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Methods for Assessing the Impact of Fog Oil Smoke on Availability, Palatability, & Food Quality of Relevant Life Stages of Insects for Threatened and Endangered Species

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Strategic Environmental Research and Development Program (SERDP)
Project Number 1262

Pacific Northwest National Laboratory, Richland, WA

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List of Acronyms

CV	coefficient of variation
DoD	Department of Defense
EPA	Environmental Protection Agency
FO	Fog oil
HEPA	High Efficiency Particulate Air
MMAD	Mass median aerodynamic diameter
PNNL	Pacific Northwest National Laboratory
PVC	Polyvinyl Chloride
SERDP	Strategic Environmental Research and Development Program
SON	statement of need
TES	Threatened and Endangered Species
V_d	Deposition velocity
W	watt

Preface

This study was conducted for the Strategic Environmental Research and Development Program (SERDP) under project number CS-1262**, "**Methods for Assessing the Impact of Fog Oil Smoke on Availability, Palatability, & Food Quality of Relevant Life Stages of Insects for Threatened and Endangered Species." The technical monitor for the project was Dr. Robert W. Holst, Compliance and Conservation Program Manager, followed by Dr. John Hall, Sustainable Infrastructure Program Manager.

The work was performed by Pacific Northwest National Laboratory (PNNL), Richland, Washington. The Principal Investigator was Dennis Strenge. Crystal Driver, Yin-Fong Su, Valarie Cullinan, Rick Herrington, and Danielle Saunders contributed to the project completion and report. Lee Rogers is employed by Washington State University, Tri-Cities Branch, Richland, Washington.

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Executive Summary

Protection of threatened and endangered species (TES) and their habitat on U.S. Department of Defense (DoD) lands while sustaining the use of those lands for military training is a major goal of the Strategic Environmental Research and Development Program's (SERDP's) conservation mission. Important components of troop training exercises at military training installations are generation of fog oil (FO) "smoke" and maneuvers under obscurant cover. To comply with the Endangered Species Act, the impact of fog oil releases on avian TES (or surrogates) have been evaluated in both field and laboratory studies. Although no direct acute effects on avian species have been observed, concern has been raised regarding a possible indirect impact via reduction in insect populations used as a food source for these species. This concern arises from the fact that petroleum oils of similar composition to that of fog oil have long been used to kill insect pests. These oils particularly target soft-bodied insects, eggs, and larvae that are important dietary components of several avian and bat TES inhabiting military lands.

To determine if training exercises with FO smoke causes depletion of TES food resources, a method was developed to evaluate the impact of FO aerosols on the survival, palatability, and activity of the consumed life stage of representative insect prey species. The method was also applied to antecedent life stages to evaluate deficits in the production of the consumed life stage. Because FO deposition in the foraging habitat of the TES of concern can be affected by wind speed and canopy structure, the influence of these key environmental factors on the population responses was also characterized.

Our approach employed an environmentally controlled re-circulating wind tunnel outfitted with a high-heat vaporization and re-condensation fog oil generator that has been shown to produce aerosols of comparable chemistry and droplet-size distribution as those of field releases of the smoke. Using an environmentally controlled wind tunnel allowed for control and reproducibility of those conditions (temperature, humidity, wind speed, sunlight) that may affect organism exposure through changes in both size and composition of the fog oil droplets and the activity and metabolism of the insects. The wind tunnel also supports canopy conditions needed for exposure realism, post-exposure re-volatilization, and insect maintenance.

Five species representative of major prey groups of the TES were used in the study. To address potential differences in susceptibility of insect taxa to fog oil that have been seen with other lubricating oils, we selected species from different orders, including a geometrid moth (*Diagrammia curvata* [Grote]), wood roach (*Parcoblatta uhleriana* [Saussure]), mosquito (*Culex* sp.), ant (*Camponotus pennsylvanicus* [DeGeer]), and beetle (*Tenebrio molitor* Linnaeus). Four species (the moth, wood roach, beetle and adult ant) were selected to represent the dominant orders and life stages of the bird food sources during pre-reproduction and reproduction periods. The beetle larvae were selected as a surrogate for arboreal beetles because of ease of culture. The mosquito along with the moth and male adult wood roach are representative of the night-flying adult forms hunted by bats.

Because of the potential of insufficient deposition of the thermal fog on vegetation or insect surfaces to elicit an adverse effect, a series of screening tests were conducted that simulated the worst-case scenario of fixed location training and 4-hour exposure duration at twice the field

levels near the generator and wind and canopy speeds that would be worst case for the species. If no adverse effect was observed compared to controls (i.e., insects treated in same manner, but without fog oil exposure) under the worst-case scenario conditions for a particular life stage of an insect, no tests with that life stage at lower concentrations were conducted. If effects were observed, exposures for that life stage were conducted over a range of field level concentrations. For dilutions of field level concentration, fog oil aerosols were aged in the wind tunnel prior to exposing the insects to simulate downwind aerosols. Additional tests at wind speeds from 0 to 3.6 m/s (0 to 8 mph) were conducted for those insect life stages that were affected by fog oil aerosols in the screening tests. These species/life-stages were also tested in a low density canopy if appropriate to their habitat.

The outcome of the tests was an evaluation of the impact of fog oil aerosols on a food resource rather than simply the toxic response of a class of organisms to the oil; therefore, the endpoints measured encompassed those that reduce not only numbers of prey, but also the consumption of prey. Accordingly, post-exposure measurements assessed the following: 1) reduction in prey numbers through mortality of the consumed life stage (larvae, adult); 2) reduced hatch or emergence of the consumed life stage; 3) reduction in prey availability because of impaired flight or decreased movement (reduced conspicuousness); and 4) reduced palatability of contaminated prey. We had also proposed to measure food quality (nutritional value) of FO exposed insects, but were unable to due to insufficient number of individuals within the life stages. In addition, because of difficulty in establishing regenerating colonies for the wood roach and mosquito within the time frame of this study and the small egg size of other species (moth and beetle), the impact of FO on hatch rates of the insect species could not be accomplished with accuracy. The use of species with larger eggs, more adaptable to induction of egg-laying in artificial systems, or for which oviposition chambers are developed should allow evaluation of the effects of FO during this possibly most sensitive life-stage.

No adverse effects from exposure to high concentrations of aerosolized FO were observed in either the immature or adult forms of two of the test species, the wood roach and beetle. Adult geometrid moths were also unaffected by FO exposure at near-source concentrations. At twice the highest near-source concentration (916 mg/m^3), however, activity, flight, and response to touch stimuli were greatly reduced.

Affected species included larval stages of the moth, mosquito, and adult ants. For these species survivability was reduced and life spans or maturation periods altered by exposure to FO aerosols. For mosquitoes, sensitivity of first and third instars to FO exposure was low; however, survival decreased at concentrations above 200 mg/m^3. At 800 mg/m^3, exposure to FO during the first larval instar appears to result in delayed pupation and adult emergence. Wind speed was an important factor influencing survival in ants and moth larvae. Response to FO exposure in the various wind speeds differed under the two canopy densities for geometrid moth larvae. For this species, reductions in progression to the last (5^{th}) larval instar, the number of 5^{th} instar larvae that pupated, and the number of adult moths that successfully emerged from the surviving 5^{th} larval instars differed with age (antecedent instar) at exposure, and with wind speed and canopy density during exposure. Palatability of moth larvae to an avian predator was not altered by exposure of the larvae to 800 mg/m^3 of FO for 2 hours.

Sensitivity of first and third instar mosquitoes was low with effects observed only at exposures above 200 mg/m^3. At high concentrations, exposure during the first larval instar appears to result in delayed pupation and adult emergence.

Analysis of these data provided, for the first time, empirical algorithms relating FO smoke concentration to reductions in insect populations. Response functions were formulated that further refined predicted impacts of FO-induced mortality in prey populations to include the impact of wind speed and canopy density conditions on FO mortality rates. For moths, a predominant prey group in all its life stages for birds, the survival to the last larval (5^{th}) instar and subsequent pupation and successful adult emergence as a function of the instar (1^{st} through 5^{th}) that was exposed were also obtained. Such response function can be coupled to transport models to estimate the fog oil impact on a population of insects following release and downwind transport during field exercises. In such a modeling effort, a transport model is used to evaluate the concentration of FO as a function of distance and direction from the release point. The response functions are coupled with the estimated air concentration and deposition rates to determine an integrated impact over the area affected by the plume. The downwind transport is modeled until concentrations are reduced to levels of no concern (as determined by the response function). Such an analysis could result in an area-weighted measure of impact. The DUSTRAN (dust transport) model is an example of a computational tool that could be adapted to couple the atmospheric transport analysis of the FO and the insect response functions to estimate a net impact on the local food insect species.

The dynamic exposure system used in this study provided 1) aerosolized FO that has undergone the same thermal generation process as used in military mechanical smoke generators; 2) production of fog oil smoke with realistic droplet size distributions, concentrations and durations; 3) control over environmental conditions that influence droplet deposition and insect metabolism (wind speed, canopy structure, temperature, and humidity); and 4) ability to replicate and adequately characterize exposures. With the ability to rapidly select and control test parameters (not possible in field trials), the wind tunnel is a cost-effective tool for estimating obscurant impacts to insect prey of TES on military lands.

The study developed and demonstrated a test method for quantifying the potential impact of FO on the food base of TES inhabiting Department of Defense lands where training activities are conducted. This method allows testing of prey species under relevant climatic and canopy conditions of specific TES and with realistic chemical and droplet size characteristics, concentrations, and durations. With the ability to replicate and adequately characterize exposures and rapidly select and control test parameters (not possible in field trials), the wind tunnel is also a cost-effective tool, as compared to field assessments, for estimating obscurant impacts to insect prey of TES on military lands.

Exposure-response information on the effects of fog oil were developed for important prey species of the red-cockaded woodpecker, several neotropical birds, and two endangered bat species in this project; therefore, response algorithms from this study directly benefit risk assessment/management efforts for these species. This method can be applied to additional insects and with different environmental conditions to obtain greater understanding of the

influence of environmental/habitat conditions on the short-term and lifespan responses of insect fauna to FO or other obscurants and for application to specific training sites.

1. Objective

The objective of this project was to develop a methodology for quantifying population dynamics and food source value of insect fauna in areas subjected to fog oil (FO) smoke. The method provides reproducible exposures of insects under realistic climatic and environmental conditions to FO aerosols that duplicate chemical and droplet-size characteristics of field releases of the smoke. The responses measured take into account reduction in food sources due to death and to changes in availability, palatability, and food quality of relevant life stages of insects that form the prey base for the listed threatened and endangered species (TES). The influence of key environmental factors, wind speed, and canopy structure on these responses were characterized. Data generated using this method was used to develop response functions related to particle size, concentration, wind speed, and canopy structure that will allow military personnel to assess and manage impacts to endangered species from FO smoke used in military training.

2. Background

Protection of TES and their habitat on Department of Defense (DoD) lands while sustaining the use of those lands for military training is a major goal of the Strategic Environmental Research and Development Program's (SERDP's) conservation mission. Important components of troop training exercises at military training installations are generation of FO "smoke" and maneuvers under obscurant cover. To comply with the Endangered Species Act, the impact of FO releases on avian TES (or surrogates) have been evaluated in both field and laboratory studies. Although no direct acute effects on avian species have been observed, concern has been raised regarding a possible indirect impact via reduction in insect populations used as a food source for these species. This concern arises from the fact that petroleum oils of similar composition to that of FO have long been used to kill insect pests. These oils particularly target soft-bodied insects, eggs, and larvae that are important dietary components of several avian and bat TES inhabiting military lands.

Fog oil is a middle distillate of crude petroleum drawn from stocks of raw industrial lubricant oil and further refined (NRC 1997, Driver et al. 1993). As a light viscosity lubricant and with a specific gravity of about 0.92 g/cm^3, it is considered a "spray oil" (MIL-F-12070C, Amendment 2, Tomlin 1997). The toxicity of this and similar oils to invertebrate species is not fully understood, but both chemical and physical effects have been attributed to it (Poston et al. 1986, Anderson et al. 1974, Rossi et al. 1976, Page et al. 1940) and is likely a combination of these effects (Shepard 1951, Hayes and Laws 1991). When lubricating oils are used as contact insecticides, suffocation or membrane disruption appears to be the major cause of mortality. Soft-bodied life stages of many insect species are vulnerable to the insecticidal properties of these oils (Harding 1979, Tomlin 1997).

However, the susceptibility to lubricating oils has been shown to vary considerably among the insect taxa, with some species exhibiting sensitivity to oils of high aromatic content (aphid eggs) while other species are more susceptible to oils low in aromatic compounds (eggs of several moth species, *Grapholitha molesta*, *Carpocapsa pomonella*, *Archips argyrospila*, and *Spilonata ocellana*). Also, fumes from low-boiling components have been shown to kill some insect species (house flies, *Musca domestica*), while other insects (*Aphididae*) are more susceptible to

the liquid phase (high-boiling fractions) of lubricating oils (Shepard 1951, Hayes and Laws 1991). These response differences based on chemical characteristics are an important consideration in designing tests to evaluate the impact of FO on insect populations.

In previous work evaluating FO toxicity in wild birds at Pacific Northwest National Laboratory (PNNL), we analyzed both stock FO and the post-generated smoke and found that the chemical composition of FO changes during generation (vaporization under high heat and re-condensation), particularly in the relative amount and species of aromatic compounds (Driver et al. 1997, Driver 2000). Other studies have found similar changes in the composition of the oil (La Rouche et al. 1997) though compositional changes were not detectable in earlier field studies (Policastro and Dunn 1985). These chemical changes, coupled with the apparent differences in species sensitivity related to composition of oils, underscore the need to use generated oil to assess the impact of FO on insect populations.

Another important consideration in assessing the impact of FO aerosols on insects is the size of the droplets. For petroleum oil to be effective as an insecticide, sufficient deposition of droplets on insects and/or foliage must occur. Although small droplet sizes result in greater distribution of oil (greater number of droplets), the mass of oil that actually deposits on foliar surfaces diminishes with decreasing size. It has long been known that for ground applications for trees and shrubs, the optimum droplet mass median aerodynamic diameter (MMAD) that will result in significant die-off of insects is between 30 and 80 microns (Potts 1959). There is little deposit of droplets less than 20 microns in diameter (Potts 1946, Reist 1993, Nicholson 1995). Thermal smokes, including those from vaporization-recondensation of petroleum oils, produce droplets of very small diameter, from submicronic to about 20 microns (Potts 1959, Hinds 1982). The MMAD of FO smoke in field tests ranges between 0.9 and 3 microns (Young et al. 1989, Dunn et al. 1998) near the generator. A MMAD value of 0.7 microns has been reported for FO droplets 25 m for the source (Liljegren et al. 1988). Droplets with aerodynamic diameters between about 0.1 and 1 microns cannot penetrate the laminar sub-layer of air that lies above the surface of objects (leaves, bark, insects) (Nicholson 1995); therefore, surface deposition of droplets of the size of those in FO smoke will be small. Indeed, a series of field tests comparing the efficacy of thermal smoke applications of lubricating oil to hydraulic spray applications showed that foliar deposition of oil from thermal smokes was very small, averaging less than 2% of that from hydraulic sprayers (Potts 1946 and 1959) with concomitant lack of insect control. Fog oil deposit to leaves and other surfaces in wind tunnel tests conducted at PNNL was also low (Cataldo et al. 1989, Driver et al. 1997, Driver et al. 2000). These data suggest that FO smoke is unlikely to deposit on vegetation and result in significant insect loss.

Further, effective application rates of petroleum oils for control of forests and orchard insect pests range from 9.4 to 46.8 L per hectare (1 to 5 gal per acre) (Environmental Protection Agency [EPA] Reg. No. 2935-405, commercial product label [e.g., Supreme-Oil, Wilbur-Ellis Co.]). The maximum "application rate" for FO generation can be calculated from the M542 Smoke Generator Set specifications, which describe a maximum screen of 90-minutes duration over a 5-km^2 (1236-acres) area generated by six military FO generator systems (M542 units) operating at 151.4 L (40 gal) per hour with a 454.2-L (120-gal) capacity. If no aerosol drift occurs (an unlikely event), the maximum application rate attainable would be 2.72 L per hectare (0.29 gal per acre), or about 30% of a minimum effective application for insecticidal petroleum

oils of similar composition. When the minimal deposit of oil related to small droplet size is considered with this low "application" rate, the expected impact of insect populations from FO smoke is minimal.

However, simulated field generations of FO conducted at the PNNL Aerosol Research Facility showed that deposition of FO to foliar surfaces was increased greatly by environmental factors such as increased wind speed and canopy structure (Cataldo et al. 1989). Increases in wind speed can provide sufficient momentum for particles to cross the laminar sub-layer and deposit on the leaf or insect surface. Leaf and bark characteristics (roughness) can affect deposition by the presence of protrusions (e.g., hairs) into the free air stream that intercepts particles (Nicholson 1995). These studies also demonstrated accumulation of FO residue on foliar surfaces with repeated exposures and significant revolatilization of the initial mass loading on plant surfaces (Cataldo et al. 1989). As noted above, revolatilization can be an important route of exposure for some insect species. In addition, small droplets pose a particular threat to flying insects as these droplets deposit on wings, legs, and antennae of insects in flight (Potts 1959).

Review of field measures of FO concentrations demonstrates the difficulty in generating reproducible exposures in field situations. The average concentration immediately adjacent to stationary generators varied by a factor of 8-fold (90 to 680 mg/m^3) for three field tests at the Chemical School at Fort McClellan (Young et al. 1989). Four-fold (33 to 120 mg/m^3 at 25 m [82 ft] downwind) differences in concentrations averaged over the duration of the FO releases in field dispersion tests at Dugway Proving Grounds (Liljegren et al. 1988). Dunn et al. (1998) compared instantaneous concentrations to the average concentration of FO over the duration of a series of field tests and showed that the instantaneous concentrations of FO smoke intermittently exceeded the average concentration by a factor of 10 or more. Complicating the issue further are the effects of weather conditions and environmental settings on FO deposition. In studies conducted in our laboratories, the effects of relative humidity, wind speed, rain-out during exposures, post-exposure rainfall, and canopy structure on FO deposition were evaluated. Deposition velocities (V_d) of FO differed among plant species (pines and sagebrush had higher V_d values compared to fescue and bean plants) and increased by a factor of 38 as wind speed increased. Canopy structure and wind speed above 6 mph had pronounced impacts on mass loading to foliar surfaces. Clearly, establishing exposure-response relationships under the variable conditions in the field is difficult.

The food sources of the listed TES are predominantly soft-bodied and/or flying insects that are specific targets of petroleum oil insecticides. With the exception of the red-cockaded woodpecker (*Picoides borealis*), which is a resident species, the avian TES listed in the statement of need (SON) are summer residents (the back-capped and least Bell's vireos, *Vireo atricapillus* and the golden-cheeked warbler, *Dendroica chryoparia*), returning to the United States (US) during the nesting season. Because the food-demanding breeding season normally coincides with the peak in abundance of herbivorous insect larvae, forest and scrubland birds, which encompass the listed TES, commonly prey on this life stage of insects (Holmes and Schultz 1988). Beetle and lepidoptera larvae are the taxa dominating the herbivorous guild feeding in forest and shrub canopies and constitute the highest proportion of the diet of bird species in these habitats (Graber 1961, Chapin 1925, Pulick 1976, Repaksy and Doerr 1991). On the other hand, the adult stage of moths, mosquitoes, and to a lesser extent, beetles are important

constituents of the diet of Indiana bats (*Myotis sodalis*, LaVal et al. 1977). Adult forms of aquatic insects such as mosquitoes and mayflies make up the diet of the gray bat (*Myotis grisescens*, Tuttle 1976, LaVal et al. 1977). Wood roaches (*Blatellidae*), adult and larval forms of beetles, and larval moths are important components of the red-cockaded woodpecker diet (Hanula et al. 2000). All the avian species also forage for spiders (Pulick 1976, Hanula et al. 2000, Repasky and Doerr 1991). Insect eggs are also significant prey of the bird species, particularly the vireos and warbler (Pulick 1976), which is of particular concern given the ovicidal activity of lubricating oils.

Changes in dietary composition can result in reduced energy intake by animals (Stephens and Krebs 1986). Reduction in surplus energy (energy intake above maintenance) in response to contaminant-induced changes in preferred prey populations can result in reduced reproductive success and survival over winter, which ultimately reduce population density of the predator species (Belovsky 1994). For birds, factors that influence which insects are selected for consumption include population density of the insects, ease of capture, palatability, body size and nutritional content, and the population density of competitive predators (Morrison et al. 1990). Measures of population density include direct mortality of the exposed life stage of arthropods and reduced emergence of the consumed life stage from exposure of antecedent life stages. These are common measures in insecticide efficacy studies including those using petroleum oils (Beattie et al. 1995, Stark et al. 1995). Detection, avoidance, and conditioned aversions (palatability) of contaminated food have been demonstrated in birds exposed to pesticides in laboratory studies (Bennet and Schafer 1988, Bennet 1989a and 1989b, Bussiere et al. 1989, Kononen et al. 1986 and 1987). Contaminant-induced changes in feeding behaviors have been observed in the field; conditioned aversions have been demonstrated in several species exposed to contaminated vegetation food sources (Robel and Morrow 1988, Benjamini 1981, Dingledine 1987). Ease of capture has been related to conspicuousness of prey (Atlegrim 1992). Prey can either become less conspicuous through inhibited movement and thus unavailable to the TES, or can become easy targets for consumption (Bildstein and Forsyth 1979). The latter may benefit the TES if oil uptake through this oral route is below toxic levels, or result in reduced food availability if competing predators are more aggressive (Belovsky 1996).

After considering the food sources of the TES, their potential vulnerability to petroleum oils and the criteria that influence prey selection by TES along with the chemical and physical aspects of FO smoke and the efficacy of pesticidal oils, it is evident that the there are six key elements needed to characterize the impact of FO on insect food sources of the listed TES to provide predictive response functions of the relationship between FO exposure and insect response. These elements include the following: 1) use of generated rather than stock FO; 2) production of FO smoke with realistic droplet size distributions, concentration, and duration; 3) control over environmental conditions that influence droplet deposition (wind speed and canopy structure); 4) ability to replicate and adequately characterize exposures; 5) selection of both soft-bodied and flying insects of dietary importance to the TES for test species; and 6) selection of endpoints that measure reduction in food source consumption and quality.

3. Materials and Methods

3.1. Approach

Our approach employed an environmentally controlled re-circulating wind tunnel (Aerosol Research Facility at PNNL) outfitted with a high-heat vaporization and re-condensation FO generator that has been shown to produce aerosols of comparable chemistry and droplet-size distribution as those of field releases of the smoke (NRC 1997). Using an environmentally controlled wind tunnel allowed for control and reproducibility of those conditions (temperature, humidity, wind speed, sunlight) that may affect organism exposure through changes in both size and composition of the FO droplets and the activity and metabolism of the insects. The wind tunnel also supports canopy conditions needed for exposure realism, post-exposure re-volatilization (Dunn et al. 1998), and insect maintenance.

Just as exposure parameters are important to experimental design, so are the response measures and selection of the test subjects. Because the outcome of the tests is an evaluation of the impact of FO on a food resource rather than simply the toxic response of a class of organisms to the oil, the endpoints measured encompassed those that reduce not only numbers of prey, but also the consumption of prey. Therefore, post-exposure measurements included 1) reduction in prey numbers through mortality of the consumed life stage (larvae, adult), 2) reduced hatch or emergence of the consumed life stage, and 3) observations of altered flight or movement activity and susceptibility to consumption by a predator of contaminated insects as compared to controls (reduction in prey availability, conspicuousness, or palatability). Nutritional differences in uncontaminated and FO-contaminated insects were not evaluated.

3.2. Test Species

Five species representative of the major prey groups of the TES were used. To address potential differences in susceptibility of insect taxa to FO that have been seen with other lubricating oils, the species were selected from different orders and included a geometrid moth (*Diagrammia curvata* [Grote]), wood roach (*Parcoblatta uhleriana* [Saussure]), beetle (*Tenebrio molitor linnaeus*), mosquito (*Culex sp*), and ant (*Camponotus pennsylvanicus* [De Geer]). Four species (the moth, wood roach, beetle, and adult ant) were selected to represent the dominant orders and life stages of the bird food sources during pre-reproduction and reproduction periods. The beetle larvae were selected as a surrogate for arboreal beetles because of ease of culture. The mosquito along with the moth and male adult wood roach are representative of the night-flying adult forms hunted by bats. Because of the ovicidal activity of petroleum oils, initial plans included exposure of eggs from all species (except ants). However, because of difficulties in obtaining eggs as a life-cycle stage in sufficient quantities to perform exposures, this portion of the study was not completed.

3.2.1. Insect Colony Development and Maintenance

Insect colonies were established for geometrid moths and beetles. Adult ants and various life stages of wood roaches were purchased ready for exposure from commercial suppliers. The ants and roaches were acclimated to home cage temperature and humidity and provided water and food prior to exposure. Mosquitoes were purchased as eggs or larvae and reared to the desired life stage for exposure. The methods used to obtain and maintain each species are described in the following sections.

3.2.1.1. Mosquito

Initially, egg rafts and larvae were acquired to develop a regenerating mosquito colony to monitor the effects of FO exposure through egg production and viability. However, we had difficulty in obtaining significant egg production to form a regenerating colony due to concern related to the recent detection of West Nile Fever in the area and using live birds to provide the females with the necessary blood meals for egg production. Use of artificial blood procedures did not result in sufficient egg production within the time-frame needed to complete the tests; therefore, mosquito egg rafts and larvae were obtained as needed from the commercial supplier and reared to the appropriate life stage in a temperature- and humidity-controlled greenhouse, as described below.

Mosquito eggs and larvae were obtained from Carolina Biological Supply Company (Burlington, North Carolina). Because the eggs have a short incubation period of only 1 – 2 days, they arrived totally hatched in transit from the supplier. The egg rafts were packaged in moist soft paper and were immediately floated in aged water (free of chlorine). The small larvae were immediately observable free-swimming in the water. The newly hatched larvae were reared in 591.5-mL (20-oz) plastic sandwich containers without lids, with the water level between about 2 and 3 cm (3/4 and 1 1/4 in.) in the 4.5-cm (1 3/4-in.) deep containers. Aged water was added as necessary to maintain the water level. Larvae were fed a prepared diet obtained from Carolina Biological Supply Company.

Larvae obtained from Carolina Biological Supply Company were received in plastic water bags in Styrofoam containers. The larvae were put into plastic containers as described above for newly hatched larvae, and fed the same prepared diet. As the larvae grew and approached the point of pupation, the containers were kept closed by placing the lids firmly in place. Individuals were removed from the rearing containers using plastic syringes when needed for exposures.

When adults were about to emerge, the rearing containers were placed in 46-cm (18-in.) cubic screened cages to await emergence. These cages containing the emerged adults were also used as the exposure container for adults with the rearing containers removed. The cages were purchased from BioQuip Products (Rancho Domingues, California).

3.2.1.2. Geometrid Moth

The selected test species is a locally occurring *Diagrammia* moth of the Geometridae family. Several species of this genus have been recorded from the Mid-Columbia region of Eastern Washington during a biodiversity study performed for The Nature Conservancy (1999), including *Diagrammia curvata, denticulate, irrorata, neptaria*, and *nubiculata*. The most prevalent of these is *curvata*, which was used for the study. The local host plant for *S. curvata* is rubber rabbitbrush, *Ericameria nauseosa* (Pallas ex Pursh) Nesom & Baird *var. speciosa* (Nutt).

Moths were obtained by field collection using a 150 watt (W) mercury vapor light suspended about 0.9 m (3 ft) above the ground over white sheets. Moths landing on the sheets were captured into plastic vials and later released into the colony cages. Both males and females were collected. The females were allowed to lay eggs, which hatched and formed the basis for the colony. The males were retained to enhance genetic diversity within the colony.

Two types of colony cages were used. The first was constructed using a frame of polyvinyl chloride (PVC) pipe covered with fine mesh netting. The dimensions of this cage were 1.2 m (4 ft) high, 1.5 m (5 ft) wide, and 2.1 m (7 ft) long (Figure 1). The second type of colony cage was constructed of window screen framing and wire or nylon mesh screening, with a small door on each end. Cages of this type were about 0.9 m (3 ft) tall by 0.9 m (3 ft) wide and 1.5 m (5 ft) long. The larger screened cage had vertical zippered openings on the two long sides and two sleeve openings on each of the ends. This allowed for addition of plants and moth specimens into and out of the cage and for movement of materials within the cage. The floor of the large cage was lined with plastic sheet material to inhibit escape of specimens (larvae or adults) through the bottom of the cage.

Potted rabbitbrush plants (Figure 1) were placed in the colony cages for egg laying and rearing of larvae. The mature larvae were observed to pupate either in the soil of the potted plant or on the floor of the cage. Adult moths for exposure tests were obtained from the colony by removing all adult moths daily in order to know the age of the moths at exposure.

Figure 1. A Geometrid Moth Colony Cage in a Temperature and Humidity Controlled Greenhouse at PNNL's Plant Growth Facility (Left), Fifth Instar of *Diagrammia curvata* on Rabbitbrush (Top Right), and Adult Stage of the Moth (Bottom Right)

3.2.1.3. Wood Roach

Wood roaches undergo incomplete metamorphosis having three life stages: eggs, nymphs, and adults. All nymphs and adults of *Parcoblata uhleriana* are wingless. Nymphs and adults are very active and must be physically contained at all times. The nymphs and adults were obtained from a commercial supplier (Roachman, Whitestone, New York). The individuals were maintained in 75 L (80 qt) and 100 L (106 qt) plastic boxes with tight-fitting lids. Each lid was modified to have 8 7.6-cm (3-in.) openings for air movement covered with nylon screening. A 7.6 cm x 7.6 cm x 2.5 cm (6 in. x 6 in. x 1 in.) plastic water container was placed in one end of the colony box and kept filled to overflowing with water. The bottom of the box was covered with a potting soil and sand mixture covered with a 1.3 cm (0.5 in.) layer of small pine bark chips. Egg carton bottoms and plastic potting containers were placed inverted on the soil to give hiding places for the wood roaches. The roach colony was provided with slices of apples, romaine lettuce, and dry dog food. A leaf of romaine lettuce was placed in the water dish to allow roaches an escape route for those falling into the water. The food pieces were checked regularly for mold and spoiled food was removed and replaced with fresh food.

The colony was observed daily and individuals were inspected for the presence of developing egg cases. Females carrying egg cases were removed into a smaller plastic box to await release of the egg case. This box contained a 1.3-cm (0.5-in.) layer of plaster of Paris kept moist, and a Petri dish of water, and another with powdered dog food and a few apple slices. Females were returned to the colony cage after dropping the egg case. The egg cases were placed in Petri dishes on moist cotton, labeled, and placed in an incubator to await hatching. The temperature in the incubator was kept at about 26.7-32.2°C (80-90°F) and a relative humidity of about 80%.

Egg cases for *P. uhleriana* contain about 25 to 30 eggs and take about 60 days to hatch. The eggs cases are very sensitive to humidity and temperature: achieving hatching is difficult. We were not successful in getting the eggs to hatch and initiate a regenerating colony. Fortunately, *P. uhleriana* are long-lived as nymphs and adults, and exposures were conducted with the individuals purchased from the supplier.

3.2.1.4. Ant

Ants (*Camponotus pennsylvanicus*) used in this study were obtained from the Carolina Biological Supply Company. Upon arrival, the ants were examined and chilled in a refrigerator in their shipping containers containing forest duff. A minimum of 24 hr prior to testing, the chilled ants were sorted and placed in 946-mL (32-oz) plastic sandwich containers. The lids of the containers were modified by removing the central portion of plastic and replacing it with 14 x 14 mesh window screen. The screen was glued to the rim of the lid with silicone glue and allowed to dry thoroughly before being used. In each maintenance container, water was provided *ad libitum* in a vial with a cotton plug. Sugar water (1:1) was provided in a 35-mm (1.4-in.) Petri dish and a thin layer of cotton placed on top to prevent drowning.

3.2.1.5. Beetle

Darkling beetles (*Tenibrio molitor*) undergo complete metamorphosis and are available commercially as larvae in various sizes. Larvae were obtained from Sunshine Mealworms (Silverton, Oregon). The larvae were maintained in 42-L (44-qt) plastic containers approximately 36 cm x 51 cm x 8 cm (14 in. x 20 in. x 8 in.). Lids were not needed to contain

the larvae as they had no tendency to crawl up walls of the containers. The containers were filled half-full with a mixture of 50% oats and 50% bran flakes. Slices of apples and potatoes were added to the containers to provide a source of moisture and food. These slices were replenished frequently with fresh pieces as they were consumed or showed signs of spoilage.

3.3. Fog Oil Exposures

3.3.1. Exposure Systems

3.3.1.1. Dynamic Exposure Chamber

The low-speed wind tunnel at the PNNL Aerosol Research Facility (Figure 2) was used to provide controlled, reproducible exposure environments under dynamic conditions (wind velocity). The primary test section is 0.6 m square, 6 m long (2 ft square, 20 ft long), and was used to house the insects during control or FO exposures. Air was conditioned to 27 ± 3ºC (80 ± 6°F) and 45 ± 10% relative humidity to simulate spring/summer climatic conditions in the Edwards Plateau, Texas. Simulated sunlight was provided by fluorescent and metal halide (400-W) lamps. Wind speeds used in the study were either 0.9, 1.8, or 3.6 m/s (2, 4, or 8 mph) within the insect exposure containers.

Figure 2. Environmentally Controlled Wind Tunnel at the Aerosol Research Laboratory at Pacific Northwest National Laboratory. This System Was Used to Provide Fog Oil Exposures in Typical Wind Conditions that are Optimal for Effective Obscuration.

The wind tunnel was operated under a slight negative air pressure to contain the FO within the wind tunnel. Exhaust from the system is passed through an 8495 L/min (300 cubic ft/min) dual-stage scrubber and then through a double (redundant) bank of high-efficiency particulate air (HEPA) filters to remove any residual aerosol or particulate matter.

3.3.1.2. Semi-dynamic Exposure Chamber

When stagnant air conditions (no laminar velocity) were needed for exposure scenarios (e.g., for mosquito larvae), a semi-dynamic exposure chamber was used (Sheet Metal Products, Young and Bertle Co., Cincinnati, Ohio, Figure 3). For the exposures, two inlet portals, one for introduction of FO aerosols and one for dilution air, were attached to the upper portions of the chamber. A small internal low-speed fan located in an upper corner of the chamber ensured mixing to uniform concentration at insect level. Two additional ports were installed in the chambers to obtain physical samples and allow a small flow to be withdrawn and passed to optical dust sensors for real-time monitoring of aerosol concentrations. A single exhaust port was used to control chamber vacuum, and directed aerosols to a wet scrubber/HEPA filtration system prior to venting to the outside. A vacuum gauge was fitted to the exposure chamber to aid in ensuring reproducibility of exposure conditions. The mean temperatures and relative humidity during exposures were 26°C [78°F] (24°C to 27°C [75°F to 80°F]) and 52.6% RH (31.9% to 66.9% RH), respectively.

3.3.2. Fog Oil

Fog oil used in this study was SGF-2, the FO in use by the US military for over 20 years to provide "smoke" screens for visual-range obscuration (US Army 1986). The oil was manufactured by American Lubricating Company, Memphis, Tennessee (Lot number 71808) and supplied to PNNL by the National Training Center, Fort Irwin, California. Upon receipt, the oil was assigned a unique and monitored barcode through the PNNL Chemical Management System. Pre- and post-generation (aerosolized) samples of the FO were chemically characterized previously (Driver et al. 2002).

3.3.3. Fog Oil Generation

Aerosols were generated by metering steady rates of liquid FO onto a heated immersion element maintained at 600°C [1112°F] (Figure 4) and contained within a 1 m (3.3 ft) long, 2.5-cm (1-in.) diameter stainless steel pipe. The liquid FO was vaporized on the element and the vapor was subsequently re-condensed as it cooled, forming a FO aerosol. Low-oxygen carrier gas (a mixture of 96% nitrogen and 4% air) was used to flush the condensing FO vapor through a temperature-controlled region at 300°C (572°F) and into a 132.5-L (35-gal) buffer volume with a residence time of 5 min. The oxygen content of the carrier gas was about 0.8%, a value typical of the oxygen content present in the exhaust of diesel engines. In the buffer volume, fresh air was mixed with the concentrated FO aerosol and the mixture drawn through a PVC pipe into the wind tunnel or the semi-dynamic exposure chamber at ambient temperature (18°C [64.4°F]). A valve was used to adjust the flow of aerosol into exposure semi-dynamic chamber or wind tunnel. A separate valve was used to regulate a flow of fresh air into the semi-dynamic chamber or wind tunnel. The feed rate of the oil was adjusted periodically, based on sensor-monitored aerosol concentration to maintain the test concentrations.

Figure 3. Semi-Dynamic Exposure Chamber Used to Deliver FO Exposures for Stagnant Air Scenarios

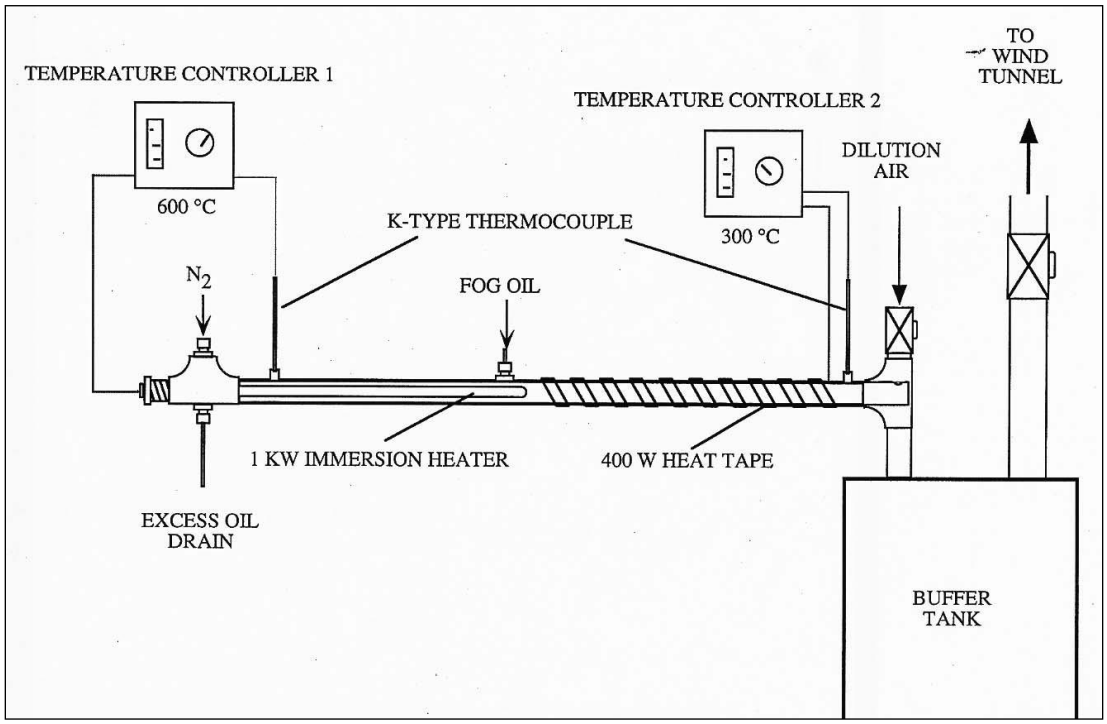

Figure 4. Temperature-Controlled FO Aerosol Generator

To ensure mixing in the semi-dynamic chamber, restrictions were installed at the aerosol inlet to the chamber. The restrictions caused the FO aerosol to jet into the upper regions of the chamber and then quickly mixed to a uniform concentration at the height of the insects.

