors? Can a listed plant reproduce vegetatively? Is the species a pollinator generalist or specialist?).

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 carbaryl 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 do not rely on a pollination mechanism for reproduction (lichens and ferns) or use wind for pollination (conifers; the one listed cycad is an exception). 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.

In our assessment of adverse indirect effects to plants, we incorporated information regarding the reproductive method(s) a listed species uses (which are captured in our assessment groupings), what type of pollinators and seed dispersers are required (e.g., insect pollinators only, insect and bird pollination with abiotic seed dispersal, insect pollination but general biotic and abiotic seed dispersal, etc.), and whether the listed plant has a generalist, specialist, or obligate relationship with its pollinators and/or seed dispersers.

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 no available data on the toxicity of carbaryl to lichen species. We assume lichens respond to carbaryl similarly to vascular plants and are not likely to experience any direct adverse effects from carbaryl exposure. In addition, since these species do not rely on pollinators or seed dispersers for reproduction, we do not anticipate there will be indirect adverse effects to individuals.

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 and dispersed by wind. Ferns and their allies can also reproduce asexually by means of vegetative reproduction in the form of bulblets or rhizomes. Available toxicity data indicate that plants are not likely to experience adverse effects to survival, growth, or reproduction with exposure to carbaryl at environmentally relevant concentrations, suggesting no direct adverse effects to individuals are likely. Similarly, since these species do not rely on pollinators for reproduction, we do not anticipate there will be indirect adverse effects to individuals. EPA determined there would be “No Effect” to all ferns and fern allies, thus these species are included in Table 1 of the *Supporting Information for the Concurrence Section of the Consultation* in Appendix A, and we do not consider these plant species in the Opinion.

Plant Assessment Group 3 – Conifers and Cycads

Conifers and cycads are gymnosperms (i.e., vascular plants, usually trees or shrubs, that reproduce by means of an exposed seed, or ovule). Gymnosperms do not produce flowers and the vast majority disperse their pollen by wind. Available toxicity data indicate that plants are not likely to experience any adverse effects to survival, growth, or reproduction with exposure to carbaryl at environmentally relevant concentrations, suggesting no direct adverse effects to individuals are likely. Similarly, since these species do not rely on biotic pollinators for reproduction (with the exception of the fading– see Appendix C), we do not anticipate there will be indirect adverse effects to individuals from loss of pollinators. However, some of these species use biotic vectors (such as birds or mammals) for seed dispersal and could experience very minimal adverse reproductive effects from decreased availability of these animal seed dispersal vectors. We anticipate these species will experience minimal adverse effects. We address these species in Appendix C.

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 any plants, including 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.

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. As carbaryl is not likely to cause different effects to monocot or dicot flowering plants, in our Integration and Synthesis assessment appendices for plants, we combined monocots and dicots in groupings.

Rationales and Conclusions

Once the overall categories for each factor are determined for each species using the Integration and Synthesis Worksheet, we continue the jeopardy analysis by considering the combination of the overall vulnerability, exposure, and toxicity rankings described above, which include any additional information relevant to the consequences of the proposed action that may reduce the species reproduction, numbers, and distribution.

Species Groupings

To streamline our discussion in this Opinion, we group species that have the same or very similar rationales for their conclusions to increase efficiency and avoid repetition. We considered relevant information and data unique to each individual species when assigning species to groups, which we incorporated into the rationales as appropriate. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species, including those species in the grouped analyses, and are presented in full in Appendices B and E. In cases where a combination of rankings and additional considerations provides a clear narrative for a determination that the proposed action is not likely to jeopardize the continued existence of a listed species, we provide a group rationale that outlines how the combination of vulnerability, exposure, toxicity rankings, and additional considerations results in this conclusion for all relevant species. Within these grouped rationales, we add additional information, when relevant, to support our conclusions. We review each grouped rationale to ensure that all vulnerability, exposure, and toxicity assumptions made are applicable for each species within the group and are expected to result in a similar determination for each species. We do not include any species in the grouped rationales when certain assumptions for each grouping are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion elsewhere in this Opinion. For these species, we provide individual *Integration and Synthesis* summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

In general (with some noted exceptions), species with low exposure and low toxicity rankings are at a low risk of jeopardy, regardless of their vulnerability ranking, as the level of adverse effects will be limited in scope and magnitude. We group these species together as we have a low concern about adverse effects. Species with low exposure are often also at low risk of jeopardy given that we anticipate only small number of individuals are likely to be exposed. We group these species together based on the metric we use to conclude they have low exposure (e.g., the amount of overlap with the action area and low usage within the range of the species). However, certain species with low exposure that are especially vulnerable to extinction (e.g., severely small population numbers, pesticides listed as a major threat to the species) are not included in these groups, as even low levels of exposure with adverse effects can have significant consequences for highly vulnerable species. For all other species (i.e., species with medium or high exposure, and medium or higher toxicity), our preliminary exposure and toxicity rankings indicate that the proposed action may result in moderate to high adverse effects. As such, we discuss each species in more detail in individual Integration and Synthesis summaries. Where applicable, we modify initial exposure and toxicity rankings due to additional information regarding exposure and effects for individual species.

Effects of the Action on Animals

In the Integration and Synthesis summaries (Appendix C), we evaluate the results of exposure to carbaryl for each taxa group (as described in the *Effects of the Action* section of this Opinion). Generally speaking, we anticipate relatively high levels of mortality for both aquatic and terrestrial invertebrates where exposure occurs. For other taxa groups, we anticipate variable levels of mortality, and indirect effects based on their life history, prey base, insect pollinators (and in some cases, seed dispersers), or host fish, and other considerations following exposure to carbaryl. We summarize these results and related conclusion rationales for the species in the sections below.

For each animal species, we considered the information described above and developed a rationale for the conclusion. Within each taxa group, we documented our determinations for each endangered and threatened species and critical habitat. Proposed species and critical habitat are included in the taxa group tables, and determinations for each are provided as part of our Conference and Biological Opinions. Our analyses for species are provided in the sub-appendices of Appendix C and for critical habitats in Appendix D. Each taxa group and associated assumptions and narratives are included in the sections below. Where rationales for conclusions could be written broadly enough to apply to multiple species within a taxa or geographic group (e.g., snails, mussels), we streamlined reporting to the different exposure groupings as discussed earlier, for clarity and to avoid redundancy. Conclusions for all species addressed in this Opinion are in Table 29 below.

Table 29. Listed and proposed species and designated and proposed critical habitats addressed in this Opinion, EPA's calls, and our determinations.[28,29]

Table 29. Species & Critical Habitat in the

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.

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., guajón) and a species that is ovoviviparous, giving birth to live young (golden coquí).

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[28] 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).

[29] To view the spreadsheet in MS Excel from the MS Word Opinion, double click on the Excel icon. To view the spreadsheet in MS Excel from the portable document format (pdf) Opinion, open the Opinion in the desktop version of Adobe Acrobat or Reader and open the embedded attachment corresponding to the numbered table.

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 which become tadpoles with 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, Houston 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).

Effects to the Amphibian Species

As described in the *Approach* section above, we considered species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) to reach our determinations as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the amphibian *Integration and Synthesis* summary (Appendix C). Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.

Because some amphibians can have both a terrestrial and aquatic phase, we considered the risk of adverse effects in both habitats in our analysis for these species (e.g., California tiger salamander, Houston toad, mountain yellow-legged frog, etc.).

Use areas for carbaryl overlap with and occur adjacent to habitats used within the ranges of all the listed amphibian species in this consultation. Exposure to this pesticide can result in mortality to aquatic and aquatic-phase amphibians from exposure to carbaryl residues dissolved in water, mortality of terrestrial-phase amphibians through dietary 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, exposure concentrations (i.e., dose), and the diet of the species considering 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 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 proposed action on each amphibian species.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include any species in the grouped rationales when certain assumptions are not applicable, require additional information to make a determination, or unique circumstances are otherwise present that warrant additional discussion elsewhere in the Opinion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

Terrestrial-phase Amphibians

Few toxicity studies are available for terrestrial amphibians exposed to carbaryl. The available toxicity data and thresholds for birds are used as a surrogate for terrestrial amphibians (see the *Assumptions and Uncertainties for All Species* section below for additional details on our use of surrogate toxicity data). As discussed in the *General Effects*, dietary exposure was determined to be primary driver of effects for terrestrial vertebrates for carbaryl, and thus we focus our discussion on that. Based on EPA's modeling results, we do not anticipate any amphibians are likely to accumulate more than low levels of carbaryl from dietary exposures, with estimated dosages ranging from 2.5-22.2 mg/kg-bw across all species. We do not anticipate mortality or sublethal adverse effects are likely to occur at these exposure levels.

We anticipate nearly all listed terrestrial-phase amphibian species will experience indirect adverse effects resulting from impacts to affected prey. Given that most amphibians consume arthropod prey (in at least one part of their life cycle) and given that that arthropod prey are highly sensitive to carbaryl exposure at estimated environmental concentrations, we anticipate listed amphibian species are likely to experience significant impacts to their prey resources, even at low levels of exposure. However, we do not anticipate all arthropod species are equally sensitive to carbaryl as variations in features like physiology, life history traits, and behaviors, will result in different prey species exhibiting different levels of mortality in response to exposure. Thus, we anticipate a range of indirect adverse effects are likely depending on an individual species' life history traits and dietary preferences as these factors can influence the level of indirect adverse effects a species is likely to experience.

Aquatic and aquatic-phase amphibians

Few toxicity studies are available for aquatic amphibians exposed to carbaryl. The available toxicity data and thresholds for fish are used as a surrogate for aquatic amphibians (see the *Assumptions and Uncertainties for All Species* section below for additional details on our use of surrogate toxicity data). Similar to our assessment of other listed aquatic species, we anticipate aqueous exposure to carbaryl residues dissolved in water is the primary route of exposure to aquatic and aquatic-phase amphibians.

Risk of adverse effects to aquatic amphibians is a function of the level of anticipated exposure and the estimated exposure concentration. In general, aquatic and aquatic-phase amphibian species that either have very little carbaryl use and usage within their range or species that occur in habitats that are not likely to accumulate more than low levels of carbaryl are at low risk of mortality and sublethal adverse effects. For instance, while species like the Texas blind salamander, Barton Springs salamander, Georgetown salamander, and Austin blind salamander, which are fully aquatic species that live entirely in subterranean aquifers, may be highly sensitive to carbaryl exposure, they are not likely to experience any significant levels of exposure as we expect carbaryl residues in surface waters are likely to degrade before surface waters can penetrate the soil column and enter the subterranean aquifers where these species live. Thus, we anticipate these species are not likely to be exposed to more than low levels of carbaryl and are not likely to experience adverse effects from exposure. Similarly, species like the Neuse River waterdog (which is fully aquatic) or the reticulated flatwoods salamander (which has an aquatic tadpole stage and semi-aquatic adult stage) occur in areas where there is extensive carbaryl use and usage within their ranges, but occupy habitats that are not likely to accumulate more than low levels of dissolved carbaryl in their aquatic habitats, indicating that, while exposure is likely to occur, no more than low levels of mortality and sublethal adverse effects are reasonably certain to result from that exposure. In contrast, aquatic and aquatic-phase amphibians at the greatest risk of adverse effects, including mortality, are those that occur in areas with high levels of carbaryl use sites within their ranges and occur in habitats that accumulate high levels of carbaryl. For example, we anticipate the Houston toad is at high risk of mortality when individuals are exposed in small waterbodies or waterbodies with low flow rates as estimated environmental concentrations in these areas are predicted to be well above levels where adverse effects are observed in reference toxicity studies.

