ECOTOXICOLOGICAL SIMULATION MODELING: EFFECTS OF AGRICULTURAL CHEMICAL EXPOSURE ON WINTERING BURROWING OWLS

A Thesis

by

CATHERINE ALLEGRA ENGELMAN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2008

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Co-Chairs of Committee,	Miguel A. Mora
	William E. Grant
Committee Members,	Russell Feagin
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ABSTRACT

Ecotoxicological Simulation Modeling: Effects of Agricultural Chemical Exposure on Wintering Burrowing Owls. (May 2008)

Catherine Allegra Engelman, B.A./B.S., The Evergreen State College

Co-Chairs of Advisory Committee: Dr. Miguel A. Mora
Dr William E. Grant

The western burrowing owl, *Athene cunicularia hypugaea*, is a Federal Species of Concern, whose numbers and range have been drastically reduced from historic levels in Texas. Burrowing owls roost and forage in agricultural areas, and it has been hypothesized that exposure to insecticides may be a factor in the decline of their population. Burrowing owls wintering in southern Texas use agricultural culverts in cotton fields as roost sites, which may increase their risk of exposure to agricultural chemicals, either through ingestion of contaminated prey or through dermal exposure to agricultural runoff.

Simulation modeling was used to characterize the risks to individual burrowing owls wintering in agricultural landscapes in southern Texas due to effects of exposure to insecticides or other agricultural chemicals. The simulation model was created using Stella® VII software (High Performance Systems, Inc., New Hampshire, USA). The model is broken into four submodels simulating (1) foraging behavior of burrowing owls, (2) chemical applications to crops, (3) chemical transfer and fate in the crop soil and prey items, and (4) chemical exposure in the burrowing owl.

This model was used to evaluate (1) which components of the model most affect the endpoints, (2) the relationship between increased concentrations of agricultural chemicals in culverts and subsequent lethal and sublethal effects from dermal exposure to agricultural runoff, and (3) which agricultural chemicals have the greatest potential to cause adverse effects in burrowing owls. Model results suggested (1) the half-lives of agricultural chemicals in birds caused the most variation in the results, and data gaps exist for several important model components (2), exposure to increased concentrations of agricultural chemicals in culverts is unlikely to result in lethal effects, but is likely to lead to sublethal effects in burrowing owls, and (3) the chemicals with the greatest potential to negatively affect burrowing owls wintering in southern Texas are the OP insecticides chlorpyrifos, dicrotophos, and disulfoton, the oxadiazine insecticide indoxacarb, the herbicide trifluralin, and the defoliants tribufos and paraquat. The results of this model demonstrate the usefulness of simulation modeling to guide future research related to the conservation of burrowing owls.

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NOMENCLATURE

ACA	Alberta Conservation Association
AChE	Acetylcholinesterase
APHIS	USDA Animal and Plant Health Inspection Service
CB	Carbamate Insecticide
ChE	Cholinesterase
DTI	Dermal to Oral Toxicity Index
FOOTPRINT	Footprint Pesticides Database- University of Hertfordshire
FS-1	Cotton/Sorghum crop scenario
FS-2	Cotton/Sorghum/Cabbage crop scenario
FS-3	Cotton/Sorghum/Onions crop scenario
HD5	Hazardous Dose resulting in mortality of 5% of the population
LD50	Lethal Dose resulting in mortality of 50% of the population
LEL	Lowest Effects Level

LOEL	Lowest Observed Effects Level
NASS	USDA National Agricultural Statistics Service
NCFAP	National Center for Food and Agricultural Policy
NOEC	No Observed Effects Concentration
NOEL	No Observed Effects Level
NRA	National Registration Authority for Agricultural and Veterinary Chemicals
OC	Organochlorine Insecticide
OP	Organophosphate Insecticide
PAN	Pesticide Action Network database
PIF	Partners in Flight
PIP	Pesticide Information Profiles database
SANCO	European Commission. Health & Consumer Protection Directorate-General
SRD	Alberta Sustainable Resource Development
TPWD	Texas Parks and Wildlife Department

USDA	U.S. Department of Agriculture
U.S. EPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service

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CHAPTER I

INTRODUCTION

The western burrowing owl, *Athene cunicularia hypugaea*, was listed as a Federal Species of Conservation Concern in 2002 due to declining populations (USFWS, 2002). While the primary reason cited for this decline is habitat loss, insecticide use has been strongly implicated as another possible cause of declines in burrowing owl populations (Klute et al., 2003). Due to awareness of environmental persistence, high toxicity to non-target organisms, and bio-magnification, the use of most organochlorine (OC) insecticides, such as DDT, were discontinued in the United States during the 1970s, and insecticide use has shifted to organophosphate (OP) and carbamate (CB) insecticides (Mineau, 1991). However, even though OP and CB insecticides are less persistent in the environment than OC insecticides, they are still dangerous to non-target organisms and have been responsible for numerous cases of mortality in owls and other raptors (Blus, 1996; Sheffield, 1997; Mineau et al., 1999). Despite the shift in insecticide use, studies of the effects of contaminants on burrowing owls in the United States remain focused on OC insecticides and their residues, and there are few published studies on how current insect control practices affect burrowing owl populations (Klute et al., 2003). In addition to insecticides, other agricultural chemicals such as herbicides have the potential to negatively impact bird populations (Newton, 2004). However, the impacts of agricultural chemicals other than insecticides have not been examined in terms of potential impacts on burrowing owl populations.

This thesis follows the style of Ecological Modelling.

Both the Gulf Coast and Rio Grande Valley areas of South Texas have a history of avian mortality events and contamination due to insecticide use. A study of aquatic bird eggs along the Texas Gulf Coast conducted in 1970, showed significant decreases in eggshell thickness. In this study, the OC insecticide DDT or its metabolites were detected in all eggs analyzed, and along with the OC insecticide dieldrin, was found at higher concentrations near agricultural areas (King et al., 1978). In addition, OC insecticide use led to annual avian mortality events in the 1970's along the Gulf Coast (Flickinger and King, 1972; Flickinger, 1979). More recent investigations have indicated OC insecticides, particularly DDT and its metabolites and toxaphene, continue to persist in at elevated concentrations in the Rio Grande Valley, in some cases at levels associated with reproductive impairment in birds (Wainwright et al., 2001, Clark et al., 1995, White et al., 1983). In addition arsenic, and possibly mercury, was found at elevated levels in willets feeding in agricultural drainages in the lower Rio Grande Valley (Custer and Mitchell, 1991). In the 1970s-1980s several large mortality events attributed to OP or CB insecticide use were documented in South Texas (White et al., 1979; Flickinger et al., 1980; Flickinger et al., 1984; Flickinger et al., 1986) OP and CB insecticide use on irrigated cotton fields has been implicated in the decline of white-winged doves in the Rio Grande Valley (Tacha et al., 1994; Burkepile et al., 2002). In addition, Custer and Mitchell (1987) documented significant decreases in brain AChE activity in great-tailed grackles and mourning doves, two species which were regularly found in cotton or sugarcane fields, after treatment with OP insecticides in the Rio Grande Valley. A recent analysis of pesticide runoff from agricultural watersheds along the Texas Gulf Coast detected the CB insecticides carbofuran and aldicarb in < 3%, and <1% of samples, and detected the triazine herbicide atrazine in 95.6 % of the samples (Pennington et al., 2001).

Cotton and sorghum are the primary crops grown in the lower Rio Grande Valley and the lower Texas Gulf Coast (NASS, 2007).Cotton is well known for intensive historical and current agricultural chemical use. An analysis of cotton soils in Georgia and South Carolina found that the OC insecticides DDT and toxaphene, as well as the dinitroaniline herbicide trifluralin were the most common organic contaminants detected. Several soil samples from these cotton fields exhibited estrogenic and androgenic or glucocorticoid activity (Kannan et al, 2003). In addition, the historic use of arsenic based herbicides or defoliants in cotton fields in the southern United States has led to increased concentrations of organoarsenicals in soil, surface water and groundwater in cotton producing areas (Bednar et al., 2002). An analysis of recent insecticide use identified cotton as one of two crops responsible for the most potential bird mortality in the United States (Mineau and Whiteside, 2006). In 2005 a reported 8,677,000 lbs of herbicides, 3,075,000 lbs of growth regulators and defoliants, and 5,946,000 lbs of insecticides were applied to cotton crops in Texas (NASS, 2006).

In South Texas wintering burrowing owls use agricultural culverts in cotton fields as roost sites (Woodin et al., 2006). The use of agricultural culverts as roost sites by burrowing owls may increase their risk of exposure to insecticides and other agricultural chemicals, either through ingestion of contaminated prey, or through dermal exposure to agricultural runoff (Texas Gulf Coast Field Research Station, 2003; Woodin, pers. comm., 2004). The occurrence of chronic insecticide exposure was confirmed by an analysis of burrowing owl pellets in south Texas that detected low levels of OP and CB insecticides (Woodin et al., 2006).

The ability of researchers to study populations of burrowing owls wintering in southern Texas is limited by the difficulty in accessing the large amount of potential habitat occurring on private land, particularly on large ranches. In addition, the majority of burrowing owl research has focused on breeding biology, resulting in very few published studies on the winter ecology of burrowing owls (Woodin, pers. comm. 2004; Holroyd et al., 2001; Wellicome and Holroyd, 2001). Due to the size of the study area, the proportion of the potential habitat occurring on private land, and the complexity involved in assessing the impacts of insecticide use on populations of burrowing owls, simulation modeling is an ideal means to evaluate the effects that current insecticide use practices may have on burrowing owl populations in south Texas.

Kendall (1994) defines wildlife toxicology as “the study of the effects of environmental contaminants on the reproduction, health, and well-being of wildlife.” Kendall (1994) elaborates on the definition by stating that “A state of well-being implies, for instance, that there is no significant increase in the probability of being preyed upon nor in aberrations in migratory behavior. A state of good general health means that the organism can maintain homeostasis and, therefore, survive in a variety of environmental situations.” Lacher (1994) discussed how the effects of agricultural chemicals on a wildlife population are either lethal or sublethal, and that both lethal and sublethal effects can occur through direct or indirect pathways. An example of this is OP and CB insecticides. Sublethal doses of OP and CB insecticides can affect avian mortality or population parameters by affecting their behavior and normal physiological functions, including alterations in thermoregulation, food consumption, and reproductive behavior including migration (Grue et al., 1997). In addition, insecticide application can reduce the prey base, and decrease the amount of food available for consumption (Hill, 2003). Both behavioral effects and reduction in prey base may indirectly result in mortality. Behavioral effects represent sublethal effects resulting from a direct exposure

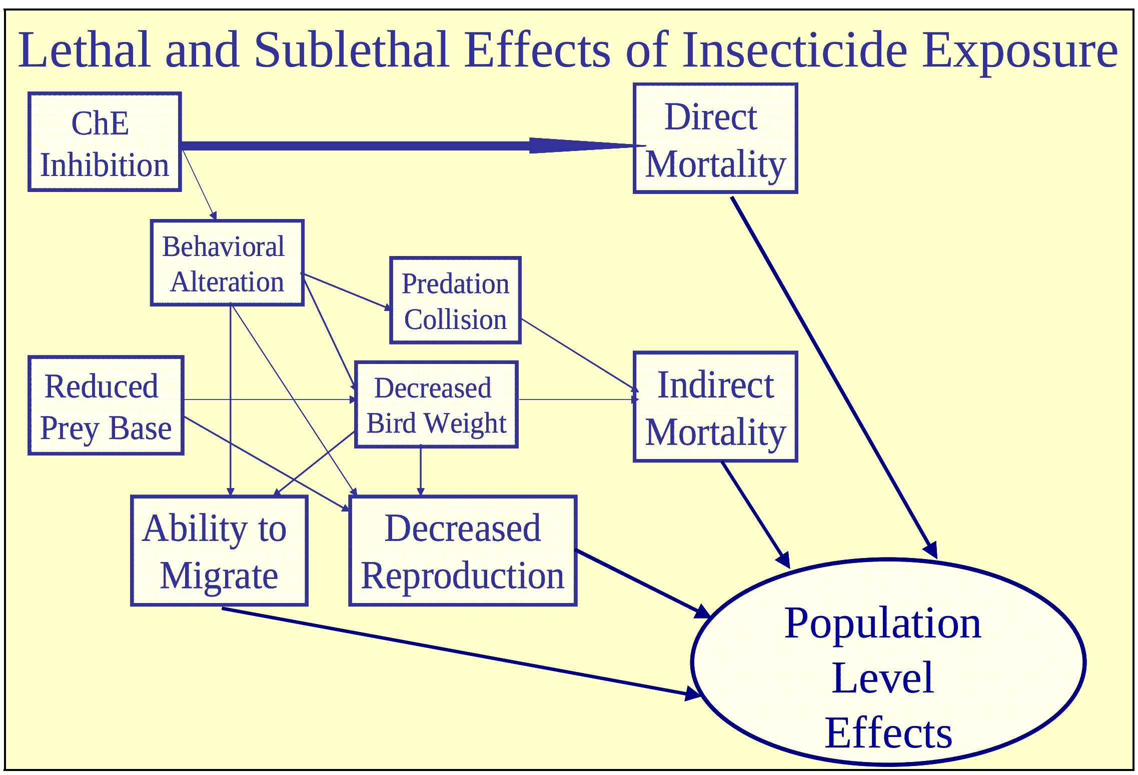

Figure 1. Examples of lethal and sublethal effects through direct and indirect pathways.

pathway, while the reduction in prey base represents sublethal effects resulting from an indirect pathway (Figure 1). Because most insecticides currently in use have low acute toxicity, the long term disturbance to a population caused by sublethal exposures may be greater than the disturbance caused by direct lethal effects (Lacher, 1994). Simulation modeling was used to determine the risk that occurs from current insecticide use practices through direct and indirect pathways to the “health and well-being” of burrowing owls wintering in south Texas. This risk was quantified by examining exposure variations in different roosting and foraging scenarios, in order to predict the insecticide use scenarios under which burrowing owl populations may be facing the greatest risk. The results can be used to guide future field studies, management decisions, and conservation efforts.

Six different objectives were addressed by this simulation model.

1) Simulate direct pathways leading to lethal & sublethal effects of chronic insecticide exposure on individual birds through the integration of dermal and oral exposure pathways.
2) Simulate direct pathways leading to lethal or sublethal effects of chronic exposure to agricultural chemicals including herbicides, defoliants, growth regulators, and fungicides.
3) Quantify uncertainty in the model in order to prioritize parameters for future research.
4) Evaluate the changes in the behavior of the model between chronic and acute exposure scenarios.

5) Examine the potential relationship between increased concentrations of agricultural chemicals in culverts and subsequent risks from dermal exposure to agricultural runoff, within the constraints of the model.

6) Evaluate the relative potential adverse effects of different agricultural chemicals on burrowing owls wintering in cotton fields in south Texas.

Objectives 1, 2, & 3 are addressed in Chapter II, where the model is described, applied, and a sensitivity analyses is conducted. Objective 4 is addressed in Chapter II, III, and IV. Objective 5 is addressed in Chapter III, where the model is used to investigate the possibility of culverts in cotton fields acting as ecological traps, and Objective 6 is addressed in Chapter IV where the model is used to compare different agricultural chemicals using all three endpoints.

CHAPTER II

SIMULATING THE EFFECTS OF AGRICULTURAL CHEMICAL EXPOSURE ON BURROWING OWLS WINTERING IN SOUTH TEXAS COTTON FIELDS

1. Introduction

In 1998, The US Environmental Protection Agency (U.S. EPA) set specific guidelines for use in ecological risk assessments, which were elaborated on for use in risk assessments of endangered species. These guidelines suggest that risk assessment occurs in three sequential stages; 1) problem formulation, in which the chemical stressors, related endpoints, and possible effects are identified, 2) analysis, in which chemical fate and transport, exposure to organisms, and effects of exposures are modeled, and 3) risk characterization, in which exposures and effects are integrated to derive risk quotients, and are sometimes supported with laboratory or field studies. Risk assessments often follow a tiered approach in which the lowest level, or tier 1, evaluates exposure to the maximum possible residues in order to determine potential effects, and if further, more site-specific assessment is required (Jones et al., 2004). There are several examples of tier 1 risk assessments used to evaluate risk to multiple species from multiple contaminants in agricultural ecosystems. In the first example, “EcoRR” uses site-specific information, separates each chemical into several different compartments, then uses the accumulation in species in each compartment to assess toxicity, and finally develops risk scores which can be used to compare different agricultural chemicals (Sanchez-Bayo et al., 2002). In another example, toxicity, exposures, and subsequent chronic avian and mammalian dietary risks were used to develop risk quotients which could then be used in a quantitative comparison of risk between different herbicides used on spring wheat (Peterson and Hulting, 2004). Mineau (2002) and Mineau and Whiteside, (2006) used a different method of risk assessment modeling to assess lethal effects of insecticide use based on their relative toxicity and application rates to determine which insecticides or crops cause the greatest increase in probability of bird mortality.

Simulation models have been used to evaluate ecological risks to birds, but have generally focused on user-specified chemical applications, rather than the comparison of relative risk between a suite of contaminants that is typically seen in Tier 1 risk assessments. These models use the effects on an individual bird to evaluate pesticide impacts, and are typically very complex models that include food web dynamics or hydrological modeling to predict lethal effects of acute oral exposure to insecticides (Corson et al., 1998; Pisani, 2006; Fite et al., 2004). Despite the complexity in these models, they do not always accurately predict the risks to birds from insecticide applications (Vyas et al., 2006). All of these risk assessment models only evaluate the effects of insecticides, despite the wide use of other agricultural chemicals such as herbicides (NASS, 2006). Corson et al. (1998), and Pisani (2006) used predictions of ChE inhibition greater than 20% as an indicator of sublethal exposure to OP or CB insecticides, while Fite et al. (2004) used risk quotients based on HD5s to evaluate lethal effects of insecticide exposure.

These simulation models focus on effects due to acute exposure, and have not examined low level chronic pesticide stress on bird populations (Corson et al., 1998; Pisani, 2006; Fite et al., 2004). Recently methods that can be used in the assessment of long-term effects of agricultural chemicals on birds have been developed (Hart and Thompson, 2005; Crocker, 2005; Shore et al., 2005; Mineau, 2005; Jones et al., 2004). These methods outline the development of a deterministic long-term toxicity/exposure ratio (TER_{lt}). The TER can be adjusted for species sensitivity based on avian reproductive NOELs or NOECs (No Observed Effects Levels or Concentrations). The TER is calculated for different phases of reproduction, which can then be incorporated into a population level model (Shore et al., 2005, Bennett et al., 2005). A probabilistic model was developed using TERs to evaluate long-term population level effects due to insecticide exposure (Roelofs et al., 2005). Topping et al. (2005) used spatial and non-spatial models in the risk assessment of long-term insecticide exposure on skylark populations. While these long-term risk assessment procedures are extremely relevant to avian species during their breeding season, they exclude the assessment of chronic, long-term exposure to birds during the non-breeding period of their life cycle.

Of these simulation models only the U.S. EPA terrestrial risk assessment model includes exposure routes other than the oral exposure route (Corson et al., 1998; Pisani, 2006; Fite et al., 2004). Similarly field and laboratory studies of insecticide impact on avian species have focused on ingestion as the primary route of exposure, and exposure occurring through inhalation, or dermal absorption, has not been adequately studied (Hill, 2003). However, Driver et al. (1991) found that up to 1 hr post-spraying inhalation was the primary route of exposure, and that from 8-48 hours post-spraying dermal exposure greatly exceeded exposure occurring through inhalation and ingestion. In addition they determined that ingestion exposure only accounted for 10-20% of the total ChE inhibition (Driver et al., 1991). Mineau (2002) also determined that insecticides with a higher dermal toxicity index increased the chance of mortality, and concluded that dermal exposure and possibly inhalation exposure need to be included in pesticide avian risk assessments. It is imperative that predictions of the insecticide effects on wildlife populations take into account the total accumulation of ChE inhibition occurring through all possible routes of exposure (Hill, 2003).

The objective of this study was to create a simplified simulation model that integrates dermal and oral exposure to evaluate the lethal and sublethal effects in birds of chronic low-level exposure to a wide range of chemical types. This model can then be used to evaluate which crops or chemicals are most likely to increase risk of lethal or sublethal effects in birds. Burrowing owls wintering in culverts in cotton fields in south Texas, which are chronically exposed to low levels of agricultural chemicals, either through ingestion of contaminated prey, or through dermal exposure to agricultural runoff, were chosen to exemplify the use of this model.

2. Study Area

Burrowing owls have resident and migratory populations in the northern part of Texas, and have a migratory population that winters in the southern part of the state. The study area is comprised of south Texas cotton and sorghum fields, where a population of burrowing owls is known to use agricultural culverts as winter roost sites. Data were used from documented burrowing owl roost sites in south Texas in two areas, 1) the Gulf Coast area including Kleberg, Nueces, San Patricio, Refugio, and Jim Wells counties, and 2) the Rio Grande Valley including Cameron and Hidalgo counties (Figure 2).

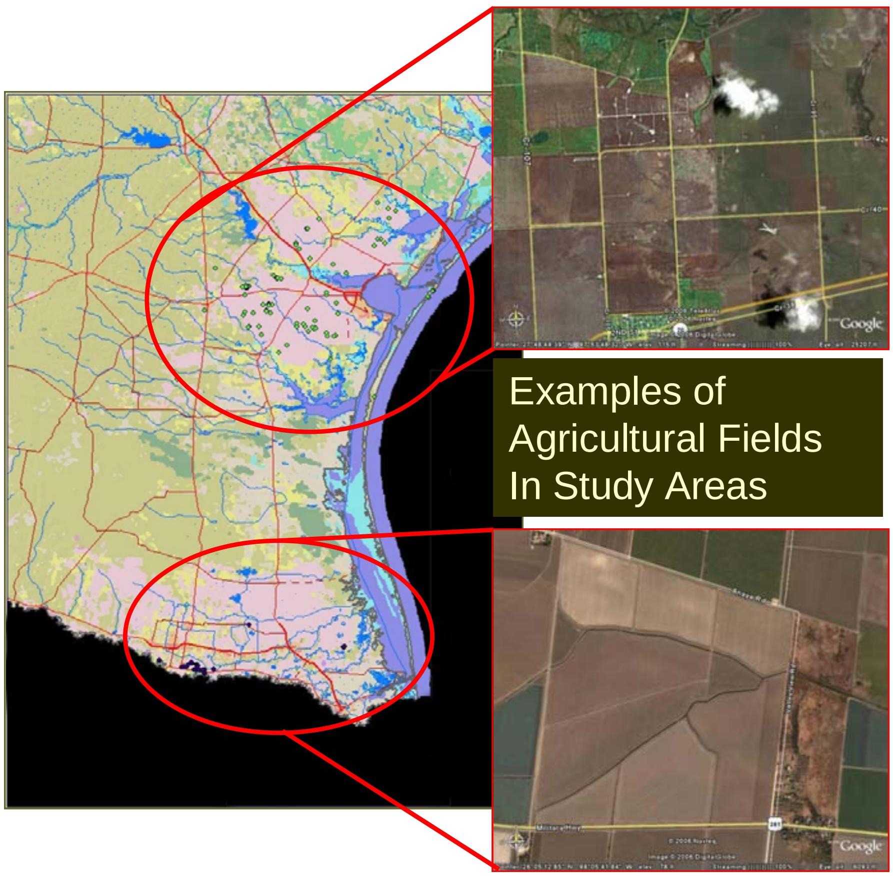

Figure 2. Study areas showing locations of roost sites and examples of agricultural fields used as roost sites.

In both study areas the crops are typically rotated annually so that if cotton crop is grown one year, the next year sorghum is grown. Burrowing owls in the Gulf Coast study area were studied intensively from 2000 -2005 by the USGS- Texas Gulf Coast Field Research Station (Woodin et al., 2006). In the Gulf Coast study area 87% of 46 roost sites were located in agricultural areas (Williford et al., 2007). Of these an estimated 67.4% of burrowing owl roosts were typically located in fields that were used for cotton, sorghum, or corn during the previous summer (Woodin et al., 2006). Of the roost sites used by burrowing owls in the Gulf Coast area, 80% were along roads. Most (74%) roost sites utilized were steel, cast-iron, or concrete culverts that lie under caliche roads. The predominant ground cover around roost sites was bare ground (Williford et al., 2007; Woodin et al., 2006; Woodin, pers. comm., 2004).

A second study area was chosen in the Rio Grande Valley and a short-term survey was conducted during the winter of 2006. This survey located 46 culverts used as roost sites by burrowing owls. Eighteen of these were defined by the presence of a burrowing owl, and the rest were defined by the presence of burrowing owl pellets, or in one instance by cached prey. Burrowing owl detections were clustered in agricultural fields in the Rio Grande floodplain north of Santa Ana National Wildlife Refuge. These culverts were most likely used as roost sites by at least 25 separate burrowing owls. Sixty-four percent of the burrowing owl roost sites were located in fields that were used for cotton or sorghum the previous summer. We were unable to determine the type of crop which was grown the previous summer in 32% of roost sites, but it is most likely that the crops were cotton or sorghum. Only one roost site (4%) was located in a field used to grow corn the previous summer. Although the majority of roost sites were completely surrounded by bare fields in which cotton or sorghum had been grown the previous summer, there were 2 roost sites located in cotton or sorghum fields adjacent to a cabbage crop and 4 roost sites located in cotton or sorghum fields adjacent to an onion crop. Both the cabbage and onion crops were being cultivated during the winter. The majority of burrowing owl roost sites in the Rio Grande Valley were cement (n =37) or plastic (n = 5) culverts, which were used to drain water off the field into irrigation canals. In addition, two owls were located roosting in natural burrows, and two owls located roosting in tires, all of which were located close to agricultural culverts.

3. Conceptual Model

The model simulates foraging and roosting behavior of an individual burrowing owl in crops that have received treatments with agricultural chemicals, resulting in estimates of dermal and oral exposure that can be used to predict risk of lethal or sublethal effects. The model consists of four submodels representing (1) behavior of burrowing owls, (2) chemical applications to crops, (3) chemical transfer and fate in the crop soil and prey items, and (4) chemical exposure in the burrowing owl.

Details of the cultivation of four different crops; cotton, sorghum, cabbage, and onions, are used to simulate three different foraging crop scenarios (FS 1-3). In all three scenarios a cotton\sorghum field is designated as a roost site. In this model the burrowing owl forages during the night in the fields surrounding its roost site, and is located at the culvert used as its roost site during the day. The primary crop scenario (FS-1), has two cotton/sorghum fields as foraging sites adjacent to the roost site. Each cotton/sorghum field alternates annually between cotton or sorghum crops grown during the summer, and the two foraging fields are offset so that there is always one cotton field and one sorghum field. The two additional crop scenarios include either a cabbage field (FS-2) or an onion field (FS-3) as a foraging site in addition to the cotton/sorghum fields.

The burrowing owl is only present in the model during the winter period, (Oct 1-Mar 1), when the post-harvest cotton/sorghum fields are wide expanses of bare soil, yet onions and cabbage are actively cultivated (Appendix A2). The primary crop scenario (FS-1) simulates chronic exposure to agricultural chemicals, while FS-2 and FS-3 add potential acute exposure scenarios.

Within these fields pesticides are applied to the crops. Once a pesticide is applied it is transferred to the soil, the owl, and its prey. The owl accumulates pesticides through dermal and ingestion pathways. ChE inhibition is calculated from the amount of insecticide accumulated with a dose-response equation. ChE inhibition, exposure > LOEL, and exposure > HD5 are used as endpoints (Figure 3).

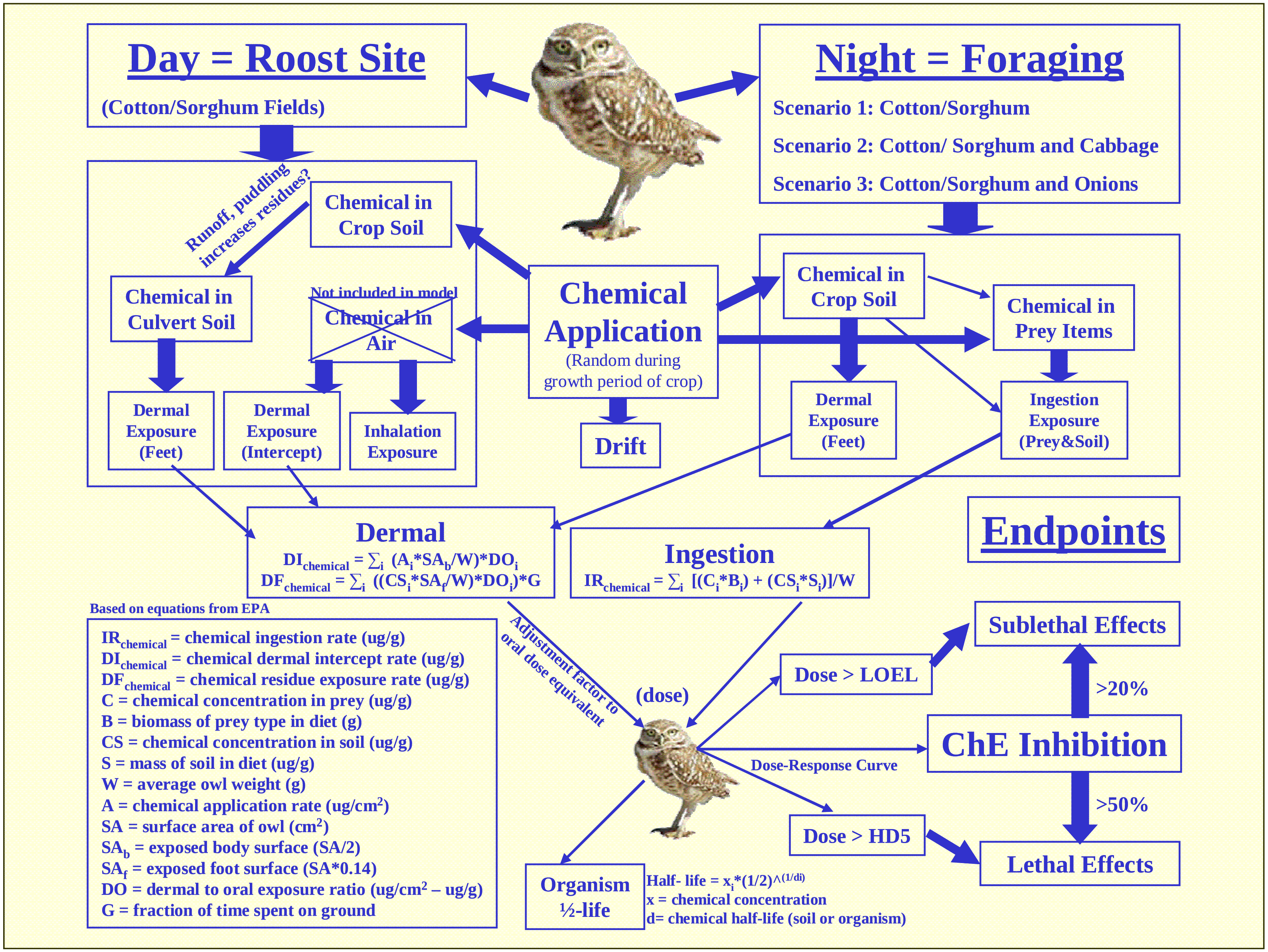

Figure 3. Conceptual Model.

4. Quantitative Model Description

The simulation model was created using Stella® VII software (High Performance Systems, Inc., NH), which uses difference equations in a bimodal compartment model with a one half day time step ($\Delta t = ½$ day). A one half day time step was chosen to represent the bimodal foraging behavior of burrowing owls during the winter. An overview of the parameters in the Stella model is shown in Appendix A1.

4.1 Foraging Scenarios

In FS-1 there is a 40% chance that the owl will forage in its roost site's field, and there is a 30% chance the owl will forage in one of the adjacent cotton/sorghum fields, because it was assumed that the owl would forage preferentially near its roost site. In FS-2 and FS-3, it was assumed that the owl would forage preferentially first in the cabbage or onion field, second near its roost site, and last in the cotton/sorghum fields further from its roost site. In these crop scenarios there is a 50% chance the owl will forage in the cabbage or onion field, a 30% chance it will forage in its roost site's field and a 10% chance each it will forage in one of the adjacent cotton/sorghum fields.

4.2 Chemical Applications

The growth period of the crops and the number of agricultural chemical treatments within a year are designated for each crop (Appendix A3). The growing seasons are based on earliest possible planting and latest possible harvest. Treatments often consist of multiple applications of the chemical selected, and multiple treatments can occur during the growing season. A date is randomly selected within the treatment date period when the treatment will be applied. For example, cotton receives 1.82

treatments, and the first treatment always occurs at a randomly selected date during the first treatment period, and there is an 82% chance that a second treatment will occur at a randomly selected date during the second treatment period. The number of treatments were calculated from NASS (2004) or NASS (2006) in this manner (total percent area applied of all pesticides within each chemical class)/(percent area each pesticide type was applied to). This assumes that the pesticides were applied at least once.

Agricultural chemicals are randomly selected to be used as treatments based on frequency distributions of crop specific use in Texas. The number of applications within each treatment and the application rate are designated for each chemical (Appendix A4).

4.3 Pesticide in Roost and Foraging Sites

In the cotton/sorghum fields used by the burrowing owl for foraging or roosting a crop is planted in the spring and grows until it is harvested. Agricultural treatments occur during the crop's growth. However by the time the owl is present, the soil in the field is bare with no vegetation. The worst case scenario in this situation is that all of the chemicals applied to the crop were either washed off of the vegetation into the soil during rain or irrigation events, or were incorporated into the soil along with the plants at harvest. In order to model this worst case scenario, at application each chemicals' residues are present in the soil and decay at the rate listed for that compound.

$$CS_{t+1} = CS_t + A_t - (CS_t * (1/2)\text{^}(1/d_s)) \quad (1)$$

CS_t represents the chemical residue concentrations in the soil (μg/cm^2) present at time *t*, A_t represents the concentration of chemical (g/cm^2) applied at time *t*, and d_s represents the half-life of the chemical in the soil (Appendix A5).

Chemical residues are transferred to insect and mammal prey items during application, and accumulate during each time step based on the amount present in the soil. Values estimating residues in prey items from Forsyth and Wescott (1994), Martin et al. (1996), Cobb et al. (2000), and Block et al. (1999) were used to derive equations to model the transfer of chemical residues to prey items. In these studies, residues on invertebrate prey items ranged from 1.57 to 7.44 times the application rate (g/cm^2). A value of 2.5 times the application rate (g/cm^2), which was the average value estimated from Forsyth and Wescott (1994), was chosen to represent the amount transferred to invertebrate prey at application. A value of the residue concentration in soil, (ug/cm^2), divided by 100 was used to estimate accumulation during each time step. An average of 0.21 times the application rate (g/cm^2) was extrapolated from Block et al. (1999) to represent the amount of residue transferred to mammalian prey at application. A value of the residue concentration in soil, (ug/cm^2), divided by 100 was used to estimate accumulation during each time step.

$$CI_{t+1} = CI_t + (A_t*2.5) + (CS_t/100) - (CI_t * (1/2)\text{^}(1/d_i)) \quad (2)$$

$$CM_{t+1} = CM_t + (A_t*0.21) + (CS_t/100) - (CM_t * (1/2)\text{^}(1/d_m)) \quad (3)$$

CI_t and CM_t represent the chemical residue concentrations (μg/g) present at time t in invertebrates and mammals, respectively; and d_i and d_m represent the half-lives of the chemical in invertebrates and mammals respectively (Appendix A6). The half-lives of the chemicals are estimated based on half-lives in soil for insects, and based on half-lives in vertebrates for mammals. Invertebrate half-lives were estimated as 1/10 the soil half-life, unless the vertebrate half-life was greater, in which case the vertebrate half-life value was used. Vertebrate half-lives were estimated from values on mammalian half-lives obtained from Pesticide Information Profiles (PIP, accessed 2007). In order to estimate half-lives for chemicals that had no information available, vertebrate half-lives and soil half-lives were fitted to a regression line ($y = 1.624x^{0.5865}$)which allowed estimates of vertebrate half-lives to be made based on soil half-lives.

Organophosphate insecticides are known to persist in the soil much longer than would be expected based on their half-lives (Ragnarsdottir, 2000). In order to build up an accumulation of low levels of several different insecticides similar to the amounts shown in the prey and pellets by Woodin et al. (2006), it was necessary to extend the half-lives of insecticides in the soil and in insects once they reached a low concentration. Several different scenarios were investigated, and a ten year initialization period, with half-lives extended by 100 times their original value when concentrations reached below 0.1(μg/g) was chosen for use in the model (Table 1a-b).

$$\text{if } CS_t < 0.1 \text{ then } CS_{t+1} = CS_t + A_t - (CS_t * (1/2)\hat{}(1/(d_s*100))) \tag{4}$$

$$\text{if } CI_t < 0.1 \text{ then } CI_{t+1} = CI_t + (A_t*2.5) + (CS_t/100) - (CI_t * (1/2)\hat{}(1/(d_i*100))) \tag{5}$$

At the burrowing owl's roost site the increased chemical concentrations in the culvert can be increased relative to the chemical concentrations in the crop soil.

$$CV_t = CS_t*x \tag{6}$$

CV represents the chemical concentration (μg/cm^2) present in the culvert soil at time t, and x is user specified multiplier.

Table 1a. Number and range of OP and CB pesticide residues detected from burrowing owl prey and pellets in south Texas.

Ranges Detected (ug/g)	Number of OP or CB Pesticides Detected Within Different Value Ranges										
	Prey Items					Range	Owl Pellets				Range
< 0.01	5	5	7	5	0	0-7	4	8	7	7	4-8
> 0.01, < 0.1	5	2	4	2	2	2-5	7	3	6	5	3-7
> 0.1, < 1.0	1	2	0	1	2	0-2	2	5	7	4	2-7
> 1.0	0	0	0	0	4	0-4	3	0	0	1	0-4

Calculated from Woodin et al. (2006)

Table 1b. Determination of the estimated increase in soil half-lives during the second phase and the start of the second phase.

Soil Half-Life Extender	Concentration below which Half-Life Extender Takes Effect	Ranges Detected (ug/g)	Number of OP or CB Insecticides in Prey: 10 Year Initialization Period	Number of OP or CB Insecticides in Prey: 5 Year Initialization Period
Soil Half-Life*1	<.1	> 0.01, < 0.1	0	x
		> 0.1, < 1.0	0	
		> 1.0	0	
Soil Half-Life*10	<.1	> 0.01, < 0.1	1	x
		> 0.1, < 1.0	0-1	
		> 1.0	0-1	
Soil Half-Life*25	<.1	> 0.01, < 0.1	0-1	0-1
		> 0.1, < 1.0	1-2	1-2
		> 1.0	0-1	0-1
Soil Half-Life*50	<.1	> 0.01, < 0.1	1-2	0-1
		> 0.1, < 1.0	1-3	1-3
		> 1.0	0-1	0-1
Soil Half-Life*100	<.1	> 0.01, < 0.1	1-4	1-3
		> 0.1, < 1.0	2-3	1-3
		> 1.0	0-1	0-1
Soil Half-Life*100	<.05	> 0.01, < 0.1	4-5	2-4
		> 0.1, < 1.0	0-2	0-1
		> 1.0	0-1	0-1

4.4 Exposure in Burrowing Owl

The burrowing owl is exposed to agricultural chemicals via ingestion and dermal pathways. Ingestion exposure occurs when an agricultural chemical enters the bird through their prey items, or through soil ingestion.

$$IR_{i,\,t+1} = \sum_i\ IR_{i,t} + [((C_{i,j,,t}*B_j) + (CS_{it}*S))/W] - (IR_{it} * (1/2)\wedge(1/d_m)) \qquad (7)$$

IR_i represents the concentration (μg/g) of each individual chemical in the owl at time *t* accrued through the ingestion exposure route. $C_{i,j}$ represents the concentration (μg/g) of each individual chemical in each type of prey at time *t*. B_j represents the biomass (g) of each prey type in the owl's diet. CS_{it} represents the concentration (μg/cm^2) of each individual chemical in the soil at time *t*, S represents the soil ingestion rate (g), and W the average burrowing owl weight. The mammalian half-lives (d_m) are used because avian half-lives were unavailable.

Dermal exposure can occur when the chemical is absorbed through the owl's legs or feet from contaminants present in the soil. This occurs as the burrowing owl roosts in their culvert during the day, and occasionally during the night while foraging.

$$DF_{i,\,t+1} = \sum_i\ DR_{i,t} + [(CS_{it}*SA_f*G)\,/W] \qquad (8)$$

DF_i represents the concentration (μg/g) of each individual chemical in the owl at time *t* to which the owl is exposed to through its legs and feet in a dermal exposure route. $DR_{i,}$ represents the combined concentration (μg/g) of each individual chemical in the owl through both dermal exposure routes at time *t*. SA_f represents the surface area (cm^2) of the owl's legs and feet. G represents the percentage of the time step that the owl's legs or feet were in contact with the soil.

Dermal exposure can also occur as a dermal intercept dose if the burrowing owl is present during or immediately after agricultural chemical treatment. The dermal intercept dose is estimated based on the amount of chemical present in the air lands on the dorsal half of the owl's body surface, and is absorbed through their skin.

$$DI_{i,\, t+1} = \sum_i \; DR_{i,t} + [(A_{it}*SA_b)\,/W] \tag{9}$$

$$DR_{i,\, t+1} = \sum_i \; [DF_{i,t} + DI_{i,t} - (DR_{it} * (1/2)\hat{}(1/d_m))]*DO_i \tag{10}$$

DI_i represents the concentration (μg/g) of each individual chemical in the owl at time *t* to which the owl is exposed to through a dermal intercept dose. SA_b represents the dorsal surface area (cm^2) of the owl. Mammalian half-lives (d_m) are used because avian half-lives were unavailable. DO_i represents a dermal to oral toxicity index (DTI) which converts a dermal dose to an amount equivalent to an oral dose for each individual chemical (Appendix A7). The additive concentrations of the converted dermal and oral doses are used to estimate the endpoints. The endpoints are estimated based on the amount of chemicals in the owl during each time step. Exposures to OP and CB insecticides are fitted to dose-response curves, resulting in ChE inhibition caused by each individual insecticide (Appendix A8). ChE inhibition from each individual chemical is summed to estimate total cumulative ChE inhibition.

4.5 Endpoints

The three estimated endpoints are ChE inhibition, exposure > LOEL, and exposure > HD5. ChE inhibition > 20% indicates an exposure level likely to result in sublethal effects, while ChE inhibition > 50% indicates an exposure level likely to result in lethal effects (Ludke et al., 1975).

Exposure to a chemical > its HD5 indicates an exposure level likely to result in lethal effects. HD5 levels were primarily obtained from Mineau et al. (2001). In the cases where a chemical's HD5 was not estimated by Mineau et al. (2001), HD5 values were plotted against avian LD50 values resulting in a regression line ($y = 0.1662x^{0.9133}$) that could be used to estimate HD5 values based on the LD50 values.

The use of reproductive NOECs, (no observed effects concentrations), are typically used in risk assessments as an endpoint to evaluate sublethal effects in birds (Mineau, 2005). However, the use of a reproductive endpoint is less relevant during the winter period than during the breeding season. For this reason exposure to a chemical > its LOEL was chosen to indicate an exposure level likely to result in sublethal effects. Due to the unavailability of information from studies using birds, values used for the LOELs were obtained from studies using mammals. Subsequently these values may be a less accurate indicator than the HD5 or ChE inhibition values. The lowest reported value of a LOEL or LEL for each chemical was chosen as the representative effect level in the model (Appendix A9). For the chemicals where no studies were conducted this endpoint was not evaluated.

5. Sensitivity Analyses

5.1 Parameterization

In order to determine which model parameters most affected the results, a series of parameters were changed to represent worst case scenario values (Appendix A1). The differences in means between crop scenarios for each endpoint were analyzed separately using a one-way ANOVA with a Bonferroni post-hoc test in SPSS statistical package

(SPSS inc., Chicago, IL). The primary crop scenario (FS-1), was used to evaluate low level chronic exposure to agricultural chemicals, while FS-2 and FS-3 were used to examine changes in the model's behavior when used to evaluate acute exposure scenarios.

5.1.1 Soil in Diet

Exposure to contaminated soil may be a source of exposure to contaminants. Estimated soil ingestion rates in birds range from < 2.0% to 30%, and vary with a species foraging habits or intentional soil ingestion for grit (Beyer et al., 1994). However to my knowledge there are no documented cases of intentional ingestion of soil in owls, and any soil ingested by burrowing owls would occur incidentally while foraging. For this reason the soil in the diet was set at the lower end of the spectrum at 3%. For this sensitivity analysis the value was increased to 10%.

5.1.2 Dermal Exposure during Foraging

During the winter burrowing owls typically forage during the night and spend the day at their roost site (Woodin, pers. comm., 2004). It was assumed that the owl spent the majority of this time flying, and spent one hour on the ground during which time it was exposed to chemicals through its legs and feet. In this sensitivity analysis the duration of time on the ground while foraging was increased to 9 hours.

5.1.3 Half Life in Bird

Once the owl was exposed to an agricultural chemical either through dermal or oral exposure, the chemical was then either excreted or metabolized by the bird which was represented by a vertebrate half-life value. These half-life values were primarily estimated or derived from studies on half-life values in mammals. Because the half-lives in mammals may differ from half-lives in birds, in this sensitivity analysis the vertebrate half-life values were increased by 5 times their original amount.

5.1.4 Drift

Drift decreases the concentration (ug/cm^2) in the field due to the pesticide landing in a larger area than the crop. In the model drift was set at 0.05%. For this sensitivity analysis was decreased to 0%.

5.1.5 Invertebrate Half-lives

In this model invertebrate half lives were primarily estimated as 1/10 the value of the soil half-lives. In this sensitivity analysis the half-lives in invertebrates was increased to the value of half-lives in soil.

5.1.6 Transfer and Accumulation of Chemicals in Insects

Estimated transfer of residues at application to prey items ranged from 1.57 to 7.44, for invertebrates, and 0.21 for mammals, times the application rate (Forsyth and Wescott, 1994; Martin et al., 1996; Cobb et al., 2000; Block et al., 1999); and a value of the concentration in soil divided by 100 was used to estimate accumulation during each time step for both invertebrates and vertebrates. In this sensitivity analysis both invertebrate and vertebrate transfer rates at application were increased to 7.44 times the application rate, and the amount of accumulation in each time step was increased to the concentration in soil divided by 10.

5.1.7 Soil Half-lives

Soil half-lives were primarily obtained from PAN (Pesticide Action Network database) and PIP (Pesticide Information Profiles database), in most cases the aerobic half-live value from PAN was used in the model. However if the PAN and PIP values differed widely, an intermediate value was chosen. In this sensitivity analysis, the highest possible soil half-life values were used.

5.1.8 Dermal Toxicity Indexes

Dermal toxicity indexes based on avian oral and dermal LD50s were only available for a handful of the chemicals evaluated in this model, and the rest were estimated by the equation ($F_{red} = LD_{50\ (avian\ oral)}/[10^{(0.84\ +\ 0.62(logLD50(oral))}]$) obtained from the U.S. EPA's terrestrial risk assessment model (Fite et al.,2004), creating a high level of uncertainty in these values. This sensitivity analysis doubles the DTI values.

5.1.9 Early Spring Spraying

In the model the dates when the first insecticide treatment on cotton or sorghum can occur and the dates that the owl is present do not overlap. This sensitivity analysis allows an eleven day overlap in these periods.