3.3.4. Fog Oil Concentration and Droplet Size

In a previous study (Driver et al. 2002), the vapor component of the FO exposures was shown to be minimal. Therefore, particle-count and aerosol mass methods were used to determine the airborne FO concentration during the exposure tests. The concentration of FO aerosol in the wind tunnel was monitored in real time using M.I.E. Model IDS-10 Optical Dust Sensors (Monitoring Instruments for the Environment, Inc., Billerica, Maryland). Actual concentrations were determined from simultaneous gravimetric samples taken by drawing chamber air through pre-weighed 47-mm (1.85-in.) high-efficiency glass-fiber filters (Gelman, Ann Arbor, Michigan) at 1 Lpm (0.26 gpm) for 15 min. The filters were weighed to the nearest 0.1 mg on a Mettler Model AE 163 Analytical Balance prior to and after sample collection to determine the mass collected. The optical dust sensor values collected during FO generation were compared to the gravimetrically derived air concentrations of FO to convert the sensor readings into air concentrations values during the exposures. Airborne FO concentrations were reported in mg/m^3. Filter samples were also taken periodically during the exposure to confirm exposure concentrations.

The particle size distribution of the FO aerosols was measured using an Andersen cascade impactor operated at a flow rate of 28 Lpm (7.4 gpm) (Figure 5). The MMAD ranged between 1.3 µm and 2.42 µm and were within the range reported for field generations of FO (Dunn et al. 1998, NRC 1997, Young et al. 1989). Temperature and relative humidity of the wind tunnel and semi-dynamic chamber were measured periodically during each test.

3.3.5. Insect Exposure Protocols

The protocols for performing exposures of each insect species and life stage are described in the following sections. In all cases, the specimens were taken from the rearing facility (a PNNL Plant Growth Facility greenhouse), transported to the wind tunnel facility, exposed to the FO, and returned to the rearing facility for observation. The distance between the two facilities is about 3.2 km (2 mi), with transfers made using passenger vehicles with conditioned air.

3.3.5.1. Mosquito Exposure Protocol

Mosquito larvae were counted and placed into fresh rearing containers. Lids were placed on the containers during transport between the rearing facility and the wind tunnel facility, but were removed during the exposure. After exposure and return to the rearing facility, the larvae were observed for survival to the adult stage.

Exposure of adult mosquitoes was performed by transporting their home cages to the wind tunnel, and placing the cages into the wind tunnel. The exposed adults were returned to the rearing facility for observation.

EXPERIMENT DATE:	5/22/2003	**PROJECT:**	SERDP
IMPACTOR ID:	ACI-14	**TEST AEROSOL:**	Fog Oil Fog
FLOW RATE:	28.720 LPM	**TEST FACILITY:**	Wind Tunnel
DENSITY:	1.00 g/cm^3	**SAMPLE LOCATION:**	Window 5

Comments: 200 mg/m^3 group

Stage Number	Stage Activity	Cumulative Activity on Stage	Cumulative Percent Less Than	Effective Cutoff Diameter	Percent Interval Activity		Chi-Square Values per Stage
					Observed	Predicted	
9	0.011 mg	0.01	0.03	0.37 µm	0.0255	0.0537	0.0148
8	0.135 mg	0.15	0.34	0.55 µm	0.3128	0.5304	0.0893
7	1.338 mg	1.48	3.44	0.90 µm	3.0999	5.0079	0.7269
6	16.141 mg	17.63	40.83	1.82 µm	37.3955	33.3749	0.4844
5	14.191 mg	31.82	73.71	2.84 µm	32.8777	32.1030	0.0187
4	7.618 mg	39.43	91.36	4.17 µm	17.6494	18.8326	0.0743
3	2.266 mg	41.70	96.61	6.10 µm	5.2499	7.7475	0.8052
2	1.110 mg	42.81	99.18	9.62 µm	2.5716	2.1247	0.0940
1	0.353 mg	43.16	100.00	0.00 µm	0.8178	0.2253	1.5578

MMAD = 2.11 µm	MMD = 2.11 µm	Sum of Chi-Squares = 3.87
GSD = 1.71	CMD = 0.90 µm	Degrees of Freedom = 6

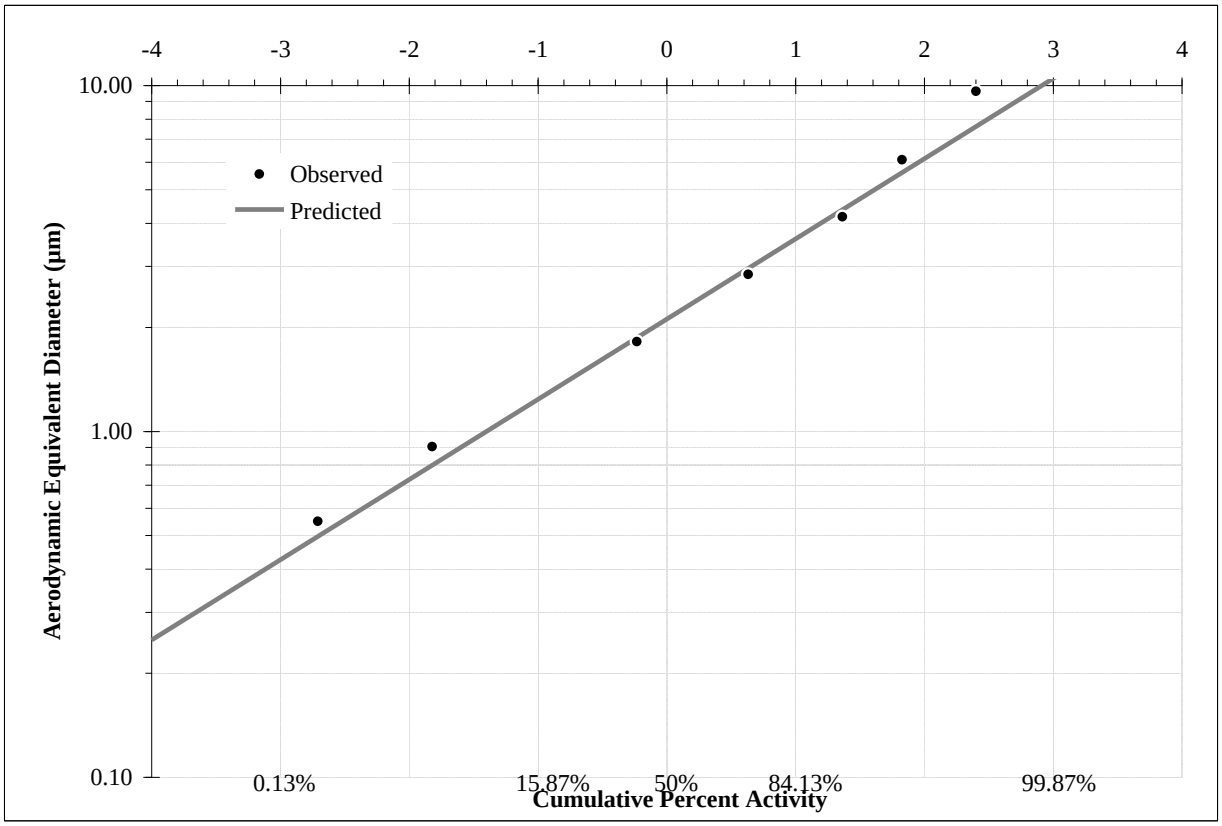

Figure 5. Example Droplet Size Distribution Data and Analysis from Cascade Impactor Sampling

3.3.5.2. Geometrid Moth Exposure Protocol

Because the adult moths have a short life span (about 10 days), it was necessary to know the age of each moth exposed. The age of each moth (days since emergence from the pupal stage) was determined by observing the colony cages daily and separating adult moths that had emerged during the previous 24-hour period. The moths to be exposed were removed from the adult moth holding enclosure using small insect vials and held individually in the vials during transport to the PNNL Aerosol Research Facility. The date of emergence was recorded for each moth.

The adult moths were exposed to FO smoke using either the wind tunnel or the semi-dynamic exposure chamber. The exposure cage was made of 8 x 8 mesh galvanized hardware cloth approximately 51 cm (20 in.) deep by 38 cm (15 in.) high by 25 cm (10 in.) wide. The 51 cm by 38 cm (20 in. by 15 in.) dimensions represent the cross-section facing the wind in the tunnel (Figure 6). A door on one side of the exposure cage allowed easy access for inserting and removing the insects from their vials. When a moth was released into the cage, it immediately settled on the wall and did not move when other moths were added to the cage. Removal was performed by individually capturing each moth in a vial by placing the vial over the moth (while at rest) and bumping it so it retreated into the vial.

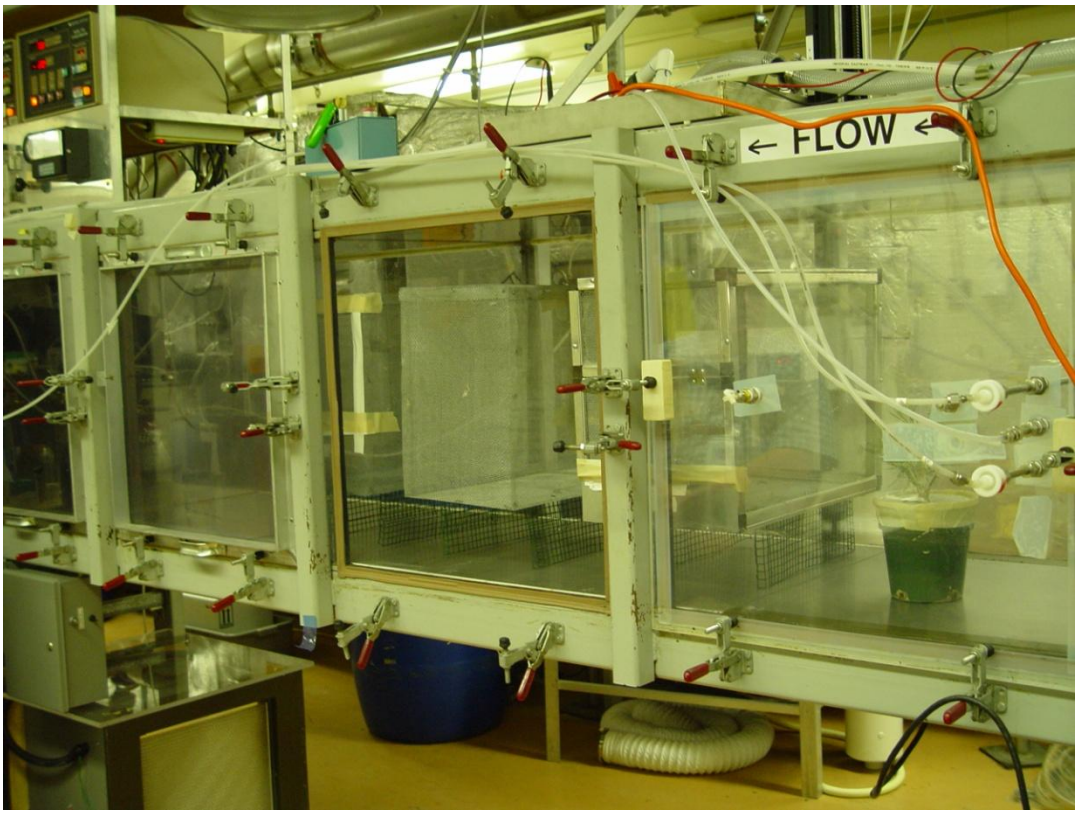

Figure 6. Exposure Cages for Adult Moths in the Environmentally Controlled Wind Tunnel

When moth larvae were to be exposed, the potted rabbitbrush plants were removed from the colony cage and searched for larvae. The larvae were divided by size into the groups needed for the specific exposures to be performed. The larvae were then placed onto potted rabbitbrush plants and transported to the wind tunnel facility in cardboard boxes to limit the impact of wind. The potted plants were placed into the wind tunnel test section and exposed (Figure 7). Following exposure, the potted plants were returned to the rearing facility and each plant was maintained in a separate screened cage for observation of larval development and survival. By keeping the plants in individual cages, wandering larvae could be captured and returned to the plant. Although this didn't happen often, it did allow better control of the individuals.

Figure 7. Fog Oil Exposure of Larval Moths

3.3.5.3. Wood Roaches Exposure Protocol

Small wood roach nymphs 1 cm to 1.9 cm (0.38 in. to 0.75 in.) were removed from the colony cage and placed in 946-mL (32-oz) plastic containers. The lids of the containers were modified by removing the central portion of plastic and replacing it with 14 x 14 mesh window screen. The screen was glued to the rim of the lid with silicone glue and allowed to dry and out-gas before being used. These exposure containers were used for exposure of small nymphs in the semi-dynamic exposure chamber. After exposure, the nymphs were returned to larger plastic containers for observation. These containers were 7.6 L (2 gal) in volume and 12.7 (5 in.) deep and contained a 1.3-cm (0.5-in.) layer of potting soil and a 60-mm (2.4-in.) Petri dish as a water container. The post-exposure observation containers were outfitted with a screened opening in the lid as described above. The nymphs were observed for survival.

Adults were exposed in the same screened cages as described above for adult moths. These exposures were performed in the wind tunnel. After exposure, the adults were placed in a colony cage and observed for generation of egg cases and survival.

3.3.5.4. Ant Exposure Protocol

Adult ants obtained from the supplier were divided into replicates of 15 individuals in 946-mL (32-oz) plastic containers, as described above for exposure of small wood roach nymphs. Water was provided in a small vial. The vial opening was closed with a cotton plug. This allowed the ants to obtain water as needed. A 1:1 mixture of sugar water was provided as a food source and

periodically replenished. The sugar water was placed in a 35-mm (1.4-in.) Petri dish and a thin layer of cotton placed on top to prevent drowning.

There were three replicates established for each exposure level and wind speed tested. Periodic counts of living and dead ants were made following exposure. Moribund ants were touched with a probe to determine if they were dead or alive. Any movement was interpreted as the ant being alive. Dead ants were placed in a small Petri dish which was labeled with the exposure level and replicate number. The Petri dishes were checked periodically for any ants that may have recovered. None recovered during the duration of this study.

To contain the active ants and simulate exposure of ants that are herbaceous or arboreal foragers, the ants were exposed to FO or uncontaminated air in 177-mL (6-oz) vials modified by placing screened material (14 x 14) on both ends. The bottom of the vial was cut off and replaced with screened material glued onto the cut edges. The glue was industrial grade craft glue, allowed to dry thoroughly before use. The lid to the vial was modified by cutting out the top, leaving just the threaded rim. The top was replaced with screened material glued on similar to the bottom modifications. The vials were held horizontally within the wind tunnel with the wind flowing lengthwise through the screened ends of the vials (Figure 8).

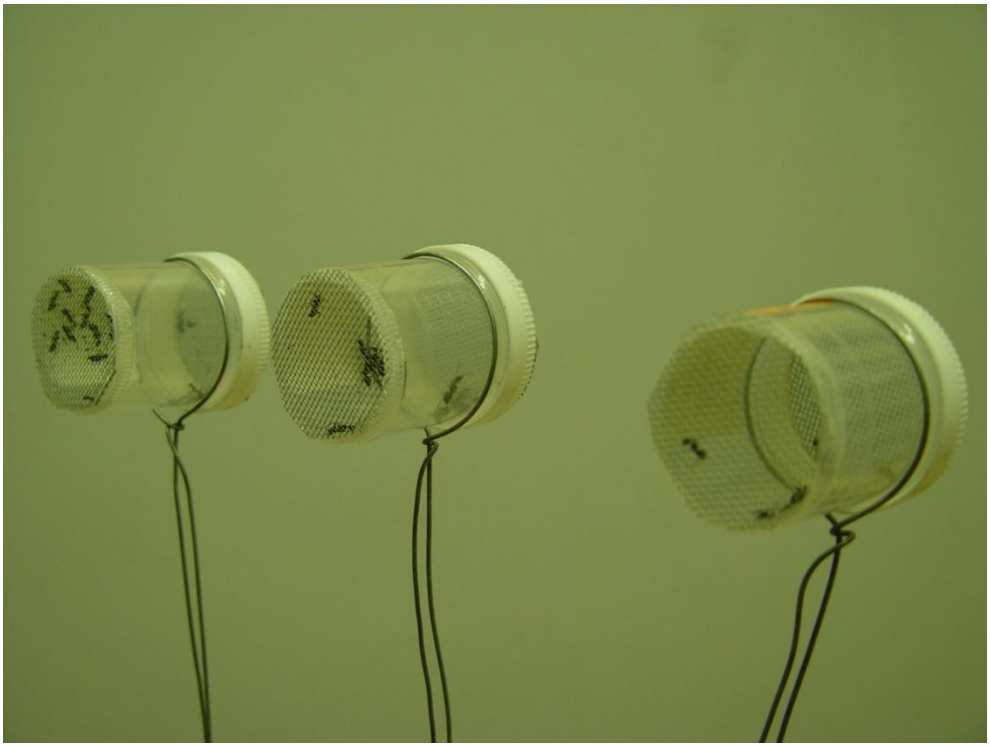

Figure 8. Exposure Containers Containing Ants: the Vials Were Placed Horizontally in the Environmentally Controlled Wind Tunnel, Parallel to the Wind Flow.

Tests were conducted to determine the effect of the screened mesh on the wind speed inside the vial relative to that outside the vial (i.e., the speed within the wind tunnel). A Pitot tube was placed inside one of the modified vials inside the wind tunnel to measure wind speed. The screens on both ends of the vial were in place during the testing. The wind speed in the wind

tunnel was set to a desired speed and the speed inside the vial was measured across the diameter of the vial. The speed inside the vial was found to be uniform across the vial to within about 6.4 mm (0.25 in.) of the side of the vial. This was the closest distance to the side of the vial that was possible to be measured with the Pitot tube. The tests indicated that the wind speed was reduced inside the vial by 50% from that of the wind tunnel. This reduction was approximately constant over wind tunnel speeds from 1.8 to 7.2 m/s (4 to 16 mph). This correction was applied to the test setup to determine the wind speed that the ants were exposed to inside the vials.

Analysis of the wind speed test data provided a correlation of wind speed inside and outside the ant exposure containers (Figure 9, where $R^2 = 0.9987$).

(Wind speed inside, mph) = 0.4914 (tunnel wind speed, mph) + 0.0894

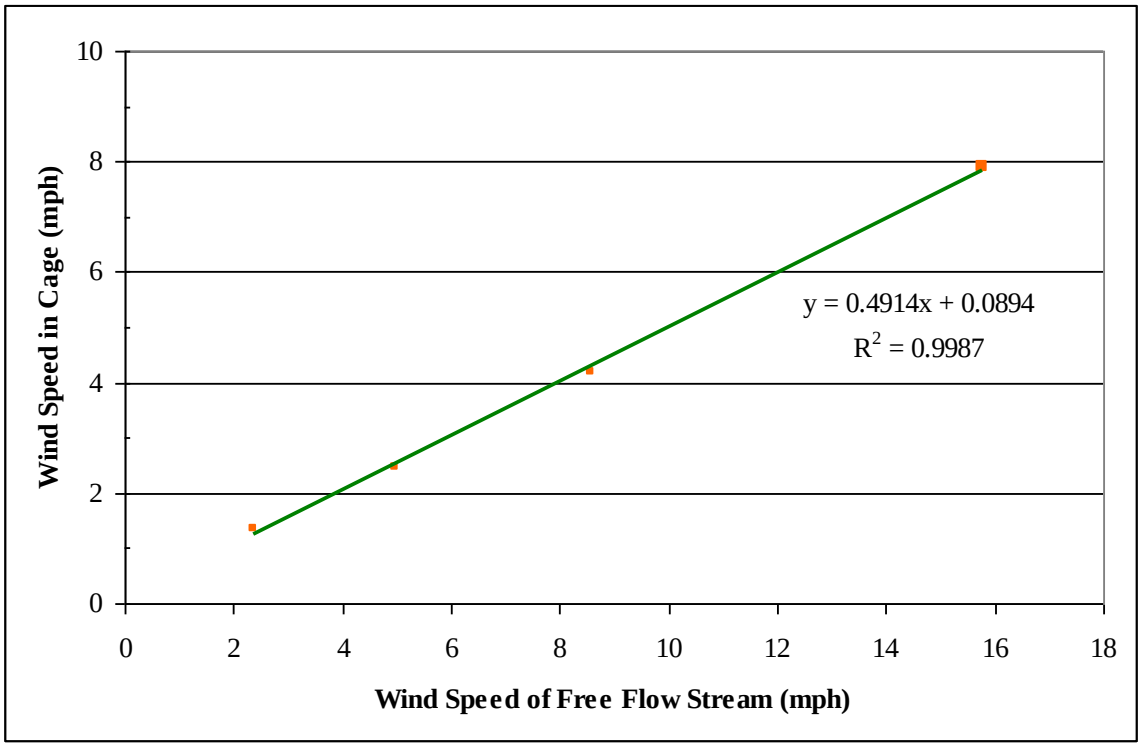

Figure 9. Regression Analysis of Wind Speed Inside the Ant Exposure Containers as a Function of Wind Speed Outside the Exposure Containers in the Wind Tunnel

3.3.5.5. Beetle Exposure Protocol

Beetle larvae were removed from the colony containers, counted, and placed into exposure cages. The first instar larvae were exposed in open 7.6-cm (3-in.) Petri dishes. After exposure, the larvae were transported back to the rearing facility and covers were placed on the Petri dishes. Food and water were supplied by placing a small amount of oatmeal/bran mixture and a small slice of apple into the dish. The individuals were counted regularly to observe development and survival. Dead individuals were removed from the containers.

Larger larvae (2nd through ~5th instars) were transported to the wind tunnel facility in covered plastic sandwich containers and placed onto inverted plastic lids 29 cm x 36 cm with a 1.3-cm rim (9 in. by 14 in. with a 0.5 in. rim) for exposure. A thin layer of oatmeal (too thin to burrow under) and a few apple slices were added to the lids to provide food and moisture and thereby retain larvae within the exposure container (Figure 10).

Figure 10. Exposure Container for >1st Instar Beetle Larvae in the Wind Tunnel; Oatmeal and Apple Slices Are Provided for Nutrient and Containment

After exposure, the larvae were placed back into the plastic sandwich containers, returned to the rearing facility, and placed into smaller colony cages for observation. These observation cages were 11 L (12 qt) containers, 23 cm x 29 cm x 13 cm (9 in. by 14in. by 5 in.) deep with a screened opening in the lid 14.0 cm by 27.3 cm (5.5 in. by 10.75 in.). The container contained about 2.5 cm (1 in.) of oatmeal/bran mixture with a few pieces of potato or apple. The individuals were counted regularly by thoroughly searching through the bran mixture and removing all individuals. After dead specimens were counted and separated, the live specimens were returned to the rearing cage. Any pupae were placed in separate rearing containers and observed regularly for emergence of adults. The adults were transferred to yet another rearing container for observation of survival.

3.3.6. Canopy Density Effects

The impact of canopy density was determined by exposing moth larvae of each instar to FO on its preferred plant (rabbitbrush) in a canopy composed of the natural rabbitbrush canopy (small leaf-area canopy) and comparing the post-exposure response of the larvae and subsequent life stages to the response observed in larvae exposed under the same environmental conditions (and host plants) but within a large leaf-area canopy (Figure 11). The rabbitbrush containing larvae

was placed such that the large leaf-area plants were upwind (intercepting the FO plume) and down wind of the rabbitbrush.

Figure 11. Simulated Large-Leaf Canopy with Imbedded Host Plant of the Test Species

3.3.7. Tests (Go/No Go Criteria)

3.3.7.1. Screening Tests

Because of the potential of insufficient deposition of the thermal fog on vegetation or insect surfaces to elicit an adverse effect, a series of screening tests were conducted during the first year that simulated the worst-case scenario of fixed location training and 4-hour exposure duration at twice the field levels near the generator (400 to 1200 mg/m^3) under wind and canopy conditions that maximized exposure of the life stage (e.g., 0.9 m/s [2 mph] in dense canopy or canopy shrub leaves with dense hair for arboreal insects or in stagnant air and no canopy for mosquito larvae). Impacts from FO exposures of larvae were monitored from the exposed larval instar through the final larval instar and pupation and to the adult stage. If no adverse effect were observed compared to controls (i.e., insects treated in same manner, but without FO exposure) under the worst-case scenario conditions for a particular life stage of an insect, no tests with that life stage at lower concentrations were deemed to be necessary.

3.3.7.2. Definitive Tests

If effects were observed, exposures for that life stage were conducted at field-level concentrations. For dilutions of field-level concentration, FO aerosols were aged in the wind tunnel prior to exposing the insects to simulate downwind aerosols. Additional tests at other wind speeds, canopy conditions, and/or exposure durations were conducted for those insect life stages that were affected by FO aerosols at the initial wind speed.

Exposures were conducted under the spring/summer temperature and humidity conditions typical of the Edwards Plateau of west central Texas, which support several of the TES that inhabit military training areas.

3.4. Response Measures

The impact of FO exposure on population dynamics and food source value of insects representative of major prey of threatened or endangered birds and bats was monitored by measuring direct mortality of the exposed life stage consumed by the predators and reduction in emergence of the consumed life stage from exposure of antecedent life stages. Observations of changes in flight or activity over time were conducted at the time of mortality counts. Determination of mortality and signs of flight/activity changes were made as detailed in Table 1. Palatability of moth larvae is described below.

Table 1. Criteria for Determining Mortality and Flight/Activity Deficits

Eggs[a]	Larvae	Pupae	Adults
No. larvae that hatch	No. moving, feeding, respond to stimulus[1] with time post exposure	No. adults emerge	No. moving, feeding, respond to stimulus[1] with time post exposure
No. larvae die prior to exposure	(for mosquitoes) No. swimming, coming to surface of water for air (for beetle) No. change color (brown)		(For moth and mosquito) No. incapable of flight as response to stimulus[1]
	No. pupate		No. eggs laid/hatched

[a] Due to problems with accurately locating and counting minute eggs/first instar larvae of some species, unsuccessful husbandry conditions for this life stage in other species, egg mortality data was not collected.
[1] touch with camel-hair brush.

3.4.1. Palatability Test with Avian Predator

Starlings (*Sturnus vulgaris*) were collected locally using bait traps and transferred to the PNNL outdoor aviary. The aviary is 9.1 m (30 ft) wide by 15.2 m (50 ft) long by 3.7 m (12 ft) high and divided into five 3-m (10 ft.) wide flight pens using a double layer of Bird-X ™ to form the internal walls. A metal roof covers one-third of each section. Roosts, covered areas, and natural vegetation were available for escape and socializing. Wooden rods suspended from the roof frame provided perches for the birds in covered portions of the aviary. Fir (*Abies* spp.), pine (*Pinus* spp) and spruce (*Picea* spp.) trees were placed in planters as natural roosts and arranged around four-foot high roost boxes located under the covered portion of the aviary. Crabapple trees (*Malus* spp.), willow trees (*Salix* spp.) spruce trees, arbovitae (*Thuja occidentalis*), and dwarf conifer shrubs

provided natural cover in the open areas of the flight pens. Continuous flowing water was provided for drinking and bathing in each flight pen.

Two starlings were randomly selected and moved into each of four pens within the aviary. Birds were maintained on a diet of Mazuri® (PMI Nutrition International, Brentwood, Missouri) soft billed bird feed, Purina® brand Moist and Meaty Chopped Burger (Nestle Purina PetCare Company, St. Louis, Missouri) dog food, fresh corn and apples, meal worms, crickets and moth larvae. Birds also had sand grit.

Two pieces of sod approximately 61 cm x 30.5 cm (2 ft x 1 ft) were placed next to each other in each pen. Cameras were positioned to view activity on both sod A and sod B from a remote location. Birds were trained to eat moth larvae from sod by placing untreated larvae on sod several times per day. Consumption of larvae was monitored by technicians. Once larvae were consumed on a regular basis testing began.

All food was removed and test pens were thoroughly cleaned a minimum of 3 hours prior to beginning testing to ensure that birds would be hungry. Larvae placement was pre-determined by flipping a coin: if "heads", the treated test diet (800 mg/m^3) was placed on “Location A”; if “tails”, the treated test diet (800 mg/m^3) was placed on “Location B.” The control test diet was placed in the opposite location of the treated test diet.

3.4.1.1. Test 1

Two moth larvae were placed on each sod A and sod B for a total of four larvae placed per replicate. Test was replicated four times in a row per pen. Testing was repeated four days in a row and the pen testing order was rotated each day. Testing occurred at approximately the same time each day and weather conditions remained consistent for all testing dates. Temperature highs ranged from 10.6-16.7°C (51-62°F) with lows ranging from -2.8-2.2°C (27-36°F) and no precipitation.

Larvae were placed on the sod by a third technician according to the predetermined placement assignment. A cardboard blind was set up to block the birds’ view of sod during placement of larvae. Larvae was dropped onto sod using gloved hands taking special care to use separate hands for treatment and control in order to avoid possible contamination of control larvae. Gloves were changed after each test. Care was taken to ensure larvae were not buried or hidden during placement. Approximate placement location was diagramed on the Larvae Placement Data Sheet. Following placement, the blind was removed and the technician exited the aviary.

Two additional technicians monitored the starling activity via camera from a remote location. Technicians were assigned a piece of sod to monitor in the pen. Sod observation responsibilities were rotated on a daily basis. Technicians were unaware of the predetermined placement assignment but were able to view larvae placement on the camera system to approximate location of the larvae on the sod. Observations began as soon as the placement technician exited the pen. Technicians observed and recorded the following information for their respective sod location: number of searches, number of attacks, number of consumptions, time to first contact, and location of first contact as well as noted any abnormal behavior. The number of consumptions was included in the number of attacks. The test was considered completed once

all larvae were consumed or birds did not return to either sod location for a period of time. Once testing was finished, the placement technician returned to verify that all larvae were consumed. If any remained, they were counted and recorded. Testing was repeated four times for each pen. Food was returned to pens when testing was complete.

3.4.1.2. Test 2

Ten moth larvae were placed on each sod A and sod B for a total of 20 larvae placed per replicate. Each test was replicated two times in a row per pen. Testing was repeated on two separate dates and the pen testing order was rotated each day. Testing occurred at approximately the same time each day. Weather conditions were consistent for both testing dates with the exception of rain on the second day of testing. Temperature highs ranged from 16.1-17.2°C (61-63°F) with lows ranging from 3.9-5.6°C (39-42°F) and precipitation on the second date. It was raining lightly when testing began and proceeded to rain harder as testing continued.

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3.5. Development of Response Functions

The exposure design resulted in serial time-mortality data (i.e., percent or proportion mortality measured over time [hours or days] for a given exposure concentration and wind speed). The proportion mortality was based on the total number dead out of the total on test from three test chambers placed within the wind tunnel at the same time. The intent of this effect modeling was to incorporate the impacts of FO on insect population dynamics over a period of time relevant to nestling/pup success in the current year and possible impacts on prey populations in subsequent migratory and reproductive periods. The general statistical approach is detailed below. Modifications for each test species are described in the Results and Accomplishments section.

Typically, proportion survival at a given point in time was modeled using a Probit, Logit, or a Spearman-Karber analysis to estimate the lethal or effective concentration associated with a 50% response (i.e., LC_{50} or EC_{50}). These analyses require a minimum of three exposure concentrations (ideally five) with at least two partial responses. If the partial responses do not bracket the 50% response, the confidence interval about the LC_{50} can be very large. Further, the Probit (or Logit) is likely to have difficulty converging when responses are not monotonic or clustered at the high or low end of the response spectrum. Observations taken over time are correlated and should not be analyzed using standard Probit analysis techniques (Robertson and Preisler 1992). Therefore, an empirical nonlinear modeling approach was applied with a comparison to the Probit results when applicable. The intent was not to define a mechanistic model, but to instead fit a smooth curve that fit the data well and could be used to provide maximum likelihood estimates of concentrations associated with selected levels of mortality and their asymptotic confidence intervals. Gaussian errors were assumed and the best-fit parameters were determined by minimizing the residual sum of squares.

Modeling the response of each test species followed the same general step-wise procedure. First, treatment response was corrected to remove background responses (e.g., spontaneous and handling-induced responses) that are not a result of exposure to FO. Assuming that background and FO responses are independent, Abbott's formula (Abbott 1925) was used to correct for control response in each treatment group. Equation 1 shows this correction as applied to percentage mortality in a test group:

$$My = \frac{(Mo - Mc)}{(100 - Mc)} x100 \tag{1}$$

where *Mc* and *Mo* are the control and exposed mortality in percent, respectively, and M_y is the corrected percentage mortality for a treatment group (Matsumura 1985).

In the second step, the corrected mortality was modeled over $\log_{10}$ exposure concentration (mg/m^3) using a logistic model with either one or two parameters (LC_{50} and a variable slope). The two parameter logistic model was expressed as:

$$y = \frac{1}{(1+10^{(\text{LogLC50} - x)\bullet \text{Hillslope}})} \tag{2}$$

where y was the Abbott's corrected mortality; $LogLC_{50}$ was the $\log_{10}$ of the dose concentration associated with 50% mortality; x was the $\log_{10}$ dose concentration; and Hillslope was the slope of the sigmoid curve. Hillslope was set equal to 1 when a one parameter logistic model was fit. The logistic model was reparameterized to estimate the $LogLC_{20}$ and the $LogLC_{80}$ by setting

$$\text{LogLC}_{50} = \text{LogLC}_{\text{F}} - (\frac{1}{\text{Hillslope}}) * \log(\frac{\text{F}}{100 - \text{F}}) \tag{3}$$

where F equals 20 or 80, respectively. The best-fit parameter estimates for each wind speed for a given species response were compared with an F-test of the full model with separate parameters for each wind speed and a reduced model with shared parameters (Ramsey and Schafer 1996).

The control mortality (Mc) was regressed across time using either simple linear regression or an exponential decay model as a function of days post exposure (x):

$$Mc = 100(e^{-Kx}) \tag{4}$$

where K is the decay coefficient. An F-test of the full model with separate decay coefficients and a reduced model with a common K was conducted to evaluate the effect of wind speed alone.

Then, the estimated control mortality was used to calculate an Abbott's corrected mortality for each exposure concentration across time. The corrected mortality was constrained to be greater than or equal to zero and monotonically increasing with time. The corrected mortality for each exposure concentration was then modeled as a one or two parameter logistic curve using Equation (2). The resulting LC_{50} or EC_{50} values from each exposure concentration were then regressed against concentration using a simple linear model or as a function of concentration and wind speed when appropriate. Some species results were not monotonic as a function of concentration. In order to model all concentrations, an exponential decay model, Equation (4), was used to model survival over time for each concentration and wind speed combination. The resulting decay coefficients were then regressed against exposure concentration and wind speed.

4. Results and Accomplishments

The impacts of fog oil exposure on five species of insects representative of major prey groups of TES of bats and birds that inhabit military lands were examined using a dynamic exposure method. This method accounted for the effect of environmental factors such as wind speed and canopy structure on the exposure and response of insects to FO. Response measures assessed availability and palatability of insect prey. Where effects were significant, algorithms of response were developed.

The following details the technical progress and accomplishments in relation to the specific study tasks. A total of 73 exposure tests were conducted and are listed in Table A1 in Appendix A.

4.1. Task 1: Establish Life-Cycle Colonies of Test Insects

Regenerating colonies of the geometrid moth and tenebrionid beetle were established. Single generation wood roach and mosquito cultures were developed but regenerating colonies could not be developed within the time frame of study. Because only the adult stage of the ant was required for the study, no colony was established for the ant species.

4.1.1. Moth colony

The moth colony was established with local (Richland, Washington) wild-caught mated females placed in a screened cage approximately 1.5 m by 1.8 m by 0.9 m high (5 ft x 6 ft x 3 ft high) in

which potted rabbitbrush, *Ericameria (Chrysothamnus) nauseosa var. speciosa* (Nutt.) Nesom & Baird, was placed and watered regularly to provide a source of moisture for the adult moths. Wild-caught mated females were placed into the cage and allowed to lay eggs on the larval food plant. Additional field collections of mated females were made over the prolonged occurrence of the species in the field throughout spring and summer of both years of the project to maintain an outbred population and sufficient number of larvae and adults for tests. The colony was maintained in an environmentally controlled greenhouse to provide breeding and life-cycle requirements throughout the year. It was self-sustaining and provided sufficient eggs, larvae, and adults through fall and winter seasons for colony perpetuation. A procedure was tested and used to maintain sufficient rabbitbrush to supply the nutritional needs of the larvae by rotating a portion of the plant colony through light/temperature-induced dormancy to induce "spring" breakout and lush leaf growth. To control aphid infestation without the use of insecticides, aphid-specific predatory wasp and midge populations have been established in the greenhouse. Although the greenhouse was maintained under specific temperature 22.2 ± 2.8ºC (72 ± 5ºF) and light (16 hr light: 8 hr dark), humidity was not controlled and approximated the outside humidity (although slightly higher) to provide local conditions for the rabbitbrush and moths.

The stages and duration of the life cycle of the moth under the colony rearing conditions were determined to provide information for designing the screening tests. The data gathered include the lifespan range of the adult male moths: number, appearance (e.g., size, morphology), and duration of larval instars; location and duration of pupation; and baseline values for larval survival, pupation rate, emergence, and egg deposition. The relationship between egg deposition and lifespan in the females and hatch rate of the eggs was refined. Information on activity patterns was also obtained. Because little has been published on the life history of *Diagrammia curvata*, a journal article was published describing the new information.

4.1.2. Beetle Colony

The *Tenebrio molitor* colony was started from commercially obtained larvae and maintained in containers containing a mixture of oatmeal and wheat bran with slices of potato and applies for moisture. Waste was removed by sieving. Young adults were moved to new containers to start each generation.

4.1.3. Wood Roach Colony

We attempted to establish a wood roach colony by purchasing live adults and advanced nymphs from a commercial supplier and applying the culture protocol developed by the supplier. The colony was maintained in large plastic boxes, layered with about 76 mm (3 in.) of potting soil and a 25 mm (1-in.) layer of pine bark and leaf debris. The soil was kept moist by regular watering. Dog food (ground pellets) was provided in Petrie dishes as food for the wood roach nymphs and adults. After 2 months of observation, the wood roaches appeared to be subsiding on the soil and debris for food instead of the dog food.