In addition to direct adverse effects, we anticipate aquatic amphibians are likely to experience indirect adverse effects resulting from impacts to affected dietary items. While we do not anticipate more than low levels of adverse effects to aquatic plant resources (like periphyton, algae, or detritus), we anticipate indirect adverse effects from the loss of arthropod prey is likely as most amphibians rely heavily on arthropod prey. However, we do not anticipate all arthropod species are equally sensitive to carbaryl as variations in features like physiology, life history traits, behaviors, will result in different prey species exhibiting different levels of mortality in response to exposure. Thus, we anticipate a range of indirect adverse effects are likely depending on an individual species' life history traits and dietary preferences as these factors can influence the level of indirect adverse effects a species is likely to experience.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include species in the grouped rationales when certain assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion elsewhere in the Opinion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The amphibian species included in this Opinion, and our conclusions for each, are presented in Table 29. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species, including those species in the grouped analyses, and are presented in full in Appendices B and E. Our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon is discussed in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all amphibians considered in this Opinion.

Bivalves (Mussels)

The mussel species in this taxa group includes individuals from the families Margaritiferidae and Unionidae. Of the approximately 103 species in this taxon, only the Alabama pearlshell and the spectaclecase occur in the family Margaritiferidae; the rest occur in the family Unionidae. In general, threats to bivalves 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.

Almost all the mussel species in this analysis use a fish host to complete their reproduction cycle, with the exception of the green floater which is able to reproduce at times without a fish host, and the salamander mussel which uses the mud puppy salamander as a host. 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 (i.e., 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.

Effects to the Mussel Species

As described in the *Approach* section above, we considered species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) to reach our determinations as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the mammals *Integration and Synthesis* summary (Appendix C). Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.

For all uses of carbaryl, we do not anticipate direct mortality to the mussels themselves, however there is the potential for sublethal effects to mussels (reduction in fecundity). We observe the sublethal effects to mussels in some lower flow or lower volume aquatic habitats. We do anticipate use of carbaryl will cause mortality to many individuals of host fish directly exposed to carbaryl either through exposure to runoff or spray drift from applications. This exposure may vary depending on waterbody type as described previously in the *General Effects* section. For example, for host fish with some or all life stages in small flowing or static waterbodies (e.g., some darters, sculpins, mosquito fish, stonerollers, some minnow), mortality effects are generally likely to be higher than those in larger water bodies, like larger rivers or lakes (e.g., large and smallmouth bass, logperch, catfish, freshwater drum, and bullhead). We anticipate variable degrees of effects to host fish, although most uses, particularly near smaller waterbodies, are likely to result in mortality (where exposure occurs) and reductions in fecundity.

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 to the host fish 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 zooplankton prey occur from applications of carbaryl, 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. In static water bodies, such has larger lakes, we anticipate localized effects to reductions in zooplankton prey would also occur from applications of carbaryl. However, these invertebrate prey resources are also likely to be replenished over a short period of time from within or close to the habitat. 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. Mussels generally consume phytoplankton and detritus, which is not anticipated to be impacted by carbaryl applications.

Overall, based on the general regions of the country where listed bivalve species occur and the relevant crops growing in these regions, we do not anticipate more than low levels of adverse effects to a small subset of the mussels or their host fish are likely to occur. Based on available toxicity data in fish, we anticipate no more than low levels of host fish mortality as estimated environmental concentrations are typically below the fish mortality HC_{05} and below the sublethal endpoint for reproduction in fish. As such, we expect most listed bivalves are not likely to experience more than low levels of indirect adverse effects.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include any species in the grouped rationales when certain assumptions for the grouping were not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion elsewhere in this Opinion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The bivalve species included in this Opinion, and our conclusions for each, are presented in Table 29. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species, including those species in the grouped analyses, and are presented in full in Appendices B and E. Our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon is discussed in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all bivalves considered in this Opinion.

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 bird species generally occurs within certain habitat types and specific geographical areas, although ranges for many bird species are 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 extensive habitat needs, requiring networks of appropriate habitats in key locations across large geographical areas that include most available 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. Effects of reductions in habitat quantity and quality, the primary causes of negative population trends for many species, are often exacerbated by the direct loss of bird life from environmental hazards. Clean air, clean water, and abundant, diverse, and healthy habitats are essential for listed bird species to survive and recover.

Effects to the Bird Species

As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all birds for effects to the proposed action. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species to reach our determinations as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the birds *Integration and Synthesis* summary (Appendix C). Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.

Exposure varied among the species based on the habitats in which they forage, breed, and shelter from low to high. While species like the Puerto Rican parrot, Inyo California towhee, and greater sage-grouse are likely to experience adverse effects from carbaryl exposure, there is a low level of overlap between the action area and their ranges, indicating that adverse effects would be limited to a very small number of individuals, which would not likely result in significant adverse effects to the species overall. In contrast, some species, like the whooping crane, Florida grasshopper sparrow, or the Everglades snail kites, have extensive carbaryl use sites within their range, but are not likely to experience any direct adverse effects as estimated exposures are well below levels where toxicity studies have observed adverse effects in birds. However, a number of listed bird species, such as the yellow-shouldered blackbird, streaked horned lark, or the piping plover, while not likely to experience mortality, are likely to experience severe sublethal adverse effects, including severe (though temporary) neurological impacts, which may reduce the long-term survival of exposed individuals.

Similarly, we anticipate listed bird species will experience a range of indirect adverse effects. Birds that exclusively feed on plant matter (e.g., masked bobwhite, Puerto Rican plain pigeon) are not likely to experience any indirect adverse effects as plants are not likely to be adversely affected by carbaryl at estimated environmental concentrations. In contrast, listed birds that exclusively rely on arthropod prey (e.g., southwestern willow flycatcher, golden-cheeked warbler) are likely to experience higher levels of adverse effects as we anticipate arthropod prey are more sensitive to insecticides than other prey groups. For birds that rely on other vertebrates for food (e.g., Puerto Rican sharp-shinned hawk, northern aplomado falcon, and wood stork), they may experience a wide range of adverse indirect effects depending on the prey items and whether the prey items are exposed to carbaryl on-field (i.e., on use sites) or off-field (i.e., in areas up to 30 meters adjacent to use sites exposed through spray drift or runoff).

We recognized carbaryl 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. It is, however, reasonable to assume some applications will occur on multiple sites on consecutive days or weeks or during the same year. Some birds occur in a single population (e.g., Yuma Ridgway's rail, Mississippi sandhill crane, Mariana crow, and Audubon's crested caracara) and their habitats are isolated and fragmented (e.g., whooping crane, Mississippi sandhill crane, Puerto Rican nightjar, Audubon's crested caracara, and eastern black rail). Currently populated areas may be lost and not recolonized in the absence of measures to reduce exposure and effects to several listed birds.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include any species in the grouped rationales when certain assumptions for the grouping are not applicable, additional information is required to make a determination, or unique circumstances are otherwise present that warrant additional discussion elsewhere in this Opinion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination. For birds, we included species that have been proposed for delisting (i.e., ʻōʻū (honeycreeper), Eskimo curlew, wood stork) in these groups and provided rationales for our determinations.

The bird species included in this Opinion, and our conclusions for each are presented in Table 29. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C.

Crustaceans

The crustaceans taxa group includes the following orders: Amphipoda (amphipods); Anostraca (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. 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).

<u>Effects to the Crustacean Species</u>

As described in the *Approach* section above, we considered species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) to reach our determinations as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the crustacean *Integration and Synthesis* summary (Appendix C). Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.

We anticipate all crustacean species will be directly affected from exposure through concentrations in water or 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 *General Effects* section. Effects to invertebrate prey or invertebrate constituents of detritus in the forage base were considered in the analysis based on the assumption that 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% of exposed individuals) from carbaryl uses where exposure occurs. For many narrow endemics, any mortality could result in species-level effects due to isolation and low population numbers. High risk to crustaceans was observed for all species of listed crustacean but overlap and usage varied from (0-57%), and high toxicity was anticipated based on available reference toxicity data. Indirect effects were analyzed for crustaceans and are discussed in each individual crustacean grouping or individual Integration and Synthesis write up. We assumed that most indirect effects for dietary items such as other aquatic invertebrates as dietary items, would also experience similar mortality. Other aquatic dietary items such as detritus, algae, or phytoplankton were not considered to be adversely impacted from exposure to carbaryl as these dietary items would not experience reductions that limit their availability to the listed crustacean due to carbaryl exposure.

However, we expect a number of listed crustacean species are not likely to experience more than low levels of exposure for a variety of reasons. Species like the Hay's spring amphipod or Shasta crayfish have very little carbaryl use sites within their watersheds. For cave-dwelling crustaceans (i.e., cave crayfish, Madison cave isopod, Peck's cave amphipod, Alabama cave shrimp, Kentucky cave shrimp, Illinois cave amphipod, Kaua'i cave amphipod), we do not anticipate that direct application or drift are likely pathways of exposure. Furthermore, given that carbaryl degrades rapidly in natural environments, we anticipate the majority of residues in surface water will degrade before surface water can percolate and recharge groundwater and enter these species' subterranean habitats. As such, we anticipate carbaryl is not reasonably certain to expose and adversely affect these species. In contrast, species like the slenderclaw crayfish and the Brawleys Fork crayfish have high amounts of carbaryl use sites within their watersheds and are likely to be exposed to concentrations of carbaryl that we expect to cause high levels of mortality.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We did not include any species in the grouped rationales when certain assumptions for the grouping are not applicable, additional information was required to make a determination, or unique circumstances were otherwise present that warrant additional discussion in the Opinion elsewhere. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The crustacean species included in this Opinion, and our conclusions for each, are presented in Table 29. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species, including those species in the grouped analyses, and are presented in full in Appendices B and E. Our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon is discussed in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all crustaceans considered in this Opinion.

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.

Effects to the Fish Species

As described in the *Approach* section above, we considered species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) to reach our determinations as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the fish *Integration and Synthesis* summary (Appendix C). Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.

Effects to fish from carbaryl uses vary depending on the extent of carbaryl use sites within the species' watersheds, anticipated usage in the species' watershed, specific life history traits, and dietary items consumed. In general, we anticipate adverse effects will be in the form of mortality and sublethal effects to reproduction from contact with carbaryl residues dissolved in waterbodies. We also anticipate there will be adverse effects resulting from reductions in the abundance of prey species (particularly arthropod prey), which may result in mortality or reduced fitness from starvation.

In general, listed fish species that we expect to have a low risk of adverse effects from the proposed action are those that prefer or exclusively occupy areas of high flow or waterbodies with large volumes or those who occur in areas with very little pesticide usage. For instance, while species like the sharpnose shiner, Boulder darter, and Waccamaw silverside have high exposure as there is a high degree of overlap between carbaryl use sites and their watersheds, these species occupy waterbodies that are not likely to accumulate high levels of carbaryl, which will not result in more than low levels of mortality or minor sublethal adverse effects to reproduction, even at maximum estimated environmental concentrations. Alternatively, while species like the Hutton tui chub, Little Kern golden trout, and Clear Creek gambusia can occupy areas that will accumulate high levels of carbaryl that are likely to cause high levels of mortality or sublethal adverse effects, we anticipate very few individuals are likely to experience these adverse effects as there are very little carbaryl use sites within their watersheds, suggesting that very few areas within the watershed are likely to accumulate carbaryl.

Listed fish species that are at the greatest risk of adverse effects are those that occupy habitats that are likely to accumulate high levels of carbaryl, such as small waterbodies with low flow rates or small water volume and occur in areas containing extensive carbaryl use sites or areas of high usage.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include species in the grouped rationales when certain assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion elsewhere in the Opinion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The fish species included in this Opinion, and our conclusions for each, are presented in Table 29. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species, including those species in the grouped analyses, and are presented in full in Appendices B and E. Our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon is discussed in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all fishes considered in this Opinion.

