**Appendix 4-7. Refined risk analysis for 13 listed birds exposed to malathion**

1. **Introduction**

The Terrestrial Investigation Model (TIM, version 3.0 beta) is a multimedia exposure/effects model that can be used to address avian mortality levels from acute pesticide exposure in generic or specific species over a user-defined exposure window. The time frame corresponds to one growing season of the treated crop or a single sub-annual pesticide application window. The spatial scale is at the field level, but specific field dimensions are undefined. In the current application of TIM, it is assumed that the model accounts for variability among fields and represents risks to listed birds exposed to malathion on different fields and orchards that are treated at the same rates and methods. It is assumed that the field and surrounding area meet habitat and dietary requirements for the modeled species. During the simulation, birds use the treated field and edge habitat to meet their requirements for food and water. TIM also accounts for exposure via dermal and inhalation routes for birds on the field or for adjacent habitat that receives spray drift. It is expected that the relative importance of these routes of exposure will vary based on the properties of the pesticide, its use, as well as the characteristics of the simulated bird species. Risk, expressed as a function of exposure (dose) and toxicity, is assessed for liquid spray applications of a pesticide made to vegetation or bare ground in the field. Pesticide application methods that may be modeled in TIM v.3.0 include: aerial, ground broadcast, air blast, ground banded and ground in furrow. For all of these application methods, exposure can be assessed on the treated field and edge habitat where spray drift is transported. The model does not currently account for exposures due to seed treatments or granular formulations. A detailed description of TIM is available online at: http://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment#tim.

The MCnest (Markov Chain nest productivity) model, is a refined risk assessment model for estimating the chronic impact of pesticides on the reproductive success of bird populations (*i.e.*, fecundity). This analysis relies upon an integrated application where MCnest utilizes the same exposure estimates generated by TIM (for individual birds and their offspring). MCnest integrates multiple effects (lines of evidence) attributed to pesticide toxicity (*i.e.,* mortality, reproduction and behavior) along with life history characteristics of specific listed species.

This analysis includes a refined risk assessment for a subset of listed birds that are listed in **Table B 4-7.1**. This analysis was conducted using the Terrestrial Investigation Model and MCnest. For malathion, “Likely to Adversely Affect” (LAA) determinations are made for all 13 species based on the weight of evidence analysis conducted using the Terrestrial Effects Determination (TED) tool. The purpose of this refined analysis is to explore the utility of currently available probabilistic, refined methods for use in biological evaluations of listed species. There is also potential utility for use of these methods in the biological opinions for these species. Only a subset of species were selected to demonstrate proof of concept and explore applications of the models that may inform future method development and identification of data needs.

**Table B 4-7.1. Listed species that are included in this refined risk assessment.**

|  |  |  |
| --- | --- | --- |
| ***Scientific Name*** | **Common Name** | **Entity ID** |
| *Ammodramus savannarum floridanus* | Florida grasshopper sparrow | 133 |
| *Amphispiza belli clementeae* | San Clemente sage sparrow | 116 |
| *Coccyzus americanus* | Yellow-billed Cuckoo (Western DPS) | 6901 |
| *Colinus virginianus ridgwayi* | Masked bobwhite (quail) | 89 |
| *Dendroica chrysoparia* | Golden-cheeked warbler (=wood) | 139 |
| *Empidonax traillii extimus* | Southwestern willow flycatcher | 149 |
| *Pipilo crissalis eremophilus* | Inyo California towhee | 137 |
| *Polioptila californica californica* | Coastal California gnatcatcher | 145 |
| *Setophaga kirtlandii (= Dendroica kirtlandii)* | Kirtland's Warbler | 94 |
| *Tympanuchus cupido attwateri* | Attwater's greater prairie-chicken | 83 |
| *Tympanuchus pallidicinctus* | Lesser prairie-chicken | 2691 |
| *Vireo atricapilla* | Black-capped Vireo | 138 |
| *Vireo bellii pusillus* | Least Bell's vireo | 123 |

As described in **ATTACHMENT 1-16**, selected species are consistent with the current domains of TIM and MCNest (*i.e.,* diets include arthropods or terrestrial plants, reproduction based on 2 parents) and their breeding range is located in the 48 contiguous states. The gunnison sage grouse (*Centrocercus minimus*; entity ID 4064) was not included because the parameters used to represent the life history of this species are still under development. The other two species that are not included here represent separate populations of the greater sage-grouse (*Centrocercus urophasianus*). These were excluded here because they are no longer candidates for listing.