The female wood roaches lay eggs in cases (or capsules) of approximately 24 eggs each which hatch in approximately 45-60 days. The young nymphs were grown in Petrie dishes until they were approximately 10 mm (0.4 in.) long, at which time they were transferred to the larger colony cages. An avian egg incubator was modified to provide precise environmental temperature and humidity control during embryonation of the eggs. Although we were

successful in raising wood roaches from egg to the intermediate nymphal stages, egg viability remained low. Because of the long incubation period of the eggs, the success of procedural adjustments was not apparent for several months. Because we were unable to increase egg capsule production in a reasonable amount of time, the tenebrionid beetle was selected as an alternative species with rapid life-cycle completion. However, we continued a single generation culture of the wood roach, purchasing the appropriate life stage for the tests and raising them through adult stage.

4.1.4. Mosquito Colony

A regenerating mosquito colony was not established due to delays in obtaining *Culex* species to initiate the colony because of safety concerns regarding source colony contamination with the West Nile virus. Similar concerns were raised regarding use of live birds to provide the necessary blood meal for the mosquito egg production. Artificial blood diets were recommended and used, but little viable egg production was obtained. Therefore, egg rafts and larvae were purchased as needed and successfully cultured to the adult stage. However, we had difficulty sustaining sufficient numbers of adults of the same age for exposure tests.

4.2. Task 2: Evaluate Colony Response with Hexadecane

Because tests against the standard larvicidal/ovicidal oil require an established, reproducing colony of mosquitoes, we were unable to complete this task.

4.3. Task 3: Standardize Response Measurements

This task involved the development of experimental protocols for exposure of insects to fog oil and observation of impacts of the exposure on the various life stages. The exposure protocols are described in the Materials and Methods Section. The measurement of the response endpoints was tested for selected exposure conditions to ensure uniformity of interpretation.

4.3.1. Measurement Protocols for the Moth, Beetle, and Wood Roach

Baseline life-cycle data from the colonies were used to estimate variability of the various response measures to determine the necessary number of replicates to detect effects. Observations were made daily and included condition of the adults, activity, response to touch of antennae, position in cage, duration of flight, and mortality. Dead insects were removed and the sex of each determined. Female moths were dissected to determine the number of eggs that remained in the abdomen to obtain information on oviposition in response to fog oil exposure. Observations were made until all adults died.

One goal in testing the geometrid moth was to conduct tests of fog oil impact on the ability and tendency of the moths to fly. The geometric moth is a weak flyer and flies primarily at night. The moths in the colony cages were seldom observed to be in flight unless disturbed by maintenance activities in the cage. Methods were considered to perform the flight tests, including use of pheromones to stimulate the males to fly in search of females. Although it was possible to identify potential pheromone chemicals that were known for related species in the same genus, the purchase or synthesis of the chemicals was cost-prohibitive. The daily observations of activity, response to stimuli, and flight proved more successful and economical than proposed flight tests. Therefore, the flight tests were not conducted. (See screening test results for the geometrid moths for an example).

For immature stages, each day following the exposure, the condition of the larvae or nymphs was noted, particularly the advancement to successive instars and pupation. Response to stimuli was evaluated on any larvae or nymphs that appeared not to be moving or had changed color. Each cage was observed through emergence of adults.

Eggs of the moth and beetle were so small and difficult to locate/observe in their culture media that counts prior to and post-exposure were not reliable. The poor hatchability of wood roach eggs in culture was not resolved (though it appeared to be related to humidity) and would have required, because of their long incubation period, significantly more time. Therefore, reliable egg hatchability data was not acquired for any of the species tested.

4.3.2. Measurement Protocols for Adult Ant

After exposure, the adult ants were observed for morbidity and mortality by touch stimuli.

4.3.3. Palatability and Food Quality

Palatability studies were proposed to be conducted with wild-trapped yellow-rumped warblers (*Dendroica coronata*) as a representative bird predator. State and Federal permits were obtained for collection and testing of this species. However, few of the warblers were observed in the area in fall when the largest number of larvae were available for testing. No warblers were collected during several collecting forays; therefore, starlings were used as an alternative species. The palatability measurement protocol is described in detail in the Materials and Methods section.

Food quality analyses were not conducted due to insufficient numbers of insects, lack of observed effect, and limited funds due to a large than expected investment in colony development and bird collection efforts.

4.4. Tasks 4, 5, and 6: Screening and Exposure Tests and Formulation of Algorithms of Response

Screening studies under worst case scenarios (concentration, duration, wind speed and cover) were possible using this system and showed that immature stages of the surrogate wood roach and tenebrionid beetle were unaffected by FO exposures that exceeded near-field concentrations. Also, no significant effect on mortality or life span of the adult forms of the wood roach or geometrid moth were detected for FO concentrations in excess of those reported for areas near the source generation. Survival of adult beetles exhibited some effect, but was not monotonic with respect to concentration. These screening tests resulted in "No Go" decisions for further testing of these life stages of these species.

Exposure tests were conducted on all five larval instars of the geometrid moth and impacts found at field relevant concentrations. Algorithms were developed from the data that model moth survival and mortality as a function of age (larval instar) at exposure and as a function of wind speed in a small leaf Area Canopy. An algorithm describing overall effect of wind speed and canopy density on survival and mortality of the geometrid moth was also derived. These and algorithms of ant survival and mortality as a function of wind speed and exposure concentration are reported below.

4.5. Geometrid Moth

4.5.1. Screening studies

4.5.1.1. Adult

Newly emerged adult female moths (Day 0 of age) were exposed to an average of 530 ± 140 mg/m^3 of FO for 4 hr. The wind speed during the test was 0.9 m/s (2 mph). Mean temperature 26ºC (78.8ºF) and relative humidity (46%) within the wind tunnel were similar to those of their rearing cages at the Plant Growth Facility green house (27ºC and 40% RH). A control population was tested in the wind tunnel under similar wind speed and environmental conditions but in the absence of FO. A second control population was maintained in their home cages in the green house facility to evaluate the effect of handling/wind stress on the lifespan of the moths. As seen in Table 1, the wind tunnel exposure scenario did not affect the mean or median life span or coefficient of variation (CV) of the female moths as compared to undisturbed moths in the greenhouse facility. Greater variability in longevity was observed in females exposed to the FO aerosols (Table 2, Figure 12); however, no statistically significant effect on life span (Kruskal-Wallis, p = 0.47) was detected (Figure 12).

Table 2. Descriptive Statistics of the Lifespan of Adult Female Moths Exposed to Fog Oil in a 0.9-m/s (2-mph) Wind

Treatment	N	Mean	Median	StDev	Minimum	Maximum	Q1	Q3	CV
C(0)	31	11.8	12.0	2.69	8	17	10.0	14.0	23%
C(2 mph))	11	11.6	12.0	2.77	8	18	10.0	13.0	24%
530(2 mph)	8	9.8	10.5	4.68	1	15	7.0	14.3	48%

Exposure to FO concentrations greater than 530 mg/m^3 may impact lifespan, so the effects of FO on adult survival were further evaluated at a higher concentration (916 ± 101 mg/m^3 FO for 4 hr) and at different ages post-emergence (Day 0, Day 1, and Day 2) under similar environmental conditions as those described for the 530 mg/m^3 exposure. Although oil was visible on the wings of the moths for up to 6 days post-exposure, no impact on adult longevity was observed (Kruskal-Wallis, p = 0.13) (Figure 13). Therefore, further tests with the adult moths were not conducted.

Although no increase in mortality was observed in moths exposed to FO aerosols of 916 mg/m^3 (LC20 > 916 mg/m^3), there was a marked change in their behavior. Control moths and moths exposed to concentrations of 530 mg/m^3 or less of FO were active and typically rested on the foliage until about 1 to 2 days prior to death, at which time they would drop to the soil. These moths responded (flight) to a touch stimulus to the antenna or tip of the abdomen. Occasionally an active individual would rest on the soil, but would fly up if disturbed (touch stimulus). In contrast, individuals exposed to 916 mg/m^3 were found resting on the soil several days prior to death and were unresponsive to touch stimuli. Therefore the NOAEL of FO on adult moths was estimated to be between 530 mg/m^3 and 916 mg/m^3 for a sustained 4-hour exposure to FO.

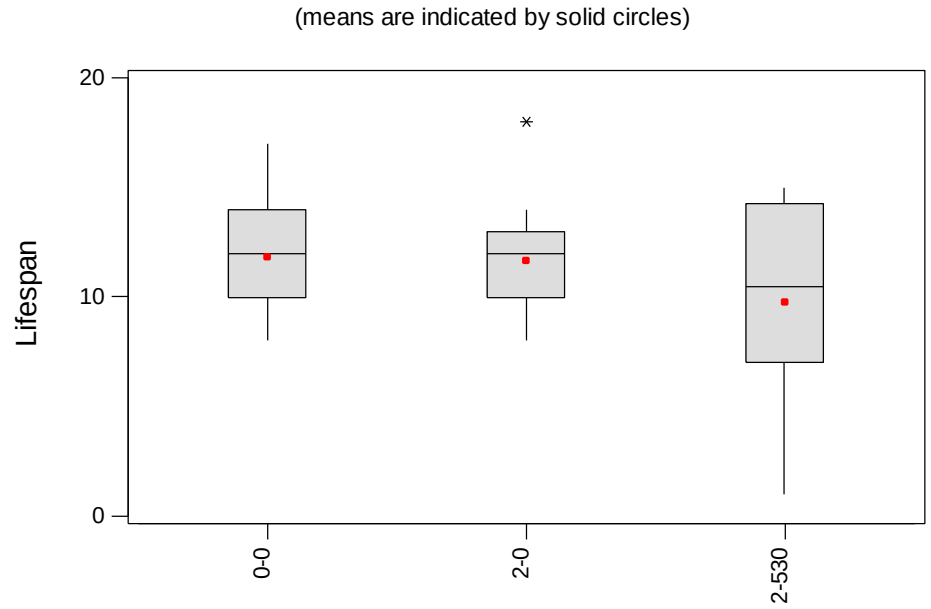


Figure 12. Life Span (in Days) of Female *Digrammia curvata* Adults Unexposed to Wind Tunnel Conditions or Fog Oil (0-0), Exposed to Wind Tunnel Conditions for 4 hr in a 0.9 m/s (2 mph) Wind without Fog Oil (2-0), or Exposed to 530 mg/m^3 of Fog Oil for 4 hr in a 0.9 m/s (2 mph) Wind

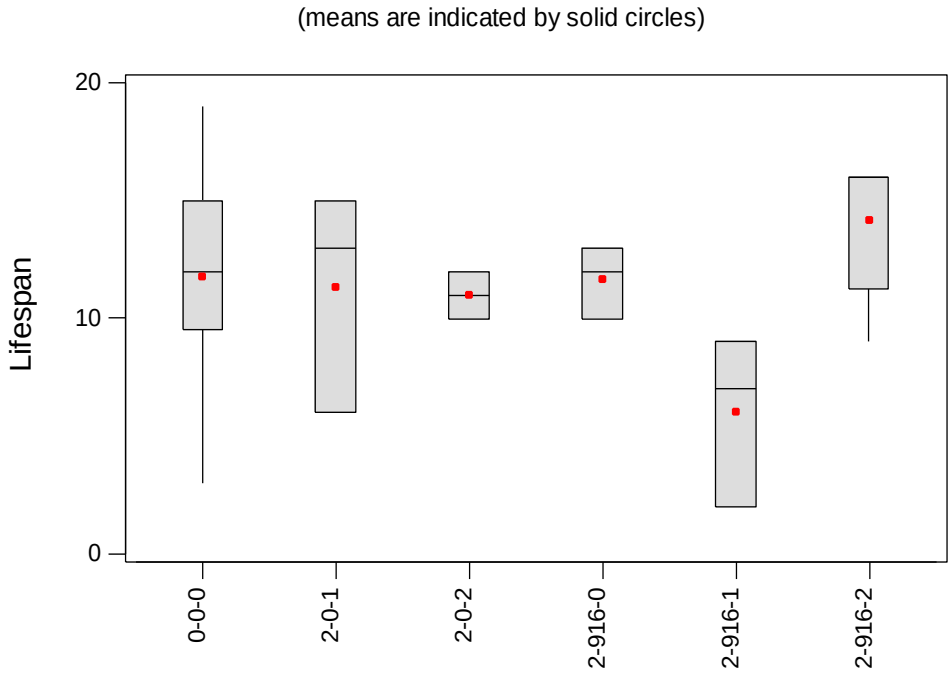


Figure 13. Longevity of Adult Female Moths Characterized by the Treatment Combination of Wind Speed = 0 or 0.9 m/s (0 or 2 mph), Fog Oil Exposure Concentration = 0 or 916 mg/m^3, and Age Post-Emergence at Exposure to Fog Oil or Wind Alone (0, 1, or 2 days)

4.5.1.2. Larval Instars

The initial screening of larval sensitivity to FO and resultant effects on production of pupa and adult emergence was conducted with 4th and 5th instars exposed to 916 mg/m^3 of FO for 4 hr. As shown in Table 3, 65% of FO exposed larvae died prior to the pupal stage compared to 20% in the wind tunnel controls. A four-fold reduction in the emergence of adult moths resulted from exposure of late larval instars (Table 3).

Table 3. Percentage Survival of Late Larval Instars of the Moth (*Digrammia curvata*) Exposed to Airborne Fog Oil

Treatment	n	%Larvae Survived	%Pupated	%Adults Emerged
Wind tunnel Control	10	80	70	40
916 mg/m^3 Fog Oil	20	35	35	10

4.5.2. Effect of Larval Age (Instar) at Exposure on Survival of Subsequent Life Stages of the Moth

Because of the observed impact on larval survival and adult emergence, a study was conducted to evaluate the effect of airborne FO on each of the larval instars of *Digrammia curvata* over a wide range of exposure concentrations. To this end, the sensitivity of each of the five larval instars of the moth to FO was evaluated by exposing each instar to FO and counting the number surviving to each of the subsequent untreated instars. Because there is a natural and/or handling loss of larvae at each instar (Table 4), the data for treated larvae were corrected at each instar by removing the expected control loss obtained from the regression of control survival over time (Figure 14). Progression to the pupal stage and successful emergence of adults was also monitored to evaluate the impact of larval exposure to FO on subsequent adult prey populations. Production of pupa and adults was also corrected for control loss using Abbott's Correction and reported as a proportion of the surviving 5th instar larvae (Figure 14). The FO concentrations to which larvae of each instar were exposed were 0, 100, 400, 800 or 1200 mg/m^3. They were exposed for 4 hr in a 0.9 m/s (2 mph) wind while on preferred vegetation (rabbitbrush).

The proportion survival to the next instar of geometrid moth larvae exposed to airborne FO is presented in Table 4. Very few larvae exposed to FO concentrations of 400 mg/m^3 and greater survived to adults. For moth larvae exposed to less than 400 mg/m^3, survival to the adult stage tended to increase when exposure occurred at later instars.

To correct the response data for FO-exposed larvae to account for natural or handling-induced reductions in survival at each instar, two models of control larvae survival were tested. The linear regression of the proportion of control survival to the next instar (Model 1) was not found to be significant ($p = 0.12$); however, the regression of the proportion survival to the final or 5th larval instar (the last instar prior to pupation) as a function of the number of remaining instars to the 5th instar (Table 4) was significant ($p = 0.04$; Table 5 and Figure 14 (1)). Therefore, Model 2, was used to estimate the expected control survival to the 5th instar as a function of the number of instars to the 5th instar.

Table 4. Observed Proportion Survival to a Given Life Stage of Moths (*Digrammia curvata*) Exposed to Fog Oil (mg/m^3) at Different Larval Instars

Exposure (mg/m^3)	Exposed Larval Instar	Number of Instars to the 5th larval Instar	Number on Test	Proportion Survival to Next Instar	Proportion Survival to 5th Instar	Proportion Survival to Pupate	Proportion Survival to Adult
0	1	4	15	0.60	0.33	0.33	0.13
0	2	3	14	0.71	0.43	0.36	0.36
0	3	2	14	1.00	0.79	0.79	0.79
0	4	1	13	0.85	0.85	0.69	0.31
0	5	0	15	0.93	1.00	0.93	0.93
100	1	4	10	0.70	0.50	0.30	0.20
100	2	3	10	0.60	0.20	0.20	0.20
100	3	2	9	0.89	0.89	0.89	0.89
100	4	1	7	0.57	0.57	0.57	0.57
100	5	0	12	0.75	1.00	0.75	0.58
400	1	4	10	0.00	0.00	0.00	0.00
400	2	3	10	0.80	0.60	0.10	0.10
400	3	2	10	0.50	0.50	0.40	0.20
400	4	1	10	0.60	0.60	0.40	0.50
400	5	0	10	0.20	1.00	0.20	0.20
800	1	4	10	0.00	0.00	0.00	0.00
800	2	3	10	0.40	0.30	0.20	0.20
800	3	2	10	0.20	0.20	0.10	0.00
800	4	1	10	0.20	0.20	0.00	0.00
800	5	0	10	0.30	1.00	0.20	0.00
1200	1	4	10	0.00	0.00	0.00	0.00
1200	2	3	10	0.00	0.00	0.00	0.00
1200	3	2	10	0.30	0.10	0.00	0.00
1200	4	1	11	0.27	0.27	0.00	0.00
1200	5	0	9	0.33	1.00	0.11	0.00

Table 5. Regression Analysis of Variance of Control Moth Survival

Model 1: Proportion Survival to Next Instar as a Function of the Starting (FO-Exposed) Instar

The regression equation is
Proportion Survival to Next Instar = 0.579 + 0.0798 Starting Instar

Predictor	Coefficient	SE of Coefficient	T-value	P-value	Significance
Constant	0.5792	0.1238	4.68	0.018	
Slope	0.0798	0.03732	2.14	0.122	NS

S = 0.1180 R-Sq = 60.4% R-Sq(adj) = 47.2%

Source	DF	SS	MS	F	P
Regression	1	0.06368	0.06368	4.57	0.122
Residual Error	3	0.04179	0.01393		
Total	4	0.10547			

Model 2: Proportion Survival to 5th Larval Instar as a Function of the Number of Instars from the Exposed Instar to the 5th Instar

The regression equation is
Proportion Survival to 5th Instar = 1.07 - 0.190 Number of Instars to 5th

Predictor	Coefficient	SE of Coefficient	T-value	P-value	Significance
Constant	1.0723	0.1092	9.82	0.01	
Slope	-0.18956	0.03988	-4.75	0.042	*

S = 0.08918 R-Sq = 91.9% R-Sq(adj) = 87.8%

Source	DF	SS	MS	F	P
Regression	1	0.17967	0.17967	22.59	0.042
Residual Error	2	0.0159	0.00795		
Total	3	0.19557			

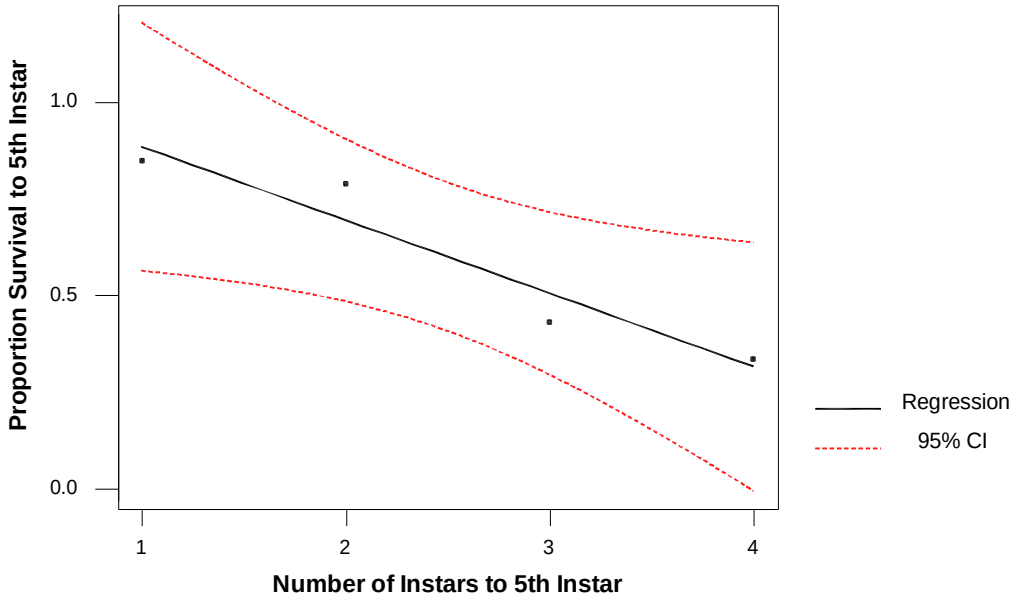


Figure 14. Control Proportion Survival of *Digrammia curvata* Larvae from the Fog Oil-Exposed Larval Instar to the 5th Instar as a Function of the Number of Instars to the 5th Larval Instar (y = 1.07 - 0.190(5-i), where i is the Exposed Larval Instar (R^2 = 0.92)

The control survival across instars was used to remove the effect of handling and natural instar loss from the FO-exposed moth response (Figure 15). Note in Figure 15 that the probability of surviving to the 5th instar starting from the 1st instar is low without any exposure and that surviving to the 5th instar starting from the 4th instar is the least sensitive to exposure concentration. Using this corrected response data, the intercepts (constant) resulting from the regression of the survival to the 5th instar for each exposure concentration against the number of instars from the exposed instar to the 5th instar were shown to decrease significantly with concentration (Table 6 and Figure 16). A 95% confidence interval was estimated for the EC20, EC50, EC80, and EC90 as a fraction of the control intercept (Table 7). The EC50 is defined here as the concentration that produces a 50% reduction in the baseline survival to the 5th larval instar. The confidence intervals are wide, in part because the response at 1200 mg/m^3 did not show a continued decline in the baseline survival, but instead leveled off.

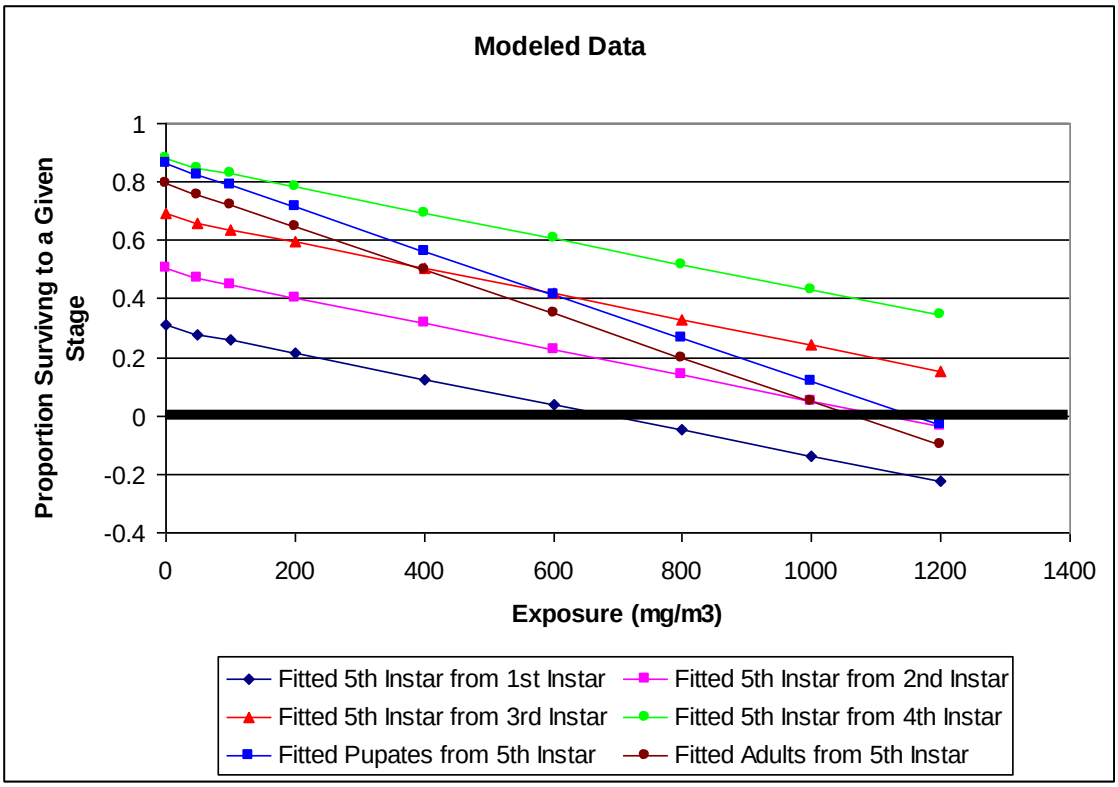


Figure 15. Proportion of Moth Life Stages Surviving to a Given Stage Following Exposure to Different Concentrations of Fog Oil (Data Is Abbott's Corrected for Control Losses at Each Life Stage)

Table 6. Linear Regression Results for the Proportion Survival of Moth Larvae to the 5th Instar of Each Fog Oil Exposure Concentration as a Function of the Number of Instars from the Fog Oil Exposed Instar to the 5th Larval Instar

Exposure (mg/m^3)	Predictor	Coeficient	Standard Error of Coeficient	T-value	P-value
0	Constant	1.0723	0.1092	9.82	0.01
100	Constant	0.765	0.3874	1.97	0.187
400	Constant	0.85	0.2779	3.06	0.092
800	Constant	0.3	0.162	1.85	0.205
1200	Constant	0.32	0.07384	4.33	0.049
0	slope	-0.18956	0.03988	-4.75	0.042
100	slope	-0.09	0.1415	-0.64	0.59
400	slope	-0.17	0.1015	-1.68	0.236
800	slope	-0.05	0.05916	-0.85	0.487
1200	slope	-0.091	0.02696	-3.38	0.078

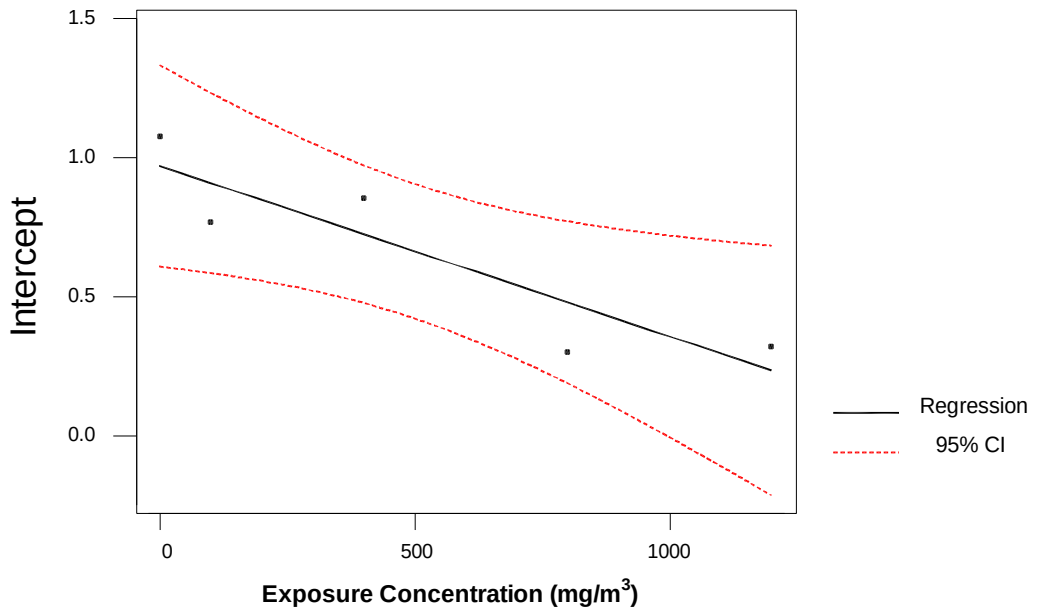


Figure 16. Intercepts from the Individual Dose Regressions of the Proportion Survival of Moth Larvae to the 5th Instar as a Function of the Number of Instars from the Fog Oil-Exposed Instar to the 5th Instar

Table 7. The Effective Concentration Resulting in a Given Percentage Reduction in the Baseline Survival of *Digrammia curvata* Larvae from the Exposed Instar to the Last (5th) Larval Instar

Percentage of Baseline Survival	ECx[a]	Lower 95% CL[b]	Upper 95% CL
20%	1291	793	6997
50%	807	382.2	3193
80%	323	0	781
90%	161	0	554.6

[a] x = the percentage in column 1, e.g., EC_{50} is 807.
[b] The confidence intervals are wide in part because the response at 1200 mg/m^3 did not show a continued decline in the baseline survival, but instead leveled off.

Residuals derived from the difference in the observed and expected proportion survival from the exposed instar to the 5th larval instar can be viewed as replicates since the control effect of the starting instar has been removed (Table 8). This assumes that the effect of the starting instar does not change with the exposure concentration tested above. The linear regression of the residuals as a function of exposure concentration (Model 3) was significant ($p < 0.001$; Table 9 and Figure 17). Despite the large variability ($R^2 = 55\%$), the residuals decreased with exposure concentration, suggesting that the effect of larval instar survival was less pronounced (although not significantly) in the exposed moths.

Table 8. Observed and Expected Proportion Survival of Moth Larvae from the Fog Oil-Exposed Instar to the 5th Larval Instar Based on Control Data and Model 2

Exposure (mg/m^3)	Instar	Instars till 5th	Observed Proportion Survival to the 5th Instar	Expected Proportion Survival to the 5th Instar Based on Model 2	Residuals = (Observed – Expected)
0	1	4	0.33	0.31406	0.019273
0	2	3	0.43	0.50362	-0.07505
0	3	2	0.79	0.69318	0.092534
0	4	1	0.85	0.88274	-0.03659
100	1	4	0.50	0.31406	0.18594
100	2	3	0.20	0.50362	-0.30362
100	3	2	0.89	0.69318	0.195709
100	4	1	0.57	0.88274	-0.31131
400	1	4	0.00	0.31406	-0.31406
400	2	3	0.60	0.50362	0.09638
400	3	2	0.50	0.69318	-0.19318
400	4	1	0.60	0.88274	-0.28274
800	1	4	0.00	0.31406	-0.31406
800	2	3	0.30	0.50362	-0.20362
800	3	2	0.20	0.69318	-0.49318
800	4	1	0.20	0.88274	-0.68274
1200	1	4	0.00	0.31406	-0.31406
1200	2	3	0.00	0.50362	-0.50362
1200	3	2	0.10	0.69318	-0.59318
1200	4	1	0.27	0.88274	-0.61001

Table 9. Regression Analysis of Variance of Residuals

Model 3: Residual of Survival to the 5th Instar from the Expected Survival from Model 2 versus Exposure mg/m^3

The regression equation is
Residuals = - 0.0120 -0.000440 Exposure mg/m^3

Predictor	Coeficient	SE of Coeficient	T-value	P-value	Significance
Constant	-0.01205	0.06006	-0.2	0.843	
Slope	-0.00044	8.95E-05	-4.91	< 0.001	**

S = 0.1791 R-Sq = 57.3% R-Sq(adj) = 54.9%

Source	DF	SS	MS	F	P
Regression	1	0.77449	0.77449	24.15	< 0.001
Residual Error	18	0.57724	0.03207		
Lack of Fit	3	0.02041	0.0068	0.18	0.906
Pure Error	15	0.55684	0.03712		
Total	19	1.35174			

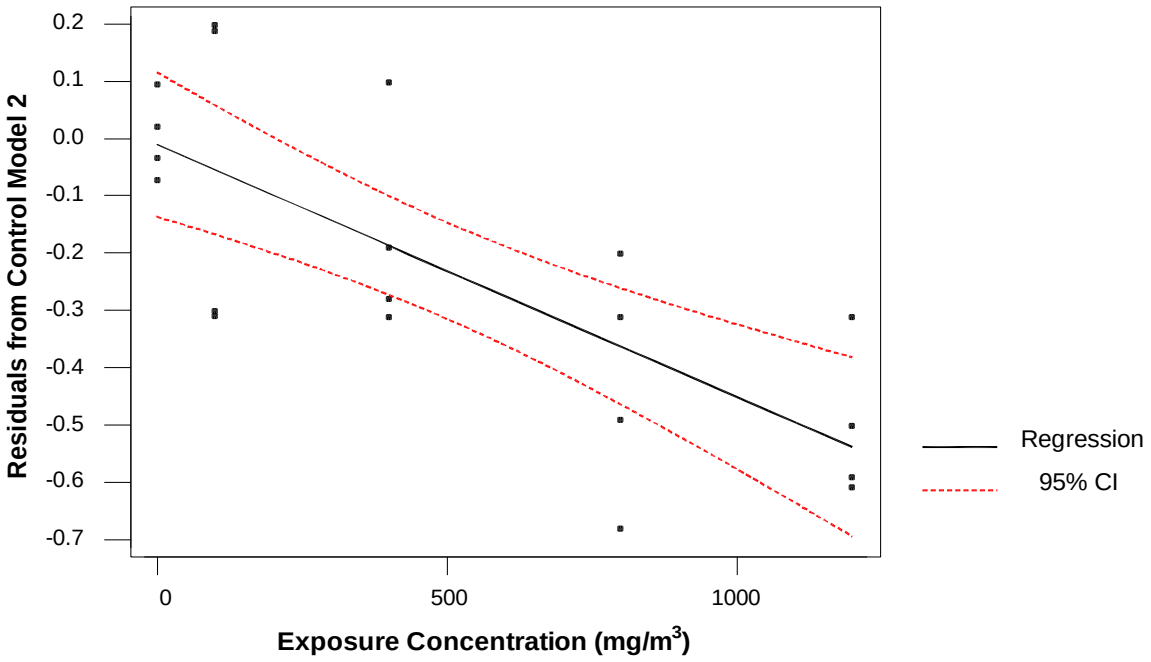


Figure 17. Regression of the Residuals from the Control Model 2 for Moth Larvae as a Function of the Exposure Concentration

The regression of the proportion of larvae that reached the 5th instar and successfully advanced to the pupa stage against exposure concentration (Model 4) was significant ($p < 0.001$; Figure 18 and Table 10). Lack of fit to the linear model was not significant ($p = 0.20$). Dunnett's test of the conditional survival to pupa stage found a significantly greater conditional survival at the control and 100 mg/m^3 FO response than was found at the higher exposure concentrations ($p < 0.001$).

For the adult survival regression analysis, three control survival responses were removed as outliers to the data. All three responses were less than 40% survival while the other two replicates had 79% and 93% survival. The regression of the proportion to reach adult given that the 5th instar was reached against exposure concentration (Model 5) was also significant ($p < 0.001$; Figure 19 and Table 10). Lack of fit to the linear model was not significant ($p = 0.22$). Dunnett's test of the conditional survival to reach adult found a significantly greater survival at the control and 100 mg/m^3 response than at the greater exposure concentrations ($p < 0.001$).