Insects (Aquatic and Terrestrial)

This taxa group includes several orders of insects, including Coleopterans (beetles), Dipterans (flies), Hemipterans (true bugs), Hymenopterans (bees), Lepidopterans (butterflies and moths), Odonates (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, as brief as a few weeks. Most 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 insects are generally capable of flight, at least in adult life stages. Some adults are not able to or naturally expected to move large distances and are restricted to small habitat patches separated by unsuitable habitat. Some aquatic insects are fully aquatic, such as riffle beetles. Others have both aquatic and terrestrial life stages, including dragonflies, damselflies, stoneflies and similar species. For species with both terrestrial and aquatic life stages, 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 in the *Approach* section above, we considered species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) to reach our determinations as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the mammals *Integration and Synthesis* summary (Appendix C). Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E. The terrestrial and aquatic insect species included in this Opinion, and our conclusions for each, are presented in Table 29. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species, including those species in the grouped analyses, and are presented in full in Appendices B and E. Our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon is discussed in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all terrestrial and aquatic species considered in this Opinion.

<u>Effects to Terrestrial Insect Species</u>

Because carbaryl is an insecticide developed specifically to kill insects, we expect that terrestrial insects are likely to experience high levels of mortality where exposure occurs. Because all or large numbers of individuals exposed to carbaryl will die across most uses, we do not generally anticipate there will be surviving individuals to experience sublethal effects.

Indirect effects (via dietary items) for terrestrial insects were analyzed similarly to the analysis for the terrestrial insect itself. We anticipate that risk will be high for terrestrial insects that consume other terrestrial invertebrate prey (e.g., American burying beetle, northeastern beach tiger beetle, and Puritan tiger beetle) and species that are reliant on other invertebrates for survival (e.g., myrmecophilous butterflies like the Fender's blue butterfly). This information was provided in the discussion for the species, and a similar effect was noted for the dietary item or obligate relationship. We do not anticipate any adverse effects to detritus or plant-based foods (e.g., nectar, leaves, berries) from exposure to carbaryl.

For species that prey on other invertebrates, we anticipate contamination or reduction of their forage base from carbaryl exposure. Reduced food availability could result in substantial effects on individuals and populations of a species, particularly in habitats where food resources may already be scarce. For species with symbiotic relationships with other insects, we expect a loss of these species from carbaryl exposure and a subsequent reduction in the proper development of the larvae of the listed species. For species that inhabit springs, streams, vernal pools, and other wetlands (e.g., Hine's emerald dragonfly and Comal Springs riffle beetle), we anticipate exposure from spray drift and runoff from use sites.

Effects to Aquatic Insect Species and Life Stages

For fully aquatic insect species, we anticipate carbaryl will kill large proportions of individuals if exposed (e.g., Hungerford's crawling water beetle). There are low to high overlaps between the species' ranges and the action area for aquatic insects (0-15%), but overall, small to moderate percentages of their ranges have experienced past carbaryl usage (0.8-9.9%). In general, even at low exposure concentrations, we anticipate exposed individuals are likely to die given the sensitivity of arthropods to carbaryl. Indirect effects were assessed for aquatic insects that consumed other insects, based on the assumption that most indirect effects would involve invertebrate dietary items that would experience similar mortality to the listed species. We do not anticipate any adverse effects to detritus or plant-based foods (e.g., nectar, leaves, berries) from exposure to carbaryl.

For terrestrial insect species with aquatic life stages (e.g., dragonflies, stoneflies), we anticipate mortality will vary by life stage and, where applicable, effects will be similar to what we described for fully terrestrial and fully aquatic species.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include species in the grouped rationales when certain assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion elsewhere in the Opinion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The terrestrial and aquatic insect species included in this Opinion, and our conclusions for each, are presented in Table 29. Species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) was considered for all species, including those species in the grouped analyses, and are presented in full in Appendices B and E. Our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon is discussed in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all terrestrial and aquatic insect species considered in this Opinion.

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 species included in this group and our conclusions for each are presented in Table 29.

Terrestrial mammals in this Opinion 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, and 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 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 others occur across many states (e.g., gray wolf, gray bat). Diet varies among species 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.

<u>Effects to Mammal Species</u>

As described in the *Approach* section above, we considered species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) to reach our determinations as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the mammals *Integration and Synthesis* summary (Appendix C). Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.

Effects to mammals from carbaryl uses vary depending on the amount of overlap with carbaryl uses, anticipated usage in the species' range, specific life history traits, and dietary items consumed. In general, we anticipate adverse effects will be in the form of mortality and sublethal effects to growth, reproduction, and impaired behavior (e.g., disrupted locomotor activity) from the consumption of contaminated food items. We also anticipate there will be adverse effects resulting from a large reduction in the abundance of some prey species, which may result in mortality or reduced fitness from starvation. In general, we anticipate impacted prey will mostly be in the form of arthropod prey on- and off-field and mammalian prey on-field.

In general, mammal species at the greatest risk of adverse effects, including mortality, are those that consume contaminated food on use sites that were recently treated with carbaryl or contaminated prey that recently foraged on carbaryl use sites. In contrast, mammal species that are not likely to forage on or near use sites or are not likely to exclusively consume prey species that have recently foraged on carbaryl use sites are unlikely to die.

We generally anticipate minor levels of sublethal effects will occur as a result of carbaryl use. Based on EPA's exposure modeling, we do not anticipate off-field exposures (i.e., consumption of prey contaminated off-field through spray drift) will result in exposures high enough to cause sublethal adverse effects. In contrast, individuals exposed to carbaryl on-field will experience much higher exposure concentrations and are most likely to die before the onset of sublethal effects to growth, reproduction, or behavior. We anticipate any individuals exposed on-field that do not die are likely to experience sublethal adverse effects to growth, reproduction, or behavior.

Indirect effects in the form of reduced abundance of food items will not occur for obligate herbivores (e.g., riparian woodrat, Columbia Basin pygmy rabbit, pocket gophers) as available toxicity data indicate that no adverse effects to plant survival, growth, or reproduction are likely to occur at environmentally relevant concentrations of carbaryl. In contrast, we anticipate a large reduction in the abundance of insect species with exposure to carbaryl, indicating that obligate insectivores (e.g., Indiana bat, gray bat, northern long-eared bat, Hawaiian hoary bat, Buena Vista Lake ornate shrew) are likely to experience high levels of prey loss. However, we do not anticipate all arthropod species are equally sensitive to carbaryl as variations in features like physiology, life history traits, behaviors, will result in different prey species exhibiting different levels of mortality in response to exposure. Thus, insectivores that can consume a wide range of arthropod species are likely to be able to find sufficient alternative food resources when sensitive arthropods die from exposure. We expect high levels of mortality for mammalian prey that forage on carbaryl use sites but low levels of mortality of mammalian prey that only forage off-field. Similarly, we do not anticipate more than low levels of bird, reptile, and terrestrial-phase amphibian prey on- or off-field. As such, we anticipate listed mammal species that are reliant on mammalian prey species that are likely to occur on carbaryl use sites (e.g., red wolf) may experience high levels of prey loss. In contrast, listed mammal species that can use a variety of food resources or those that are not likely to rely on prey that occur on or near agricultural areas (e.g., gray wolf and Gulf Coast jaguarundi) will likely only experience low to moderate levels of prey loss, resulting in low to moderate levels of indirect effects.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include any species in the grouped rationales when certain assumptions for the grouping are not applicable, additional information is required to make a determination, or unique circumstances are otherwise present that warrant additional discussion in the Opinion elsewhere. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The mammal species included in this Opinion, and our conclusions for each, are presented in Table 29. In addition to the species vulnerability assessments and summarized Environmental

Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all mammals considered in this Opinion. Additional information on the status of the species can be found in Appendix B and additional information on the vulnerability, exposure, and toxicity for all species can be found in Appendix E.

Reptiles

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 wetlands (e.g., bog turtle), to forests (e.g., Louisiana pine snake) and to drier environments including creosote bush scrub (e.g., desert tortoise) and wind-blown sandy environments (e.g., Coachella Valley fringe-toed lizard). 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). 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.

<u>Effects to the Reptile Species</u>

As described in the *Approach* section above, we considered species-specific information (e.g., environmental baseline, cumulative effects, status of the species, exposure, and toxicity) to reach our determinations as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the reptiles *Integration and Synthesis* summary (Appendix C). Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.

Use areas for carbaryl overlap with and/or occur adjacent to habitats within the ranges of nearly all the listed reptile species in this consultation. Exposure to this pesticide at high concentrations can result in direct mortality from the consumption of contaminated food resources, and indirect effects from 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 considering 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.

The majority of reptiles have high vulnerabilities due to small and isolated populations (e.g., blunt-nosed leopard lizard, San Francisco garter snake, St. Croix ground lizard, New Mexican ridge-nosed rattlesnake, flattened musk turtle, and many others); 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. Listed reptiles are likely to be exposed to carbaryl through the consumption of contaminated food resources but can also experience indirect adverse effects through reductions in prey availability, which vary from low to high levels depending on the where exposure occurs (i.e., on-field or off-field) and dietary preferences of the listed species. Expected usage within the species' range also varied for reptiles from extremely low levels (<1% range treated annually) to high levels (18.7% range treated annually). One factor that influenced the likelihood of exposure to carbaryl was whether the species was expected to forage on carbaryl use sites. When available information indicated individuals would not be exposed on use sites, the effects anticipated for these species were lower as estimated environmental concentrations are much lower in adjacent areas than concentrations within use sites. For example, available information regarding the bog turtle's propensity to travel through and possibly rarely feed but not shelter or breed in agricultural areas was noted to reduce but not eliminate the possibility of individuals in the population to be exposed. Other species found to feed primarily on-field on prey that may accumulate carbaryl (e.g., amphibians) were likely to have greater exposures (e.g., Eastern indigo snake or the Eastern Massasauga rattlesnake).

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include any species in the grouped rationales when certain assumptions are not applicable, additional information is required to make a determination, or unique circumstances are otherwise present that warrant additional discussion elsewhere in this Opinion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The reptile species included in this Opinion, and our conclusions for each, are presented in Table 29. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all reptiles considered in this Opinion. Additional information on the status of the species can be found in Appendix B and additional information on the vulnerability, exposure, and toxicity for all species can be found in Appendix E.

Snails

This taxa group is divided into two subsections: terrestrial and aquatic snails.

Effects to the Terrestrial Snail Species

We reviewed listed terrestrial snails that occur within the United States and its territories. The species included in this group are presented in Table 29. 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 and Critical Habitat* (Appendix B) for these species and *Environmental Baseline*. Relevant life history traits are discussed below for a general understanding of ecology of each species.

In general, we do not anticipate effects to terrestrial snails as a result of exposure to carbaryl. Data available from toxicity tests for terrestrial snails indicate that these species have relatively high tolerance to carbaryl and are not likely to experience direct adverse effects from exposure. As such, these species have a low risk of mortality at estimated environmental concentrations (see *Effects to Terrestrial Invertebrates* in the *General Effects* section).

Some species of terrestrial snails may also be considered low risk due to their life history traits, such as those of 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. Oʻahu tree snails are restricted to remnant native forest in the deep interior on the highest ridges of the Koʻolau and Waiʻanae ranges on the island of Oʻahu. We do not expect agricultural or non-agricultural uses of carbaryl to occur in these areas, nor would the surrounding thick vegetation allow spray drift to penetrate the forest as it would act as a wind break. Similarly for the Sisi snail (*Ostodes strigatus*), which occurs on the ground in leaf litter within closed-canopy forests, any impacts from carbaryl would be minimal due to their closed canopy forested habitat in the western portion of the island of Tutuila in American Sāmoa where there is very little agriculture. The Morro shoulderband snail is also less likely to be exposed to carbaryl as their preferred habitat is in coastal dune, coastal dune scrub, and maritime chaparral plant communities in back dunes and stabilized dune systems, which are genearlly not near use sites. As such, we do not anticipate adverse effects will occur to these species due to the lack of exposure of individuals or their food resources, in addition to the low toxicity of carbaryl on these snails.

For other terrestrial snail species considered (e.g., Stock Island tree snail, Flat-spired three-toothed snail), their life histories may or may not include aspects that would preclude exposure; however, again, based on the terrestrial snail toxicity data, carbaryl uses are not expected to result in the mortality of individuals of these species should exposure occur. Available toxicity data in plants indicate that the food resources terrestrial snail species rely on (such as moss, algae, lichen, or other detritus) are not likely to experience more than low levels of adverse effects (if any adverse effects at all). As such, we do not anticipate adverse effects will occur to these terrestrial snails from exposure or impacts to food resources.