This analysis focuses on a refined risk assessment for direct effects to listed birds, including effects to mortality, growth, reproduction and behavior. This analysis does not consider indirect effects due to declines in prey or impacts to habitat.

Section 2 of this report describes the input parameters used in TIM and MCnest to simulate specific species and properties of malathion, including use, fate and toxicity. Section 3 includes the results and discussion of the TIM/MCnest model runs for the 13 species.

1. **TIM and MCnest input parameters**

For those species with individuals potentially exposed to malathion, TIM and MCnest are run to estimate the probability and magnitude of mortality and decline in fecundity. This section describes the input parameters used to simulate the specific species, uses of malathion and toxicity and physical/chemical properties of malathion.

* 1. **Species Life History**

A species library has been developed to designate model parameters which are intended to be representative of the diets, body weights and reproductive timing associated with each species considered in this assessment. These parameter values are defined in Supplemental Information 1, along with source information.

* 1. **Number of birds simulated**

In order to sufficiently capture the stochasticity incorporated into TIM and MCnest, 10,000 individual birds are simulated initially. The fraction of mortality in these birds is used to calculate the probability associated with different magnitudes of mortality among exposed birds (referred to in model documentation as a “flock”). For this analysis, a flock size of 100 is used (as it represents percent).

* 1. **Exposure routes simulated**

TIM has the ability to account for exposures via multiple routes, including diet, drinking water, dermal and inhalation. Acute oral toxicity data with birds indicate that malathion is highly toxic via the oral route (chapter 2). This suggests that dietary and drinking water routes are potentially of concern. Toxicity data are not available for inhalation exposures involving birds; however, TIM utilizes mammalian data as a surrogate for understanding the relative sensitivities via oral and inhalation routes. In several acute inhalation studies with laboratory rats, no mortality was observed at 5 mg a.i./L-air, which is equivalent to 310 mg a.i./kg-bw (MRID 00159878). Due to a lack of observed toxicity in these studies, inhalation exposure is not considered to be of concern for this analysis. Even if inhalation is included, with 310 mg a.i./kg-bw used as a surrogate for the rat inhalation LD50, inhalation does not contribute to mortality.

The version of TIM/MCnest used in this assessment does not consider several possible routes of exposure, including ingestion of or dermal contact with contaminated soil.

One notable uncertainty associated with exposure through consumption of arthropods is the conservative nature of the residues. Since TIM is used to simulate exposures and resulting risks on a field scale, the arthropod residue values were selected to represent a 90th percentile field/orchard. For cases where risks are assessed to a small number of individuals exposed (e.g., <10), this conservative approach is not as influential on confidence in risk conclusions (as it is possible that they are only being exposed on one field). When a larger number of individuals is exposed, a landscape level approach is more appropriate, where individuals within the population are exposed to malathion on multiple fields. In that case, it is unlikely that all individuals will be exposed to malathion on 90th percentile fields. Therefore, there may be an overestimation in risk to the number of individuals impacted (overestimate in probabilities of mortality and fecundity declines). Since this analysis relies upon a beta version of TIM and MCnest, this uncertainty may be explored in future updates to the model.