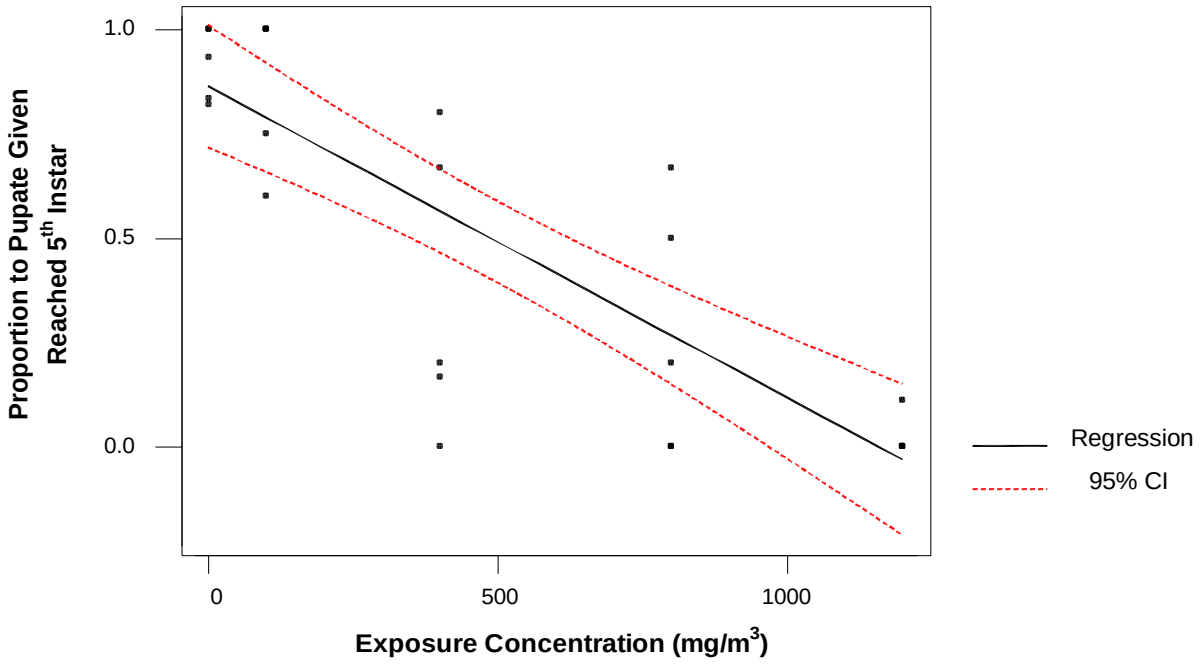


Figure 18. Regression of the Proportion of Moth Larvae that Reached the 5th Instar and Pupated as a Function of the Exposure Concentration

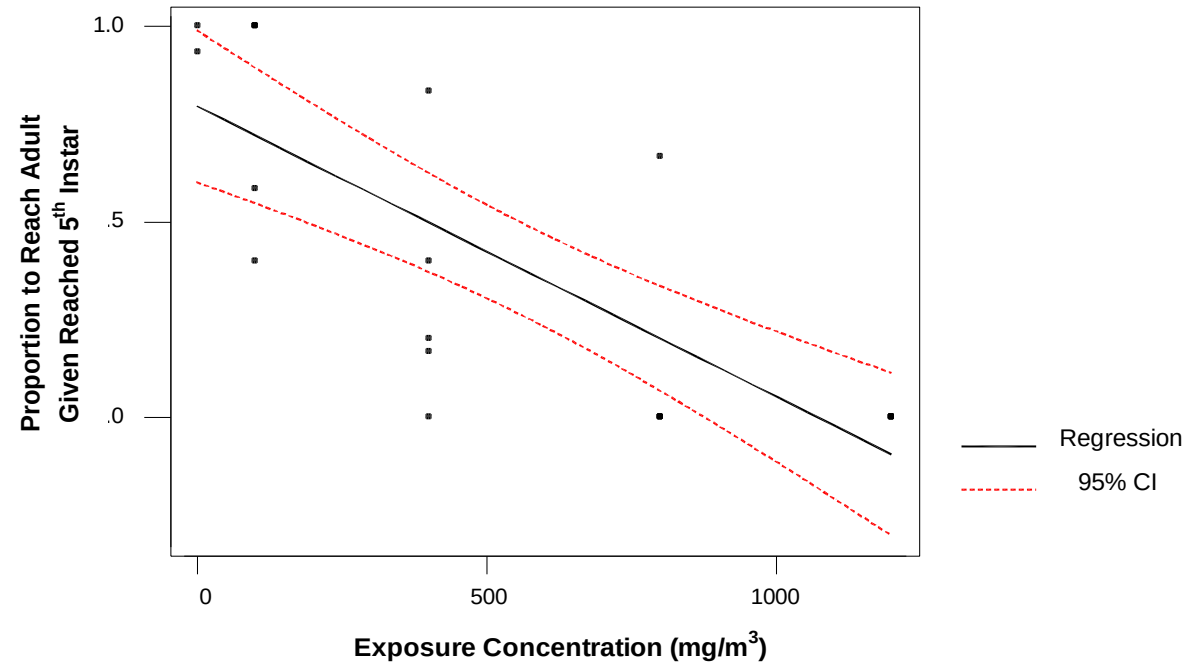


Figure 19. Regression of the Proportion of 5th Instar Moth Larvae that Successfully Emerge as Adults as a Function of the Exposure Concentration

Table 10. Regression Results of the Conditional Proportion of Pupae and Adult Survival of 5th Instar Moth Larvae as a function of Exposure Concentration

Model 4: Conditional Proportion to Pupate versus Exposure mg/m^3

The regression equation is

Proportion to of 5th Pupate Given Reached 5th Instar = 0.863 -0.000746 Exposure mg/m^3

Predictor	Coeficient	SE of Coeficient	T-value	P-value	Significance
Constant	0.86264	0.07073	12.2	< 0.001	
Slope	-0.00075	0.000105	-7.07	< 0.001	**

S = 0.2358 R-Sq = 68.5% R-Sq(adj) = 67.1%

Source	DF	SS	MS	F	P
Regression	1	2.7796	2.7796	50.01	< 0.001
Residual Error	23	1.2784	0.0556		
Lack of Fit	3	0.2588	0.0863	1.69	0.201
Pure Error	20	1.0196	0.051		
Total	24	4.0579			

Model 5: Conditional Proportion to Reach Adult versus Exposure mg/m^3

The regression equation is

Proportion to Reach Adult Given Reached 5th Instar = 0.794 -0.000742 Exposure mg/m^3

Predictor	Coeficient	SE of Coeficient	T-value	P-value	Significance
Constant	0.79361	0.09323	8.51	< 0.001	
Slope	-0.00074	0.00013	-5.69	< 0.001	**

S = 0.2655 R-Sq = 61.8% R-Sq(adj) = 59.9%

Source	DF	SS	MS	F	P
Regression	1	2.2841	2.2841	32.4	< 0.001
Residual Error	20	1.41	0.0705		
Lack of Fit	3	0.3151	0.105	1.63	0.219
Pure Error	17	1.0949	0.0644		
Total	21	3.6941			

4.5.2.1. Algorithms of Moth Survival and Mortality as a Function of Age (Laval Instar) at Exposure

To model survival of the geometrid moth from any one of the five larval instars to the adult form as a function of FO exposure, Models 2 through 5 described above are combined in the following sequence:

Model 2 (Control Larvae Survival to 5th Instar) provides the starting proportion of larvae that survive to the 5th instar from the ith instar (R^2=88%),

$$pi(0) = 1.07 - 0.190(5-i) \quad (7)$$

where pi(0) is the proportion of larvae surviving from the ith to the 5th larval instar for 0 mg/m^3 exposure and i is the starting instar (the instar at which exposure occurred);

Model 3 (FO-Exposed Larvae Survival to the 5^{th} Instar; determined from a regression of the residuals from Model 1 as a function of the exposure concentration) decreases the starting proportion survival based on FO exposure concentration (R^2=55%)

$$pi(x) = pi(0) - 0.012 - 0.00044(x) \quad (8)$$

where pi(x) is the proportion of larvae surviving from the i^{th} to the 5^{th} instar when the i^{th} instar is exposed to FO, x is the concentration of FO in mg/m^3;

Model 4 (Successful Pupation of Larvae that Survived to 5^{th} Instar) provides the proportion larvae that successfully pupate given that they reached the 5^{th} instar (R^2=67%)

$$pp(x) = 0.863 - 0.000746(x) \quad (9)$$

where $p_p(x)$ is the proportion of pupa produced from FO-exposed larvae that matured through the 5^{th} instar;

Model 5 (Successful Emergence of Adults from Larvae Surviving to 5^{th} Instar) provides the proportion of adults that were produced from FO-exposed larvae that matured though the 5^{th} instar (R^2=60%)

$$pa(x) = 0.794 - 0.000742(x) \quad (10)$$

where $p_a(x)$ is the proportion of adults produced from FO-exposed larvae that matured through the 5^{th} instar.

To model mortality rather than survival of the moth larvae, pupae and adult stages as a function of exposure concentration (x), simply subtract the survival function from 1. Specifically: control mortality is modeled as

$$qi(0) = 1 - pi(0) \quad (11)$$

where qi(0) is the proportion of control larvae dying from the i^{th} to the 5^{th} larval instar; larval mortality from the i^{th} to the 5^{th} instar of exposed larvae is modeled as:

$$qi(x) = 1 - pi(x) \quad (12)$$

and proportion of 5^{th} instar larvae that failed to pupate or to emerge as adults are modeled by equations 13 and 14, respectively.

$$qp(x) = 1 - pp(x) \quad (13)$$
$$qa(x) = 1 - pa(x) \quad (14)$$

4.5.3. Effect of Wind Speed and Canopy Density on Moth Survival and Maturation Post-Exposure to Airborne Fog Oil

4.5.3.1. Small Leaf-Area Canopies

In small leaf-area canopies, the wind speed during a 2-hour exposure period affected percentage survival of both control and FO-exposed moths as they subsequently matured from early stage larvae (1^{st}-3^{rd} instars) through adult form. Percentage survival of control moths exposed in a small canopy fit an exponential decay model with R^2 values of 0.98, 0.82, and 0.92 for winds speed of 0.9, 1.8, and 3.6 m/s (2, 4, and 8 mph), respectively (Figure 20 and Table 11). A linear model, y = 111.4 – 2.454 days, fit the observed survival with an R^2 value of 0.97 when the wind speed was 1.8 m/s (4 mph); however, the exponential decay model was used for consistency with the 0.9 and 3.6 m/s (2 and 8 mph) modeled responses. The estimated survival rates (K) under the three wind speeds were significantly different ($p < 0.001$).

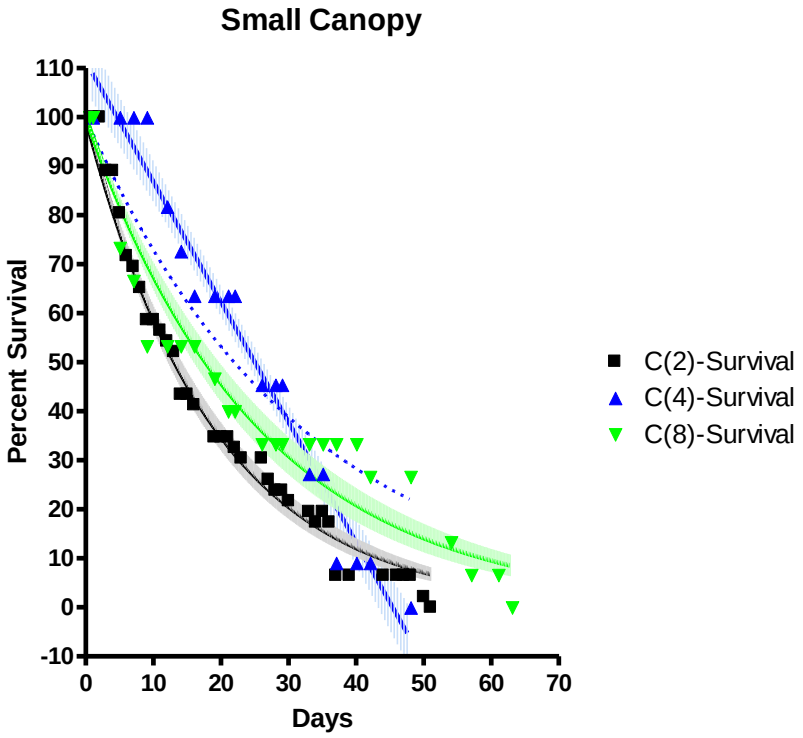


Figure 20. Observed and Expected Control Survival of *Digrammia curvata* Exposed as Early Instar Larvae to Wind Speeds of 0.9, 1.8, and 3.6 m/s (2, 4, and 8 mph) in a Small Leaf-Area Canopy for 2 hr. Each treatment is expressed as an exposure level with the wind speed in parentheses where C equals the control dose. Solid lines are the best-fit for each wind speed and the blue dashed line is an exponential decay model fit to the 2 mph control survival.

Table 11. Best Fit Parameters to the Exponential Decay Model of Survival of Control Moths Exposed as Early Larval Instars to Wind Speeds of 0.9, 1.8, and 3.6 m/s (2, 4, and 8 mph) within a Small Leaf-Area Canopy

Statistic/Parameter	C(2)	C(4)	C(8)
SPAN	100	100	100
K	0.05271	0.03155	0.03912
PLATEAU	0	0	0
HalfLife	13.15	21.97	17.72
Std. Error			
K	0.001114	0.003326	0.001985
95% Confidence Intervals			
K	0.05045 to 0.05497	0.02456 to 0.03854	0.03501 to 0.04323
HalfLife	13.74 to 12.61	17.99 to 28.22	16.04 to 19.80
Goodness of Fit			
Degrees of Freedom	37	18	23
R^2	0.9827	0.8208	0.9171

For consistency between all canopy exposures, the exponential decay model was fit separately to each exposure concentration and wind speed combination so that all concentrations could be modeled (Figure 21). For the wind speed of 0.9 m/s (2 mph) (Table 12), the survival rates (K) for the control and 100 mg/m^3 exposure concentrations were not significantly different ($p = 0.14$). The K-values for the remaining concentrations were significantly different ($p < 0.05$) and increased with exposure concentration. For the wind speed of 1.8 m/s (4 mph), K-values for concentrations of 50 and 100 mg/m^3 were not significantly different ($p = 0.53$). The remaining concentrations were significantly different and tended to increase with exposure concentration (Table 13). The data for 400 mg/m^3 did not converge. For the wind speed of 3.6 m/s (8 mph), K-values for concentrations of 50 and 100 mg/m^3 were not significantly different ($p = 0.25$). The remaining K-values were significantly different ($p < 0.001$) and, except for the 200 mg/m^3 exposure, increased with concentration (Table 14).

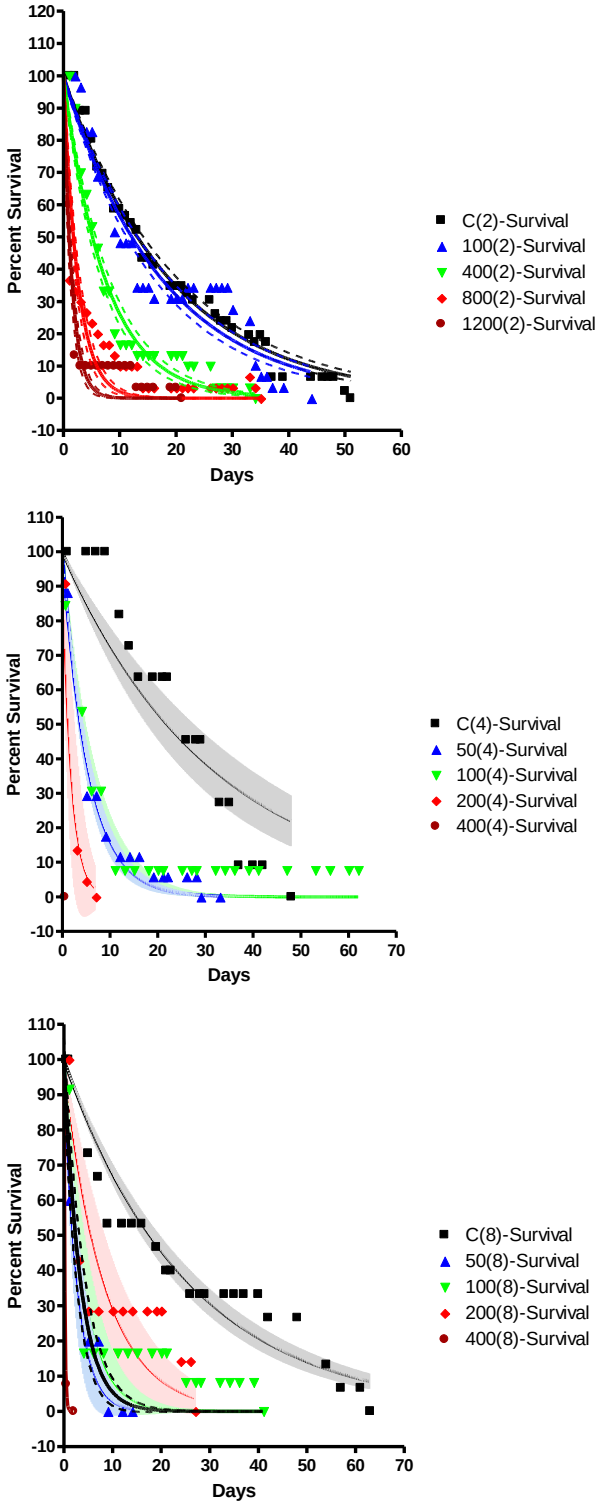


Figure 21. Observed and Expected Survival of *Digrammia curvata* Exposed to Fog Oil as Early Instar Larvae within a Small Leaf-Area Canopy for 2 hr at Wind Speeds of 0.9, 1.8, and 3.6 m/s (2, 4, or 8 mph). Each treatment is expressed as an exposure level with the wind speed in parentheses where C equals the control dose.

Table 12. Best Fit for Separate Exponential Decay Coefficients for Moth Survival for Each Exposure Concentration and Wind Speed of 0.9 m/s (2 mph) in a Small Leaf-Area Canopy

Statistic/Parameter	C(2)	100(2)	400(2)	800(2)	1200(2)
SPAN	100	100	100	100	100
K	0.05271	0.05699	0.1339	0.3862	0.6601
PLATEAU	0	0	0	0	0
HalfLife	13.15	12.16	5.178	1.795	1.05
Std. Error					
K	0.001114	0.002846	0.005949	0.04249	0.08056
95% Confidence Intervals					
K	0.05045 to 0.05497	0.05119 to 0.06280	0.1217 to 0.1461	0.2992 to 0.4732	0.4909 to 0.8294
HalfLife	13.74 to 12.61	13.54 to 11.04	5.698 to 4.745	2.317 to 1.465	1.412 to 0.8357
Goodness of Fit					
Degrees of Freedom	37	31	27	28	18
R^2	0.9827	0.895	0.9532	0.2726	0.6511
Absolute Sum of Squares	526.2	2254	916.1	2204	1004
Sy.x	3.771	8.527	5.825	8.873	7.468

Table 13. Best Fit for Separate Exponential Decay Coefficients for Moth Survival for Each Exposure Concentration and Wind Speed of 1.8 m/s (4 mph) in a Small Leaf-Area Canopy

Statistic/Parameter	C(4)	50(4)	100(4)	200(4)
SPAN	100	100	100	100
K	0.03155	0.1825	0.1692	0.5299
PLATEAU	0	0	0	0
HalfLife	21.97	3.799	4.098	1.308
Std. Error				
K	0.003326	0.01182	0.01407	0.1132
95% Confidence Intervals				
K	0.02456 to 0.03854	0.1569 to 0.2080	0.1400 to 0.1983	0.1698 to 0.8901
HalfLife	17.99 to 28.22	3.333 to 4.417	3.495 to 4.952	0.7787 to 4.083
Goodness of Fit				
Degrees of Freedom	18	13	22	3
R^2	0.8208	0.956	0.8803	0.9528
Absolute Sum of Squares	3687	293.1	942	259.3
Sy.x	14.31	4.748	6.543	9.297

Table 14. Best Fit for Separate Exponential Decay Coefficients for Moth Survival for Each Exposure Concentration and Wind Speed of 3.6 m/s (8 mph) in a Small Leaf-Area Canopy

Statistic/Parameter	C(8)	50(8)	100(8)	200(8)	400(8)
SPAN	100	100	100	100	100
K	0.03912	0.3516	0.2407	0.1207	5.13
PLATEAU	0	0	0	0	0
HalfLife	17.72	1.972	2.88	5.741	0.1351
Std. Error					
K	0.001985	0.05472	0.0427	0.02033	0.0009103
95% Confidence Intervals					
K	0.03501 to 0.04323	0.2109 to 0.4922	0.1506 to 0.3308	0.07643 to 0.1650	5.118 to 5.141
HalfLife	16.04 to 19.80	1.408 to 3.287	2.096 to 4.603	4.200 to 9.068	0.1348 to 0.1354
Goodness of Fit					
Degrees of Freedom	23	5	17	12	1
R^2	0.9171	0.9024	0.6332	0.5317	1
Absolute Sum of Squares	1238	266.9	2344	3029	1.23E-05
Sy.x	7.335	7.306	11.74	15.89	0.003501

The regression of decay coefficients (survival rates) against exposure concentration for wind speeds of 0.9 and 1.8 m/s (2 and 4 mph) was significant ($p < 0.05$); the wind speed of 3.6 m/s (8 mph) did not have a monotonic response with concentration when the decay coefficient for the 400 mg/m^3 exposure dose (k = 5.13) was not included in the analysis (Figure 22 and Table 15). This value would have an extreme level of influence on the regression and was considered a statistical outlier. Because concentration-response was not monotonic in moths exposed to FO in 3.6 m/s (8 mph) winds, it is not included in the response algorithms described below.

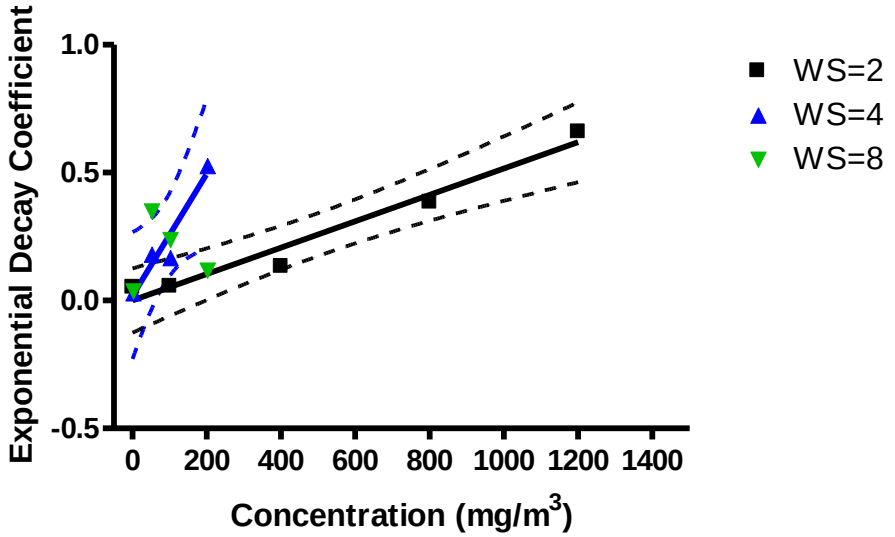


Figure 22. Best-Fit (Solid Line) and 95% Confidence Bands for the Exponential Decay Coefficient of Moth Survival for Each Wind Speed (WS) as a function of Exposure Concentration for a Small Canopy

Table 15. Best-Fit for Linear Regression of the Exponential Decay Coefficients of Moth Survival against Exposure Concentration with a Small Leaf-Area Canopy

Statistic/Parameter	WS=2	WS=4	WS=8
Slope	0.0005154 ± 0.00005900	0.002383 ± 0.0005028	-0.0000009371 ± 0.001134
Y-intercept	0.0002855 ± 0.03958	0.01979 ± 0.05760	0.1881 ± 0.1299
X-intercept	-0.554	-8.305	200700
1/slope	1940	419.7	-1067000
95% Confidence Intervals			
Slope	0.0003276 to 0.0007031	0.0002193 to 0.004546	-0.004880 to 0.004878
Goodness of Fit			
r^2	0.9622	0.9182	3.42E-07
Sy.x	0.059	0.07436	0.1677
Is slope significantly non-zero?			
F	76.3	22.46	6.83E-07
DFn, DFd	1.000, 3.000	1.000, 2.000	1.000, 2.000
P value	0.0032	0.0418	0.9994

4.5.3.2. Algorithms Describing Moth Survival and Mortality as a Function of Wind Speed in a Small Leaf-Area Canopy

Equations 15 through 17 describe the exponential decay models for percentage survival of control and FO-exposed early instar moth larvae as a function of wind speed as they mature from larvae through adult stages post-exposure:

$$\%\text{Survival Control} = 100*\exp[-(0.09209 - 0.0078364*\text{Wind Speed}) *(\text{Age in Days})] \quad (15)$$

$$\%\ \text{Survival FO-2mph} = 100*\exp\ [-((0.00029 + 0.00052\ (x))*(\text{Age in Days})] \quad (16)$$

$$\%\ \text{Survival FO-4mph} = 100*\exp\ [-((0.0198 + 0.00238\ (x))*(\text{Age in Days})] \quad (17)$$

where FO is fog oil exposures under either 2 mph or 4 mph winds and x is the exposure concentration. Percentage mortality during maturation is calculated by subtracting the "% Survival" value determined for a particular age in days from 100%.

4.5.3.3. Large Leaf-Area Canopies

Percentage survival of control moths in a large leaf-area canopy fit an exponential decay model with R^2 values ranging from 0.90 to 0.94 for winds speed of 0.9, 1.8, and 3.6 m/s (2, 4, and 8 mph) (Figure 23 and Table 16). The estimated values of K were significantly different ($p < 0.001$) because moth survival was slightly greater with a wind speed of 1.8 m/s (4 mph). However, the R^2 value for the model with a common decay coefficient was 0.89. This implies that a single model could be used to calculate an Abbott's correction; however, separate decay coefficients were used to calculate the expected control survival to reduce error.

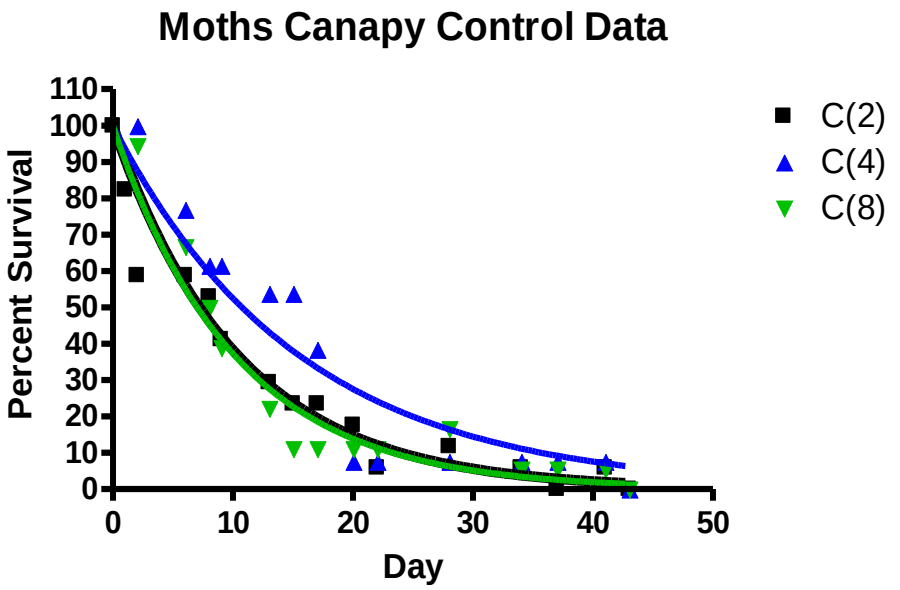


Figure 23. Observed and Expected Control Survival of Earlier Instar Moth Larvae Exposed to Wind Speeds of 0.9, 1.8, and 3.6 m/s (2, 4, and 8 mph) in a Large Leaf-Area Canopy for 2 hr. Each treatment is expressed as an exposure level with the wind speed in parentheses where C equals the control dose.

Table 16. Best Fit Parameters to the Exponential Decay Model for Control Moth Survival in Wind of 0.9, 1.8, and 3.6 m/s (2, 4, or 8 mph) in a Large Leaf-Area Canopy

Statistic/Parameter	C(2)	C(4)	C(8)
SPAN	100	100	100
K	0.09588	0.06441	0.09872
PLATEAU	0	0	0
HalfLife	7.229	10.76	7.021
Std. Error			
K	0.007167	0.006232	0.007372
95% Confidence Intervals			
K	0.08061 to 0.1112	0.05094 to 0.07787	0.08280 to 0.1146
HalfLife	8.599 to 6.236	13.61 to 8.902	8.372 to 6.046
Goodness of Fit			
Degrees of Freedom	15	13	13
R^2	0.9425	0.8952	0.9323

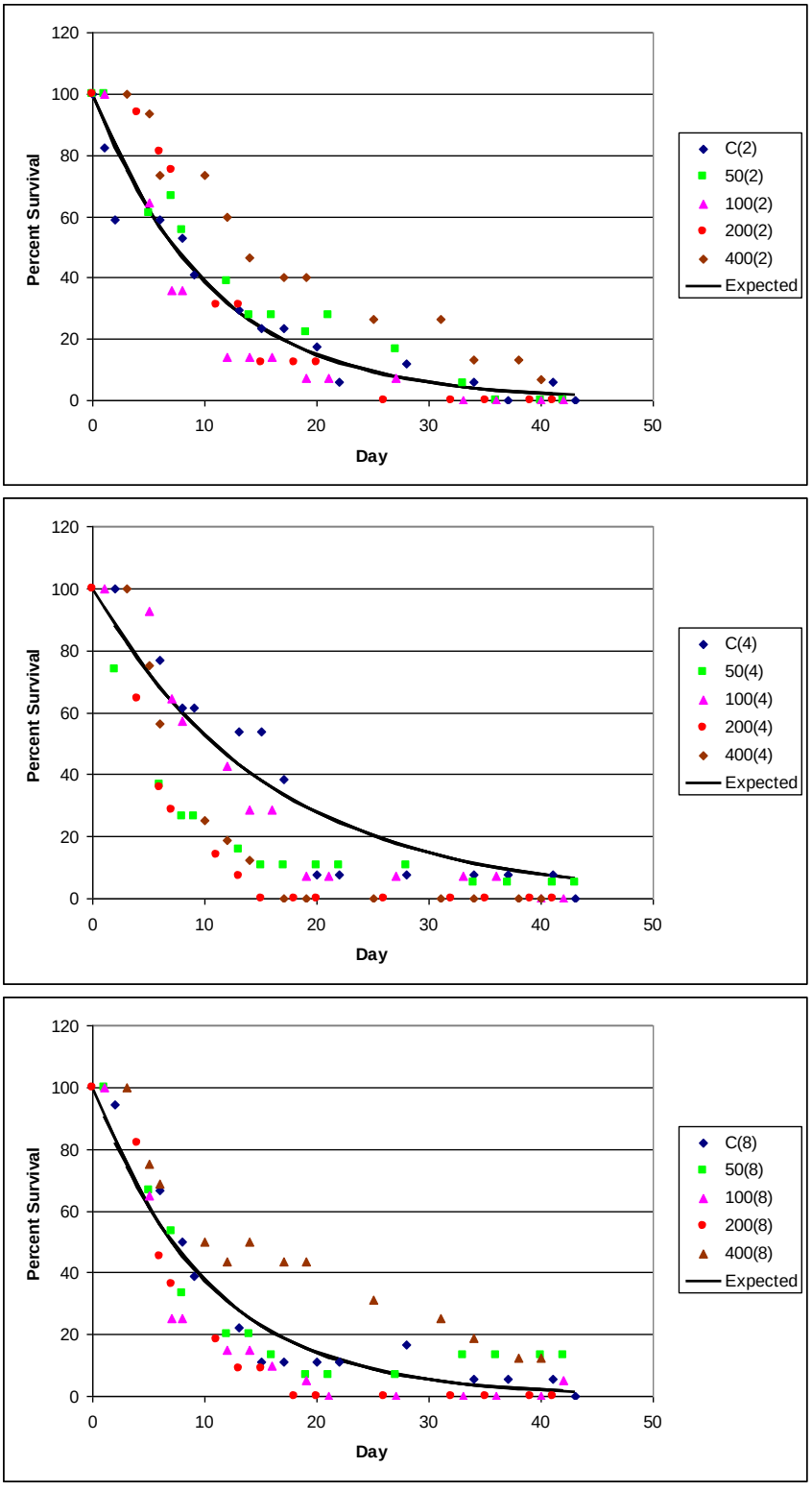


Figure 24. Observed and Expected, Based on the Exponential Decay Model, Survival of Early Instar Moth Larvae Exposed to Fog Oil in Winds of 0.9, 1.8, and 3.6 m/s (2, 4, and 8 mph) in a Large Leaf-Area Canopy for 2 hr. Each treatment is expressed as an exposure level with the wind speed in parentheses where C equals the control dose.

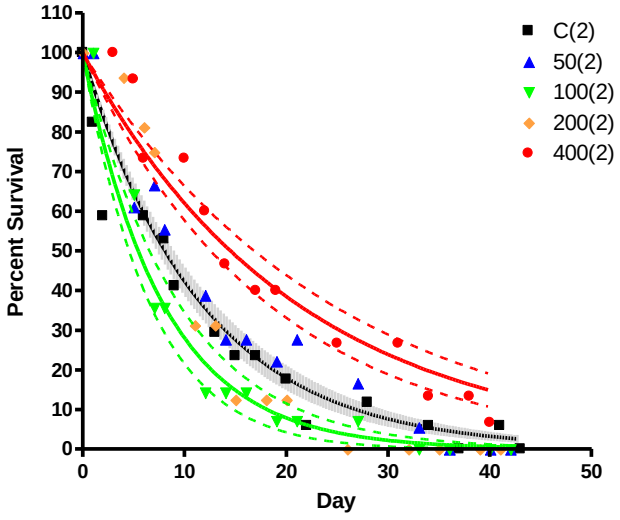
Observed survival of the FO-exposed early instar moth larvae did not consistently decrease with exposure concentration (Figure 24). For wind speeds of 0.9 and 3.6 m/s (2 and 8 mph), moths exposed to 400 mg/m^3 tended to exhibit greater survival than the controls. Abbott's corrected mortality was bounded by the control, thus for several exposure concentrations, mortality was no greater than the expected. Alternatively, the exponential decay model was fit separately to each exposure concentration and wind speed combination so that all concentrations could be modeled (Figure 25 and Table 17). For the wind speed of 0.9 m/s (2 mph), the decay coefficient (K) for the control and 50 and 200 mg/m^3 exposure concentrations was not significantly different ($p = 0.23$). The K-value for 100 was significantly lower and the value for 400 mg/m^3 was significantly higher ($p < 0.001$). For the wind speed of 1.8 m/s (4 mph), K-values were significantly different ($p < 0.001$) and tended to increase with exposure concentration but not significantly. For the wind speed of 3.6 m/s (8 mph), K-values were significantly different ($p < 0.001$) and were more similar in pattern to the results obtained at 0.9 m/s (2 mph).

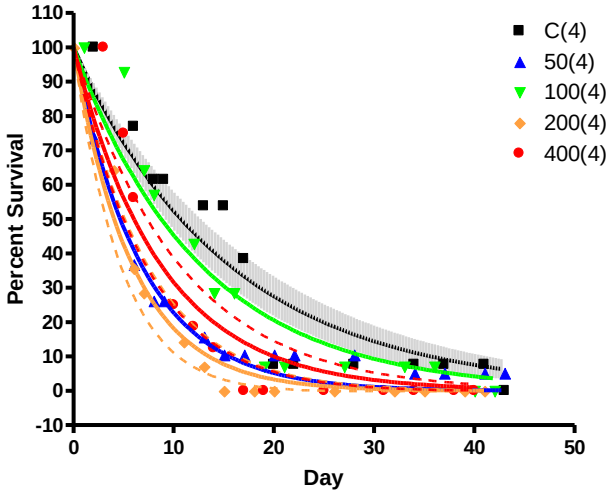
The regression of decay coefficients against wind speed and exposure concentration was not significant ($p = 0.57$) in large leaf-area canopies because of the lack of a monotonic response with concentration. Because the slopes were not significantly different from controls or each other ($p > 0.21$), the percentage survival as a function of wind speed of moths exposed during early larval instars could not be modeled for moths exposed in large leaf-area canopies.

4.5.3.4. Comparison between Canopy Sizes

Large leaf-area canopies tended to decrease the survival time of moths (Table 18 and Figure 26). The K-values were significantly different ($p < 0.001$) and tended to be large for the bigger canopy scenarios. The K-value for small canopy scenarios were nearly significantly different ($p = 0.06$), and the K-values for large canopy and wind speeds of 0.9 and 3.6 m/s (2 and 8 mph) were not significantly different ($p = 0.79$).

There is not enough data to evaluate the significance of a linear relationship between the decay coefficient and wind speed for each canopy size (Figure 27); however, the slope can be estimated for modeling purposes using a relative canopy size based on the leaf area such that the small canopy would be defined as 1 and the large canopy as 10 (Figure 28). For wind speeds of 1.8 m/s (4 mph), the relationship is given as $K = 0.0037c + 0.0279$ and for wind speeds of 3.6 m/s (8 mph) as $K = 0.0066c + 0.0325$ where c is the relative canopy size. Because of the small number of canopy sizes and wind speed combinations, an overall effect can be estimated from the average of the wind speed responses (Figure 29). Thus, the average canopy and wind speed effect is given as $K = 0.0051c + 0.0302$.





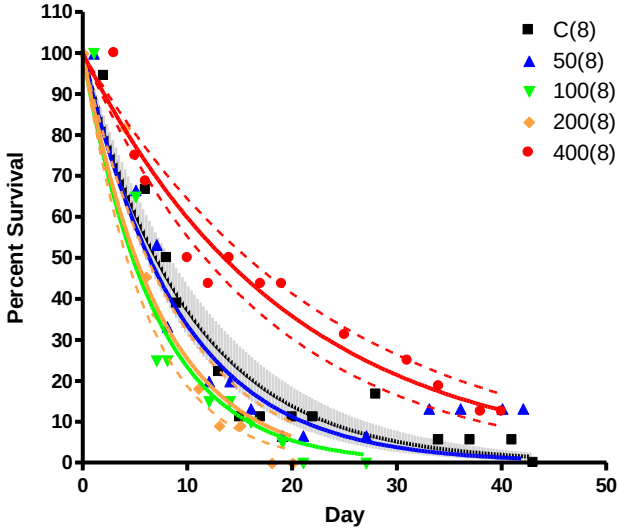


Figure 25. Exponential Decay of Moth Survival Post-Exposure to FO in a Large Leaf-Area Canopy for 2 hr. Each treatment is expressed as an exposure level with the wind speed in parentheses where C equals the control dose.

Table 17. Best Fit for Separate Exponential Decay Coefficients for Moth Survival for Each Exposure Concentration and Wind Speed Combination in a Large Leaf-Area Canopy

Statistic/Parameter	C(2)	50(2)	100(2)	200(2)	400(2)
K	0.09588	0.07744	0.1271	0.08559	0.04774
HalfLife	7.229	8.951	5.453	8.098	14.52
Std. Error					
K	0.007167	0.003892	0.007911	0.0106	0.003396
95% Confidence Intervals					
K	0.08061 to 0.1112	0.06909 to 0.08579	0.1100 to 0.1442	0.06269 to 0.1085	0.04034 to 0.05514
HalfLife	8.599 to 6.236	10.03 to 8.080	6.300 to 4.807	11.06 to 6.389	17.18 to 12.57
Goodness of Fit					
Degrees of Freedom	15	14	13	13	12
R^2	0.9425	0.9759	0.965	0.8952	0.9365
Absolute Sum of Squares	803.8	378.3	386	1988	719.2
Sy.x	7.32	5.198	5.449	12.37	7.742
	C(4)	**50(4)**	**100(4)**	**200(4)**	**400(4)**
K	0.06441	0.1478	0.07903	0.1701	0.1149
HalfLife	10.76	4.69	8.771	4.075	6.032
Std. Error					
K	0.006231	0.008629	0.007478	0.01054	0.01529
95% Confidence Intervals					
K	0.05095 to 0.07787	0.1292 to 0.1664	0.06288 to 0.09518	0.1473 to 0.1929	0.08161 to 0.1482
HalfLife	13.61 to 8.902	5.367 to 4.165	11.02 to 7.282	4.704 to 3.594	8.494 to 4.677
Goodness of Fit					
Degrees of Freedom	13	13	13	13	12
R^2	0.8952	0.9351	0.9194	0.975	0.8707
Absolute Sum of Squares	1447	293.9	1232	300.9	1754
Sy.x	10.55	4.755	9.736	4.811	12.09
	C(8)	**50(8)**	**100(8)**	**200(8)**	**400(8)**
K	0.09872	0.1093	0.1455	0.1372	0.05139
HalfLife	7.021	6.34	4.764	5.052	13.49
Std. Error					
K	0.007372	0.01009	0.01515	0.01613	0.003106
95% Confidence Intervals					
K	0.08280 to 0.1146	0.08752 to 0.1311	0.1112 to 0.1798	0.1000 to 0.1744	0.04462 to 0.05816
HalfLife	8.372 to 6.046	7.920 to 5.286	6.231 to 3.856	6.930 to 3.974	15.53 to 11.92
Goodness of Fit					
Degrees of Freedom	13	13	9	8	12
R^2	0.9323	0.9035	0.9288	0.9257	0.9351
Absolute Sum of Squares	675.6	955.8	661.7	786.1	514.8
Sy.x	7.209	8.575	8.575	9.912	6.55

Table 18. Best Fit Value for Separate Exponential Decay Coefficient for Control Moth Survival for Each Wind Speed and Canopy Size Combination

Canopy+Wind Speed	WS2-LC[a]	WS4-SC	WS4-LC	WS8-SC	WS8-LC
Statistic/Parameter					
K	0.09588	0.03155	0.06441	0.03913	0.09872
HalfLife	7.229	21.97	10.76	17.72	7.021
Std. Error					
K	0.007167	0.003326	0.006232	0.002027	0.007372
95% Confidence Intervals					
K	0.08061 to 0.1112	0.02456 to 0.03854	0.05094 to 0.07787	0.03492 to 0.04333	0.08280 to 0.1146
HalfLife	8.599 to 6.236	28.22 to 17.99	13.61 to 8.902	19.85 to 16.00	8.372 to 6.046
Goodness of Fit					
Degrees of Freedom	15	18	13	22	13
R^2	0.9425	0.8208	0.8952	0.8913	0.9323
Absolute Sum of Squares	803.8	3687	1447	1234	675.6
Sy.x	7.32	14.31	10.55	7.489	7.209
Total number of values	16	19	14	23	14

[a] WS = wind speed followed by the mph (2,4, or 8); LC= large leaf-area canopy, SC = small leaf-area canopy

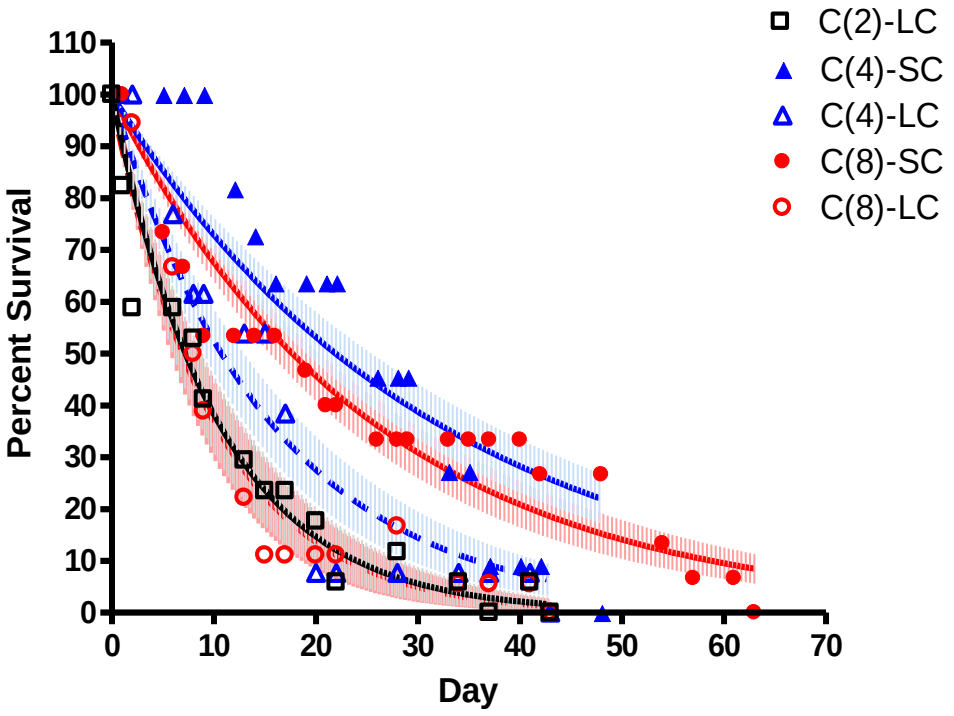


Figure 26. Comparison of Wind Speed and Canopy Size Using Moth Control Data. Each treatment is expressed as an exposure level with the wind speed in parentheses followed by a canopy size (large=LC and small=SC) where C equals the control dose.