In conclusion, we anticipate that over the duration of the proposed action, carbaryl exposure is likely to occur for some, but not all of the listed terrestrial snail species and their food sources, as described above. However, we do not anticipate direct exposure would lead to mortality of terrestrial snails based on their assumed tolerance to carbaryl as determined from available toxicity data, and any impacts to food resources are not expected to result in adverse effects to these snails. For several of these species, we also anticipate that their life history strategy would lead to a low level of exposure (i.e., Virginia fringed mountain snail due to the low exposure anticipated in view of its burrowing life history). Thus, we do not anticipate measurable adverse effects to these species. After adding the effects of the action and cumulative effects to the environmental baseline, and in light of the status of the species, we have determined the proposed action is not expected to appreciably reduce the likelihood survival and recovery of these species in the wild. Thus, it is our biological opinion that the proposed action is not likely to jeopardize the continued existence of the terrestrial snail species in Table 29

Effects to the Aquatic Snail Species

We reviewed listed and proposed freshwater aquatic snails that occur within the United States. The species included in this group are presented in Table 29, including two non-essential experimental populations for the Anthony's riversnail (Entity IDs 9507 and 3842). 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). For additional information, see the *Status of the Species and Critical Habitat* (Appendix B) for these species and *Environmental Baseline*. Relevant life history traits are discussed below for a general understanding of ecology of each species.

In general, we expect that aquatic snails will have a low risk of mortality and sublethal effects as a result of exposure to carbaryl based on acute toxicity data for freshwater snails to carbamate pesticides (see section *Effects to Aquatic Invertebrates)*. In particular, several species used in the SSD developed for carbaryl for mollusks were freshwater snails from multiple studies such as *Biomphalaria glabrata*, *Bellamya bengalensis*, *Pomacea patula,* and *Pila globose*. Due to the lower sensitivity to related carbamates exhibited by freshwater snails as compared to other aquatic invertebrates, aquatic snails were considered separately from other aquatic invertebrates in our analyses.

The endangered and threatened freshwater snails live in springs (e.g., Alamosa spring snail, Koster's spring snail, Chupadera spring snail, Lacy elimia, magnificent ramshorn) or flowing waters such as streams and rivers (e.g., Anthony's river snail, Snake River physa snail, Bliss Rapids snail, Tulotoma snail) and require pristine water quality with specific levels of temperature, rates of water flow, oxygenation, and pH in order to thrive. While we anticipate carbaryl use sites occur in or near the ranges of most listed snail species (indicating that exposure is reasonably certain to occur), because of the relative tolerance of aquatic snails to carbaryl, we expect there is a low risk of adverse effects from exposure to carbaryl. In addition, the Census of Agriculture indicates that there are low levels of past carbaryl usage within the range of all listed aquatic snails (less than 5% of their ranges have been treated with any insecticide), indicating exposure is likely to be low. In addition to low usage in carbaryl use areas within the species ranges, we anticipate exposure will be low for both those aquatic snails that inhabit rivers and streams or other water bodies with higher flow and those in lower flow and lower volume aquatic habitats such as springs, seeps, ponds, or creeks. EECs are not expected to reach levels that will cause mortality or sublethal effects in any of these aquatic habitats. As such, we do not anticipate mortality or sublethal effects will occur from exposure for any of the listed aquatic snails. In addition, available toxicity data in plants indicate that the food resources most aquatic snails require (e.g., algae, periphyton, detritus) are not likely to experience more than low levels of adverse effects at estimated environmental concentrations of carbaryl. As such, we generally do not anticipate listed aquatic snail species are likely to experience indirect adverse effects from carbaryl use.

In conclusion, we anticipate that over the duration of the proposed action, carbaryl exposure is likely to occur for the listed and proposed aquatic snail species and their food sources. However, we do not anticipate exposure or effects to food resources will lead to measurable levels of adverse effects to these species. After adding the effects of the action and cumulative effects to the environmental baseline, and in light of the status of the species, we have determined the proposed action is not expected to appreciably reduce the likelihood survival and recovery of these species in the wild. Thus, it is our biological opinion that the proposed action is not likely to jeopardize the continued existence of the aquatic snail species in Table 29.

Effects of the Action on Plants

In the Integration and Synthesis summaries (Appendix C), we evaluate the results of exposure to carbaryl for each Plant Assessment Group combination (as described in the *Toxicity* and *Effects of the Action* section of this Opinion). As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all plants for effects to the proposed action. In addition, we integrate the reproductive methods indicated by the species' Assessment Group placement to determine how those characteristics (e.g., pollination vector, ability to reproduce vegetatively) may modify the plant species reproductive response to exposure and potential loss of their pollinators on the landscape. Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.As discussed in the *Approach to the Effects Analysis* section, after considering a plant species' Plant Assessment Group placement, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We do not include any species in the grouped rationales when certain assumptions upon which the grouping is based are not applicable, additional information is required to make a determination, or unique circumstances are otherwise present that warrant additional discussion elsewhere in the Opinion. For these species, we provide an integration and synthesis summary where we discuss the necessary details needed to make a final determination. In situations where the combination of rankings indicates that additional information was analyzed before a jeopardy determination is made, we provide a species-specific narrative that outlines the information that informed the rankings the species was assigned, as well as incorporates any additional, species-specific information that is relevant to its final determination. While the general approach taken is the same for all listed species, our assessment for plant species included additional factors and life history characteristics not applicable to animal species that could modify the reproductive response of the plant species. These characteristics include its seed dispersal mechanism and whether it uses a few (specialist) or many (generalist) pollinator species for reproduction. We describe these characteristics in more detail below.

For each plant species, we considered all the information described above, and developed a rationale for the conclusion. Within each Plant Assessment Group, we documented our determinations for each endangered and threatened species. Proposed species are included in the Plant Assessment Group tables and individual rationales, although determinations for these species are provided as part of our Conference and Biological Opinions. Our analyses for these species are provided in the sub-appendices of Appendix C. Information on the status of the species can be found in Appendix B and information on all species vulnerability, exposure, and toxicity (including species summarized in grouped rationales) can be found in Appendix E.

Effects to Plant Species

Mortality and Sublethal Effects[30]

We used the studies and data provided in EPA's BE (2021), that measured effects to plants from exposure to carbaryl during post-emergent time frames and applied these data to all plants (flowering plants, ferns, allies, conifers, cycads) and lichens under consultation, as there are no data on the effects of carbaryl to listed plant or lichen species (details available in General Effects – Plants). Effects to terrestrial plants (monocot or dicot) reported from studies of post-emergent exposure to carbaryl indicate that minor adverse effects to growth occur at high levels of exposure (see Plant Toxicity data in the General Effects to Plants section in this Opinion).

Effects to Pollinators and Seed Dispersers[31]

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 to Plants* section, impacts to insect pollinators and seed dispersers for listed plants can be significant because carbaryl is designed to kill insects, including those that act as pollinators and/or seed dispersers of listed and proposed plant species. Successful pollination leads to seed production and is a critical step in 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,

[30] Mortality and sublethal effects correspond to risk assessment terminology of "direct effects."

[31] Effects to pollinators and seed dispersers correspond to risk assessment terminology of "indirect effects."

fragmented, or isolated populations where pollinating animals may provide the only connection among populations. Thus, loss of a portion of the pollinator community could lead to adverse reproductive effects in the form of decreased reproductive output for a listed plant species.

While available toxicity data indicate that insects, including those that act as pollinators and seed dispersers for listed plants, are sensitive to carbaryl at estimated environmental concentrations and are likely to die from exposure on both application sites and adjacent areas exposed via drift, we expect insect species to exhibit a range of sensitivities to carbaryl and do not anticipate the entire insect pollinator community will die.

In addition, we consider the following life history characteristics of each plant species to help evaluate the magnitude of indirect effects. We chose these characteristics as they can modify the response of the plant species to loss of pollinators and/or seed dispersal vectors from carbaryl exposure.

Dependence on biotic outcrossing and type of pollination vector (general reproductive method)

These characteristics are addressed through the Plant Assessment Groups. Generally speaking, plants that depend on insect outcrossing for successful reproduction are more likely to experience reproductive effects from loss of pollinators than plant species that can self-pollinate, use asexual forms of reproduction (i.e., vegetative reproduction), or that use abiotic pollination vectors. Likewise, a plant species that uses birds or mammals as pollination vectors are less likely to experience reproductive effects than those species reliant on insect vectors. This is because bird and mammal pollinators/seed dispersers are less sensitive to carbaryl exposure than insects. While carbaryl exposure in birds and mammals can cause mortality under specific circumstances (i.e., by consuming exclusively contaminated food items on carbaryl use sites) we do not expect carbaryl use is likely to appreciably diminish the availability of bird or mammal pollinators or seed dispersers. For species where the relationship with pollinators and seed dispersers is unknown, we make the conservative assumption that the species has a specialist-type relationship exclusively with insect pollinators and seed dispersers.

Seed Dispersal Vector

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 carbaryl on abiotic seed dispersal mechanisms such as wind, water, and gravity, among others, as there is no reasonable, functional tie between carbaryl 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. Similar to pollinator species, plants that rely on insects for seed dispersal are more likely to experience adverse reproductive effects from seed disperser loss than those species that rely on birds and/or mammals due to the minimal effects of carbaryl to these taxa groups as explained above.

Pollination or seed dispersal by one or a few species

Plants that depend upon a few or one specific pollinator species may see a disproportionately greater negative effect from the action since these plant species cannot utilize other insect species in the community for pollination if the specific pollinator they rely upon has been reduced or temporarily extirpated from the area due to carbaryl use (See discussion; *General Effects to Plants*).

Plants that rely on a select few species of pollinators or seed dispersers (i.e., specialists) are likely to experience high levels of indirect effect as high mortality in a few insect pollinator species can significantly reduce pollination and seed dispersal. In contrast, generalist plants that can use a wide range of insect species are likely able to recover more quickly from temporary losses of some insect species, resulting in lower levels of indirect effects from the proposed action.

<u>Effects to Plant Assessment Groups</u>

Groups 1-3: lichens, ferns and allies, and conifers and cycads

As mentioned previously, these Plant Assessment Groups contain plant species that do not use pollinators or seed dispersers for reproduction (e.g., lichens – group 1, ferns – group 2) or use abiotic vectors for pollination and/or seed dispersal (e.g., conifers – group 3). As such, EPA determined that the majority of these species had "No Effect" from the proposed action or the action was "Not Likely to Adversely Affect" the species. Therefore, our discussions about most of these species can be found in the *Supporting Information for the Concurrence Section of the Consultation* (Appendix A) and are not included in this Opinion. One notable exception is the fadang, a cycad species endemic to the island of Guam. This cycad uses wind for pollination, but can also use certain species of butterfly, therefore indirect effects to these pollinating butterflies are likely where exposure to carbaryl occurs. However, overlap of the species range with carbaryl is low (1.1%), the species can rely on wind for pollination in addition to butterflies, the species can also reproduce vegetatively, and seed dispersers are birds and mammals that are expected to experience minimal effects from carbaryl exposure. As a result, we expect minimal adverse reproductive effects to this species.

Groups 4 and 8: monocot and dicot flowering plants with abiotic pollination vectors

Plant species in these groups use abiotic vectors to accomplish pollination, such as wind or water. In addition, many of these species can reproduce vegetatively and disperse their seeds by wind or water. Thus, we anticipate most of the species in these groups will have minimal or no adverse reproductive effects from the proposed action since insects do not have a role in their life cycle. However, some species use mammals or birds as seed dispersal vectors. As explained previously, these taxa groups are expected to experience minimal effects from carbaryl exposure, thus very minimal adverse reproductive effects are expected for plants that depend on them for seed dispersal. Example species include golden sedge, Solano grass, and Hinckley oak. As a result, EPA determined that the proposed action was "Not Likely to Adversely Affect," or had "No Effect" on many of the species in these Plant Assessment Groups, and they can be found in in our discussions in the *Supporting Information for the Concurrence Section of the Consultation* (Appendix A). EPA determined the proposed action is "Likely to Adversely Affect" the remaining species and they are found in the Plants Assessment Groups 3, 4, & 8 I&S Summary in Appendix C. These species are anticipated to have minimal adverse reproductive effects from the proposed action because they may rely on mammals or birds for seed dispersal but use abiotic vectors for pollination.