* 1. **Simulated Uses**

Malathion is used on a wide variety of use sites, including corn, cotton, orchard/vineyard, other crop, other grains, other tree, pasture/hay, rice, vegetables and ground fruit, wheat, and mosquito adulticide. A detailed description of the specific crops is provided in the problem formulation (**APPENDIX 1-3**). For each species, malathion use on pasture and other crop are simulated as these uses represent the greatest acreage in the counties inhabited by species (**Table B 4-7.2**). Maximum application rates corresponding to those uses simulated.

**Table B 4-7.2. Simulated uses for each species.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Use site** | **Application Method** | **Application Rate**  **(lb a.i./A)** | **Number of Applications** | **Application Interval**  **(days)** |
| Pasture (*i.e*., alfalfa) | Aerial | 1.25 | 2 | 14 |
| Other Crops (*i.e.,* clover) | Aerial | 1.25 | 2 | 14 |

*Pasture and Other Crops*

For pastures and other crops (*e.g.,* clover), all applications may be made via aerial or ground spray. Given common practices, it is expected that aerial application will be the most likely method for pastures, and therefore, this method is simulated using TIM/MCnest.

A crop height of 1 m will be used for pastures and other crops. Since inhalation exposure is not of concern for malathion, the crop biomass parameter is not needed, so a value of 1 will be used.

Timing of application does not impact TIM outputs; however it has a substantial influence on MCnest estimates of fecundity. In cases where MCnest is run for a species, a range of dates (from April-September) are simulated to explore the influence of application timing on fecundity.

* 1. **Frequency on Field (FOF)**

Frequency on field (FOF) is the amount of time in a simulation that a bird spends on the treated field. TIM requires input values for mean, minimum and maximum FOF values in order to generate a *beta pert* distribution of FOF values for the simulated species of birds. For each simulated bird, a unique FOF value is selected from this distribution. For this analysis, the species habitat and its relationship to potential malathion use sites is used to derive the FOF parameters for each simulated species.

Based on the available information on species habitats (**Table B 4-7.3**), Attwater’s prairie chicken, lesser prairie chicken, and the masked bobwhite are expected to heavily use the malathion target areas evaluated here. The FOF values for mean, min and max values of the distribution are set at 0.9, 0 and 1. The remaining species are not expected to use malathion target areas with great frequency; therefore, the FOF values for mean, min and min values of the distribution will be 0.1, 0 and 0.2. Each of these species may also be exposed to malathion through spray drift to edge habitats.

**Table B 4-7.3. Habitat descriptions of 13 species.**

|  |  |  |
| --- | --- | --- |
| ***Scientific Name*** | **Common Name** | **Habitat\*** |
| *Ammodramus savannarum floridanus* | Florida grasshopper sparrow | large (>50 ha), treeless, relatively poorly-drained grasslands that have a history of frequent fires |
| *Amphispiza belli clementeae* | San Clemente sage sparrow | Canyon shrub/woodland and maritime desert scrub boxthorn habitat |
| *Coccyzus americanus* | Yellow-billed Cuckoo (Western DPS) | Open woodland with clearings and scrubs that are associated with watercourses. Breeds in riparian areas. |
| *Colinus virginianus ridgwayi* | Masked bobwhite (quail) | savanna grasslands |
| *Dendroica chrysoparia* | Golden-cheeked warbler (=wood) | Forest |
| *Empidonax traillii extimus* | Southwestern willow flycatcher | Breeding: Forested wetlands or scrub-shrub wetlands-dense riparian habitat of rivers, swamps, wetlands, lakes  Wintering: brushy savanna edges, second growth, shrubby clearings and pastures, woodlands near water |
| *Pipilo crissalis eremophilus* | Inyo California towhee | Riparian – nest and forage in areas of dense riparian vegetation dominated by willows, Fremont cottonwood, and desert olive with associated rubber rabbit brush and squaw waterweed. Also nest in shrubs of the upland community adjacent to riparian habitat |
| *Polioptila californica californica* | Coastal California gnatcatcher | Coastal scrub vegetation communities |
| *Setophaga kirtlandii (= Dendroica kirtlandii)* | Kirtland's Warbler | Forests |
| *Tympanuchus cupido attwateri* | Attwater's greater prairie-chicken | Grasslands and open space, woodland, brushland, fallow land, cultivated land |
| *Tympanuchus pallidicinctus* | Lesser prairie-chicken | shrub-mixed grass habitat associated with sandy soil; Mixed grass prairie and conservation reserve program land |
| *Vireo atricapilla* | Black-capped Vireo | Forest grassland ecotone; deciduous/evergreen shrubland |
| *Vireo bellii pusillus* | Least Bell's vireo | Woodland including cotton-wood willow forest, Oak wood lands, and mule fat scrub;  Scrub vegetation; Palm groves and hedgerows associated with agricultural fields and residential areas;  Breed in riparian habitat, typically inhabiting structurally diverse woodlands along watercourses |