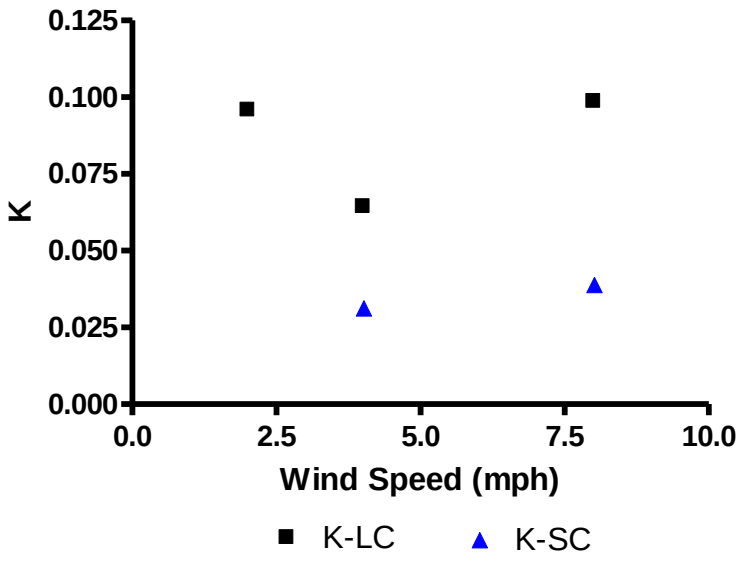


Figure 27. Best Fit Decay Coefficient for Each Wind Speed and Canopy Size Using Moth Control Data

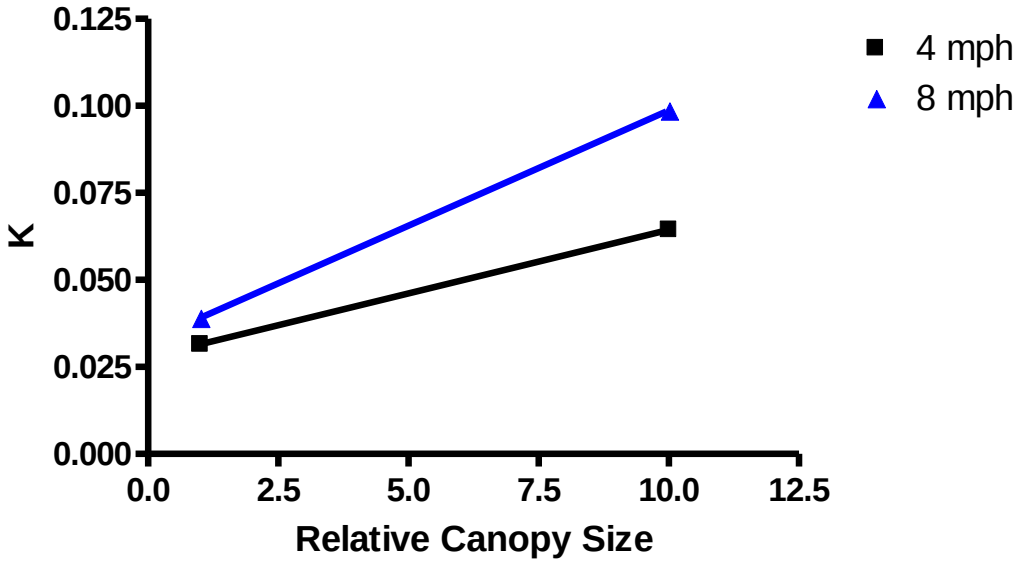


Figure 28. Exponential Decay Coefficient as a Function of Relative Canopy size Using the Moth Control Data

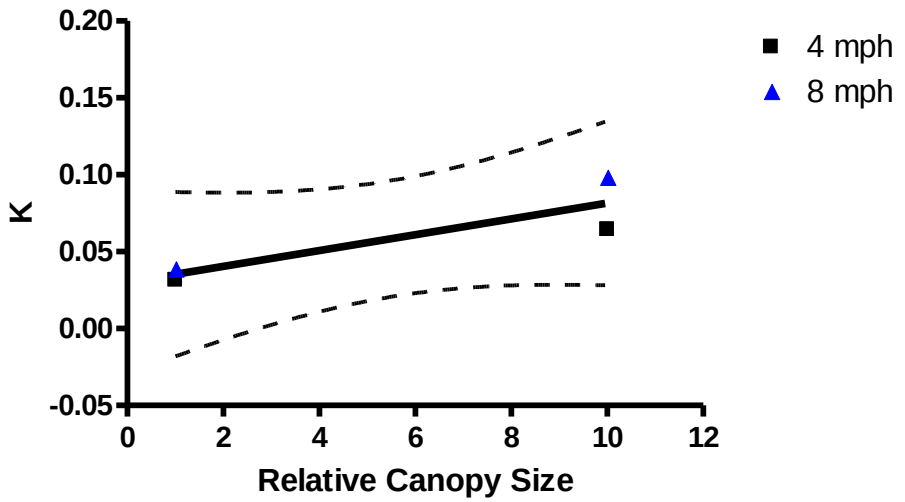


Figure 29. Exponential Decay Coefficient as a Function of Relative Canopy Size Averaged Over Wind Speed Using the Moth Control Data 95% CI

4.5.3.5. Algorithms Describing Overall Effect of Wind speed and Canopy Density on Survival and Mortality of a Geometrid Moth

Although the intention of the modeling was to combine the effects of wind speed and canopy size, the effects of wind speed and canopy density during exposure of early larval instars on survival through the adult were not clearly separable and the effects from these two environmental variables could not be combined. Therefore, the exponential decay coefficient was modeled as either a function of wind speed (Equation 18) or relative canopy size (Equation 19). The wind speed effect on survival was statistically significant, but was relatively minimal and is expressed as:

$$\%\text{Survival}_{\underline{ws}} = 100*\exp[-(0.09209 - 0.0078364*\text{Wind Speed}) *(\text{Age in Days})] \quad (18)$$

where $\%\text{Survival}_{ws}$ is the percentage survival as a function of wind speed of moth instars post-exposure to FO during early larval stages. A dense canopy, however, appears to alter survival time of moths more than wind speed. Percentage survival of moth instars post-exposure to FO during early larval stages as a function of relative canopy density (cd) is given as

$$\%\ \text{Survival}_{cd} = 100*\exp\ [-(K_{cd})*(\text{Age in Days})] \quad (19)$$

where K_{cd} is the effect of canopy averaged over wind speeds. K_{cd} is given as:

$$K_{cd} = 0.0051(\text{Relative Canopy Density}) +0.0302 \quad (20)$$

where Relative Canopy Density is estimated based on the number of times greater the larger leaf-area canopy is compared to the small area canopy. The small leaf-area canopy for that season, area, plant type, etc., is assigned a value of 1.

To express the above effects as percentage mortality, subtract the "%Survival" value calculated in equation 10 or 11 from 100%.

4.6. Palatability of Fog Oil Exposed Moth Larvae to Avian Predators

No difference in the number of searches, attacks on larvae, or larvae consumed by the birds were found in either the scarce (2 larvae per trial) or abundant (10 larvae per trial) palatability tests (Table 19). No aversion to consuming the larvae occurred during the four replicates per test day, nor over the 6 days of tests. Therefore, it appears that starlings did not reject the contaminated prey (larvae exposed to 800 mg/m^3 of FO) based on palatability. Exposed as well as control larvae were able to move to deep areas within the sod; however, the birds were able to find FO-exposed larvae with about the same proficiency as they were able to locate control larvae. It is not known if detectability of cryptic insects in their natural habitat would be unaffected by FO exposure or if discrimination between FO-exposed and control insects would be unaffected if predators were not competing for the food source.

Table 19. Descriptive Statistics of the Searches, Attacks, and Consumption of Uncontaminated and Fog Oil-Exposed Larvae by an Avian Predator during 6 Days of Palatability Trials (Four Replicate Trials per Day).

Variable	Larvae/ Site	N	Mean	Median	StDev	Min	Max	Q1	Q3	CV
Control										
C-Searches	2	64	5.766	5	4.356	0	21	3	7.75	76%
	10	16	3.125	2	3.384	0	12	1	4.75	108%
C-Attacks	2	64	3.781	3	2.831	0	13	2	4	75%
	10	16	11.75	11	3	4	18	11	13	26%
C-Consumption	2	64	1.9219	2	0.3239	0	2	2	2	17%
	10	16	9.313	10	1.815	3	10	10	10	19%
Dosed										
D-Search	2	64	6.156	5	4.798	0	21	3	7.75	78%
	10	16	2.563	2	2.421	0	7	0	4.75	94%
D-Attack	2	64	3.516	3	2.204	0	10	2	4	63%
	10	16	10.813	11	2.713	4	15	10	12	25%
D-Consumption	2	64	1.9063	2	0.3436	0	2	2	2	18%
	10	16	8.563	10	2.529	3	10	8	10	30%

4.6.1. Mosquitoes

4.6.1.1. Adult

One small test was conducted with adult mosquitoes. The mosquitoes were exposed to 200 mg/m^3 of aerosolized FO for 2 hr in a 0.9 m/s (2 mph) wind in the wind tunnel. All adults (male and female) died within 2 days of exposure, which is shorter than their typical lifespan (2 weeks or more). However, because we could not establish a regenerating mosquito colony over the course of the study (see Materials and Methods), too few adults were within the same age range to form an adequate control group to correct for wind and handling effects.

4.6.1.2. First Instar Larvae

First instar mosquito larvae were exposed to 25, 50, 100, 200, or 800 mg/m^3 of FO for 2 hr. Percentage mortality of control larvae exposed to the wind tunnel environment (without FO) during the 1st instar increased linearly over the post-exposure period. A regression was fitted to the data and the expected mortality used to correct the response of FO-exposed larvae. Regression analysis of the corrected larval mortality over time up to pupation was not significant for exposure concentrations between 25 and 200 mg/m^3 (p=0.786). Exposure of 1st instar larvae holding chambers in 800 mg/m^3 aerosols of FO resulted in mortality of up to 50% at late larval stages (Figure 30). A 2-hr exposure of 1st instar mosquito larvae in 800 mg/m^3 FO also resulted in delayed maturation of the larvae with larvae exposed to FO taking up to 69% longer to pupate than controls. Time to peak adult emergence was nearly twice that of controls.

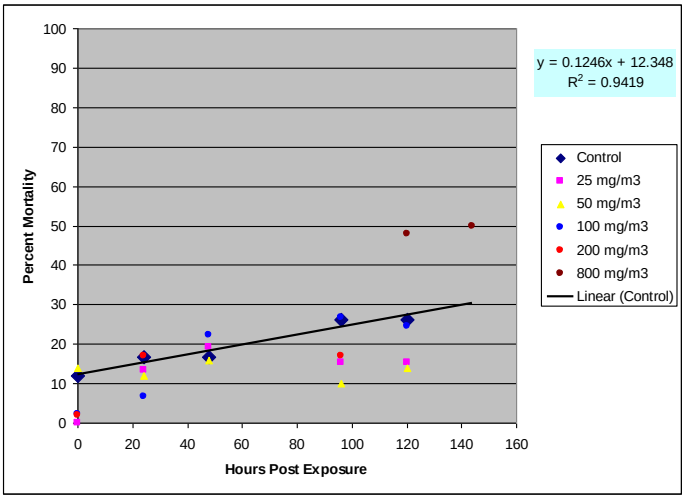


Figure 30. Abbott's Corrected Mortality Over Time Post-Exposure of First Instar Mosquito Larvae Exposed to Fog Oil Aerosols in 0.9 m/s (2 mph) winds for 2 hr

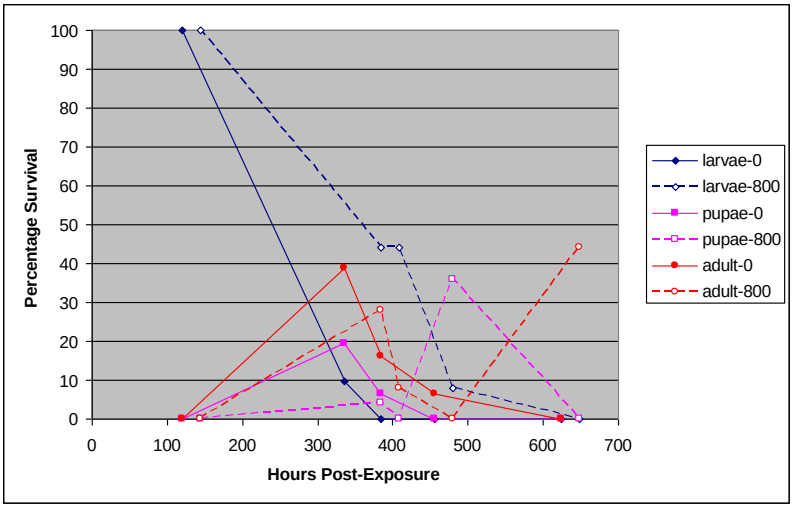


Figure 31. Percentage Survival of the Larval, Pupal, and Adult Life Stages of Mosquitoes Exposed to Fog Oil Aerosols in a 0.9 m/s (2 mph) Wind for 2 hr During the First Larval Instar

4.6.1.3. Third Instar Larvae

Because significant impact on survival and maturation of mosquitoes occurred when 1st instar larvae were exposed to 800 mg/m^3, the high concentration for the 3rd larval instar tests was reduced to 400 mg/m^3. For control mosquitoes placed in the wind tunnel during the 3rd instar, larval survival significantly declined over time ($p < 0.001$; Figure 32). The expected survival was used to calculate the Abbott's corrected mortality of exposed mosquito larvae. Mortalities in exposure concentrations of 25 to 200 mg/m^3 were all less than 5% except for the last observed time period. These concentrations were not modeled further. The 400 mg/m^3 exposure, however, was fit successfully with a two parameter logistic model ($R^2 = 0.99$, Figure 33). No delay in maturation was observed in mosquitoes exposed during the 3rd larval instar; larval maturation period and time to peak pupation and adult emergence were identical to those of controls.

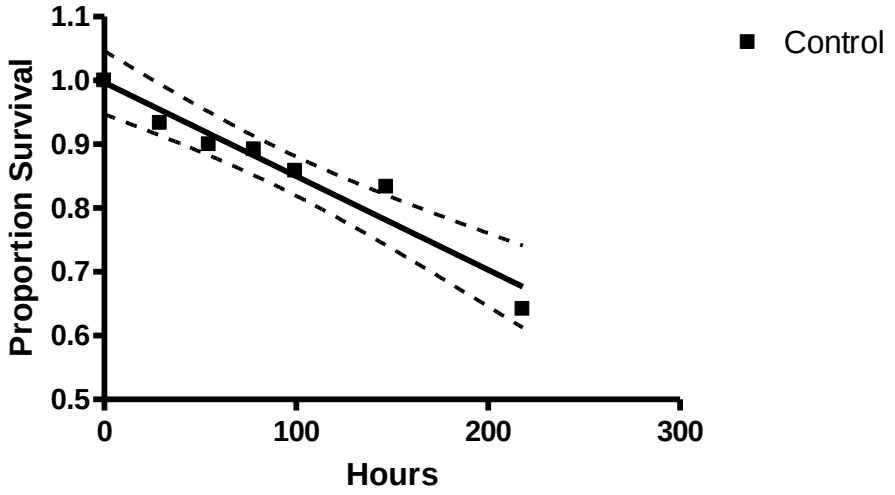


Figure 32. Observed and Expected Control Mosquito Larvae Survival Over Time

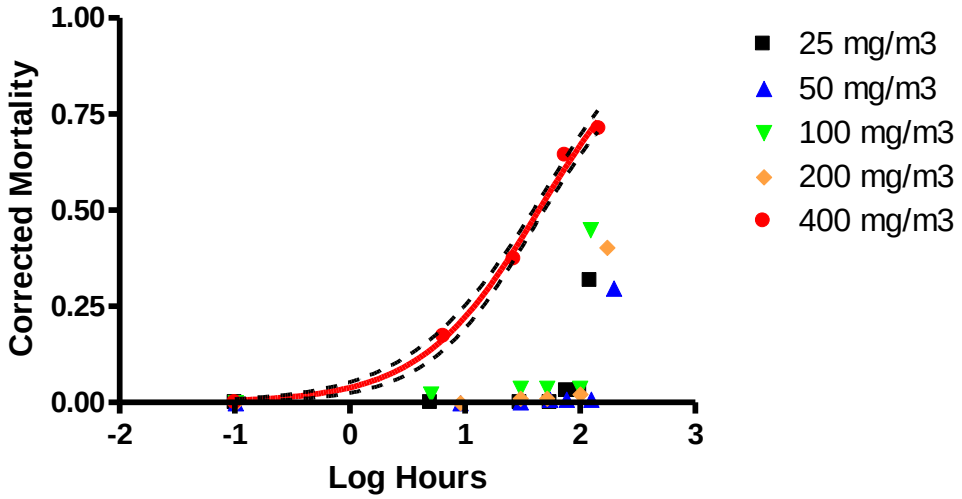


Figure 33. Logistic Regression of Corrected Mosquito Larvae Mortality for Each Fog Oil Exposure Concentration (mg/m^3)

4.6.2. Wood Roaches

4.6.2.1. Adults

Adult wood roaches were exposed to an average of 530 ± 140 mg/m^3 FO for 4 hr and observed for 77 days post-exposure. The wind speed during the test was 0.9 m/s (2 mph). Temperature 26ºC (78.8ºF) and relative humidity (46%) within the wind tunnel were similar to those of their rearing cages at the greenhouse (27ºC [80.6ºF] and 40%RH). No significant differences were observed in the proportion survival (Z-test of proportions, p = 0.35), time to production of egg cases, or number of egg cases produced. Viability of produced eggs could not be determined because of the low survival of control eggs.

Table 20. Survival and Egg Production of Control and FO-Exposed Wood Roaches Over 77 Days Post Exposure.

Parameter	Exposed n = 18	Control n = 7
Survival	88.9%	71.4%
No. Egg Cases/F	4.33	4
Days/Egg Case/F	18	19.5

4.6.2.2. Small Nymphs

The 22-day survival of wood roach small nymphs exposed to 0, 50, 100, 200, 400, or 800 mg/m^3 FO was used to evaluate the impact on the soft body stage of the wood roach. Three replicate groups of 10 nymphs per replicate per concentration were exposed to control or FO contaminated atmospheres for 2 hr. Abbott's corrected mortality was plotted and an LC20 was estimated when possible by linear interpolation. As seen in Table 21, the corrected mortality did not reach 5%; the LC_{20} was greater than 800 mg/m^3. No further tests were conducted with wood roaches.

Table 21. Observed Wood Roach Larvae 22-Day Survival and Corrected Mortality When Exposed to FO with a Wind Speed of 0.9 m/s (2 mph)

Concentration (mg/m^3)	Observed 22-Day Survival	Corrected Mortality[1]
0	0.97	
50	1.00	-0.03
100	0.96	0.01
200	0.96	0.01
400	1.00	-0.03
800	1.00	-0.03

[1] Negative values can be truncated to zero

4.6.3. Ants

Ants were exposed to 0, 50, 100, 200, or 400 mg/m^3 of FO in 0.9, 1.8, and 3.6 m/s (2, 4, and 8 mph) winds. Percentage survival fit an exponential decay model with R^2 values ranging from 0.78 to 0.97 for control ants in winds of 0, 0.9, 1.8, and 3.6 m/s (0, 2, 4, and 8 mph) (Table 22 and Figure 34). The estimated values of K were significantly different ($p < 0.001$) mainly because ant survival was greater in winds of 0.9 m/s (2 mph). The decay coefficient from the

control data wind speeds of 0, 1.8, and 3.6 m/s (0, 4, and 8 mph) were still significantly different ($p < 0.001$), however, the R^2 value for the model with a common decay coefficient was 0.92. This implies that a single model could be used to calculate an Abbott's correction; however, separate decay coefficients were used to calculate the expected control survival to reduce error. Further, ignoring the results for control ants in 2-mph winds produced a significant regression of estimated decay coefficients against wind speed ($p = 0.05$; Figure 35).

Table 22. Best Fit Parameters for the One-Phase Exponential Decay Model for Control Ant Survival in Winds of 0, 0.9, 1.8, and 3.6 m/s (0, 2, 4, and 8 mph)

Statistic/Parameter	C(0)	C(2)	C(4)	C(8)
K	0.04898	0.01433	0.06536	0.08694
HalfLife	14.15	48.36	10.6	7.973
Std. Error				
K	0.001719	0.001551	0.006507	0.00861
95% Confidence Intervals				
K	0.04540 to 0.05255	0.01107 to 0.01759	0.05157 to 0.07916	0.06859 to 0.1053
HalfLife	13.19 to 15.27	39.41 to 62.59	8.757 to 13.44	6.583 to 10.11
Goodness of Fit				
Degrees of Freedom	21	18	16	15
R^2	0.979	0.7834	0.9366	0.9295
Absolute Sum of Squares	399.8	1856	1621	1295
Sy.x	4.363	10.16	10.07	9.293
Total number of values	22	19	17	16

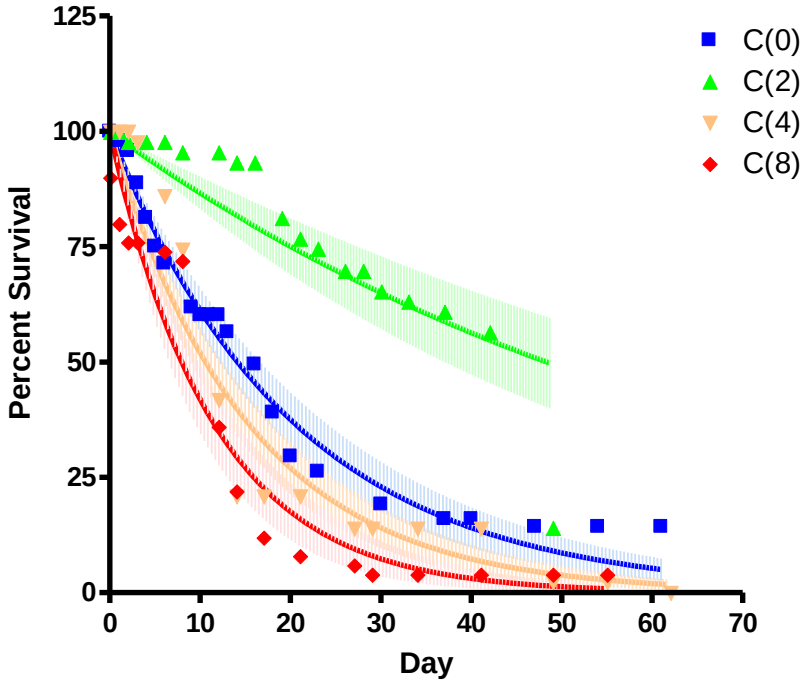


Figure 34. One-Phase Exponential Decay Model for Control Ant Survival in 0, 0.9, 1.8, and 3.6 m/s (0, 2, 4, and 8 mph)

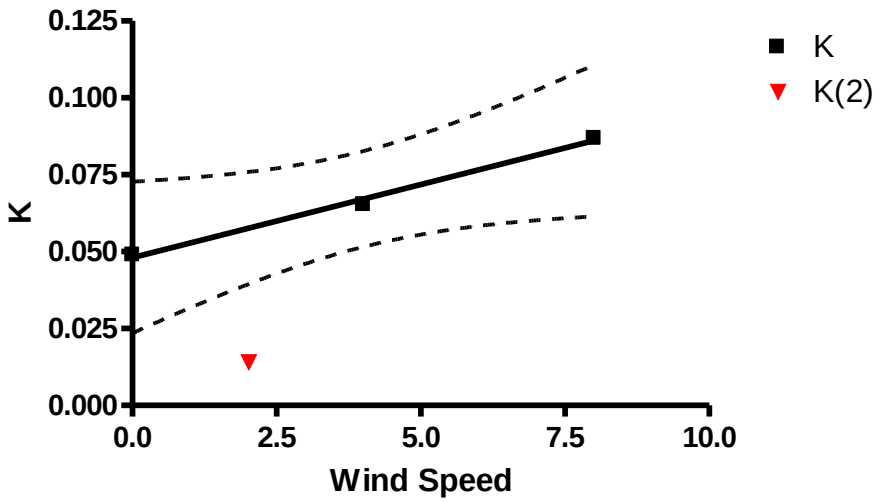


Figure 35. Control Decay Coefficients as a Function of Wind Speed (mph). The result for a wind speed of 0.9 m/s (2 mph), K(2), was not ssed in the regression.

For many of the exposure concentrations with wind speed of 0 m/s (0 mph), the Abbott's corrected mortality was no greater than expected and could not be modeled further. Thus, an alternative approach of fitting an exponential decay model to all exposure concentrations was conducted.

The exponential decay model fit all exposure concentrations with a wind speed of 0 m/s (0 mph) in the tunnel except for the 400 mg/m^3 exposure (Table 23 and Figure 36). Of those exposure concentrations that did fit the model, the R^2 values ranged from 0.87 to 0.98. The decay coefficients for each of the exposure concentrations were significantly different ($p < 0.001$). The resulting decay coefficients, however, did not have a monotonic relationship with the exposure concentration. Both the 50 and 100 mg/m^3 concentrations showed greater survival times than the control exposure.

The exponential decay model fit all exposure concentrations with a wind speed of 2 mph (Table 24 and Figure 37) with R^2 values ranged from 0.70 to 0.89. The decay coefficients for each of the exposure concentrations were significantly different ($p < 0.001$) mainly because of the decreased survival in the exposures greater than or equal to 200 mg/m^3. The decay coefficients for the 200, 400, and 800 mg/m^3 exposure concentrations were not significantly different ($p = 0.56$). The resulting decay coefficients tended to increase with the exposure concentration until the 200 mg/m^3 concentration was reached.

Table 23. Best Fit Parameters for the One-Phase Exponential Decay Model for Ant Survival Using a Wind Speeds of 0 m/s (0 mph)

Statistic/Parameter	C(0)	50(0)	100(0)	400(0)	800(0)
K	0.04898	0.02803	0.03369	Does not Converge	0.08419
HalfLife	14.15	24.73	20.58		8.233
Std. Error					
K	0.001719	0.001868	0.001201		0.006764
95% Confidence Intervals					
K	0.04540 to 0.05255	0.02413 to 0.03193	0.03117 to 0.03620		0.06998 to 0.09840
HalfLife	15.27 to 13.19	28.72 to 21.71	22.23 to 19.15		9.906 to 7.044
Goodness of Fit					
Degrees of Freedom	21	20	19	19	18
R^2	0.979	0.8681	0.9797		0.8827
Absolute Sum of Squares	399.8	1215	329.5		1431
Sy.x	4.363	7.795	4.164		8.917
Total number of values	22	21	20	20	19

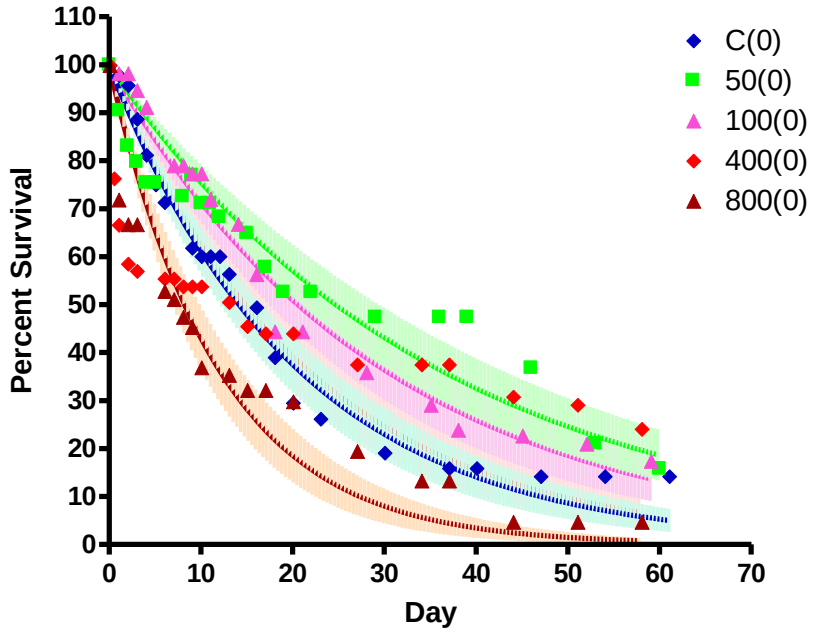


Figure 36. Observed and Fitted Exponential Decay Survival of Fog-Oil-Exposed Ants with a Wind Speed of 0 m/s (0 mph) in the Wind Tunnel. Note that the 400-mg/m^3 exposure did not converge.

Table 24. Best Fit Parameters for the One-Phase Exponential Decay Model for Ant Survival Using a Wind Speeds of 0.9 m/s (2 mph)

Statistic/Parameter	C(2)	100(2)	200(2)	400(2)	800(2)
K	0.01433	0.01979	0.07085	0.06319	0.05595
HalfLife	48.36	35.03	9.784	10.97	12.39
Std. Error					
K	0.001551	0.001514	0.007378	0.01299	0.01323
95% Confidence Intervals					
K	0.01107 to 0.01759	0.01659 to 0.02298	0.05520 to 0.08649	0.03382 to 0.09257	0.02603 to 0.08588
HalfLife	62.59 to 39.41	41.77 to 30.16	12.56 to 8.014	20.50 to 7.488	26.63 to 8.071
Goodness of Fit					
Degrees of Freedom	18	17	16	9	9
R^2	0.7834	0.8736	0.8875	0.7741	0.6994
Absolute Sum of Squares	1856	1197	2224	3026	3839
Sy.x	10.16	8.393	11.79	18.34	20.65
Number of values	19	18	17	10	10

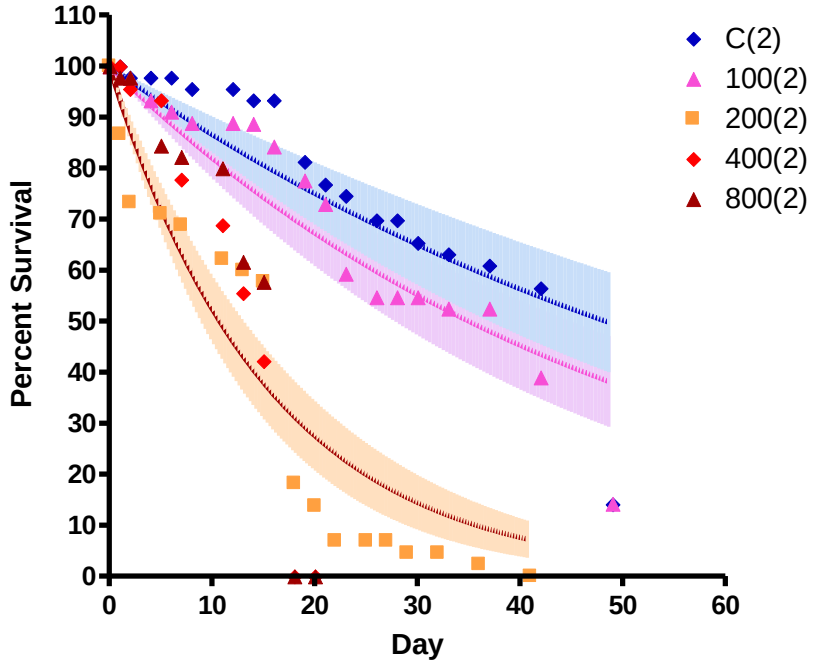


Figure 37. Observed and Fitted Exponential Decay Survival of Fog Oil Exposed Ants with a Wind Speed of 0.9 m/s (2 mph)

The exponential decay model fit all exposure concentrations with a wind speed of 1.8 m/s (4 mph) (Table 25 and Figure 38) with R^2 values ranged from 0.89 to 0.99. The decay coefficients for each of the exposure concentrations were significantly different ($p < 0.001$) mainly because of the greater survival in the control and lower survival in the exposures greater than or equal to 200 mg/m^3. The decay coefficients for the 50 and 100 mg/m^3 exposure

concentrations were not significantly different (p = 0.94), and the 200 and 400 mg/m^3 exposure concentrations were not significantly different (p = 0.07). The resulting decay coefficients tended to increase with the exposure concentration.

Table 25. Best Fit Parameters for the One-Phase Exponential Decay Model for Ant Survival Using a Wind Speeds of 1.8 m/s (4 mph)

Statistic/Parameter	C(4)	50(4)	100(4)	200(4)	400(4)
K	0.06536	0.124	0.1251	0.158	0.2189
HalfLife	10.6	5.591	5.54	4.388	3.167
Std. Error					
K	0.006508	0.004959	0.01398	0.01258	0.03084
95% Confidence Intervals					
K	0.05157 to 0.07916	0.1132 to 0.1348	0.09532 to 0.1549	0.1299 to 0.1860	0.1523 to 0.2855
HalfLife	13.44 to 8.756	6.125 to 5.143	7.272 to 4.475	5.334 to 3.726	4.553 to 2.428
Goodness of Fit					
Degrees of Freedom	16	12	15	10	13
R^2	0.9366	0.9911	0.9163	0.9764	0.8869
Absolute Sum of Squares	1621	128.7	1207	337.1	1046
Sy.x	10.07	3.274	8.97	5.806	8.968
Number of values	17	13	16	11	14

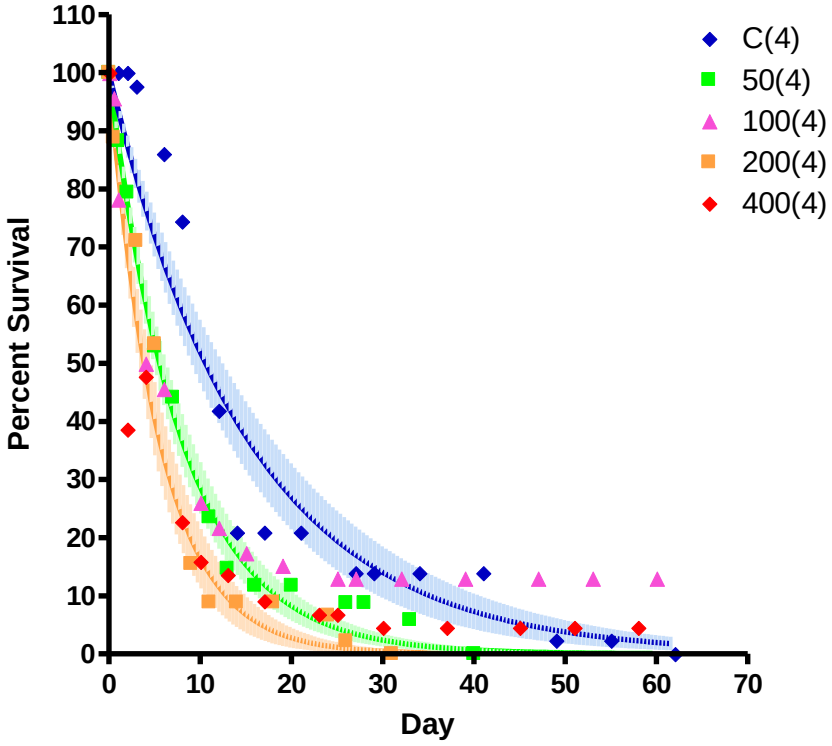


Figure 38. Observed and Fitted Exponential Decay Survival of Fog Oil Exposed Ants with a Wind Speed of 1.8 m/s (4 mph)

The exponential decay model fit all exposure concentrations with a wind speed of 8 mph (Table 26 and Figure 39) with R^2 values ranged from 0.88 to 0.99. The decay coefficients for each of the exposure concentrations were significantly different ($p < 0.001$) mainly because of the very low survival in the 400 mg/m^3 exposure concentration (all ants were dead by day 8) and the greater survival in the control. The decay coefficients for the 50, 100 and 200 mg/m^3 exposure concentrations were not significantly different ($p = 0.11$). The resulting decay coefficients tended to increase with the exposure concentration.