Table 2. Parameter changes resulting in a significant change (p < 0.05) from the baseline predicted values for each endpoint in each chemical class. (Significant changes are designated with an "x".) (Sensitivity Analyses: 0- Baseline with no changes, 1- Increased soil in diet, 2- Increased dermal exposure during foraging, 3- Increased half-life in bird, 4- Decreased loss due to drift, 5- Increased half-life in insects, 6- Increased accumulation in prey, 7- Used highest soil half-life values, 8- Increased the dermal to oral toxicity indexes, 9- Allowed possible early spring spraying prior to owl departure)

Crop Scenario	Endpoint	Chemical Class	Data Type	Sensitivity Analyses 1	2	3	4	5	6	7	8	9	TOTAL
Cotton/Sorghum								Cotton/Sorghum Total					**39**
	ChE	OP/CB Insecticides	Maximum			X				X	X		3
			Mean			X				X			2
			Duration > 20%			X							1
			Duration > 50%			X							1
	LOEL	Insecticides	Maximum		X	X				X	X		4
			Duration										0
		Herbicides	Maximum		X	X			X		X		4
			Duration		X	X				X	X		4
		Growth Regulators & Defoliants	Maximum			X		X	X			X	4
			Duration		X	X		X	X	X			5
	HD5	Insecticides	Maximum					X		X			2
			Duration			X		X		X			3
		Herbicides	Maximum										0
			Duration										0
		Growth Regulators & Defoliants	Maximum			X		X	X				3
			Duration			X		X	X				3
Cotton/Sorghum/Cabbage								Cotton/Sorghum/Cabbage Total					**44**
	ChE	OP/CB Insecticides	Maximum			X							1
			Mean			X				X			2
			Duration > 20%			X							1
			Duration > 50%			X							1
	LOEL	Insecticides	Maximum		X	X		X	X	X	X		6
			Duration										0
		Herbicides	Maximum		X	X		X	X		X		5
			Duration		X	X		X	X	X	X		6
		Growth Regulators & Defoliants	Maximum		X	X		X	X	X			5
			Duration			X		X	X	X	X		5
	HD5	Insecticides	Maximum			X	X	X		X			4
			Duration			X		X	X	X	X		5
		Herbicides	Maximum										0
			Duration										0
		Growth Regulators & Defoliants	Maximum			X			X				2
			Duration			X							1
Cotton/Sorghum/Onions								Cotton/Sorghum/Onions Total					**47**
	ChE	OP/CB Insecticides	Maximum					X					1
			Mean		X	X		X	X	X			5
			Duration > 20%		X	X		X	X	X			5
			Duration > 50%			X		X	X				3
	LOEL	Insecticides	Maximum		X	X			X	X	X		5
			Duration										0
		Herbicides	Maximum		X	X		X	X		X		5
			Duration		X	X		X					3
		Growth Regulators & Defoliants	Maximum		X	X		X	X				4
			Duration			X		X	X	X			4
	HD5	Insecticides	Maximum					X	X	X			3
			Duration			X		X	X	X	X		5
		Herbicides	Maximum										0
			Duration										0
		Growth Regulators & Defoliants	Maximum			X		X	X				3
			Duration			X							1
Sensitivity Analyses Totals				**0**	**14**	**36**	**1**	**24**	**22**	**20**	**12**	**1**	

5.2 Model Sensitivities

The model proved sensitive to most of the parameters altered, and showed an increase in sensitive parameters in the crop scenarios that added potential acute chemical exposure (FS-2, FS-3). The foraging related sensitivity analyses (#5 & #6), accounted for more significant differences in these scenarios, than in FS-1 (Table 2). This is likely due to higher concentrations of chemicals in the foraging areas after insecticide treatments while the owl is present. The model was sensitive to the half-lives in invertebrates, as well as to the accumulation and transfer rates in prey, especially in the crop scenarios that received chemical treatments during the period the owl was present (Table 2). This suggests that the pesticide residues in prey items are likely to be most important in the period immediately after chemical treatments. Driver et al. (1991) showed that oral exposure was most important during the 4-24 hour period shortly after spraying and decreased in importance afterward. The studies by Forsyth and Wescott (1994), Martin et al. (1996), and Cobb et al. (2000) provides a good baseline to estimate residues in invertebrate. More information is needed on the accumulation of insecticide residues in small mammals, because the study by Block et al. (1999) was based on a granular insecticide, and accumulation and transfer rates may differ substantially in liquid formulations.

The parameter that caused the most significant increases in the endpoint values was the half-lives of chemicals in the burrowing owl. Significant increases were seen in the majority of the combinations of different crop scenarios and chemical classes (Table 2). Unfortunately, this is also a parameter with large data gaps. The mammalian half-life values used in the model may not be accurate when applied to birds. In addition, the half-lives of agricultural chemicals in the bird were assumed to be the same regardless of whether the exposure occurred dermally or orally. However, the duration of exposure may vary between dermal exposure and oral exposure. Henderson et al. (1994) showed that pigeons did not recover from dermal exposure to OP insecticides for up to 6 weeks after dosing, while recovery from an oral dose took approximately 5 days. The high sensitivity of the model to this parameter illustrates the importance of obtaining accurate values of the half-lives of agricultural chemicals in birds.

The model was also sensitive to the parameters which were related to dermal exposure, (sensitivity analyses #2, #7, & #8), the duration of chemical exposure while foraging, the half-lives of agricultural chemicals in soil, and the dermal to oral toxicity ratios (Table 2). Information of the duration of time spent on the ground while foraging in the winter would increase the accuracy of the model. There are well documented half-lives in soil for most of the agricultural chemicals evaluated, however using the upper limits of the reported values resulted in a large number of significant increases in the endpoints evaluated (Table 2, Appendix A5). There is very little data available which can be used to evaluate dermal toxicity in birds, particularly for classes of agricultural chemicals other than insecticides, and the majority of values were estimated from an equation rather than based on actual bioassay data (Appendix A6). The results of this sensitivity analysis confirm of the importance of dermal exposure in birds demonstrated by Driver et al. (1991) and Mineau (2002), and exemplify the necessity for more information that can be used to estimate risk to birds from dermal exposure to insecticides and other agricultural chemicals.

The amount of soil in the diet, the amount of drift, and the possibility of early spring spraying did not result in significant changes in the model (Table 2). Although the amount of soil in the diet did not seem to be an important factor for burrowing owls, it may be an important factor for species such as sandpipers that have a higher percentage of soil in their diet (Beyer et al., 1994). The amount of drift was set at an amount close to 0% in the baseline simulations, and may be more important with greater variation in the drift rates. Early spring spraying did not occur frequently enough to cause significant changes in the endpoints (Table 2), but may be more important than suggested by the model. Organophosphate insecticides have been shown to alter migration in adult birds, most likely by affecting memory of the migration route (Vyas et al., 1995). Early spring spraying prior to the departure of burrowing owls could occur at a critical period when memory of the migration route becomes vital. This would be most likely to occur if the use of pre-planting treatments overlaps with the period when burrowing owls are present. Pre-planting treatments are most commonly used for control of white grubs, corn rootworm, or wireworms in sorghum fields (Cronholm et al., 1998).

Corson et al. (1998) examined foraging location, diet selection, and food intake/body weight ratio in the sensitivity analysis for his avian pesticide exposure simulation model. The model was sensitive to all of these factors, but was highly sensitive to foraging location. Likewise, an analysis of variability in risk assessments found that bird movements between treated and untreated areas was one of the most important factors and led to substantial differences in observed effects (Hart, 1990). However, model sensitivity foraging location was not investigated in this scenario. Due to the agricultural homogeneity of the landscape, in which the owl roosts and forages in agricultural fields, and there was virtually no untreated habitat available in which the owl could forage. Although burrowing owls in South Texas have been shown to primarily forage in the ditches separating fields (Woodin, pers. comm., 2004), the differences between agricultural chemical residues in the fields and the ditches surrounding the fields were unknown and were assumed to be equal. If the residue concentrations differ between the fields and the surrounding ditches varies, it may cause variations from the results observed in these simulations.

An analysis of wildlife risk assessments found eight dietary related exposure factors likely to cause variations in the assessment of risk; food ingestion rate, diet composition, ingestion of soil, trophic transfer levels, bioavailability, chemical concentration in soil or prey, and the amount of available habitat (Fairbrother, 2003). An analysis of long-term avian or mammal wildlife risk assessments identified several spatial or temporal factors which may cause the greatest variations between long-term and acute risk assessment. These included food intake rate, changes in body weight, pesticide concentrations on food, differences in spray regimes, wildlife avoidance of pesticides, diet composition, and the proportion of diet from the treated area (Crocker, 2005). Of these variables, diet composition, trophic transfer levels, and chemical concentrations in food or soil were also identified in the sensitivity analyses as causing significant variations in potential risk. The results of Fairbrother’s (2003) and Crocker’s

(2005) analyses concur with the dietary exposure related sensitivities observed in the simulations with potential acute exposure. Detailed graphs and tables of the results of the sensitivity analyses can be found in Appendix B.

6. Model Application

6.1 Introduction

This model can be used to quantify risk by examining variations in the effects of exposure to agricultural chemicals in different roosting and foraging scenarios, in order to predict the crops or chemicals pose the greatest risk to bird populations. This model was used to evaluate which crops or chemical classes are most likely to increase risk of lethal or sublethal exposure to agricultural chemicals in burrowing owls wintering in South Texas.

6.2 Experimental Design for Simulations

In order to evaluate lethal and sublethal exposures to OP and CB insecticides, the maximum value and mean value of ChE inhibition that occurred over the winter, as well as the duration of ChE inhibition greater than 20% and 50%, was recorded for each simulation.

In order to evaluate lethal and sublethal exposures to agricultural chemicals including insecticides, herbicides, growth regulators, and defoliants, the number of chemicals with exposure levels greater than their HD5 (NH_c) or LOEL (NL_c) was recorded at each time step. NH and NL represents the number of chemicals to which the owl is exposed to a level greater than the HD5, or LOEL, respectively, while c represents the different chemical classes, which can be further defined as i = insecticides, *h* = herbicides, and *g* = growth regulators or defoliants. The maximum values of NH_c or NL_c that occured throughout the winter; as well as duration of exposure greater than an HD5 or LOEL throughout the winter; were recorded for each simulation.

The primary crop scenario, FS-1, was used to represent chronic exposure to agricultural chemicals, while FS-2 and FS-3 represent the addition of acute exposure. Two hundred simulations were run for each foraging crop scenario, and an equal number of simulations were run with either cotton or sorghum grown in the roost or foraging fields in the summer prior to the arrival of the wintering burrowing owl. The simulated data were then analyzed in SPSS statistical package (SPSS inc., Chicago, IL). with a one-way ANOVA using a Bonferroni post-hoc test to compare means between crop scenarios for each endpoint. Significance was defined as ($p < 0.05$).

6.3 Model Application Results

6.3.1 ChE Inhibition

The average maximum and average mean ChE inhibition varied between all three crop scenarios, although it was slightly, but insignificantly, higher between FS-1 (3.9%-maximum, 2.3%-mean) and FS-2 (10.0%-maximum, 3.9%-mean). With the addition of an adjacent onion field (FS-3), ChE inhibition (58.2%-maximum, 16.5%-mean), was significantly increased compared to FS-1 and FS-2 ($p< 0.000$) (Figure 4a). Likewise, average duration of ChE inhibition greater than 20% and 50% was also slightly, but not significantly, longer in FS-2 (1.8 days- > 20%, 0.7 days- > 50%) than in FS-1 (0.0 days- > 20%, 0.0 days- > 50%). Average duration of ChE inhibition greater than 20% and 50%

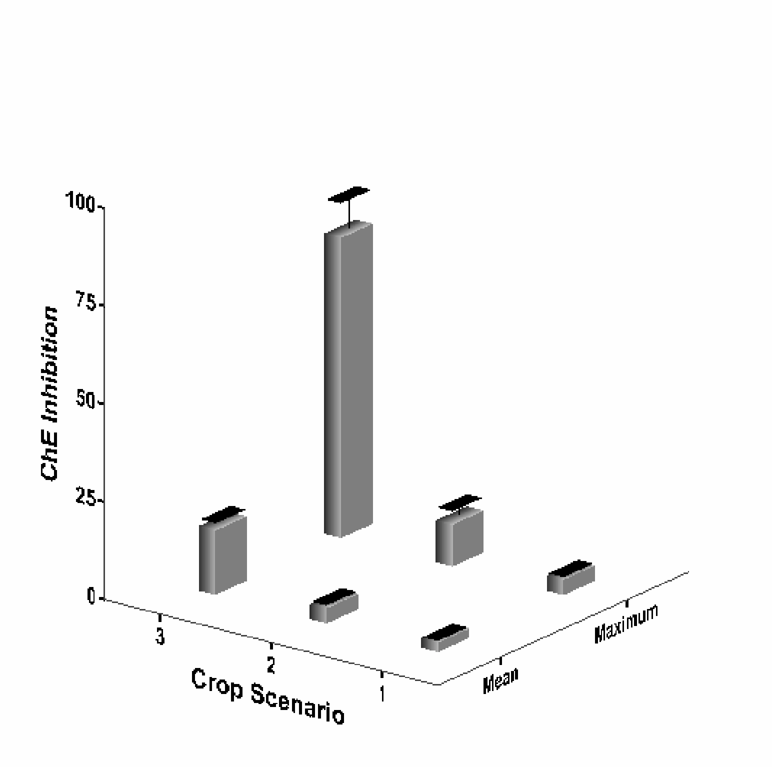

Figure 4a. Differences in maximum and mean ChE inhibition between crop scenarios. (Crop Scenario: 1 = Cotton/Sorghum, 2 = Cotton/Sorghum/Cabbage, 3 = Cotton/Sorghum/Onions)

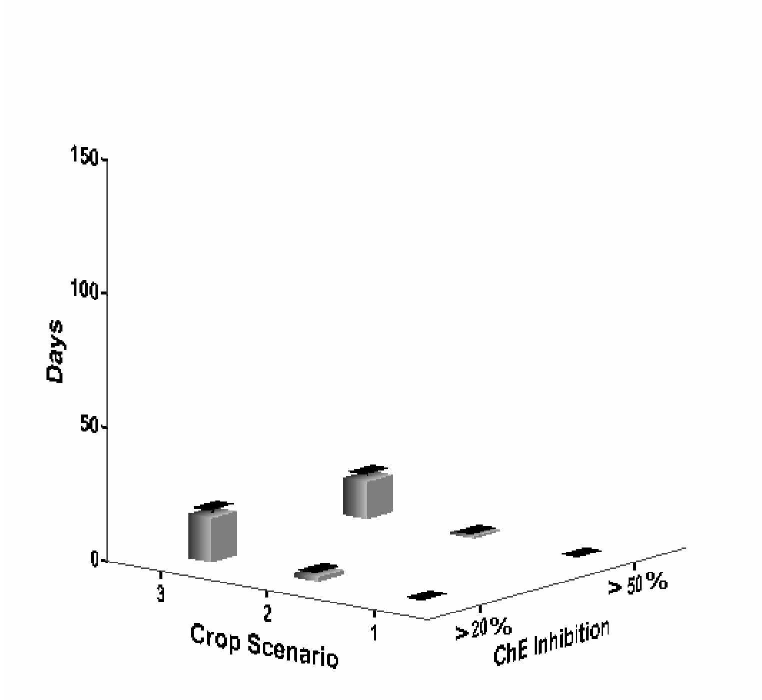

Figure 4b. Differences in duration of ChE inhibition > 20% or > 50% between crop scenarios. (Crop Scenario: 1 =Cotton/Sorghum, 2 =Cotton/Sorghum/Cabbage, 3 =Cotton/Sorghum/Onions)

was significantly longer in FS-3 from FS-1 and FS-2 (16.5 days- > 20%, 14.0 days- > 50%; $p < 0.000$) (Figure 4b).

6.3.2 LOELs

In all three crop scenarios the burrowing owl was exposed to a greater number of insecticides over their LOEL than any other chemical class. Average insecticide exposure greater than an LOEL occurred throughout the entire winter, (144-147 days) in all three crop scenarios. In FS-1 the burrowing owl was exposed to a greater number of growth regulators or defoliants over their LOEL than herbicides (NL_h = 1.025, NL_g = 1.290). However, when cabbage or onions were added as a foraging site, the burrowing owl was exposed to a greater number of herbicides over their LOEL than growth regulators or defoliants (NL_h = 1.365, & NL_g = 1.050; NL_h = 1.470, & NL_g = 1.025; in FS-2 and FS-3 respectively) (Figure 5a). In all three scenarios the burrowing owl was exposed to growth regulators or defoliants over their LOEL for a longer period, (96-119 days), than herbicides, (71-85 days), (Figure 5b).

FS-2 had the highest average maximum value of NL_i (1.670), and was significantly greater, ($p = 0.010$), than the average maximum value of NL_i in FS-1 (1.485). FS-3 had an intermediate value (1.605), but was not significantly different from the other two scenarios (Figure 5a). The duration of exposure greater than an LOEL was not different between the three scenarios (Figure 5b).

The average maximum value of NL_h was significantly greater, ($p < 0.000$), in FS-2, (1.365), and FS-3, (1.470), than in FS-1 (1.025). FS-3 had the highest average maximum value of NL_h of all three crop scenarios (Figure 5a). The duration of exposure to herbicides greater than their LOELs was lowest in FS-1, (70.5 days), and highest FS-3, (85.6 days), however these differences were not significant (Figure 5b).

The average maximum value of NL_g was significantly higher ($p < 0.000$) in FS-1, (1.290), than the other two crop scenarios, (FS-2 = 1.050, F-3 = 1.025) (Figure 5a). In addition the duration of exposure to levels of growth regulators or defoliants greater than their LOEL was greatest in FS-1 (118.7 days) (Figure 5b).

6.3.3 HD5

Insecticides were the only chemical class to which the owl was exposed to levels greater than the HD5, and the duration of exposure only encompassed a small portion, (5-9 days), of the winter period (Figure 6a-b). The average maximum value of NH_i, (FS-1 = 0.125, FS-2 = 0.380, FS-3 = 0.335), was significantly greater in the FS-2, and FS-3 than in FS-1 ($p < 0.000$), and was highest in FS-2 (Figure 6a). The duration of exposure to an insecticide greater than its HD5 was also significantly longer in FS-2 (FS-1 = 4.9 days, FS-2 = 8.8 days, FS-3 = 5.2 days) (Figure 6b).

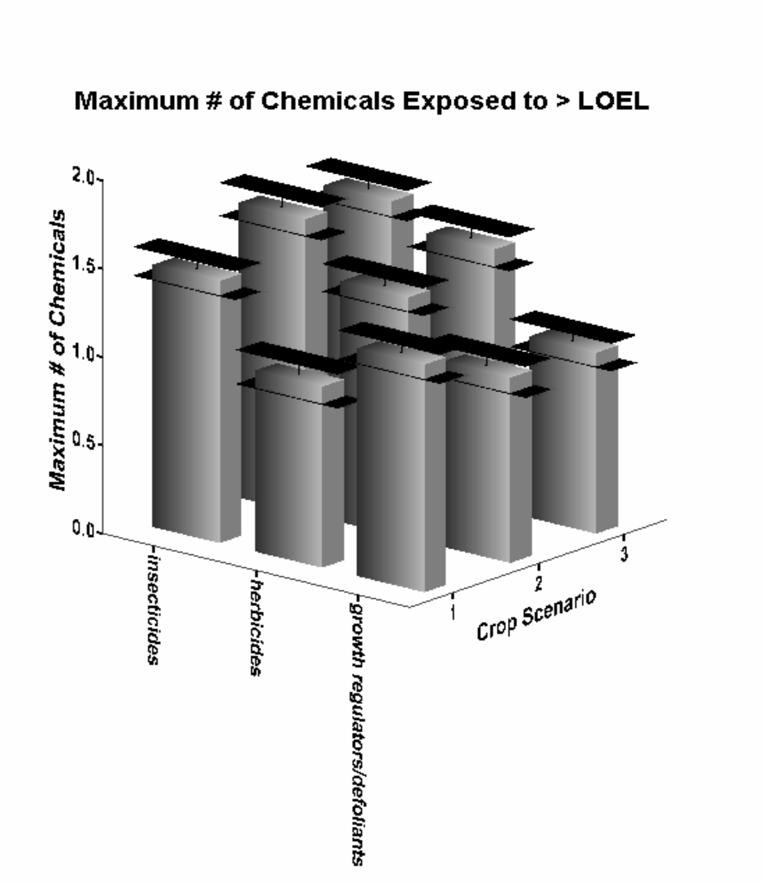

Figure 5a. The average maximum number of agricultural chemicals to which the owl is exposed to an amount > the LOEL over the winter by crop scenario. (Crop Scenario: 1-Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)

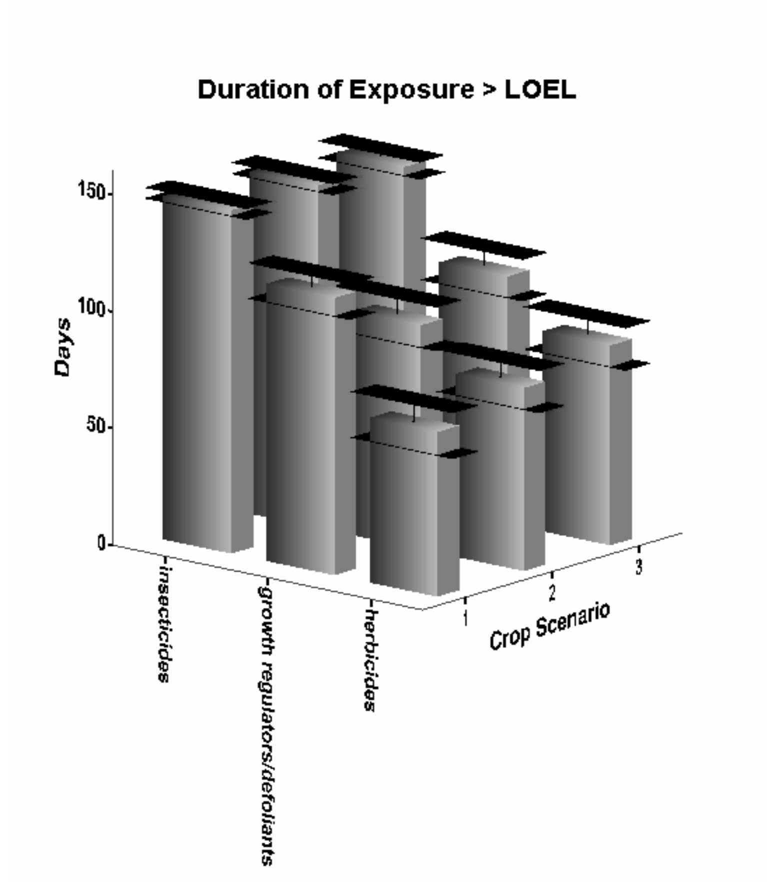

Figure 5b. The duration of exposure to agricultural chemicals > the LOEL over the winter by crop scenario. (Crop Scenario: 1-Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)

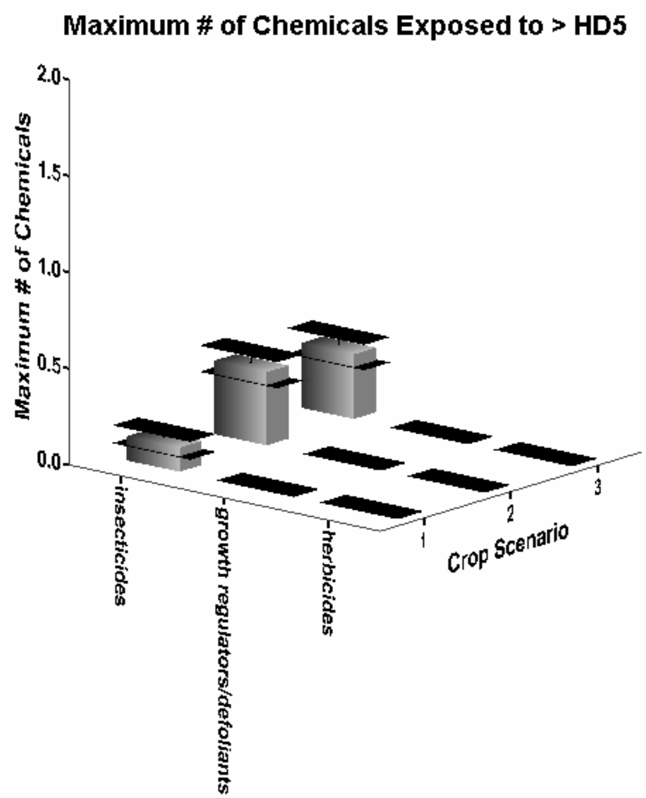

Figure 6a. The average maximum number of agricultural chemicals to which the owl is exposed to an amount > the HD5 over the winter by crop scenario. (Crop Scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)

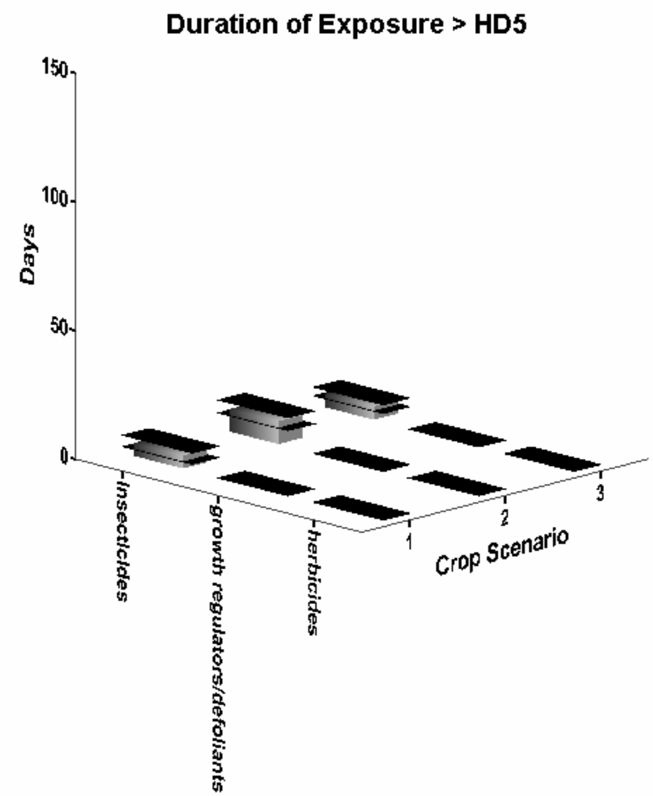

Figure 6b. The duration of exposure to agricultural chemicals > the HD5 over the winter by crop scenario. (Crop Scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)

6.3.4 Summary of Model Application Results

The risk of chemical classes to burrowing owls wintering in south Texas cotton/sorghum fields can be described as insecticides>growth regulators and defoliants>herbicides. The presence of cabbage or onion fields as a foraging site adjacent to the roost site increases the risk posed by insecticides and herbicides, most likely due to more frequent spraying of these chemicals on onion or cabbage crops during the period that the owls are present. It is also clear that, with the exception of growth regulators and defoliants which are only applied to cotton fields, risk of lethal or sublethal effects of agricultural chemical exposure increase in the presence of a crop which is receiving treatments during the period the owl is present, which is represented in this case by cabbage or onions.

ChE inhibition due to exposure to OP and CB insecticides was greatest when an onion field was used as a foraging site, followed by the presence of cabbage fields as a foraging site. Similiarly, Mineau and Whiteside (2006) found that onion crops had a higher potential lethal risk to birds than cabbage in an analysis of NASS 2000-2003 data for the entire United States. However, lethal and sublethal effects of all insecticides based on LOELs and HD5s were greatest in the presence of a cabbage field, followed by the presence of onion fields. The large increase in ChE inhibition in onion fields most likely occurred because over 80% of insecticide treatments in onion fields are based on OP or CB insecticides compared to 24% of insecticide treatments in cabbage fields. In addition, the two insecticides which comprise all of the reported OP and CB insecticide use on onion fields, diazinon and methomyl, are extremely toxic to birds (characterized by an LD50s below 40 mg/kg) (Smith, 1993; Appendix A4). Diazinon and methomyl are also used on cabbage, along with dimethoate, which also is extremely toxic to birds. However over 75% of the insecticide use is from other types of insecticides, including the highly toxic organochlorine insecticide endosulfan, which probably created the discrepancy between the ChE endpoint data and the LOEL and HD5 data (Smith, 1993; Appendix A4).

7. Discussion

This model provides a framework for a simple stochastic simulation model which can be used to compare different classes of chemicals or individual chemicals, as well as different crops, based on current agricultural practices, in terms of potential lethal or sublethal effects in burrowing owls. ChE inhibition has been used by Corson et al. (1998) and Pisani (2006) to predict ChE inhibition due to OP and CB insecticide exposure on birds. Mineau (2002), and Mineau and Whiteside (2006), used HD5 values to predict risk of lethal exposure to insecticides in birds. Although reproductive NOELs or NOECs are used in long-term exposure assessments used to model population level effects (Shore et al., 2005; Mineau, 2005; Bennett et al., 2005), to my knowledge this is the first model to use LOEL values to assess the effects of agricultural chemicals currently in use on birds during the non-breeding period of their life cycle. The combined use of these three different endpoints in this model allows for the risk of both lethal and sublethal effects in birds due to exposure to chemical classes in addition to insecticides to be investigated. In addition concurring results from all three endpoints can provide a stronger assessment of a chemical or crop than from one endpoint alone.

Fairbrother (2003) suggested that a “bottom up” approach used in Tier 1 risk assessments can rule out exposure pathways, species, or contaminants with negligible ecological risk. This can then guide the “top down” approaches in higher tiered risk assessments as to which contaminants, pathways, or species further site specific studies should be focused. Likewise, simulation modeling used for single species ecological risk assessment can guide the direction in which higher assessments should be focused. In the case of burrowing owls, following the approach of Fairbrother (2003), future studies should focus on gathering more site specific data on contaminant residues in prey items and in the soil, and laboratory bioassays on contaminants that were indicated as potential risk factors. If these studies still indicate potential risk of effects of contaminant exposure to burrowing owls in South Texas, then field studies should be conducted to evaluate the possibility of the occurrence of lethal or sublethal effects that may reduce individual fitness and subsequently lead to population level effects.

CHAPTER III

BURROWING OWLS AND CULVERTS IN COTTON FIELDS: AN ECOLOGICAL TRAP?

1. Introduction

The Committee on the Status of Endangered Wildlife in Canada classified burrowing owls as endangered due to significantly declining populations and range restriction. Despite intensive conservation efforts, burrowing owls have been extirpated from Manitoba and British Columbia, and burrowing owl populations have declined 58-94% in Alberta and 95% in Saskatchewan over the past 10 years (SRD & ACA, 2005). Chronically low return rates suggest that this burrowing owl population may face its greatest threats on its wintering grounds, which include south Texas (Clayton and Schmutz, 1999).

Known threats to burrowing owl populations include habitat loss and fragmentation, loss of burrows, weather, predation, road kills, and rodenticide or insecticide use. Habitat loss of grasslands and desert areas through conversion to agriculture or urbanization resulting in the loss of burrows and foraging habitat is most frequently cited as the cause of declines in burrowing owl populations (Klute et al., 2003; Woodin, pers. comm., 2004). Burrowing owls are dependent on the burrows of black-tailed prairie dogs, or other burrowing mammals, for nesting and wintering habitat, but may use other types of shelter in the absence of their preferred burrow types. Burrowing owl populations in areas where black-tailed prairie dogs have been eradicated have been extirpated, or have severely declined (Butts and Lewis, 1982; Desmond et. al., 2000). In Texas, the historic range of black-tailed prairie dogs covered the western half of the state. Black-tailed prairie dogs are now extirpated from most of their historic range, due to active control through rodenticides, and conversion of their native habitat to agriculture. One former colony in Texas was 64,000 km^2 and supported a population of 400 million prairie dogs (TPWD, 1997).

Outside of the Migratory Bird Treaty Act of 1918, the burrowing owl has no protected legal status in Texas. The USFWS Natural Heritage Program listed the burrowing owl population as vulnerable in Texas, before the program in Texas was discontinued (Klute et al., 2003). Burrowing owls historically bred across most of Texas, including south Texas until the 1920’s. Today the breeding range of burrowing owls only includes the northwestern region of Texas, and the population that may have once bred in south Texas is now a migratory population that winters along the lower Gulf Coast and the Rio Grande Valley (Wellicome and Holroyd, 2001; Woodin, pers. comm., 2004). Widespread landscape conversion to agriculture in the Eastern and Central U.S. has been correlated with the decline of grassland associated bird species (Murphy, 2003). Concern over loss of grasslands in Texas began as far back as 1878, when writers noted the intrusion of woody vegetation into grassland areas, primarily due to fire suppression (Johnston, 1963). Today conversion to agricultural fields has occurred on up to 99% of the native prairies and grasslands in the coastal prairies of Texas. The remaining grassland areas have been further degraded through cattle grazing and invasive species (PIF, 2005).

Although burrowing owls are historically associated with grassland habitat characterized by the presence of the burrows of prairie dogs or other fossorial mammals, burrowing owls have recently become strongly associated with agriculture (Moulton et al., 2006; Conway et al., 2006). Burrowing owls wintering in south Texas agro-ecosystems primarily use culverts as roost sites (Texas Gulf Coast Field Research Station, 2003). In addition, it has been implied that the creation or restoration of culverts in agricultural areas can be used as a management tool in burrowing owl conservation (Williford et al., 2007). However, if the culverts used by burrowing owls are actually a source of agricultural chemical exposure they may have the potential to act as "ecological traps".

Ecological traps were defined by Schlaepfer et al. (2002) as "in an environment that has been altered suddenly by human activities, an organism makes a maladaptive habitat choice based on formerly reliable environmental cues, despite the availability of higher quality habitat". Robertson and Hutto (2006) further elaborate on this description by describing ecological traps as resulting from "decoupling the attractiveness of and the suitability in the altered habitat". Habitat alterations can lead to ecological traps in three ways, 1) by altering the settlement cue set, resulting in an increased attractiveness in the altered habitat, 2) by decreasing the suitability of a habitat, or 3) by simultaneous increasing attractiveness and decreasing suitability in the altered habitat (Robertson and Hutto, 2006). The response of mayflies to asphalt is one of the most thoroughly described ecological traps. In this example, asphalt sometimes reflects horizontally polarized light in a manner similar to ponds. Mayflies use the horizontally polarized light from ponds as a cue for suitable habitat for oviposition, and the horizontally polarized light reflected from asphalt leads to oviposition on the dry asphalt rather than in nearby ponds (Kriska et al.,1998).

The mechanism driving the apparent preferential use of agricultural areas by burrowing owls is unclear. However, Moulton et al. (2006) found that increased prey resources may be a driving mechanism of burrowing owl associations with agriculture. Burrowing owls wintering in south Texas agro-ecosystems seem to show a preference for culverts in dormant agricultural fields as roost sites (Texas Gulf Coast Field Research Station, 2003). Culverts in fields which are left bare over the winter in South Texas may be attractive to burrowing owls because of their superficial resemblance to clustered mammal burrows in a shortgrass prairie, or because of increased food resources in agricultural areas.

Despite the apparent increased prey availability in agricultural areas, a recent demographic study indicated that burrowing owls in agricultural areas represent population sinks, and hypothesized that persistence of these populations is dependent on immigration (Conway et al., 2006). Burrowing owls living in agricultural areas are likely to be exposed to contaminants, and the presence of contaminants combined with natural stressors can negatively affect population level processes (Gervais et al., 2006). It was determined that burrowing owls forage in cropland areas after treatment with pesticides, and it is possible that they may be attracted to the availability of dead and dying prey that occurs after pesticide use (Gervais et al., 2003). In addition, the use of agricultural culverts within agricultural fields as roost sites may increase their risk of exposure to insecticides and other agricultural chemicals through dermal exposure to agricultural runoff. This increased risk of insecticide exposure was confirmed by an analysis of burrowing owl pellets in south Texas that detected OP insecticides (Woodin et al., 2006).

Based on the limited research that has been conducted, it appears that one of the most common habitats currently utilized by burrowing owls in south Texas argro-ecosystems are cotton and sorghum fields. Of all the crops grown in the United States cotton is one of the most notorious for intensive historical and current agricultural chemical that has resulted in increased concentrations of contaminants (Kannan et al, 2003). In addition cotton is one of two crops with the highest risk of lethal effects to birds in the United States, and has been responsible for several large mortality events (Mineau and Whiteside, 2006). Herbicides, insecticides, and growth regulators and defoliants are typically applied to cotton crops in Texas (NASS, 2005).

Of the agricultural chemicals most commonly used today, OP and CB insecticides are the most dangerous to non-target organisms and have been responsible for numerous cases of mortality in owls and other raptors (Blus, 1996; Sheffield, 1997; Mineau et al., 1999). OP and CB compounds prevent normal physiological functions of organisms, and disrupt nerve function by acting as cholinesterase (ChE) inhibitors (Walker and Thompson, 1991). OP and CB insecticides primarily function by either phosphorylation (OPs) or carbamylation (CBs) of the acetylcholinesterase (AChE) enzyme’s active site serine residue. In the case of OPs this binding is irreversible, while with CBs the binding is somewhat reversible (Hill, 2003). Following binding of AChE molecules, acetylcholine accumulates in the central or peripheral nervous system synapses, the cholinergic receptors are overstimulated, and normal cellular function is altered in response to the overstimulation of the cholinergic receptors. This eventually leads to autonomic dysfunction (especially excessive secretions), tremors or convulsions, muscle fasciculations, and eventually respiratory failure (Pope, 1999).

Even sublethal doses of OP and CB insecticides can affect avian mortality by affecting their behavior and normal physiological functions. The greatest effects include alterations in thermoregulation, food consumption, and reproductive behavior including migration (Grue et al., 1997). Exposure to OP and CB insecticides can occur through ingestion of contaminated prey, water, vegetation, seeds, or soil, as well as through direct contact with the pesticide during application, or through contact with contaminated soil or water (Hill, 2003). Although risk assessments have traditionally focused on oral exposure, the importance of dermal exposure has recently become apparent (Fite et al., 2004; Mineau, 2002; Henderson et al., 1994; Driver et al., 1991).

Spatial variability in concentrations of pesticide residues has been shown in several field studies (Harris, 2000; Cobb et al., 2000; Kendall et al., 1992; Kendall et al., 1993). If runoff or puddling cause pesticide residues to concentrate in the culverts, resulting in levels of dermal exposure to agricultural chemicals sufficient to lead to decreased fitness, it is possible that culverts in cotton fields may represent ecological traps for burrowing owls. The purpose of this study is to use simulation modeling to determine the relationship between increased concentrations of agricultural chemicals in culverts and subsequent lethal and sublethal risks from dermal exposure to agricultural runoff.

2. Study Area

Refer to Chapter II.2

3. Model Overview

3.1 Conceptual Model

The model simulates foraging and roosting behavior of an individual burrowing owl in crops that have received treatments with agricultural chemicals, resulting in estimates of dermal and oral exposure that can be used to predict risk of lethal or sublethal effects. The model consists of four submodels representing (1) behavior of burrowing owls, (2) chemical applications to crops, (3) chemical transfer and fate in the crop soil and prey items, and (4) chemical exposure in the burrowing owl.

Details of the cultivation of four different crops; cotton, sorghum, cabbage, and onions, are used to simulate three different foraging crop scenarios (FS 1-3). In all three scenarios a cotton\sorghum field is designated as a roost site. In this model the burrowing owl forages during the night in the fields surrounding its roost site, and is located at the culvert used as its roost site during the day. The primary crop scenario (FS-1), has two cotton/sorghum fields as foraging sites adjacent to the roost site. Each cotton/sorghum field alternates annually between cotton or sorghum crops grown during the summer, and the two foraging fields are offset so that there is always one cotton field and one sorghum field. The two additional crop scenarios include either a cabbage field

(FS-2) or an onion field (FS-3) as a foraging site in addition to the cotton/sorghum fields.

The burrowing owl is only present in the model during the winter period, (Oct 1-Mar 1), when the post-harvest cotton/sorghum fields are wide expanses of bare soil, yet onions and cabbage are actively cultivated (Appendix A2). The primary crop scenario (FS-1), simulates chronic exposure to agricultural chemicals, while FS-2 and FS-3 add potential acute exposure scenarios.

Within these fields pesticides are applied to the crops. Once a pesticide is applied it is transferred to the soil, the owl, and its prey. The owl accumulates pesticides through dermal and ingestion pathways. ChE inhibition is calculated from the amount of insecticide accumulated with a dose-response equation. ChE inhibition and exposure > HD5 are used as endpoints (Figure 3).

At the burrowing owl's roost site the possibility of increased chemical concentrations transferred to the culvert though runoff will be simulated by increasing the chemical concentrations in culverts relative to the chemical concentrations in the crop soil. For a more complete model description please refer to Chapter II.4.

4. Methods

An equal number of simulations were run with either cotton or sorghum grown in the roost or foraging fields in the summer prior to the arrival of the wintering burrowing owl, and an equal number of simulations were run for each crop scenario.

At the burrowing owl's roost site the increased chemical concentrations in culverts were simulated by increasing the chemical concentrations in culverts relative to the chemical concentrations in the crop soil. Two hundred simulations were run in each crop scenario in order to obtain baseline values for the endpoints. Then the concentrations of chemicals in the culvert were increased by multiplying the concentration of chemicals in the crop soil by a range of values to create a gradient of increased concentrations of chemicals in the culverts. The values chosen were 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, & 50 times the concentrations in the crop soil. Sixty simulations were run at each value.

The maximum and mean values of NH_c, (Chapter II.5.2), were chosen as endpoints to evaluate lethal exposures to agricultural chemicals including insecticides, herbicides, growth regulators, and defoliants. In order to evaluate lethal and sublethal exposures to OP and CB insecticides, the maximum value and mean value of ChE inhibition that occurred over the winter were also recorded for each simulation. These endpoint values were fitted to linear regression lines with a separate regression performed in each crop scenario for each class of agricultural chemicals, (OP and CB insecticides, insecticides, herbicides, and growth regulators and defoliants, (Appendix A4)). These regression lines were then used to estimate the increase in chemical concentrations in culverts necessary to cause lethal or sublethal effects.

5. Results

5.1 OP and CB Insecticides

The estimated maximum ChE values increased with increasing insecticide concentrations in the culvert soil. However, foraging in a crop where chemicals were actively being sprayed dramatically increased maximum ChE inhibition values. The average maximum ChE inhibition values were increased by 2.56 and 14.92 times the values predicted in the cotton/sorghum only scenarios (FS-1) with the addition of cabbage fields (FS-2) or onion fields (FS-3) respectively (Table 3). The linear regression equations fitted to the simulation data using maximum ChE values were $y = 1.3291x + 12.544$ in FS-1, $y = 1.2253x + 17.619$ in FS-2, and $y = 0.4497x + 65.095$ in FS-3. Although there was an increase in the intercept values between FS-1 and the crop scenarios with active spraying (FS-2 and FS-3), the slopes became less steep in the scenarios with active spraying (Figure 7a-c).

Similar to the average maximum ChE values, the average mean ChE values increased with increasing insecticide concentrations in the culvert soil. However the increase due to foraging in a crop where chemicals were actively being sprayed was less substantial than was observed in the maximum ChE values, and increased by 1.7 and 7.2 times the average value in FS-1 due to foraging in FS-2 and FS-3 respectively (Table 4). The linear regression equations fitted to the simulation data using mean ChE values were $y = 1.3291x + 12.544$ in FS-1, $y = 1.2253x + 17.619$ in FS-2, and $y = 0.4497x + 65.095$ in FS-3. Although there was an increase in the intercept values between FS-1 and the crop scenarios with active spraying, the slopes were similar in all crop scenarios (Figure 8a-c).

An estimated maximum value of 20% ChE inhibition occurs when concentrations of OP or CB insecticides in the culvert soil reach 5.6 and 1.9 times the concentrations of insecticides in the crop soil in FS-1, and FS-2 respectively. An estimated maximum value of 50% ChE inhibition occurs when concentrations of insecticides in the culvert soil reach 28.2 and 26.4 times the concentrations of insecticides in the crop soil in FS-1, and FS-2 respectively. The average maximum ChE inhibition value was greater than 50% prior to increasing concentrations in FS-3 (Figure 7a-c). An estimated mean value of 20% ChE inhibition occurs when concentrations of insecticides in the culvert soil reach 10.2 and 9.1 times the concentrations of insecticides in the crop soil in FS-1, and FS-2 respectively. An estimated maximum value of 50% ChE inhibition occurs when concentrations of insecticides in the culvert soil reach 34.4, 34.3, and 30.1 times the concentrations of insecticides in the crop soil in FS-1, FS-2, and FS-3 respectively. The average mean ChE inhibition value was greater than 20% prior to increasing concentrations in FS-3 (Figure 8a-c).

Table 3. Increases in maximum % ChE inhibition occuring over the winter due to increased insecticide concentrations in culvert soil.