Groups 5 and 9: Monocot and dicot flowering plants that require outcrossing with biotic pollination vectors

Group 5 and 9 species, such as the Eastern prairie fringed orchid, persistent trillium, Monterey clover, Tobusch fishhook cactus, and many others use a variety of biotic pollinating vectors, and require outcrossing, the transfer of pollen between individuals, 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. Anticipated adverse reproductive effects to these species vary widely depending on extent of exposure, presence or absence of the modifying life history characteristics described above, and their overall vulnerability. However, given most species in these groups rely on insect pollinator outcrossing for successful reproduction (only a few rely on birds and/or mammals for outcrossing), high levels of adverse reproductive effects are seen for a subset of these species. For example, the Kincaid's lupine exists only in the fragmented remaining grasslands of the Willamette Valley in Oregon. This area is highly agricultural, with high overlap and usage of carbaryl use sites leading to significant loss of pollinators within a large portion of the species' restricted range. Given this and the species reliance on insects for pollination and outcrossing, and inability to withstand additional stressors (i.e., high vulnerability) we determined high adverse reproductive effects to this species.

Groups 6 and 10: Monocot and dicot flowering plants that can use self-fertilization and/or vegetative methods for reproduction

Group 6 and 10 species, such as the Pitkin marsh lily, Munz's onion, Tiburon jewelflower, marsh sandwort, and many others use a variety of biotic pollinating vectors to transfer pollen between individuals, but can also reproduce, at least partially, by self-pollination (i.e., 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 communities. Many species in this group have low overlap and/or usage of carbaryl across their range and combined with their ability to reproduce without pollinators are not expected to experience significant negative reproductive effects. However, to maintain their genetic diversity over time, some species in these groups still need pollinators to transport pollen (their genetic material) between individual plants. If these species also had high exposure and toxicity rankings, and/or possessed other life history characteristics that increased the potential for indirect effects (such as use of one or a few pollinator species), we anticipated high adverse reproductive effects for these species. For example, the Yadon's piperia is an orchid endemic to California and exists in a very restricted range in the Monterey peninsula. It also relies on a limited number of nocturnal hawk moths for pollination and experiences increased seed production when outcrossed versus when it reproduces using self-pollination. The high overlap of carbaryl use sites combined with these factors leads us to determined high adverse reproductive effects for this species.

Groups 7 and 11: Monocot and dicot flowering plants that use biotic pollination vectors, but other characteristics of their reproductive mechanisms are unknown

Group 7 and 11 species, including the purple amole, Harper's beauty, autumn buttercup, tiny polygala, and many more 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. To be conservative, we assumed these species need outcrossing, at least partially, by their biotic vectors to reproduce successfully. As for the other Assessment Groups, anticipated adverse reproductive effects to these species vary widely depending on extent of exposure, presence or absence of the modifying life history characteristics described above, and their overall vulnerability. As such, those species with high overlap and/or usage, high toxicity rankings, those with modifying life history characteristics that increased their magnitude of indirect reproductive effects (such as requiring one or a few pollinator species), and/or high vulnerability factors (including pre-existing pollinator declines or reproductive failure) were anticipated to have high adverse reproductive effects. For example, the scrub mint is endemic to yellow sand scrub habitat of Lake Wales Ridge in Highlands County, Florida, and likely only has five extant populations (all of which are surrounded by agriculture and developed areas). While the scrub mint is self-compatible in addition to being insect pollinated, the species requires insect visits for seed production with very little dispersal capabilities. Given that this species has a high overlap (25.6% total overlap with agricultural areas) and high levels of past usage (up to 12.1% range treated annually from agricultural usage alone), we determined high adverse reproductive effects to this species.

All plants addressed in this Biological Opinion can be found in Table 29 above.

Critical Habitat Assessment

We assessed whether the registration of carbaryl is likely to result in destruction or adverse modification of designated or proposed critical habitat. 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 (50 CFR 402.02). We analyze effects to critical habitat separately from effects to the species. Our analysis of destruction or adverse modification is centered around the exposure and adverse effects to the physical and biological features (PBFs) of designated and proposed critical habitat. 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 in critical habitat for adverse effects to the critical habitat to occur.

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. 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 first evaluate areas currently occupied by the species and consider what PBFs a species needs for life processes and successful reproduction. For an unoccupied area to be designated as critical habitat, we must determine that there is a reasonable certainty that the area will contribute to the conservation of the species and that the area contains one or more of the PBFs essential to the conservation of the species. These areas may require special management considerations or protection, as described in designation rules. General PBFs of critical habitats include space for individual and population growth and for normal behavior; cover or shelter; food, water, air, light, minerals, or other nutritional or physiological requirements; sites for breeding and rearing offspring; habitats that are protected from disturbance or are representative of the historical, geographic, and ecological distributions of a species; and other features. 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 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 whether any direct or indirect alteration would appreciably diminish the value of critical habitat as a whole 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. 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 will be negatively affected by the proposed action. We identified four categories of PBFs that are likely susceptible to the effects of carbaryl:

(1) water quality,

(2) arthropods as prey, pollinators, or seed dispersers,

(3) non-arthropods, including prey, pollinators/seed dispersers and host fish, and

(4) general habitat function requiring no or low levels of chemical contaminants.

These types of PBFs are collectively referred to herein as the "relevant PBFs." We reviewed each critical habitat designation to determine if any relevant PBFs are identified as essential features of critical habitat for a listed or proposed species. For those critical habitats with rules that do not include specific PBFs, we assigned any relevant PBFs based on available information regarding specific needs of the listed species. Any critical habitats that do not contain relevant PBFs are given "no destruction or adverse modification" determinations as there are no links between carbaryl exposure and impacts to critical habitat function. For each critical habitat containing at least one relevant PBF, we assessed the overall exposure of critical habitat to carbaryl, the expected impact of carbaryl exposure to each relevant PBF, and the expected overall impact to the conservation value of the critical habitat as a whole. We use this process to determine if a critical habitat is likely to experience destruction or adverse modification.

Exposure of Critical Habitat to Carbaryl

Similar to the assessment of exposure to listed species, we consider the extent of agricultural overlap, the level of past carbaryl usage on or adjacent to critical habitat, the likelihood of exposure from non-agricultural uses, and any additional exposure information pertinent to a given critical habitat (e.g., USDA Census of Agriculture all insecticide usage data, specific habitat characteristics that result in higher or lower levels of carbaryl accumulation).

<u>Overlap</u>

Similar to our analysis of listed species, we use the agricultural overlap between the action area and designated critical habitat units as a metric of exposure. The EPA provided the overlap between carbaryl use sites and designated or proposed critical habitats (i.e., on-field overlap) and the overlap between carbaryl use sites buffered out to 30-meters (which is the maximum distance at which EPA determined adverse effects are likely to occur to listed species) and designated or proposed critical habitat units (i.e., off-field overlap). We determine the total overlap between critical habitat and the action area by summing the on- and off-field area overlaps for each relevant use type. Critical habitats with greater than 10% total overlap are assigned a high overlap score. Critical habitats with 5-10% overlap are assigned a medium overlap score, and critical habitats with less than 5% total overlap are assigned a low overlap score. This assignment of high, medium, or low rankings to these specific percentages of overlap are used for purposes of organizing our analyses along assumptions that generally apply with all the critical habitats evaluated in this Opinion. For example, while we generally expect critical habitats with high overlap with use sites and spray drift areas will have greater exposure to carbaryl, available information may indicate that general assumption does not apply to certain critical habitats. For example, even if the critical habitat of a species has a high overlap with use and spray drift sites, the Service may have information indicating that areas of critical habitat that contain or produce the necessary PBFs are not located on or near use sites.

For critical habitats designated for aquatic species, the EPA uses the HUC-12 watersheds that contain the designated critical habitat units to calculate the extent of overlap and past carbaryl usage. Unlike the ranges for listed aquatic species, critical habitat units for listed aquatic species are typically designated or proposed as highly refined areas demarcating specific (often small) waterbodies or smaller areas or reaches of larger waterbodies. Spray drift and runoff entering waterbodies can be transported far downstream in relatively short periods of time within watersheds, indicating that critical habitat for aquatic species can be exposed to carbaryl used in areas beyond 30-meters from the border of the designated units. Thus, the EPA calculated overlap and past usage using the broader watershed in order to better capture the potential exposure to critical habitat designated or proposed for aquatic species. As such, on-field overlap for aquatic critical habitat represents that amount of agriculture occurring within the watershed containing critical habitat. Given that this metric of use sites occurring within the broader watershed, we did not extend overlap 30 meters like for terrestrial species as this watershed level approach already encompasses that 30 meter off-field distance.

Exposure to Non-Agricultural Uses

Similar to our assessment of listed species' exposure to non-agricultural uses of carbaryl, we assess exposure of critical habitat to non-agricultural uses of carbaryl in a qualitative manner by considering whether non-agricultural use sites are likely to contain or produce many of the PBF requirements, the life history of species, methods of pesticide application, available past usage data, and any existing conservation measures to reduce drift and runoff or otherwise limit exposure to critical habitat.

<u>Usage</u>

Similar to our analysis of listed species, we use past carbaryl usage data in our assessment of exposure to critical habitat. The EPA applied the level of past carbaryl usage, as summarized by the State Summary and Usage Matrix (SUUM) in the BE, to calculate the percent of a critical habitat that is likely treated with carbaryl annually. We determine the total portion of the critical habitat treated with carbaryl annually by aggregating the percent critical habitat treated of all non-highly redundant crop groups (i.e., we sum all relevant crop type adjusted overlaps with either corn or soybean and either citrus, grapes, or other orchards in our total usage calculations). Unlike in our analysis for listed species, the percent of a critical habitat likely to be treated annually is almost always the same as the percent overlap as the conservative assumptions used in the application of SUUM data coupled with the small area covered by critical habitat relative to the species' ranges often results in the suggestion of high levels of carbaryl usage across critical habitats.

Similar to our analysis of listed species occurring entirely in California, we use data from the California Department of Pesticide Regulation's California Pesticide Use Report to determine the percent of critical habitat treated annually with carbaryl in place of SSUM data when available and applicable. For critical habitats in California, we report the percent of critical habitat that has been treated with any pesticides, percent of critical habitat treated with any insecticide, and the percent of critical habitat treated with carbaryl over a 10-year period (2013-2022). The EPA also provides estimates of the average number of growers/applicators that report pesticide usage within sections containing critical habitat in that same 10-year period, which we use as a surrogate metric for the potential variability in pesticide usage over time (e.g., a large number of growers reporting pesticide usage in a section containing critical habitat indicates less variability in the total area treated each year as changes in pesticide usage of a few growers is not likely to affect the proportion of the range treated).

We score total usage based on the total percent area that is likely to be treated with carbaryl annually. Critical habitats for which data indicate will have a large portion of their range (>10%) treated with carbaryl each year are assigned a high usage score. Critical habitats that will have a medium portion of their range (5-10%) treated with carbaryl each year are assigned a medium usage score, and critical habitats that data indicate will have a low portion of their range (<5%) treated with carbaryl each year are assigned a low usage score. Similar to overlap scores, this assignment of high, medium, or low rankings to these specific percentages of usage are used for purposes of organizing our analyses along assumptions that generally apply with all the critical habitats evaluated in this Opinion. While we generally expect high past usage can be indicative of increased exposure of critical habitat to carbaryl, available information may indicate that general assumption does not apply to certain critical habitats. For example, even in areas of high usage, the Service may have information indicating that the specific areas required by a listed species will not accumulate more than low levels of carbaryl (e.g., waterbodies with high flow and clearance rates).