\*Species specific sources provided in **ATTACHMENT 1-16**.

* 1. **Pesticide Characteristics (Fate and Effects)**

The malathion specific input parameters that are used to define the physical, chemical and transport properties that define the fate of malathion are provided in **Table B 4-7.4**. Several of these parameter values were selected to be consistent with the values used in aquatic models.

**Table B 4-7.4. Fate input parameter values used for malathion.**

| **Parameter** | **Value** | **Source/comments** |
| --- | --- | --- |
| Pesticide half-life in puddles (days) | 15.9 | Table 3-5 of Chapter 3 (exposure characterization for malathion) |
| Koc (L/kg-oc) | 217 | Table 3-5 of Chapter 3 |
| Kow | 799 | Table 3-5 of Chapter 3 |
| Henry’s law constant (atm/m3-mol) | 1.2e-7 | Calculated using the following formula  HENRY = (VP/760)/(Solubility/MW)  (TIM manual, appendix A), where:  MW = 330.36 g/mol (Table 3-5, chapter 3)  VP= 4×10-5 torr (Table 3-5, chapter 3) |
| Solubility in water (mg/L) | 145 | Table 3-5 of Chapter 3 |
| Dislodgeable foliar residue adjustment factor | 0.62 | Default (TIM manual, appendix A) |
| Dermal adsorption fraction | 1 | Default (TIM manual, appendix A) |
| Contaminated fractions of food items | 1 | Assume that 100% of food items are treated. Default (TIM manual, appendix A) |
| Half-life on food items (days) | 6.1, 10.9 | 37 values reported in Willis and McDowell (1987). Upper 90th, and maximum of reported results. |

**Tables B 4-7.5 and B 4-7.6** include the parameter values used in TIM and MCnest to define the toxicity of malathion. The results generated by TIM are sensitive to avian acute oral LD50 and the foliar dissipation half-life. Therefore, alternative values are explored in this analysis in order to capture the influence of variability in the malathion data on the model’s predictions. For malathion, the foliar dissipation half-lives selected represent high and low-end conservative estimates that highlight the influence this value has on model predictions. Although the model is also sensitive to the fraction of the pesticide retained on an hourly basis, data are not available to determine chemical-specific variability in this parameter value.

**Table B 4-7.5. TIM toxicity input parameter values used for malathion.**

| **Parameter (units)** | **Value** | **Source/comments** |
| --- | --- | --- |
| Avian acute oral LD50 (mg a.i./kg-bw) | 107.97, 331.1, and 819.1 | HC5, HC50 and HC95 from SSD used to bracket risk results. Details on the SSD are provided in Appendix 2-9. |
| Body weight of animals from LD50 (g) | 100 | SSD scaled to 100 g |
| Mineau scaling factor | 1.15 | Default value from Mineau et al. 1996. |
| Slope of avian oral LD50 | 6.6 | This value represent the low (ring-necked pheasant). |
| Avian acute inhalation LD50 (mg a.i./kg-bw) (enter 0 if no value is available) | 0 | No value is available for malathion |
| Rat inhalation LD50 (mg a.i./kg-bw) | 310 | MRID 00159878; no mortality was observed in the study so this value represents the NOAEC |
| Rat acute oral LD50 (mg a.i./kg-bw) | 1560 | MRID 49127003 |
| Chemical specific avian dermal LD50 (enter 0 if no value is available) | 0 | No value is available for malathion |
| Food matrix adjustment factor | 1 | Default (See TIM manual, appendix A) |
| Fraction of pesticide retained from one hour to the next | 0.986 | Default (See TIM manual, appendix A) |
| Ratio of juvenile to adult toxicity | 1 | Default (See TIM manual, appendix A) |