Chemical in Culvert Soil /Chemical in Crop Soil	Scenario 1: Cotton/Sorghum Maximum ChE Inhibition (Mean ± S.D.)	n	Scenario 2: Cotton/Sorghum/Cabbage Maximum ChE Inhibition (Mean ± S.D.)	n	Scenario 3: Cotton/Sorghum/Onions Maximum ChE Inhibition (Mean ± S.D.)	n
1	3.9 ± 3.7	200	10.0 ± 20.0	200	58.2 ± 43.9	200
2	7.6 ± 7.9	60	12.0 ± 18.2	60	67.6 ± 40.1	60
3	14.4 ± 17.7	60	16.0 ± 19.7	60	65.6 ± 38.8	60
4	15.3 ± 22.8	60	20.2 ± 24.6	60	68.6 ± 38.6	60
5	25.5 ± 32.7	60	26.3 ± 35.1	60	75.9 ± 36.1	60
6	25.8 ± 32.8	60	30.8 ± 36.1	60	77.1 ± 36.5	60
7	20.7 ± 32.7	60	33.9 ± 36.1	60	74.4 ± 38.1	60
8	37.4 ± 43.1	60	37.9 ± 41.2	60	70.8 ± 39.0	60
9	38.1 ± 42.4	60	33.9 ± 38.2	60	66.4 ± 40.8	60
10	32.2 ± 40.5	60	42.9 ± 41.7	60	70.9 ± 39.6	60
15	42.9 ± 40.1	60	44.2 ± 40.7	60	72.1 ± 38.0	60
20	38.3 ± 39.4	60	43.4 ± 40.4	60	75.2 ± 37.1	60
50	70.4 ± 36.8	60	70.1 ± 35.9	60	84.5 ± 26.5	60

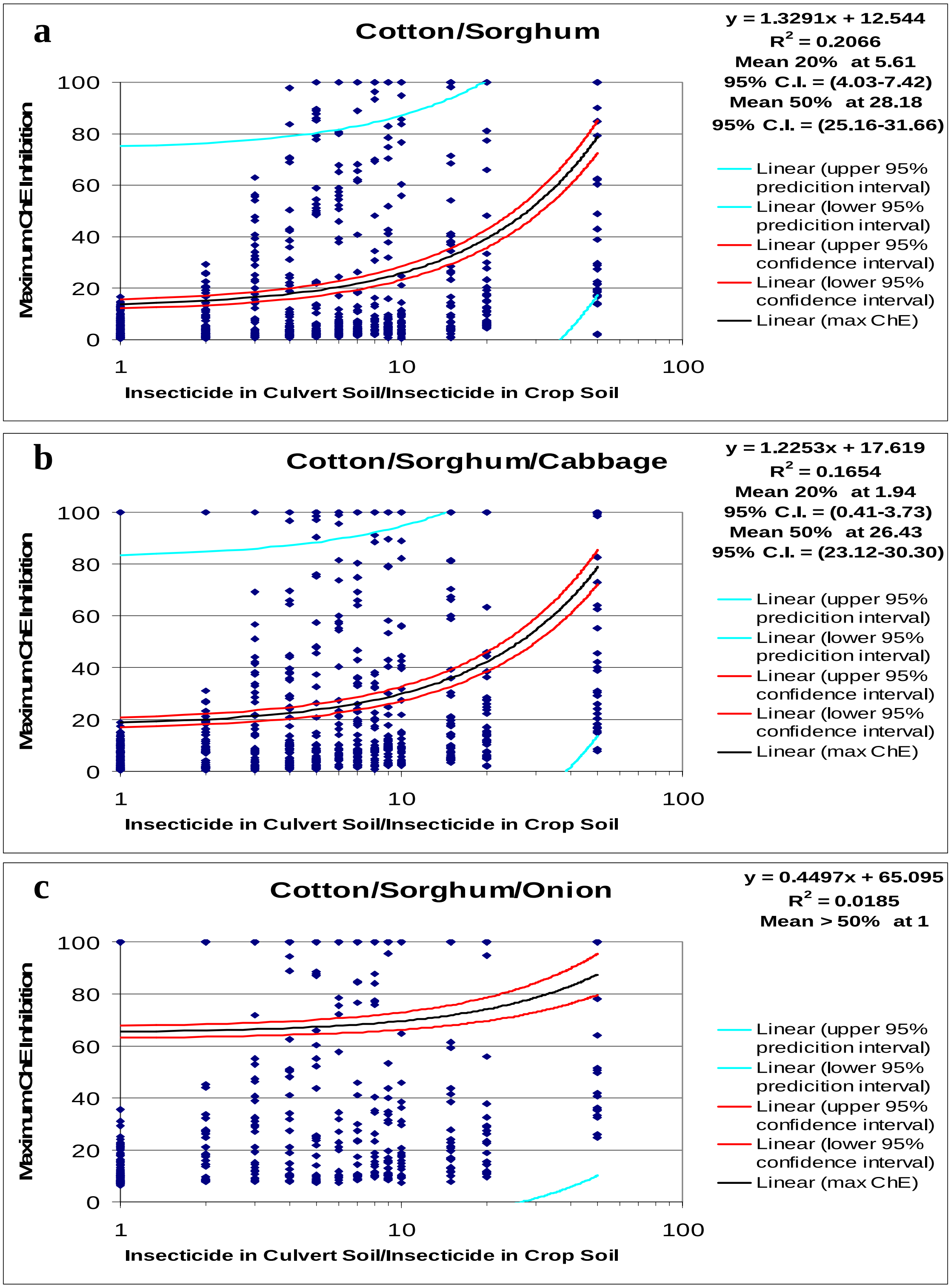

Figure 7 (a-c). Increase in the maximum % ChE inhibition occurring during the winter due to increased insecticide concentrations in culverts by crop scenario.

Table 4. Increases in mean % ChE inhibition occuring over the winter due to increased insecticide concentrations in culvert soil.

Chemical in Culvert Soil /Chemical in Crop Soil	Scenario 1: Cotton/Sorghum Mean ChE Inhibition (Mean ± S.D.)			n	Scenario 2: Cotton/Sorghum/Cabbage Mean ChE Inhibition (Mean ± S.D.)			n	Scenario 3: Cotton/Sorghum/Onions Mean ChE Inhibition (Mean ± S.D.)			n
1	2.3	±	2.3	200	3.9	±	4.2	200	16.5	±	12.1	200
2	4.4	±	4.5	60	5.8	±	6.5	60	21.9	±	12.3	60
3	8.2	±	9.6	60	8.4	±	9.2	60	22.0	±	14.1	60
4	8.6	±	12.1	60	11.8	±	13.8	60	24.2	±	16.7	60
5	14.4	±	17.3	60	15.7	±	21.2	60	30.0	±	20.1	60
6	16.0	±	21.0	60	18.5	±	22.4	60	32.4	±	24.7	60
7	13.4	±	22.0	60	22.5	±	26.7	60	36.9	±	28.2	60
8	26.2	±	31.9	60	26.9	±	32.9	60	35.9	±	29.3	60
9	31.9	±	38.7	60	25.3	±	31.7	60	34.5	±	30.4	60
10	25.6	±	34.8	60	28.7	±	32.5	60	37.6	±	32.8	60
15	37.3	±	40.1	60	36.2	±	38.4	60	44.5	±	36.6	60
20	33.6	±	39.2	60	36.0	±	38.3	60	42.4	±	33.6	60
50	61.6	±	37.9	60	61.0	±	36.9	60	61.3	±	29.3	60

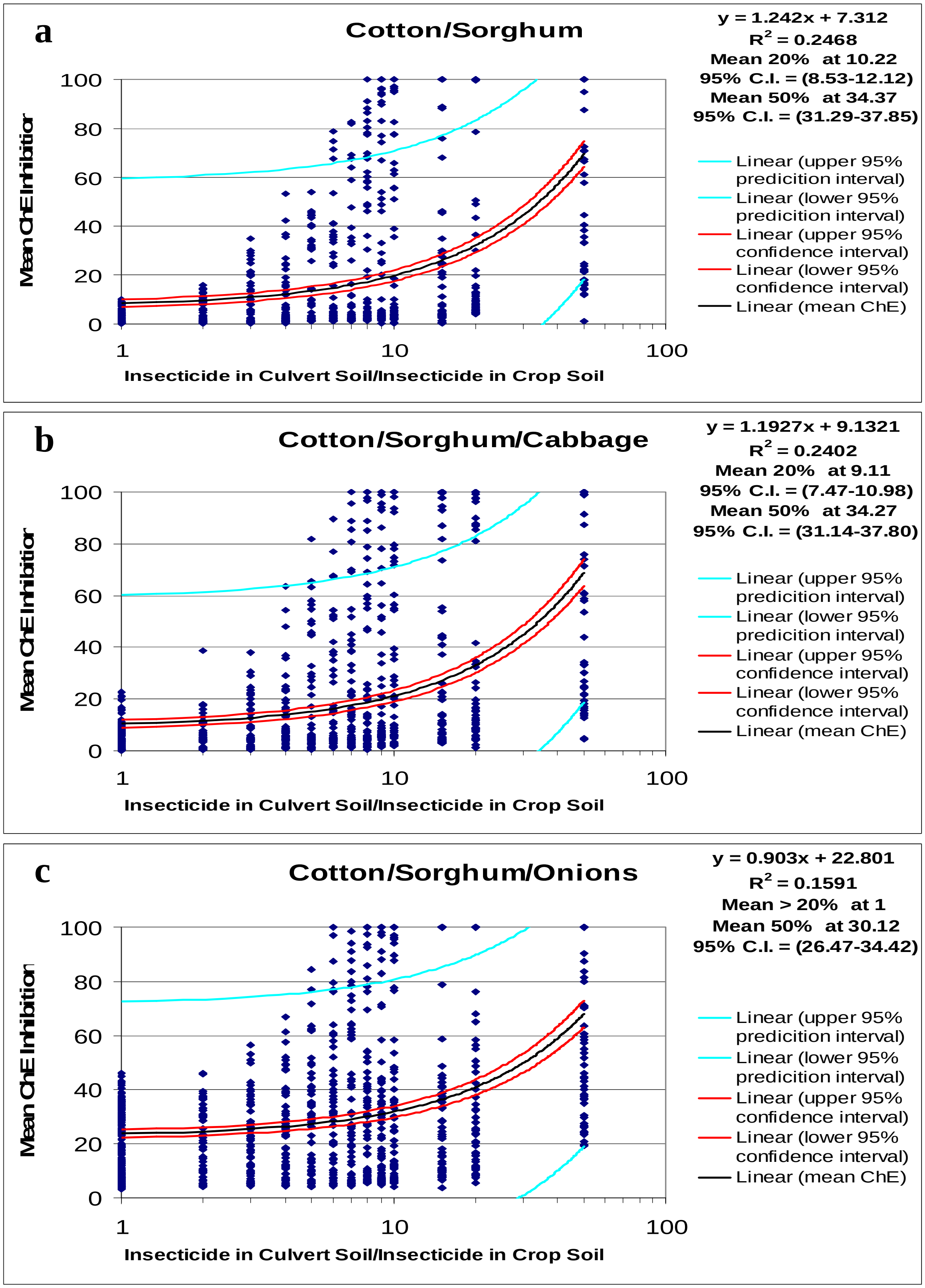

Figure 8 (a-c). Increase in the mean % ChE inhibition occurring during the winter due to increased insecticide concentrations in culverts by crop scenario.

5.2 Insecticides

The estimated maximum value of NH_i increased with increasing insecticide concentrations in the culvert soil. However in all three crop scenarios the estimated maximum and mean value of NH_i did not reach 1 until the concentrations in culverts were increased to around 30 times the concentration in the crop soil (Figure 9a-c, Figure 10a-c). However, in all three crop scenarios several maximum values of NH_i from individual simulations runs were greater than 1 prior to increasing concentrations in the culvert soil (Figure 9a-c). In addition, in all three crop scenarios several mean values of NH_i from individual simulations runs were greater than 1 after doubling concentrations in the culvert soil (Figure 10a-c).

The linear regression equations fitted to the simulation data using the maximum values of NH_i were y = 0.0248x + 0.1529 in FS-1, y = 0.0265x + 0.4548 in FS-2, and y = 0.0243x + 0.3875 in FS-3 (Figure 9a-c). The linear regression equations fitted to the simulation data using the mean values of NH_i were y = 0.0233x + 0.0843 in FS-1, y = 0.0256x + 0.1214 in FS-2, and y = 0.0231x + 0.1204 in FS-3 (Figure10a-c). These regression equations show an increase in the intercept values between the cotton/sorghum crop scenarios and the crop scenarios with active spraying, while the slopes are similar between all scenarios.

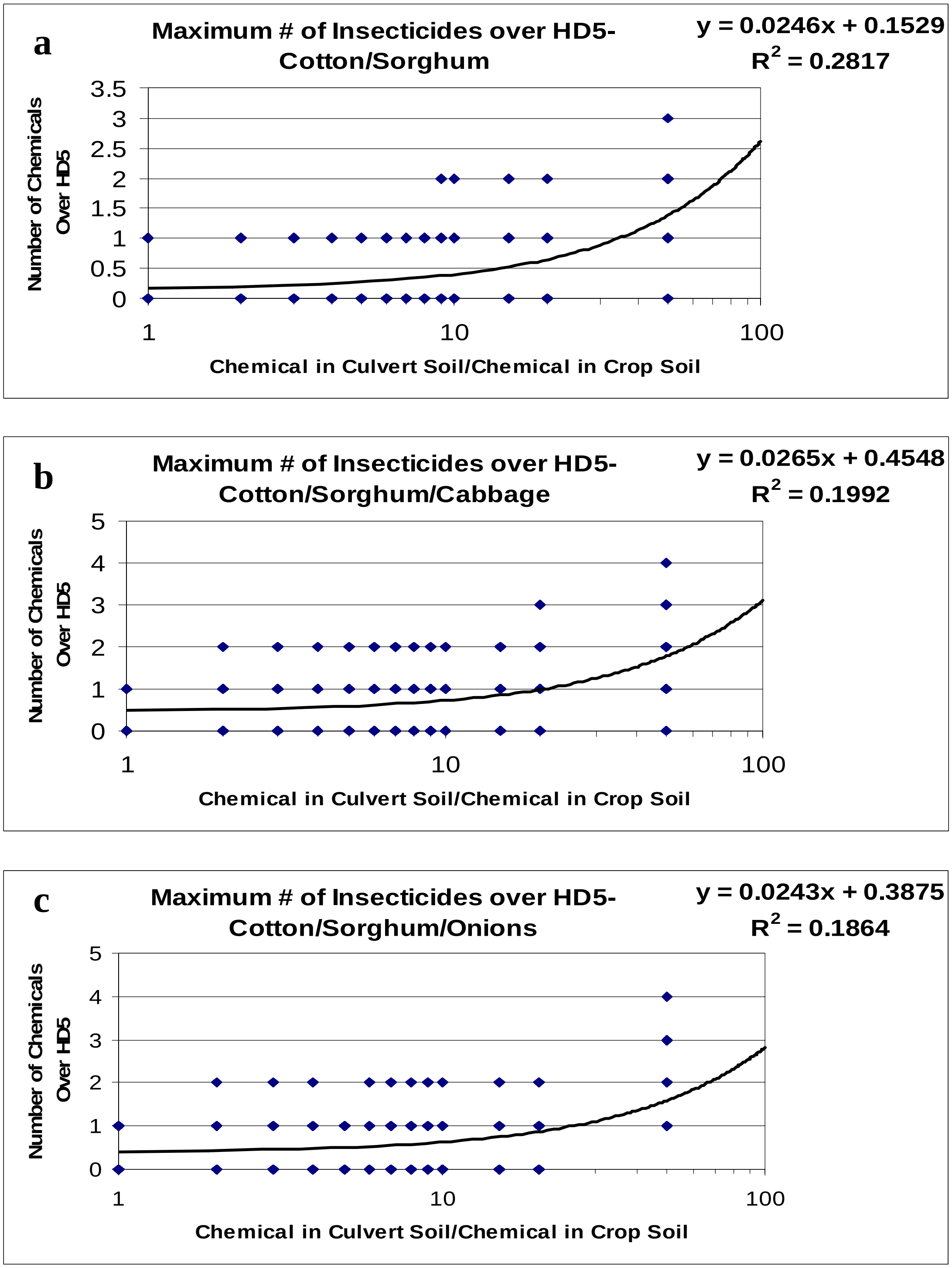

Figure 9 (a-c). Increase in the maximum number of insecticides the owl is exposed to > their HD5 during the winter due to increased insecticide concentrations in culverts by crop scenario.

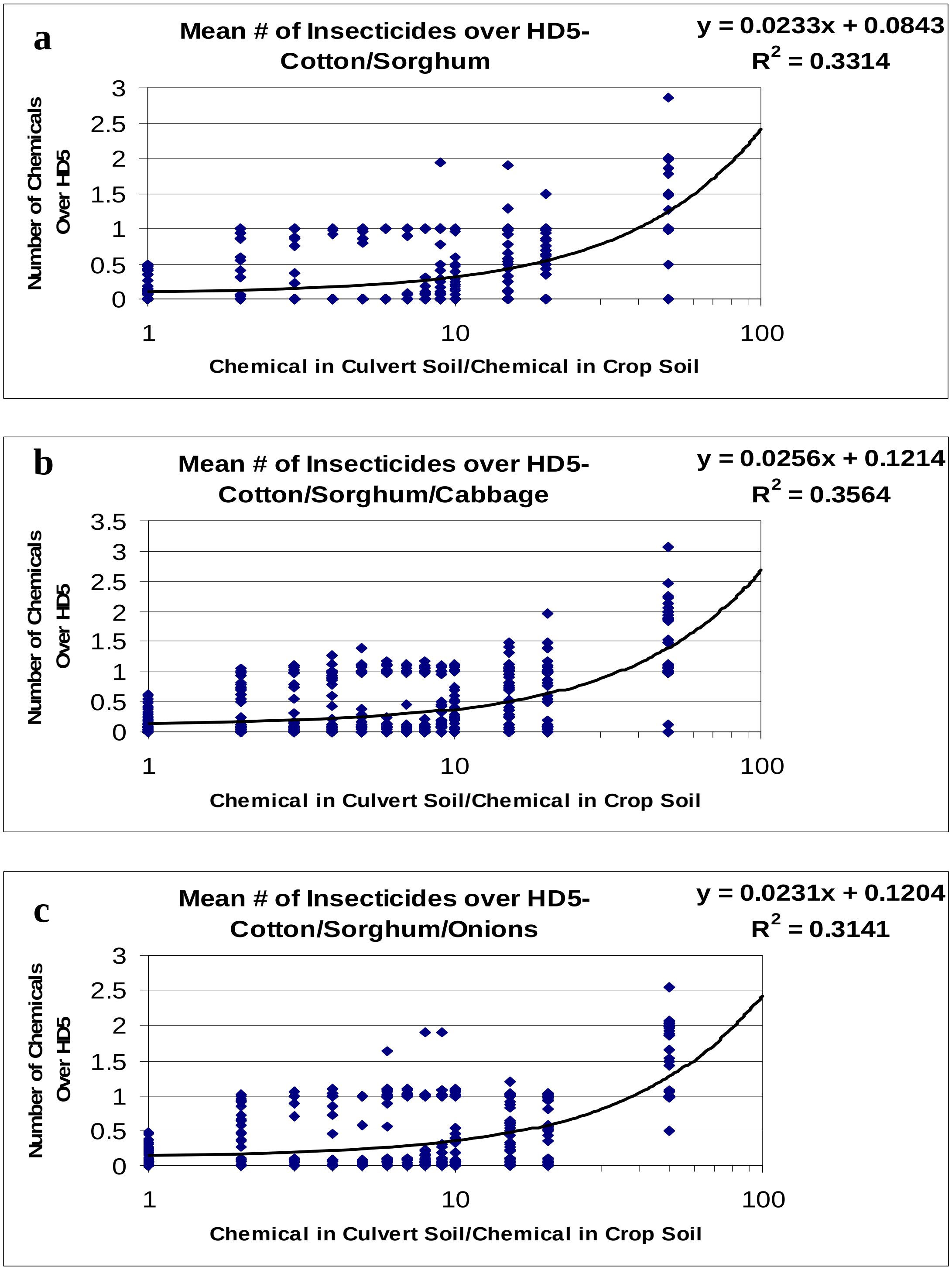

Figure 10 (a-c). Increase in the mean number of insecticides the owl is exposed to > their HD5 during the winter due to increased insecticide concentrations in culverts by crop scenario.

5.3 Herbicides

The estimated maximum value of NH_h increased with increasing herbicide concentrations in the culvert soil. However in all three crop scenarios the estimated maximum value of NH_h 1 until the concentrations in culverts were increased to around 40 times the concentration in the crop soil, and the estimated mean value of NH_h did not reach 1 until the concentrations in culverts were increased to over 100 times the concentration in the crop soil (Figure 11a-c, Figure 12a-c). In all three crop scenarios several maximum values of NH_h from individual simulations runs were greater than 1 after increasing concentrations in the culvert soil to around 7 times the concentration in the crop soil (Figure 11a-c). However, in all three crop scenarios individual mean values of NH_h from individual simulations runs did not reach values greater than 1 until concentrations in the culvert soil were around 20 times the concentration in crop soil (Figure 12a-c).

The linear regression equations fitted to the simulation data using the maximum values of NH_h were y = 0.0234x in FS-1, y = 0.0258x in FS-2, and y = 0.0244x in FS-3 (Figure 11a-c). The linear regression equations fitted to the simulation data using the mean values of NH_h were y = 0.0078x in FS-1, y = 0.0089x in FS-2, and y = 0.0076x in FS-3 (Figure 12a-c). The slopes are similar between all crop scenarios, and the intercept values for all these regression equations were set to 0 because no individual simulation runs were greater than 0 prior to increasing concentrations in the culvert soil.

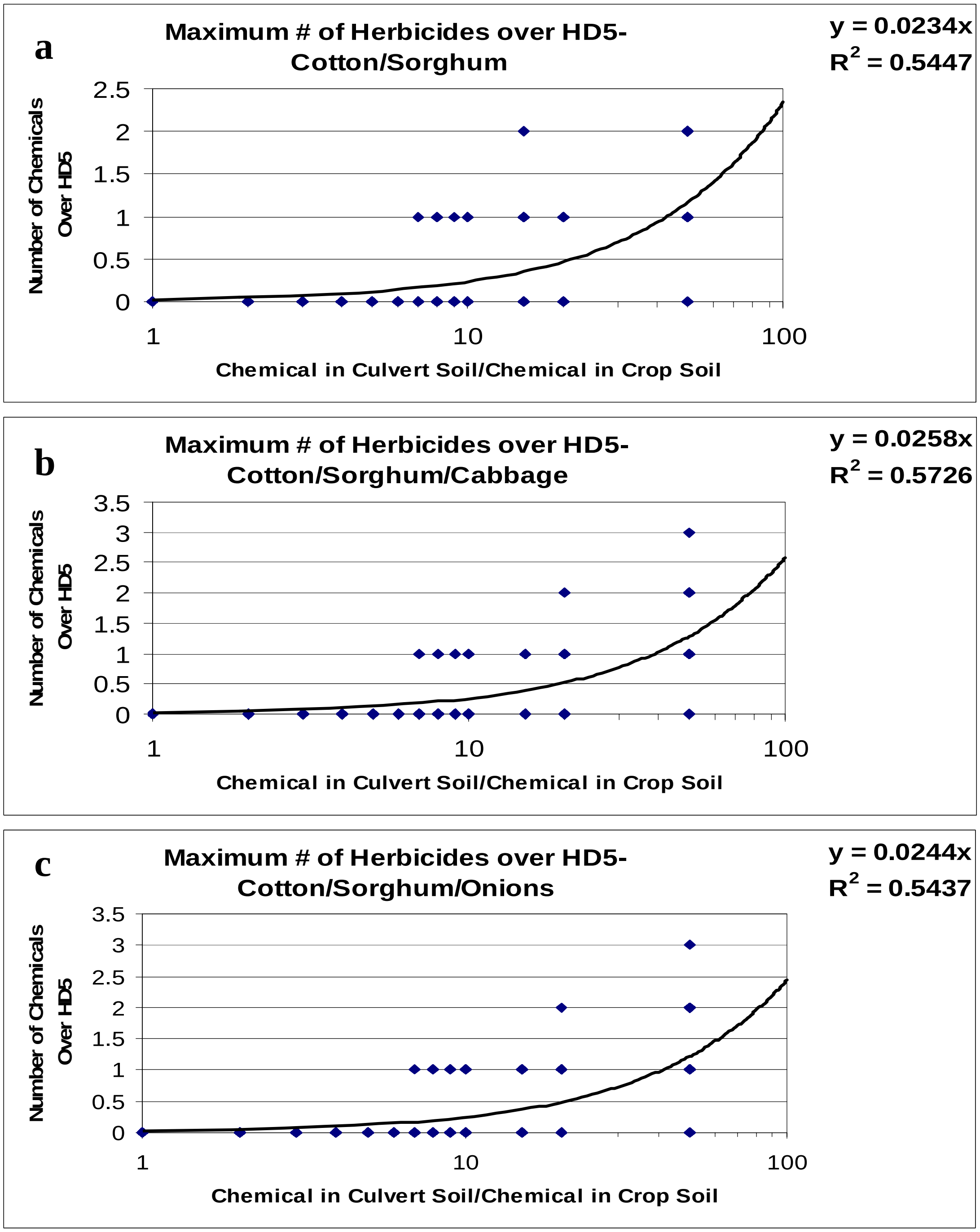

Figure 11 (a-c). Increase in the maximum number of herbicides the owl is exposed to > their HD5 during the winter due to increased herbicide concentrations in culverts by crop scenario.

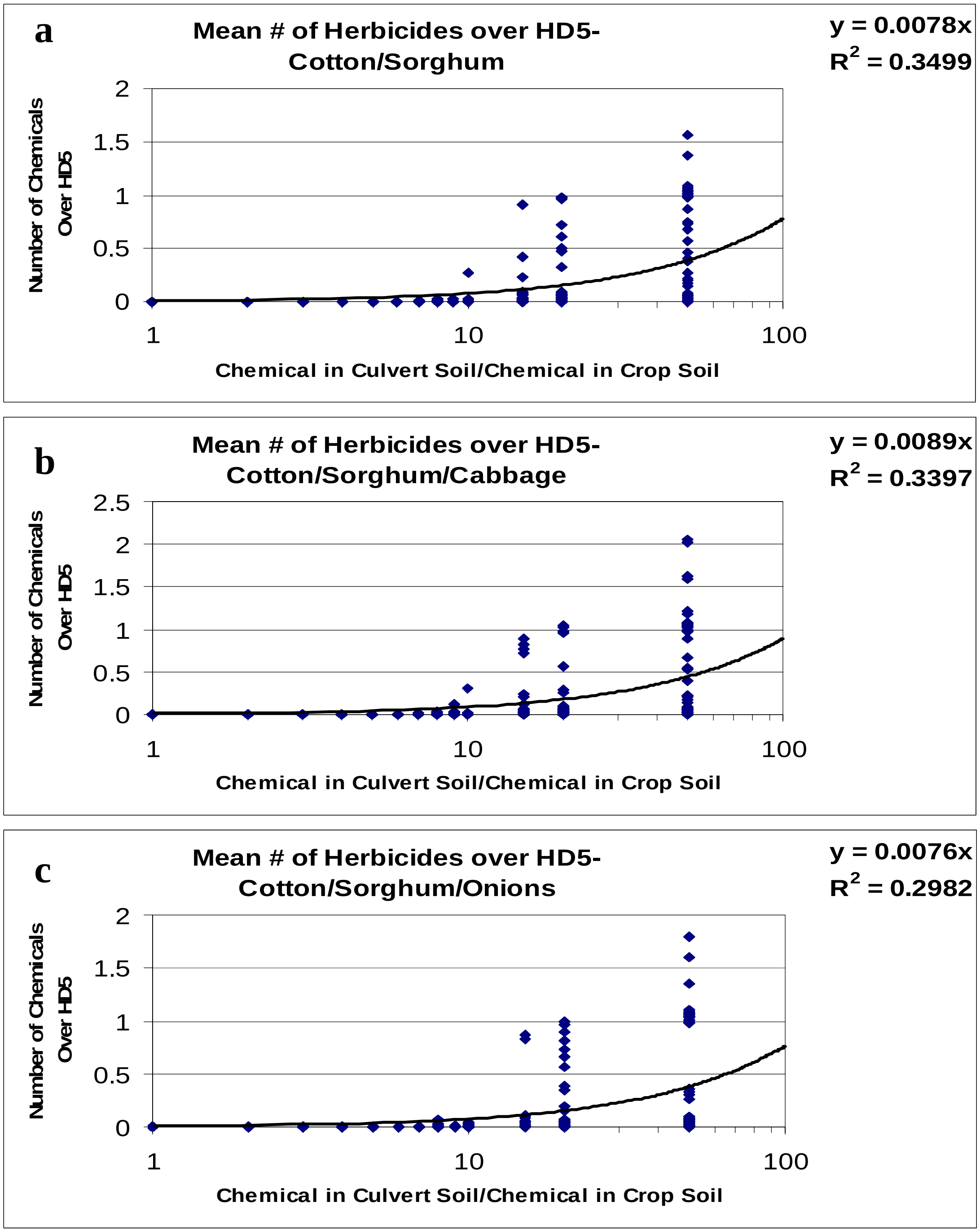

Figure 12 (a-c). Increase in the mean number of herbicides the owl is exposed to > their HD5 during the winter due to increased herbicide concentrations in culverts by crop scenario.

5.4 Growth Regulators and Defoliants

The estimated maximum value of NH_g increased with increasing growth regulators and defoliant concentrations in the culvert soil. However in all three crop scenarios the estimated maximum and mean values of NH_g did not reach 1 until the concentrations in culverts were increased to around 50 times the concentration in the crop soil (Figure 13a-c, Figure 14a-c). In all crop scenarios several maximum and mean values of NH_g from individual simulations runs were greater than 1 after increasing concentrations in the culvert soil to around 3 times the concentration in the crop soil (Figure 13a-c, Figure 14a-c).

The linear regression equations fitted to the simulation data using the maximum values of NH_g were y = 0.0199x in FS-1, y = 0.0194x in FS-2, and y = 0.0198x in FS-3 (Figure 13a-c). The linear regression equations fitted to the simulation data using the mean values of NH_g were y = 0.0182x in FS-1, y = 0.0157x in FS-2, and y = 0.0172x in FS-3 (Figure 14a-c). The slopes are similar between all crop scenarios, and the intercept values for all these regression equations were set to 0 because no individual simulation runs were greater than 0 prior to increasing concentrations in the culvert soil.

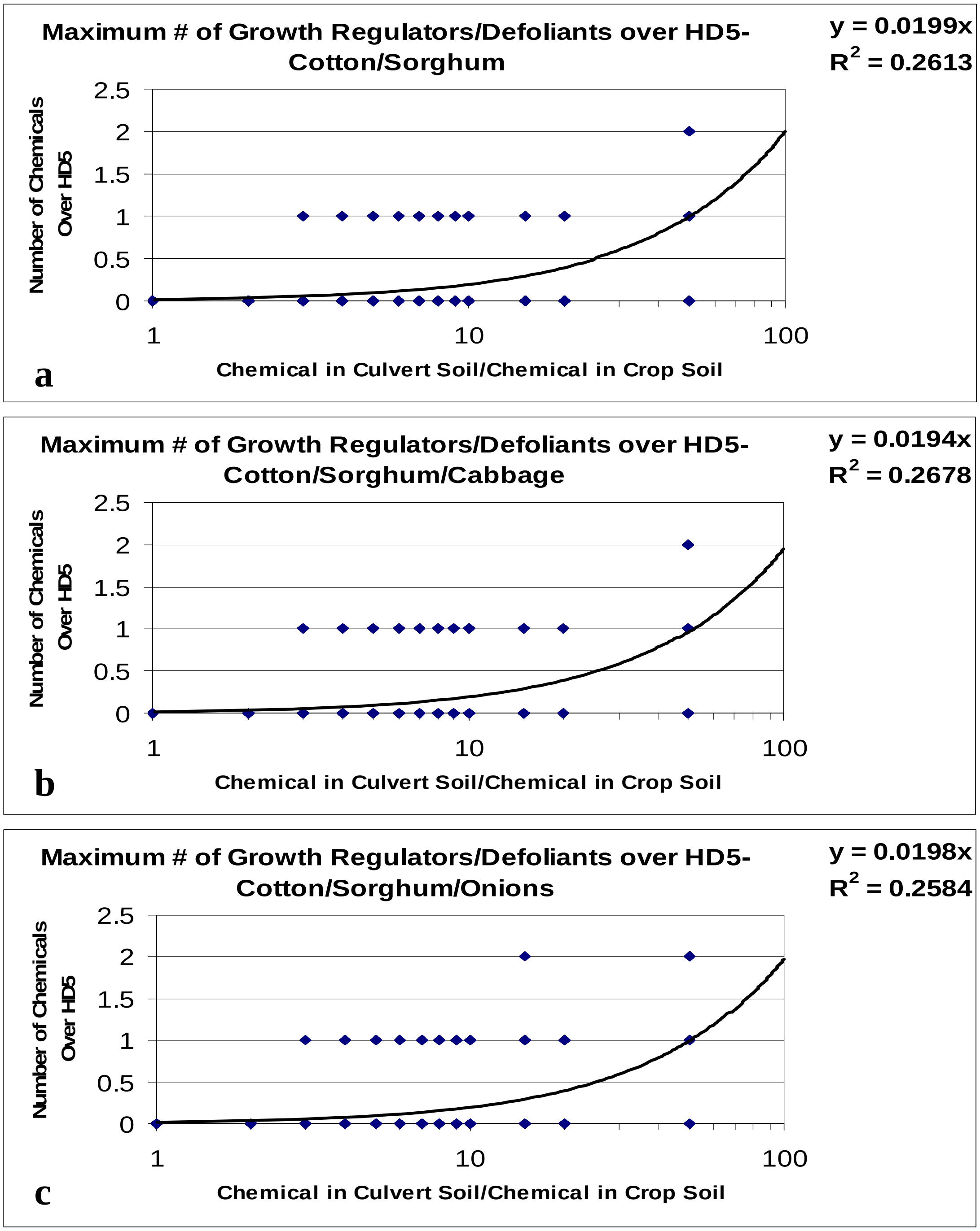

Figure 13 (a-c). Increase in the maximum number of growth regulators and defoliants the owl is exposed to > their HD5 during the winter due to increased growth regulators and defoliant concentrations in culverts by crop scenario.

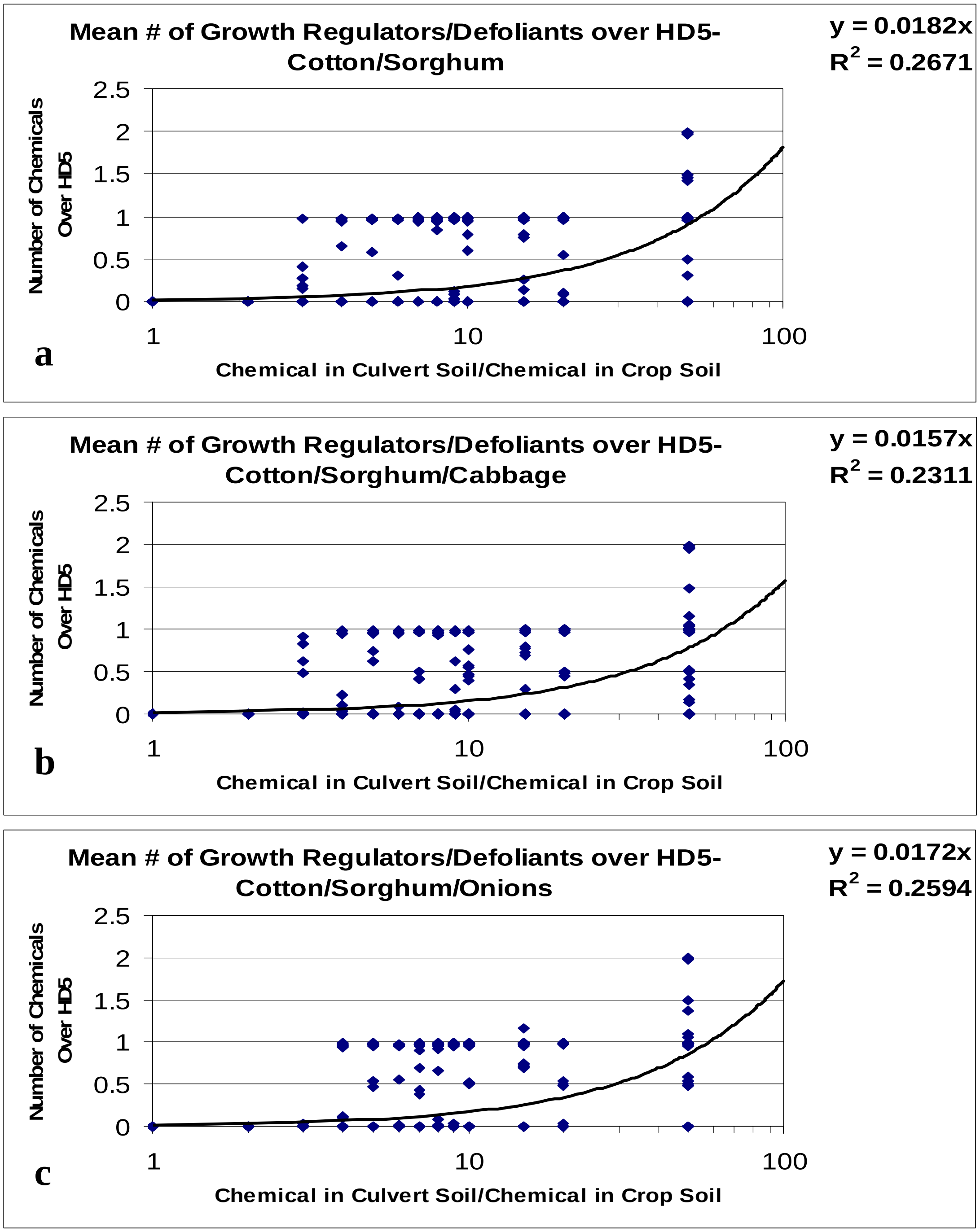

Figure 14 (a-c). Increase in the mean number of growth regulators and defoliants the owl is exposed to > their HD5 during the winter due to increased growth regulators and defoliant concentrations in culverts by crop scenario.

6. Summary/Discussion

The analysis using exposure > HD5 as an endpoint indicates that risks due to increased concentrations in culvert soil vary between chemical classes. Insecticides showed values of exposure greater than an HD5 from individual simulation runs prior to increasing chemical concentrations in culvert soil. Growth regulators and defoliants showed values of exposure greater than an HD5 from individual simulation runs after increasing chemical concentrations in culvert soil to 3-4 times the concentration in the crop soil. Herbicides showed values of exposure greater than an HD5 from individual simulation runs after increasing chemical concentrations in culvert soil to 7 times the concentration in the crop soil. However, for all three chemical classes the increase in chemical concentrations in the culvert soil relative to the crop soil required for the predicted maximum value averaged from all simulation runs to be greater than the HD5 was fairly large. Attaining a predicted average maximum value greater than an HD5 required an increase of 30 times for insecticides, an increase of 40 times for herbicides, and an increase of 50 times for growth regulators and defoliants. These results suggest that among the chemical classes evaluated, insecticides are the chemical class to which a burrowing owl is most likely to be exposed to an amount greater than the HD5. However the increases in chemical concentrations in the culvert soil required to cause the predicted average maximum exposure to be greater than an HD5 were quite large, and ranged from 30-100 times the concentration in the crop soil.

ChE inhibition used as an endpoint the model seemed very sensitive to increasing concentrations of OP and CB insecticides in the culvert soil. ChE inhibition increased greatly when owls foraged in cabbage or onion fields, however only a very small percentage of burrowing owls wintering in south Texas had roost sites adjacent to fields where crops were grown during the winter (Chapter II.2). Although ChE inhibition increased most dramatically due to active spraying, an increase of only 5.61 times the amount in the crop soil caused the predicted average maximum ChE inhibition to reach 20% in FS-1 (Figure 7a-c). In addition, maximum ChE inhibition in individual simulation runs began to reach values greater than 20% at an increase of only 2 times the amount in the crop soil (Figure 7a). However, it took an increase of 28.18 times the concentration in the crop soil to cause the average maximum inhibition to reach 50%, while several individual simulation runs began to show ChE inhibition values greater than 50% at just 3 times the amount in the crop soil in FS-1 (Figure 7a).

Although to my knowledge no one has tested pesticide concentration in the surface soil of culverts, spatial variability in concentrations of pesticide residues has been shown to vary by 1.6 to up to 25 times the mean value in several field studies (Harris, 2000; Cobb et al., 2000; Kendall et al., 1992; Kendall et al., 1993). The maximum concentration of residues in earthworms from an orchard treated with diazinon 12-15 days earlier varied from 2.1 -3.7 times the mean values for an orchard with individual values ranging as much as 115 times the minimum value detected (Cobb et al., 2000). The maximum concentration of residues in grass samples of diazinon applied to a golf course 7 days earlier varied by 1.6 times the mean, with individual values ranging up to 3.5 times the minimum value detected (Kendall et al., 1992). Kendall et al. (1993) found increased diazinon concentrations in puddles relative to other water bodies on the treated golf course. An analysis of organophosphate residues in carrots showed that individual roots could vary by up to 25 times the mean or composite residue concentration (Harris, 2000).

A comparison of the spatial variability in pesticide residues discussed above, with the increased concentrations in culverts necessary to result in exposure greater than an HD5, indicates that while it is unlikely for burrowing owls wintering in cotton fields to be consistently experiencing lethal effects due to increased concentrations of OP and CB insecticides or other agricultural chemicals in culverts, it is likely that owls may experience sublethal effects due to dermal exposure to OP and CB insecticides if these insecticides accumulate in culverts.

Sublethal doses of OP and CB insecticides can decrease avian fitness by affecting their behavior and normal physiological functions. Birds exposed to ChE inhibitors may experience lethargy, gastrointestinal distress, impaired vision, impaired learning and memory function, and alterations in endogenous rhythms, all of which may decrease their ability to forage effectively (Grue et al., 1997). In addition, insecticide application can reduce the prey base, and decrease the amount of food available for consumption (Hill, 2003). OP and CB insecticides can affect reproduction through alteration of the levels of reproductive hormones, impairment of male gametogenic function, and through reduction of food consumption. This can lead to alterations in sexual behavior, testicular injury, reductions in egg laying, reductions in parental care, and reductions in nest success (Stromborg, 1977; Stromborg, 1986; Rattner et al., 1986; Rattner et al., 1982; Maitra and Sarkar, 1996; Grue et al., 1997). In addition, OP and CB intoxication may affect the hippocampal complex, leading to impaired spatial reference memory, including migratory orientation and memory of the migratory route (Grue et al., 1997; Vyas et al., 1995; Vyas et al., 1996).

Several potential issues were not evaluated by the model, but may increase the results demonstrated in the model. The first is that sublethal effects of chemicals other than OP and CB insecticides were not evaluated, and may still be of concern. For example, chronic low-level exposure to broiler chicks to the organochlorine insecticide endosulfan and the pyrethroid fenvalerate, in addition to the OP insecticide monocrotophos, all resulted in impaired metabolism and immune systems (Garg et al., 2004). The second is that burrowing owls cache food inside culverts (Moulton et al., 2006). Although it was not evaluated in this analysis, if chemical concentrations are increased in the soil in culverts, ingestion of culvert soil due to cached food may be another source of increased exposure in burrowing owls roosting in agricultural areas burrowing. The third issue is that dermal exposure may result in a longer duration of effects than was estimated by the model which assumed the duration of effects due to dermal exposure was similar to values observed in ingestion exposure. However, Henderson et al. (1994) showed that pigeons did not recover from dermal exposure to OP insecticides for up to 6 weeks after dosing, while recovery from an oral dose took approximately 5 days.

Robertson and Hutto (2006) set three criteria to define an ecological trap, “1) individuals should have exhibited a preference for one habitat over another (in a severe trap), or an equal preference for both habitats (in an equal-preference trap); 2) a reasonable surrogate measure of individual fitness should have differed among habitats; and 3) the fitness outcome for individuals settling in the preferred habitat or equally preferred habitat…..must have been lower than the fitness attained in other available habitats." Based on these criteria it will be necessary to determine 1) if burrowing owls in South Texas show an increased or equal preference for agricultural culverts over natural burrows, and 2) if fitness in burrowing owls using agricultural culverts is decreased in comparison to burrowing owls using natural burrows; in order to demonstrate if culverts in cotton or sorghum fields in South Texas represent ecological traps for burrowing owls.

It is clear that the primary habitat used by burrowing owls in South Texas is agricultural culverts (Woodin et al., 2006; Chapter II.2). However, it has not been demonstrated whether burrowing owls actually prefer agricultural culverts over natural burrows, or if the use of agricultural culverts simply reflects a lack of availability of natural burrows in South Texas. If a lack of availability of natural burrows in South Texas drives the apparent preference for agricultural culverts, the scenario may actually reflect a blatant disturbance; which was defined by Schlaepfer et al. (2002) as "an anthropogenic alteration in the environment that results in decreased fitness of an organism independent of its behavior"; rather than an ecological trap.

Conway et al. (2006) suggested that burrowing owls in agricultural areas of Washington represented a population sink compared to burrowing owls in non-agricultural areas. Unfortunately, a similar analysis of fitness between agricultural and non-agricultural areas has not been conducted in South Texas. Mortality rates of wintering burrowing owls in South Texas and Mexico were estimated at 17.4%-30.0% over 107 days (Holroyd, pers. comm., 2006). However, these winter mortality rates have not been examined comparatively between agricultural and non-agricultural areas. The return rates of juvenile owls are one of the demographic factors with the greatest impact on the decline of Canadian burrowing owl populations (Wellicome et al., 2006). Juvenile birds spending their first winter in South Texas may be more susceptible to effects of pesticide exposure because age-dependent increases in effects of pesticide exposure have been observed in birds (Wolfe and Kendall, 1998; Gard and Hooper, 1993; Bennett and Bennett, 1991). The results of this modeling analysis suggest that if OP or CB insecticides accumulate in culverts, then sublethal effects have the potential to occur. Sublethal effects could subsequently lead to a decrease in the fitness of burrowing owls roosting in agricultural culverts in South Texas.

If the use of agricultural culverts results in decreased fitness in burrowing owls, the distinction between whether it represents an ecological trap or blatant disturbance may become more important, as the effects of ecological traps are more easily corrected through conservation actions than blatant disturbances (Schlaepfer et al., 2002). If fitness is decreased in burrowing owls using agricultural culverts possible conservation actions may include attempting to decrease the attractiveness of agricultural culverts, or the provision of culverts or other artificial burrows in non-agricultural areas. However, if fitness is confidently increased in burrowing owls using agricultural culverts then the provision or restoration of existing culverts used to attract owls to agricultural or grassland areas may be an invaluable tool in the management of burrowing owl populations.

The recognition and description of ecological traps is important in developing a better understanding of the mechanisms leading to ecological traps, and in recognizing factors leading to a maladaptive preference. Descriptions of ecological traps can help in their future identification, correction, and prevention in order to conserve wildlife (Robertson and Hutto, 2006). For this reason it is suggested that the possibility of culverts in agricultural fields in South Texas acting as ecological traps for burrowing owls be further investigated by 1) analyzing the soil in culverts used as roost sites for OP and CB residues to help determine the amount of dermal exposure occurring through this exposure route, 2) determining if the apparent preference for agricultural culverts represents an actual preference or is a response to a lack of suitable habitat, and 3) compare fitness between burrowing owls in agricultural and non-agricultural areas in South Texas.

CHAPTER IV

SIMULATING THE EFFECTS OF AGRICULTURAL CHEMICAL EXPOSURE ON BURROWING OWLS WINTERING IN SOUTH TEXAS COTTON FIELDS: A LOOK AT INDIVIDUAL CHEMICALS

1. Introduction

The western burrowing owl, *Athene cunicularia hypugaea*, was listed as a Federal Species of Conservation Concern in 2002 due to declining populations (USFWS, 2002). While the primary reason cited for this decline is habitat loss, insecticide use has been strongly implicated as another possible cause of declines in burrowing owl populations (Blus, 1996; Sheffield, 1997; Klute et al., 2003). The majority of studies of the effects of contaminants on burrowing owls have focused on OC insecticides and their residues, and there are few published studies on how current agricultural chemical use affects burrowing owl populations (Klute et al., 2003). Sublethal effects of contaminant exposure observed in burrowing owls include decreased reproductive success, weight reductions, and egg shell thinning (James, 1987; James et al., 1990; Gervais et al., 2000; Gervais and Anthony, 2003).

James (1987) correlated decreased reproductive success in burrowing owls with the use of carbamate insecticides in Canada. James et al. (1990) showed that while the use of strychnine grain had no effect on mortality and reproductive success of burrowing owls in the short-term, adults had a significantly lower body weight than adults in control fields suggesting sublethal effects. In the U.S. the disappearance of burrowing owls from historic habitats has been linked to the extirpation of burrowing mammals, which often occurred through the use of rodenticides (Sheffield, 1997). Gervais et al., (2000) and Gervais and Anthony (2003) documented egg shell thinning, and decreased reproductive productivity in burrowing owls due to exposure to p,p'-DDE combined with reduced rodent biomass in the diet.

Several contaminant studies on burrowing owls in the United States have detected exposure to the contaminants chlorpyrifos, selenium, hexachlorobenzene, arochlor 1260, PCBs, and p,p'-DDE (a metabolite of DDT) in burrowing owls. Even though use of DDT was discontinued in the US in the 1970's, these studies have detected p,p'-DDE in the majority of their samples (Gervais et al., 2000; Gervais and Anthony, 2003; Gervais and Catlin, 2004).