Additional Exposure Considerations

When information on a specific species' use of critical habitat areas indicates that exposure assumptions are not likely true (e.g., for species where use site are not likely to contain or produce many of the PBF requirements or critical habitats located in protected areas where agricultural or non-agricultural pesticide usage is not expected), we qualitatively incorporate that information into our exposure rankings. Some examples of relevant information include knowledge of a species' preferred habitat characteristics (e.g., species that only occupy waterbodies with high flow rates, species that only consume certain taxa of prey) or additional sources of usage data, such as the USDA CoA. We use the percent of a critical habitat treated with any insecticide as an additional line of evidence to characterize the level of exposure a critical habitat will experience. Given that these data are more spatially specific than usage data provided by the SUUM (with the exception of California, where data are available at a sub-county level) and covers all insecticides used (not just carbaryl), we consider instances where the CoA reports low levels of usage for all insecticide within a species' range as strong evidence that carbaryl usage is unlikely to exceed low levels of usage throughout the course of the action. When additional exposure considerations are available, we qualitatively adjust our exposure assessment to reflect this additional information as appropriate.

Adverse Effects to Critical Habitat PBFs

We characterize the expected impacts to critical habitats based on the anticipated level of adverse effects to PBFs. Our analysis of toxicity assumes critical habitats are exposed to carbaryl at levels estimated by EPA's environmental exposure modeling and is focused on determining the level of adverse effect expected to occur once exposure has taken place. We compare estimated concentrations of carbaryl in critical habitat to toxic effects reported in available toxicity studies of various taxa of organisms to determine the level of impact to relevant PBFs. We also include any additional considerations regarding a listed species' life history that provides additional context to the specific parameters that PBFs need to meet to maintain their function (e.g., how sensitive a listed species is to carbaryl may influence the level of impact to a water quality PBF relative to another species).

Water Quality

Critical habitats that list water quality as a relevant PBF (e.g., low levels of chemical contaminants, high quality water) are likely to experience adverse effects from the presence of carbaryl within waterbodies found inside critical habitat boundaries (whether through direct application or exposure through spray drift deposition or runoff). If a listed species is sensitive to chemical pollutants, exposure to carbaryl could result in toxic effects to individuals. Thus, the presence of carbaryl will likely result in adverse effects to the water quality PBF as individuals of the listed species may not be able to fully use or occupy critical habitat. The level of impact to water quality is dependent on the expected environmental concentration of carbaryl likely to occur in critical habitat and the sensitivity of a listed species to carbaryl.

We compare estimated environmental concentrations of carbaryl provided by the EPA to available reference toxicity data for the most appropriate surrogate taxa or species to assess the anticipated impact of carbaryl use on critical habitat water quality. The EPA models carbaryl concentrations using a variety of models to provide estimates that generally correspond with different types of waterbodies required by listed species in critical habitat (i.e., waterbodies with high flow rates, large volume waterbodies, low volume/low flow rate waterbodies) at a national scale. We use the maximum estimated environmental concentrations of carbaryl corresponding to the use sites with the greatest overlap with critical habitat (which we anticipate are the exposures most reasonably certain to occur) from the most appropriate models to estimate impacts to water quality in critical habitat. We compared these estimated environmental concentrations to the aquatic invertebrate HC_{05} reference toxicity value to assess impacts to water quality in critical habitat designated for listed aquatic invertebrates. We compare maximum estimated environmental concentrations to the fish HC_{05} reference toxicity value to assess impacts to water quality in critical habitat designated for listed fish and aquatic-phase amphibians.

We qualitatively rate the impact to the water quality PBF as high, medium, or low. In cases where the predicted level of carbaryl in critical habitat waterbodies would cause high levels of mortality of individuals, we assign a high impact rating to the water quality PBF. We assign a low impact rating in cases where predicted carbaryl concentrations are not likely to cause more than low levels of mortality. When a range of adverse effects are likely to occur (e.g., for species that can use habitats with a wide range of flow rates and depth profiles), we assign a medium impact rating to indicate that a range of adverse effects are likely to occur to emphasize that impacts to water quality are likely dependent on the specific areas within critical habitat where exposure occurs.

If available life history information indicates a listed aquatic species prefers a particular type of waterbody, we qualitatively adjust our assessment of adverse effects to weigh impacts to the waterbodies preferred by the species more heavily. Additionally, since we expect carbaryl will rapidly degrade in natural environments (on the order of days to weeks), we anticipate water quality will recover once residues degrade. The time to recovery depends on many factors (e.g., how much carbaryl accumulates in a waterbody, variations in temperature, flow rate and other environmental conditions, if repeated exposures are likely). We incorporate this information when available and relevant in our critical habitat determination rationales.

Arthropods as Prey, Pollinators, and Seed Dispersers

Critical habitats that list the presence of arthropods as a relevant PBF (e.g., insect or crustacean prey, insect pollinators or seed dispersers) are likely to experience adverse effects from carbaryl exposure, whether through direct application or exposure through spray drift. If a listed species is highly reliant on arthropods, carbaryl residues in critical habitat will result in high levels of indirect effects to the species. Thus, the presence of carbaryl will likely result in adverse effects to the arthropod PBF as individuals of the listed species may not have the necessary prey, pollinator, or seed disperser resources required for survival, reproduction, or recovery.

Based on available toxicity data, we generally anticipate arthropod species are sensitive to carbaryl and are likely to experience high levels of mortality even at low levels of exposure. As such, we generally expect areas of critical habitat exposed to carbaryl will experience large reductions in the abundance of arthropod prey, pollinators, and seed dispersers. Given this general sensitivity to carbaryl, we anticipate most critical habitats that list the presence of arthropods as an essential component will likely be assigned a high impact rating to the arthropod prey/pollinator/seed disperser PBF.

However, we do not expect all arthropod species are equally sensitive to carbaryl as variations in physiology, life history traits, and individual behaviors would result in a range of sensitivities to carbaryl across multiple species. Thus, while we anticipate those areas of critical habitat exposed to carbaryl will experience large reductions in the abundance of sensitive arthropod species, we expect other, less sensitive arthropod species would still be present and available within those areas of critical habitat to function as prey or pollinators/seed dispersers. We expect this range of sensitivities is most relevant for critical habitats designated for listed species that can capitalize on a wide range of arthropod species (e.g., generalist invertivores, plants that can be pollinated by a wide range of insect species), as these species can more easily switch to using less sensitive arthropod species as food or pollinators/seed dispersers. We incorporate this information into our critical habitat determination rationales as available.

Additionally, since we expect carbaryl will rapidly degrade in natural environments (on the order of days to weeks), we anticipate the arthropod community will recover over time once residues degrade. The time to recovery depends on many factors (e.g., the ability of the affected species to rebound, the level of exposure within critical habitat, variations in environmental conditions like temperature or amount of sunlight, and if repeated exposures are likely). We incorporate this information when available and relevant in our critical habitat determination rationales.

Non-arthropods as Prey, Pollinators/Seed Dispersers, and Host Fish

Critical habitats that list non-arthropod species as a relevant PBF (e.g., mollusk and annelid prey, vertebrate prey, fish hosts) are likely to experience adverse effects from carbaryl exposure. If a listed species is highly dependent on a specific non-arthropod species that is sensitive to carbaryl at estimated environmental concentrations, then the presence of carbaryl within critical habitat will result in high levels of indirect effects to the species. Thus, exposure to carbaryl may result in adverse effects to the non-arthropod PBF as individuals of the listed species may not have the necessary prey or host fish resources necessary for survival and recovery.

The overall impact of carbaryl to non-arthropod prey will vary greatly between the different taxa included in this PBF category. We compare estimated environmental concentrations generated by the EPA to available toxicity data provided in the BE to determine the overall effect to the non-arthropod PBF. Available toxicity data indicate that mollusk and annelid species are not sensitive to carbaryl. As such, we anticipate non-arthropod invertebrate prey within critical habitat are not likely to experience more than very low levels of adverse effects, even at the highest concentrations of carbaryl predicted to occur in the environment. As such, critical habitats that only list mollusk prey species as an essential feature are likely to be assigned a low impact rating for the non-arthropod PBF.

Vertebrate prey and host species will experience a wide range of adverse effects from carbaryl exposure depending on the exposure conditions. Fish and aquatic phase amphibian prey and fish host species are generally not likely to die unless exposed to very high levels of carbaryl (which, based on EPA's modeling, anticipate will occur very rarely) and typically only under specific exposure conditions (i.e., in waterbodies with low flow rates or small volumes). As such, critical habitats that list fish or aquatic phase amphibian prey or fish host species as an essential feature may be assigned a low to high impact rating for the non-arthropod PBF, depending on the specific habitat characteristics the listed species needs. We use information about the listed species' preferred aquatic habitat conditions (when that information is available) to determine the most relevant exposure conditions and the associated impact rating to the fish or amphibian prey base or fish host community.

In our analyses of impacts to fish host species in particular, we qualitatively adjust our impact rating depending on the range and abundance of fish hosts the listed species can use to successfully reproduce. While we anticipate a high level of mortality of fish species in certain types of waterbodies, we do not anticipate all fish species are equally sensitive as variations in physiology, life history, and individual behavior will result in differing sensitivities to carbaryl. As such, while we anticipate a large reduction in the abundance of sensitive fish host species in some areas of low flow or low water volume, we do not anticipate there will be complete mortality of fish hosts and that there will still be some hosts available for listed bivalves to use. We anticipate the fish host PBF in critical habitats designated for listed bivalves that can use a wide range of fish host species will be more robust to adverse effects of carbaryl as there is a higher probability that the remaining, less sensitive fish species can be used as hosts for their glochidia. In contrast, the non-arthropod PBF in critical habitat designated for listed bivalve species that are fish host specialists (i.e., can only use a narrow range of host species) may still experience high levels of impacts despite there being a reduction in the abundance of only some fish species. We incorporate this information into our rationale as information is available.

Terrestrial vertebrate prey will experience a range of adverse effect from carbaryl exposure depending on where the prey is exposed. Mammalian prey are all likely to experience high levels of mortality when individuals forage on contaminated food items on use sites within a short period after carbaryl applications are made. We expect mammalian prey that are exposed in off-field areas are not likely to experience more than low levels of mortality. We do not anticipate bird, reptile, or terrestrial phase amphibian prey are likely to experience more than low levels of mortality when foraging on- or off-field. Our default assumption is that terrestrial prey species are likely to consume contaminated food both on- and off-field. As such, we anticipate critical habitats designated for listed species that exclusively consume bird, reptile, or terrestrial-phase amphibians will experience low impacts to the non-arthropod PBF as we do not anticipate significant reductions in vertebrate prey are reasonably certain to occur. For critical habitats designated for listed species that exclusively consume mammalian prey, we anticipate there will be high levels of prey mortality on-field and low prey mortality off-field, indicating an overall medium level of impacts to the non-arthropod prey PBF. We assign a range of low to high impact ratings for the non-arthropod PBF for critical habitats designated for species that consume a mix of mammalian and non-mammalian prey depending on available information on the relative importance of the different prey taxa to the listed species.

General Habitat Function

Critical habitats that require low levels of chemical contaminants for proper function as a relevant PBF (i.e., general habitat function PBF) are likely to experience adverse effects from the presence of carbaryl within critical habitat boundaries. If a listed species is sensitive to chemical pollutants, exposure to carbaryl residues on various surfaces within critical habitat would result in toxic effects to individuals, preventing them from using critical habitat. Thus, the presence of carbaryl will likely result in adverse effects to the habitat function PBF as individuals of the listed species may not be able to fully use or occupy critical habitat. The level of impact to habitat function is dependent on the expected environmental concentration of carbaryl likely to occur and the sensitivity of a listed species to carbaryl.