**Table B 4-7.6. MCnest toxicity input parameter values used for malathion.**

| **Parameter (units)** | **Value (for different treatments)** | | | **Source/comments** |
| --- | --- | --- | --- | --- |
| **Level 1** | **Level 2** | **Level 3** |
| Measured concentrations (mg a.i./kg-diet) | 112 | 358 | 1260 | X indicates level where NOEL was established for endpoint of interest. NOELs at level 3 represent levels where LOELs were not established.  Test species: Bobwhite quail; MRID 48153114;  Effects observed at LOECs:  1. Decrease in number of eggs laid per hen  2. Decrease in the percent of viable eggs per eggs set  3. Decrease in egg-shell thickness |
| Average food consumption (g/bird/day) | 24 | 25 | 23 |
| Average initial female body weight (g) | 195 | 194 | 190 |
| Average initial male body weight (g) | 193 | 192 | 193 |
| Average final female body weight (g) | 250 | 228 | 202 |
| Average final male body weight (g) | 221 | 219 | 206 |
| NOAEL for # eggs laid |  | X |  |
| NOAEL for % viable eggs/eggs set |  | X |  |
| NOAEL for % live 3-wk embryos of viable eggs |  |  | X |
| NOAEL for % hatchlings of eggs set |  |  | X |
| NOAEL for % 14-d chicks of hatchlings |  |  | X |
| NOAEL for % 14-d chicks of eggs set |  |  | X |
| NOAEL for egg shell thickness |  | X |  |
| NOAEL for hatchling weight |  |  | X |
| NOAEL for 14-d chick weight |  |  | X |
| NOAEL for prelaying female weight |  |  | X |
| NOAEL for prelaying male weight |  |  | X |
| Alternative behavioral threshold (for adults)\* (mg a.i./kg-bw) | 63 | | | Behavioral NOAEL from acute oral toxicity study with ring-necked pheasant (MRID 48963305); birds exposed to 105 mg a.i./kg-bw were observed with wing droop, ruffled appearance, loss of coordination, lower limb weakness, prostrate posture, convulsions, shallow and rapid respiration, lower limb rigidity and salivation |
| LC50 (mg a.i./kg-food) | 2022 | | | Lowest available LC50; test species was bobwhite quail; MRID 48153106 |
| Fraction of LC50 | 0.5 | | |
| Mean body weight (g) from LC50 test | 22.5 | | |
| Mean food ingestion rate from LC50 test (g/day) | 7.7 | | |

NA = not available

* 1. **Other Parameters**

TIM uses a handful of additional parameters that are not described above. Those parameters are listed in **Table B 4-7.7**. Default assumptions are made for all of these parameters.

**Table B 4-7.7. Additional parameters used by TIM.**

| **Parameter** | **Value** | **Source/Comments** |
| --- | --- | --- |
| Random seed | 0 | No seed set by user |
| Fraction of edge habitat receiving drift | 1 | Default (See TIM manual, appendix A) |
| Length of in-field spray drift buffer (ft) | 0 | Default (See TIM manual, appendix A) |
| Fraction of organic carbon in soil | 0.015 | Default (See TIM manual, appendix A)\* |
| Bulk density of soil (kg/L) | 1.5 | Default (See TIM manual, appendix A)\* |
| Spray height (m) | 0.5 (ground/airblast)  3 (aerial) | Default (See TIM manual, appendix A); ground height is based on low boom |
| Spray duration (min) | 0.5 (ground/airblast)  1.5 (aerial) | Default (See TIM manual, appendix A) |
| Application time | 8 | It is assumed that all applications are made at 8 am. |

\*If drinking water from puddles is a substantial exposure route for birds, this parameter can be made more geographically specific based on the range of the species.