In south Texas burrowing owls primarily roost in culverts in cotton or sorghum fields. Cotton was recently identified as one of two crops responsible for the greatest amount of potential bird mortality in the United States (Mineau and Whiteside, 2006). Although use of insecticides on agricultural fields is widespread; cotton is well known for intensive historical and current agricultural chemical use (Kannan et al, 2003). Concentrations of contaminants historically used for cotton agriculture such as DDE and its metabolites, toxaphene, and arsenic can be elevated in areas used for cotton production (Bednar et al., 2002; Kannan et al., 2003).

In 2005 a reported 8,677,000 lbs of herbicides, 3,075,000 lbs of growth regulators and defoliants, and 5,946,000 lbs of insecticides were applied to cotton crops in Texas (NASS, 2006). Over 60% of the herbicides and defoliants typically used in agriculture are potential endocrine or reproductive system disruptors (Colborn and Short, 1999). However, the most toxic class of these agricultural chemicals is the organophosphate (OP) and carbamate (CB) insecticides. OP and CB insecticides prevent normal physiological functions of organisms by acting as cholinesterase (ChE) inhibitors, and have been directly responsible for numerous cases of mortality in raptors (Mineau et al., 1999). Exposure to OP and CB insecticides, as well as other agricultural chemicals, can occur through ingestion of contaminated prey, water, vegetation, seeds, or soil, as well as through direct contact with the pesticide during application, or through contact with contaminated soil or water (Hill, 2003).

The use of agricultural fields as foraging areas along with the use of agricultural culverts as roost sites by burrowing owls may increase their risk of exposure to insecticides and other agricultural chemicals, either through ingestion of contaminated prey, or through dermal exposure to agricultural runoff. This analysis examines the comparative risks of different agricultural chemicals currently used on cotton or sorghum fields to burrowing owls in South Texas.

2. Study Area

Refer to Chapter II.2.

3. Model Overview

3.1 Conceptual Model

The model simulates foraging and roosting behavior of an individual burrowing owl in crops that have received treatments with agricultural chemicals, resulting in estimates of dermal and oral exposure that can be used to predict risk of lethal or sublethal effects. The model consists of four submodels representing (1) behavior of burrowing owls, (2) chemical applications to crops, (3) chemical transfer and fate in the crop soil and prey items, and (4) chemical exposure in the burrowing owl.

Details of the cultivation of four different crops; cotton, sorghum, cabbage, and onions, are used to simulate three different foraging crop scenarios (FS 1-3). In all three scenarios a cotton\sorghum field is designated as a roost site. In this model the burrowing owl forages during the night in the fields surrounding its roost site, and is located at the culvert used as its roost site during the day. The primary crop scenario (FS-1), has two cotton/sorghum fields as foraging sites adjacent to the roost site. Each cotton/sorghum field alternates annually between cotton or sorghum crops grown during the summer, and the two foraging fields are offset so that there is always one cotton field and one sorghum field. The two additional crop scenarios include either a cabbage field (FS-2) or an onion field (FS-3) as a foraging site in addition to the cotton/sorghum fields.

The burrowing owl is only present in the model during the winter period, (Oct 1-Mar 1), when the post-harvest cotton/sorghum fields are wide expanses of bare soil, yet onions and cabbage are actively cultivated (Appendix A2). The primary crop scenario (FS-1), simulates chronic exposure to agricultural chemicals, while FS-2 and FS-3 add potential acute exposure scenarios.

Within these fields pesticides are applied to the crops. Once a pesticide is applied it is transferred to the soil, the owl, and its prey. The owl accumulates pesticides through dermal and ingestion pathways. ChE inhibition is calculated from the amount of insecticide accumulated with a dose-response equation. ChE inhibition, exposure > LOEL, and exposure > HD5 are used as endpoints (Figure 3).

For a more complete model description please refer to Chapter II.4.

4. Methods

An equal number of simulations were run with either cotton or sorghum grown in the roost sites field in the summer prior to the arrival of the wintering burrowing owl, and an equal number of simulations were run for each crop scenario.

Two hundred simulations were run in each crop scenario and results for each individual chemical for each endpoint were saved. Because herbicides and growth regulators did not cause exposure greater than a HD5 prior to increasing their concentrations in culvert soil by 3-7 times (Chapter III), the concentrations of agricultural chemicals in the culvert soil was set to 10 times the concentrations of agricultural chemicals in the crop soil, and a separate set of 200 simulations in each crop scenario were run in order to show which chemicals were increased to levels above their HD5 when concentrations in the culvert soil were increased.

In order to evaluate lethal or sublethal exposures to agricultural chemicals including insecticides, herbicides, growth regulators, and defoliants, the model records the occurrence of exposures to a chemical greater than the HD5 or LOEL (H_c or L_c) for that chemical. H_c and L_c represent the concentration of a chemical in the owl (CO)/HD5, or CO/LOEL respectively, while c represents the individual chemicals and can be replaced by i, h, g, or f, to represent individual insecticides, herbicides, growth regulators and defoliants, or fungicides. H_c and L_c are recorded at each time step. The maximum value of H_c and L_c that occurred throughout the winter, as well as the duration of exposure greater than the HD5 or LOEL throughout the winter were recorded for each chemical in each simulation run.

In order to evaluate lethal and sublethal exposures to OP and CB insecticides, the maximum value and mean value of ChE inhibition that occurred over the winter were also recorded for each simulation, as well as the duration of any ChE inhibition, and the duration of ChE inhibition greater than 20%.

A comparison of these endpoints was then used to determine which agricultural chemicals currently in use are most likely to cause lethal or sublethal effects in burrowing owls wintering in South Texas cotton fields.

5. Results

5.1 OP and CB Insecticides

The greatest amount of both average maximum and average mean ChE inhibition was caused by the carbamate insecticide methomyl in FS-3 (maximum = 57.23%, mean = 14.41%), followed by methomyl in FS-2 (maximum = 7.19%, mean = 2.05%). In FS-1 which does not have active spraying during the winter, the highest amount of average maximum and average mean ChE inhibition were due to chlorpyrifos (maximum = 1.83%, mean = 1.08%), followed by dicrotophos (maximum = 1.80%, mean = 0.98%), and oxamyl (maximum = 0.34%, mean = 0.18%) (Figure 15, Figure 16). The only insecticide exposure which caused ChE inhibition levels greater than 20% was methomyl in FS-3 and FS-2 (Figure 17). There were low levels of ChE inhibition attributed to nearly all of the chemicals evaluated. Average duration of exposure to the insecticides chlorpyrifos and malathion occurred throughout the entire wintering period (~ 150 days) in all crop scenarios, and exposure to methomyl occurred throughout the entire wintering period in FS-3. The next longest average durations of exposure were to acephate (75-98 days), dicrotophos (71-96 days), and oxamyl (61-75 days) (Figure 18). The average maximum and mean ChE inhibition values as well as duration of exposure values are listed in Appendix C1a-c.

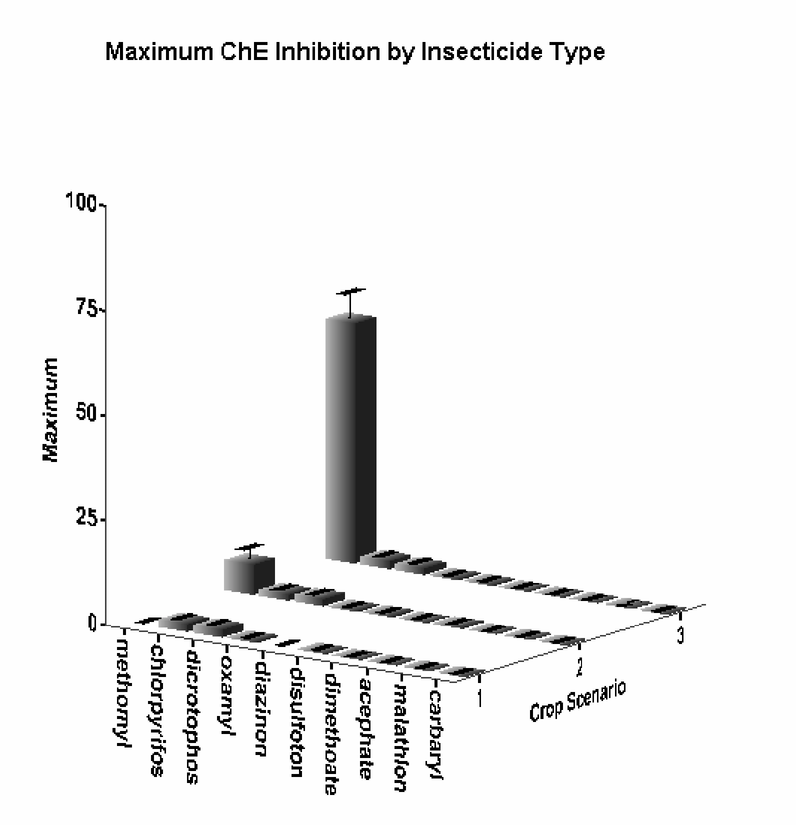

Figure 15. Maximum amount of ChE inhibition caused by each insecticide type. (Crop scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabbage, 3-Cotton/Sorghum/Onions) (Appendix C1a-c)

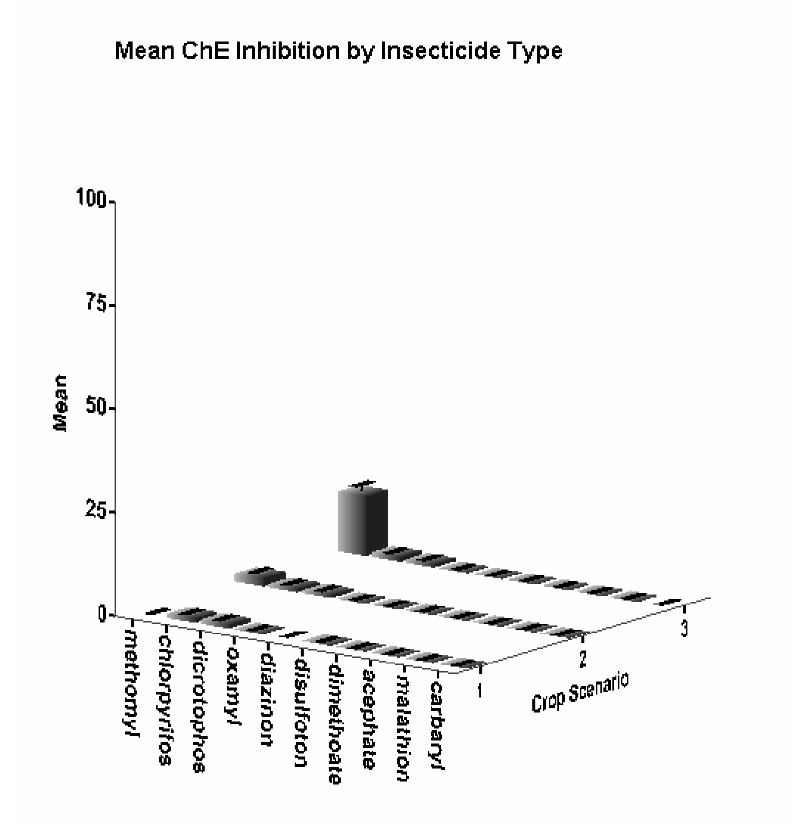

Figure 16. Mean amount of ChE inhibition caused by each insecticide type. (Crop scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabbage, 3-Cotton/Sorghum/Onions) (Appendix C1a-c)

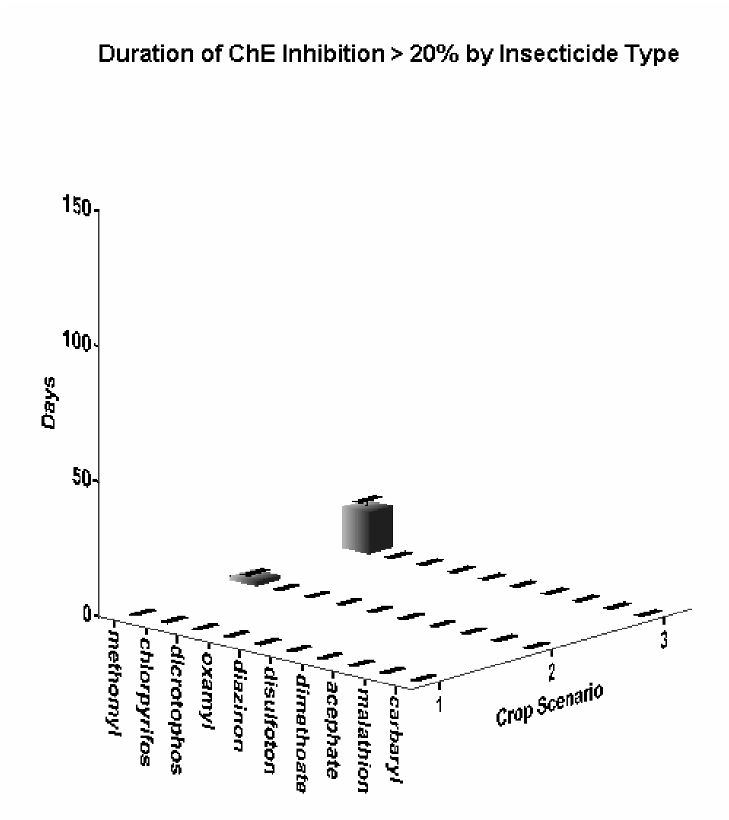

Figure 17. Duration of ChE inhibition > 20% caused by each insecticide type. (Crop scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabbage, 3-Cotton/Sorghum/Onions) (Appendix C1a-c)

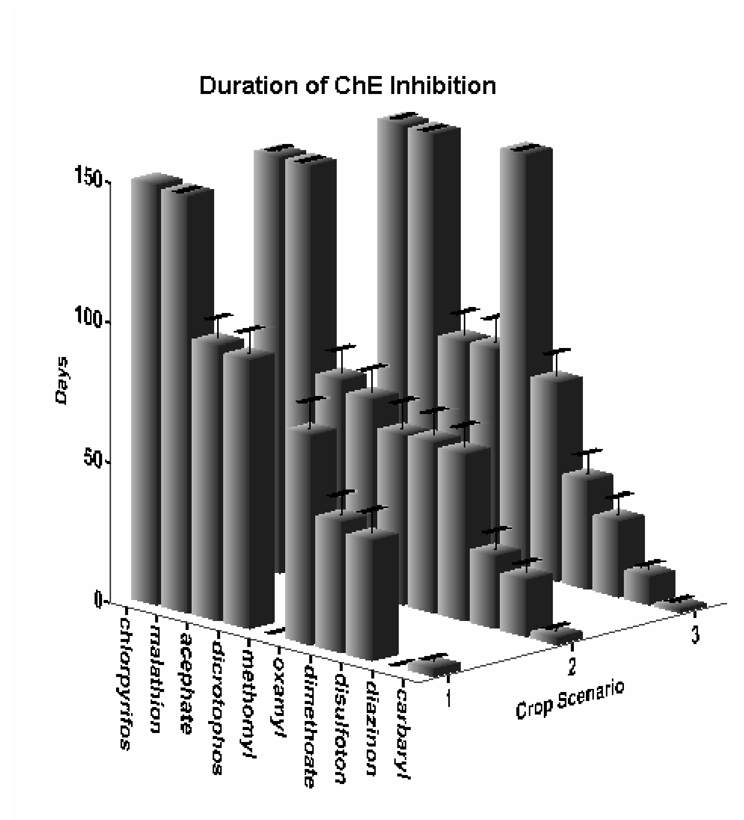

Figure 18. Duration of ChE inhibition caused by each insecticide type. (Crop scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabbage, 3-Cotton/Sorghum/Onions) (Appendix C1a-c)

5.2 Insecticides

5.2.1 LOELs

The insecticides with an average maximum value of $L_i > 0$ were chlorpyrifos (L_i = 10.98-13.66), endosulfan (L_i = 0.00-4.81), lambda-cyhaltothrin (L_i = 1.01-1.35), disulfoton (L_i = 0.22-0.35), cypermethrin (L_i = 0.04-0.10), dimethoate (L_i = 0.00-0.15), indoxacarb (L_i = 0.01-0.02), and esfenvalerate (L_i = 0.00-0.01). While exposure to chlorpyrifos, lambda-cyhalothrin, disulfoton, cypermethrin, and indoxacarb greater than their respective LOELs occurred in all three crop scenarios, exposure to endosulfan, dimethoate, and esfenvalerate greater than their LOELs only occurred in FS-2 (Figure 19, Figure 20). Of these insecticides chlorpyrifos (141-146 days) had the longest average duration of exposure to a concentration greater than its LOEL, followed by lambda-cyhalothrin (56-65 days), disulfoton (7-10 days), endosulfan (7 days), cypermethrin (2-4 days), indoxacarb (0-1 days), esfenvalerate (0.1 days), and dimethoate (0.04 days) (Figure 21). The average maximum exposure values are shown in Appendix C2a-c.

5.2.2 HD5s

When the ratio of concentrations of insecticides in culvert soil to concentrations of insecticides in the crop soil was set to 1 (equal concentrations), the insecticide chlorpyrifos (average maximum H_i = 0.14) was the only insecticide to which the owl was exposed to a concentration greater than its HD5 in FS-1. In FS-2, the owl was exposed to the insecticides chlorpyrifos (average maximum H_i = 0.14), diazinon (average maximum H_i = 1.81), and endosulfan (average maximum H_i = 0.09) at concentrations greater than their HD5s. In FS-3, the owl was exposed to the insecticides chlorpyrifos (average maximum H_i = 0.12), and diazinon (average maximum H_i = 1.50) at concentrations greater than their HD5s (Figure 22, Figure 23). Of these insecticides diazinon (2.1-4.4 days) had the longest duration of exposure greater than its HD5, followed by chlorpyrifos (3.2-3.5 days), and disulfoton (1.3 days) (Figure 24).

When the ratio of concentrations of insecticides in culvert soil to concentrations of insecticides in the crop soil was set to 10, the owl was also exposed to the insecticides disulfoton (average maximum H_i = 0.11-0.18), dicrotophos (average maximum H_i = 0.05-0.08), and indoxacarb (average maximum H_i = 0.03); in addition to chlorpyrifos (average maximum H_i = 2.26-2.69), at a concentration greater than their HD5s, in all three crop scenarios. In FS-2 the owl was also exposed to endosulfan (average maximum H_i = 0.25), and diazinon (average maximum H_i = 1.98) at a concentration greater than their HD5s, and in FS-3 the owl was also exposed to diazinon (average maximum H_i = 1.90) at a concentration greater than its HD5 (Figure 22, Figure 23). Of these insecticides chlorpyrifos (35.4-45.2 days) had the longest average duration of exposure to a concentration greater than its HD5, followed by disulfoton (4.5-5.9 days), diazinon (3.1-5.4 days), dicrotophos (2.9-4.3 days), endosulfan (3.5 days), and indoxacarb (1.2-2.3 days) (Figure 24). The average maximum exposure values are shown in Appendix C3a-c.

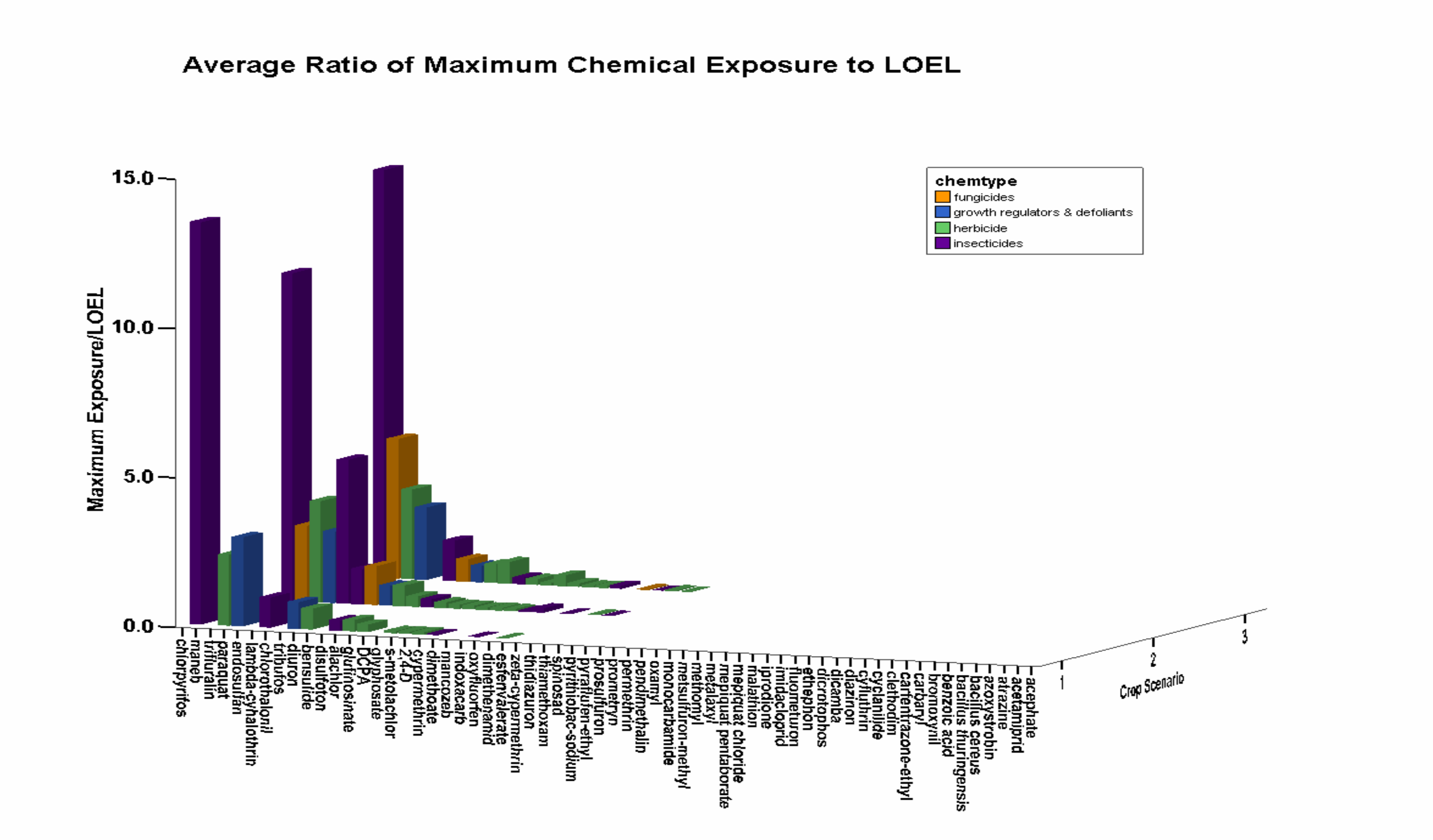

Figure 19. Ratio of average maximum exposure to LOEL by chemical type. (Crop Scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabbage, 3-Cotton/Sorghum/Onions). (Insecticides (Appendix C2a-c), Herbicides (Appendix C4a-c), Growth Regulators & Defoliants (Appendix C6a-c), Fungicides (Appendix C8a-b)).

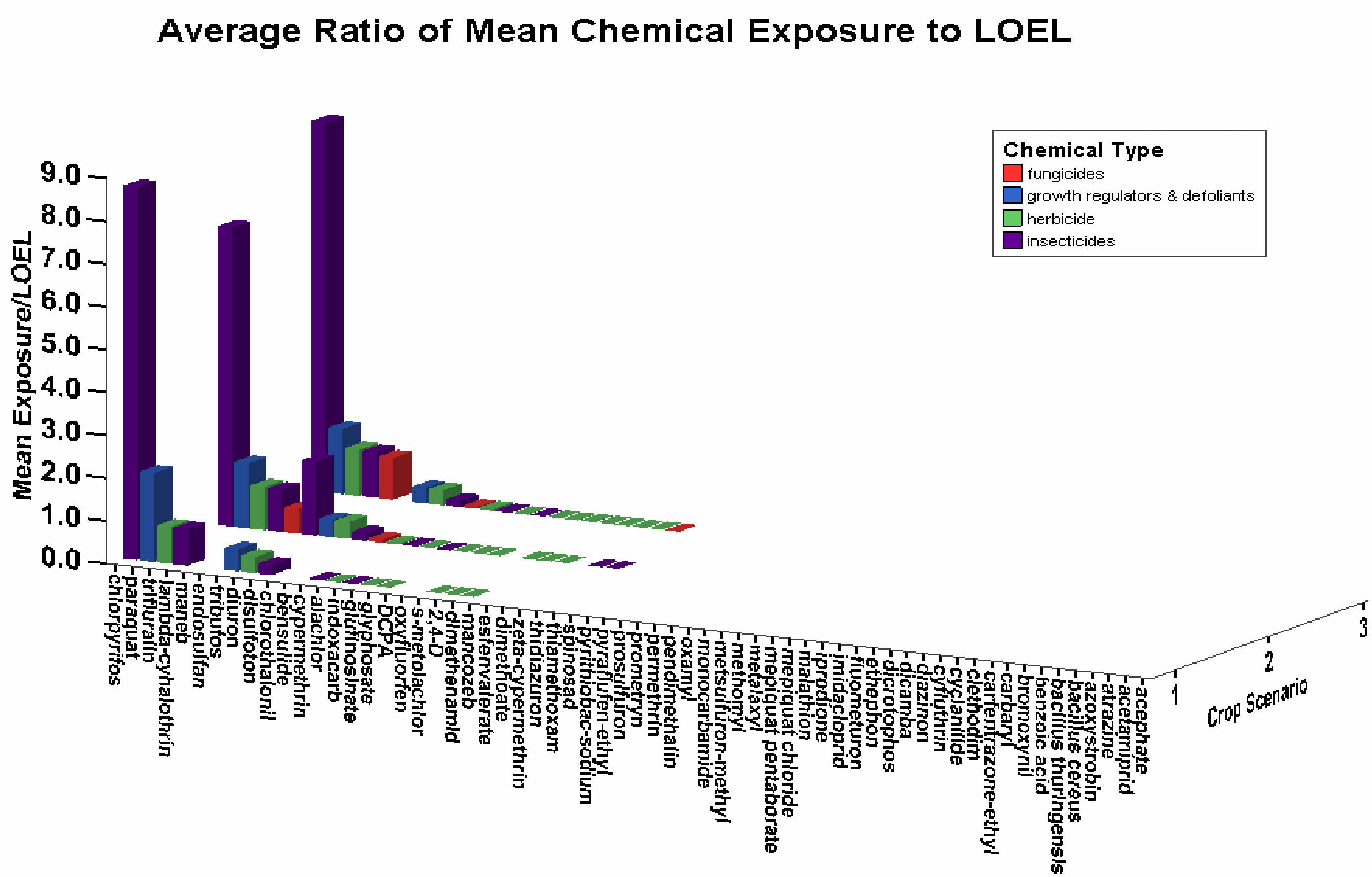

Figure 20. Ratio of average mean exposure to LOEL by chemical type. (Crop Scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabage, 3-Cotton/Sorghum/Onions). (Insecticides (Appendix C2a-c), Herbicides (Appendix C4a-c), Growth Regulators & Defoliants (Appendix C6a-c), Fungicides (Appendix C8a-b)).

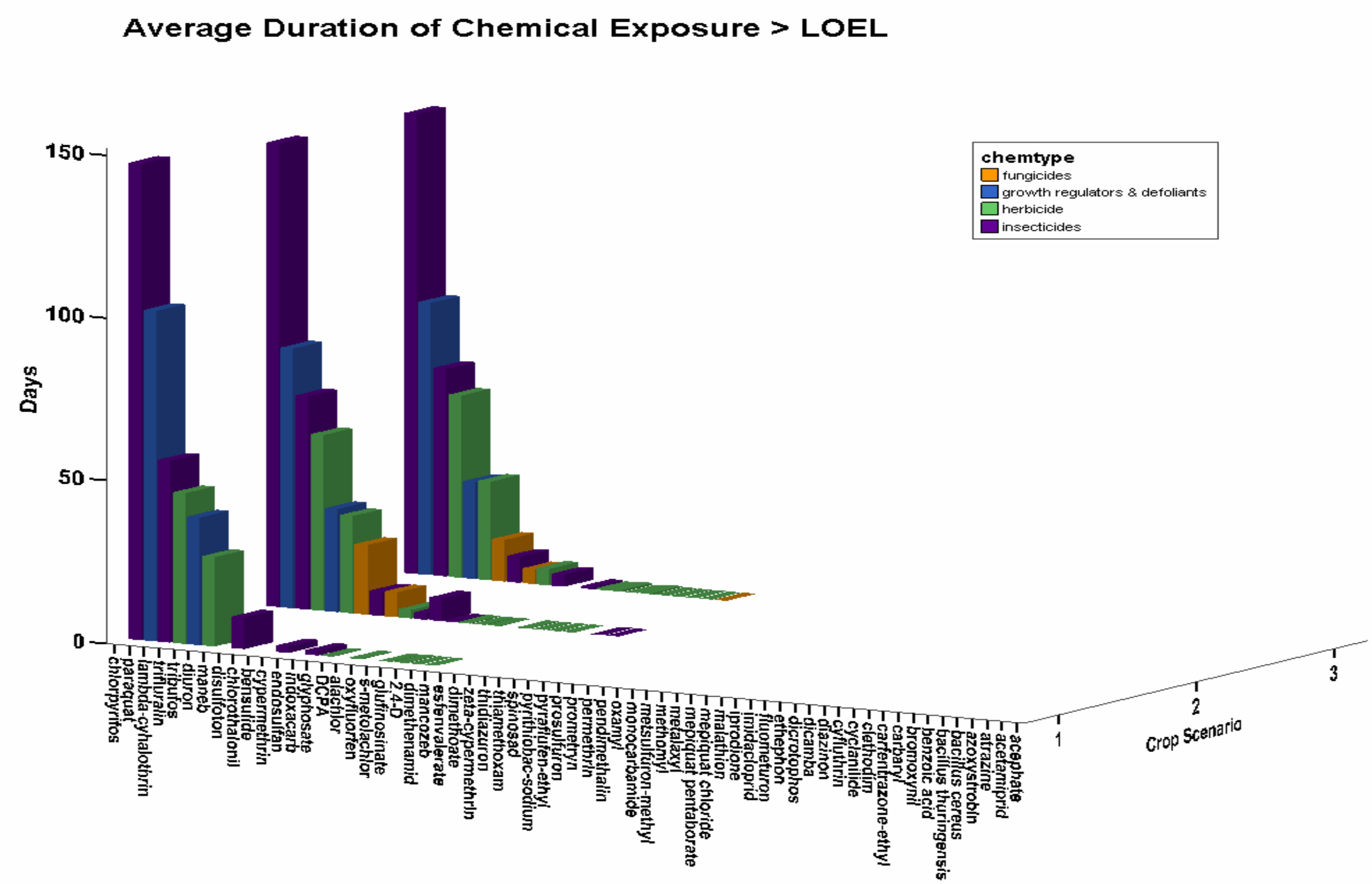

Figure 21. Duration of exposure > LOEL by chemical type. (Crop Scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabage, 3-Cotton/Sorghum/Onions). (Insecticides (Appendix C2a-c), Herbicides (Appendix C4a-c), Growth Regulators & Defoliants (Appendix C6a-c), Fungicides (Appendix C8a-b)).

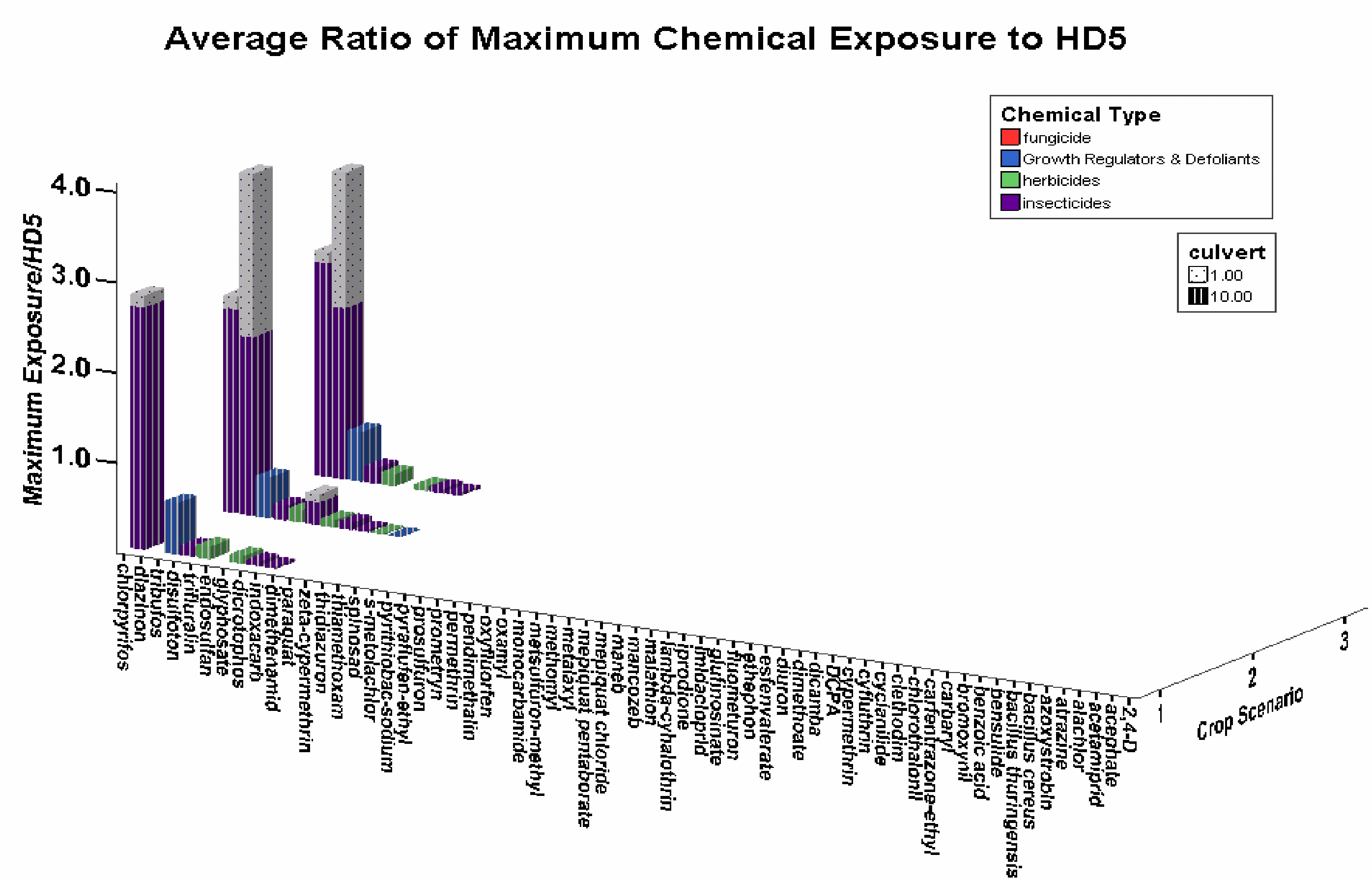

Figure 22. Ratio of average maximum exposure to HD5 by chemical type. (Crop Scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabage, 3-Cotton/Sorghum/Onions). (Insecticides (Appendix C3a-c), Herbicides (Appendix C5a-c), Growth Regulators & Defoliants (Appendix C7a-c), Fungicides (Appendix C9a-b)).

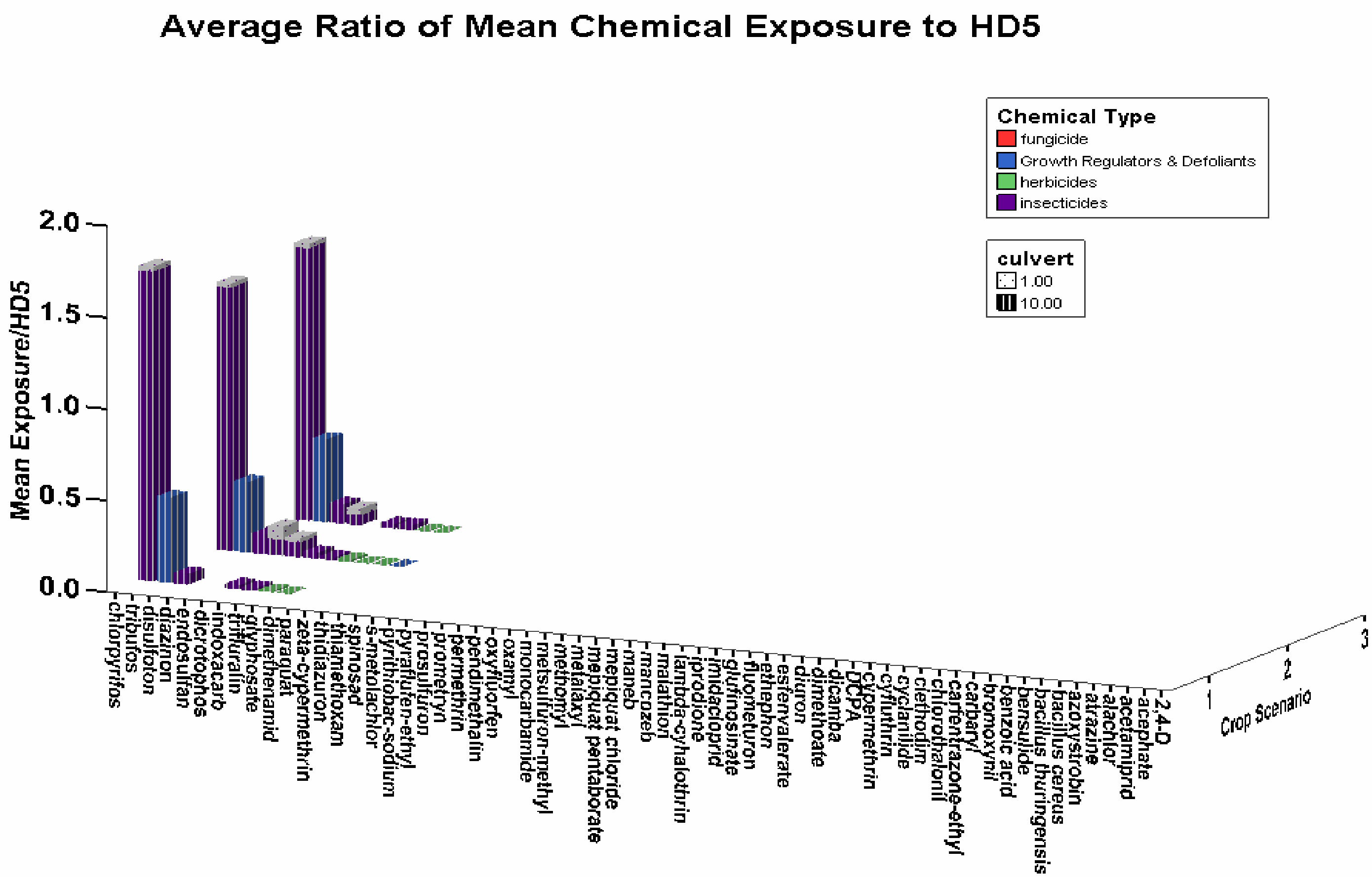

Figure 23. Ratio of average mean exposure to HD5 by chemical type. (Crop Scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabage, 3-Cotton/Sorghum/Onions). (Insecticides (Appendix C3a-c), Herbicides (Appendix C5a-c), Growth Regulators & Defoliants (Appendix C7a-c), Fungicides (Appendix C9a-b)).

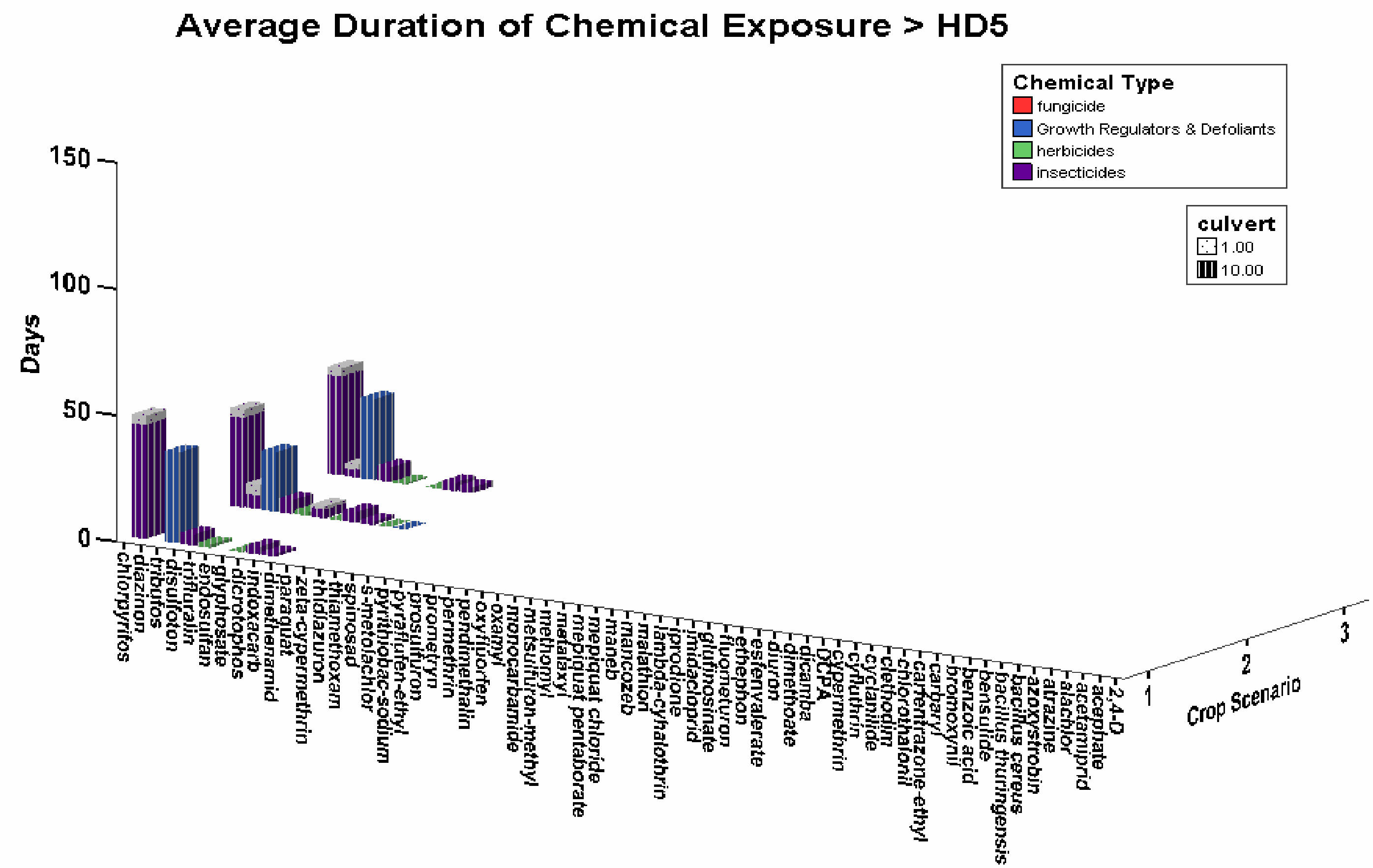

Figure 24. Duration of exposure > HD5 by chemical type. (Crop Scenario: 1-Cotton/Sorghum, 2-Cotton/Sorghum/Cabage, 3-Cotton/Sorghum/Onions). (Insecticides (Appendix C3a-c), Herbicides (Appendix C5a-c), Growth Regulators & Defoliants (Appendix C7a-c), Fungicides (Appendix C9a-b)).

5.3 Herbicides

5.3.1 LOELs

The herbicides with an average maximum value of $L_h > 0$ were trifluralin, diuron, bensulide, alachlor, glufinosinate, DCPA, 2,4-D, glyphosate, s-metolachlor, oxyfluorfen, and dimethenamid. Exposure to concentrations of trifluralin (average maximum L_h = 2.37-3.38), diuron (average maximum L_h = 0.63-0.70), alachlor (average maximum L_h = 0.19-0.38), glufinosinate (average maximum L_h = 0.10-0.26), 2,4-D (average maximum L_h = 0.08), glyphosate (average maximum L_h = 0.08-0.12), s-metolachlor (average maximum L_h = 0.07-0.09), and dimethenamid (average maximum L_h = 0.01-0.02) greater than their LOELs occurred in all three crop scenarios. Exposure to concentrations of bensulide (average maximum L_h = 0.36-0.73), and DCPA (average maximum L_h = 0.13-0.37) greater than their LOELs occurred in FS-2 and FS-3, while exposure to a concentration of oxyflourfen (average maximum L_h = 0.04) greater than its LOEL only occurred in FS-3 (Figure 19, Figure 20). Of these herbicides trifluralin (46-56 days), diuron (27-30 days), and bensulide (3-5 days), had the longest average duration of exposure to concentrations greater than their LOEL (Figure 21). The average maximum exposure values are shown in Appendix C4a-c.

5.3.2 HD5s

When the ratio of concentrations of insecticides in culvert soil to concentrations of insecticides in the crop soil was set to 1 (equal concentrations), there were no herbicides to which the owl was exposed to a level greater than the HD5 in the all three crop scenarios (Figure 22, Figure 23).

When the ratio of concentrations of herbicides in culvert soil to concentrations of herbicides in the crop soil was set to 10, the owl was exposed to concentrations of the herbicides trifluralin (average maximum H_h = 0.14) and glyphosate (average maximum H_h = 0.05-0.09) greater than their HD5s, in all three crop scenarios, and to the herbicide dimethenamid (average maximum H_h = 0.01) in FS-2 (Figure 22, Figure 23). Of these herbicides trifluralin (0.5-1.8 days) had the longest duration of exposure to a concentration greater than its HD5, however the time periods of average exposure to concentrations of these chemicals greater than their HD5s was extremely short (0.03-1.76 days) (Figure 24). The average maximum exposure values are shown in Appendix C5a-c.

5.4 Growth Regulators and Defoliants

5.4.1 LOELs

The only growth regulators or defoliants to which the owl was exposed to a concentration greater than their LOELs were the defoliants paraquat (average maximum L_g = 2.40-2.98) and tribufos (average maximum L_g = 0.56-0.89) (Figure 19, Figure 20). The average duration of exposure to concentrations greater than their LOELs was longer to paraquat (80-101 days), than to tribufos (30-39 days) (Figure 21). The average maximum exposure values are shown in Appendix C6a-c.

5.4.2 HD5s

When the ratio of concentrations of growth regulators or defoliants in culvert soil to concentrations of growth regulators or defoliants in the crop soil was set to 1 (equal concentrations), there were no growth regulators or defoliants to which the owl was exposed to concentrations greater than their HD5s in all three crop scenarios (Figure 22, Figure 23).

When the ratio of concentrations of growth regulators or defoliants in culvert soil to concentrations of growth regulators or defoliants in the crop soil was set to 10, the owl was exposed to concentrations of tribufos (average maximum H_g = 0.45-0.57) and paraquat (average maximum H_g = 0.00-0.01) greater than their HD5s (Figure 22, Figure 23). Of these two chemicals tribufos (24-36 days) had the longest average duration of exposure greater than its HD5 (Figure 24). The average maximum exposure values are shown in Appendix C7a-c.