Table 26. Best Fit Parameters for the One-Phase Exponential Decay Model for Ant Survival Using a Wind Speeds of 3.6 m/s (8 mph)

Statistic/Parameter	C(8)	50(8)	100(8)	200(8)	400(8)
K	0.08694	0.1207	0.112	0.1671	1.289
HalfLife	7.973	5.74	6.189	4.148	0.5378
Std. Error					
K	0.008612	0.02195	0.0129	0.01593	0.231
95% Confidence Intervals					
K	0.06858 to 0.1053	0.06704 to 0.1745	0.08452 to 0.1395	0.1304 to 0.2038	0.5540 to 2.024
HalfLife	10.11 to 6.583	10.34 to 3.973	8.201 to 4.969	5.317 to 3.400	1.251 to 0.3425
Goodness of Fit					
Degrees of Freedom	15	6	15	8	3
R^2	0.9295	0.8837	0.9037	0.9593	0.9945
Absolute Sum of Squares	1295	1028	1391	367.2	37.95
Sy.x	9.293	13.09	9.628	6.775	3.557
Number of values	16	7	16	9	4

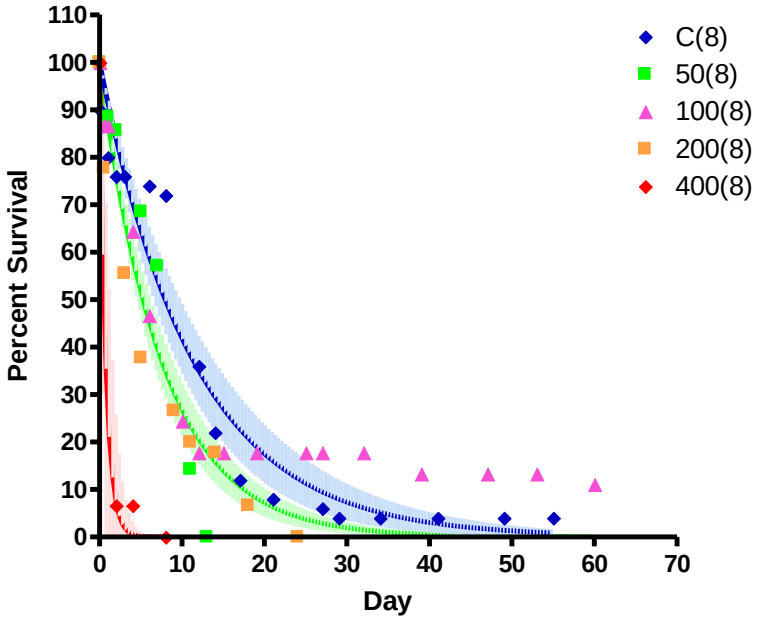


Figure 39. Observed and Fitted Exponential Decay Survival of Fog Oil Exposed Ants with a Wind Speed of 3.6 m/s (8 mph)

The regression of the decay coefficients against exposure concentration was not significant ($p > 0.09$) for wind speeds of 0 and 0.9 m/s (0 and 2 mph) (Table 27). The slopes and intercepts for wind speeds of 0 and 2 mph were not significantly different ($p > 0.59$; Figure 40). The resulting model for this set of wind speeds was given as:

$$K_{(0,2)} = 0.032 + 5.42e\text{-}5(\text{Exposure Concentration}).$$

The regression of the decay coefficients for wind speeds of 1.8 and 3.6 m/s (4 and 8 mph) was significant ($p < 0.03$). However, the K-value resulting from the 400 mg/m^3 exposure ($K = 1.289$) was nearly ten times greater than all other decay coefficients and had a large influence on the regression. When it was removed from the regression analysis, the regression was nearly significant ($p = 0.06$). The regression results for 4 and 8 mph were not significantly different ($p > 0.64$) with this K-value removed from the analysis. The resulting model for this set of wind speeds was given as:

$$K_{(4,8)} = 0.089 + 3.47e\text{-}4\ (\text{Exposure Concentration}).$$

Table 27. Linear Regression of the Fitted Exponential Decay Coefficients of Ant Survival against Exposure Concentration of Fog Oil (mg/m^3)

Statistic/Parameter	K(0)	K(2)	K(4)	K(8)
Slope	0.00006052 ± 0.00002021	0.00004738 ± 0.00003870	0.0003417 ± 0.00005508	0.002999 ± 0.0008044
Y-intercept	0.03434 ± 0.008163	0.03061 ± 0.01596	0.08702 ± 0.01136	-0.09469 ± 0.1658
X-intercept	-567.5	-646	-254.7	31.58
1/slope	16520	21110	2927	333.5
95% Confidence Intervals				
Slope	-0.00002645 to 0.0001475	-0.00007576 to 0.0001705	0.0001664 to 0.0005169	0.0004395 to 0.005558
Goodness of Fit				
r^2	0.8176	0.3332	0.9277	0.8225
Sy.x	0.01321	0.02448	0.01742	0.2544
Is slope significantly non-zero?				
F	8.966	1.499	38.47	13.9
DFn, DFd	1.000, 2.000	1.000, 3.000	1.000, 3.000	1.000, 3.000
P value	0.0958	0.3082	0.0084	0.0336
Deviation from zero?	Not Significant	Not Significant	Significant	Significant
Number of values	4	5	5	5

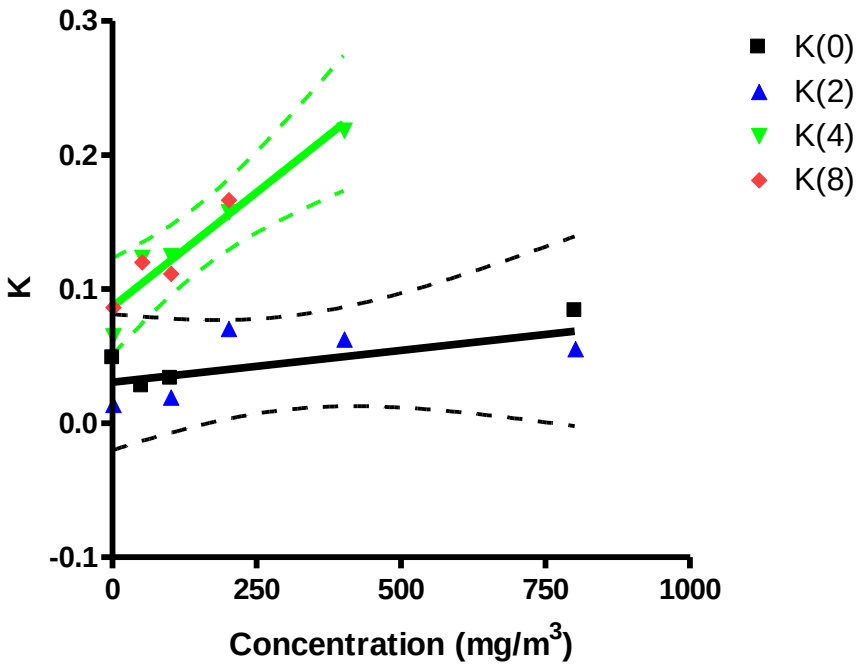


Figure 40. Exponential Decay Coefficients for Ant Survival as a Function of Exposure Concentration

4.6.3.1. Algorithms of Ant Survival and Mortality as a Function of Wind Speed and Exposure Concentration

Survival over time of adult ants exposed to FO for 2 hr in winds of 0 and 0.9 m/s (0 or 2 mph) is described by:

$$\% \text{ Survival} = 100\ (e^{-kx})$$

where k = 0.032 + 5.42e-5(Exposure Concentration) for wind speeds of 0 and 0.9 m/s (0 and 2 mph) and k = 0.089 + 3.47e-4 (Exposure Concentration) for 4 and 8 mph winds.

Percentage mortality is calculated as 100 - % Survival.

4.6.4. Beetles (Tenebrio molitar)

4.6.4.1. Larval Stages

No significant effects of FO exposure on beetle larvae were observed at field relevant and greater exposure concentrations. The successful maturation through the last larval instar of larvae exposed to FO during the 1st instar is shown Figure 41. The control survival was only collected through day 7 due to a fungal infection. The corrected mortality beyond this time is based on a simple linear assumption (p = 0.047; Figure 42). A linear model is suggested by the linear survival over time relationships observed for the 2nd through 5th larval instars (Figure 43); however, it is not clear from the limited control observations that a linear model is appropriate

for the remainder of the test period in this first instar. If the linear model for control survival is assumed, FO appears to affect the survival of the beetle larvae over time, but the response to FO concentration is not monotonic (Figure 43 and Figure 44) and a regression of the individual estimates of EC50 (survival) against concentration was not significant (p = 0.37).

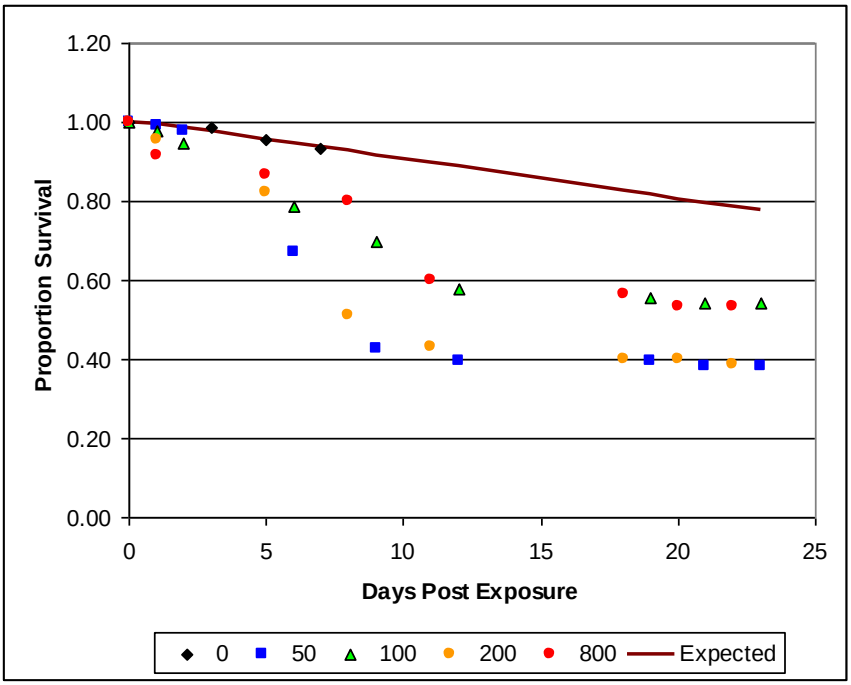


Figure 41. Observed and Expected Survival of Beetle Larvae Exposed to Fog Oil During Their 1st Instar in a 0.9 m/s (2 mph) Wind for 2 hr

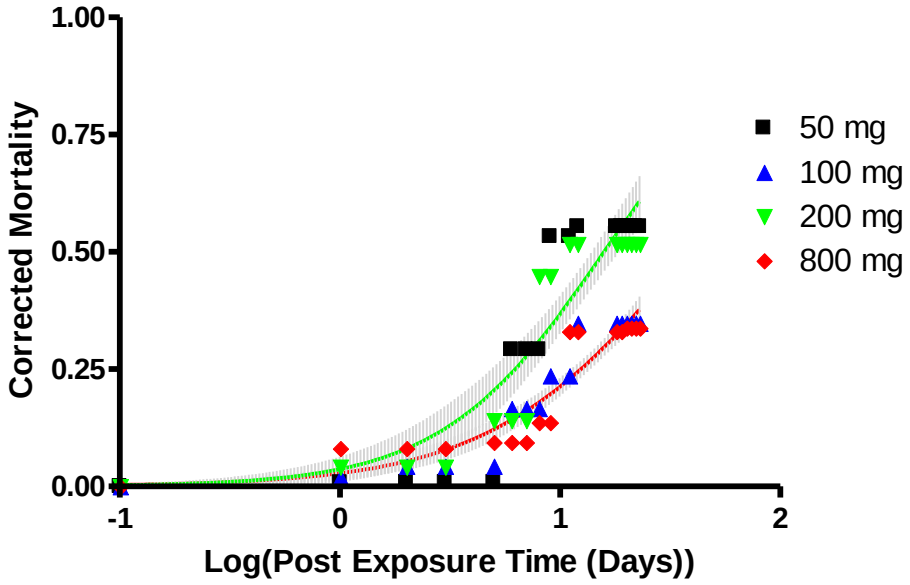


Figure 42. Corrected Mortality of Beetle Larvae (1st Instar) Modeled as a Logisitic Over Time Post-Exposure to Fog Oil in a 0.9 m/s (2 mph) Wind for 2 hr

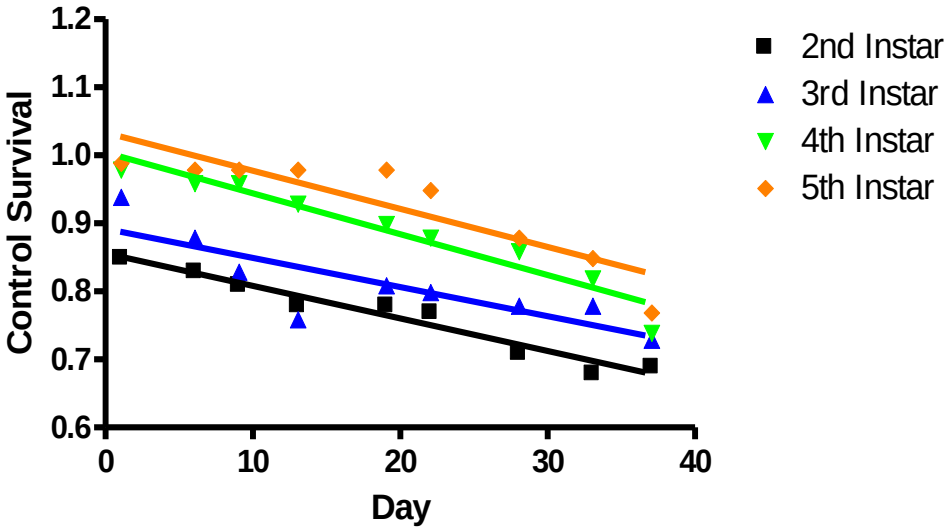


Figure 43. Control Beetle Larvae Survival in 0.9 m/s (2 mph) Wind as a Function of Time

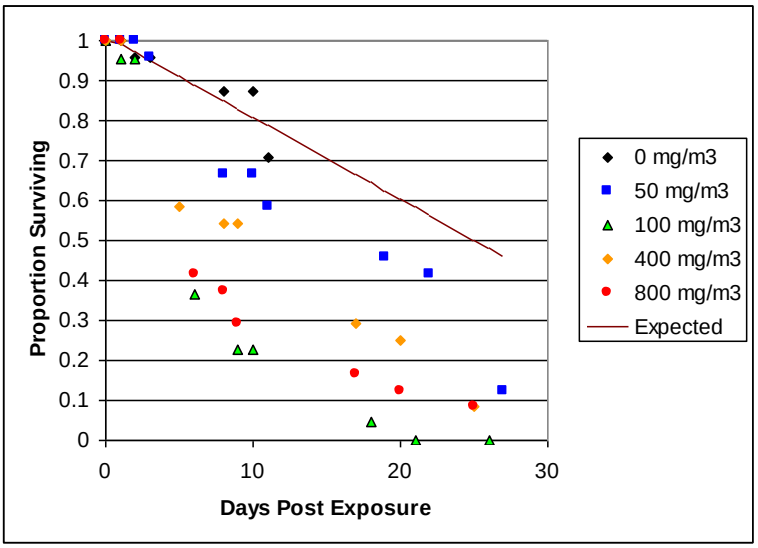


Figure 44. Observed and Expected Survival of Adult Beetles Post- Exposure to FO in No Wind

Control survival for all older larvae (2nd through ~5th instars) decreased significantly through time ($p < 0.01$) with slopes that were not significantly different ($p = 0.48$; Figure 43). Corrected mortalities for older larvae, however, did not reach values greater than 20% for all exposure concentrations (Figure 44). Thus, they were not modeled further.

Survival of control adult beetles also decreased significantly through time ($p = 0.005$; Figure 44) but survival data was not collected beyond day 11 due to a mold infection in the control

population. Corrected mortality was fit to a two parameter logistic model with R^2 values of 0.78 for the 50 mg/m^3 concentration and greater than 0.93 for all other exposure concentrations (Figure 45). The parameter values were significantly different ($p < 0.001$) but were not a monotonic function of concentration ($p = 0.47$; Figure 46).

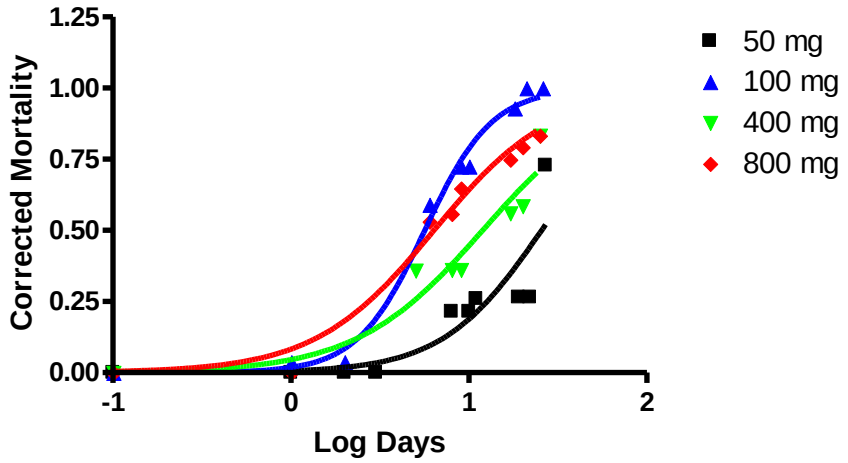


Figure 45. Corrected Mortality of Adult Beetle Survival Post-Exposure to Fog Oil in No Wind

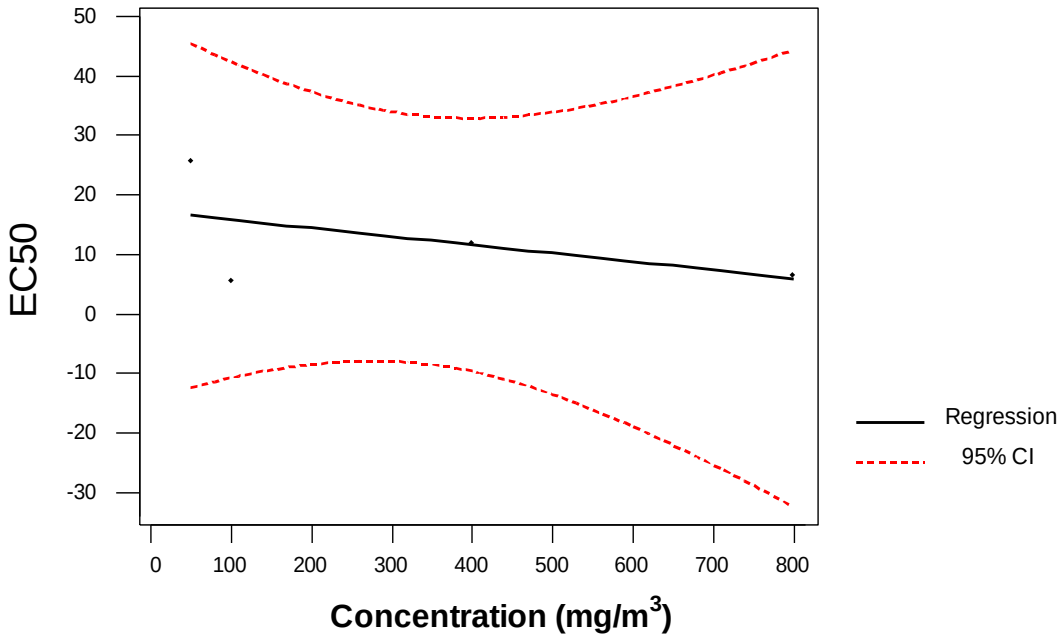


Figure 46. Regression of EC50 (Survival) Values Resulting from Adult Beetle Survival Post-Exposure to Fog Oil in No Wind

4.7. Task 7: Technology Transfer

4.7.1. Publications

The results of the study are published in this final project report that describes in detail the materials and methods, the exposure conditions and supporting data, and the data analysis methods and results. This information will also be summarized in journal articles submitted to appropriate journals for publication. During the processes of colony development, considerable information was obtained on the life history of the Geometrid moth *Digrammia curvata*. Because little has been published on the life history of this moth, a journal article will be prepared describing the new information and submitted to an entomological journal for publication.

The publications anticipated to be generated by this project (in addition to this final project report) are the following journal articles:

- Journal article: "Impacts of Fog Oil Smoke on Insect Fauna Used as Food Sources by Threatened and Endangered Species of Birds and Bats"

- Journal article: "A Method for Predicting Insect Loss Due to Fog Oil Generation at Military Training Installations"

- Strenge, DL, CJ Driver, RS Herrington, and RS Zack. "Notes on the Life History of *Macaria curvata* (*Lepidoptera: Geometridae*) in Southcentral Washington State," *The Pan-Pacific Entomologist* 82(1):91-96 (2006). Note: the name of the genus for this moth was changed after publication of the journal article.

4.7.2. Applications

One product of the study is a set of response functions describing mortality and food availability of insect prey of TES in terms of fog oil air concentration, wind speed during generations, and canopy structure. Such response functions can be coupled to transport models to estimate the fog oil impact on a population of insects following release and downwind transport during field exercises. In such a modeling effort, a transport model is used to evaluate the concentration of FO as a function of distance and direction from the release point. The response functions are coupled with the estimated air concentration and deposition rates to determine an integrated impact over the area affected by the plume. The downwind transport is modeled until concentrations are reduced to levels of no concern (as determined by the response function). Such an analysis could result in an area-weighted measure of impact. The DUSTRAN (dust transport) model is an example of a computational tool that could be adapted to couple the atmospheric transport analysis of the FO and the insect response functions to estimate a net impact on the local food insect species.

5. Conclusions

Using a low speed, environmentally controlled wind tunnel coupled with a thermal FO generator, a method for assessing the impact of FO smoke on insect prey of TES was developed. Response measures encompassed not only direct mortality of the exposed life stage, but reduced emergence of the consumed life stage from exposure of antecedent life stages, palatability to an avian predator, and activity/flight observations that could affect availability of prey. Five species of insects representative of major prey groups of TES of bats and birds that inhabit military lands were exposed to FO in the wind tunnel under differing conditions of wind speed and/or canopy density. Analysis of these data provide, for the first time, empirical functions relating FO smoke concentration to reductions in insect populations. Moreover, the density of the canopy in which insects were exposed and/or the wind speed during FO exposure were shown to affect survivability of some insect species. Response algorithms were formulated that further refined predicted impacts of FO-induced mortality in prey populations to include the impact of wind speed and canopy density conditions on FO mortality rates. For moths, a predominant prey group in all of its life stages for birds, the survival to the last larval (5^{th}) instar and subsequent pupation and successful adult emergence as a function of the instar (1^{st} through 5^{th}) that was exposed were also obtained.

These response functions provide DoD biologists a means of estimating potential insect population reductions in areas exposed to FO smoke. Because the algorithms relate insect survival to airborne FO concentration, they can be coupled, mathematically, to dispersion conditions to indicate the impacts for specific FO smoke dispersion conditions. The impact on a species and life stage can be quantified using the following general expression:

$$I = \frac{1}{A_T} \int A(c) F(c,u) dc$$

where
- I = impact on insect population over area of the fog-oil smoke plume expressed as the expected survival of a uniformly distributed population (fraction)
- A(c) = incremental area covered at a concentration level c in the plume of fog-oil smoke under the specific dispersion conditions (m^2 per mg/m^3)
- A_T = total area covered by the fog-oil plume (m^2)
- c = concentration of the fog-oil smoke in the plume (mg/m^3)
- F(c,u) = fractional survival (likelihood of individual impact such as death) for a 2-hr exposure to fog-oil smoke at a concentration c and wind speed u (fraction)
- u = constant wind speed for the 2-hr dispersion period (mph)

The incremental area function is evaluated from the plume dispersion equation and the release rate of FO. The evaluation can be performed using a finite difference analysis with integration over the length of the plume at or above the concentration of interest. This evaluation would be programmed into the software that performs the impact assessment.

The impact function F(c,u) is defined from the results of the present study for each species and life stage for which impacts were quantified. The impact endpoint could be death of the individual, change in activity/flight, or change in palatability. When there is no impact, the function F has a constant value of 1.0 and the above equation returns an impact result of 1.0,

indicating no impact on the species/life stage population. A value less than 1.0 indicates an impact on the species/life stage from the postulated exposure.

An inherent assumption in the use of the above equation is that the dispersion conditions (wind speed and atmospheric stability) are constant for a 2-hr period and that temperature and humidity are similar to the conditions employed in the current study (26.7°C [80°F] and approximately 40-60% relative humidity). These conditions are not unusual for reproductive seasons in military lands inhabited by many of the TES species identified in this SON. The test method could, of course, be applied to additional ranges of environmental conditions.

The dynamic exposure system used in this study provided 1) aerosolized FO that has undergone the same thermal generation process as used in military mechanical smoke generators; 2) production of fog oil smoke with realistic droplet size distributions, concentrations, and durations; 3) control over environmental conditions that influence droplet deposition and insect metabolism (wind speed and canopy structure, temperature, and humidity); and 4) ability to replicate and adequately characterize exposures. Because of the attributes of controlled conditions and reproducibility on the one hand, and the ability to conduct contaminant research in dynamic environments simulating natural field conditions on the other, the low-speed, environmental wind tunnel exposure system provides a link between the controlled, but unrealistic static conditions of laboratory exposure tests and the uncontrollable conditions of field studies wherein even the direction and concentration of the plume in specific areas where pre-exposure data must be collected (let alone wind speed and meteorological conditions) cannot be adequately predicted or repeated. With the ability to rapidly select and control test parameters (not possible in field trials), the wind tunnel is a cost-effective tool for estimating obscurant impacts to insect prey of TES on military lands.

In addition to the exposure system, the selection of insect species and the response measures are important to the usefulness of the data and response algorithms generated by this method. The species selected for this study represented the major insects that are consumed by bird and bat TES and a wide range of sensitivity to FO smoke exposure. For two species, the wood roach and beetle, adult and larval stages were unaffected by FO. Adult moths also showed little adverse response to FO exposure. However, moth and mosquito larvae and adult ants survivability and life spans were affected by exposure to FO aerosols. That populations of multiple groups of prey species may be reduced by FO exposure is of concern because birds often can compensate for major losses in a single food source, but cannot compensate for a reduction in the relative abundance of the total prey base. Reduction in abundance of prey at critical times (e.g., initiation of egg laying, nestling growth, fledgling survival prior to independence) is also important and can result in reduction in seasonal productivity (Martin 1987, Marshall et al. 2002). Indeed, reduced success of future nests in the same season (Slagsvold 1984) and the subsequent year (Roskaft 1985) have been attributed to reduced energy reserves in parents. Determining an area-weighted measure of impact through use of the response algorithms coupled with dispersion modeling that takes into account the conditions (wind speed/relative canopy density) during exposure will aid in minimizing impacts on the productivity of the prey of TES. The timing of the FO generations throughout the year should also be evaluated in regards to the impact of FO exposure on current and subsequent year populations of uni- and multi-voltine species.

Another aspect of species selection is the ease of colony maintenance and the time to establish viable, regenerating colonies. Although problems with establishing mosquito colonies largely stemmed from the unfortunate development of safety concerns relative to outbreaks of West Nile Fever, culture of the wood roach was impacted by the length of egg incubation (60 days) which limited our ability to make the necessary trials and adjustments to establish a productive, self-perpetuating colony within the time frame of the study. Food quality analysis was not conducted because insufficient numbers of the life stages of the insects were available, and because of additional cost of colony development.

Species selection also impacted response measures in that the egg size of the moths and beetles were so small that locating and accurately enumerating the eggs (and 1st instar of the moths) could not be accomplished with accuracy. A species with larger eggs, more adaptable to induction of egg laying in artificial systems, or for which oviposition chambers are developed would have allowed evaluation of the effects of FO on all, and possibly most sensitive, life stages.

The flight tests that were to be incorporated into the test method to evaluate FO-induced impacts on availability of flying insects to bats was replaced with simple flight/activity assessments during the daily observations. This provided more data that extended over the entire observation period rather than for the shorter observation period of the flight tests and reduced the overall cost of the test method.

The study developed and demonstrated a cost-effective method, as compared to field assessments, for quantifying the potential impact of fog oil on the food base of TES inhabiting Department of Defense lands where training activities are conducted. This method will allow testing of prey species under relevant climatic and canopy conditions of specific TES. Because information on the effects of fog oil on important prey species of the red-cockaded woodpecker, several neotropical birds, and two endangered bat species were tested in this project, the exposure-response data from the study directly benefit risk assessment/management efforts for these species.

The final product is a set of response functions describing mortality and food availability of insect prey of TES in terms of fog oil air concentration, wind speed during generations, and canopy structure. The information will be useable with transport models and will be released as SERDP reports and public refereed journal publications.

6. References

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology* 18:265-267.

Altegrim, O. 1992. Mechanisms regulating bird predation on a herbivorous larva guild in boreal coniferous forests. *Ecography* 15:19–24.

Anderson, J., J. Neff, B. Cox, H. Tatem, and G. Hightower. 1974. Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish. *Marine Biology* 27:75-88.

Beattie, G. A. C., Z. M. Liu, D. M. Watson, A. D. Clift, and L. Jiang. 1995. Evaluation of petroleum spray oils and polysaccharide for control of *Phyllocnistis citrella* Stainton (*Lepioptera: Gracillariidae*). *J. Aust. Entomol. Soc.* 34:349-353.

Belovsky, G. E. 1996. Generalist herbivore foraging and its role in competitive interactions. *Am Zool.* 26:51-69.

Benjamini, L. 1981. The efficacy of seed treatment with aldicarb to establish conditioned aversion in birds to sprouting sugar beets. *Phyotparasitica* 9:3-9.

Bennett, R. S. 1989. Role of dietary choices in the ability of bobwhite to discriminate between insecticide-treated and untreated food. *Environ. Toxicol. Chem*. 8: 731-738

Bennett, R. S., and D. W. Schafer. 1988. Procedure for evaluating the potential of birds to avoid chemically contaminated food. *Environ. Toxicol. Chem*. 7:359-362.

Bildstein K.L. and D. J. Forsyth. 1979. Effects of dietary dieldrin on behavior of white-footed mice *(Peromyscus leucopus)* towards an avian predator. Bull Environ Contam. Toxicol. 21:93-97.

Bussiere, J. L., R. J. Kendall, T. E. Lacher, Jr., and R. S. Bennett. 1989. Effect of methylparation on food discrimination in northern bobwhite (*Colinus virginianus*). *Environ. Toxicol. Chem*. 8:1125-1131.

Cataldo, D., P. Van Voris, M. Ligotke, R. Fellows, B. McVeety, S. Li, H. Bolton, Jr., and J. Frederickson. 1989. *Evaluate and Characterize Mechanisms Controlling Transport, Fate, and Effects of Army Smokes in an Aerosol Wind Tunnel: Transport, Transport, Transformations, Fate and Terrestrial Ecological Effects of Fog Oil Obscurant Smokes*. AD-A20414, Pacific Northwest National Laboratory, Richland, Washington.

Chapin, E. A. 1925. *Food Habits of the Vireos*. U.S.D.A. Agricultural Bulletin.

Dingledine, J. 1987. *An Active Avoidance Study with Canada Goose on Turf.* Presented at 8th Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, FL, November 9-12.

Driver, C., M. Ligotke, H. Galloway-Gorby, G. Dennis, K. Reinbold, and H. Balbach. 2002. *Acute Inhalation Toxicity of Fog Oil Smoke in the Red-winged Blackbird, a Size-specific Inhalation Surrogate for the Red-cockaded Woodpecker.* ERDC/CERL TR-02-6, U.S. Army Engineer Research and Development Center (ERDC),U.S. Army Corps of Engineers Construction Engineering Research laboratory (CERL), Champaign, Illinois.

Driver, C., M. Ligotke, J. Downs, B. Tiller, T. Poston, E. Moore, Jr., D. Cataldo. 1993. *Environmental and Health Effects Review for Obscurant Fog Oil*. ERDEC-CR- 071, Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, Maryland.

Driver, C., M. Ligotke, H. Galloway-Gorby, G. Dennis, and K. Reinbold. 1997. *Acute Inhalation Toxicity of Fog Oil Smoke in the Red-Winged Blackbird, A Size-Specific Inhalation Surrogate for the Red-Cockaded Woodpecker*. USACERL Technical Report, U.S. Army Corps of Engineers, Construction Engineering Research Laboratories, Champaign, Illinois.

Dunn, W. E., D. F. Brown, and A. J. Policastro. 1998. *Modeling fog oil smoke dispersion using the smoke model.* Presented at the Air and Waste Management. Assn. Federal Facilities Compliance Conference in Washington, D. C., Nov. 1998.

Graber, J. 1961. Distribution and habitat requirements, and life history of the Black-capped Vireo (*Vireo atricapilla*). *Ecol. Monogr*. 31:313-331.

Hanula, J., D. Lipscomb, K. Franzreb, and S. Loeb. Diet of nestling red-cockaded woodpeckers at three locations. 2000. *J. Field Ornithol.* 71:126-134.

Harding, W.C. 1979. *Pesticide Profiles ,Part One: Insecticides and Miticides.* Univ. Maryland, Coop. Ext. Serv. Bull. 267. 30 pp.

Hayes, W., Jr., and E. Laws, Jr. 1991. Solvents and petroleum oils. Pp. 639-645 in *Handbook of Pesticide Toxicology Volume 2: Classes of Pesticides*, Academic Press, San Diego.

Hinds, W. C. 1982. *Aerosol Technology*. John Wiley & Sons, New York

Lai, A. C. K. and W. W. Nazaroff. 1999. *Review of Particle Deposition Indoors*. unpublished report. Department of Civil and Environmental Engineering, University of California, Berkeley.

Holmes, R., and J. Schultz. 1988. Food availability for forest birds: Effects of prey distribution and abundance on bird foraging. *Can. J. Zool.* 66:720-728.

Kononen, D., H. Hochstein, and R. Ringer. 1986. A quantitative method for evaluating avian food avoidance behavior. *Environment. Toxicol. Chem*. 5:823-830.

Kononen, D., H. Hochstein, and R. Ringer. 1987. Avoidance behavior of mallards and northern bobwhite exposed to carbofuran-contaminated food and water. *Environ. Toxicol. Chem.* 6:41-50.

LaVal, R. K., R. L. Clawson, M.L. LaVal, and W. Caire. 1977. Foraging behavior and nocturnal activity patterns of Missouri Bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. *J.Mammal*. 58:592-599.

La Rouche, A., S. Kapila, V. Flanigan, M. Trueblood, P. Whitehfield, and P. Nam. 1997. Qualitative and quantitative determination of poly-aromatic hydrocarbons (PAH) in fog oil obscurant smoke. In E. Erickson, M.Rankin, S. Grant and J. McDonald, eds., *Proceedings of the*

12th Annual Conference on Hazardous Waste Research, May 19-22, 1997, Kansas City, Missouri.

Liljegren, H. W. Dunn, G. DeVaull, and A. Policastro. 1988. *Field Measurement and Model Evaluation Program for Assessment of the Environmental Effects of Military Smokes: Field Study of Fog-Oil Smokes.* AD-A205 344, Argonne National Laboratory, Argonne, Ill.

Marshall, M. R., R. J. Cooper, J. A. DeCecco, J. Strazanac, and L. Bulter. 2002. Effects of experimentally reduced prey abundance on the breeding ecology of the Red-Eyed Vireo. *Ecological Applications* 12(1): 261-280.

A. Page, O. Lubatti, and H. Martin. 1940. *The Scientific Principles of Plant Protection with Special Reference to Chemical Control* (3rd Edition). Great Britain Department of Scientific and Industrial Research, Eyre and Spottiswoode, Limited, London, England.

Martin, T. E. 1987. *Food as a limit on breeding birds: a life-history perspective*. Annual Review of Ecology and Systematics. 18:453-487.

Matsumura, F. 1985. *Toxicology of Insecticides* (2nd ed.), Plenum Press, New York.
Ramsey, F.L., and D.W. Schafer. 1996. *The Statistical Sleuth: A Course in Methods of Data Analysis.* Duxbury Press, New York.

Morrison, M. L., C. J. Ralph, J. Verner, and J. R. Jehl, Jr., Eds. 1990. *Avian Foraging: Theory, Methodology, and Applications*. Studies in Avian Biology, no. 13, Cooper Ornithological Society, Western Foundation of Vertebrate Zoology, Camarillo, California.

National Research Council.(NRC) 1997. Fog oil smoke. Pp. 60-97 in *Toxicology of Military Smokes and Obscurants*, Vol. 1. Committee on Toxicology, NRC, National Academy Press, Washington DC.

The Nature Conservancy of Washington. 1999. *Biodiversity Inventory and Analsysis of the Hanford Site*, Final Report 1995-1999. The Nature Conservancy of Washington. Seattle, Washington.

Nicholson, K. W. 1988. The dry deposition of small particles: A review of experimental measurements, *Atmos. Environ.* 22, 2653-2666

Policastro, A. J., and W. E. Dunn. 1985. *Survey and Evaluation of Field Data Suitable for Smoke Hazard Model Evaluation*. ANL/ER-85-3. AD-A161 880 . Argonne National Laboratory, Ill.

Poston, T., K. McFadden, R. Bean, M. Clark, B. Thomas, B. Killand, L. Prohammer, and D. Kalkwarf. 1986. *Acute Toxicity of Smoke Screen Materials to Aquatic Organisms., White Phosphorus-Felt, Red Phosphorus-Butyl Rubber and SFG Nol 2 Fog Oil.* U.S. Army Medical Research and Development Command, Fort Detrick, Gredierick, Maryland.

Pulick, W. 1976. *The Golden-cheeked Warbler: A Bioecological Study*. Texas Parcs and Wildlife Department, Austin.

Ramsey, F. L., and D. W. Schafer. 1996. *The Statistical Sleuth: A Course in Methods of Data Analysis*. Duxbury Press, New York.

Reist, P.C. 1993. *Aerosol Science and Technology*. McGraw-Hill: New York.

Repasky, R. R., and P. D. Doerr. (1991). Home range and substrate use by two family groups of red-cockaded woodpeckers in the North Carolina Sandhills. *Brimleyana* 17: 37-52.

Robel, R. J., and M. E. Morrow. 1988. Feeding by bobwhites on sprouting corn reduced by bendiocarb. *Trans. Kan. Acad. Sci.* 90:35-40.

Robertson, J. L., and H. K. Preisler. 1992. *Pesticide Bioassays with Arthropods*. CRC, Boca Raton, FL.

Roskaft, E. 1985. The effect of enlarged brood size on the future reproductive potential of the rook. *J. Anim. Ecol*. 54:255–260.