1. **Results and Discussion**
   1. **TIM Analysis**

*Likelihood of mortality to an individual*

TIM was run to examine the likelihood of mortality to birds exposed to malathion from spray drift from orchard crops, ground fruit and vegetables and nurseries. As noted in section 2, the most sensitive input parameters for TIM include the LD50 and the foliar dissipation half-life (**Table B 4-7.8**). When less conservative estimates of these parameters are used (*i.e.,* LD50 = 331 mg a.i./kg-bw and foliar dissipation half-life = 6.1 d), the following conclusions can be drawn:

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

**Table B 4-7.8. Likelihood of mortality to > 1 individual out of 100 exposed per year. Applications of 1.25 lb a.i./A to pasture and other crops.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Species** | **Estimates of LD50 and Foliar Dissipation Half-life** | | |
| **HC05 species and max half-life1** | **HC50 species and upper bound half-life2** | **HC95 and upper bound half-life3** |
| Attwater's Prairie Chicken | 0.19 | <0.01 | <0.01 |
| Kirtlands Warbler | 0.99 | 0.99 | <0.01 |
| Black-capped Vireo | 0.99 | 0.99 | <0.01 |
| Golden-cheeked Warbler | 0.99 | 0.99 | <0.01 |
| Southwestern Willow Flycatcher | 0.99 | 0.99 | <0.01 |
| California Gnatcatcher | 0.99 | 0.99 | 0.08 |
| Inyo California Towhee | 0.26 | <0.01 | <0.01 |
| San Clemente Sage Sparrow (Bell's) | 0.99 | 0.03 | <0.01 |
| Florida Grasshopper Sparrow | 0.99 | 0.08 | <0.01 |
| Yellow-billed Cuckoo | 0.99 | <0.01 | <0.01 |
| Least Bell's Vireo | 0.99 | 0.99 | 0.01 |
| Lesser Prairie Chicken | 0.67 | <0.01 | <0.01 |
| Masked Bobwhite | 0.99 | <0.01 | <0.01 |

**1** Conservative scenario represented by LD50 = 108 mg/kg-bw; foliar t1/2 = 10.9 d

**2** Central scenario represented by LD50 = 331 mg/kg-bw; foliar t1/2 = 6.1 d

**3** Least conservative represented by LD50 = 819 mg/kg-bw; foliar t1/2 = 6.1 d

There is uncertainty associated with the relative sensitivity the actual dissipation half-life of malathion in areas inhabited by these species. If the chemical dissipates more slowly (*e.g.*, dissipation half-life is 10.9 days), then the percent mortality of exposed individual increases. If the chemical dissipates more quickly (*e.g.,* foliar dissipation half-life = 0.3 days), then the risk to an individual would decrease. Given the high likelihood of mortality when the central tendency estimates for these parameters are used (*i.e.,* HC50 and upper bound foliar dissipation half-life), there is confidence that an exposed individual will die.

Dietary and dermal exposure were the greatest sources of exposure leading to mortality. Based on this information, it is likely that species diet is highly influential on the estimates of mortality. For instance, insectivore species (e.g., kirtland’s warbler, vireos) have greater likelihoods of mortality compared to the two prairie chicken species, which have diets that include seeds and leaves (these food items have lower pesticide residues compared to insects).

It should be noted that this analysis focuses on probabilities associated with mortalities of one or more birds out of 100 exposed. It is expected that the number of exposed individuals will vary by species and by use. The magnitude of the probability estimates for an individual may change depending on the number of individuals exposed.