5.5 Fungicides

5.5.1 LOELs

The fungicides with an average maximum value of $L_f > 0$ were copper hydroxide, maneb, chlorothalonil, and mancozeb. Fungicide exposure was only evaluated FS-2 and FS-3 crop scenarios because fungicides were not applied to cotton or sorghum fields. Exposure to concentrations of maneb (average maximum L_f = 2.55-4.67) and chlorothalonil (average maximum L_f = 0.76-1.30) greater than their LOELs occurred in both crop scenarios; while exposure to concentrations of copper hydroxide (average maximum L_f = 33.51) and mancozeb (average maximum L_f = 0.03) greater than their LOELs only occurred in FS-3 (Figure 19, Figure 20, Appendix C8a-b). Of these fungicides copper hydroxide (149 days) had the longest average duration of exposure to a concentration greater than its LOEL, followed by maneb (13-21 days), chlorothalonil

(5-8 days), and mancozeb (0.07 days) (Figure 21, Appendix C8a-b). The average maximum exposure values are shown in Appendix C8a-b.

5.5.2 HD5s

Because fungicides are not typically used in cotton or sorghum crops, there was no difference in exposure due to increasing the ratio of concentrations of fungicides in culvert soil to concentrations of fungicides in the crop soil. The only fungicide to which the owl was exposed to a concentration greater than its HD5 was copper hydroxide (average maximum H_f = 42.73) in FS-3 (Appendix C9a-b). The owl was exposed to a concentration of copper hydroxide > its HD5 was throughout the entire winter (Appendix C9a-b). The average maximum exposure values are shown in Appendix C9a-b.

6. Discussion

6.1 OP and CB Insecticides

In all three crop scenarios the OP and CB insecticides predicted to have the greatest potential to negatively affect burrowing owls wintering in south Texas were chlorpyrifos, dicrotophos, disulfoton, and oxamyl (Figures 15-23). The insecticides methomyl and diazinon also showed potential to negatively affect burrowing owls foraging in cabbage or onion fields (FS-2 & FS-3) (Figures 15-23). Exposure to sublethal concentrations of methomyl and diazinon resulted in reduced and abnormal growth in mallard embryos (Hoffman and Albers, 1984). Diazinon has been responsible for a greatest number of avian mortality events of all the insecticides used in the model, and in one case was responsible for a mortality of 14 Canada geese on a golf course in Missouri three months after its application (Zinkl et al., 1978).

Avian mortality events have occurred due to the usage of several of the insecticides used in this model. At least three confirmed large avian mortality events have been attributed to chlorpyrifos with a total minimum mortality of 43 birds, two to dicrotophos with a total minimum mortality of 244 birds, three to disulfoton with a total minimum mortality of 43 birds, one to oxamyl with a total minimum mortality of 146 birds, and 34 to diazinon with a total minimum mortality of 833 birds. Diazinon is also suspected in four large mortality events with a total minimum mortality of 126 birds (Fleischli et al., 2004). Methomyl is suspected in one mortality event with a total minimum mortality of 107 birds, and was responsible for the mortality of an endangered griffon vulture, *Gyps fulvus*, in Croatia (Fleischli et al., 2004, Sabocanec et al., 2005). Several of these mortality events have occurred in Texas, such as the mortality of a large number of birds on the Texas Gulf Coast in 1982 due to intentional poisoning with dicrotophos (Flickinger et al., 1984).

Of the insecticides evaluated, the OP insecticides chlorpyrifos, diazinon, and disulfoton, as well as the CB insecticides carbaryl, and methomyl, were detected in burrowing owl pellets from south Texas (Woodin et al., 2006). In addition, diazinon and malathion were detected, along with several other insecticides, in burrowing owl eggs in the Colorado River delta, Mexico (Garcia-Hernandez et al., 2006).

Based on all three endpoints the insecticide chlorpyrifos had the greatest potential to negatively affect burrowing owls wintering in South Texas. Burrowing owls were likely to be exposed to concentrations of chlorpyrifos that may result in lethal or sublethal effects. In addition, the average duration of exposure to chlorpyrifos typically encompassed the entire wintering period (Figures 18, 21). Chlorpyrifos was detected in burrowing owl footwash samples from a study site in California (Gervais et al., 2000). In addition to acute toxic effects, chlorpyrifos also has been associated with decreased reproductive productivity in robins (Decarie et al., 1993). Due to human health risks chlorpyrifos was ordered by the U.S. EPA to be phased out for some uses in 2000 (U.S. EPA, 2000a).

There were several limitations in the accurate evaluation of OP and CB insecticides. The first limitation is that NASS does not currently report agricultural chemical use for sorghum, so the data used in the model was NCFAP data from 1997. Therefore the usage of chlorpyrifos, disulfoton, and carbaryl, which were only used on sorghum crops in the model, may not accurately reflect the current usage scenario on sorghum crops in Texas.

The second limitation is the lack of dose response curves for some of the insecticides. The carbamate insecticides methomyl and oxamyl caused some of the highest levels of ChE inhibition, however exposure to oxamyl or methomyl did not reach levels greater than their LOELs or HD5s (Figures 15, 19, 22). These discrepancies may be due to a lack of insecticide specific data, which resulted in the estimation of the dose-response curves for oxamyl and methomyl from the dose-response curves for the OP insecticides ethyl parathion and dicrotophos, respectively (Appendix A8). More research leading towards the development of an accurate dose-response curve is necessary in order to accurately evaluate the effects of oxamyl and methomyl on ChE inhibition.

The third limitation is that ChE inhibition was assumed to be additive. However, exposure to multiple cholinesterase inhibiting pesticides can sometimes result in synergistic ChE inhibition. For example, exposure to malathion occurred at extremely low levels throughout the entire wintering period, most likely due to its repeated use in the treatment of boll weevil. Although malathion was one of the lowest inhibitors of ChE in the model, it has been demonstrated to cause potentiation of carbaryl toxicity (Johnston et al., 1994). This may have resulted in higher levels of ChE inhibition than was simulated.

The fourth limitation is that granular insecticides were excluded from the model. A highly toxic OP insecticide used in granular formation on sorghum for the control of white grubs is the OP insecticide terbufos (Cronholm et al., 1998). The granular formation of terbufos was one of several granular insecticides implicated in the mortality of a large number of raptors in British Columbia because of their persistence for a long duration after application (Wilson et al., 2002). If terbufos is still used on sorghum, it may negatively affect burrowing owls wintering in south Texas.

6.2 Other Insecticides

The insecticides, other than OP and CB insecticides, with the greatest potential to negatively affect burrowing owls wintering in South Texas were the OC endosulfan, followed by the pyrethroids lambda-cyhalothrin and cypermethrin, and the oxadiazine indoxacarb. Although exposure to all of these insecticides reached concentrations greater than their LOELs, only exposure to endosulfan reached concentrations greater than their HD5s prior to increasing concentrations in the culvert soil. After increasing concentrations in the culvert soil, exposure to indoxacarb also reached concentrations greater than its HD5 (Figures 19, 22).

Like other OC insecticides, endosulfan is highly toxic to aquatic fauna, mammals, and birds, can bioaccumulate in aquatic food chains, and can cause eggshell thinning in predatory birds (Cem Oktay et al., 2003). Endocrine disruptive effects due to endosulfan exposure have been observed in fish, birds, mammals, and amphibians (Cerrillo et al., 2005). Chronic low-level exposure to endosulfan, as well as to a pyrethroid insecticide and an OP insecticide, in broiler chicks resulted in impairments in their metabolism and immune systems (Garg et al., 2004). In addition, endosulfan has been implicated as a factor in amphibian declines (Sparling et al., 2001, Park and Propper, 2002). However, in the model endosulfan was only applied in FS-2.

6.3 Herbicides

The herbicides with the greatest potential to negatively affect burrowing owls wintering in South Texas were trifluralin, glyphosate, dimethenamid, diuron, bensulide, and alachlor. Although exposure to these herbicides all reached concentrations greater than their LOELs, only exposure to trifluralin, glyphosate, and dimethenamid reached concentrations greater than their HD5s, and only after concentrations in the culvert soil had been increased (Figure 19, Figure 22). Of these herbicides the greatest potential risk to burrowing owls wintering in South Texas is due to trifluralin. Trifluralin, along with alachlor, is one of several herbicides implicated as a disruptor of endocrine or reproductive systems (Colbourne and Short, 1999). Of several herbicides tested for toxicity to mallard eggs trifluralin was one of the top two most toxic herbicides. Trifluralin also had the highest level of avian hazard of several herbicides evaluated based on permissible levels of application (Hoffman, 2003). Trifluralin is also one of the most common contaminants detected in cotton fields (Kannan et al., 2003).

6.4 Growth Regulators and Defoliants

The growth regulators and defoliants with the greatest potential to negatively affect burrowing owls wintering in South Texas were tribufos and paraquat. Exposure to tribufos and paraquat reached concentrations greater than their LOELs, and reached concentrations greater than their HD5s, but only after concentrations in the culvert soil had been increased (Figure 19, Figure 22). There is little information regarding avian effects due to exposure to tribufos. However, paraquat administered to nestling American kestrels resulted in high levels of mortality, reduced growth, and altered physiology (Hoffman et al., 1985, Hoffman et al., 1987). Of several herbicides tested for toxicity to mallard eggs paraquat was one of the top two most toxic herbicides, and had the second highest level of hazard based on permissible levels of application (Hoffman, 2003). A sublethal concentration of paraquat resulted in reduced growth in mallard embryos (Hoffman and Albers, 1984). In addition, paraquat is one of several herbicides and defoliants implicated as a disruptor of endocrine or reproductive systems (Colbourne and Short, 1999).

6.5 Fungicides

The fungicides with the greatest potential to negatively affect burrowing owls wintering in South Texas were copper hydroxide, maneb, chlorothalonil, and mancozeb. Exposure to these fungicides reached concentrations greater than their LOELs, but only exposure to copper hydroxide reached concentrations greater than its HD5 (Appendix C8a-b, Appendix C9a-b). However, the model was probably inadequate to evaluate copper hydroxide. Copper hydroxide is metal based, and behaves differently from the other chemicals examined in this model. Copper hydroxide was assumed to not have a half-life, and because the model does not account for transfers of material off the fields it accumulated at a rate much greater than any of the other fungicides in this model, leading to high exposure levels. In addition fungicides were only applied to FS-2, and FS-3, and subsequently may not be as important in terms of potential risks to burrowing owls in South Texas compared to the other chemical classes.

6.6 Summary

Although agricultural chemical exposure was evaluated for all three foraging scenarios, the Cotton/Sorghum crop scenario (FS-1) represents the majority of burrowing owl roost sites in South Texas. Based on the results of these simulations in appears that the chemicals with the greatest potential to negatively affect burrowing owls wintering in south Texas cotton and sorghum fields are the OP insecticides chlorpyrifos, dicrotophos, and disulfoton; the pyrethroid insecticide lambda-cyhalothrin, and the oxadiazine insecticide indoxacarb; the herbicides trifluralin, glyphosate, and dimethenamid; and the defoliants tribufos and paraquat. When the burrowing owl foraged in cabbage or onion fields (FS-2 & FS-3), the OP insecticides methomyl and diazinon, as well as the OC insecticide endosulfan also showed potential to negatively affect burrowing owls wintering in South Texas.

Several of the insecticides that posed the greatest risk to burrowing owls were only used on sorghum crops in the model. However, NASS does not currently report agricultural chemical use for sorghum, so the data used for sorghum insecticide use in the model was from 1997. An accurate analysis of the risks of agricultural chemical use to burrowing owls living in cotton/sorghum fields is dependent on accurate and current information regarding chemical use; therefore it is crucial that data on current agricultural chemical use in sorghum crops be reported. Other limitations of the model included the lack of dose-response curves for some of the OP or CB insecticides, the exclusion of granular insecticides, and exclusion of possible synergistic effects between currently applied pesticides.

In addition to synergistic effects between currently used agricultural chemicals, synergistic effects between currently used agricultural chemicals and elevated levels of contaminants related to historical agricultural use may also be of concern, although they were not evaluated in the model. DDE or its metabolites have been shown to sometimes occur in concentrations high enough to affect avian reproduction in the Rio Grande Valley (Wainwright et al., 2001). This is significant because exposure to an OP insecticide after previous exposure to p,p-DDE may increase ChE inhibition (Ludke, 1977), and may cause anemia or affect the immune system (Gill et al., 2004). In addition, elevated levels of mercury and arsenic have been detected in relation to agriculture in South Texas (Custer and Mitchell, 1991). Exposure to mercury has also been shown to increase the cholinesterase inhibiting activity of OP and CB insecticides (Dieter and Ludke, 1975; Dieter and Ludke, 1978). Synergistic effects in birds have also been shown between fungicides and OP insecticides, and some chemical mixtures have been shown to result in as much as 100 fold toxicity (Thompson, 1996).

Results from several other multichemical risk assessments in different situations concur with the results of this model. Three of the herbicides used in this model, (glyphosate, 2,4-D, and trifluralin), were evaluated, along with an assortment of other herbicides, in a risk assessment that compared the relative risks of acute avian exposure in spring wheat. 2,4-D was determined to have an equal relative risk to glyphosate, while trifluralin was determined to have an increased relative risk of 1.3 times glyphosate (Peterson and Hulting, 2004). In this simulation model the risk to burrowing owls from the three herbicides is greatest for trifluralin, followed by glyphosate, then 2,4-D (Figure 19, Figure 22). A risk assessment of cotton pyrethroids showed that cypermethrin and lambda-cyhalothrin posed a greater risk to aquatic organisms than several other pyrethroids including cyfluthrin and esfenvalerate (Solomon et al., 2001). Similiarly, in this simulation model the pyrethroid lambda-cyhalothrin represented the greatest potential risk to burrowing owls, followed by the pyrethroid cypermethrin, then by esfenvalerate and cyfluthrin (Figure 19, Figure 22). A third model compared the ecological relative risks of 37 chemicals used on cotton. Of the chemicals used in the burrowing owl model, the insecticides endosulfan and chlorpyrifos were identified as posing a high ecological risk, the insecticide methomyl was identified as posing a medium ecological risk, the insecticides dimethoate and lambda-cyhalothrin were identified as posing low ecological risks, and the insecticides spinosad and cypermethrin were classified as posing negligible risks (Sanchez-Bayo et al., 2002). Similarly chlorpyrifos, endosulfan, and methomyl were identified as a potential risk to burrowing owls, while exposure to spinosad did not represent a potential risk to burrowing owls (Figures 15, 19, 22).

Simulation modeling proved an ideal means to identify from a wide number of agricultural chemicals, in several different chemical classes, based on toxicity levels, frequency of application, and application rates, which agricultural chemicals had the greatest predicted potential to negatively affect burrowing owl populations in south Texas.

CHAPTER V

CONCLUSIONS

A simulation model was constructed that integrated dermal and oral exposure to evaluate the lethal and sublethal effects in birds of chronic low-level exposure to a wide range of chemical types. Burrowing owls wintering in cotton fields in south Texas, which are chronically exposed to low levels of agricultural chemicals were chosen to exemplify the use of this model. The model was used to evaluate the potential of culverts to act as ecological traps, and to determine which agricultural chemicals currently in use in cotton/sorghum fields in south Texas had the greatest potential to negatively affect burrowing owl populations.

The results of these simulations identified several important data gaps. These data gaps include 1) half-lives of agricultural chemicals in birds, 2) agricultural chemical half-lives in insects and their accumulation and transfer rates in prey, 3) accurate dermal to oral toxicity indexes and expanded research on the duration of effects due to dermal exposure, 4) avian dose-response curves for the inhibition of ChE due to exposure to the insecticides methomyl and oxamyl, 5) LOELs based on avian data, 6) current agricultural chemical use data for sorghum in Texas, 7) the frequency and timing of pre-planting insecticide treatment in sorghum, 8) the concentrations of agricultural chemicals in culverts in the cotton/sorghum fields used as roost sites by burrowing owls, and 9) more general research on chronic low-level exposures to common agricultural chemical mixtures in birds.

The risk of chemical classes to burrowing owls wintering in south Texas cotton/sorghum fields can be described as insecticides>growth regulators and defoliants>herbicides, and the greatest risk of lethal or sublethal effects was due to OP and CB insecticides. Lethal or sublethal effects of exposure to insecticides increased in the presence of an adjacent crop that received agricultural chemical treatments (Chapter II).

Simulations investigating the potential of agricultural culverts to act as ecological traps using ChE inhibition and HD5s indicated that lethal effects due to increased chemical concentrations in culverts are unlikely in burrowing owls wintering in south Texas. However the results using ChE inhibition as an endpoint indicated that sublethal effects may be likely if concentrations of OP and CB insecticides are increased in the culvert soil. Analysis of the soil in culverts used as roost sites by burrowing owls in south Texas cotton fields for OP and CB residues would help determine the amount of dermal exposure occurring through this exposure route (Chapter III).

Simulation results predicted that the agricultural chemicals with the greatest potential to negatively affect burrowing owls wintering in south Texas cotton and sorghum fields are the OP insecticides chlorpyrifos, dicrotophos, and disulfoton; the oxadiazine insecticide indoxacarb; the herbicides trifluralin, glyphosate, and dimethenamid; and the defoliants tribufos and paraquat (Chapter IV).

This model provided a framework for a simple stochastic simulation model which can be used to evaluate different classes of chemicals or individual chemicals, as well as different crops, based on current agricultural practices, in terms of the lethal or sublethal effects on avian wildlife. The combined use of three different endpoints in this model allows for the risk of both lethal and sublethal effects in birds due to exposure to chemical classes in addition to insecticides to be investigated. Concurring results from all three endpoints, such as occurred with the insecticide chlorpyrifos, can provide a stronger assessment of a chemical or crop than from one endpoint alone. Simulation modeling proved an ideal means to identify from a wide number of agricultural chemicals, in several different chemical classes, based on toxicity levels, frequency of application, and application rates, which agricultural chemicals had the greatest potential to negatively affect burrowing owl populations in south Texas.

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APPENDIX A

MODEL DESCRIPTION DATA

Table A1. Stella model parameters.

Overview of Model Parameters Used in Stella Model					
Parameters (* = an endpoint)	Explanation	Values Used in Model	Table	Values Used for Sensitivity Analysis	Sensitivity Analysis #
Counters					
day	counts 1/2 day time steps and resets after 1 year	n/a			
year	counts years	n/a			
alternate years	alternates from 0 and 1 between years	n/a			
day & night	alternates from 0 and 1 between each time step	0 = day, 1 = night			
owls present	determines if owls are present in agroecosystem	0 = no owls, 1= owls, see table for dates	2	extended owl presence to julian day 75 instead of 60	9
Crop Growth					
growing days	counts days in crop growing season	n/a			
plant day	first day of planting crop (first day of growing season)	see table	3		
harvest day	last harvest day of crop (last day of growing season)	see table	3		

Table A1. cont.

Parameters (* = an endpoint)	Explanation	Values Used in Model	Table	Values Used for Sensitivity Analysis	Sensitivity Analysis #
	Overview of Model Parameters Used in Stella Model				
Sector 1- Agricultural Chemical Use					
individual chemical names (e.g. acephate)	application rate	see table	4		
type chance	random number generator	value between 0 & 1			
type of chemical	randomly picks chemical to be applied based on a usage frequency distribution and the random number generator	see table	4		
day selectors	randomly selects a day during the crop growing season for treatment to occur and resets at the end of the crop growing season (treatments only occur during the day)	see table	3	changed the early bound of the selection period to julian day 56 instead of 62	9
selector for additional treatments	selects the probability of a treatment occuring if the average treatments a crop recieves is not a whole number (e.g. if cotton recieves 1.72 treatments, there is a 72% chance of a second treatment)	see table	3		
apply chemical	applies the randomly selected chemical on the randomly selected day to the crop	n/a			
apply boll weevil insecticide	applies malathion every seven days for seven weeks to cotton/sorghum crops during the growing season beginning in the eighth year of simulations	see table	3&4		

Table A1. cont.

Overview of Model Parameters Used in Stella Model					
Parameters (* = an endpoint)	**Explanation**	**Values Used in Model**	**Table**	**Values Used for Sensitivity Analysis**	**Sensitivity Analysis #**
Sector 2- Agricultural Chemicals in Roost and Foraging Sites					
chemical application	applies first application to crop with some loss due to drift. Type of treatment alternates between years between cotton& sorghum (unless the crop is onions or cabbage).	n/a			
drift	loss of chemical application due to drift	.0005 (.05%)		0	4
days to next application	counts days between application	7 days			
apply again	applies additional applications to crop with some loss due to drift. Additional applications are based on typical number of applications in a treatment (eg if dimethoate recieves 2.1 applications, two applications occur with a 10% chance of a third applic	see table	4		
chemical degradation	decay of pesticides based on an initial half-life value in soil and a second phase half-life value in soil	n/a			
soil half-life	first phase pesticide half-life in soil	see table	5	see table 5	7
second phase half-life extender	"chemical degradation"multiplies pesticide half-life in soil by this value to obtain the second phase pesticide half-life	100			
second phase start	determines the concentration below which the second phase half-life comes into effect	.1 ug/cm2			
chemical in culvert soil *	concentration of chemical in the soil of the roost culverts	n/a			
soil to culvert soil ratio	used to increase the concentration of chemicals in culvert soil (e.g. 1=equal to chemical concentrations in the rest of the crop, 2=double thechemical concentrations in the rest of the crop)	user specified			
chemical in mammals	chemical in mammals in ug/g	n/a			
in mammals (application day)	chemical transfer to prey mammals on application day	(ug/cm2 in soil)*0.21		changed 0.21 to 7.44	6
in mammals (all other days)	chemical transfer to prey mammals on post-application days	(ug/cm2 in soil)/100		changed 100 to 10	6
chemical in insects	chemical in insects in ug/g	n/a			
in insects (application day)	chemical transfer to prey insects on application day	(ug/1cm2 in soil)*2.5		changed 2.5 to 7.44	6
in insects (all other days)	chemical transfer to prey insects on post application days	(ug/1cm2 in soil)/100		changed 100 to 10	6
decay in insects or mammals	decay of pesticides in organism based on half-life				
insect half-life	used 1/10 of soil half-life value unless the organism half-life value was greater in which case the organism half-life value was used	see table	6	soil values, table 5	5
organism half-life (mammals)	used half-life values from organisms, primarily mammals, values are estimated when no data was available	see table	6	these values are based on mammals so were not changed	

Table A1. cont.

Overview of Model Parameters Used in Stella Model					
Parameters (* = an endpoint)	**Explanation**	**Values Used in Model**	**Table**	**Values Used for Sensitivity Analysis**	**Sensitivity Analysis #**
Sector 3- Owl Location and Exposure Selectors					
bird in patch #	selects where to send bird to forage and roost which determines the type and amount of exposure. During the day the bird is always at the roost site, while at night the bird is randomly sent somewhere to forage using the random number generator.	**FS-1**= 40% chance of foraging in roost site, and 30% chance at each adjacent cotton/sorghum field **FS-2/3**= 30% chance of foraging in roost site, 10% chance fat each adjacent cotton/sorghum field, and 50% chance of foraging in cabbage/onion field			
select chemical in soil	Selects which crop soil the bird is exposed to through the feet based on bird in patch #, also sets the amount of time exposed through the feet during nighttime foraging	currently set to 1 hour of dermal exposure during foraging		9 hours of dermal exposure	2
select dermal intercept	Selects for the possibility of dermal interception exposure, (spray on dorsal surface of bird), based on bird in patch #	dermal interception exposure occurs when bird in patch# = 0, (daytime and at roost site)			
select chemical in edible soil	Selects which crop soil the bird is exposed to through incidental soil ingestion, based on bird in patch #	soil ingestion occurs only during nighttime foraging, (bird in patch # does not = 0)			
select chemical in insects	Selects which crop's insect prey the bird is exposed to through ingestion, based on bird in patch #	prey ingestion occurs only during nighttime foraging, (bird in patch # does not = 0)			
select chemical in mammals	Selects which crop's mammal prey the bird is exposed to through ingestion, based on bird in patch #	prey ingestion occurs only during nighttime foraging, (bird in patch # does not = 0)			

Table A1. cont.

Overview of Model Parameters Used in Stella Model					
Parameters (* = an endpoint)	**Explanation**	**Values Used in Model**	**Table**	**Values Used for Sensitivity Analysis**	**Sensitivity Analysis #**
Sector 4- Agricultural Chemical Exposure in Owl					
field scenario	determines the scenario being run, either cotton/sorghum fields only, or cotton/sorghum with an adjacent cabbage or onion field	1= cotton/sorghum, 2= cotton/sorghum with adjacent cabbage field, 3= cotton/sorghum with adjacent onion field			
Insect biomass in diet	grams of prey item type consumed per day	16.17467029			
mammal biomass in diet	grams of prey item type consumed per day	2.854353581			
soil in diet	grams of soil in consumed, (insect biomass+mammal biomass)*percent soil in diet	3%		10%	1
toxin ingested	intake of toxin based on amount in soil and prey consumed and divided by body weight				
bird weight	average bird weight	167.9	2		
dermal foot dose	amount of dermal exposure via the feet	(chemical in soil (cm2)*surface area of foot(cm2))/bird weight			
foot surface area	surface area of feet and legs	42.7	2	already guessed high	
dermal intercept	amount of exposure occuring due to dermal exposure (estimated 1/2 the body surface area), if the owl is present during application	application rate(cm2) * intercept surface area(cm2)			
intercept surface area	1/2 the body surface area	152.4	2		
dermal intercept dose	amount of dermal exposure via the dorsal surface	dermal intercept/bird weight			
toxin on	intake of toxin based on amount exposed to via the dermal foot dose and the dermal intercept dose				
oral, or dermal	amount of toxin in bird via each exposure route				
toxin loss	decay of pesticide based on half-life, used organism half-life values	see table	6	value*5	3
dermal to oral dose ratio (DTI)	equivalates a dermal dose to an oral dose equivalent for use with an oral dose-response curve	Values based on ecofram equations, unless actual avain data is available	7	value*2	8
dermal adjusted	amount of dermal exposure adjusted for an oral dose-response curve	dermal *dermal to oral dose ratio			
d or o ChE inhibit	dose response curves to get ChE inhibition	dose response equations	8		
d or o ChE	total ChE inhibition for all chemicals for each exposure route	sums all che inhibition for each exposure route			
ChE Inhibition *	total ChE inhibition for all chemicals and routes	d ChE + o ChE			
HD5	Hazardous dose 5 for each chemical	see table	10		
HD5 count	Counts a 1 value if a HD5 is exceeded	=1 if (oral+(dermal*DTI))>HD5			
year exceed HD5s *	counts # of days a year the HD5s are exceeded for each chemical				
HD5 amount *	calculates percentage of the HD5 if the dose exceeds the HD5	(oral+(dermal*DTI))/HD5			
LOELs	Lowest observed effects level for each chemical	see table	9		
LOEL count	Counts a 1 value if a LOEL is exceeded	=1 if (oral+(dermal*DTI))>LOEL			
year exceed LOELs *	counts # of days a year the LOELs are exceeded for each chemical				
LOEL amount *	calculates percentage of the LOEL if the dose exceeds the LOEL	(oral+(dermal*DTI))/LOEL			

Table A2. Model parameters associated with western burrowing owl (*Athene cunicularia hypugaea*) ecology.

	Burrowing Owl Information		Reference
Arrival	1-Oct, 274 (Julian Date)	1-Oct	estimated from Woodin et al.-2006
Departure	1-Mar, 60 (Julian Date)	1-Mar	estimated from Woodin et al.-2006
Weight (g)	167.9		estimated from Woodin et al.-2006
Respiration (l/hr)	3.53		estimated from U.S. EPA - Fite et al.-2004
Surface Area (cm2)	304.9		estimated from U.S. EPA - Fite et al.-2004
Interceptable Surface Area (cm2)	152.4	50% of surface area	estimated from U.S. EPA - Fite et al.-2004
Leg & Foot Surface Area (cm2) *2	42.7	7% of surface area, doubled to account for larger legs of the owl	estimated from U.S. EPA - Fite et al.-2004
food ingestion rate (g/day)	19.03		estimated from U.S. EPA - McVey et al.-1993
insects ingested (g/day)	16.17	85% of diet	estimated from Woodin et al.-2006
mammals ingested (g/day)	2.85	15% of diet	estimated from Woodin et al.-2006

Table A3. Crop treatment information.

		Crop Type			
		Cotton	Sorghum	Onion	Cabbage
Growing Season (estimated from Dept. of Agricultural Communications,1996; Livingston and Bade, 1996a)	Growing Season Start Date	52	52	349	305
	Growing Season End Date	227	210	166	166
Insecticides (estimated from NASS,2006; NASS,2005; NCFAP,1997; Knutson et al.,2000a; Knutson et al.,2000b; Norman and Sparks,2000a;Norman and Sparks,2000b;Cronholm et al.,1998)	Number of Treatments	1.72	1- (no data)	1.69	3.13
	First Treatment Date	52-220	52-200	1-60	305-365
	Second Treatment Date	52-220	N/A	61-166	1-60
	Third Treatment Date	N/A	N/A	N/A	60-166
	Fourth Treatment Date	N/A	N/A	N/A	1-166
Insecticide, boll weevil (estimated from APHIS,2002; Txbollweevil.org,2006)	Application Dates	167, 174, 181, 188, 195, 202, 209	167, 174, 181, 188, 195, 202, 209	N/A	N/A
Herbicides (estimated from NASS,2006; NASS,2005; NASS, 2004; NCFAP,1997; Baumann,1998; Stichler et al.,1997)	Number of Treatments	1.82	1- (no data)	2.20	1.17
	First Treatment Date (Preemergence)	45-59	45-59	349-365	298-365
	Second Treatment Date	60-220	60-220	1-60	1-166
	Third Treatment Date	N/A	N/A	61-166	N/A
Defoliants (estimated from NASS,2006; Stichler et al.,1995)	Number of Treatments	1	N/A	N/A	N/A
	First Treatment Date	208-216	N/A	N/A	N/A
Growth Regulators (estimated from NASS,2006; Livingston et al.,1996b)	Number of Treatments	1	N/A	N/A	N/A
	First Treatment Date	37-87 (crop growth days)	N/A	N/A	N/A
Fungicides (estimated from NASS,2005)	Number of Treatments	N/A	N/A	2.81	2.45
	First Treatment Date	N/A	N/A	349-365	305-365
	Second Treatment Date	N/A	N/A	1-60	1-60
	Third Treatment Date	N/A	N/A	61-166	61-166

Dates are Julian Dates

Table A4. Agricultural chemical treatment information.

Cotton

	Application rate (lbs/acre)	Application frequency distribution	Number of repeat applications
Herbicides			
2,4-D dimeth. salt	0.767	0.012	1.000
Carfentrazone-ethyl	0.016	0.030	1.000
Clethodim	0.112	0.006	1.000
Diuron	0.369	0.100	1.000
Fluometuron	0.915	0.012	1.000
Glufosinate-ammonium	0.391	0.030	1.600
Glyphosate iso. Salt	0.702	0.314	1.700
Pendimethalin	0.794	0.059	1.000
Prometryn	0.594	0.018	1.100
Pyraflufen-ethyl	0.003	0.012	1.000
Pyrithiobac-sodium	0.035	0.047	1.000
S-Metolachlor	1.110	0.018	1.100
Trifluralin	0.858	0.343	1.000
Insecticides			
Acephate	0.345	0.165	1.500
Acetamiprid	0.034	0.132	1.000
Aldicarb	0.464	0.121	1.000
Cyfluthrin	0.039	0.033	1.300
Cypermethrin	0.068	0.099	1.100
Dicrotophos	0.160	0.044	1.400
Dimethoate	0.176	0.011	2.100
Esfenvalerate	0.035	0.033	1.000
Indoxacarb	0.099	0.010	1.500
Lambda-cyhalothrin	0.039	0.055	1.400
Malathion	0.948	0.209	4.600
Oxamyl	0.258	0.022	1.300
Thiamethoxam	0.027	0.022	1.100
Zeta-cypermethrin	0.017	0.044	1.300
Malathion for boll weevil	0.750	n/a	7.000
Growth Regulators			
Bacillus cereus	<.0005	0.054	1.200
Cyclanilide	0.082	0.054	1.000
Ethephon	0.959	0.459	1.000
Mepiquat Chloride	0.017	0.351	1.300
Mepiquat Pentaborate	0.041	0.081	2.900
Defoliants			
Ethephon	0.959	0.254	1.000
Monocarbamide dihyd.	1.164	0.028	1.000
Paraquat	0.291	0.338	1.100
Thidiazuron	0.057	0.254	1.200
Tribufos	0.634	0.127	1.000

Sorghum

	Application rate (lbs/acre)	Application frequency distribution	Number of repeat applications
Herbicides			
2,4-D dimeth. salt	0.350	0.075	1.0
Alachlor	1.250	0.050	1.0
Atrazine	0.870	0.492	1.1
Dicamba	0.120	0.050	1.0
Dimethenamid	0.600	0.025	1.0
Glyphosate	0.570	0.100	1.4
Metsulfuron-methyl	0.002	0.058	1.1
Prosulfuron	0.020	0.083	1.0
S-Metolachlor	0.770	0.067	1.0
Insecticides			
Carbaryl	1.350	0.037	no data
Carbofuran*	0.710	0.000	no data
Chlorpyrifos	0.490	0.296	no data
Dimethoate	0.430	0.148	no data
Disulfoton	0.500	0.037	no data
Esfenvalerate	0.020	0.075	no data
Ethyl Parathion*	0.910	0.000	no data
Malathion	1.680	0.037	no data
Terbufos	0.730	0.371	no data
Malathion for boll weevil	0.750	n/a	7.0

* = ethyl parathion and carbofuran are no longer used for sorghum

Onions

	Application rate (lbs/acre)	Application frequency distribution	Number of repeat applications
Herbicides			
Bensulide	2.720	0.232	1.3
Bromoxynil	0.080	0.121	1.9
DCPA	3.860	0.197	1.0
Oxyfluorfen	0.080	0.197	1.6
Pendimethalin	0.730	0.121	1.0
Trifluralin	0.940	0.131	1.0
Insecticides			
Cypermethrin	0.070	0.092	1.4
Diazinon	1.050	0.276	1.8
Lambda cyhalothrin	0.040	0.092	1.0
Methomyl	0.390	0.539	2.5
Fungicides			
Azoxystrobin	0.190	0.086	1.8
Chlorothalonil	1.170	0.145	2.1
Copper hydroxide	0.840	0.148	3.0
Iprodione	0.510	0.172	2.7
Mancozeb	1.110	0.137	2.1
Maneb	1.430	0.117	3.2
Mefenoxam	0.120	0.098	1.2
Metalaxyl	0.150	0.098	1.1

Cabbage

	Application rate (lbs/acre)	Application frequency distribution	Number of repeat applications
Herbicides			
Bensulide	2.080	0.190	1.8
DCPA	3.070	0.143	1.0
Trifluralin	0.710	0.667	1.0
Insecticides			
Bacillus thurengensis	0.120	0.086	3.4
Diazinon	0.780	0.181	2.8
Dimethoate	0.180	0.046	1.0
Endosulfan	1.140	0.016	1.8
Imidacloprid	0.220	0.105	1.1
Indoxacarb	0.060	0.092	1.8
Methomyl	0.360	0.016	1.2
Permethrin	0.160	0.184	2.8
Spinosad	0.060	0.273	2.9
Fungicides			
Azoxystrobin	0.160	0.194	2.0
Benzoic acid	0.070	0.097	2.4
Chlorothalonil	1.130	0.376	1.7
Maneb	1.020	0.183	1.6
Mefenoxam	0.070	0.108	1.0
Metalaxyl	0.130	0.043	3.3

estimated from (NASS, 2006; NASS, 2005; NASS, 2004; NCFAP, 1997; APHIS, 2002; Txbollweevil.org, 2006)

Table A5. Soil half-life values.

	Soil Half-Life Values		Reference Soil Half-Life Values (Days)			
	Sensitivity Analysis Half-Life Values	Soil Half-Life Values Used in Model	Soil (PIP, accessed 2007)	Aerobic Soil (PAN, accessed 2007)	Anaerobic Soil (PAN, accessed 2007)	Reference (When PIP or PAN values were unavailable)
Herbicides						
2,4-D dimeth. salt	34	34	7	34.0	333.0	
Alachlor	20	20	8	20.0	5.00	
Atrazine	365	146	>365	146.0	159.0	
Bensulide	432	180	120-180	432.0	1890	
Bromoxynil	14	10	10-14			
Carfentrazone-ethyl	0.58	0.58		0.58	0.55	
Clethodim	3	3	3	3.00	191.0	
DCPA	30.3	30.3		30.3		
Dicamba	28	10	7-28	10.0	88.0	
Dimethenamid	20	20	20*	(general half-life)		(Hartzler, 2002)
Diuron	372	372	30-365	372.0	995.0	
Fluometuron	171	10.9	12-171	10.9	28.6	
Glufosinate-ammonium	20	20		20.0		
Glyphosate	174	47	1-174,47			
Glyphosate iso. Salt	96	96		96.0	22.0	
Metsulfuron-methyl	180	24	14-180	24.0	338.1	
Oxyfluorfen	434.5	180	30-40,180	434.5	603.0	
Pendimethalin	1320	40	40	1320	60.0	
Prometryn	440	274	30-90, 360-440	274.0	316.0	
Prosulfuron	10	10	10*			(Vogue et al. 1994)
Pyraflufen-ethyl	496	71	1-71,7*	16-496*	191-392*	(SANCO, 2002)
Pyrithiobac-sodium	60	60		60.0	60.0	
S-Metolachlor	70	38.4	15-70	38.4	60.5	
Trifluralin	240	168.7	45-240	168.7	37.3	
Insecticides						
Acephate	6	3	3-6	3.00	6.00	
Acetamiprid	18	8.2	<18*	8.2*		(U.S. EPA, accessed 2006b)
Aldicarb	2	2		2.00	2.00	
Bacillus thuringiensin	120	120	120			
Carbaryl	28	6	7-28	6.00	87.0	
Carbofuran	120	22	30-120	22.0	20.0	
Chlorpyrifos	365	113.3	14-365	113.3	135.5	
Cyfluthrin	63	59.5	2-63	59.5	33.6	
Cypermethrin	1103	56	4-56	1103	94.2	
Diazinon	40	40	14-28	40.0	16.0	
Dicrotophos	5	5		5.00		
Dimethoate	122	2	4-122, 20	2.00	22.0	
Disulfoton	7	2	7	2.00		
Endosulfan	50	31.5	50	31.5	147.5	
Esfenvalerate	105	105	15-90	105.0		
Ethyl Parathion	14	14	14*			(USDA, accessed 2006b)
Imidacloprid	997	190	48-190	997.0	27.0	
Indoxacarb	693	300		3-693*	147-233*	(U.S. EPA, accessed 2006b)
Lambda cyhalothrin	84	61.8	28-84	61.8	128.0	
Malathion	25	2	1-25	2.00	30.0	
Methomyl	46	46	14	46.0	1.00	
Oxamyl	20	10.7	4-20	10.7	5.63	
Permethrin	38	25.1	30-38	25.1	50.0	
Spinosad	17.3	9.4	0.3-0.5*	9.4-17.3*	161-250* (anaerobic water)	(U.S. EPA, accessed 2006b)
Terbufos	30	5	5-30			
Thiamethoxam	353	294		294-353*	15-24*	(NRA, 2001)
Zeta-cypermethrin**	1103	56	4-56	1103	94.2	Used values for cypermethrin
Growth Regulators /Defoliants						
Bacillus cereus	120	120	120**			used values for Bacillus thuringiensin
Cyclanilide	114	95	35-114*	95*	does not degrade*	(U.S. EPA, accessed 2006b)
Ethephon	7.5	7.5		7.50	5.30	
Mepiquat Chloride	39	39		39.0	359.0	
Mepiquat Pentaborate	39	39		39**	359**	no data, used values for mepiquat chloride
Monocarbamide dihyd.	22.3	22.3		22.3**	201**	used values for siduron for all except water 1/2 life
Paraquat	4680	620	480-4680	620.0	644.0	
Thidiazuron	144	75		26-144*	<30*	(USDA, accessed 2006a)
Tribufos	745	745		745.0	221.6	
Fungicides						
Azoxystrobin	112	112		112.0	119.0	
Benzoic acid	28	10	7-28**	10**	88**	used values for dicamba
Chlorothalonil	90	35	30-90	35.0	8.00	
Copper hydroxide						does not degrade
Iprodione	64	64	7-60	64.0	32.0	
Mancozeb	7.56	7.56	1-7	7.56	2.00	
Maneb	36	24	12-36			(U.S. EPA, 2005b)
Mefenoxam***	170	62	7-170,70	62.0	68.0	*** = mefenoxam and metalaxyl are two names for the same fungicide
Metalaxyl***	170	62	7-170,70	62.0	68.0	*** = mefenoxam and metalaxyl are two names for the same fungicide

* = values obtained from a source other than PIP or PAN

** = values estimated from a similar chemical

Table A6. Vertebrate and invertebrate half-life values.

Half-Life Values Used in Model (Days)				
	Classification	Vertebrate		Invertebrate*****
Herbicides				
2,4-D dimeth. salt	phenoxy	0.833	*	3.4
Alachlor	amide	3	**	3
Atrazine	triazine	1.2	**	14.6
Bensulide	organophosphorous	2.62	****	18
Bromoxynil	nitrile	2.8	**	2.8
Carfentrazone-ethyl	triazolone	2	***	2
Clethodim	cyclohexene oxime	1.05	****	1.05
DCPA	aromatic acid	1.5	**	3.03
Dicamba	aromatic acid	0.75	**	1
Dimethenamid	amide	20	**	20
Diuron	urea	2.83	****	37.2
Fluometuron	urea	2	**	2
Glufosinate-ammonium	organophosphorous	1.9	****	2
Glyphosate	organophosphorous	3	**	4.7
Glyphosate iso. Salt	organophosphorous	2.43	****	9.6
Metsulfuron-methyl	urea	1.2083	*	2.4
Oxyfluorfen	diphenyl ether	10	***	18
Pendimethalin	dinitroaniline	1.3	**	4
Prometryn	triazine	0.6	**	27.4
Prosulfuron	urea	1.62	****	1.62
Pyraflufen-ethyl	pyrazole	2.33	****	7.1
Pyrithiobac-sodium	aromatic acid	2.27	****	6
S-Metolachlor	amide	1.25	**	3.84
Trifluralin	dinitroaniline	2.6	****	16.87
Insecticides				
Acephate	organophosphate	1.05	****	1.05
Acetamiprid	nicotinoid	1.54	****	1.54
Aldicarb	carbamate	0.4	**	0.4
Bacillus thuringiensin	antibiotic	2.49	****	12
Carbaryl	carbamate	0.4	**	0.6
Carbofuran	carbamate	0.25	**	2.2
Chlorpyrifos	organophosphate	2.583	*	11.33
Cyfluthrin	pyrethroid	0.6	**	5.95
Cypermethrin	pyrethroid	18	*	18
Diazinon	organophosphate	0.5	*	4
Dicrotophos	organophosphate	0.3	**	0.5
Dimethoate	organophosphate	0.3	**	0.3
Disulfoton	organophosphate	1.333	*	1.333
Endosulfan	organochlorine	21.00	*	21
Esfenvalerate	pyrethroid	14	*	14
Ethyl Parathion	organophosphate	1.76	****	1.76
Imidacloprid	nicotinoid	2	*	19
Indoxacarb	oxadiazine	10	****	30
Lambda cyhalothrin	pyrethroid	10	***	10
Malathion	organophosphate	2	*	2
Methomyl	carbamate	2.19	****	4.6
Oxamyl	carbamate	1.65	****	1.65
Permethrin	pyrethroid	5	*	5
Spinosad	antibiotic	1.6	****	1.6
Terbufos	organophosphate	2.8	**	2.8
Thiamethoxam	nicotinoid	2.76	****	29.4
Zeta-cypermethrin	pyrethroid	18	*	18
Growth Regulators/Defoliants				
Bacillus cereus	soil bacterium/ growth regulator	2.49	****	12
Cyclanilide	unclassified plant growth regulator	2.42	****	9.5
Ethephon	defoliant, ethylene releaser	1.5	****	1.5
Mepiquat Chloride	growth inhibitor	2.13	****	3.9
Mepiquat Pentaborate	growth inhibitor	2.13	****	3.9
Monocarbamide dihyd.	herbicide/dessicant	1.94	****	2.23
Paraquat	quaternary ammonium herbicide	1	**	62
Thidiazuron	urea herbicide, defoliant	2.34	****	7.5
Tribufos	defoliant	3.01	****	74.5
Fungicides				
Azoxystrobin	antibiotic	2.47	****	11.2
Benzoic acid	triforine	1.62	****	1.62
Chlorothalonil	aromatic	1	*	3.5
Copper hydroxide	inorganic, copper	10	***	10
Iprodione	dicarboximide,imidozole	2.3	****	6.4
Mancozeb	dithiocarbamate	4	*	4
Maneb	dithiocarbamate	5	*	5
Mefenoxam	triforine	2.29	****	6.2
Metalaxyl	triforine	2.29	****	6.2

* = actual half life value from PIP, accessed 2007

** = estimated half life value from PIP, accessed 2007

*** = used value from a chemical with a similar chlassification

**** = fit values (* & **) to a trend line based on mammal metabolism rates vs soil half-life ($y = 1.624x^{0.5865}$) and used to estimate unknown values

***** = invertebrate 1/2 life values were estimated as (1/10 soil 1/2 life, unless vertebrate 1/2 life wass greater, then the vertebrate 1/2 life value was used

Table A7. Dermal toxicity index.

	DTI values used in model	Actual DTI Values **	Fred-EPA(Fite et al., 2004)***
Herbicides			
2,4-D dimeth. salt	1.533		1.533
Alachlor	2.349		2.349
Atrazine	3.454		3.454
Bensulide	2.259		2.259
Bromoxynil	1.116		1.116
Carfentrazone-ethyl	2.715		2.715
Clethodim	2.597		2.597
DCPA	2.715		2.715
Dicamba	2.597		2.597
Dimethenamid	2.550		2.550
Diuron	2.457		2.457
Fluometuron	3.019		3.019
Glufosinate-ammonium	2.597		2.597
Glyphosate	2.597		2.597
Metsulfuron-methyl	2.831		2.831
Oxyfluorfen	2.692		2.692
Pendimethalin	2.280		2.280
Prometryn	2.669		2.669
Prosulfuron	1.995		1.995
Pyraflufen-ethyl	2.597		2.597
Pyrithiobac-sodium	2.385		2.385
S-Metolachlor	2.597		2.597
Trifluralin	2.597		2.597
Insecticides			
Acephate	1.339		1.339
Acetamiprid	0.825		0.825
Aldicarb	0.057	0.057	0.230
Bacillus thuringiensin	3.678		3.678
Carbaryl	2.706		2.706
Carbofuran	0.013	0.013, 0.0042	0.099
Chlorpyrifos	1.522		1.522
Cyfluthrin	2.597		2.597
Cypermethrin	4.786		4.786
Diazinon	0.245		0.245
Dicrotophos	2.330	0.299, 2.33, 1	0.342
Dimethoate	0.597		0.597
Disulfoton	10.000	0.034, 10, 3.2	0.582
Endosulfan	0.865		0.865
Esfenvalerate	2.212		2.212
Ethyl Parathion	1.000	0.083, 0.722, 1	0.192
Imidacloprid	0.975		0.975
Indoxacarb	0.825		0.825
Lambda cyhalothrin	3.363		3.363
Malathion	2.319		2.319
Methomyl	0.414		0.414
Oxamyl	0.224		0.224
Permethrin	4.750		4.750
Spinosad	1.082		1.082
Terbufos	1.051		1.051
Thiamethoxam	1.618		1.618
Zeta-cypermethrin	4.831		4.831
Methyl parathion	1.129	1.129	0.319
Growth Regulators/Defoliants			
Bacillus cereus*	3.678		
Cyclanilide	1.115		1.115
Ethephon	2.049		2.049
Mepiquat Chloride	2.221		2.221
Mepiquat Pentaborate	2.221		2.221
Monocarbamide dihyd.*	2.000		
Paraquat	0.332	0.332	1.981
Thidiazuron	5.722		5.722
Tribufos	0.950		0.950
Fungicides			
Azoxystrobin	1.995		1.995
Benzoic acid*	2.000		
Chlorothalonil	3.575		3.575
Copper hydroxide	3.177		3.177
Iprodione	2.597		2.597
Mancozeb	4.040		4.040
Maneb	4.786		4.786
Metalaxyl	1.935		1.935

* = not enough data to complete equation, values are based on similar chemicals

** = Dermal to Oral Toxicity Indexes based on LD50 values from Hudson et al. (1979), or Schafer et al. (1973)

*** = EPA equation used to estimate a dermal route equivalency factor based on the avian oral LD50

Table A8. Dose-response curve equations used to estimate ChE inhibition from exposure to OP or CB insecticides.