We qualitatively rate the impact to the habitat function PBF as high, medium, or low based on the level of adverse effects likely to occur at predicted environmental concentrations. In cases where the predicted level of carbaryl in critical habitat would cause high levels of mortality of individuals, we assign a high impact rating to the habitat function PBF. We assign a low impact rating in cases where predicted carbaryl concentrations are not likely to cause more than low levels of mortality. If available life history information indicates specific behaviors or habitat preferences that would alter the likelihood of exposure to carbaryl residues (e.g., individuals are attracted to agricultural areas or individuals tend to aggregate in areas away from cultivated lands), we qualitatively adjust our assessment of adverse effects to weigh impacts to the habitat function PBF based on the likely exposure of individuals to carbaryl residues within critical habitat.

Since we expect carbaryl will rapidly degrade in natural environments (on the order of days to weeks), we anticipate habitat function will recover over time once carbaryl residues degrade. The time to recovery depends on many factors (e.g., the level of exposure within critical habitat, variations environmental conditions like temperature or amount of sunlight, and if repeated exposures are likely). We incorporate this information when available and relevant in our critical habitat determination rationales.

Critical Habitat Determinations

To determine the overall impact of the proposed action to designated or proposed critical habitat, we assess the impact score of each relevant PBF alongside the exposure ranking to determine both the overall adverse effect of carbaryl exposure and the footprint of the anticipated adverse effect across the entire critical habitat. Our results can be found in Appendix D. To streamline our discussion in this Opinion, we group critical habitats that have the same or very similar rationales for their conclusions to increase efficiency and avoid repetition. We considered relevant information and data unique to each individual species when assigning species to groups, which we incorporated into the rationales as appropriate. Species- and critical habitat-specific information (e.g., environmental baseline, cumulative effects, status of the critical habitat, exposure, and toxicity) was considered for all critical habitats, including those in the grouped analyses, and are presented in full in Appendices B and E. In cases where a combination of rankings and additional considerations provides a clear narrative for a determination that the proposed action is not likely to destroy or adversely modify a critical habitat, we provide a group rationale that outlines how the combination of species vulnerability, critical habitat exposure, and PBF impact rankings, and additional considerations results in this conclusion for all relevant critical habitats. Within these grouped rationales, we add additional information, when relevant, to support our conclusions. We review each grouped rationale to ensure that all assumptions made are applicable for each critical habitat within the group and are expected to result in a similar determination for each critical habitat.

We do not include any critical habitats in the grouped rationales when certain assumptions upon which the grouping is based are not applicable, additional information is required to make an adverse modification determination, or unique circumstances are otherwise present that warrant additional discussion elsewhere in the Opinion. For those critical habitats, we provide an additional discussion for this specific designation to convey the necessary details supporting our determination. For instance, we did not include critical habitats in grouped rationales when we determined that CalPUR data did not have a sufficient sample size for the respective critical habitat in order for us to confidently conclude that exposure was unlikely to occur. In other cases, we had information suggesting that there may be impacts from carbaryl to certain areas of a designation that are biologically significant to the species, even if there is low overlap between critical habitat and the action area or if data from the Census of Agriculture indicated low levels of past usage. These critical habitats have an individualized discussion in Appendix D.

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 have limited abilities to address directly due to lack of relevant data or appropriate models. In all circumstances, we based our ESA section 7 analyses on the best scientific and commercial data available.

Below we identify several assumptions and uncertainties we have considered in our analysis for the overall approach, as well as specific to the effects analyses. In some instances, we are aware that certain assumptions, when considered 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 destroy or adversely modify critical habitat. For example, we lack data to quantitatively assess the effects of carbaryl to individual species in combination with other stressors in the environment (e.g., temperature, other chemicals; exposure to multiple stressors). However, by making conservative assumptions about exposure to carbaryl 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* 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 carbaryl. 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 use 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 *Effects to Reptiles*, *Effects to Terrestrial Amphibians, and Effects to Fish and Aquatic-Phase Amphibians* sections. More specifically, we use fish and bird data for aquatic and terrestrial amphibians, respectively 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 (e.g., sublethal, 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 group (e.g., honey bee toxicity data to address effects to all insects) or a taxa group for which data are lacking (e.g., fish toxicity data to address effects to aquatic-phase amphibians).

Estimated Environmental Concentrations

For this analysis of the effects of carbaryl to different taxonomic groups in this Opinion, we assume that individuals will be exposed to a range of modeled annual maximum pesticide concentrations for a species that inhabits higher flow/volume waterbodies or if they inhabit low flow/volume waterbodies or both, the range of EECs always provides for a conservative assumption for the concentrations of the pesticide in the given waterbody. We present the maximum EECs in our Integration and Synthesis analyses to address the effects to species in the most conservative way that captures the breadth of effects to species or critical habitat. In addition, exposures are based on pesticide crop use scenarios that generate the highest EECs, which also may overestimate effects. For aquatic species, distribution within aquatic habitats is assessed based on very generic habitat flow volumes and rates and may over- or underestimate exposures to listed fishes, crustaceans, aquatic insects, aquatic snails, and mussels. However, effects are limited to a single exposure of carbaryl, 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. These assumptions vary in whether 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 proposed action is likely to jeopardize listed species or destroy 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 carbaryl. 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 carbaryl 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 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 likely 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. Through internal Service efforts to refine species ranges, 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 Hawaiʻi plants), based on the best scientific and commercial data available at the time. However, even refined range maps may include areas not specific to species' habitat requirements.

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, or from Service species leads directly (e.g., Moapa Dace, Lange's metalmark butterfly). 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 carbaryl 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 even section-level analysis may include areas that are not within the species' range, and uncertainties in the reporting exist. As such, while we have greater confidence in these data, we acknowledge that it may still over- or under-estimate exposure to listed species.

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 carbaryl 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.

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 30 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. However, overall, our analysis in this Opinion contains reasonable assumptions in determining whether the proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat.

Table 30. Assumptions and Uncertainties for the Effects Analysis.[32]

Final Table 30
Assumptions and U

CONCLUSION

The proposed registration that is being reviewed for carbaryl, with general conservation measures and species-specific conservation measures that have voluntarily been incorporated into the action, where appropriate, is not likely to jeopardize the continued existence of 1,179 species. Our Conference Opinion considers 29 proposed species and Biological Opinion considers 1,150 listed species (see individual taxa/group tables in the *Integration and Synthesis* section of this Opinion). Although we determined that some species were likely to be jeopardized in our draft Opinion, this determination has changed due to the conservation measures that were incorporated into the action. For many species, species-specific conservation measures were not necessary because the general conservation measures sufficiently reduced the overall level of adverse effects to the species to avoid the likelihood of jeopardy. For example, with these general measures in place, some species are either now less vulnerable to overall threats and/or will not be exposed to more than low levels of carbaryl. While we anticipate that for some of these species, residual exposure is likely to result in mortality of a small number of individuals, sublethal effects to growth or reproduction, or reduced food resources, host fish, or pollinators, we do not anticipate species-level adverse effects that are likely to rise to the level of jeopardy after incorporating general conservation measures.

For other species, species-specific measures were needed, in addition to the other general measures, to avoid the likelihood of jeopardy described in our draft Opinion. These species generally have high vulnerabilities (e.g., they are represented by a single or a few populations, their populations are declining, populations are small or isolated and fragmented across their range) and/or have medium to high exposure to carbaryl due to the extent of overlapping use sites or usage across their ranges (even with the general measures in place). Therefore, we anticipated that exposure (without additional species-specific measures in place) would result in mortality and/or adverse effects to food resources or pollinators that were likely to result in species-level effects. After incorporating species-specific conservation measures that were developed between our draft and final Opinions, we now anticipate mortality of only small numbers of individuals for these species. With the specific measures in place, some of these species are expected to experience low levels of reduced fitness due to a decrease in the number of available prey resources, host fish (for mussels), and pollinators (for plants). In some cases, individuals may experience multiple adverse effects concurrently (e.g., loss of food resources, direct effects) within a given application area. However, after adding the effects of the action and cumulative effects to the environmental baseline, accounting for general and specific

[32] To view the spreadsheet in MS Excel from the MS Word Opinion, double click on the Excel icon. To view the spreadsheet in MS Excel from the portable document format (pdf) Opinion, open the Opinion in the desktop version of Adobe Acrobat or Reader and open the embedded attachment corresponding to the numbered table.

conservation measures, and in light of the statuses of these species, it is the Service's opinion that the registration of carbaryl is not likely to appreciably reduce the survival and recovery of the threatened, endangered, and proposed species addressed in this Opinion in the wild and, thus, it will not jeopardize the continued existence of these species.

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 carbaryl. 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 carbaryl and the consequences for each critical habitat was evaluated, and our assessments and conclusions are included in Appendix D.

Our Conference and Biological Opinions cover designated and proposed critical habitats for 485 species (see individual taxa/group tables in the *Integration and Synthesis* section of this Opinion). There were 29 proposed and 456 designated critical habitats. Based on the critical habitat analysis described above and presented in Appendix D, adverse effects are anticipated for some critical habitats. After incorporating general and specific measures where appropriate, the proposed registration of carbaryl is not likely to destroy or adversely modify proposed or designated critical habitats. Based on the critical habitat analysis described above, although some adverse effects are anticipated for certain critical habitats, we do not anticipate that the proposed action, after incorporating conservation measures, would adversely impact these critical habitats to a level that would appreciably diminish the value of those critical habitats for the conservation of their respective species, as a whole. Therefore, it is our biological opinion that the proposed action is not likely to result in the destruction or adverse modification of 485 critical habitats.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. *Harm* is defined by the Service as an act that actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). *Harass* is defined by the Service as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that: 1) the action is not likely to jeopardize the continued existence of listed species or implements a reasonable and prudent alternative to avoid the likelihood of jeopardy, and 2) such taking is in compliance with the terms and conditions of this 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 proposed 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 (Table 31). In addition, although we cannot precisely quantify the number of individuals anticipated to be taken as a result of this proposed action, we have provided a clear, measurable usage value and an overlap value for each species by which the relative levels of incidental take associated with the usage and overlap data that we analyzed in this Opinion can allow EPA to recognize when that threshold has been exceeded and that re-initiation of consultation is warranted in order to evaluate our relevant assumptions and conclusions in this Opinion. As explained in more detail below, if the specific values pertaining to usage or overlap are exceeded during the course of this proposed action, re-initiation of consultation would be required pursuant to 50 C.F.R. 402.16(a). If EPA believes the value has been exceeded, EPA will promptly inform the Service, and the agencies will coordinate accordingly.

Table 31. Anticipated incidental take.[33]

Table 31_Anticipated incidental take.xlsx

Partially due to the characteristics of many of the species analyzed in this Opinion, the express number of individuals taken incidental to the proposed 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 an inhabitant of 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 reasonably certain to occur as a result of direct exposure and impacts on prey and other resources upon which the listed species depends. In addition, losses of individuals caused by carbaryl exposure 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 proposed action evaluated in this Opinion makes it difficult to detect and measure incidental take. The proposed 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 chemical use, species' exposure, and resultant incidental take, if any. 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

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 proposed 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

[33] To view the spreadsheet in MS Excel from the MS Word Opinion, double click on the Excel icon. To view the spreadsheet in MS Excel from the portable document format (pdf) Opinion, open the Opinion in the desktop version of Adobe Acrobat or Reader and open the embedded attachment corresponding to the numbered table.