*Magnitude of mortality in exposed individuals*

Probability distribution functions (PDFs) can be used to identify the most likely magnitude of mortality exposed birds from a given use. PDFs for different uses can also be compared when considering relative risks associated with different uses. For instance, PDFs are provided in the figures below. These figures depict the most likely magnitudes of mortality associated with malathion applications to pasture and other crops for each of the evaluated species (**Figures B 4-7.1** through **B 4-7.13**). The magnitude of mortality associated with malathion applications on pasture and other crops varies widely among the assessed species. In general, the largest magnitude of mortality, based on median assumptions of toxicity and half-life, are observed for Kirtland’s warbler (15-35%), black-capped vireo (5-25%), golden-cheeked warbler (5-25%), southwestern willow flycatcher (1-18%), California gnatcatcher (25-50%), and least Bell’s vireo (10-30%). This information is considered useful in estimating the magnitude of effect in the portion of the population that is exposed and may be used in evaluating potential population-level impacts of malathion on listed birds.

**Figure 4-7.1. Probability distribution functions describing probability associated with killing x% of exposed Florida grasshopper sparrows. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.2. Probability distribution functions describing probability associated with killing x% of exposed yellow billed cuckoos. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.3. Probability distribution functions describing probability associated with killing x% of exposed masked bobwhite quails. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.4. Probability distribution functions describing probability associated with killing x% of exposed golden-cheeked warblers. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.5. Probability distribution functions describing probability associated with killing x% of exposed southwester willow flycatchers. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.6. Probability distribution functions describing probability associated with killing x% of exposed coastal California gnatchaters. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.7. Probability distribution functions describing probability associated with killing x% of exposed Kirtland’s warblers. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.8. Probability distribution functions describing probability associated with killing x% of exposed Attwater’s greater prairie-chicken. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.9. Probability distribution functions describing probability associated with killing x% of exposed lesser prairie-chickens. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.10. Probability distribution functions describing probability associated with killing x% of exposed black-capped vireos. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.11. Probability distribution functions describing probability associated with killing x% of exposed least Bell’s vireo. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.12. Probability distribution functions describing probability associated with killing x% of exposed Inyo California towhee. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

**Figure 4-7.13. Probability distribution functions describing probability associated with killing x% of exposed San Clemente sage sparrow. Exposures based on two aerial applications of 1.25 lb a.i./A malathion to pasture with a 14 day application interval.**

* 1. **MCnest Analysis**

When considering impacts to fecundity, mortality is the major contributor to declines for some of the species; however, reproductive effects do occur in surviving birds. In general, applications made after the breeding period occur do not result in declines in fecundity because exposed adults are able to successfully reproduce prior to exposures that lead to mortality. **Tables B 4-7.9** through **B 4-7.11** provides estimates of fecundity declines for 13 species based on conservative, central, and least conservative estimates of toxicity and foliar dissipation half-life.

**Table B 4-7.9. Fecundity declines estimated from applications of malathion on pasture and other crops using the HC05 species and maximum foliar dissipation half-life.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | **1-Mar** | **29-Mar** | **26-Apr** | **24-May** | **21-Jun** | **19-Jul** | **16-Aug** | **13-Sep** |
| Attwater's Prairie Chicken | -7% | 70% | 100% | 100% | 35% | -2% | -- | -- |
| Black-capped Vireo | 93% | 95% | 96% | 72% | 39% | 5% | -- | -- |
| California Gnatcatcher | 99% | 99% | 81% | 59% | 36% | 16% | -- | -- |
| Florida Grasshopper Sparrow | 45% | 44% | 40% | 31% | 19% | -1% | -- | -- |
| Golden-cheeked Warbler | 91% | 95% | 100% | 31% | -- | -- | -- | -- |
| Inyo California Towhee | 1% | 2% | 2% | 1% | 0% | -- | -- | -- |
| Kirtlands Warbler | 80% | 79% | 82% | 90% | 42% | 6% | -- | -- |
| Least Bell's Vireo | 94% | 96% | 86% | 62% | 40% | 21% | 3% | -- |
| Lesser Prairie Chicken | -3% | -9% | 32% | 94% | 100% | 100% | 100% | -- |
| Masked Bobwhite | 3% | -1% | 3% | 1% | 41% | 55% | 41% | -- |
| San Clemente Sage Sparrow (Bell's) | 25% | 40% | 57% | 43% | 36% | 10% | -- | -- |
| Southwestern Willow Flycatcher | 82% | 82% | 82% | 86% | 93% | 28% | 4% | -- |
| Yellow-billed Cuckoo | 3% | 1% | 1% | 4% | -- | -- | -- | -- |