Insecticides	Classification	Avian LD50	ChE Equation	Species	References
Acephate	organophosphate	350	y = 4E-06x3 - 0.0047x2 + 1.2402x	dark-eyed junco, American kestrel, chicken	(Wilson et al.,1990; Rudolph et al.,1984; Zinkl et al.,1981)
Aldicarb	carbamate	3.4	used ethyl parathion		
Carbaryl	carbamate	2230	y = 2E-08x3 - 0.0001x2 + 0.1716x based on dermal or injection	japanese quail, chicken	(Hill,1979; Ehrich et al.,1992; Ehrich et al.,1995)
Carbofuran	carbamate	0.37	y = 0.0302x3 - 1.6574x2 + 21.303x	japanese quail, chicken	(Dieter and Ludke,1978; Hill 1989a; Hill 1989b; Martin et al.,1991; Vyas et al.,1998)
Chlorpyrifos	organophosphate	490	y = 0.008x3 - 0.0909x2 + 3.0134x	japanese quail, chicken	(Soler,Rodriguez et al.,1998; Thompson et al.,1991)
Diazinon	organophosphate	4	y = 3E-06x3 - 0.0031x2 + 0.7415x	japanese quail, chicken	(Henderson et al.,1994; Wolfe and Kendall,1998; Abdelsalam,1999)
Dicrotophos	organophosphate	9.63	y = 18.889x3 - 117.45x2 + 202.63x	japanese quail, chicken	(Fleming and Grue,1981)
Dimethoate	organophosphate	41.7	y = 0.0056x3 - 0.4149x2 + 9.3325x	japanese quail, chicken	(Radvanyi et al.,1986)
Disulfoton	organophosphate	39	used dimethoate		
Ethyl Parathion	organophosphate	2.1	y = 0.3594x3 - 6.1999x2 + 32.655x	American kestrel, laughing gull, red-winged blackbird	(Fleming et al.,1982; Nicolaus and Lee,1999)
Malathion	organophosphate	1485	y = -4E-06x2 + 0.0641x	mallard	(Fleming and Bradbury,1981)
Methomyl	carbamate	15.9	used dicrotophos		
Oxamyl	carbamate	3.16	used ethyl parathion		
Terbufos	organophosphate	185	y = 0.0403x3 - 2.0137x2 + 25.912x	European starling, red-winged blackbird (removed adult eust)	(Wolfe and Kendall,1998)
Methyl Parathion	organophosphate	8	y = 1.1068x3 - 14.47x2 + 54.114x	American kestrel	(Rattner and Franson, 1984)

Table A9. LOEL values.

	Lowest LELor LOEL (mg/kg)	References
Herbicides		
2,4-D dimeth. salt	5	Keith (1997)
Alachlor	3	Keith (1997)
Atrazine	70	Keith (1997)
Bensulide	15	(U.S. EPA, 1999c)
Bromoxynil	30	(U.S. EPA, accessed 2007)
Carfentrazone-ethyl	110	(U.S. EPA, 1998b)
Clethodim	75	(U.S. EPA, 1995)
DCPA	10	(U.S. EPA, accessed 2007)
Dicamba	10	(U.S. EPA, accessed 2007)
Dimethenamid	33	(U.S. EPA, 2004a)
Diuron	3.125	(U.S. EPA, accessed 2007)
Fluometuron	50	(U.S. EPA, accessed 2007)
Glufosinate-ammonium	1.6	(U.S. EPA, accessed 2007)
Glyphosate	30	(U.S. EPA, accessed 2007)
Metsulfuron-methyl	100	(U.S. EPA, accessed 2007)
Oxyfluorfen	3	(U.S. EPA, accessed 2007)
Pendimethalin	50	(U.S. EPA, accessed 2007)
Prometryn	37.5	(U.S. EPA, accessed 2007)
Prosulfuron	250	(U.S. EPA, 2002c)
Pyraflufen-ethyl	60	(U.S. EPA, 2003)
Pyrithiobac-sodium	31.8	(U.S. EPA, 2002d)
S-Metolachlor	15	Keith (1997)
Trifluralin	3.75	Keith (1997)
Insecticides		
Acephate	0.25	(U.S. EPA, accessed 2007)
Acetamiprid	17.5	(U.S. EPA, accessed 2006a)
Aldicarb	0.01	Keith (1997)
Bacillus thuringiensin	???	
Carbaryl	5	Keith (1997)
Carbofuran	5	(U.S. EPA, accessed 2007)
Chlorpyrifos	0.1	Keith (1997)
Cyfluthrin	6.2	(U.S. EPA, 1999b)
Cypermethrin	5	Keith (1997)
Diazinon	5	(U.S. EPA, 2004b)
Dicrotophos*	1.5	(U.S. EPA, 2002a)
Dimethoate	0.25	(U.S. EPA, accessed 2007)
Disulfoton	0.05	(U.S. EPA, accessed 2007)
Endosulfan	0.27	Keith (1997)
Esfenvalerate	2.5	(U.S. EPA, 1998a)
Ethyl Parathion	0.01	(U.S. EPA, 2000c)
Imidacloprid	16.9	(U.S. 2001)
Indoxacarb	3.6	(U.S. EPA, accessed 2006a)
Lambda cyhalothrin	0.5	(U.S. EPA, 1997a)
Malathion	0.34	Keith (1997)
Methomyl	10	Keith (1997)
Oxamyl	3.75	(U.S. EPA, accessed 2007)
Permethrin	25	(U.S. EPA, accessed 2007)
Spinosad	8.22	(U.S. EPA, accessed 2006a)
Terbufos	0.25	(U.S. EPA, accessed 2006d)
Thiamethoxam	1.8	(U.S. EPA, 2005c)
Zeta-cypermethrin	5	(U.S. EPA, 1997c)
Growth Regulators/Defoliants		
Bacillus cereus	???	
Cyclanilide	2	(U.S. EPA, 1997b)
Ethephon	0.5	(U.S. EPA, accessed 2007)
Mepiquat Chloride	75	(U.S. EPA, accessed 2007)
Mepiquat Pentaborate	75	used mepiquat chloride values (U.S. EPA, 2002b)
Monocarbamide dihyd.	???	?????- EPA does not require tolerance tests
Paraquat	0.93	(U.S. EPA, accessed 2007)
Thidiazuron	???	?????- EPA does not require tolerance tests
Tribufos	7	(U.S. EPA, 2000b)
Fungicides		
Azoxystrobin	34	(U.S. EPA, 1999a)
Benzoic acid	40	(U.S. EPA, accessed 2007)
Chlorothalonil	3	(U.S. EPA, accessed 2007)
Copper hydroxide	289	(U.S. EPA, 2006c)
Iprodione	15	(U.S. EPA, accessed 2007)
Mancozeb	17.2	(U.S. EPA, 2005a)
Maneb	2	(U.S. EPA, accessed 2007)
Metalaxyl	25	(U.S. EPA, accessed 2007)

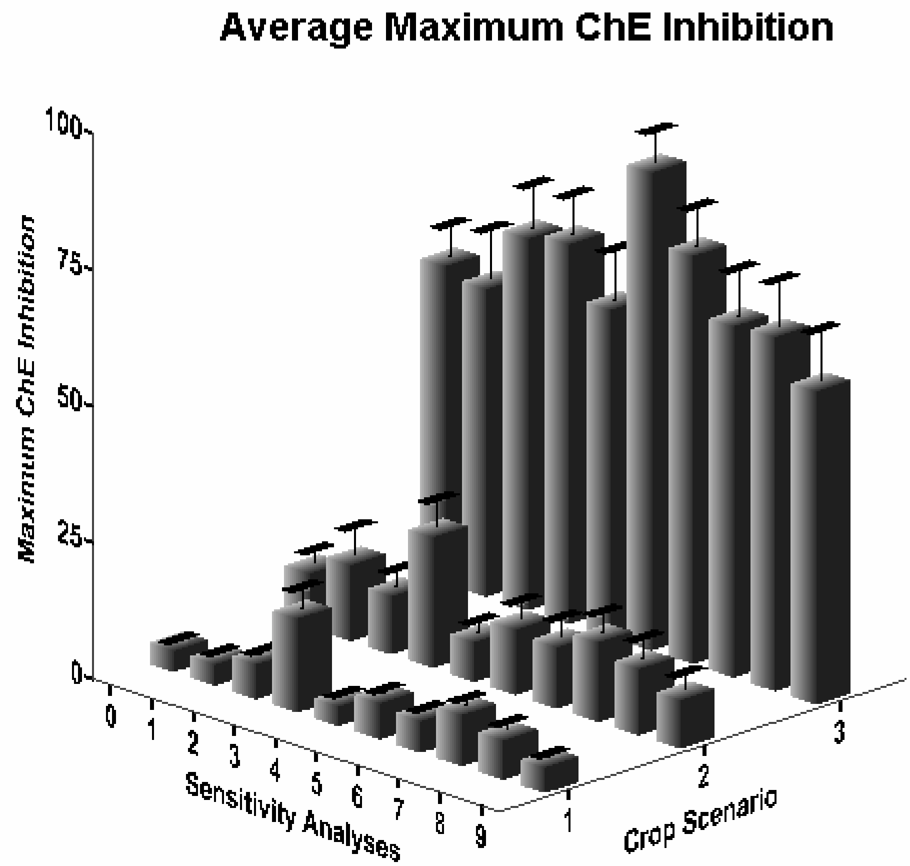
Table A10. Avian HD5 values.

	Avian Oral LD50* (mg/kg)	Avian HD5 Values Used in Model**** (mg/kg)	Avian HD5** (mg/kg)	Predicted Avian HD5*** (mg/kg)
Herbicides				
2,4-D dimeth. salt	500	132.90	132.9	48.48
Alachlor	1536	330.42	330.42	135.13
Atrazine	4237	408.98	408.98	341.37
Bensulide	1386	160.98	160.98	123.03
Bromoxynil	217	21.68	21.68	22.62
Carfentrazone-ethyl	2250	191.50		191.50
Clethodim	2000	232.29	232.29	171.97
DCPA	2250	191.50		191.50
Dicamba	2000	62.26	62.26	171.97
Dimethenamid	1908	221.60	221.6	164.73
Diuron	1730	193.04	193.04	150.64
Fluometuron	2974	192.68	192.68	247.08
Glufosinate-ammonium	2000	232.29	232.29	171.97
Glyphosate	2000	232.29	232.29	171.97
Metsulfuron-methyl	2510	261.19	261.19	211.62
Oxyfluorfen	2200	614.58	614.58	187.61
Pendimethalin	1421	125.86		125.86
Prometryn	2150	183.72		183.72
Prosulfuron	1000	159.59	159.59	91.31
Pyraflufen-ethyl	2000	171.97		171.97
Pyrithiobac-sodium	1599	185.71	185.71	140.19
S-Metolachlor	2000	241.81	241.81	171.97
Trifluralin	2000	245.55	245.55	171.97
Insecticides				
Acephate	350	18.52	18.52	35.00
Acetamiprid	98	20.91	20.91	10.95
Aldicarb	3.4	0.43	0.43	0.51
Bacillus thuringiensin	5000	397.10		397.10
Carbaryl	2230	30.05	30.05	189.95
Carbofuran	0.37	0.21	0.21	0.07
Chlorpyrifos	490	3.76	3.76	47.60
Cyfluthrin	2000	485.44	485.44	171.97
Cypermethrin	10000	579.15	579.15	747.88
Diazinon	4	0.59	0.59	0.59
Dicrotophos	9.63	0.42	0.42	1.32
Dimethoate	41.7	5.78	5.78	5.02
Disulfoton	39	0.81	0.81	4.72
Endosulfan	111	9.53	9.53	12.26
Esfenvalerate	1312	131.24	131.24	117.01
Ethyl Parathion	2.1	0.40	0.4	0.33
Imidacloprid	152	8.43	8.43	16.34
Indoxacarb	98	10.95		10.95
Lambda cyhalothrin	3950	428.14	428.14	320.19
Malathion	1485	139.10	139.1	131.03
Methomyl	15.9	8.46	8.46	2.08
Oxamyl	3.16	0.78	0.78	0.48
Permethrin	9800	3127.53	3127.53	734.21
Spinosad	200	21.00		21.00
Terbufos	185	0.16	0.16	19.55
Thiamethoxam	576	55.17		55.17
Zeta-cypermethrin	10248	764.80		764.80
Growth Regulators/Defoliants				
Bacillus cereus******	5000	397.10		397.10
Cyclanilide	216	22.42	22.42	22.53
Ethephon	1072	372.20	372.2	97.30
Mepiquat Chloride	1326	232.29	232.29	118.15
Mepiquat Pentaborate	1326	232.29		118.15
Monocarbamide dihyd.*****	775	72.35		72.35
Paraquat	981	88.50	88.5	89.73
Thidiazuron	16000	367.02	367.02	1148.82
Tribufos	142	51.13	51.13	15.36
Fungicides				
Azoxystrobin	1000	232.29	232.29	91.31
Benzoic acid*****	1700	148.25		148.25
Chlorothalonil	4640	193.05	193.05	370.90
Copper hydroxide	3400	219.11	219.11	279.21
Iprodione	2000	158.40	158.4	171.97
Mancozeb	6400	710.95	710.95	497.53
Maneb	10000	345.34	345.34	747.88
Metalaxyl	923	89.09	89.09	84.87

* = (Footprint, 2007; PIP, accessed 2007; DuPont, 2003)
** = Mineau et al. (2001)
*** = estimated HD5 from a trend line, (y = 0.1662x^0.9133), using HD5 values and LD50 values
**** = Used values from Mineau et al. (2001), unless no data was available then used HD5 estimated from trend line
***** = Mammalian LD50
****** = Used Bacillus thuringiensin

APPENDIX B

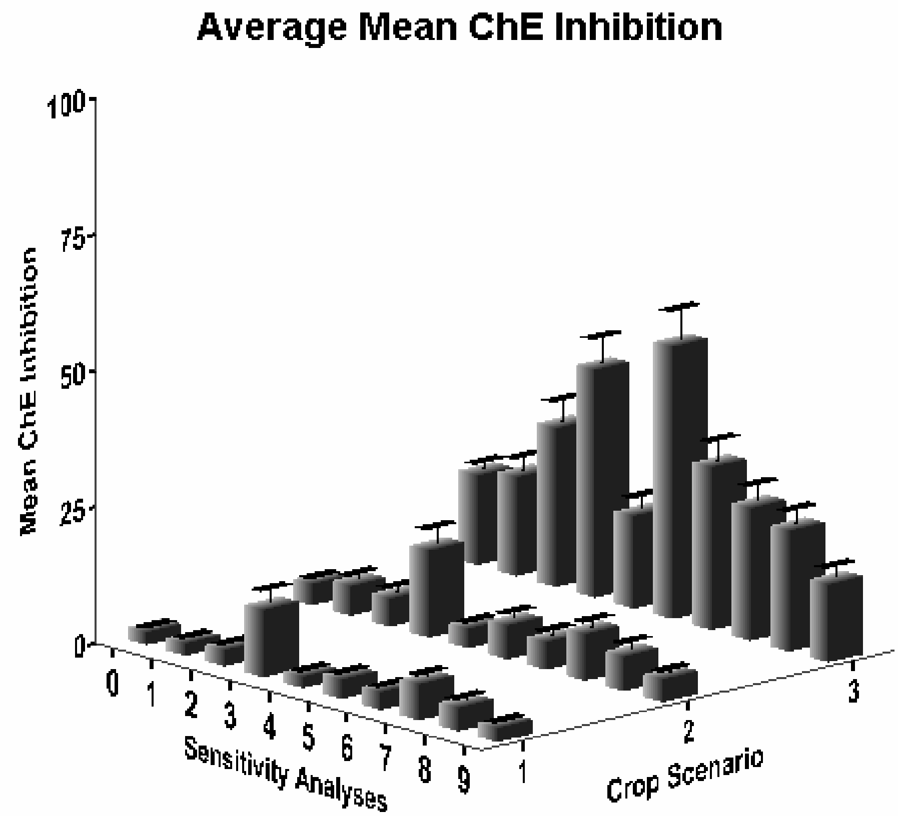
SENSITIVITY ANALYSES FIGURES AND TABLES



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

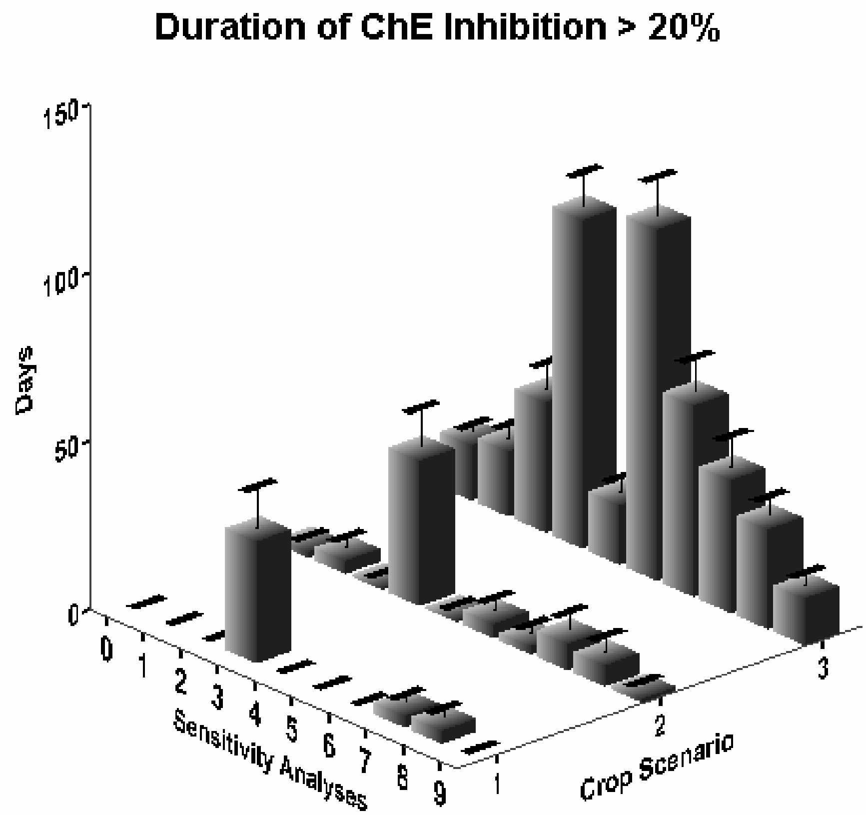
Figure B1a. Sensitivity Analyses: Changes in the average maximum ChE inhibition over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

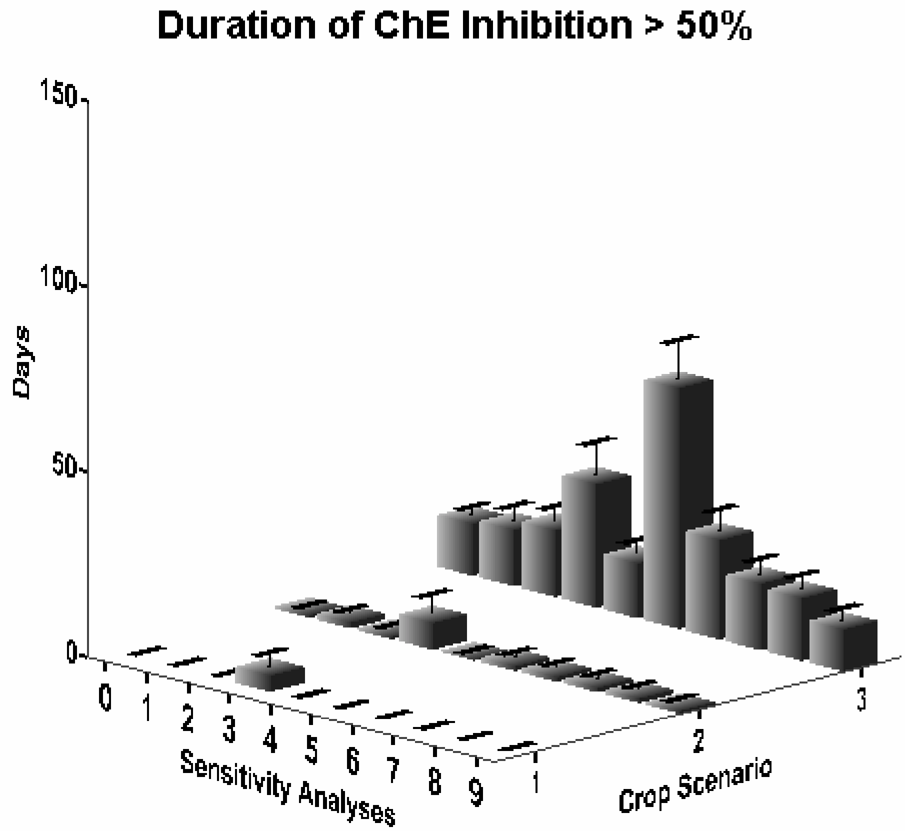
Figure B1b. Sensitivity Analyses: Changes in the average mean ChE inhibition over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

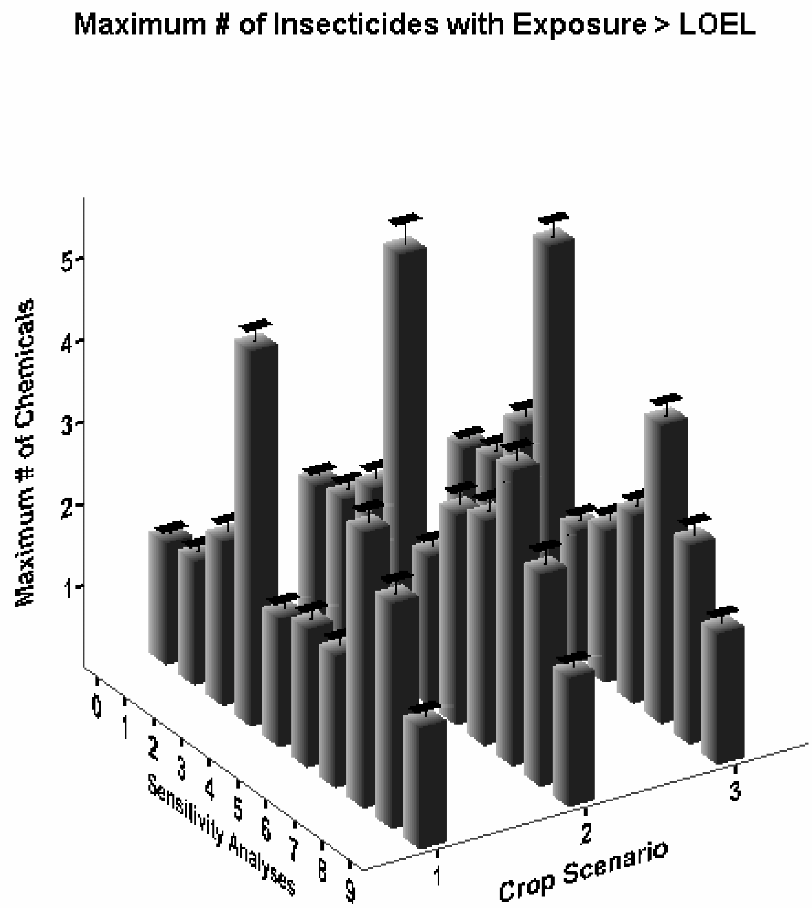
Figure B1c. Sensitivity Analyses: Changes in duration of ChE Inhibition > 20% over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

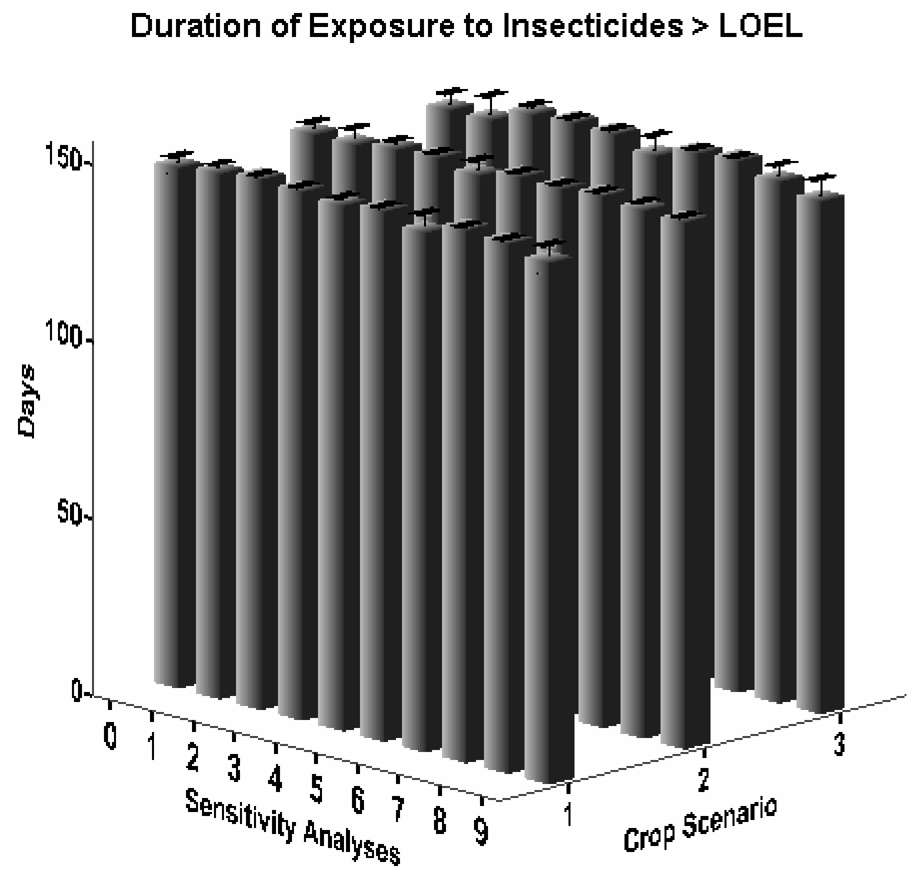
0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

Figure B1d. Sensitivity Analyses: Changes in duration of ChE Inhibition > 50% over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



<u>Sensitivity Analyses</u> **0= Baseline- no changes** **1= Increased soil in diet** **2= Increased dermal exposure during foraging** **3= Increased half-life in bird** **4= Decreased loss due to drift** **5= Increased half-life in insects** **6= Increased accumulation in prey** **7= Used highest soil half-life values** **8= Increased the dermal to oral toxicity indexes** **9= Allowed possible early spring spraying prior to owl departure**

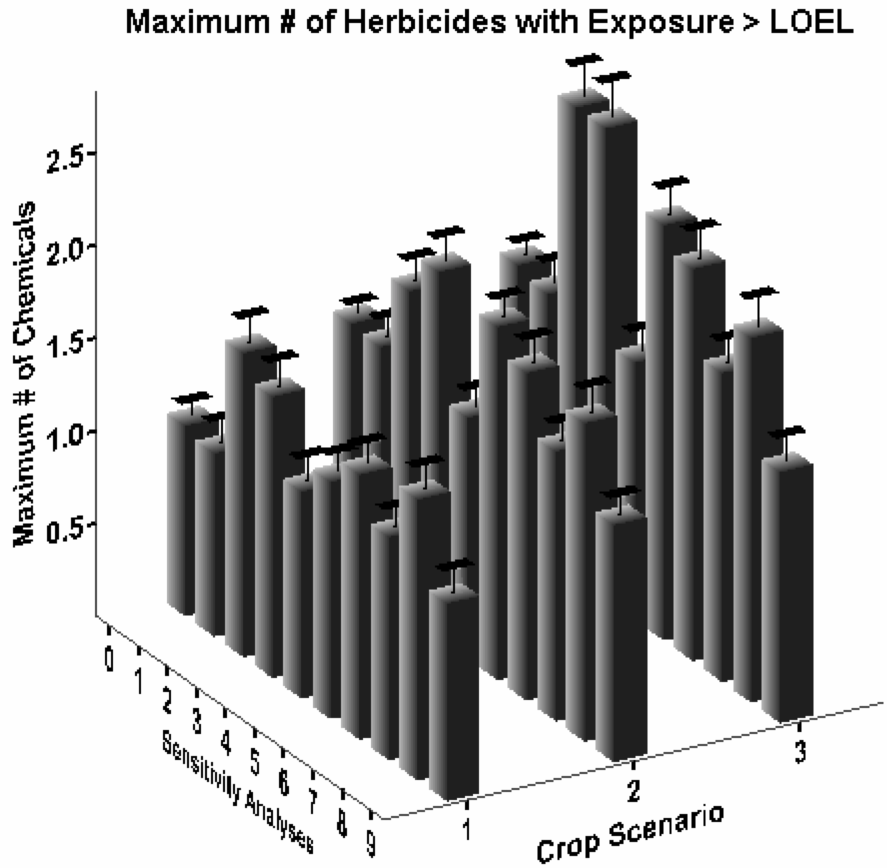
Figure B2a. Sensitivity Analyses: Changes in maximum # of insecticides the owl is exposed to > LOEL over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

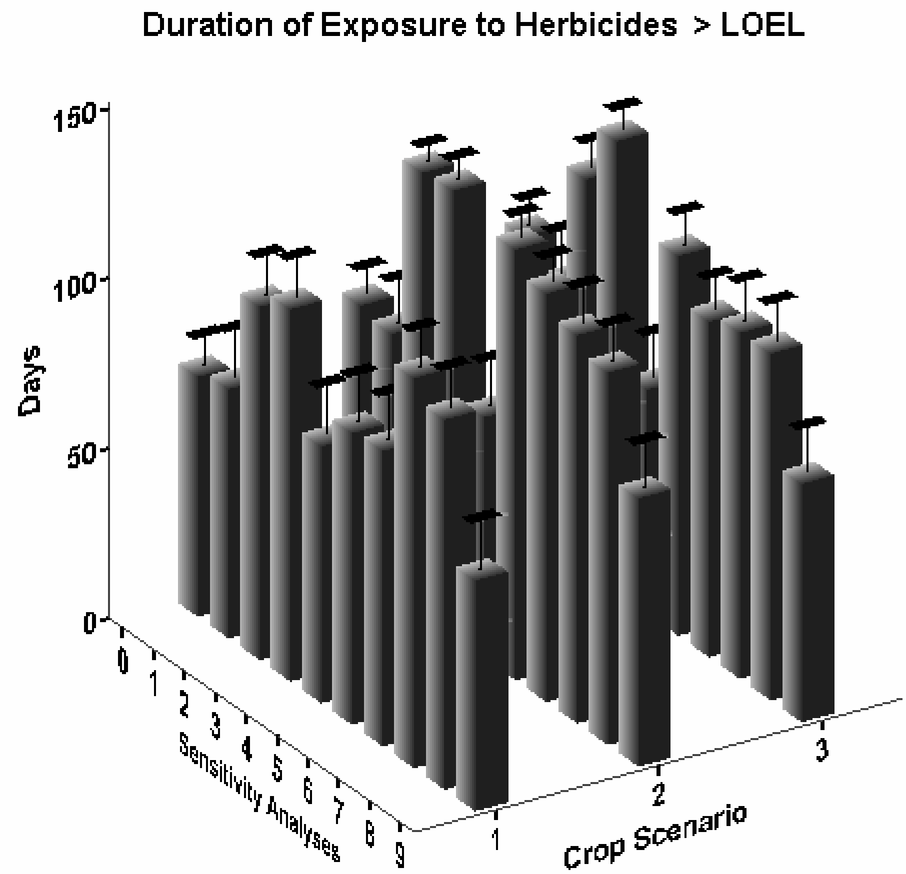
Figure B2b. Sensitivity Analyses: Changes in the duration of insecticide exposure > LOEL over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

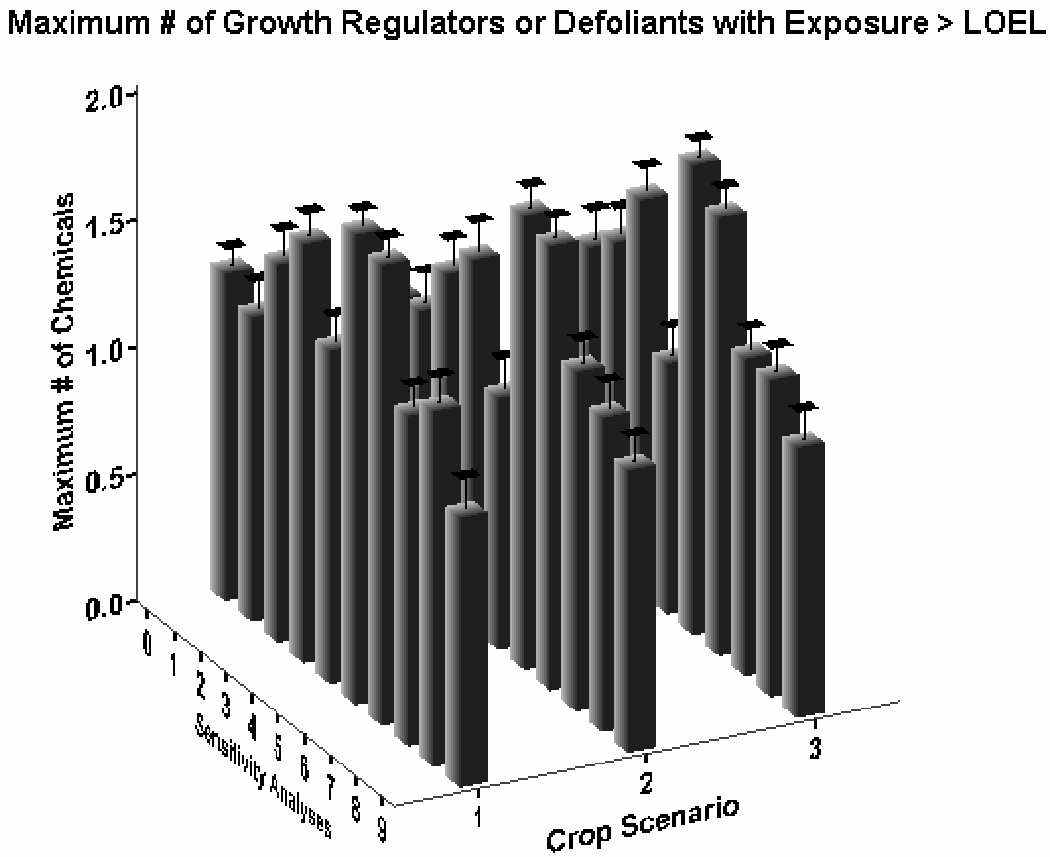
Figure B3a. Sensitivity Analyses: Changes in maximum # of herbicides the owl is exposed to > LOEL over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

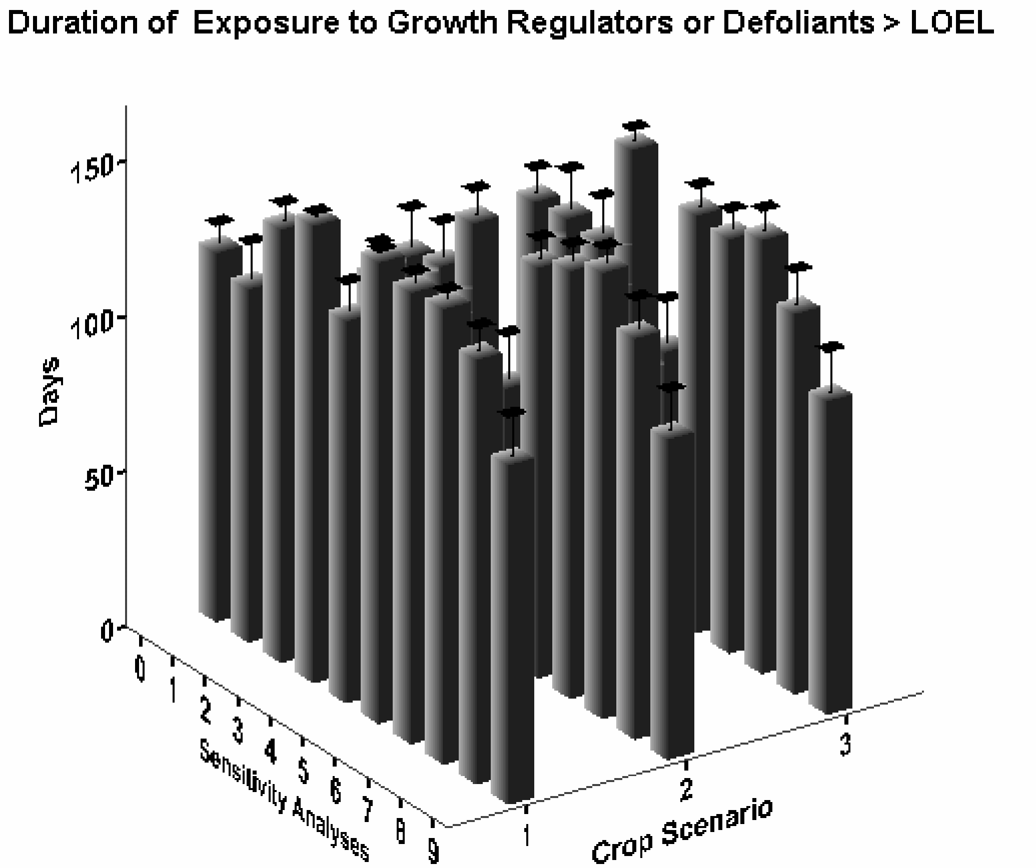
Figure B3b. Sensitivity Analyses: Changes in the duration of herbicide exposure > LOEL over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

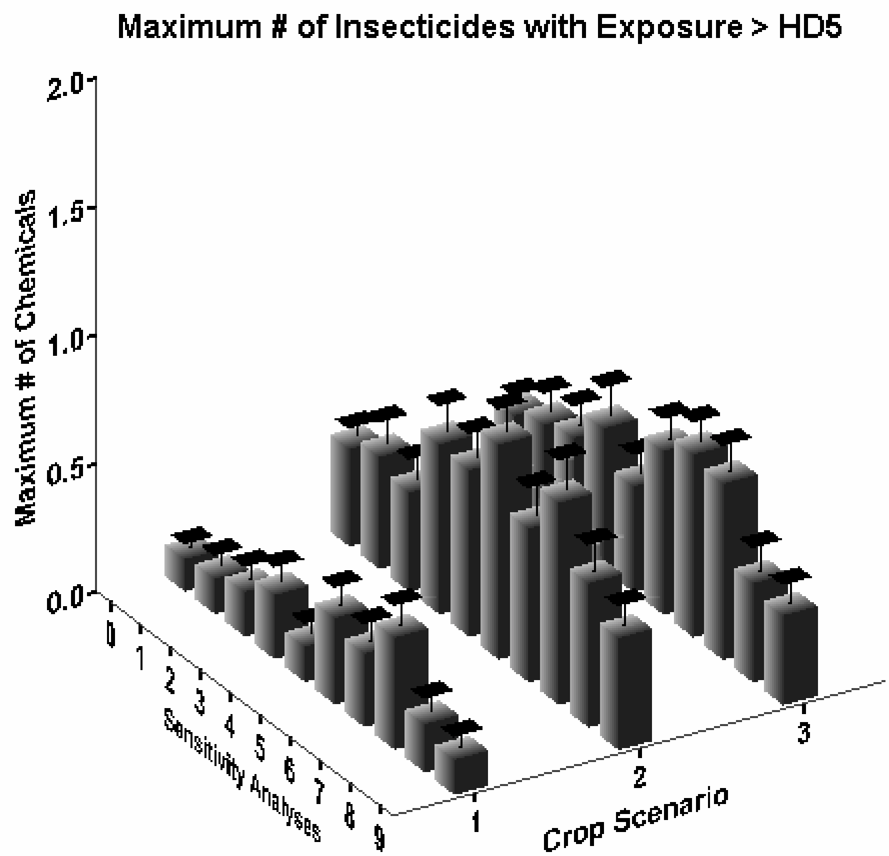
Figure B4a. Sensitivity Analyses: Changes in maximum # of growth regulators or defoliants the owl is exposed to > LOEL over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

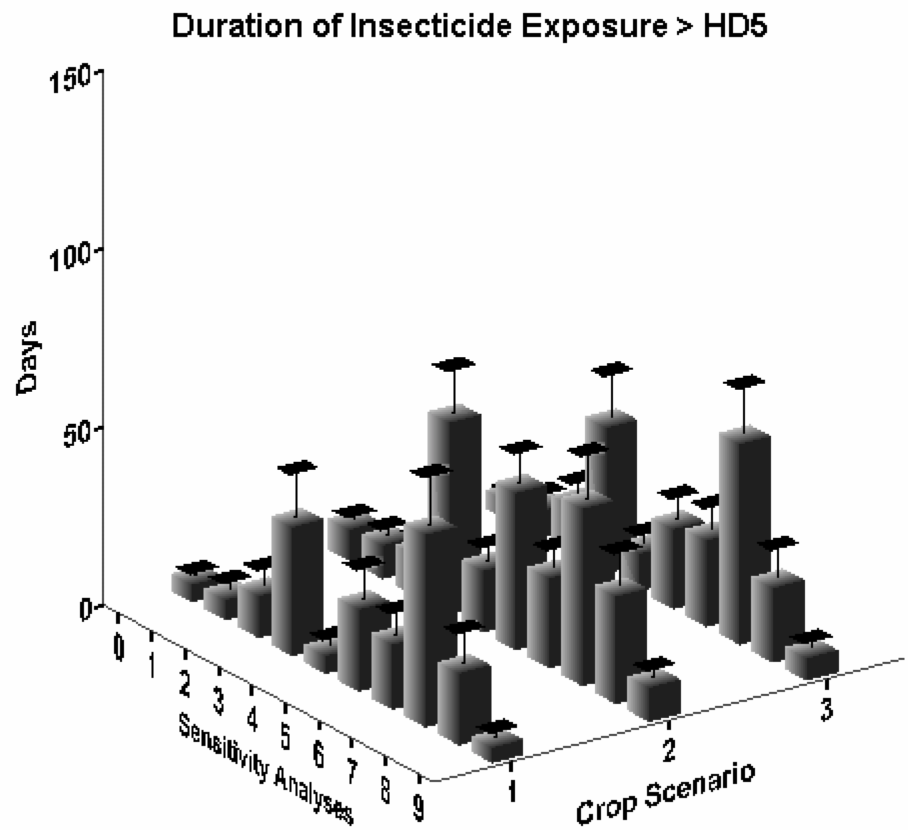
0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

Figure B4b. Sensitivity Analyses: Changes in the duration of growth regulator or defoliant exposure > LOEL over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses
0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

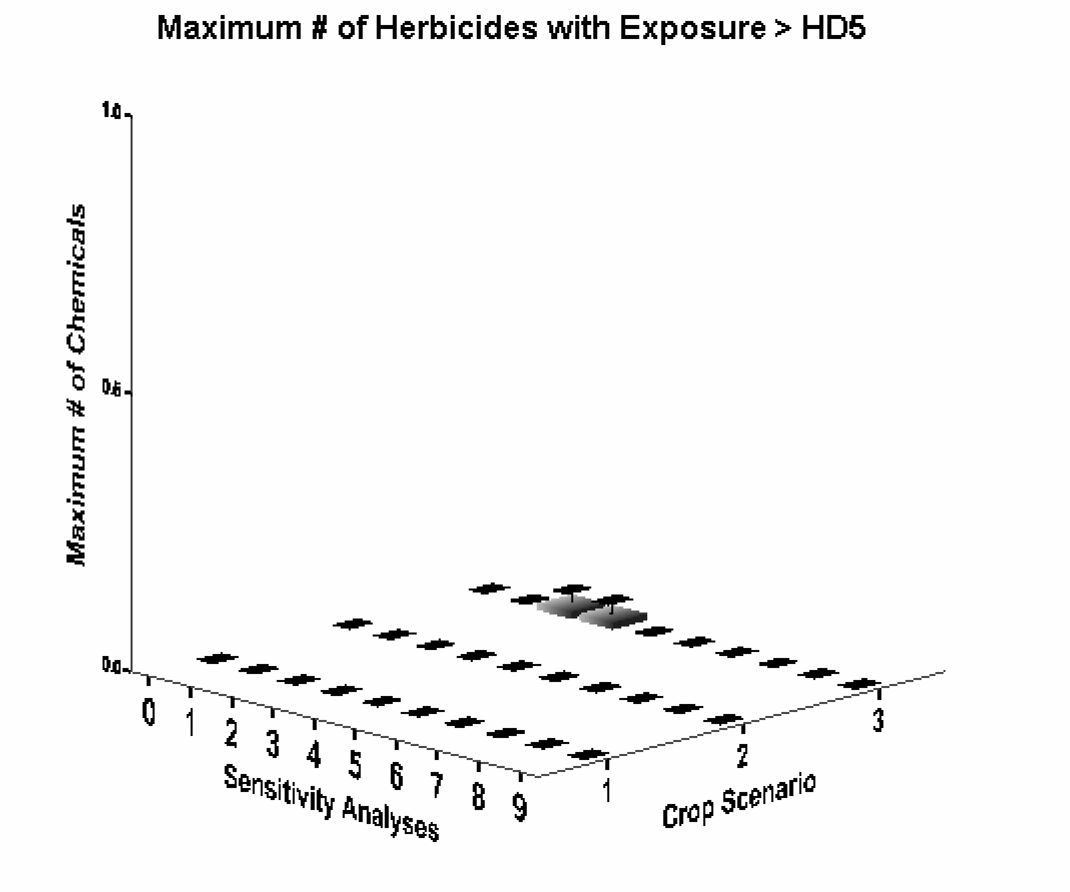
Figure B5a. Sensitivity Analyses: Changes in maximum # of insecticides the owl is exposed to > HD5 over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