Rossi, S., J. Anderson, and G. Ward. 1976. Toxicity of water-soluble fractions of four test oils for the polychaetous annelids, *Neanthes arebaceidebtata* and *Capitella capitata*. *Environ. Pollut*. 10:9-18.

Shepard, H. 1951. Petroleum, animal and vegetable oils, soaps, creosotes. Pp 191-209.in *The Chemistry and Action of Insecticides*. McGraw–Hill, New York.

Slagsvold, T. 1984. Clutch size variation of birds in relation to nest predation: On the cost of reproduction. *Journal of Animal Ecology* 53:945–953.

Stark, J. D., P. C. Jepson, and C. F. Geroge Thomas. 1995. The effects of pesticides on spiders from the lab to the landscape. *Rev. Pestic. Toxic*. 3::83-110.

Stephens, D. W., and J. R. Krebs. 1986. *Foraging Theory*. Princeton University Press, Princeton, NJ.

Tomlin, C. 1997. *The Pesticide Manual: World Compendium*, 11th ed. British Crop Protection Council, Farnham, Surrey, United Kingdom.

Tuttle, M. 1976. *Population Ecology of the Gray Bat (Myotis grisescens): Philopatry, Timing, and Patterns of Movement, Weight Loss During Migration, and Seasonal Adaptive Strategies. Occas. Pap. Mus. Nat. Hist. Univ. Kans*. 54:1-38.

Tuttle, M. 1979. Status, causes of decline, and management of endangered gray bats. *J. Wildl. Manage.* 43 (1):1-17.

U.S. Army. 1986. *Workshop to Select Test Systems for Ecological Assessment and Monitoring*. January 19-22, 1986, U.S. Army Construction Engineering Research Laboratory (CERL), at the University of Illinois at Urbana-Champaign, Illinois.

Young, J., D. Smart, J. Allen, D. Parmer, A. Rosencrance, E. Brueggeman, and F. Broski. 1989. *Field Exposure of Chemical School Students and Cadre to Fog Oil and Hexachloroethane (HC) Smokes.* Tech. Rep. 8908. U. S. Army Biomedical Research and Development Laboratory, Fort Detrick, Frederick, Maryland.

Appendix A. Supporting Data

Table A1. Supporting Data

Exposed Insect	Life Stage	Target Concentration (mg/m^3)	Actual Concentration (mg/m^3)	Wind Speed (mph)	Exposure Duration (hr)
Ants (*Camponotus sp.*)	Adult	Control, 50,100, 400, 800	46, 104, 391, 804	0	4
Ants (*Camponotus sp.*)	Adult	Control, 100, 200, 400, 800	57, 99, 194, 343, 734	2	2
Ants (*Camponotus sp.*)	Adult	Control, 50, 100, 200, 400	52, 100, 184, 397	4	2
Ants (*Camponotus sp.*)	Adult	Control, 50, 100, 200, 400	51, 95, 196, 390	8	2
Beetle *Tenebrio molitar*	2^{nd}-5^{th} instar Larvae	Control, 25, 50, 100, 200, 400	24, 48, 104, 208, 353	2	4
Beetle *Tenebrio molitar*	Adult	50, 100, 400, 800	46, 104, 391, 804	0	4
Beetle *Tenebrio molitar*	1^{st} instar larvae	Control, 50, 100, 200, 400, 800	57, 99, 194, 343, 734	2	2
Mosquito *Culex* sp.	1^{st} instar larvae	25, 800	25, 804	0	4
Mosquito *Culex* sp.	3^{rd} instar larvae	25, 50, 100, 200, 400	46, 104, 209, 391	0	4
Mosquito *Culex* sp.	1^{st} instar larvae	Control, 50, 100, 200	24, 54, 107, 207	0	2
Mosquito *Culex* sp.	Adult	200	194	0	2
Moth *Macaria curvata*	Adult	500	526	2	4
Moth *Macaria curvata*	Adult	Controls	0	2	4
Moth *Macaria curvata*	Larvae (4^{th} & 5^{th} instar)	Control, 1000	916	2	4
Moth *Macaria curvata*	Larvae (all 5 instars)	Control, 100, 400, 800, 1200	99, 390, 749, 1265	2	4
Moth *Macaria curvata*	Larvae (1^{st}-3^{rd} instar)	Control, 50, 100, 200, 400	50, 88, 216, 406	4	2
Moth *Macaria curvata*	Larvae (1^{st}-3^{rd} instar)	Control, 50, 100, 200, 400	52, 100, 184, 397	8	2
Moth *Macaria curvata*	Larvae (1^{st}-3^{rd} instar)	* Control, 50, 100, 200, 400	51, 93, 195, 389	2	2
Moth *Macaria curvata*	Larvae (1^{st}-3^{rd} instar)	* Control, 50, 100, 200, 400	49, 113, 195, 393	4	2
Moth *Macaria curvata*	Larvae (1^{st}-3^{rd} instar)	* Control, 50, 100, 200, 400	47, 100, 206, 387	8	2
Wood Roach (*Parcoblatta uhelriana*)	Adult	Control, 500	526	2	4
Wood Roach *Parcoblatta uhelriana*)	Small nymphs	Control, 50, 100, 200, 400, 800	57, 99, 194, 343, 734	2	2

* Large leaf-area canopy

Table A2-1. Geometrid Moth Lifespan (Lifespan Data for Unexposed Moths [Initial Set Followed])

Range of emergence dates			
Ages at death			
Male	**All Females**	**Female with eggs**	**Female laid eggs**
8.31	8.31	8.31	
14	10.31		10.31
12.00	10.31		10.31
7.00	11.31	11.31	
13.25	14.31	14.31	
10.00	12.31		12.31
8.00	8.00	8.00	
9.00	15.00	15.00	
12.00	12.00		12.00
8.00	17.00	17.00	
16	14	14.00	
5.00	17	17.00	
6.00	15.00	15.00	
9.00	8.00	8.00	
	9.00		9.00
	12.25	12.25	
	12.25	12.25	
	12.25	12.25	
	13.00	13.00	
	10.00	10.00	
	11.00		11.00
	11.00		11.00
	11.00		11.00
	13.00	13.00	
	9.00		9.00
	11.00	11.00	
	14.00	14.00	
	17.00	17.00	
	8.00		8.00
	8.00		8.00
	12.00		12.00
Average Lifespan, days			
9.83	11.83	12.77	10.33
Standard Deviation of Lifespann			
3.20	2.69	2.87	1.52
Number in each group			
14	31	19	12

Table A2-2. Geometrid Moth Lifespan (Days after Emergence – Control)

Age	Date cage started	Moth No.	Male	Female
	28-Sep-02			
2		1 M	3.00	
2		2 M	4.00	
2		3 M	5.00	
2		4 F		8.00
2		5 F		9.00
2		6 F		10.00
2		7 F		10.00
2		8 F		12.00
2		9 F		12.00
2		10 F		12.00
	29-Sep-02			
1		1 F		10
1		2 M	14	
	30-Sep-02			
0		1 F		13.00
0		2 F		14.00
0		3 F		18.00

Table A2-3. Geometrid Moth Lifespan (Days after Emergence - 530 mg/m^3)

Age	Date Emerged	Moth	Male	All Females	Comments
	2-Sep-02				
6		1 F			lost
6		2 F			lost
6		3 F		12.00	
6		4 M	6.00		
6		5 M	10.00		
	4-Sep-02				
2		1 F		15.00	
2		2 F		15.00	
2		3 M	5.00		
2		4 M	5.00		
	5-Sep-02				
1		1 F		7.00	
1		2 F		11.00	
1		3 M	5.00		
1		4 M	6.00		
	6-Sep-02				
0		1 F		1.00	
0		2 F		7.00	
0		3 F		10.00	
0		4 F			lost
0		5 M			lost

Table A2-4. Geometrid Moth Lifespan (Exposure Test Data for 22-Oct-2002)

Exposed Group, 916 mg/m3 at 2.15 mph (SD = 0.22 mph)								
Date cage started	**Moth No.**	**Time zero**	**Age at death (days)**	**Lifespan (days)**	**Age at Exposure, (days)**	**Life (days)**	**Life beyond test (days)**	**Died**
20-Oct-02								
	1	0.5	11	11.50	2	11	9*	1
	2	0.5	14	14.50	2	14	12*	1
	3	0.5	18	18.50	2	18	16*	1
	4	0.5	18	18.50	2	18	16*	1
	5	0.5	18	18.50	2	18	16*	1
	6	0.5	18	18.50	2	18	16*	1
21-Oct-02								
	1	0	3	3.00	1	3	2	1
	2	0	3	3.00	1	3	2*	1
	3	0	4	4.00	1	4	3	1
	4	0	4	4.00	1	4	3	1
	5	0	6	6.00	1	6	5	1
	6	0	8	8.00	1	8	7*	1
	7	0	10	10.00	1	10	9*	1
	8	0	14	14.00	1	14	13	1
22-Oct-02								
	1	0	5	5.00	0	5	5	1
	2	0	9	9.00	0	9	9	1
	3	0	10	10.00	0	10	10*	1
	4	0	12	12.00	0	12	12*	1
	5	0	13	13.00	0	13	13*	1
Total moths								19
Summary	Average Life		10.42105				9.368421	
	Days		5.347022				5.002339	
* Female								
Control Group exposed to handling and wind tunnel, 2.08 mph (SD = 0.29 mph)								
Date cage started	**Moth No.**	**Time zero**	**Age at death (days)**	**Lifespan (days)**	**Age at Exposure, (days)**	**Life (days)**	**Life beyond test (days)**	**Died**
20-Oct-02								
	1	0.5	12	12.50	2	12	10	1
	2	0.5	14	14.50	2	14	12	1
	3	0.5	15	15.50	2	15	13	1
	4	0.5	15	15.50	2	15	13	1
21-Oct-02								
	1	0	5	5.00	1	5	4	1
	2	0	7	7.00	1	7	6	1
	3	0	11	11.00	1	11	10	1
	4	0	14	14.00	1	14	13	1
	5	0	15	15.00	1	15	14	1
Total moths							9	
Summary	Average Life			12.22				
	Days							Std Dev
Control Group remaining in Greenhouse								
Date cage started	**Moth No.**	**Time zero**	**Age at death (days)**	**Lifespan (days)**	**Age at Exposure, (days)**	**Life (days)**	**Life beyond test (days)**	**Died**
17-Oct-02								
	1	0	5	5.00	0	5	5	1

	2	0	5	5.00	0	5	5	1
	3	0	6	6.00	0	6	6	1
	4	0	7	7.00	0	7	7	1
	5	0	12	12.00	0	12	12	1
	6	0	14	14.00	0	14	14	1
	7	0	18	18.00	0	18	18	1
18-Oct-02								
	1	0	11	11.00	0	11	11	1
	2	0	12	12.00	0	12	12	1
	3	0	12	12.00	0	12	12	1
	4	0	14	14.00	0	14	14	1
	5	0	17	17.00	0	17	17	1
	6	0	18	18.00	0	18	18	1
23-Oct-02								
	1	0	8	8.00	0	8	8	1
	2	0	11	11.00	0	11	11	1
	3	0	12	12.00	0	12	12	1
	4	0	12	12.00	0	12	12	1
24-Oct-02	1	0	9	9.00	0	9	9	1
	2	0	12	12.00	0	12	12	1
	3	0	13	13.00	0	13	13	1
	4	0	14	14.00	0	14	14	1
	5	0	15	15.00	0	15	15	1
25-Oct-02	1	0	9	9.00	0	9	9	1
	2	0	11	11.00	0	11	11	1
	3	0	11	11.00	0	11	11	1
	4	0	19	19.00	0	19	19	1
26-Oct-02	1	0	3	3.00	0	3	3	1
	2	0	10	10.00	0	10	10	1
	3	0	11	11.00	0	11	11	1
	4	0	12	12.00	0	12	12	1
	5	0	13	13.00	0	13	13	1
	6	0	13	13.00	0	13	13	1
	7	0	13	13.00	0	13	13	1
	8	0	15	15.00	0	15	15	1
	9	0	16	16.00	0	16	16	1
	10	0	19	19.00	0	19	19	1
27-Oct-02	1	0	15	15.00	0	15	15	1
	2	0	15	15.00	0	15	15	1
	3	0	missing		0			
	4	0	missing		0			
28-Oct-02	1	0	7	7.00	0	7	7	1
	2	0	15	15.00	0	15	15	1
	3	0	17	17.00	0	17	17	1
29-Oct-02	1	0	16	16.00	0	16	16	1
	2	0	17	17.00	1	17	17	1
30-Oct-02	1	0	10	10.00	0	10	10	1
	2	0	16	16.00	0	16	16	1

Table A3-1. Geometrid Moth Instar Survival

Exposure Concentration	Group Instar	Initial Number	Matured to next instar	Matured to 5th instar	Pupated	Reached Adult
Control	1st	15	9	5	5	2
Control	2nd	14	10	6	5	5
Control	3rd	14	14	11	11	11
Control	4th	13	11	11	9	4
Control	5th	15	14		14	14
100 mg/m3	1st	10	7	5	3	2
100 mg/m3	2nd	10	6	2	2	2
100 mg/m3	3rd	9	8	8	8	8
100 mg/m3	4th	7	4	4	4	4
100 mg/m3	5th	12	9		9	7
400 mg/m3	1st	10	0	0	0	0
400 mg/m3	2nd	10	8	6	1	1
400 mg/m3	3rd	10	5	5	4	2
400 mg/m3	4th	10	6	6	4	5
400 mg/m3	5th	10	2		2	2
800 mg/m3	1st	10	0	0	0	0
800 mg/m3	2nd	10	4	3	2	2
800 mg/m3	3rd	10	2	2	1	0
800 mg/m3	4th	10	2	2	0	0
800 mg/m3	5th	10	3		2	0
1200 mg/m3	1st	10	0	0	0	0
1200 mg/m3	2nd	10	0	0	0	0
1200 mg/m3	3rd	10	3	1	0	0
1200 mg/m3	4th	11	3	3	0	0
1200 mg/m3	5th	9	3		1	0

Table A4-1. Geometrid Moth Canopy Test (Larvae, Small Canopy, Wind Speed = 2 mph)

	Control								100 mg/m^3								400 mg/m^3								800 mg/m^3								1200 mg/m^3							
Date	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.
13-Nov-02	0	46	0		46				0	29			29				Note day change																Note day change							
14-Nov-02	1								1								0	30	0	100	30	0	0		0	30	0	100	30	0	0		0	30		100	30	0	0	
15-Nov-02	2	46	0	100	46	0	0		2	29	0	100	29	0	0		1	30	1	100	30	0	0		1	11	3	37	11	0	0		0	29	1	97	29	0	0	
16-Nov-02	3	41	0	89	41	0	0		3	28	1	97	28	0	0		2	27	1	90	27	0	0		2	11	1	33	10	0	0		1	18	4	60	18	0	0	
17-Nov-02	4	41	0	89	41	0	0		4	24	0	83	24	0	0		3	21	0	70	21	0	0		3	11	0	30	9	0	0		2	4	14	13	4	0	0	
18-Nov-02	5	37	1	80	37	0	0		5	24	0	83	24	0	0		4	19	1	63	19	0	0		4	11	1	27	8	0	0		3	3	1	10	3	0	0	
19-Nov-02	6	33	0	72	33	0	0		6	20	1	69	20	0	0		5	16	0	53	16	0	0		5	11	0	23	7	0	0		4	3	0	10	3	0	0	
20-Nov-02	7	32	1	70	32	0	0		7	20	0	69	20	0	0		6	14	0	47	14	0	0		6	11	2	20	6	0	0		5	3	0	10	3	0	0	
21-Nov-02	8	30	0	65	27	3	0		8	19	0	66	19	0	0		7	10	1	33	10	0	0		7	11	1	17	5	0	0		6	3	0	10	3	0	0	
22-Nov-02	9	27	0	59	24	3	0		9	15	0	52	14	1	0		8	10	0	33	8	2	0		8	11	0	17	5	0	0		7	3	0	10	3	0	0	
23-Nov-02	10	27	0	59	24	3	0		10	14	0	48	12	2	0		9	6	0	20	4	2	0		9	11	0	13	4	0	0		8	3	0	10	3	0	0	
24-Nov-02	11	26	0	57	20	6	0		11	14	2	48	12	2	0		10	5	1	17	4	1	0		10	11	0	10	3	0	0		9	3	0	10	3	0	0	
25-Nov-02	12	25	0	54	20	5	0		12	14	0	48	12	2	0		11	5	0	17	3	2	0		11	11	0	10	3	0	0		10	3	0	10	3	0	0	
26-Nov-02	13	24	1	52	18	6	0		13	10	0	34	6	4	0		12	5	2	17	3	2	0		12	11	0	10	3	0	0		11	3	0	10	3	0	0	
27-Nov-02	14	20	0	43	13	7	0		14	10	0	34	4	6	0		13	4	0	13	1	3	0		13	11	0	10	3	0	0		12	3	0	10	3	0	0	
28-Nov-02	15	20	0	43	13	7	0		15	10	1	34	5	5	0		14	4		13	1	3	0		14	11	2	3	0	1	0		13	1	2	3	1	0	0	
29-Nov-02	16	19	1	41	13	6	0		16	9	1	31	4	5	0		15	4		13	1	3	0		15	11	0	3	0	1	0		14	1	0	3	1	0	0	
2-Dec-02	19	16	0	35	9	7	0		19	9	0	31	1	8			16	4		13	1	3	0		16	11	0	3	0	1	0		15	1	0	3	1	0	0	
3-Dec-02	20	16	0	35	6	9	1		20	9	0	31	1	8	0		19	4		13	0	4	0		19	11	0	3	0	1	0		16	1	0	3	1	0	0	
4-Dec-02	21	16	0	35	5	11	0		21	9	0	31	0	9	0		20	4		13	0	4	0		20	11	0	3	0	1	0		19	1	0	3	1	0	0	
5-Dec-02	22	15	0	33	5	10	0		22	10	0	34	0	9	1		21	4		13	0	4	0		21	11	0	3	0	1	0		20	1	0	3	1	0	0	
6-Dec-02	23	14	0	30	3	10	1		23	10	0	34	0	9	1		22	3		10	0	3	0		22	11	0	3	0	1	0		21	0	1	0	0	0	0	
9-Dec-02	26	14	0	30	1	9	4		26	10	0	34	0	6	4		23	3		10	0	1	2		23	11	0	3	0	1	0									
10-Dec-02	27	12	0	26	1	7	4		27	10	0	34	0	7	3		26	3		10	0	1	2		26	11	0	3	0	1	0									
11-Dec-02	28	11	0	24	0	9	2		28	10	0	34	0	7	3		27	1		3	0	1	0		27	11	0	3	0	1	0									
12-Dec-02	29	11	0	24	0	5	6		29	10	0	34	0	5	5		28	1		3	0	1	0		28	11	0	3	0	1	0									
13-Dec-02	30	10	0	22	0	8	2		30	8	0	28	0	4	4		29	1		3	0	1	0		29	11	0	3	0	1	0									
16-Dec-02	33	9	0	20	0	9	0		33	7	0	24	0	3	4		30	1		3	0	1	0		30	11	0	3	0	1	0									
17-Dec-02	34	8	0	17	0	8	0		34	3	0	10	0	3	0		33	1		3	0	1	0		33	11	0	7	0	1	1									
18-Dec-02	35	9	0	20	0	6	3		35	2	0	7	0	1	1		34	0		0	0	0	0		34	11	0	3	0	0	1									
19-Dec-02	36	8	2	17	0	7	1		36	2	0	7	0	1	1										35	11	0	0	0	0	0									
20-Dec-02	37	3	0	7	0	2	1		37	1	0	3	0	0	1																									
22-Dec-02	39	3	0	7	0	2	1		39	1	0	3	0	0	1																									
27-Dec-02	44	3	0	7	0	2	1		44	0	0	0	0	0	0																									
29-Dec-02	46	3	0	7	0	2	1																																	
30-Dec-02	47	3	0	7	0	2	1																																	
31-Dec-02	48	3	2	7	0	0	3																																	
2-Jan-03	50	1	0	2	0	0	1																																	
3-Jan-03	51	0	0	0	0	0	0																																	

Table A4-2. Geometrid Moth Canopy Test (Larvae, Small Canopy, Wind Speed = 2 mph)

	Control								50 mg/m^3								100 mg/m^3								200 mg/m^3								400 mg/m^3							
Date	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.
16-Jul-03	0	11							0	17							0	13								22					0	15						
17-Jul-03*	1	11	0	100.00	11	0	0	11	1	15	2	88.23529	15	0	0	17	0	11	2	84.62	11	0	0	13	0	20	2	90.91	20	0		22	0	0	15	0				15
21-Jul-03	5	11	0	100.00	11	0	0	11	5	5	3	29.41176	5	3	0	10	4	7	4	53.85	7	0	0	13	3	3	1	13.64	3	0	0	6		0	0	0	0	0	0	15
23-Jul-03	7	11	0	100.00	11	0	0	11	7	5	0	29.41176	5	0	0	10	6	4	2	30.77	4	0	0	12	5	1	2	4.55	1	0	0	6		0	0	0				15
25-Jul-03	9	11	0	100.00	11	0	0	11	9	3	2	17.64706	3	0	0	10	8	4	0	30.77	4	0	0	12	7	0	2	0.00	0	0	0	7		0	0	0				15
28-Jul-03	12	9	0	81.82	9	0	0	9	12	2	0	11.76471	1	1	0	9	11	1	3	7.69	1	0	0	12	10	0	0	0.00				7		0	1	0	0	0	0	16
30-Jul-03	14	8	1	72.73	7	1	0	9	14	2	0	11.76471	1	1	0	9	13	1	0	7.69	1	0	0	12		0	0	0.00				7		0	1	0	0	0	0	17
1-Aug-03	16	7	0	63.64	4	3	0	8	16	2	0	11.76471	1	1	0	9	15	1	0	7.69	1	0	0	12		0	0	0.00				7		0	0	0				17
4-Aug-03	19	7	1	63.64	5	2	0	9	19	1	1	5.88	0	1	0	9	18	1	0	7.69	1	0	0	12		0	0	0.00				7		0	0	0				17
6-Aug-03	21	7	0	63.64	1	6	0	9	21	1	0	5.88	1	0	0	9	20	1	0	7.69	0	1	0	12		0	0	0.00				7		0	0	0				17
7-Aug-03	22	7	0	63.64	1	6	0	9	22	1	0	5.88	0	1	0	9	21	1	0	7.69	0	1	0	12		0	0	0.00				7		0	0	0				17
11-Aug-03	26	5	2	45.45	1	4	0	9	26	1	0	5.88	0	1	0	9	25	1	0	7.69	0	1	0	12		0	0	0.00				7		0	0	0				17
13-Aug-03	28	5	1	45.45	1	4	0	10	28	1	0	5.88	0	1	0	9	27	1	0	7.69	0	1	0	12		0	0	0.00				7		0	0	0				17
14-Aug-03	29	5	0	45.45	1	2	3,2	10	29	0	1	0.00	0	0	1	9	28	1	0	7.69	0	1	0	12		0	0	0.00				7		0	0	0				17
18-Aug-03	33	3	0	27.27	1	1	1	8	33	0	0	0.00	0	0	0	9	32	1	0	7.69	0	1	0	12		0	0	0.00				7		0	0	0				17
20-Aug-03	35	3	1	27.27	0	1	2	9		0	0	0.00				9	34	1	0	7.69	0	1	0	12		0	0	0.00				7		0	0	0				17
22-Aug-03	37	1	0	9.09	0	0	1	7		0	0	0.00				9	36	1	0	7.69	0	1	0	12		0	0	0.00				7		0	0	0				17
25-Aug-03	40	1	0	9.09	0	0	1	7		0	0	0.00				9	39	0	1	0.00	0	0	0	12		0	0	0.00				7		0	0	0				17
27-Aug-03	42	0	1	0.00	0	0	1	7		0	0	0.00				9	41	1	0	7.69	0	1	0	13		0	0	0.00				7		0	0	0				17
2-Sep-03	48	0	0	0.00	0	0	0	7		0	0	0.00				9	47	1	0	7.69	0	1	0	13		0	0	0.00				7		0	0	0				17
8-Sep-03	54	0	0	0.00	0	0	0	7		0	0	0.00				9	53	1	0	7.69	0	1	0	13		0	0	0.00				7		0	0	0				17
11-Sep-03	57	0	0	0.00	0	0	0	7		0	0	0.00				9	56	1	0	7.69	0	1	0	13		0	0	0.00				7		0	0	0				17
15-Sep-03	61	0	0	0.00	0	0	0	7		0	0	0.00				9	60	1	0	7.69	0	1	0	13		0	0	0.00				7		0	0	0				17
17-Sep-03	63	0	1	0.00	0	0	1	8	63	0	0	0.00	0	0	0	9	62	1	0	7.69	0	1	0	13		0	0	0.00	0	0	0	7		0	0	0	0	0	0	17

*Not all data in this row was taken on the 17. Some data were taken on the date of exposure, after the exposure (July 18-19).
The days since exposure column should be used to determine the time of data count.

Table A4-3. Geometrid Moth Canopy Test (Larvae, Small Canopy, Wind Speed = 8 mph)

	Control								50 mg/m^3								100 mg/m^3								200 mg/m^3								400 mg/m^3							
Date	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.
16-Jul-03	0	15							0	10							0	12								7							0	13						
17-Jul-03*	1	15	0	100.00	15	0	0	15	1	6	4	60.00	6	0	0	10	0	11	1	91.67	11	0	0	12	0	7	0	100.00	7	0	0	7	0	1	12	7.69				13
21-Jul-03	5	11	3	73.33	11	0	0	14	5	2	1	20.00	2	0	0	7	4	2	3	16.67	2	0	0	6	3	3	1	42.86	3	0	0	4	2	0	0	0.00	0	0	0	12
23-Jul-03	7	10	1	66.67	10	0	0	14	7	2	0	20.00	2	0	0	7	6	2	0	16.67	2	0	0	6	5	2	1	28.57	2	0	0	4		0	0	0.00				12
25-Jul-03	9	8	1	53.33	8	0	0	13	9	0	2	0.00	0	0	0	7	8	2	0	16.67	2	0	0	6	7	2	0	28.57	2	0	0	4		0	0	0.00				12
28-Jul-03	12	8	0	53.33	8	0	0	13	12	0	0	0.00	0	0	0	7	11	2	0	16.67	2	0	0	6	10	2	0	28.57	2	0	0	4		0	0	0.00				12
30-Jul-03	14	8	0	53.33	8	0	0	13	14	0	0	0.00	0	0	0	7	13	2	0	16.67	2	0	0	6	12	2	0	28.57	2	0	0	4		0	0	0.00				12
1-Aug-03	16	8	0	53.33	8	0	0	13		0	0	0.00				7	15	2	0	16.67	2	0	0	6	14	2	0	28.57	2	0	0	4		0	0	0.00				12
4-Aug-03	19	7	0	46.67	7	0	0	12		0	0	0.00				7	18	2	0	16.67	2	0	0	6	17	2	0	28.57	2	0	0	4		0	0	0.00				12
6-Aug-03	21	6	0	40.00	6	0	0	11		0	0	0.00				7	20	2	0	16.67	2	0	0	6	19	2	0	28.57	2	0	0	4		0	0	0.00				12
7-Aug-03	22	6	0	40.00	5	1	0	11		0	0	0.00				7	21	2	0	16.67	2	0	0	6	20	2	0	28.57	1	1	0	4		0	0	0.00				12
11-Aug-03	26	5	0	33.33	5	0	0	10		0	0	0.00				7	25	1	1	8.33	1	0	0	6	24	1	1	14.29	1	0	0	4		0	0	0.00				12
13-Aug-03	28	5	2	33.33	3	2	0	12		0	0	0.00				7	27	1	0	8.33	1	0	0	6	26	1	0	14.29	1	0	0	4		0	0	0.00				12
14-Aug-03	29	5	0	33.33	3	2	0	12		0	0	0.00				7	28	1	0	8.33	1	0	0	6	27	0	1	0.00	0	0	0	4		0	0	0.00				12
18-Aug-03	33	5	0	33.33	3	2	0	12		0	0	0.00				7	32	1	0	8.33	1	0	0	6		0	0	0.00				4	30	0	0	0.00	0	0	0	12
20-Aug-03	35	5	0	33.33	2	2	1	12		0	0	0.00				7	34	1	0	8.33	1	0	0	6		0	0	0.00				4		0	0	0.00				12
22-Aug-03	37	5	0	33.33	2	2	1	12		0	0	0.00				7	36	1	0	8.33	1	0	0	6		0	0	0.00				4		0	0	0.00				12
25-Aug-03	40	5	0	33.33	0	4	1	12		0	0	0.00				7	39	1	0	8.33	0	1	0	6		0	0	0.00				4		0	0	0.00				12
27-Aug-03	42	4	0	26.67	0	4	0	11		0	0	0.00				7	41	0	1	0.00	0	0	0	6		0	0	0.00				4		0	0	0.00				12
2-Sep-03	48	4	0	26.67	0	2	2,1	11		0	0	0.00				7	47	0	0	0.00	0	0	0	6		0	0	0.00				4		0	0	0.00				12
8-Sep-03	54	2	0	13.33	0	1	1	9		0	0	0.00				7	53	0	0	0.00	0	0	0	6		0	0	0.00				4		0	0	0.00				12
11-Sep-03	57	1	0	6.67	0	1	0	8		0	0	0.00				7	56	0	0	0.00	0	0	0	6		0	0	0.00				4		0	0	0.00				12
15-Sep-03	61	1	0	6.67	0	0	1	8				0.00				7				0.00				6				0.00				4				0.00				12
17-Sep-03	63	0	0	0.00	0	0	0	7	63	1	0	10.00	1	0	0	8	62	0	0	0.00	0	0	0	6	61	0	0	0.00	0	0	0	4	60	0	0	0.00	0	0	0	12

*Not all data in this row was taken on the 17. Some data were taken on the date of exposure, after the exposure (July 18-19).
The days since exposure column should be used to determine the time of data count.

Table A4-4. Geometrid Moth Canopy Test (Larvae, Large Canopy, Wind Speed = 2 mph)

	Control								50 mg/m^3								100 mg/m^3								200 mg/m^3								400 mg/m^3							
Date	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.
5-Aug-03	0	17	0	100.00	17	0	0	17																																
6-Aug-03	1	14	1	82.35	14	0	0	15	0	18	1	100.00	18	0	0	19	0																							
7-Aug-03	2	10	1	58.82	10	0	0	12	1	18	0	100.00	18	0	0	19	1	14	1	100.00	14	0	0	15	0	16	0	100.00	16	0	0	16								
11-Aug-03	6	10	0	58.82	10	0	0	12	5	11	0	61.11	11	0	0	12	5	9	1	64.29	9	0	0	11	4	15	0	93.75	15	0	0	15	3	15	0	100.00	15	0	0	15
13-Aug-03	8	9	0	52.94	9	0	0	11	7	12	0	66.67	12	0	0	13	7	5	4	35.71	5	0	0	11	6	13	0	81.25	13	0	0	13	5	14	0	93.33	14	0	0	14
14-Aug-03	9	7	2	41.18	7	0	0	11	8	10	1	55.56	10	0	0	12	8	5	0	35.71	5	0	0	11	7	12	0	75.00	12	0	0	12	6	11	0	73.33	11	0	0	11
18-Aug-03	13	5	0	29.41	5	0	0	9	12	7	1	38.89	7	0	0	10	12	2	0	14.29	2	0	0	8	11	5	2	31.25	5	0	0	7	10	11	0	73.33	11	0	0	11
20-Aug-03	15	4	0	23.53	4	0	0	8	14	5	0	27.78	5	0	0	8	14	2	1	14.29	2	0	0	9	13	5	0	31.25	5	0	0	7	12	9	1	60.00	9	0	0	10
22-Aug-03	17	4	0	23.53	4	0	0	8	16	5	0	27.78	5	0	0	8	16	2	0	14.29	2	0	0	9	15	2	3	12.50	2	0	0	7	14	7	0	46.67	7	0	0	8
25-Aug-03	20	3	1	17.65	3	0	0	8	19	4	0	22.22	4	0	0	7	19	1	0	7.14	1	0	0	8	18	2	0	12.50	2	0	0	7	17	6	1	40.00	5	1	0	8
27-Aug-03	22	1	1	5.88	1	0	0	7	21	5	1	27.78	2	3	0	9	21	1	0	7.14	1	0	0	8	20	2	0	12.50	2	0	0	7	19	6	0	40.00	3	3	0	8
2-Sep-03	28	2	0	11.76	1	1	0	8	27	3	0	16.67	2	0	1	7	27	1	0	7.14	1	0	0	8	26	0	2	0.00	0	0	0	7	25	4	2	26.67	1	3	0	8
8-Sep-03	34	1	0	5.88	0	0	1	7	33	1	2	5.56	0	0	1	7	33	0	1	0.00	0	0	1	8	32	0	0	0.00	0	0	0	7	31	4	0	26.67	1	1	2	8
11-Sep-03	37	0	0	0.00	0	0	0	6	36	0	0	0.00	0	0	0	6	36	0	0	0.00	0	0	0	8	35	0	0	0.00	0	0	0	7	34	2	0	13.33	0	0	2	6
15-Sep-03	41	1	0	5.88	0	0	1	7	40	0	0	0.00	0	0	0	6	40	0	0	0.00	0	0	0	8	39	0	1	0.00	0	0	0	8	38	2	0	13.33	1	0	1	6
17-Sep-03	43	0	0	0.00	0	0	0	6	42	0	0	0.00	0	0	0	6	42	0	0	0.00	0	0	0	8	41	0	0	0.00	0	0	0	8	40	1	0	6.67	1	0	0	5

Table A4-5. Geometrid Moth Canopy Test (Larvae, Large Canopy, Wind Speed = 4 mph)

	Control								50 mg/m^3								100 mg/m^3								200 mg/m^3								400 mg/m^3							
Date	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.
6-Aug-03	0								0																															
6-Aug-03	1	13	0					13	1	19	0					19	0																							
7-Aug-03	2	13	0	100.00	13	0	0	13	2	14	0	73.68	14	0	0	14	1	14	1	100.00	14	0	0	15	0	14	0	100.00	14	0	0	14								
11-Aug-03	6	10	1	76.92	10	0	0	11	6	7	0	36.84	7	0	0	7	5	13	1	92.86	13	0	0	15	4	9	2	64.29	9	0	0	11	3	16	0	100.00	16	0	0	16
13-Aug-03	8	8	0	61.54	8	0	0	9	8	5	2	26.32	5	0	0	7	7	9	4	64.29	9	0	0	15	6	5	2	35.71	5	0	0	9	5	12	2	75.00	12	0	0	14
14-Aug-03	9	8	0	61.54	8	0	0	9	9	5	0	26.32	5	0	0	7	8	8	1	57.14	8	0	0	15	7	4	0	28.57	4	0	0	8	6	9	2	56.25	9	0	0	13
18-Aug-03	13	7	1	53.85	7	0	0	9	13	3	0	15.79	3	0	0	5	12	6	0	42.86	6	0	0	13	11	2	1	14.29	2	0	1	7	10	4	2	25.00	4	0	0	10
20-Aug-03	15	7	0	53.85	7	0	0	9	15	2	1	10.53	2	0	0	5	14	4	0	28.57	4	0	0	11	13	1	0	7.14	1	0	0	6	12	3	0	18.75	3	0	0	9
22-Aug-03	17	5	0	38.46	5	0	0	7	17	2	0	10.53	2	0	0	5	16	4	1	28.57	4	0	0	12	15	0	1	0.00	0	0	0	6	14	2	1	12.50	2	0	0	9
25-Aug-03	20	2	0	7.69	2	0	0	4	20	2	0	10.53	2	0	0	5	19	1	1	7.14	1	0	0	10	18	0	0	0.00	0	0	0	6	17	0	2	0.00	0	0	0	9
27-Aug-03	22	1	1	7.69	1	0	0	4	22	2	0	10.53	2	0	0	5	21	1	0	7.14	1	0	0	10	20	0	0	0.00	0	0	0	6	19	0	0	0.00	0	0	0	9
2-Sep-03	28	1	1	7.69	1	0	0	5	28	2	0	10.53	2	0	0	5	27	1	0	7.14	1	0	0	10	26	0	0	0.00	0	0	0	6	25	0	0	0.00	0	0	0	9
8-Sep-03	34	1	0	7.69	1	0	0	5	34	1	1	5.26	0	1	0	5	33	1	0	7.14	1	0	0	10	32	0	0	0.00	0	0	0	6	31	0	0	0.00	0	0	0	9
11-Sep-03	37	1	0	7.69	1	0	0	5	37	1	0	5.26	0	1	0	5	36	1	0	7.14	0	1	0	10	35	0	0	0.00	0	0	0	6	34	0	0	0.00	0	0	0	9
15-Sep-03	41	1	0	7.69	1	0	0	5	41	1	0	5.26	0	1	0	5	40	0	0	0.00	0	0	0	9	39	0	0	0.00	0	0	0	6	38	0	0	0.00	0	0	0	9
17-Sep-03	43	1	0	0.00	1	0	0	5	43	1	0	5.26	0	1	0	5	42	0	0	0.00	0	0	0	9	41	0	0	0.00	0	0	0	6	40	0	0	0.00	0	0	0	9

Table A4-6. Geometrid Moth Canopy Test (Larvae, Large Canopy, Wind Speed = 8 mph)