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

**Table B 4-7.10. Fecundity declines estimated from applications of malathion on pasture and other crops using the HC50 species and upper bound foliar dissipation half-life.**

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

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

**Table B 4-7.11. Fecundity declines estimated from applications of malathion on pasture and other crops using the HC95 species and upper bound foliar dissipation half-life.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Row Labels** | **1-Mar** | **29-Mar** | **26-Apr** | **24-May** | **21-Jun** | **19-Jul** | **16-Aug** | **13-Sep** |
| Attwater's Prairie Chicken | 26% | 2% | 0% | -2% | -9% | -2% | -- | -- |
| Black-capped Vireo | -1% | 8% | 36% | 32% | 27% | 1% | -- | -- |
| California Gnatcatcher | 9% | 35% | 33% | 32% | 32% | 12% | -- | -- |
| Florida Grasshopper Sparrow | 8% | 8% | 6% | 5% | 3% | -1% | -- | -- |
| Golden-cheeked Warbler | -1% | 33% | 64% | 12% | -- | -- | -- | -- |
| Inyo California Towhee | 0% | 1% | 0% | 1% | 0% | -- | -- | -- |
| Kirtlands Warbler | -1% | 0% | 2% | 30% | 17% | 0% | -- | -- |
| Least Bell's Vireo | 1% | 21% | 20% | 24% | 17% | 13% | 0% | -- |
| Lesser Prairie Chicken | -15% | 0% | 6% | -3% | -6% | 0% | -9% | -3% |
| Masked Bobwhite | 0% | 1% | 1% | 9% | 18% | 21% | 19% | 6% |
| San Clemente Sage Sparrow (Bell's) | 0% | 9% | 5% | 5% | 4% | -1% | -- | -- |
| Southwestern Willow Flycatcher | -1% | -1% | -1% | 12% | 15% | 9% | -1% | -- |
| Yellow-billed Cuckoo | 0% | 0% | 0% | 1% | 4% | 4% | -1% | 1% |

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

1. **Conclusions**

Based on the analyses, there is a high likelihood (99% or greater for multiple scenarios) that exposure to malathion from use on pastures and other crops will result in mortality to at least one individual for six of the thirteen assessed species, *i.e.,* Kirtland’s warbler, black-capped vireo, golden-cheeked warbler, southwestern willow flycatcher, California gnatcatcher, and least Bell’s vireo. For the remaining six species, *i.e.,* Attwater’s prairie-chicken, Inyo California towhee, San Clemente sage sparrow, Florida grasshopper sparrow, yellow-billed cuckoo, lesser prairie-chicken, and masked bobwhite, the likelihood of mortality to one or more individuals varied widely depending on the LD50 and foliar dissipation half-life considered, with the majority of scenarios resulting in a <1% chance.

Probability distribution functions for different uses were compared to investigate the relative risks associated with different assumptions of toxicity and foliar dissipation half-life for the different species. The magnitude of mortality associated with malathion applications on pasture and other crops varies widely among the assessed species. In general, the largest magnitude of mortality, based on median assumptions of toxicity and half-life, are observed for Kirtland’s warbler (15-35%), black-capped vireo (5-25%), golden-cheeked warbler (5-25%), southwestern willow flycatcher (1-18%), California gnatcatcher (25-50%), and least Bell’s vireo (10-30%).

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