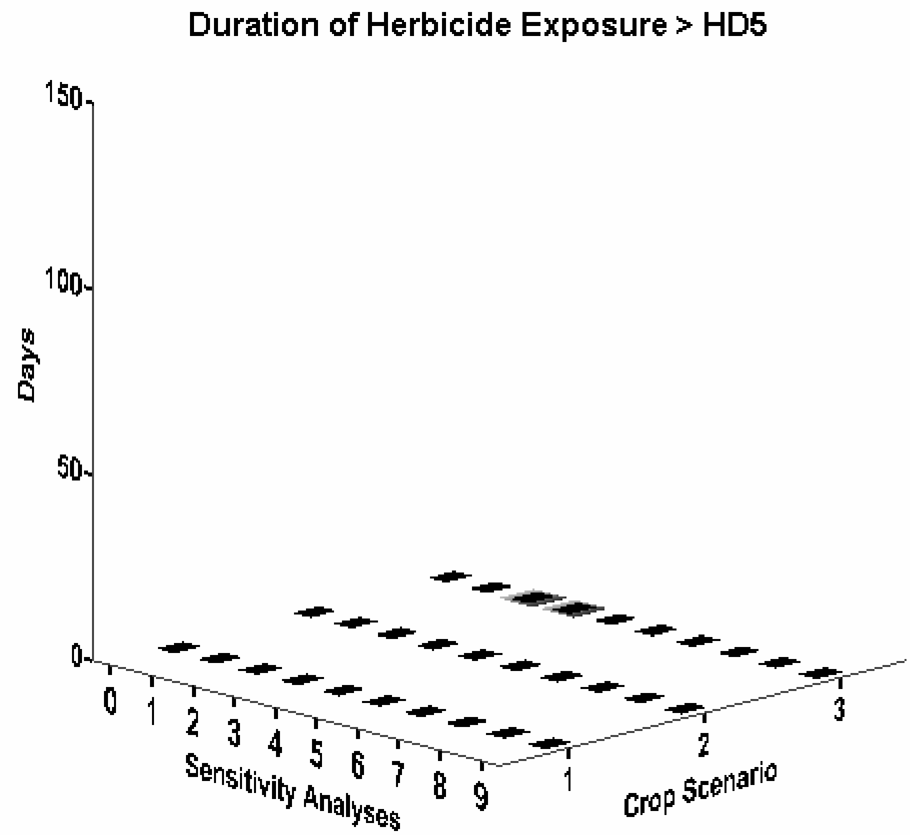
Figure B5b. Sensitivity Analyses: Changes in the duration of insecticide exposure > HD5 over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



<u>Sensitivity Analyses</u>

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

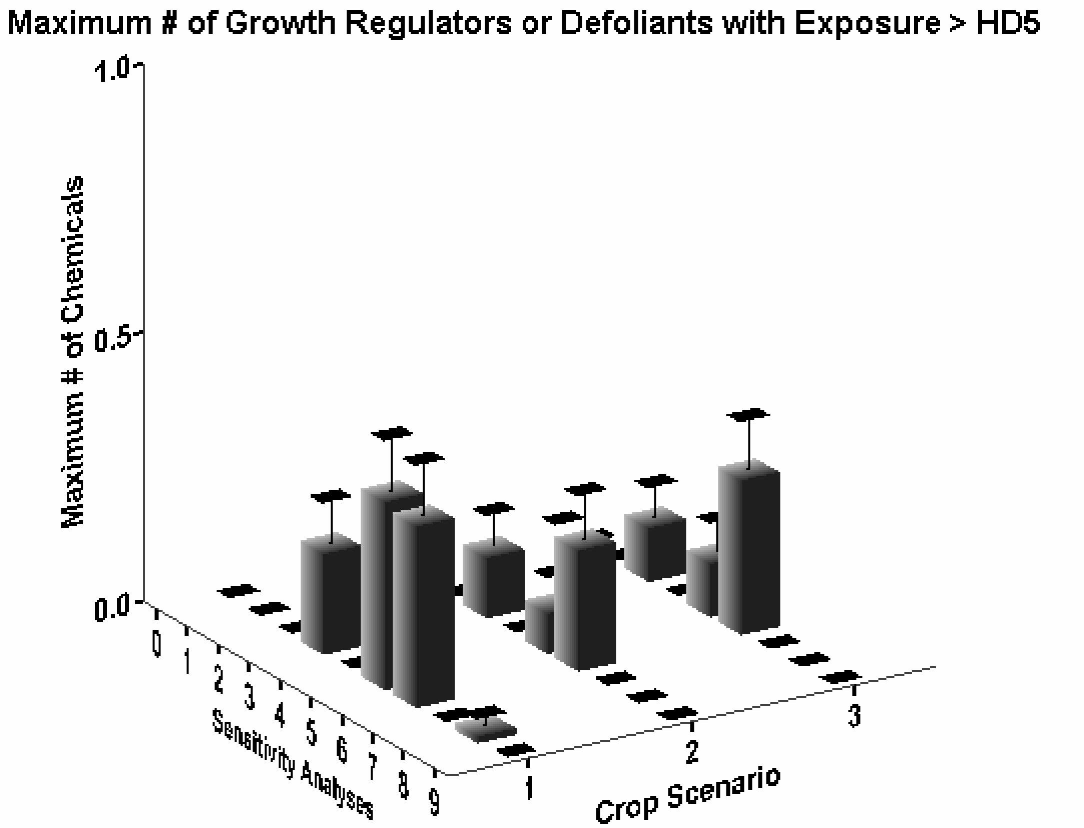
Figure B6a. Sensitivity Analyses: Changes in maximum # of herbicides the owl is exposed to > HD5 over the winter (Crop Scenario: 1- Cotton/Sorghum, 2-Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

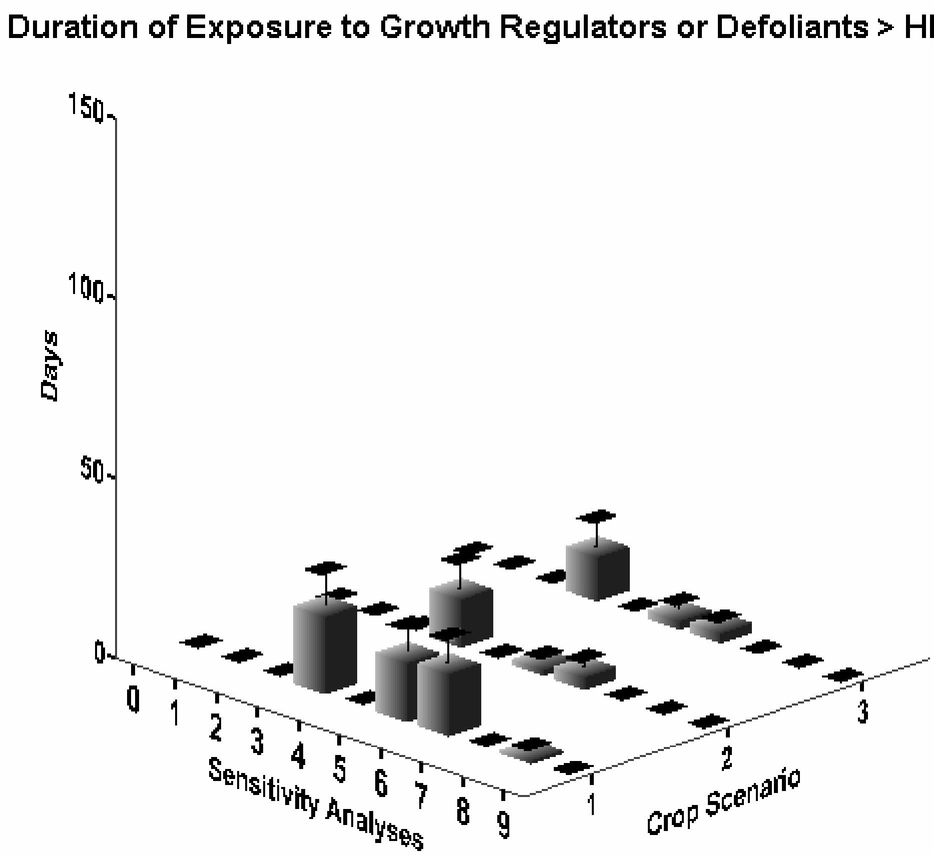
Figure B6b. Sensitivity Analyses: Changes in the duration of herbicide exposure > HD5 over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



<u>Sensitivity Analyses</u>

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

Figure B7a. Sensitivity Analyses: Changes in maximum # of growth regulators or defoliants the owl is exposed to > HD5 over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)



Sensitivity Analyses

0= Baseline- no changes
1= Increased soil in diet
2= Increased dermal exposure during foraging
3= Increased half-life in bird
4= Decreased loss due to drift
5= Increased half-life in insects
6= Increased accumulation in prey
7= Used highest soil half-life values
8= Increased the dermal to oral toxicity indexes
9= Allowed possible early spring spraying prior to owl departure

Figure B7b. Sensitivity Analyses: Changes in the duration of growth regulator or defoliant exposure > HD5 over the winter. (Crop Scenario: 1- Cotton/Sorghum, 2- Cotton/Sorghum/Cabbage, 3- Cotton/Sorghum/Onions)

Table B1a. Sensitivity Analyses: Changes in maximum ChE inhibition in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	3.90	3.73	200					
1.00- Soil in Diet	3.87	3.50	80	0.04	0.96	1.00	-3.12	3.19
2.00- Dermal Exposure Time	6.29	4.58	80	-2.39	0.96	0.61	-5.54	0.77
3.00- Half-life in Bird	17.15	19.03	80	-13.25(*)	0.96	0.00	-16.40	-10.09
4.00- Drift	3.62	3.71	80	0.28	0.96	1.00	-2.87	3.44
5.00- Insect Half-life	6.63	4.53	80	-2.73	0.96	0.22	-5.88	0.43
6.00- Accumulation in Prey	5.83	3.79	80	-1.93	0.96	1.00	-5.09	1.23
7.00- Soil Half-life	9.39	6.99	80	-5.49(*)	0.96	0.00	-8.64	-2.33
8.00- Dermal to Oral Toxicity	7.23	8.03	80	-3.32(*)	0.96	0.03	-6.48	-0.17
9.00- Early Spring Spraying	4.67	4.48	80	-0.77	0.96	1.00	-3.92	2.39

Table B1b. Sensitivity Analyses: Changes in mean ChE inhibition in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	2.34	2.35	200					
1.00- Soil in Diet	2.26	2.24	80	0.09	0.66	1.00	-2.07	2.24
2.00- Dermal Exposure Time	3.03	2.46	80	-0.68	0.66	1.00	-2.84	1.48
3.00- Half-life in Bird	12.39	13.55	80	-10.04(*)	0.66	0.00	-12.20	-7.88
4.00- Drift	2.08	2.36	80	0.26	0.66	1.00	-1.90	2.42
5.00- Insect Half-life	3.55	2.79	80	-1.21	0.66	1.00	-3.37	0.95
6.00- Accumulation in Prey	3.19	2.36	80	-0.84	0.66	1.00	-3.00	1.32
7.00- Soil Half-life	6.69	5.35	80	-4.35(*)	0.66	0.00	-6.51	-2.19
8.00- Dermal to Oral Toxicity	4.35	4.87	80	-2.00	0.66	0.11	-4.16	0.16
9.00- Early Spring Spraying	2.56	2.55	80	-0.21	0.66	1.00	-2.37	1.94

Table B1c. Sensitivity Analyses: Changes in duration of ChE inhibition > 20% in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	0.00	0.00	200					
1.00- Soil in Diet	0.00	0.00	80	0.00	2.35	1.00	-7.68	7.68
2.00- Dermal Exposure Time	0.00	0.00	80	0.00	2.35	1.00	-7.68	7.68
3.00- Half-life in Bird	36.24	57.45	80	-36.24(*)	2.35	0.00	-43.93	-28.56
4.00- Drift	0.00	0.00	80	0.00	2.35	1.00	-7.68	7.68
5.00- Insect Half-life	0.00	0.00	80	0.00	2.35	1.00	-7.68	7.68
6.00- Accumulation in Prey	0.00	0.00	80	0.00	2.35	1.00	-7.68	7.68
7.00- Soil Half-life	3.65	12.24	80	-3.65	2.35	1.00	-11.33	4.03
8.00- Dermal to Oral Toxicity	3.97	13.49	80	-3.97	2.35	1.00	-11.65	3.72
9.00- Early Spring Spraying	0.00	0.00	80	0.00	2.35	1.00	-7.68	7.68

Table B1d. Sensitivity Analyses: Changes in duration of ChE inhibition > 50% in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	0.00	0.00	200					
1.00- Soil in Diet	0.00	0.00	80	0.00	0.69	1.00	-2.27	2.27
2.00- Dermal Exposure Time	0.00	0.00	80	0.00	0.69	1.00	-2.27	2.27
3.00- Half-life in Bird	4.39	17.77	80	-4.39(*)	0.69	0.00	-6.65	-2.12
4.00- Drift	0.00	0.00	80	0.00	0.69	1.00	-2.27	2.27
5.00- Insect Half-life	0.00	0.00	80	0.00	0.69	1.00	-2.27	2.27
6.00- Accumulation in Prey	0.00	0.00	80	0.00	0.69	1.00	-2.27	2.27
7.00- Soil Half-life	0.00	0.00	80	0.00	0.69	1.00	-2.27	2.27
8.00- Dermal to Oral Toxicity	0.00	0.00	80	0.00	0.69	1.00	-2.27	2.27
9.00- Early Spring Spraying	0.00	0.00	80	0.00	0.69	1.00	-2.27	2.27

Table B1e. Sensitivity Analyses: Changes in maximum ChE inhibition in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	9.97	20.04	200					
1.00- Soil in Diet	13.93	24.99	80	-3.96	2.51	1.00	-12.16	4.24
2.00- Dermal Exposure Time	10.69	15.45	80	-0.73	2.51	1.00	-8.93	7.48
3.00- Half-life in Bird	23.96	24.61	80	-13.99(*)	2.51	0.00	-22.20	-5.79
4.00- Drift	7.16	11.15	80	2.81	2.51	1.00	-5.39	11.01
5.00- Insect Half-life	11.94	16.99	80	-1.98	2.51	1.00	-10.18	6.22
6.00- Accumulation in Prey	11.16	17.77	80	-1.20	2.51	1.00	-9.40	7.01
7.00- Soil Half-life	14.49	18.47	80	-4.53	2.51	1.00	-12.73	3.67
8.00- Dermal to Oral Toxicity	12.12	18.81	80	-2.15	2.51	1.00	-10.35	6.05
9.00- Early Spring Spraying	8.91	15.29	80	1.05	2.51	1.00	-7.15	9.26

Table B1f. Sensitivity Analyses: Changes in mean ChE inhibition in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	3.87	4.19	200					
1.00- Soil in Diet	5.50	6.40	80	-1.63	0.99	1.00	-4.86	1.60
2.00- Dermal Exposure Time	5.12	6.93	80	-1.25	0.99	1.00	-4.48	1.98
3.00- Half-life in Bird	15.95	15.59	80	-12.08(*)	0.99	0.00	-15.31	-8.85
4.00- Drift	3.57	3.15	80	0.30	0.99	1.00	-2.93	3.53
5.00- Insect Half-life	6.15	7.58	80	-2.28	0.99	0.96	-5.51	0.95
6.00- Accumulation in Prey	5.07	6.71	80	-1.20	0.99	1.00	-4.43	2.03
7.00- Soil Half-life	8.55	7.84	80	-4.68(*)	0.99	0.00	-7.91	-1.45
8.00- Dermal to Oral Toxicity	6.41	8.55	80	-2.54	0.99	0.46	-5.77	0.69
9.00- Early Spring Spraying	4.20	4.31	80	-0.33	0.99	1.00	-3.56	2.90

Table B1g. Sensitivity Analyses: Changes in duration of ChE inhibition > 20% in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.80	8.84	200					
1.00- Soil in Diet	3.96	16.04	80	-2.17	2.85	1.00	-11.48	7.14
2.00- Dermal Exposure Time	0.62	4.49	80	1.18	2.85	1.00	-8.13	10.48
3.00- Half-life in Bird	43.17	54.68	80	-41.37(*)	2.85	0.00	-50.68	-32.07
4.00- Drift	0.58	5.20	80	1.21	2.85	1.00	-8.09	10.52
5.00- Insect Half-life	4.33	18.74	80	-2.53	2.85	1.00	-11.84	6.78
6.00- Accumulation in Prey	2.44	13.64	80	-0.64	2.85	1.00	-9.95	8.67
7.00- Soil Half-life	7.96	26.31	80	-6.16	2.85	1.00	-15.47	3.15
8.00- Dermal to Oral Toxicity	6.34	23.61	80	-4.55	2.85	1.00	-13.86	4.76
9.00- Early Spring Spraying	1.14	7.22	80	0.65	2.85	1.00	-8.66	9.96

Table B1h. Sensitivity Analyses: Changes in duration of ChE inhibition > 50% in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	0.72	3.47	200					
1.00- Soil in Diet	1.61	6.17	80	-0.88	1.19	1.00	-4.79	3.02
2.00- Dermal Exposure Time	0.59	4.48	80	0.14	1.19	1.00	-3.77	4.04
3.00- Half-life in Bird	7.21	25.00	80	-6.49(*)	1.19	0.00	-10.39	-2.59
4.00- Drift	0.18	1.57	80	0.55	1.19	1.00	-3.36	4.45
5.00- Insect Half-life	1.29	7.27	80	-0.57	1.19	1.00	-4.47	3.34
6.00- Accumulation in Prey	1.29	7.23	80	-0.57	1.19	1.00	-4.47	3.34
7.00- Soil Half-life	1.24	7.27	80	-0.52	1.19	1.00	-4.42	3.38
8.00- Dermal to Oral Toxicity	1.18	6.17	80	-0.46	1.19	1.00	-4.36	3.44
9.00- Early Spring Spraying	0.73	4.99	80	-0.01	1.19	1.00	-3.91	3.89

Table B1i. Sensitivity Analyses: Changes in maximum ChE inhibition in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	58.19	43.86	200					
1.00- Soil in Diet	56.47	43.18	80	1.73	5.30	1.00	-15.61	19.06
2.00- Dermal Exposure Time	68.22	37.77	80	-10.03	5.30	1.00	-27.36	7.31
3.00- Half-life in Bird	69.65	34.25	80	-11.46	5.30	1.00	-28.79	5.88
4.00- Drift	60.01	43.67	80	-1.82	5.30	1.00	-19.15	15.52
5.00- Insect Half-life	87.68	28.06	80	-29.49(*)	5.30	0.00	-46.82	-12.15
6.00- Accumulation in Prey	74.82	34.36	80	-16.63	5.30	0.08	-33.96	0.71
7.00- Soil Half-life	64.37	41.03	80	-6.18	5.30	1.00	-23.51	11.16
8.00- Dermal to Oral Toxicity	64.85	40.72	80	-6.66	5.30	1.00	-24.00	10.67
9.00- Early Spring Spraying	57.39	44.26	80	0.80	5.30	1.00	-16.54	18.14

Table B1j. Sensitivity Analyses: Changes in mean ChE inhibition in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	16.45	12.14	200					
1.00- Soil in Diet	18.13	13.41	80	-1.68	2.26	1.00	-9.08	5.73
2.00- Dermal Exposure Time	29.06	19.99	80	-12.60(*)	2.26	0.00	-20.01	-5.20
3.00- Half-life in Bird	41.74	23.67	80	-25.29(*)	2.26	0.00	-32.69	-17.88
4.00- Drift	16.92	12.82	80	-0.47	2.26	1.00	-7.87	6.93
5.00- Insect Half-life	49.98	27.37	80	-33.52(*)	2.26	0.00	-40.93	-26.12
6.00- Accumulation in Prey	29.85	18.81	80	-13.39(*)	2.26	0.00	-20.80	-5.99
7.00- Soil Half-life	24.33	16.27	80	-7.87(*)	2.26	0.02	-15.28	-0.47
8.00- Dermal to Oral Toxicity	22.17	14.12	80	-5.72	2.26	0.53	-13.12	1.68
9.00- Early Spring Spraying	14.32	11.37	80	2.13	2.26	1.00	-5.28	9.53

Table B1k. Sensitivity Analyses: Changes in duration of ChE inhibition > 20% in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	16.47	18.51	200					
1.00- Soil in Diet	19.36	21.20	80	-2.89	4.56	1.00	-17.80	12.03
2.00- Dermal Exposure Time	38.74	37.21	80	-22.27(*)	4.56	0.00	-37.19	-7.36
3.00- Half-life in Bird	97.67	47.89	80	-81.20(*)	4.56	0.00	-96.11	-66.29
4.00- Drift	17.78	21.33	80	-1.31	4.56	1.00	-16.22	13.60
5.00- Insect Half-life	104.37	54.26	80	-87.90(*)	4.56	0.00	-102.81	-72.99
6.00- Accumulation in Prey	56.89	47.89	80	-40.42(*)	4.56	0.00	-55.34	-25.51
7.00- Soil Half-life	39.53	43.38	80	-23.06(*)	4.56	0.00	-37.97	-8.15
8.00- Dermal to Oral Toxicity	29.69	27.78	80	-13.22	4.56	0.17	-28.14	1.69
9.00- Early Spring Spraying	13.93	18.51	80	2.54	4.56	1.00	-12.37	17.45

Table B1l. Sensitivity Analyses: Changes in duration of ChE inhibition > 50% in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	13.99	16.88	200					
1.00- Soil in Diet	15.23	19.04	80	-1.24	3.38	1.00	-12.29	9.82
2.00- Dermal Exposure Time	17.93	19.13	80	-3.94	3.38	1.00	-15.00	7.11
3.00- Half-life in Bird	33.28	41.03	80	-19.29(*)	3.38	0.00	-30.35	-8.24
4.00- Drift	14.81	17.89	80	-0.83	3.38	1.00	-11.88	10.23
5.00- Insect Half-life	64.92	48.44	80	-50.93(*)	3.38	0.00	-61.98	-39.88
6.00- Accumulation in Prey	26.79	27.25	80	-12.80(*)	3.38	0.01	-23.85	-1.75
7.00- Soil Half-life	17.91	20.12	80	-3.92	3.38	1.00	-14.97	7.13
8.00- Dermal to Oral Toxicity	16.89	18.18	80	-2.90	3.38	1.00	-13.95	8.15
9.00- Early Spring Spraying	11.32	15.50	80	2.67	3.38	1.00	-8.38	13.72

Table B2a. Sensitivity Analyses: Changes in maximum # of insecticides the owl is exposed to > LOEL in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.485	0.584	200					
1.00- Soil in Diet	1.513	0.574	80	-0.0275	0.0958	1.0000	-0.3407	0.2857
2.00- Dermal Exposure Time	2.000	0.779	80	-0.5150(*)	0.0958	0.0000	-0.8282	-0.2018
3.00- Half-life in Bird	4.575	0.897	80	-3.0900(*)	0.0958	0.0000	-3.4032	-2.7768
4.00- Drift	1.563	0.592	80	-0.0775	0.0958	1.0000	-0.3907	0.2357
5.00- Insect Half-life	1.688	0.704	80	-0.2025	0.0958	1.0000	-0.5157	0.1107
6.00- Accumulation in Prey	1.613	0.684	80	-0.1275	0.0958	1.0000	-0.4407	0.1857
7.00- Soil Half-life	3.363	0.945	80	-1.8775(*)	0.0958	0.0000	-2.1907	-1.5643
8.00- Dermal to Oral Toxicity	2.750	0.935	80	-1.2650(*)	0.0958	0.0000	-1.5782	-0.9518
9.00- Early Spring Spraying	1.488	0.595	80	-0.0025	0.0958	1.0000	-0.3157	0.3107

* The mean difference is significant at the .05 level.

Table B2b. Sensitivity Analyses: Changes in the duration of insecticide exposure > LOEL in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	147.038	16.532	200					
1.00- Soil in Diet	148.356	7.033	80	-1.3188	1.4715	1.0000	-6.1322	3.4947
2.00- Dermal Exposure Time	149.775	0.584	80	-2.7375	1.4715	1.0000	-7.5509	2.0759
3.00- Half-life in Bird	149.294	1.366	80	-2.2563	1.4715	1.0000	-7.0697	2.5572
4.00- Drift	148.363	5.417	80	-1.3250	1.4715	1.0000	-6.1384	3.4884
5.00- Insect Half-life	149.794	0.863	80	-2.7563	1.4715	1.0000	-7.5697	2.0572
6.00- Accumulation in Prey	146.744	19.192	80	0.2938	1.4715	1.0000	-4.5197	5.1072
7.00- Soil Half-life	150.500	0.000	80	-3.4625	1.4715	0.8470	-8.2759	1.3509
8.00- Dermal to Oral Toxicity	149.750	0.540	80	-2.7125	1.4715	1.0000	-7.5259	2.1009
9.00- Early Spring Spraying	147.306	16.922	80	-0.2688	1.4715	1.0000	-5.0822	4.5447

* The mean difference is significant at the .05 level.

Table B2c. Sensitivity Analyses: Changes in maximum # of insecticides the owl is exposed to > LOEL in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.670	0.673	200					
1.00- Soil in Diet	1.750	0.684	80	-0.0800	0.1157	1.0000	-0.4586	0.2986
2.00- Dermal Exposure Time	2.125	0.817	80	-0.4550(*)	0.1157	0.0040	-0.8336	-0.0764
3.00- Half-life in Bird	5.238	1.416	80	-3.5675(*)	0.1157	0.0000	-3.9461	-3.1889
4.00- Drift	1.800	0.644	80	-0.1300	0.1157	1.0000	-0.5086	0.2486
5.00- Insect Half-life	2.563	0.992	80	-0.8925(*)	0.1157	0.0000	-1.2711	-0.5139
6.00- Accumulation in Prey	2.738	0.910	80	-1.0675(*)	0.1157	0.0000	-1.4461	-0.6889
7.00- Soil Half-life	3.600	0.908	80	-1.9300(*)	0.1157	0.0000	-2.3086	-1.5514
8.00- Dermal to Oral Toxicity	2.588	1.052	80	-0.9175(*)	0.1157	0.0000	-1.2961	-0.5389
9.00- Early Spring Spraying	1.575	0.612	80	0.0950	0.1157	1.0000	-0.2836	0.4736

* The mean difference is significant at the .05 level.

Table B2d. Sensitivity Analyses: Changes in the duration of insecticide exposure > LOEL in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	146.603	17.113	200					
1.00- Soil in Diet	146.663	16.138	80	-0.0600	1.4052	1.0000	-4.6568	4.5368
2.00- Dermal Exposure Time	148.356	6.101	80	-1.7538	1.4052	1.0000	-6.3505	2.8430
3.00- Half-life in Bird	149.044	1.401	80	-2.4413	1.4052	1.0000	-7.0380	2.1555
4.00- Drift	146.913	15.176	80	-0.3100	1.4052	1.0000	-4.9068	4.2868
5.00- Insect Half-life	149.463	0.974	80	-2.8600	1.4052	1.0000	-7.4568	1.7368
6.00- Accumulation in Prey	149.150	1.210	80	-2.5475	1.4052	1.0000	-7.1443	2.0493
7.00- Soil Half-life	150.263	0.251	80	-3.6600	1.4052	0.4210	-8.2568	0.9368
8.00- Dermal to Oral Toxicity	149.125	5.250	80	-2.5225	1.4052	1.0000	-7.1193	2.0743
9.00- Early Spring Spraying	148.863	1.463	80	-2.2600	1.4052	1.0000	-6.8568	2.3368

* The mean difference is significant at the .05 level.

Table B2e. Sensitivity Analyses: Changes in maximum # of insecticides the owl is exposed to > LOEL in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.605	0.617	200					
1.00- Soil in Diet	1.713	0.640	80	-0.1075	0.0970	1.0000	-0.4248	0.2098
2.00- Dermal Exposure Time	2.375	0.682	80	-0.7700(*)	0.0970	0.0000	-1.0873	-0.4527
3.00- Half-life in Bird	4.825	1.016	80	-3.2200(*)	0.0970	0.0000	-3.5373	-2.9027
4.00- Drift	1.613	0.584	80	-0.0075	0.0970	1.0000	-0.3248	0.3098
5.00- Insect Half-life	1.850	0.677	80	-0.2450	0.0970	0.5270	-0.5623	0.0723
6.00- Accumulation in Prey	2.288	0.640	80	-0.6825(*)	0.0970	0.0000	-0.9998	-0.3652
7.00- Soil Half-life	3.638	0.917	80	-2.0325(*)	0.0970	0.0000	-2.3498	-1.7152
8.00- Dermal to Oral Toxicity	2.425	0.897	80	-0.8200(*)	0.0970	0.0000	-1.1373	-0.5027
9.00- Early Spring Spraying	1.600	0.686	80	0.0050	0.0970	1.0000	-0.3123	0.3223

* The mean difference is significant at the .05 level.

Table B2f. Sensitivity Analyses: Changes in the duration of insecticide exposure > LOEL in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	143.615	26.039	200					
1.00- Soil in Diet	143.750	25.920	80	-0.1350	2.3498	1.0000	-7.8216	7.5516
2.00- Dermal Exposure Time	148.331	6.907	80	-4.7163	2.3498	1.0000	-12.4028	2.9703
3.00- Half-life in Bird	149.006	1.328	80	-5.3913	2.3498	0.9900	-13.0778	2.2953
4.00- Drift	148.806	1.429	80	-5.1913	2.3498	1.0000	-12.8778	2.4953
5.00- Insect Half-life	145.656	20.797	80	-2.0413	2.3498	1.0000	-9.7278	5.6453
6.00- Accumulation in Prey	149.388	1.034	80	-5.7725	2.3498	0.6390	-13.4591	1.9141
7.00- Soil Half-life	150.300	0.246	80	-6.6850	2.3498	0.2040	-14.3716	1.0016
8.00- Dermal to Oral Toxicity	147.319	16.151	80	-3.7038	2.3498	1.0000	-11.3903	3.9828
9.00- Early Spring Spraying	144.800	22.551	80	-1.1850	2.3498	1.0000	-8.8716	6.5016

* The mean difference is significant at the .05 level.

Table B3a. Sensitivity Analyses: Changes in maximum # of herbicides the owl is exposed to > LOEL in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.025	0.690	200					
1.00- Soil in Diet	0.988	0.665	80	0.0375	0.0881	1.0000	-0.2506	0.3256
2.00- Dermal Exposure Time	1.638	0.733	80	-.6125(*)	0.0881	0.0000	-0.9006	-0.3244
3.00- Half-life in Bird	1.513	0.729	80	-.4875(*)	0.0881	0.0000	-0.7756	-0.1994
4.00- Drift	1.113	0.693	80	-0.0875	0.0881	1.0000	-0.3756	0.2006
5.00- Insect Half-life	1.275	0.551	80	-0.2500	0.0881	0.2080	-0.5381	0.0381
6.00- Accumulation in Prey	1.425	0.612	80	-.4000(*)	0.0881	0.0000	-0.6881	-0.1119
7.00- Soil Half-life	1.200	0.560	80	-0.1750	0.0881	1.0000	-0.4631	0.1131
8.00- Dermal to Oral Toxicity	1.513	0.675	80	-.4875(*)	0.0881	0.0000	-0.7756	-0.1994
9.00- Early Spring Spraying	1.063	0.681	80	-0.0375	0.0881	1.0000	-0.3256	0.2506

* The mean difference is significant at the .05 level.

Table B3b. Sensitivity Analyses: Changes in the duration of herbicide exposure > LOEL in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	70.533	70.432	200					
1.00- Soil in Diet	73.313	69.474	80	-2.7800	8.6900	1.0000	-31.2069	25.6469
2.00- Dermal Exposure Time	103.894	58.520	80	-33.3613(*)	8.6900	0.0060	-61.7882	-4.9343
3.00- Half-life in Bird	109.519	59.108	80	-38.9863(*)	8.6900	0.0000	-67.4132	-10.5593
4.00- Drift	75.675	70.720	80	-5.1425	8.6900	1.0000	-33.5694	23.2844
5.00- Insect Half-life	85.913	67.730	80	-15.3800	8.6900	1.0000	-43.8069	13.0469
6.00- Accumulation in Prey	87.081	65.920	80	-16.5488	8.6900	1.0000	-44.9757	11.8782
7.00- Soil Half-life	114.725	55.984	80	-44.1925(*)	8.6900	0.0000	-72.6194	-15.7656
8.00- Dermal to Oral Toxicity	108.981	58.756	80	-38.4488(*)	8.6900	0.0000	-66.8757	-10.0218
9.00- Early Spring Spraying	68.006	70.326	80	2.5263	8.6900	1.0000	-25.9007	30.9532

* The mean difference is significant at the .05 level.

Table B3c. Sensitivity Analyses: Changes in maximum # of herbicides the owl is exposed to > LOEL in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.365	0.560	200					
1.00- Soil in Diet	1.350	0.576	80	0.0150	0.0811	1.0000	-0.2501	0.2801
2.00- Dermal Exposure Time	1.763	0.641	80	-.3975(*)	0.0811	0.0000	-0.6626	-0.1324
3.00- Half-life in Bird	1.975	0.711	80	-.6100(*)	0.0811	0.0000	-0.8751	-0.3449
4.00- Drift	1.300	0.560	80	0.0650	0.0811	1.0000	-0.2001	0.3301
5.00- Insect Half-life	1.900	0.565	80	-.5350(*)	0.0811	0.0000	-0.8001	-0.2699
6.00- Accumulation in Prey	1.763	0.698	80	-.3975(*)	0.0811	0.0000	-0.6626	-0.1324
7.00- Soil Half-life	1.450	0.571	80	-0.0850	0.0811	1.0000	-0.3501	0.1801
8.00- Dermal to Oral Toxicity	1.713	0.733	80	-.3475(*)	0.0811	0.0010	-0.6126	-0.0824
9.00- Early Spring Spraying	1.275	0.551	80	0.0900	0.0811	1.0000	-0.1751	0.3551

* The mean difference is significant at the .05 level.

Table B3d. Sensitivity Analyses: Changes in the duration of herbicide exposure > LOEL in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	78.385	64.765	200					
1.00- Soil in Diet	76.369	63.463	80	2.0163	7.2107	1.0000	-21.5714	25.6039
2.00- Dermal Exposure Time	130.238	27.470	80	-51.8525(*)	7.2107	0.0000	-75.4401	-28.2649
3.00- Half-life in Bird	131.288	34.047	80	-52.9025(*)	7.2107	0.0000	-76.4901	-29.3149
4.00- Drift	71.075	66.294	80	7.3100	7.2107	1.0000	-16.2776	30.8976
5.00- Insect Half-life	126.706	37.345	80	-48.3213(*)	7.2107	0.0000	-71.9089	-24.7336
6.00- Accumulation in Prey	120.100	39.994	80	-41.7150(*)	7.2107	0.0000	-65.3026	-18.1274
7.00- Soil Half-life	114.200	55.905	80	-35.8150(*)	7.2107	0.0000	-59.4026	-12.2274
8.00- Dermal to Oral Toxicity	109.569	54.563	80	-31.1838(*)	7.2107	0.0010	-54.7714	-7.5961
9.00- Early Spring Spraying	79.050	64.998	80	-0.6650	7.2107	1.0000	-24.2526	22.9226

* The mean difference is significant at the .05 level.

Table B3e. Sensitivity Analyses: Changes in maximum # of herbicides the owl is exposed to > LOEL in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.470	0.687	200					
1.00- Soil in Diet	1.425	0.671	80	0.0450	0.1013	1.0000	-0.2864	0.3764
2.00- Dermal Exposure Time	2.538	0.899	80	-1.0675(*)	0.1013	0.0000	-1.3989	-0.7361
3.00- Half-life in Bird	2.538	0.980	80	-1.0675(*)	0.1013	0.0000	-1.3989	-0.7361
4.00- Drift	1.388	0.646	80	0.0825	0.1013	1.0000	-0.2489	0.4139
5.00- Insect Half-life	2.238	0.783	80	-.7675(*)	0.1013	0.0000	-1.0989	-0.4361
6.00- Accumulation in Prey	2.113	0.811	80	-.6425(*)	0.1013	0.0000	-0.9739	-0.3111
7.00- Soil Half-life	1.663	0.674	80	-0.1925	0.1013	1.0000	-0.5239	0.1389
8.00- Dermal to Oral Toxicity	1.963	0.834	80	-.4925(*)	0.1013	0.0000	-0.8239	-0.1611
9.00- Early Spring Spraying	1.350	0.713	80	0.1200	0.1013	1.0000	-0.2114	0.4514

* The mean difference is significant at the .05 level.

Table B3f. Sensitivity Analyses: Changes in the duration of herbicide exposure > LOEL in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	85.625	65.094	200					
1.00- Soil in Diet	76.881	67.061	80	8.7438	7.6501	1.0000	-16.2813	33.7688
2.00- Dermal Exposure Time	115.144	41.372	80	-29.5188(*)	7.6501	0.0050	-54.5438	-4.4937
3.00- Half-life in Bird	132.744	34.393	80	-47.1188(*)	7.6501	0.0000	-72.1438	-22.0937
4.00- Drift	66.013	64.951	80	19.6125	7.6501	0.4730	-5.4126	44.6376
5.00- Insect Half-life	111.650	48.392	80	-26.0250(*)	7.6501	0.0310	-51.0501	-0.9999
6.00- Accumulation in Prey	98.719	49.981	80	-13.0938	7.6501	1.0000	-38.1188	11.9313
7.00- Soil Half-life	101.813	60.026	80	-16.1875	7.6501	1.0000	-41.2126	8.8376
8.00- Dermal to Oral Toxicity	102.044	59.129	80	-16.4188	7.6501	1.0000	-41.4438	8.6063
9.00- Early Spring Spraying	70.200	65.563	80	15.4250	7.6501	1.0000	-9.6001	40.4501

* The mean difference is significant at the .05 level.

Table B4a. Sensitivity Analyses: Changes in maximum # of growth regulators and defoliants the owl is exposed to > LOEL in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.290	0.590	200					
1.00- Soil in Diet	1.200	0.560	80	0.0900	0.0694	1.0000	-0.1370	0.3170
2.00- Dermal Exposure Time	1.488	0.528	80	-0.1975	0.0694	0.2040	-0.4245	0.0295
3.00- Half-life in Bird	1.650	0.480	80	-.3600(*)	0.0694	0.0000	-0.5870	-0.1330
4.00- Drift	1.313	0.542	80	-0.0225	0.0694	1.0000	-0.2495	0.2045
5.00- Insect Half-life	1.850	0.359	80	-.5600(*)	0.0694	0.0000	-0.7870	-0.3330
6.00- Accumulation in Prey	1.813	0.393	80	-.5225(*)	0.0694	0.0000	-0.7495	-0.2955
7.00- Soil Half-life	1.300	0.461	80	-0.0100	0.0694	1.0000	-0.2370	0.2170
8.00- Dermal to Oral Toxicity	1.400	0.542	80	-0.1100	0.0694	1.0000	-0.3370	0.1170
9.00- Early Spring Spraying	1.063	0.623	80	.2275(*)	0.0694	0.0490	0.0005	0.4545

* The mean difference is significant at the .05 level.

Table B4b. Sensitivity Analyses: Changes in the duration of growth regulator and defoliant exposure > LOEL in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	118.698	54.689	200					
1.00- Soil in Diet	113.631	58.772	80	5.0663	5.5943	1.0000	-13.2340	23.3665
2.00- Dermal Exposure Time	139.331	28.725	80	-20.6338(*)	5.5943	0.0110	-38.9340	-2.3335
3.00- Half-life in Bird	147.106	10.096	80	-28.4088(*)	5.5943	0.0000	-46.7090	-10.1085
4.00- Drift	122.994	47.741	80	-4.2963	5.5943	1.0000	-22.5965	14.0040
5.00- Insect Half-life	148.363	9.932	80	-29.6650(*)	5.5943	0.0000	-47.9653	-11.3647
6.00- Accumulation in Prey	145.219	20.413	80	-26.5213(*)	5.5943	0.0000	-44.8215	-8.2210
7.00- Soil Half-life	146.525	17.668	80	-27.8275(*)	5.5943	0.0000	-46.1278	-9.5272
8.00- Dermal to Oral Toxicity	136.756	39.323	80	-18.0588	5.5943	0.0580	-36.3590	0.2415
9.00- Early Spring Spraying	109.313	63.500	80	9.3850	5.5943	1.0000	-8.9153	27.6853

* The mean difference is significant at the .05 level.

Table B4c. Sensitivity Analyses: Changes in maximum # of growth regulators and defoliants the owl is exposed to > LOEL in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.050	0.632	200					
1.00- Soil in Diet	1.088	0.599	80	-0.0375	0.0740	1.0000	-0.2795	0.2045
2.00- Dermal Exposure Time	1.313	0.542	80	-.2625(*)	0.0740	0.0180	-0.5045	-0.0205
3.00- Half-life in Bird	1.450	0.593	80	-.4000(*)	0.0740	0.0000	-0.6420	-0.1580
4.00- Drift	0.988	0.626	80	0.0625	0.0740	1.0000	-0.1795	0.3045
5.00- Insect Half-life	1.788	0.441	80	-.7375(*)	0.0740	0.0000	-0.9795	-0.4955
6.00- Accumulation in Prey	1.750	0.436	80	-.7000(*)	0.0740	0.0000	-0.9420	-0.4580
7.00- Soil Half-life	1.338	0.476	80	-.2875(*)	0.0740	0.0050	-0.5295	-0.0455
8.00- Dermal to Oral Toxicity	1.238	0.557	80	-0.1875	0.0740	0.5140	-0.4295	0.0545
9.00- Early Spring Spraying	1.113	0.528	80	-0.0625	0.0740	1.0000	-0.3045	0.1795

* The mean difference is significant at the .05 level.

Table B4d. Sensitivity Analyses: Changes in the duration of growth regulator and defoliant exposure > LOEL in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	96.050	67.235	200					
1.00- Soil in Diet	109.425	60.744	80	-13.3750	7.1756	1.0000	-36.8478	10.0978
2.00- Dermal Exposure Time	112.875	55.283	80	-16.8250	7.1756	0.8660	-40.2978	6.6478
3.00- Half-life in Bird	133.269	40.198	80	-37.2188(*)	7.1756	0.0000	-60.6916	-13.7459
4.00- Drift	86.750	69.623	80	9.3000	7.1756	1.0000	-14.1728	32.7728
5.00- Insect Half-life	132.088	34.238	80	-36.0375(*)	7.1756	0.0000	-59.5103	-12.5647
6.00- Accumulation in Prey	137.619	28.954	80	-41.5688(*)	7.1756	0.0000	-65.0416	-18.0959
7.00- Soil Half-life	143.556	28.567	80	-47.5063(*)	7.1756	0.0000	-70.9791	-24.0334
8.00- Dermal to Oral Toxicity	129.100	49.150	80	-33.0500(*)	7.1756	0.0000	-56.5228	-9.5772
9.00- Early Spring Spraying	102.994	63.659	80	-6.9438	7.1756	1.0000	-30.4166	16.5291

* The mean difference is significant at the .05 level.

Table B4e. Sensitivity Analyses: Changes in maximum # of growth regulators and defoliants the owl is exposed to > LOEL in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	1.025	0.562	200					
1.00- Soil in Diet	1.200	0.582	80	-0.1750	0.0688	0.5010	-0.4000	0.0500
2.00- Dermal Exposure Time	1.300	0.537	80	-.2750(*)	0.0688	0.0030	-0.5000	-0.0500
3.00- Half-life in Bird	1.550	0.501	80	-.5250(*)	0.0688	0.0000	-0.7500	-0.3000
4.00- Drift	0.988	0.562	80	0.0375	0.0688	1.0000	-0.1875	0.2625
5.00- Insect Half-life	1.850	0.359	80	-.8250(*)	0.0688	0.0000	-1.0500	-0.6000
6.00- Accumulation in Prey	1.725	0.449	80	-.7000(*)	0.0688	0.0000	-0.9250	-0.4750
7.00- Soil Half-life	1.250	0.464	80	-0.2250	0.0688	0.0500	-0.4500	0.0000
8.00- Dermal to Oral Toxicity	1.250	0.490	80	-0.2250	0.0688	0.0500	-0.4500	0.0000
9.00- Early Spring Spraying	1.063	0.581	80	-0.0375	0.0688	1.0000	-0.2625	0.1875

* The mean difference is significant at the .05 level.

Table B4f. Sensitivity Analyses: Changes in the duration of growth regulator and defoliant exposure > LOEL in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	105.918	63.808	200					
1.00- Soil in Diet	107.088	61.934	80	-1.1700	7.1195	1.0000	-24.4595	22.1195
2.00- Dermal Exposure Time	105.950	57.356	80	-0.0325	7.1195	1.0000	-23.3220	23.2570
3.00- Half-life in Bird	142.244	22.676	80	-36.3263(*)	7.1195	0.0000	-59.6157	-13.0368
4.00- Drift	83.788	67.226	80	22.1300	7.1195	0.0870	-1.1595	45.4195
5.00- Insect Half-life	134.269	34.173	80	-28.3513(*)	7.1195	0.0030	-51.6407	-5.0618
6.00- Accumulation in Prey	133.275	33.929	80	-27.3575(*)	7.1195	0.0060	-50.6470	-4.0680
7.00- Soil Half-life	139.475	36.420	80	-33.5575(*)	7.1195	0.0000	-56.8470	-10.2680
8.00- Dermal to Oral Toxicity	122.331	54.262	80	-16.4138	7.1195	0.9610	-39.7032	6.8757
9.00- Early Spring Spraying	100.763	66.022	80	5.1550	7.1195	1.0000	-18.1345	28.4445

* The mean difference is significant at the .05 level.

Table B5a. Sensitivity Analyses: Changes in maximum # of insecticides the owl is exposed to > HD5 in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	0.1250	0.3316	200					
1.00- Soil in Diet	0.1375	0.3466	80	-0.0125	0.05245	1.000	-0.1841	0.1591
2.00- Dermal Exposure Time	0.1750	0.3824	80	-0.0500	0.05245	1.000	-0.2216	0.1216
3.00- Half-life in Bird	0.2500	0.4357	80	-0.1250	0.05245	0.781	-0.2966	0.0466
4.00- Drift	0.1375	0.3466	80	-0.0125	0.05245	1.000	-0.1841	0.1591
5.00- Insect Half-life	0.3375	0.4758	80	-.2125(*)	0.05245	0.002	-0.3841	-0.0409
6.00- Accumulation in Prey	0.2875	0.4555	80	-0.1625	0.05245	0.090	-0.3341	0.0091
7.00- Soil Half-life	0.4375	0.4992	80	-.3125(*)	0.05245	0.000	-0.4841	-0.1409
8.00- Dermal to Oral Toxicity	0.1875	0.3928	80	-0.0625	0.05245	1.000	-0.2341	0.1091
9.00- Early Spring Spraying	0.1375	0.3466	80	-0.0125	0.05245	1.000	-0.1841	0.1591

* The mean difference is significant at the .05 level.

Table B5b. Sensitivity Analyses: Changes in duration of exposure to an amount of insecticides > HD5 in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	4.9325	15.67250	200					
1.00- Soil in Diet	5.7250	16.93956	80	-.7925	4.97014	1.000	-17.0509	15.4659
2.00- Dermal Exposure Time	11.7813	28.64888	80	-6.8488	4.97014	1.000	-23.1072	9.4097
3.00- Half-life in Bird	36.1000	63.00680	80	-31.1675(*)	4.97014	.000	-47.4259	-14.9091
4.00- Drift	5.0625	16.11909	80	-.1300	4.97014	1.000	-16.3884	16.1284
5.00- Insect Half-life	23.1250	46.02259	80	-18.1925(*)	4.97014	.012	-34.4509	-1.9341
6.00- Accumulation in Prey	18.2188	35.41757	80	-13.2863	4.97014	.344	-29.5447	2.9722
7.00- Soil Half-life	54.0750	68.06136	80	-49.1425(*)	4.97014	.000	-65.4009	-32.8841
8.00- Dermal to Oral Toxicity	20.2375	45.76190	80	-15.3050	4.97014	.096	-31.5634	.9534
9.00- Early Spring Spraying	4.3625	14.30455	80	.5700	4.97014	1.000	-15.6884	16.8284

* The mean difference is significant at the .05 level.