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 proposed action (Table 31), as described in the Integration and Synthesis summaries (Appendix C). 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 carbaryl in light of: (1) the best available scientific and commercial data (e.g., use sites and usage within the range) 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 incorporation of conservation measures in the proposed action that will avoid the likelihood of jeopardy and adverse modification by reducing exposure to carbaryl, we anticipate that low levels of incidental take are still reasonably certain to 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 C). In Table 31, we indicate the levels of individuals that we anticipate would experience mortality, sublethal effects (e.g., survival, growth, or reproduction), or impacts to fitness (e.g., from impacts to prey or forage base) over the duration of the proposed action. For example, for bivalves, we do not anticipate mortality, but for some mussel species that occur in smaller-sized flowing or static waterbodies, we anticipate sublethal effects with respect to the reproduction of individual mussels from direct exposure to carbaryl as well as a reduction in host fish availability. Similarly, for listed fish species, we anticipate individuals of a few listed fish species will be killed or experience sublethal effects in smaller waterbodies; we also anticipate that individuals of other listed fish species in a variety of types of waterbodies will also experience reductions to fitness through a reduction in prey or forage base. For other species, such as certain listed amphibian, bird, and mammal species, we anticipate individuals will be killed or experience sublethal impacts to growth or reproduction from exposure to carbaryl, resulting reductions in fitness due to losses of prey or other food resources.

Overlap and Usage Data Used for Extent of Take

Due to the nature of the proposed 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, overlap and usage information that we evaluated in this Opinion, as described for each species or species group in its Integration and Synthesis summary (Appendix C), can be used to detect trends or changes in use and usage patterns over the duration of the Action. Because the expected level of incidental take for each species is linked to the level of overlap and usage that we anticipated for each species in this consultation, certain measures of exposure (e.g., overlap of species range with crop data layers, the percentage of crops treated for agricultural uses within species ranges, the number of pounds applied or acres treated for non-agricultural use sites) 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). Regular monitoring for changes in overlap and 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, changes in certain types of data will not likely be of concern. For example, where general or species-specific conservation measures would effectively minimize the level of off-site transport of carbaryl from use sites and measures that restrict application rates and when applications can be made reduces exposure to listed species, their food resources, pollinators, or hosts, such that increases in the overlap or usage measures that we anticipated in this Opinion (i.e., exceedances) will not necessarily increase exposure and change the incidental take levels described in this statement. Similarly, where changes in patterns or levels would only affect uses that are not of concern to a species, we would not likely anticipate exceedances of incidental take. In contrast, in some cases, changes in use or usage patterns may indicate the anticipated levels of incidental take have been exceeded. This will be determined after evaluation of changes in use and usage patterns, identified, as appropriate, through required monitoring over the project duration.

To further illustrate, given the anticipated toxicity to the host fish of species of freshwater mussels in the example used above, we expect some number of host fish will be killed each year resulting in incremental levels of take for some species of mussels. Should subsequent information reveal an increase in carbaryl exposure over time, then this information would be a basis for EPA and the Service to evaluate if the increase in exposure was reasonably certain to result in an increase in host fish mortality, and consequently, a higher decrease in reproduction of the listed mussel than anticipated in this opinion. On the other hand, if subsequent years of carbaryl exposure information reveals a general downward or stable usage trend, we would generally not anticipate the need for reinitiation unless additional factors (e.g., change in species status, new information about the toxicity to species localized increase in usage affecting discrete areas important to the species, its prey, or its habitat) become apparent. Thus, one of the triggers for evaluating the need for reinitiation of consultation would be an increase in use or usage patterns that would be likely to result in exceedances of incidental take for any of the animal species in this Opinion. This will be determined using a two-part assessment of both the risk to the species based on our understanding of the toxicity of carbaryl and increases in levels of exposure from the anticipated overlap with carbaryl use sites and usage of carbaryl in the habitats of the species.

As use and usage data is acquired in monitoring implementation of the proposed 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 use and 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 use and 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 inform periodic evaluations to determine whether reinitiation of consultation is required.

The use of carbaryl usage and overlap 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. While data to assess the overlap of agricultural use sites with species' ranges is widely available, we recognize that there are significant gaps for usage data. For example, usage data are not uniform across the action area, and the data are not available for each use within the same time frame. In addition, usage data are reported at varying spatial scales. However, the usage data, which represents a portion of the best scientific and commercial data available, was an important component of our analysis in this Opinion, and, with the overlap data, 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 in this opinion, based on state-level agricultural data for carbaryl, county-level agricultural data for pesticide classes (e.g., all insecticide usage, all herbicide usage) from the USDA Census of Agriculture, section-level CalPUR data (described in the *Effects of the Action* section of this Opinion and for each species in Appendix C), and regional- or national-level non-agricultural usage data. As detailed in the *Usage Analysis* section above, for each state within most species' ranges[34], EPA estimated agricultural usage for each UDL overlapping the species range considering maximum PCT values over the 5-year reporting period in EPA's SUUM (Appendix 1-4 in the BE). 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 many species, we were able to apply additional usage data on pesticide class usage (i.e., all insecticides) at the county level using data from the Census of Agriculture. For species that reside wholly or mostly within California, we were able to apply more geographically specific (section-level) agricultural usage data from CalPUR regarding carbaryl applied within each species' range. For non-agricultural uses where conservation measures were not already in place to reduce species exposure (e.g., rights of way, forestry) we considered the number of pounds applied or acres treated across regional or national scales to assess the likelihood that species found on or near those use sites would be exposed.

For all use sites, we can assess whether we expect a change from the number of acres we estimated to be treated with carbaryl in the range of each species by monitoring the base information we used to make this estimate (e.g., PCT for state-level agricultural data and acres treated for California agricultural data). This information will be considered in light of species range information to assess whether or not reinitiation is required. An increase of a usage or overlap value resulting in a higher overall exposure ranking (e.g., from low to medium or medium to high) would be an example of a scenario that could trigger reinitiation. Put another way, when a usage or overlap value exceeds the estimate within the species' Integration and Synthesis Summaries in Appendix C, EPA will alert us to the possibility of levels of take exceeding those anticipated in this Opinion. Data indicating changes in use and usage will be evaluated, with coordination between EPA and the Service (as referenced in the Terms and Conditions listed below), to determine whether the exceedance indicates that reinitiation of consultation is warranted (e.g., the data indicates the amount or extent of taking specified in this incidental take statement is exceeded). We recognize the burden on the action agency and

[34] Refer 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 carbaryl is used will apply.

enormity of the task of revisiting analyses repeatedly in the course of an action to test assumptions. While all species analyzed in this Opinion are at some level of risk (i.e., those identified with may affect, likely to adversely affect determinations), we anticipate a targeted focus on those species where individual mitigation measures were not identified, but where overlap is estimated, where toxicological information indicates a threat, and where incidental take is anticipated.

As previously mentioned, we note that the usage data utilized in this Opinion are not uniform. For example, the Census of Agriculture and 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 Census of Agriculture or CalPUR data, as opposed to changes in aggregated usage data at the state level or pounds applied at a national level, may be more likely to reflect an exceedance in incidental take. EPA will provide us state-level, Census of Agriculture, and CalPUR agricultural data and regional and national non-agricultural data as outlined in our Terms and Conditions below. We believe that by examining these usage values, we will be able to identify potential exceedances.

REASONABLE AND PRUDENT MEASURES

"Reasonable and prudent measures" ("RPM") are those actions the Service believes necessary or appropriate to minimize the impact of incidental take on the species. (50 CFR 402.02). It is the Service's opinion that the following reasonable and prudent measures are necessary, appropriate, and 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[35]. For the initial annual reporting, the

[35] 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.

Service expects that the first report will be transmitted no later than April 30, 2026, 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 April 30, 2026.

    b) Each annual report will include, at a minimum: (1) water quality monitoring data and (2) ecological incident data. Beginning with the April 30, 2028, 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 range treated and non-agricultural use sites (regional or national values, as available) 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 the general label changes (described in the PID) are implemented in a timely manner and provide confirmation on the status of that implementation to the Service. These label changes that are part of the proposed action include spray drift, runoff and application measures described in the PID and in the *Changes to the Action through FIFRA Registration Review – Carbaryl PID Agreements* section in this Opinion.

    a) 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 carbaryl exposure to ESA listed species and critical habitat designations described in this Opinion related to a) water quality monitoring data (i.e., carbaryl concentration in the environment); b) ecological incidents; c) carbaryl use; and d) carbaryl 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 carbaryl 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, 2026). 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 carbaryl have caused unforeseen ecological impacts.

i) EPA shall include this information in its annual reports to the Service, and specify any information related to carbaryl-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 carbaryl.

(3) Where no reports were submitted, EPA shall document this in the annual report referenced in Paragraph 1.

ii) 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 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 the subsequent annual report to the Service following the conclusion of this analysis.

d) Usage data:

i) No later than 5 years following publication of this Opinion, and at 5-year intervals to coincide with the publication of the USDA NASS Census of Agriculture, EPA will review available agricultural usage data from the Census of Agriculture, sources reported in EPA's State Use and Usage Summary Matrix, and California State's Pesticide Use Report, and as appropriate, indicate changes and/or exceedances to usage information that supported species analysis within this Opinion.

ii) No later than 5 years after the release of the Opinion and in coordination with required agricultural reporting in i) above, EPA will review available non-agricultural usage data from sources reported in EPA's 2020 State Use and Usage Summary Matrix for carbaryl, and as appropriate, indicate changes and/or exceedances to usage information that supported species analysis within this Opinion.

iii) As appropriate to communicate any meaningful changes identified, EPA will provide 5-year summary usage metrics that describe both pesticide type (e.g., insecticide, herbicide, fungicide), usage patterns, as well as active ingredient (i.e., carbaryl) specific usage data. EPA will provide any updates to relevant usage data at the scale and specificity appropriate for the purposes to demonstrating meaningful changes. Findings shall be included in the subsequent annual report to the Service following the conclusion of this analysis.

iv) If provided usage summaries do not sufficiently allow FWS the ability to evaluate the continued exposure of listed species to carbaryl such that unexpected incidental take may have occurred, if requested by FWS, EPA will coordinate with FWS to identify relevant additional usage information, as available.

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 carbaryl requirements for listed species, with a particular focus on the implementation of mitigations for pesticide applicators. EPA will provide a link to this voluntary training/educational material within the specific carbaryl 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 carbaryl labels 5 years after the Opinion is issued.

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.

5) Salvage, care, and reporting of dead or injured animals: Upon locating any dead, injured, or adversely affected endangered or threatened species, pesticide users, applicators or the public are asked to contact the Service’s Law Enforcement Office (lawenforcement@fws.gov or (703) 358-1949) and, if known, the pesticide manufacturer per the contact information on the pesticide label. Noting the time and place of the encounter is requested, and extreme caution should be taken if the dead or injured animal(s) are thought to have been exposed to harmful chemicals, as these chemicals may still be present in the environment and on affected animals. Appropriate personal protective equipment should be employed and only by individuals trained for such events. If salvage or collection is not possible (e.g., concern about human health, or a fish kill, or an animal too large to transport), photographs and reporting are appropriate and appreciated. Care should be taken in handling sick or injured individuals to ensure effective and proper treatment. Care should also be taken in handling dead specimens to preserve biological material in the best possible state for analysis of cause of death.

6) Red wolf: To monitor our expectations regarding exposure and effects to the red wolf, EPA will track cause of death of wolf mortalities. If any mortalities result from application of pesticides (particularly carbaryl), the EPA will confer with the Service to determine next steps, such as developing additional mitigation measures or reinitiating consultation, as appropriate.

CONFERENCE REPORT

CONFERENCING ON PROPOSED 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 proposed 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 proposed action is not likely to jeopardize any proposed or candidate species (at the time of this final Opinion, listing determinations were made for all candidate species that had been included in the BE, so those species are now listed and included in the consultation or removed if they were not listed, and only proposed species are included in the conference) or result in the destruction or adverse modification of any proposed critical habitat designations that were analyzed in this Conference Opinion.

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, Agencies, and other interested parties 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, stakeholders, and other interested parties 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 carbaryl 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 other interested parties to develop conservation guidelines.

10. Facilitate outreach to growers so they are educated about issues related to pesticides and ESA-listed resources, and work with them, other stakeholders, and agencies to minimize impacts to listed and proposed species and designated and proposed critical habitat.

REINITIATION NOTICE

Issuance of a final Biological Opinion will conclude formal consultation on the proposed 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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