Table B5c. Sensitivity Analyses: Changes in maximum # of insecticides the owl is exposed to > HD5 in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.3800	.48660	200					
1.00- Soil in Diet	.4375	.54758	80	-.0575	.07503	1.000	-.3029	.1879
2.00- Dermal Exposure Time	.3875	.51543	80	-.0075	.07503	1.000	-.2529	.2379
3.00- Half-life in Bird	.6625	.61508	80	-.2825(*)	.07503	.008	-.5279	-.0371
4.00- Drift	.6500	.57589	80	-.2700(*)	.07503	.015	-.5154	-.0246
5.00- Insect Half-life	.8375	.56128	80	-.4575(*)	.07503	.000	-.7029	-.2121
6.00- Accumulation in Prey	.6000	.64827	80	-.2200	.07503	.155	-.4654	.0254
7.00- Soil Half-life	.7875	.68794	80	-.4075(*)	.07503	.000	-.6529	-.1621
8.00- Dermal to Oral Toxicity	.5625	.61302	80	-.1825	.07503	.684	-.4279	.0629
9.00- Early Spring Spraying	.4375	.49921	80	-.0575	.07503	1.000	-.3029	.1879

* The mean difference is significant at the .05 level.

Table B5d. Sensitivity Analyses: Changes in duration of exposure to an amount of insecticides > HD5 in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	8.8450	17.91264	200					
1.00- Soil in Diet	9.4688	15.50609	80	-.6238	4.86251	1.000	-16.5301	15.2826
2.00- Dermal Exposure Time	11.5313	20.27740	80	-2.6863	4.86251	1.000	-18.5926	13.2201
3.00- Half-life in Bird	53.8813	61.09560	80	-45.0363(*)	4.86251	.000	-60.9426	-29.1299
4.00- Drift	17.3063	24.83891	80	-8.4613	4.86251	1.000	-24.3676	7.4451
5.00- Insect Half-life	44.1500	45.57935	80	-35.3050(*)	4.86251	.000	-51.2113	-19.3987
6.00- Accumulation in Prey	25.2750	31.42430	80	-16.4300(*)	4.86251	.034	-32.3363	-.5237
7.00- Soil Half-life	49.7500	62.30778	80	-40.9050(*)	4.86251	.000	-56.8113	-24.9987
8.00- Dermal to Oral Toxicity	30.1625	50.03200	80	-21.3175(*)	4.86251	.001	-37.2238	-5.4112
9.00- Early Spring Spraying	9.6188	17.41348	80	-.7738	4.86251	1.000	-16.6801	15.1326

* The mean difference is significant at the .05 level.

Table B5e. Sensitivity Analyses: Changes in maximum # of insecticides the owl is exposed to > HD5 in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.3350	.47317	200					
1.00- Soil in Diet	.3875	.49025	80	-.0525	.06927	1.000	-.2791	.1741
2.00- Dermal Exposure Time	.4250	.49746	80	-.0900	.06927	1.000	-.3166	.1366
3.00- Half-life in Bird	.5500	.65410	80	-.2150	.06927	.089	-.4416	.0116
4.00- Drift	.4125	.49539	80	-.0775	.06927	1.000	-.3041	.1491
5.00- Insect Half-life	.6375	.50925	80	-.3025(*)	.06927	.001	-.5291	-.0759
6.00- Accumulation in Prey	.7125	.50801	80	-.3775(*)	.06927	.000	-.6041	-.1509
7.00- Soil Half-life	.6875	.60783	80	-.3525(*)	.06927	.000	-.5791	-.1259
8.00- Dermal to Oral Toxicity	.3875	.56240	80	-.0525	.06927	1.000	-.2791	.1741
9.00- Early Spring Spraying	.3500	.47998	80	-.0150	.06927	1.000	-.2416	.2116

* The mean difference is significant at the .05 level.

Table B5f. Sensitivity Analyses: Changes in duration of exposure to an amount of insecticides > HD5 in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	5.2200	11.99263	200					
1.00- Soil in Diet	7.4063	15.83381	80	-2.1863	4.67140	1.000	-17.4674	13.0949
2.00- Dermal Exposure Time	13.6375	24.69600	80	-8.4175	4.67140	1.000	-23.6987	6.8637
3.00- Half-life in Bird	40.8375	61.18833	80	-35.6175(*)	4.67140	.000	-50.8987	-20.3363
4.00- Drift	10.5688	19.01228	80	-5.3488	4.67140	1.000	-20.6299	9.9324
5.00- Insect Half-life	22.4125	34.44513	80	-17.1925(*)	4.67140	.011	-32.4737	-1.9113
6.00- Accumulation in Prey	24.3000	36.40156	80	-19.0800(*)	4.67140	.002	-34.3612	-3.7988
7.00- Soil Half-life	56.3188	65.91413	80	-51.0988(*)	4.67140	.000	-66.3799	-35.8176
8.00- Dermal to Oral Toxicity	20.9500	44.13541	80	-15.7300(*)	4.67140	.036	-31.0112	-.4488
9.00- Early Spring Spraying	6.2688	15.21012	80	-1.0488	4.67140	1.000	-16.3299	14.2324

* The mean difference is significant at the .05 level.

Table B6a. Sensitivity Analyses: Changes in maximum # of herbicides the owl is exposed to > HD5 in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval
0.00- Baseline	.0000	.00000	200				
1.00- Soil in Diet	.0000	.00000	80				
2.00- Dermal Exposure Time	.0000	.00000	80				
3.00- Half-life in Bird	.0000	.00000	80				
4.00- Drift	.0000	.00000	80				
5.00- Insect Half-life	.0000	.00000	80				
6.00- Accumulation in Prey	.0000	.00000	80				
7.00- Soil Half-life	.0000	.00000	80				
8.00- Dermal to Oral Toxicity	.0000	.00000	80				
9.00- Early Spring Spraying	.0000	.00000	80				

* The mean difference is significant at the .05 level.

Table B6b. Sensitivity Analyses: Changes in duration of exposure to an amount of herbicides > HD5 in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval
0.00- Baseline	.0000	.00000	200				
1.00- Soil in Diet	.0000	.00000	80				
2.00- Dermal Exposure Time	.0000	.00000	80				
3.00- Half-life in Bird	.0000	.00000	80				
4.00- Drift	.0000	.00000	80				
5.00- Insect Half-life	.0000	.00000	80				
6.00- Accumulation in Prey	.0000	.00000	80				
7.00- Soil Half-life	.0000	.00000	80				
8.00- Dermal to Oral Toxicity	.0000	.00000	80				
9.00- Early Spring Spraying	.0000	.00000	80				

* The mean difference is significant at the .05 level.

Table B6c. Sensitivity Analyses: Changes in maximum # of herbicides the owl is exposed to > HD5 in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval
0.00- Baseline	.0000	.00000	200				
1.00- Soil in Diet	.0000	.00000	80				
2.00- Dermal Exposure Time	.0000	.00000	80				
3.00- Half-life in Bird	.0000	.00000	80				
4.00- Drift	.0000	.00000	80				
5.00- Insect Half-life	.0000	.00000	80				
6.00- Accumulation in Prey	.0000	.00000	80				
7.00- Soil Half-life	.0000	.00000	80				
8.00- Dermal to Oral Toxicity	.0000	.00000	80				
9.00- Early Spring Spraying	.0000	.00000	80				

* The mean difference is significant at the .05 level.

Table B6d. Sensitivity Analyses: Changes in duration of exposure to an amount of herbicides > HD5 in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval
0.00- Baseline	.0000	.00000	200				
1.00- Soil in Diet	.0000	.00000	80				
2.00- Dermal Exposure Time	.0000	.00000	80				
3.00- Half-life in Bird	.0000	.00000	80				
4.00- Drift	.0000	.00000	80				
5.00- Insect Half-life	.0000	.00000	80				
6.00- Accumulation in Prey	.0000	.00000	80				
7.00- Soil Half-life	.0000	.00000	80				
8.00- Dermal to Oral Toxicity	.0000	.00000	80				
9.00- Early Spring Spraying	.0000	.00000	80				

* The mean difference is significant at the .05 level.

Table B6e. Sensitivity Analyses: Changes in maximum # of herbicides the owl is exposed to > HD5 in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.0000	.00000	200					
1.00- Soil in Diet	.0000	.00000	80	.0000	.00616	1.000	-.0202	.0202
2.00- Dermal Exposure Time	.0125	.11180	80	-.0125	.00616	1.000	-.0327	.0077
3.00- Half-life in Bird	.0125	.11180	80	-.0125	.00616	1.000	-.0327	.0077
4.00- Drift	.0000	.00000	80	.0000	.00616	1.000	-.0202	.0202
5.00- Insect Half-life	.0000	.00000	80	.0000	.00616	1.000	-.0202	.0202
6.00- Accumulation in Prey	.0000	.00000	80	.0000	.00616	1.000	-.0202	.0202
7.00- Soil Half-life	.0000	.00000	80	.0000	.00616	1.000	-.0202	.0202
8.00- Dermal to Oral Toxicity	.0000	.00000	80	.0000	.00616	1.000	-.0202	.0202
9.00- Early Spring Spraying	.0000	.00000	80	.0000	.00616	1.000	-.0202	.0202

* The mean difference is significant at the .05 level.

Table B6f. Sensitivity Analyses: Changes in duration of exposure to an amount of herbicides > HD5 in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.0000	.00000	200					
1.00- Soil in Diet	.0000	.00000	80	.0000	.01757	1.000	-.0575	.0575
2.00- Dermal Exposure Time	.0438	.39131	80	-.0438	.01757	.582	-.1012	.0137
3.00- Half-life in Bird	.0250	.22361	80	-.0250	.01757	1.000	-.0825	.0325
4.00- Drift	.0000	.00000	80	.0000	.01757	1.000	-.0575	.0575
5.00- Insect Half-life	.0000	.00000	80	.0000	.01757	1.000	-.0575	.0575
6.00- Accumulation in Prey	.0000	.00000	80	.0000	.01757	1.000	-.0575	.0575
7.00- Soil Half-life	.0000	.00000	80	.0000	.01757	1.000	-.0575	.0575
8.00- Dermal to Oral Toxicity	.0000	.00000	80	.0000	.01757	1.000	-.0575	.0575
9.00- Early Spring Spraying	.0000	.00000	80	.0000	.01757	1.000	-.0575	.0575

* The mean difference is significant at the .05 level.

Table B7a. Sensitivity Analyses: Changes in maximum # of growth regulators and defoliants the owl is exposed to > HD5 in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.0000	.00000	200					
1.00- Soil in Diet	.0000	.00000	80	.0000	.03078	1.000	-.1007	.1007
2.00- Dermal Exposure Time	.0000	.00000	80	.0000	.03078	1.000	-.1007	.1007
3.00- Half-life in Bird	.1875	.39277	80	-.1875(*)	.03078	.000	-.2882	-.0868
4.00- Drift	.0000	.00000	80	.0000	.03078	1.000	-.1007	.1007
5.00- Insect Half-life	.3500	.47998	80	-.3500(*)	.03078	.000	-.4507	-.2493
6.00- Accumulation in Prey	.3375	.47584	80	-.3375(*)	.03078	.000	-.4382	-.2368
7.00- Soil Half-life	.0000	.00000	80	.0000	.03078	1.000	-.1007	.1007
8.00- Dermal to Oral Toxicity	.0125	.11180	80	-.0125	.03078	1.000	-.1132	.0882
9.00- Early Spring Spraying	.0000	.00000	80	.0000	.03078	1.000	-.1007	.1007

* The mean difference is significant at the .05 level.

Table B7b. Sensitivity Analyses: Changes in duration of exposure to an amount of growth regulators and defoliants > HD5 in the cotton/sorghum crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.0000	.00000	200					
1.00- Soil in Diet	.0000	.00000	80	.0000	2.74396	1.000	-8.9761	8.9761
2.00- Dermal Exposure Time	.0000	.00000	80	.0000	2.74396	1.000	-8.9761	8.9761
3.00- Half-life in Bird	21.4688	47.17516	80	-21.4688(*)	2.74396	.000	-30.4449	-12.4926
4.00- Drift	.0000	.00000	80	.0000	2.74396	1.000	-8.9761	8.9761
5.00- Insect Half-life	16.4688	36.35717	80	-16.4688(*)	2.74396	.000	-25.4449	-7.4926
6.00- Accumulation in Prey	17.2750	36.68329	80	-17.2750(*)	2.74396	.000	-26.2511	-8.2989
7.00- Soil Half-life	.0000	.00000	80	.0000	2.74396	1.000	-8.9761	8.9761
8.00- Dermal to Oral Toxicity	.8875	7.93804	80	-.8875	2.74396	1.000	-9.8636	8.0886
9.00- Early Spring Spraying	.0000	.00000	80	.0000	2.74396	1.000	-8.9761	8.9761

* The mean difference is significant at the .05 level.

Table B7c. Sensitivity Analyses: Changes in maximum # of growth regulators and defoliants the owl is exposed to > HD5 in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.0000	.00000	200					
1.00- Soil in Diet	.0000	.00000	80	.0000	.02299	1.000	-.0752	.0752
2.00- Dermal Exposure Time	.0000	.00000	80	.0000	.02299	1.000	-.0752	.0752
3.00- Half-life in Bird	.1125	.31797	80	-.1125(*)	.02299	.000	-.1877	-.0373
4.00- Drift	.0000	.00000	80	.0000	.02299	1.000	-.0752	.0752
5.00- Insect Half-life	.0750	.26505	80	-.0750	.02299	.052	-.1502	.0002
6.00- Accumulation in Prey	.2250	.42022	80	-.2250(*)	.02299	.000	-.3002	-.1498
7.00- Soil Half-life	.0000	.00000	80	.0000	.02299	1.000	-.0752	.0752
8.00- Dermal to Oral Toxicity	.0000	.00000	80	.0000	.02299	1.000	-.0752	.0752
9.00- Early Spring Spraying	.0000	.00000	80	.0000	.02299	1.000	-.0752	.0752

* The mean difference is significant at the .05 level.

Table B7d. Sensitivity Analyses: Changes in duration of exposure to an amount of growth regulators and defoliants > HD5 in the cotton/sorghum/cabbage crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.0000	.00000	200					
1.00- Soil in Diet	.0000	.00000	80	.0000	1.60919	1.000	-5.2640	5.2640
2.00- Dermal Exposure Time	.0000	.00000	80	.0000	1.60919	1.000	-5.2640	5.2640
3.00- Half-life in Bird	13.3875	38.07496	80	-13.3875(*)	1.60919	.000	-18.6515	-8.1235
4.00- Drift	.0000	.00000	80	.0000	1.60919	1.000	-5.2640	5.2640
5.00- Insect Half-life	1.6250	8.39360	80	-1.6250	1.60919	1.000	-6.8890	3.6390
6.00- Accumulation in Prey	3.4500	13.57646	80	-3.4500	1.60919	1.000	-8.7140	1.8140
7.00- Soil Half-life	.0000	.00000	80	.0000	1.60919	1.000	-5.2640	5.2640
8.00- Dermal to Oral Toxicity	.0000	.00000	80	.0000	1.60919	1.000	-5.2640	5.2640
9.00- Early Spring Spraying	.0000	.00000	80	.0000	1.60919	1.000	-5.2640	5.2640

* The mean difference is significant at the .05 level.

Table B7e. Sensitivity Analyses: Changes in maximum # of growth regulators and defoliants the owl is exposed to > HD5 in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.0000	.00000	200					
1.00- Soil in Diet	.0000	.00000	80	.0000	.02433	1.000	-.0796	.0796
2.00- Dermal Exposure Time	.0000	.00000	80	.0000	.02433	1.000	-.0796	.0796
3.00- Half-life in Bird	.1000	.30189	80	-.1000(*)	.02433	.002	-.1796	-.0204
4.00- Drift	.0000	.00000	80	.0000	.02433	1.000	-.0796	.0796
5.00- Insect Half-life	.1000	.30189	80	-.1000(*)	.02433	.002	-.1796	-.0204
6.00- Accumulation in Prey	.2875	.45545	80	-.2875(*)	.02433	.000	-.3671	-.2079
7.00- Soil Half-life	.0000	.00000	80	.0000	.02433	1.000	-.0796	.0796
8.00- Dermal to Oral Toxicity	.0000	.00000	80	.0000	.02433	1.000	-.0796	.0796
9.00- Early Spring Spraying	.0000	.00000	80	.0000	.02433	1.000	-.0796	.0796

* The mean difference is significant at the .05 level.

Table B7f. Sensitivity Analyses: Changes in duration of exposure to an amount of growth regulators and defoliants > HD5 in the cotton/sorghum/onions crop scenario.

Sensitivity Analyses	Mean	± S.D.	n	Mean Difference [Baseline (0) - x]	Std. Error	Sig.	95% Confidence Interval	
0.00- Baseline	.0000	.00000	200					
1.00- Soil in Diet	.0000	.00000	80	.0000	1.57720	1.000	-5.1594	5.1594
2.00- Dermal Exposure Time	.0000	.00000	80	.0000	1.57720	1.000	-5.1594	5.1594
3.00- Half-life in Bird	12.2125	37.11654	80	-12.2125(*)	1.57720	.000	-17.3719	-7.0531
4.00- Drift	.0000	.00000	80	.0000	1.57720	1.000	-5.1594	5.1594
5.00- Insect Half-life	2.3313	13.93655	80	-2.3313	1.57720	1.000	-7.4906	2.8281
6.00- Accumulation in Prey	2.8250	8.09403	80	-2.8250	1.57720	1.000	-7.9844	2.3344
7.00- Soil Half-life	.0000	.00000	80	.0000	1.57720	1.000	-5.1594	5.1594
8.00- Dermal to Oral Toxicity	.0000	.00000	80	.0000	1.57720	1.000	-5.1594	5.1594
9.00- Early Spring Spraying	.0000	.00000	80	.0000	1.57720	1.000	-5.1594	5.1594

* The mean difference is significant at the .05 level.

APPENDIX C

VALUES OF EXPOSURE GREATER THAN LOEL OR HD5 BY CHEMICAL TYPE

Table C1a. The maximum, mean, and duration of ChE inhibition caused by each insecticide type during winter period in the cotton/sorghum crop scenario.

	Maximum		Mean		Duration		Duration > 20%		
chemical	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	n
acephate	0.03	0.02	0.02	0.02	98.43	56.90	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	3.00	14.73	0.00	0.00	200
chlorpyrifos	1.83	2.63	1.08	1.50	150.46	0.27	0.00	0.00	200
dicrotophos	1.80	2.88	0.98	1.85	96.22	60.69	0.00	0.00	200
dimethoate	0.02	0.03	0.01	0.01	46.89	56.65	0.00	0.00	200
disulfoton	0.15	0.50	0.09	0.35	43.07	63.26	0.00	0.00	200
malathion	0.01	0.00	0.01	0.00	149.00	0.00	0.00	0.00	200
oxamyl	0.34	0.36	0.16	0.20	74.99	73.78	0.00	0.00	200

Table C1b. The maximum, mean, and duration of ChE inhibition caused by each insecticide type during winter period in the cotton/sorghum/cabbage crop scenario.

	Maximum		Mean		Duration		Duration > 20%		
chemical	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	n
acephate	0.02	0.02	0.01	0.02	74.69	66.05	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	2.66	13.82	0.00	0.00	200
chlorpyrifos	1.47	2.29	0.85	1.31	148.68	8.13	0.00	0.00	200
diazinon	0.31	0.46	0.02	0.03	20.62	28.90	0.00	0.00	200
dicrotophos	1.65	2.68	0.74	1.65	70.64	65.55	0.00	0.00	200
dimethoate	0.29	0.91	0.01	0.02	59.63	60.28	0.00	0.00	200
disulfoton	0.12	0.45	0.07	0.31	26.17	49.88	0.00	0.00	200
malathion	0.01	0.00	0.01	0.00	148.45	0.54	0.00	0.00	200
methomyl	7.19	20.48	2.05	3.59	60.72	72.60	1.72	8.42	200
oxamyl	0.29	0.33	0.10	0.16	61.02	64.94	0.00	0.00	200

Table C1c. The maximum, mean, and duration of ChE inhibition caused by each insecticide type during winter period in the cotton/sorghum/onions crop scenario.

	Maximum		Mean		Duration		Duration > 20%		
chemical	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	n
acephate	0.03	0.02	0.01	0.02	76.86	63.46	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	1.50	10.53	0.00	0.00	200
chlorpyrifos	1.86	2.49	1.07	1.43	148.63	7.19	0.00	0.00	200
diazinon	0.28	0.49	0.01	0.02	10.32	17.04	0.00	0.00	200
dicrotophos	1.52	2.61	0.75	1.60	77.24	67.05	0.00	0.00	200
dimethoate	0.02	0.03	0.01	0.01	38.75	56.87	0.00	0.00	200
disulfoton	0.10	0.36	0.06	0.25	27.18	49.69	0.00	0.00	200
malathion	0.01	0.00	0.01	0.00	148.36	0.63	0.00	0.00	200
methomyl	57.23	44.79	14.41	11.81	149.65	1.31	15.41	18.03	200
oxamyl	0.33	0.33	0.12	0.16	70.81	64.91	0.00	0.00	200

Table C2a. Maximum & mean exposure that occurred over the winter to each insecticide divided by each insecticide's LOEL, as well as duration of exposure > LOEL in the cotton/sorghum crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Insecticide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
acephate	0.00	0.00	0.00	0.00	0.00	0.00	200
acetamiprid	0.00	0.00	0.00	0.00	0.00	0.00	200
bacillus thuringensis	0.00	0.00	0.00	0.00	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	0.00	0.00	200
chlorpyrifos	13.47	16.46	8.72	10.77	146.27	19.51	200
cyfluthrin	0.00	0.00	0.00	0.00	0.00	0.00	200
cypermethrin	0.04	0.24	0.02	0.13	1.96	13.03	200
diazinon	0.00	0.00	0.00	0.00	0.00	0.00	200
dicrotophos	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethoate	0.00	0.00	0.00	0.00	0.00	0.00	200
disulfoton	0.35	1.47	0.23	1.02	9.64	36.20	200
endosulfan	0.00	0.00	0.00	0.00	0.00	0.00	200
esfenvalerate	0.00	0.00	0.00	0.00	0.00	0.00	200
imidacloprid	0.00	0.00	0.00	0.00	0.00	0.00	200
indoxacarb	0.02	0.18	0.01	0.14	1.38	13.77	200
lambda-cyhalothrin	1.01	1.37	0.85	1.12	55.64	69.77	200
malathion	0.00	0.00	0.00	0.00	0.00	0.00	200
methomyl	0.00	0.00	0.00	0.00	0.00	0.00	200
oxamyl	0.00	0.00	0.00	0.00	0.00	0.00	200
permethrin	0.00	0.00	0.00	0.00	0.00	0.00	200
spinosad	0.00	0.00	0.00	0.00	0.00	0.00	200
thiamethoxam	0.00	0.00	0.00	0.00	0.00	0.00	200
zeta-cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200

Table C2b. Maximum & mean exposure that occurred over the winter to each insecticide divided by each insecticide's LOEL, as well as duration of exposure > LOEL in the cotton/sorghum/cabbage crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Insecticide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
acephate	0.00	0.00	0.00	0.00	0.00	0.00	200
acetamiprid	0.00	0.00	0.00	0.00	0.00	0.00	200
bacillus thuringensis	0.00	0.00	0.00	0.00	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	0.00	0.00	200
chlorpyrifos	10.98	14.73	6.98	9.56	142.33	29.58	200
cyfluthrin	0.00	0.00	0.00	0.00	0.00	0.00	200
cypermethrin	0.04	0.24	0.02	0.11	1.98	12.18	200
diazinon	0.00	0.00	0.00	0.00	0.00	0.00	200
dicrotophos	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethoate	0.15	0.54	0.00	0.00	0.04	0.13	200
disulfoton	0.28	1.31	0.19	0.91	7.45	32.55	200
endosulfan	4.81	28.29	1.72	10.54	6.90	26.96	200
esfenvalerate	0.01	0.07	0.00	0.01	0.10	1.41	200
imidacloprid	0.00	0.00	0.00	0.00	0.00	0.00	200
indoxacarb	0.02	0.14	0.00	0.01	0.21	2.04	200
lambda-cyhalothrin	1.18	1.48	0.98	1.15	65.47	71.12	200
malathion	0.00	0.00	0.00	0.00	0.00	0.00	200
methomyl	0.00	0.00	0.00	0.00	0.00	0.00	200
oxamyl	0.00	0.00	0.00	0.00	0.00	0.00	200
permethrin	0.00	0.00	0.00	0.00	0.00	0.00	200
spinosad	0.00	0.00	0.00	0.00	0.00	0.00	200
thiamethoxam	0.00	0.00	0.00	0.00	0.00	0.00	200
zeta-cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200

Table C2c. Maximum & mean exposure that occurred over the winter to each insecticide divided by each insecticide's LOEL, as well as duration of exposure > LOEL in the cotton/sorghum/onions crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Insecticide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
acephate	0.00	0.00	0.00	0.00	0.00	0.00	200
acetamiprid	0.00	0.00	0.00	0.00	0.00	0.00	200
bacillus thuringensis	0.00	0.00	0.00	0.00	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	0.00	0.00	200
chlorpyrifos	13.66	16.11	8.65	10.51	141.27	31.49	200
cyfluthrin	0.00	0.00	0.00	0.00	0.00	0.00	200
cypermethrin	0.10	0.36	0.03	0.16	3.67	16.82	200
diazinon	0.00	0.00	0.00	0.00	0.00	0.00	200
dicrotophos	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethoate	0.00	0.00	0.00	0.00	0.00	0.00	200
disulfoton	0.22	1.06	0.15	0.73	7.97	33.18	200
endosulfan	0.00	0.00	0.00	0.00	0.00	0.00	200
esfenvalerate	0.00	0.00	0.00	0.00	0.00	0.00	200
imidacloprid	0.00	0.00	0.00	0.00	0.00	0.00	200
indoxacarb	0.01	0.12	0.01	0.10	0.70	9.83	200
lambda-cyhalothrin	1.35	1.60	1.06	1.26	63.75	71.02	200
malathion	0.00	0.00	0.00	0.00	0.00	0.00	200
methomyl	0.00	0.00	0.00	0.00	0.00	0.00	200
oxamyl	0.00	0.00	0.00	0.00	0.00	0.00	200
permethrin	0.00	0.00	0.00	0.00	0.00	0.00	200
spinosad	0.00	0.00	0.00	0.00	0.00	0.00	200
thiamethoxam	0.00	0.00	0.00	0.00	0.00	0.00	200
zeta-cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200

Table C3a. Maximum & mean exposure that occurred over the winter to each insecticide divided by each insecticide's HD5, as well as duration of exposure > HD5 in the cotton/sorghum crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/ HD5		Mean Exposure/ HD5		Duration (Exposure >			Max. Exposure/ HD5		Mean Exposure/ HD5		Duration (Exposure >		
Insecticide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
acephate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
acetamiprid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bacillus thuringensis	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
chlorpyrifos	0.14	0.39	0.03	0.10	3.49	12.64	200	2.69	4.23	1.69	2.82	45.18	65.46	200
cyfluthrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
diazinon	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
dicrotophos	0.00	0.00	0.00	0.00	0.00	0.00	200	0.05	0.26	0.02	0.11	2.92	14.36	200
dimethoate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
disulfoton	0.00	0.00	0.00	0.00	0.00	0.00	200	0.11	0.52	0.06	0.33	4.45	21.74	200
endosulfan	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
esfenvalerate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
imidacloprid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
indoxacarb	0.00	0.00	0.00	0.00	0.00	0.00	200	0.03	0.23	0.02	0.18	1.21	11.93	200
lambda-cyhalothrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
malathion	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
methomyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
oxamyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
permethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
spinosad	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
thiamethoxam	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
zeta-cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200

Table C3b. Maximum & mean exposure that occurred over the winter to each insecticide divided by each insecticide's HD5, as well as duration of exposure > HD5 in the cotton/sorghum/cabbage crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/ HD5		Mean Exposure/ HD5		Duration (Exposure >			Max. Exposure/ HD5		Mean Exposure/ HD5		Duration (Exposure >		
Insecticide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
acephate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
acetamiprid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bacillus thuringensis	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
chlorpyrifos	0.14	0.39	0.02	0.09	3.20	11.27	200	2.26	4.19	1.44	2.78	35.38	61.34	200
cyfluthrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
diazinon	1.81	2.66	0.07	0.12	4.37	6.93	200	1.98	2.63	0.09	0.14	5.44	8.29	200
dicrotophos	0.00	0.00	0.00	0.00	0.00	0.00	200	0.08	0.31	0.03	0.13	4.30	17.12	200
dimethoate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
disulfoton	0.00	0.00	0.00	0.00	0.00	0.00	200	0.16	0.80	0.11	0.56	5.46	27.68	200
endosulfan	0.09	0.56	0.02	0.19	1.30	10.38	200	0.25	1.10	0.08	0.38	3.52	15.79	200
esfenvalerate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
imidacloprid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
indoxacarb	0.00	0.00	0.00	0.00	0.00	0.00	200	0.03	0.22	0.02	0.17	1.41	14.07	200
lambda-cyhalothrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
malathion	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
methomyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
oxamyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
permethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
spinosad	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
thiamethoxam	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
zeta-cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200

Table C3c. Maximum & mean exposure that occurred over the winter to each insecticide divided by each insecticide's HD5, as well as duration of exposure > HD5 in the cotton/sorghum/onions crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/		Mean Exposure/		Duration			Max. Exposure/		Mean Exposure/		Duration		
Insecticide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
acephate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
acetamiprid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bacillus thuringensis	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
carbaryl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
chlorpyrifos	0.12	0.38	0.03	0.10	3.28	12.60	200	2.37	4.12	1.49	2.74	39.20	62.30	200
cyfluthrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
diazinon	1.50	2.68	0.04	0.07	2.06	4.07	200	1.90	2.91	0.05	0.09	3.05	5.05	200
dicrotophos	0.00	0.00	0.00	0.00	0.00	0.00	200	0.06	0.26	0.03	0.12	3.31	15.29	200
dimethoate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
disulfoton	0.00	0.00	0.00	0.00	0.00	0.00	200	0.18	0.81	0.11	0.56	5.88	26.67	200
endosulfan	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
esfenvalerate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
imidacloprid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
indoxacarb	0.00	0.00	0.00	0.00	0.00	0.00	200	0.03	0.25	0.03	0.20	2.29	17.30	200
lambda-cyhalothrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
malathion	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
methomyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
oxamyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
permethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
spinosad	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
thiamethoxam	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
zeta-cypermethrin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200

Table C4a. Maximum & mean exposure that occurred over the winter to each herbicide divided by each herbicide's LOEL, as well as duration of exposure > LOEL in the cotton/sorghum crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Herbicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
2,4-D	0.08	0.33	0.00	0.01	0.10	0.73	200
alachlor	0.38	1.99	0.01	0.06	0.28	1.19	200
atrazine	0.00	0.00	0.00	0.00	0.00	0.00	200
bensulide	0.00	0.00	0.00	0.00	0.00	0.00	200
bromoxynil	0.00	0.00	0.00	0.00	0.00	0.00	200
carfentrazone-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200
clethodim	0.00	0.00	0.00	0.00	0.00	0.00	200
dcpa	0.00	0.00	0.00	0.00	0.00	0.00	200
dicamba	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethenamid	0.01	0.09	0.00	0.00	0.01	0.18	200
diuron	0.70	1.35	0.37	0.82	27.35	56.50	200
fluometuron	0.00	0.00	0.00	0.00	0.00	0.00	200
glufinosinate	0.26	1.49	0.01	0.06	0.21	1.34	200
glyphosate	0.08	0.35	0.00	0.01	0.21	0.96	200
metsulfuron-methyl	0.00	0.00	0.00	0.00	0.00	0.00	200
oxyfluorfen	0.00	0.00	0.00	0.00	0.00	0.00	200
pendimethalin	0.00	0.00	0.00	0.00	0.00	0.00	200
prometryn	0.00	0.00	0.00	0.00	0.00	0.00	200
prosulfuron	0.00	0.00	0.00	0.00	0.00	0.00	200
pyraflufen-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200
pyrithiobac-sodium	0.00	0.00	0.00	0.00	0.00	0.00	200
s-metolachlor	0.08	0.34	0.00	0.00	0.12	0.51	200
trifluralin	2.37	2.96	0.86	1.41	46.12	65.58	200

Table C4b. Maximum & mean exposure that occurred over the winter to each herbicide divided by each herbicide's LOEL, as well as duration of exposure > LOEL in the cotton/sorghum/cabbage crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Herbicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
2,4-D	0.08	0.36	0.00	0.01	0.09	0.58	200
alachlor	0.19	1.48	0.01	0.11	0.20	1.55	200
atrazine	0.00	0.00	0.00	0.00	0.00	0.00	200
bensulide	0.36	0.73	0.02	0.05	2.64	5.86	200
bromoxynil	0.00	0.00	0.00	0.00	0.00	0.00	200
carfentrazone-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200
clethodim	0.00	0.00	0.00	0.00	0.00	0.00	200
dcpa	0.13	0.38	0.00	0.00	0.14	0.54	200
dicamba	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethenamid	0.02	0.17	0.00	0.01	0.09	0.77	200
diuron	0.70	1.30	0.40	0.84	29.79	58.04	200
fluometuron	0.00	0.00	0.00	0.00	0.00	0.00	200
glufinosinate	0.14	0.93	0.00	0.02	0.09	0.62	200
glyphosate	0.09	0.36	0.00	0.01	0.26	1.09	200
metsulfuron-methyl	0.00	0.00	0.00	0.00	0.00	0.00	200
oxyfluorfen	0.00	0.00	0.00	0.00	0.00	0.00	200
pendimethalin	0.00	0.00	0.00	0.00	0.00	0.00	200
prometryn	0.00	0.00	0.00	0.00	0.00	0.00	200
prosulfuron	0.00	0.00	0.00	0.00	0.00	0.00	200
pyraflufen-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200
pyrithiobac-sodium	0.00	0.00	0.00	0.00	0.00	0.00	200
s-metolachlor	0.09	0.38	0.00	0.01	0.17	0.73	200
trifluralin	3.38	2.92	1.01	1.50	53.92	62.43	200

Table C4c- Maximum & mean exposure that occurred over the winter to each herbicide divided by each herbicide's LOEL, as well as duration of exposure > LOEL in the cotton/sorghum/onions crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Herbicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
2,4-D	0.08	0.33	0.00	0.00	0.07	0.51	200
alachlor	0.20	1.55	0.01	0.07	0.11	0.88	200
atrazine	0.00	0.00	0.00	0.00	0.00	0.00	200
bensulide	0.73	0.99	0.05	0.10	5.06	9.68	200
bromoxynil	0.00	0.00	0.00	0.00	0.00	0.00	200
carfentrazone-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200
clethodim	0.00	0.00	0.00	0.00	0.00	0.00	200
dcpa	0.37	0.65	0.01	0.01	0.63	1.40	200
dicamba	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethenamid	0.01	0.09	0.00	0.00	0.02	0.32	200
diuron	0.63	1.28	0.36	0.74	30.14	57.76	200
fluometuron	0.00	0.00	0.00	0.00	0.00	0.00	200
glufinosinate	0.10	0.98	0.00	0.04	0.11	1.10	200
glyphosate	0.12	0.41	0.00	0.01	0.39	1.41	200
metsulfuron-methyl	0.00	0.00	0.00	0.00	0.00	0.00	200
oxyfluorfen	0.04	0.22	0.00	0.03	0.44	3.45	200
pendimethalin	0.00	0.00	0.00	0.00	0.00	0.00	200
prometryn	0.00	0.00	0.00	0.00	0.00	0.00	200
prosulfuron	0.00	0.00	0.00	0.00	0.00	0.00	200
pyraflufen-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200
pyrithiobac-sodium	0.00	0.00	0.00	0.00	0.00	0.00	200
s-metolachlor	0.07	0.31	0.00	0.01	0.15	0.74	200
trifluralin	3.00	3.02	1.09	1.48	55.91	66.79	200

Table C5a. Maximum & mean exposure that occurred over the winter to each herbicide divided by each herbicide's HD5, as well as duration of exposure > HD5 in the cotton/sorghum crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/		Mean Exposure/		Duration			Max. Exposure/		Mean Exposure/		Duration		
Herbicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
2,4-D	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
alachlor	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
atrazine	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bensulide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bromoxynil	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
carfentrazone-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
clethodim	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
DCPA	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
dicamba	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethenamid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
diuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
fluometuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
glufinosinate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
glyphosate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.09	0.35	0.00	0.01	0.21	0.96	200
metsulfuron-methyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
oxyfluorfen	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pendimethalin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
prometryn	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
prosulfuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pyraflufen-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pyrithiobac-sodium	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
s-metolachlor	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
trifluralin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.14	0.37	0.01	0.05	1.23	6.93	200

Table C5b. Maximum & mean exposure that occurred over the winter to each herbicide divided by each herbicide's HD5, as well as duration of exposure > HD5 in the cotton/sorghum/cabbage crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/		Mean Exposure/		Duration			Max. Exposure/		Mean Exposure/		Duration		
Herbicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
2,4-D	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
alachlor	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
atrazine	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bensulide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bromoxynil	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
carfentrazone-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
clethodim	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
DCPA	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
dicamba	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethenamid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.01	0.12	0.00	0.00	0.03	0.29	200
diuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
fluometuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
glufinosinate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
glyphosate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.08	0.32	0.00	0.01	0.14	0.67	200
metsulfuron-methyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
oxyfluorfen	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pendimethalin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
prometryn	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
prosulfuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pyraflufen-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pyrithiobac-sodium	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
s-metolachlor	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
trifluralin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.14	0.37	0.01	0.05	1.76	7.27	200

Table C5c. Maximum & mean exposure that occurred over the winter to each herbicide divided by each herbicide's HD5, as well as duration of exposure > HD5 in the cotton/sorghum/onions crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/		Mean Exposure/		Duration			Max. Exposure/		Mean Exposure/		Duration		
Herbicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
2,4-D	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
alachlor	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
atrazine	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bensulide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
bromoxynil	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
carfentrazone-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
clethodim	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
DCPA	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
dicamba	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
dimethenamid	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
diuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
fluometuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
glufinosinate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
glyphosate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.05	0.27	0.00	0.01	0.12	0.69	200
metsulfuron-methyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
oxyfluorfen	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pendimethalin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
prometryn	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
prosulfuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pyraflufen-ethyl	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
pyrithiobac-sodium	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
s-metolachlor	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
trifluralin	0.00	0.00	0.00	0.00	0.00	0.00	200	0.14	0.36	0.00	0.02	0.53	2.90	200

Table C6a. Maximum & mean exposure that occurred over the winter to each growth regulator or defoliant divided by each chemical's LOEL, as well as duration of exposure > LOEL, in the cotton/sorghum crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Growth Regulator or Defoliant Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
bacillus cereus	0.00	0.00	0.00	0.00	0.00	0.00	200
cyclanilide	0.00	0.00	0.00	0.00	0.00	0.00	200
ethephon	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat chloride	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat pentaborate	0.00	0.00	0.00	0.00	0.00	0.00	200
monocarbamide	0.00	0.00	0.00	0.00	0.00	0.00	200
paraquat	2.98	2.29	2.08	1.91	101.42	64.27	200
thidiazuron	0.00	0.00	0.00	0.00	0.00	0.00	200
tribufos	0.89	1.17	0.50	0.90	39.08	59.70	200

Table C6b. Maximum & mean exposure that occurred over the winter to each growth regulator or defoliant divided by each chemical's LOEL, as well as duration of exposure > LOEL, in the cotton/sorghum/cabbage crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Growth Regulator or Defoliant Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
bacillus cereus	0.00	0.00	0.00	0.00	0.00	0.00	200
Cyclanilide	0.00	0.00	0.00	0.00	0.00	0.00	200
Ethephon	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat chloride	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat pentaborate	0.00	0.00	0.00	0.00	0.00	0.00	200
monocarbamide	0.00	0.00	0.00	0.00	0.00	0.00	200
Paraquat	2.40	2.18	1.51	1.73	79.78	70.38	200
thidiazuron	0.00	0.00	0.00	0.00	0.00	0.00	200
Tribufos	0.67	1.09	0.40	0.82	31.52	58.67	200

Table C6c. Maximum & mean exposure that occurred over the winter to each growth regulator or defoliant divided by each chemical's LOEL, as well as duration of exposure > LOEL, in the cotton/sorghum/onions crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Growth Regulator or Defoliant Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
bacillus cereus	0.00	0.00	0.00	0.00	0.00	0.00	200
Cyclanilide	0.00	0.00	0.00	0.00	0.00	0.00	200
Ethephon	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat chloride	0.00	0.00	0.00	0.00	0.00	0.00	200
Mepiquat pentaborate	0.00	0.00	0.00	0.00	0.00	0.00	200
monocarbamide	0.00	0.00	0.00	0.00	0.00	0.00	200
Paraquat	2.42	2.13	1.53	1.69	83.66	70.53	200
thidiazuron	0.00	0.00	0.00	0.00	0.00	0.00	200
Tribufos	0.56	1.03	0.37	0.80	29.62	57.56	200

Table C7a. Maximum & mean exposure that occurred over the winter to each growth regulator or defoliant divided by each growth regulator or defoliant's HD5, as well as duration of exposure > HD5 in the cotton/sorghum crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/		Mean Exposure/		Duration			Max. Exposure/		Mean Exposure/		Duration		
Growth Regulator or Defoliant Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
bacillus cereus	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
cyclanilide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
ethephon	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat chloride	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat pentaborate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
monocarbamide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
paraquat	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
thidiazuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
tribufos	0.00	0.00	0.00	0.00	0.00	0.00	200	0.57	1.03	0.47	0.88	35.86	61.44	200

Table C7b. Maximum & mean exposure that occurred over the winter to each growth regulator or defoliant divided by each growth regulator or defoliant's HD5, as well as duration of exposure > HD5 in the cotton/sorghum/cabbage crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/		Mean Exposure/		Duration			Max. Exposure/		Mean Exposure/		Duration		
Growth Regulator or Defoliant Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
bacillus cereus	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
cyclanilide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
ethephon	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat chloride	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat pentaborate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
monocarbamide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
paraquat	0.00	0.00	0.00	0.00	0.00	0.00	200	0.01	0.07	0.00	0.00	0.00	0.04	200
thidiazuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
tribufos	0.00	0.00	0.00	0.00	0.00	0.00	200	0.45	1.09	0.38	0.95	23.55	54.05	200

Table C7c. Maximum & mean exposure that occurred over the winter to each growth regulator or defoliant divided by each growth regulator or defoliant's HD5, as well as duration of exposure > HD5 in the cotton/sorghum/onions crop scenario, with normal concentrations in culvert soil, and concentrations increased to 10 times the amount in the crop soil.

	Culvert Soil Chemicals/Crop Soil Chemicals =1							Culvert Soil Chemicals/Crop Soil Chemicals =10						
	Max. Exposure/		Mean Exposure/		Duration			Max. Exposure/		Mean Exposure/		Duration		
Growth Regulator or Defoliant Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
bacillus cereus	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
cyclanilide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
ethephon	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat chloride	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
mepiquat pentaborate	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
monocarbamide	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
paraquat	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
thidiazuron	0.00	0.00	0.00	0.00	0.00	0.00	200	0.00	0.00	0.00	0.00	0.00	0.00	200
tribufos	0.00	0.00	0.00	0.00	0.00	0.00	200	0.55	1.10	0.45	0.94	31.97	58.29	200

Table C8a. Maximum & mean exposure that occurred over the winter to each fungicide divided by each fungicide's LOEL, as well as duration of exposure > LOEL in the cotton/sorghum/cabbage crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Fungicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
azoxystrobin	0.00	0.00	0.00	0.00	0.00	0.00	200
benzoic acid	0.00	0.00	0.00	0.00	0.00	0.00	200
chlorothalonil	1.30	1.22	0.08	0.10	7.60	9.38	200
copper hydroxide	0.00	0.00	0.00	0.00	0.00	0.00	200
iprodione	0.00	0.00	0.00	0.00	0.00	0.00	200
mancozeb	0.00	0.00	0.00	0.00	0.00	0.00	200
maneb	2.55	3.90	0.58	0.96	21.30	34.13	200
metalaxyl	0.00	0.00	0.00	0.00	0.00	0.00	200

Table C8b - Maximum & mean exposure that occurred over the winter to each fungicide divided by each fungicide's LOEL, as well as duration of exposure > LOEL in the cotton/sorghum/onions crop scenario.

	Max. Exposure/ LOEL		Mean Exposure/ LOEL		Duration (Exposure > LOEL)		
Fungicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
azoxystrobin	0.00	0.00	0.00	0.00	0.00	0.00	200
benzoic acid	0.00	0.00	0.00	0.00	0.00	0.00	200
chlorothalonil	0.76	1.28	0.05	0.10	4.51	8.77	200
copper hydroxide	33.51	15.53	22.84	10.73	149.07	2.18	200
iprodione	0.00	0.00	0.00	0.00	0.00	0.00	200
mancozeb	0.03	0.19	0.00	0.00	0.07	0.60	200
maneb	4.67	8.82	0.98	1.98	12.76	24.76	200
metalaxyl	0.00	0.00	0.00	0.00	0.00	0.00	200

Table C9a. Maximum & mean exposure that occurred over the winter to each fungicide divided by each fungicide's HD5, as well as duration of exposure > HD5 in the cotton/sorghum/cabbage crop scenario, with normal concentrations in culvert soil and concentrations increased to 10 times the amount in the crop soil combined because there was no difference between ratios.

	Max. Exposure/		Mean Exposure/		Duration (Exposure		
Fungicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
azoxystrobin	0.00	0.00	0.00	0.00	0.00	0.00	400
benzoic acid	0.00	0.00	0.00	0.00	0.00	0.00	400
chlorothalonil	0.00	0.00	0.00	0.00	0.00	0.00	400
copper hydroxide	0.00	0.00	0.00	0.00	0.00	0.00	400
iprodione	0.00	0.00	0.00	0.00	0.00	0.00	400
mancozeb	0.00	0.00	0.00	0.00	0.00	0.00	400
maneb	0.00	0.00	0.00	0.00	0.00	0.00	400
metalaxyl	0.00	0.00	0.00	0.00	0.00	0.00	400

Table C9b. Maximum & mean exposure that occurred over the winter to each fungicide divided by each fungicide's HD5, as well as duration of exposure > HD5 in the cotton/sorghum/onions crop scenario, with normal concentrations in culvert soil and concentrations increased to 10 times the amount in the crop soil combined because there was no difference between ratios.

	Max. Exposure/		Mean Exposure/		Duration (Exposure		
Fungicide Type	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	N
azoxystrobin	0.00	0.00	0.00	0.00	0.00	0.00	400
benzoic acid	0.00	0.00	0.00	0.00	0.00	0.00	400
chlorothalonil	0.00	0.00	0.00	0.00	0.00	0.00	400
copper hydroxide	42.73	21.26	29.16	14.65	148.25	10.88	400
iprodione	0.00	0.00	0.00	0.00	0.00	0.00	400
mancozeb	0.00	0.00	0.00	0.00	0.00	0.00	400
maneb	0.00	0.00	0.00	0.00	0.00	0.00	400
metalaxyl	0.00	0.00	0.00	0.00	0.00	0.00	400

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