	Control								50 mg/m^3								100 mg/m^3								200 mg/m^3								400 mg/m^3							
Date	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.	Days	Alive	Dead	%Alive	Larvae	Pupa	Adult	No.
5-Aug-03	0																																							
6-Aug-03	1	18	0						0								0																							
7-Aug-03	2	17	0	94.444	17	0	0	17	1	15	0	100.00	15	0	0	15	1	20	0	100.00	20	0	0	20	0	11	0	100.00	11	0	0	11								
11-Aug-03	6	12	1	66.667	12	0	0	13	5	10	0	66.67	10	0	0	10	5	13	2	65.00	13	0	0	15	4	9	0	81.82	9	0	0	9	3	16	2	100.00				18
13-Aug-03	8	9	0	50	9	0	0	10	7	8	2	53.33	8	0	0	10	7	5	8	25.00	5	0	0	15	6	5	2	45.45	5	0	0	7	5	12	0	75.00	12	0	0	14
14-Aug-03	9	7	2	38.889	7	0	0	10	8	5	1	33.33	5	0	0	8	8	5	1	25.00	5	0	0	16	7	4	0	36.36	4	0	0	6	6	11	1	68.75	11	0	0	14
18-Aug-03	13	4	1	22.222	3	1	0	8	12	3	2	20.00	3	0	0	8	12	3	2	15.00	3	0	0	16	11	2	2	18.18	2	0	0	6	10	8	3	50.00	8	0	0	14
20-Aug-03	15	2	1	11.111	1	1	0	7	14	3	0	20.00	3	0	0	8	14	3	0	15.00	3	0	0	16	13	1	3	9.09	1	0	2	8	12	7	0	43.75	7	0	0	13
22-Aug-03	17	2	0	11.111	1	1	0	7	16	2	1	13.33	2	0	0	8	16	2	0	10.00	2	0	0	15	15	1	0	9.09	1	0	0	8	14	8	0	50.00	8	0	0	14
25-Aug-03	20	2	0	11.111	1	1	0	7	19	1	1	6.67	1	0	0	8	19	1	1	5.00	1	0	0	15	18	0	1	0.00	0	0	0	8	17	7	0	43.75	6	1	0	13
27-Aug-03	22	2	0	11.111	1	1	0	7	21	1	0	6.67	1	0	0	8	21	0	0	0.00	0	0	0	14	20	0	0	0.00	0	0	0	8	19	7	1	43.75	5	2	0	14
2-Sep-03	28	3	0	16.667	0	1	2	8	27	1	0	6.67	0	1	0	8	27	0	0	0.00	0	0	0	14	26	0	0	0.00	0	0	0	8	25	5	2	31.25	3	2	0	14
8-Sep-03	34	1	0	5.5556	0	1	0	6	33	2	0	13.33	1	1	0	9	33	0	0	0.00	0	0	0	14	32	0	0	0.00	0	0	0	8	31	4	1	25.00	0	2	2	14
11-Sep-03	37	1	0	5.5556	0	1	0	6	36	2	0	13.33	2	0	0	9	36	0	0	0.00	0	0	0	14	35	0	0	0.00	0	0	0	8	34	3	0	18.75	0	2	1	13
15-Sep-03	41	1	0	5.5556	0	0	1	6	40	2	0	13.33	2	0	0	9	40	0	0	0.00	0	0	0	14	39	0	0	0.00	0	0	0	8	38	2	0	12.50	0	2	0	12
17-Sep-03	43	0	0	0.00	0	0	0	5	42	2	0	13.33	2	0	0	9	42	1	0	5.00	1	0	0	15	41	0	0	0.00	0	0	0	8	40	2	0	12.50	0	2	0	12

Table A5-1. Geometrid Moth Palatability

													Location A Statistics						Location B Statistics					
Date	Pen No.	Day Test Order No.	Run No.	Location A	Location B	Randomized Location Assignment[2]	Number of Larvae placed on Sod A	Number of Larvae placed on Sod B	Total No. of Larvae Placed on Sod (Location A+B)	Number of Larvae Consumed on Sod A	Number of Larvae Consumed on Sod B	Total No. of Larvae Consumed (Location A+B)	No. of Searches	No. of Attacks[1]	No. of Consumptions[1]	Time to First Contact	First Contact Location	Technician	No. of Searches	No. of Attacks[1]	No. of Consumptions[1]	Time to First Contact	First Contact Location	Technician
10/25/04	1	1	1	Control	800 mg/m^3	T	2	2	4	2	2	4	15	7	2	14:16:10	B, A	JV	20	2	2	14:16:09	A, B	RS
10/25/04	1	1	2	800 mg/m^3	Control	H	2	2	4	2	2	4	2	2	2	14:21:05	B	JV	5	2	2	14:20:54	B	RS
10/25/04	1	1	3	800 mg/m^3	Control	H	2	2	4	2	2	4	6	2	2	14:24:51	B	JV	5	2	2	14:24:40	B	RS
10/25/04	1	1	4	800 mg/m^3	Control	H	2	2	4	2	2	4	5	3	2	14:28:35	B	JV	4	2	2	14:28:27	B	RS
10/25/04	2	2	1	Control	800 mg/m^3	T	2	2	4	2	2	4	3	2	2	14:33:34	B	JV	8	2	2	14:32:58	B	RS
10/25/04	2	2	2	800 mg/m^3	Control	H	2	2	4	2	2	4	8	3	2	14:37:34	B	JV	9	3	2	14:37:28	B	RS
10/25/04	2	2	3	800 mg/m^3	Control	H	2	2	4	2	2	4	5	2	2	14:42:53	B	JV	4	2	2	14:42:48	B	RS
10/25/04	2	2	4	800 mg/m^3	Control	H	2	2	4	1	2	3	2	1	1	14:46:28	B	JV	8	4	2	14:46:23	B	RS
10/25/04	3	3	1	Control	800 mg/m^3	T	2	2	4	1	2	3	9	1	1	14:58:22	A	JV	15	3	2	14:58:24	A	RS
10/25/04	3	3	2	800 mg/m^3	Control	H	2	2	4	2	2	4	19	5	2	15:07:33	A	JV	12	2	2	15:07:55	A	RS
10/25/04	3	3	3	800 mg/m^3	Control	H	2	2	4	2	2	4	5	2	2	15:12:02	A	JV	5	4	2	15:12:03	A	RS
10/25/04	3	3	4	800 mg/m^3	Control	H	2	2	4	2	2	4	7	5	2	15:16:38	A	JV	8	2	1	15:16:49	A	RS
10/25/04	4	4	1	Control	800 mg/m^3	T	2	2	4	2	1	3	0	0	0	NA	B	JV	1	1	1	15:28:09	B	RS
10/25/04	4	4	2	800 mg/m^3	Control	H	2	2	4	2	2	4	10	4	2	15:38:02	B	JV	11	2	2	15:38:00	B	RS
10/25/04	4	4	3	800 mg/m^3	Control	H	2	2	4	1	2	3	5	3	1	15:42:17	A	JV	5	2	2	15:42:20	A	RS
10/25/04	4	4	4	800 mg/m^3	Control	H	2	2	4	2	2	4	5	3	2	15:48:50	A,B	JV	7	3	2	15:48:50		RS
10/26/04	1	4	1	800 mg/m^3	Control	H	2	2	4	2	2	4	21	4		14:34:04	B	RS	18	8	2	14:33:53	B	JV
10/26/04	1	4	2	Control	800 mg/m^3	T	2	2	4	2	2	4	21	5	2	14:39:35	B	RS	19	10	2	14:39:31	B	JV
10/26/04	1	4	3	800 mg/m^3	Control	H	2	2	4	2	2	4	12	8	2	14:45:58	B	RS	19	11	2	14:45:39	B	JV
10/26/04	1	4	4	Control	800 mg/m^3	T	2	2	4	2	2	4	6	2	2	14:50:40	B	RS	9	3	2	14:50:29	B	JV
10/26/04	2	1	1	800 mg/m^3	Control	H	2	2	4	2	2	4	2	2	2	13:35:25	A	RS	9	6	2	13:35:28	A	JV
10/26/04	2	1	2	Control	800 mg/m^3	T	2	2	4	2	2	4	10	7	2	13:38:38	B	RS	14	9	2	13:38:36	B	JV
10/26/04	2	1	3	800 mg/m^3	Control	H	2	2	4	2	2	4	2	2	2	13:53:38	B	RS	3	2	2	13:53:00	B	JV
10/26/04	2	1	4	Control	800 mg/m^3	T	2	2	4	2	2	4	5	2	2	13:55:31	A	RS	9	3	2	13:55:34	A	JV
10/26/04	3	2	1	800 mg/m^3	Control	H	2	2	4	2	2	4	2	2	2	13:59:11	B	RS	1	2	2	13:59:10	B	JV
10/26/04	3	2	2	Control	800 mg/m^3	T	2	2	4	2	2	4	4	2	2	14:02:06	A	RS	5	2	2	14:02:09	A	JV
10/26/04	3	2	3	800 mg/m^3	Control	H	2	2	4	2	1	3	0	0	2	14:05:18	B	RS	3	2	1	14:05:17	B	JV
10/26/04	3	2	4	Control	800 mg/m^3	T	2	2	4	2	2	4	1	2	2	14:12:08	A	RS	3	2	2	14:12:10	A	JV

													Location A Statistics						Location B Statistics					
Date	**Pen No.**	**Day Test Order No.**	**Run No.**	**Location A**	**Location B**	**Randomized Location Assignment[2]**	**Number of Larvae placed on Sod A**	**Number of Larvae placed on Sod B**	**Total No. of Larvae Placed on Sod (Location A+B)**	**Number of Larvae Consumed on Sod A**	**Number of Larvae Consumed on Sod B**	**Total No. of Larvae Consumed (Location A+B)**	**No. of Searches**	**No. of Attacks[1]**	**No. of Consumptions[1]**	**Time to First Contact**	**First Contact Location**	**Technician**	**No. of Searches**	**No. of Attacks[1]**	**No. of Consumptions[1]**	**Time to First Contact**	**First Contact Location**	**Technician**
10/26/04	4	3	1	800 mg/m^3	Control	H	2	2	4	2	2	4	3	4	2	14:17:11	B	RS	6	3	2	14:17:09	B	JV
10/26/04	4	3	2	Control	800 mg/m^3	T	2	2	4	2	2	4	8	4	2	14:21:05	B	RS	12	6	2	14:21:03	B	JV
10/26/04	4	3	3	800 mg/m^3	Control	H	2	2	4	2	2	4	4	5	2	14:25:36	B	RS	6	3	2	14:25:33	B	JV
10/26/04	4	3	4	Control	800 mg/m^3	T	2	2	4	2	2	4	0	11	**2**	14:29:40	B	RS	4	2	2	14:29:38	B	JV
10/27/04	1	3	1	800 mg/m3	Control	H	2	2	4	2	2	4	3	3	2	14:26:18	A	JV	4	2	2	14:26:13	B	RS
10/27/04	1	3	2	Control	800 mg/m3	T	2	2	4	2	2	4	3	4	2	14:30:01	A	JV	5	4	2	14:30:03	A	RS
10/27/04	1	3	3	Control	800 mg/m3	T	2	2	4	2	2	4	1	2	2	14:37:38	A/B	JV	6	4	2	14:37:38	A/B	RS
10/27/04	1	3	4	800 mg/m3	Control	H	2	2	4	2	2	4	4	3	2	14:42:10	B	JV	3	2	2	14:42:02	B	RS
10/27/04	2	4	1	800 mg/m3	Control	H	2	2	4	2	2	4	5	2	2	14:48:43	B	JV	3	2	2	14:48:43	B	RS
10/27/04	2	4	2	Control	800 mg/m3	T	2	2	4	2	2	4	1	3	2	14:53:53	B	JV	2	2	2	14:53:48	B	RS
10/27/04	2	4	3	Control	800 mg/m3	T	2	2	4	2	2	4	2	2	2	14:57:28	B	JV	1	3	2	14:57:24	B	RS
10/27/04	2	4	4	800 mg/m3	Control	H	2	2	4	2	2	4	1	2	2			JV	1	3	2	15:01:03	B	RS
10/27/04	3	1	1	800 mg/m3	Control	H	2	2	4	2	2	4	4	3	2	13:41:03	B	JV	8	3	2	13:40:58	B	RS
10/27/04	3	1	2	Control	800 mg/m3	T	2	2	4	2	2	4	8	3	2	13:44:12	A	JV	6	3	2	13:44:15	A	RS
10/27/04	3	1	3	Control	800 mg/m3	T	2	2	4	2	2	4	2	4	2	13:47:19	B	JV	6	3	2	13:47:18	B	RS
10/27/04	3	1	4	800 mg/m3	Control	H	2	2	4	1	2	3	3	1	1	13:50:31	A	JV	3	2	2	13:50:32	A	RS
10/27/04	4	2	1	800 mg/m3	Control	H	2	2	4	2	2	4	7	3	2	13:59:11	A	JV	5	3	2	13:59:12	A	RS
10/27/04	4	2	2	Control	800 mg/m3	T	2	2	4	2	2	4	5	9	2	14:03:05	B	JV	11	8	2	14:03:01	B	RS
10/27/04	4	2	3	Control	800 mg/m3	T	2	2	4	2	2	4	7	4	2	14:08:38	B	JV	7	4	2	14:08:36	B	RS
10/27/04	4	2	4	800 mg/m3	Control	H	2	2	4	2	2	4	5	2	2	14:12:15	B	JV	3	2	2	14:12:11	B	RS
10/28/07	1	2	1	Control	800 mg/m3	T	2	2	4	2	2	4	3	4	2	13:43:32	B	RS	4	2	2	13:43:30	B	JV
10/28/07	1	2	2	800 mg/m3	Control	H	2	2	4	2	2	4	4	2	2	13:47:20	A	RS	3	2	2	13:47:21	A	JV
10/28/07	1	2	3	Control	800 mg/m3	T	2	2	4	2	2	4	5	11	2	13:51:01	B	RS	8	9	2	13:50:59	B	JV
10/28/07	1	2	4	Control	800 mg/m3	T	2	2	4	2	2	4	4	2	2	13:54:35	B	RS	2	2	2	13:54:32	B	JV
10/28/07	2	3	1	Control	800 mg/m3	T	2	2	4	2	2	4	4	2	2	13:59:30	B	RS	2	5	2	13:59:28	B	JV
10/28/07	2	3	2	800 mg/m3	Control	H	2	2	4	2	2	4	3	5	2	14:03:47	A,B	RS	7	13	2	14:03:47	A, B	JV
10/28/07	2	3	3	Control	800 mg/m3	T	2	2	4	2	2	4	5	2	2	14:07:49	B	RS	2	2	2	14:07:46	B	JV
10/28/07	2	3	4	Control	800 mg/m3	T	2	2	4	2	2	4	2	2	2	14:11:12	B	RS	4	5	2	14:11:07	B	JV
10/28/07	3	4	1	Control	800 mg/m3	T	2	2	4	2	2	4	13	5	2	14:15:48	A	RS	6	10	2	14:15:52	A	JV
10/28/07	3	4	2	800 mg/m3	Control	H	2	2	4	2	2	4	11	4	2	14:21:43	A	RS	3	8	2	14:22:11	A	JV

													Location A Statistics						Location B Statistics					
Date	**Pen No.**	**Day Test Order No.**	**Run No.**	**Location A**	**Location B**	**Randomized Location Assignment[2]**	**Number of Larvae placed on Sod A**	**Number of Larvae placed on Sod B**	**Total No. of Larvae Placed on Sod (Location A+B)**	**Number of Larvae Consumed on Sod A**	**Number of Larvae Consumed on Sod B**	**Total No. of Larvae Consumed (Location A+B)**	**No. of Searches**	**No. of Attacks[1]**	**No. of Consumptions[1]**	**Time to First Contact**	**First Contact Location**	**Technician**	**No. of Searches**	**No. of Attacks[1]**	**No. of Consumptions[1]**	**Time to First Contact**	**First Contact Location**	**Technician**
10/28/07	3	4	3	Control	800 mg/m3	T	2	2	4	2	2	4	7	11	2	14:26:22	B	RS	7	7	2	14:26:16	B	JV
10/28/07	3	4	4	Control	800 mg/m3	T	2	2	4	2	2	4	3	3	2	14:31:08	B	RS	1	3	2	14:31:02	B	JV
10/28/07	4	1	1	Control	800 mg/m3	T	2	2	4	2	2	4	6	3	2	13:28:17	A	RS	6	2	2	13:28:27	A	JV
10/28/07	4	1	2	800 mg/m3	Control	H	2	2	4	2	2	4	7	3	2	13:32:38	B	RS	7	3	2	13:32:36	B	JV
10/28/07	4	1	3	Control	800 mg/m3	T	2	2	4	2	2	4	6	5	2	13:35:58	A	RS	4	2	2	13:35:59	B	JV
10/28/07	4	1	4	Control	800 mg/m3	T	2	2	4	2	2	4	2	4	2	13:39:30	B	RS	3	5	2	13:39:28	B	JV
10/29/04	1	1	1	Control	800 mg/m3	T	10	10	20	10	10	20	1	10	10	13:47:29	B	JV	0	12	10	13:47:24	B	RS
10/29/04	1	1	2	800 mg/m3	Control	H	10	10	20	10	10	20	0	11	10	13:51:38	B	JV	0	11	10	13:51:36	B	RS
10/29/04	2	2	1	Control	800 mg/m3	T	10	10	20	10	10	20	5	13	10	13:57:12	B	JV	3	12	10	13:57:09	B	RS
10/29/04	2	2	2	800 mg/m3	Control	H	10	10	20	3	10	13	0	6	3	14:01:56	B	JV	0	11	10	14:01:29	B	RS
10/29/04	3	3	1	Control	800 mg/m3	T	10	10	20	10	10	20	8	14	10	14:12:52	A	JV	6	11	10	14:12:53	A	RS
10/29/04	3	3	2	800 mg/m3	Control	H	10	10	20	8	10	18	0	14	8	14:19:22		JV	1	11	10	14:19:26	A	RS
10/29/04	4	4	1	Control	800 mg/m3	T	10	10	20	10	10	20	4	12	10	14:27:12	B	JV	4	10	10	14:27:08	B	RS
10/29/04	4	4	2	800 mg/m3	Control	H	10	10	20	7	6	13	0	4	4	14:41:41	A	JV	1	4	3	14:46:06	A	RS
11/02/04	1	4	1	800 mg/m3	Control	H	10	10	20	10	10	20	1	10	10	14:45:33	A,B	RS	3	12	10	14:45:33	A, B	JV
11/02/04	1	4	2	800 mg/m3	Control	H	10	10	20	4	10	14	2	10	4	14:49:58	B	RS	1	11	10	14:49:42	B	JV
11/02/04	2	1	1	800 mg/m3	Control	H	10	10	20	10	10	20	2	12	10	13:52:08	B	RS	2	11	10	13:51:53	B	JV
11/02/04	2	1	2	800 mg/m3	Control	H	10	10	20	8	8	16	5	10	8	13:55:53	B	RS	3	16	8	13:55:50	B	JV
11/02/04	3	2	1	800 mg/m3	Control	H	10	10	20	10	10	20	2	13	10	14:01:51	B	RS	0	10	10	14:01:41	B	JV
11/02/04	3	2	2	800 mg/m3	Control	H	10	10	20	10	8	18	3	15	10	14:06:52	A	RS	2	11	8	14:11:37	A	JV
11/02/04	4	3	1	800 mg/m3	Control	H	10	10	20	10	10	20	6	12	10	14:26:14	B	RS	7	13	10	14:25:16	B	JV
11/02/04	4	3	2	800 mg/m3	Control	H	10	10	20	10	10	20	7	11	10	14:32:50	B	RS	12	18	10	14:32:41	B	JV

Table A6-1. Mosquito First Instar

Exposure Group: 0 mg/m3							
			Set 1			Corrected	As counted
Date	Time	Post Exp Hours	Alive	Dead	Total	No. Dead	% dead
19-Mar-03		0	37	5	42	5	11.9
20-Mar-03		24	35	6	41	7	16.7
21-Mar-03		48	35	6	41	7	16.7
23-Mar-03		96	31	2	33	11	26.2
24-Mar-03		120	31	0	31	11	26.2
2-Apr-03		336	21			21	50.0
4-Apr-03		384	7	2	9	35	83.3
7-Apr-03		456	2	0	2	40	95.2
14-Apr-03		624	0	0	0	42	100.0
Exposure Group: 25 mg/m3							
			Set 1			Corrected	
Date	Time	Post Exp Hours	Alive	Dead	Total	No. Dead	% Mort
19-Mar-03		0	52	0	52	0	0.0
20-Mar-03		24	45	4	49	7	13.5
21-Mar-03		48	42	8	50	10	19.2
23-Mar-03		96	44	3	47	8	15.4
24-Mar-03		120	44	0	44	8	15.4
4-Apr-03		384	3	0	3	49	94.2
7-Apr-03		456	2	0	2	50	96.2
14-Apr-03		624	0	0	0	52	100.0
Exposure Group: 50 mg/m3							
			Set 1			Corrected	
Date	Time	Post Exp Hours	Alive	Dead	Total	No. Dead	% Mort
19-Mar-03		0	43	3	46	3	6.5
20-Mar-03		24	44	4	48	2	4.3
21-Mar-03		48	42	5	47	4	8.7
23-Mar-03		96	45	0	45	1	2.2
24-Mar-03		120	43		43	3	6.5
4-Apr-03		384	19	4	23	27	58.7
7-Apr-03		456	18	1	19	28	60.9
14-Apr-03		624	11	1	12	35	76.1
Exposure Group: 100 mg/m3							
			Set 1			Corrected	
Date	Time	Post Exp Hours	Alive	Dead	Total	No. Dead	% Mort
19-Mar-03		0	44	1	45	1	2.2
20-Mar-03		24	42	2	44	3	6.7
21-Mar-03		48	35	8	43	10	22.2
23-Mar-03		96	33	5	38	12	26.7
24-Mar-03		120	34	2	36	11	24.4
4-Apr-03		384	spilled				
7-Apr-03		456					
14-Apr-03		624					

Exposure Group: 200 mg/m3							
			Set 1			Corrected	
Date	Time	Post Exp Hours	Alive	Dead	Total	No. Dead	% Mort
19-Mar-03							
20-Mar-03		0	51	1	52	1	1.9
21-Mar-03		24	43	8	51	9	17.3
23-Mar-03		72	42	4	46	10	19.2
24-Mar-03		96	43	1	44	9	17.3
4-Apr-03		360	22	1	23	30	57.7
7-Apr-03		432	21	1	22	31	59.6
14-Apr-03		600	18	1	19	34	65.4
Exposure Group: 800 mg/m3							
			Set 1			Corrected	
Date	Time	Post Exp Hours	Alive	Dead	Total	No. Dead	% Mort
18-Mar-03		0	50				
19-Mar-03		24					
20-Mar-03		48					
21-Mar-03		72					
23-Mar-03		120	26	1	27	24	48.0
24-Mar-03		144	25	1	26	25	50.0
4-Apr-03		408	13	0	13	37	74.0
7-Apr-03		480	11	0		39	78.0
14-Apr-03		648	11	0		39	78.0

Table A7-1. Mosquito Third Instar

Exposure Control Group																				
			Set 1						Set 2						Set 3					
Date	Time	Post Exp Hours	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total
15-Mar-03	7:30 AM	0	40	0	0	0	40	40	40	0	0	0	40	40	40	0	0	0	40	40
16-Mar-03	12:30 PM	29	39	0	0	1	39	40	38	0	0	2	38	40	35	0	0	5	35	40
17-Mar-03	2:00 PM	54.5	34	3	0	2	37	40	35	2	0	1	37	40	34	0	0	1	34	40
18-Mar-03	1:30 PM	78	30	6	0	1	36	40	34	3	0	0	37	40	34	0	0	0	34	40
19-Mar-03	11:00 AM	99.5	24	10	2	0	36	40	28	6	1	2	35	40	29	3	0	2	32	40
21-Mar-03	10:30 AM	147	10	14	10	0	36	40	8	20	7	0	36	41	11	17	3	1	31	40
24-Mar-03	9:30 AM	218	0	6	16	2	34	40	2	1	25	0	36	41	0	5	22	1	30	40

Exposure Group: 25 mg/m3																				
			Set 1						Set 2						Set 3					
Date	Time	Post Exp Hours	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total
16-Mar-03	7:30 AM	0	40	0	0	0	40	40	40	0	0	0	40	40	40	0	0	0	40	40
16-Mar-03	12:30 PM	5	40	0	0	0	40	46	39	0	0	1	39	45	39	1	0	0	40	50
17-Mar-03	1:30 PM	30	38	1	0	1	39	46	40	0	0	0	40	46	36	2	0	2	38	50
18-Mar-03	2:00 PM	54.5	30	5	0	4	35	46	34	3	0	3	37	46	33	4	1	0	38	50
19-Mar-03	11:00 AM	75.5	21	12	0	2	33	46	29	6	0	2	35	46	25	10	0	2	36	50
21-Mar-03	10:30 AM	99	0	23	9	1	32	46	12	16	5	2	33	46	6	20	8	2	34	50
24-Mar-03	9:00 AM	121.5	0	0	19	4	28	46	2	3	20	3	30	46	0	0	23	2	32	50

Exposure Group: 50 mg/m3																				
			Set 1						Set 1						Set 1					
Date	Time	Post Exp Hours	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total
16-Mar-03	7:30 AM	0	40	0	0	0	40	40	40	0	0	0	40	40	40	0	0	0	40	40
16-Mar-03	4:15 PM	9	40	0	0	0	40	58	39			1	39	56	40	0	0	0	40	58
17-Mar-03	1:45 PM	30	39	0	0	1	39	58	36	0	0	3	36	56	37	2	0	1	39	58
18-Mar-03	1:45	54	32	6	0	1	38	58	29	5		2	34	56	19	18	0	2	37	58
19-Mar-03	10:30	75	23	13	2	0	38	58	26	8	0	0	34	56	13	23	1	0	37	58
21-Mar-03	10:30	123	4	20	10	2	36	58	9	16	7	2	32	56	3	11	21	1	36	58
24-Mar-03	9:00 AM	193.5	0	1	21	2	34	58	0	4	20	1	31	56	0	2	12	0	36	58
							0	24					0	25					0	22
							0	24					0	25					0	22

Exposure Group: 100 mg/m3																				
		Post Exp	Set 1						Set 1						Set 1					
Date	Time	Hours	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total
17-Mar-03	7:30 AM	0	40	0	0	0	40	40	40	0	0	0	40	40	40	0	0	0	40	40
17-Mar-03	12:20 PM	5	37	1	0	2	38	64	39	0	0	1	39	65	39	0	0	1	39	62
18-Mar-03	1:45 AM	30	28	8	0	2	36	64	27	9	0	3	36	65	26	12	0	1	38	62
19-Mar-03	10:30 AM	51	21	14	0	1	35	64	19	16	0	1	35	65	18	20	0	0	38	62
21-Mar-03	10:00 AM	98.5	3	16	15	1	34	64	6	12	15	2	33	65	4	14	16	4	34	62
24-Mar-03	9:00 AM	121.5	0	1	17	1	33	64	0	4	14	0	33	65	0	0	18	0	34	62

Exposure Group: 200 mg/m3																				
		Post Exp	Set 1						Set 1						Set 1					
Date	Time	Hours	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total
17-Mar-03	7:30 AM	0	40	0	0	0	40	40	39	0	0	0	39	39	40	0	0	0	40	40
17-Mar-03	4:15 PM	9	39			1	39	71	39				39	71	39			1	39	68
18-Mar-03	1:30 AM	30	29	8		2	37	71	31	6		2	37	71	32	6		1	38	68
19-Mar-03	10:15 AM	51	19	17		1	36	71	20	18	0	0	38	72	22	15		1	37	68
21-Mar-03	10:00 AM	99	5	12	13	6	30	71	5	16	16	1	37	72	7	13	12	5	32	68
24-Mar-03	8:30 AM	169.5	1	0	14	2	28	71	0	0	19	2	35	72	0	1	18	1	31	68

Exposure Group: 400 mg/m3																				
		Post Exp	Set 1						Set 1						Set 1					
Date	Time	Hours	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total	Larvae	Pupae	Adults	Dead	Alive	Total
18-Mar-03	7:30 AM	0	40	0	0	0	40	40	40	0	0	0	40	40	40	0	0	0	40	40
18-Mar-03	2:00 PM	6.5	29	2		9	31	83	34	0	0	6	34	77	33	0	0	7	33	77
19-Mar-03	10:00 AM	26.5	17	3		11	20	83	28	0		6	28	77	23	1		9	24	77
21-Mar-03	9:30 AM	74	6	0	2	12	8	83	15	1	0	12	16	77	14	0	0	10	14	77
24-Mar-03	8:30 AM	145	1	1	1	3	5	83	3	8	2	3	13	77	6	5	0	3	11	77

Table A8-1. Wood Roach Adults

Wood Roach Observations				
Date	Egg case Production		Deaths	
	Exposed	Unexposed	Exposed	Unexposed
6-Sep-02			1	
7-Sep-02				
8-Sep-02				
9-Sep-02				1
10-Sep-02		1		
11-Sep-02	1			
12-Sep-02	1			
13-Sep-02	1			
14-Sep-02				
15-Sep-02				
16-Sep-02	1			
17-Sep-02				
18-Sep-02	1			
19-Sep-02		1		
20-Sep-02				
21-Sep-02				
22-Sep-02				
23-Sep-02				
24-Sep-02				
25-Sep-02				
26-Sep-02				
27-Sep-02				
28-Sep-02				
29-Sep-02			1	
30-Sep-02				
1-Oct-02				
2-Oct-02				
3-Oct-02	1			
4-Oct-02				
5-Oct-02				
6-Oct-02				
7-Oct-02	2			
8-Oct-02	1	1		
9-Oct-02				
10-Oct-02				
11-Oct-02				
12-Oct-02				
13-Oct-02				
14-Oct-02				
15-Oct-02				
16-Oct-02				
17-Oct-02				
18-Oct-02				
19-Oct-02				
20-Oct-02	1	1		
21-Oct-02				
22-Oct-02				
23-Oct-02				
24-Oct-02		1		
25-Oct-02				
26-Oct-02				
27-Oct-02	1			
28-Oct-02				
29-Oct-02	1			

Wood Roach Observations				
Date	Egg case Production		Deaths	
	Exposed	Unexposed	Exposed	Unexposed
30-Oct-02		1		
31-Oct-02				
1-Nov-02	2			
2-Nov-02	1	1		
3-Nov-02				
4-Nov-02				
5-Nov-02				
6-Nov-02				
7-Nov-02				
8-Nov-02				
9-Nov-02	2	1		
10-Nov-02				
11-Nov-02	2			
12-Nov-02	1			
13-Nov-02				
14-Nov-02				
15-Nov-02				
16-Nov-02	1			
17-Nov-02				
18-Nov-02	2			
19-Nov-02	2			
20-Nov-02	1			
21-Nov-02				
22-Nov-02				1

Egg cases	26	8	
Days	78	78	
Females (F)	6	2	Minimum number estimated
cases/F	4.33	4	
days/case	3	9.75	
days/case per F	18	19.5	
Colony #	18	7	
Cases/roach	1.44	1.14	(Initial males and females)

Table A9-1. Wood Roach Nymphs (Control Group Exposed AM of 21 May 2003)

Observations of Wood Roach Nymph Survival for Exposure on May 21-22 2003															
Size		**Date**	**Start**	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**19**	**21**	**23**
			21 May 2003	**22 May 2003**	**23 May 2003**	**25 May 2003**	**27 May 2003**	**29 May 2003**	**31 May 2003**	**2 Jun 2003**	**4 Jun 2003**	**6 Jun 2003**	**9 Jun 2003**	**11 Jun 2003**	**13 Jun 2003**
Set 1	Nymphs	Alive	10	10	9	9	9	8	8	8	7	8	8	8	8
		Dead	0	0	0	0	0	0	0	0	0	0	0	0	
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0	
		Lost	0	0	1	0	0	1	0	0	1	-1	0	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	10	9	9	9	8	8	8	7	8	8	8	8
		Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0	0
Set 2	Nymphs	Alive	10	9	6	6	6	5	5	5	3	1	1	1	1
		Dead	0	0	0	0	0	0	0	0	0	0	0	0	
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0	
		Lost	0	1	3	0	0	1	0	0	2	2	0	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	9	6	6	6	5	5	5	3	1	1	1	1
		Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0	0
Set 3	Nymphs	Alive	10	10	10	10	10	10	9	9	9	9	10	10	10
		Dead	0	0	0	0	0	0	1	0	0	0	0	0	
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0	
		Lost	0	0	0	0	0	0	0	0	0	0	-1	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	10	10	10	10	10	9	9	9	9	10	10	10
		Fraction	1.000	1.000	1.000	1.000	1.000	1.000	0.900	0.900	0.900	0.900	0.909	0.909	0.909
		Skins	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A9-2. Wood Roach Nymphs (50 mg/m^3 Group Exposed AM of 21 May 2003)

Observations of Wood Roach Nymph Survival for Exposure on May 21-22 2003															
			0	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**19**	**21**	**23**
Size		**Date**	**21 May 2003**	**22 May 2003**	**23 May 2003**	**25 May 2003**	**27 May 2003**	**29 May 2003**	**31 May 2003**	**2 Jun 2003**	**4 Jun 2003**	**6 Jun 2003**	**9 Jun 2003**	**11 Jun 2003**	**13 Jun 2003**
Set 1	Nymphs	Alive	10	9	9	9	9	9	8	8	8	8	8	8	8
		Dead	0	0	0	0	0	0	0	0	0	0	0	0	
		Shed Skins	0	0	0	0	1	0	0	0	0	0	0	0	
		Lost	0	1	0	0	0	0	1	0	0	0	0	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	9	9	9	9	9	8	8	8	8	8	8	8
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	1	1	1	1	1	1	1	1	1
Set 2	Nymphs	Alive	10	10	10	10	10	9	9	9	9	10	10	10	10
		Dead	0	0	0	0	0	0	0	0	0	0	0	0	
		Shed Skins	0	0	0	0	1	0	0	1	0	0	0	0	
		Lost	0	0	0	0	0	1	0	0	0	-1	0	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	10	10	10	10	9	9	9	9	10	10	10	10
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	1	1	1	2	2	2	2	2	2
Set 3	Nymphs	Alive	10	9	9	9	9	8	8	8	8	8	8	8	8
		Dead	0	0	0	0	0	0	0	0	0	0	0	0	
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0	
		Lost	0	1	0	0	0	1	0	0	0	0	0	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	9	9	9	9	8	8	8	8	8	8	8	8
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A9-3. Wood Roach Nymphs (100 mg/m^3 Group Exposed PM of 21 May 2003)

Observations of Wood Roach Nymph Survival for Exposure on May 21-22 2003															
			0	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**19**	**21**	**23**
Size		**Date**	**21 May 2003**	**22 May 2003**	**23 May 2003**	**25 May 2003**	**27 May 2003**	**29 May 2003**	**31 May 2003**	**2 Jun 2003**	**4 Jun 2003**	**6 Jun 2003**	**9 Jun 2003**	**11 Jun 2003**	**13 Jun 2003**
Set 1	Nymphs	Alive	10	9	9	9	8	8	9	9	9	9	9	9	8
		Dead	0	0	0	0	1	0	0	0	0	0	0	0	
		Shed Skins	0	0	0	1	0	0	0	0	0	0	0	0	
		Lost	0	1	0	0	0	0	-1	0	0	0	0	0	1
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	9	9	9	8	8	9	9	9	9	9	9	8
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	1	1	1	1	1	1	1	1	1	1
Set 2	Nymphs	Alive	10	10	10	9	9	10	10	10	10	9	9	9	9
		Dead	0	0	0	0	0	0	0	0	0	0	0	0	
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0	
		Lost	0	0	0	1	0	-1	0	0	0	1	0	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	10	10	9	9	10	10	10	10	9	9	9	9
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0	0
Set 3	Nymphs	Alive	10	10	10	10	10	10	10	10	10	10	10	10	10
		Dead	0	0	0	0	0	0	0	0	0	0	0	0	
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0	
		Lost	0	0	0	0	0	0	0	0	0	0	0	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	10	10	10	10	10	10	10	10	10	10	10	10	10
		Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A9-4. Wood Roach Nymphs (200 mg/m^3 Group Exposed AM of 22 May 2003)

Observations of Wood Roach Nymph Survival for Exposure on May 21-22 2003														
			0	**1**	**3**	**5**	**7**	**9**	**11**	**13**	**15**	**18**	**20**	**22**
Size		**Date**	**22 May 2003**	**23 May 2003**	**25 May 2003**	**27 May 2003**	**29 May 2003**	**31 May 2003**	**2 Jun 2003**	**4 Jun 2003**	**6 Jun 2003**	**9 Jun 2003**	**11 Jun 2003**	**13 Jun 2003**
Set 1	Nymphs	Alive	10	8	8	8	9	9	9	9	9	8	8	8
		Dead	0	0	0	0	0	0	0	0	0	0	0	0
		Shed Skins	0	0	1	0	0	0	0	0	0	0	0	0
		Lost	0	2	0	0	-1	0	0	0	0	1	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	8	8	8	9	9	9	9	9	8	8	8
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	1	1	1	1	1	1	1	1	1	1
Set 2	Nymphs	Alive	10	10	10	10	9	9	9	9	9	9	9	9
		Dead	0	0	0	0	0	0	0	0	0	0	0	0
		Shed Skins	0	0	0	0	0	0	0	0	0	1	0	0
		Lost	0	0	0	0	1	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	10	10	10	9	9	9	9	9	9	9	9
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	0	0	0	0	0	1	1	1
Set 3	Nymphs	Alive	10	10	8	7	7	8	8	8	8	8	8	8
		Dead	0	0	1	0	0	0	0	0	0	0	0	0
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0
		Lost	0	0	1	1	0	-1	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	10	8	7	7	8	8	8	8	8	8	8
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0

Table A9-5. Wood Roach Nymphs (400 mg/m^3 Group Exposed AM of 22 May 2003)

Observations of Wood Roach Nymph Survival for Exposure on May 21-22 2003														
			0	**1**	**3**	**5**	**7**	**9**	**11**	**13**	**15**	**18**	**20**	**22**
Size		**Date**	**22 May 2003**	**23 May 2003**	**25 May 2003**	**27 May 2003**	**29 May 2003**	**31 May 2003**	**2 Jun 2003**	**4 Jun 2003**	**6 Jun 2003**	**9 Jun 2003**	**11 Jun 2003**	**13 Jun 2003**
Set 1	Nymphs	Alive	10	10	10	8	9	9	9	9	9	9	9	9
		Dead	0	0	0	0	0	0	0	0	0	0	0	0
		Shed Skins	0	1	0	1	0	0	0	0	0	0	0	0
		Lost	0	0	0	2	-1	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	10	10	8	9	9	9	9	9	9	9	9
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	1	1	2	2	2	2	2	2	2	2	2
Set 2	Nymphs	Alive	10	9	9	8	8	9	9	9	8	7	7	7
		Dead	0	0	0	0	0	0	0	0	0	0	0	0
		Shed Skins	0	1	0	0	0	0	0	0	0	0	0	0
		Lost	0	1	0	1	0	-1	0	0	1	1	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	9	9	8	8	9	9	9	8	7	7	7
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	1	1	1	1	1	1	1	1	1	1	1
Set 3	Nymphs	Alive	10	8	8	7	7	7	7	7	6	6	6	6
		Dead	0	0	0	0	0	0	0	0	0	0	0	0
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0
		Lost	0	2	0	1	0	0	0	0	1	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	8	8	7	7	7	7	7	6	6	6	6
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0

Table A9-6. Wood Roach Nymphs (800 mg/m^3 Group Exposed PM of 22 May 2003)

Observations of Wood Roach Nymph Survival for Exposure on May 21-22 2003														
			0	**1**	**3**	**5**	**7**	**9**	**11**	**13**	**15**	**18**	**20**	**22**
Size		**Date**	**22 May 2003**	**23 May 2003**	**25 May 2003**	**27 May 2003**	**29 May 2003**	**31 May 2003**	**2 Jun 2003**	**4 Jun 2003**	**6 Jun 2003**	**9 Jun 2003**	**11 Jun 2003**	**13 Jun 2003**
Set 1	Nymphs	Alive	10	9	9	9	9	8	8	7	8	8	8	8
		Dead	0	0	0	0	0	0	0	0	0	0	0	0
		Shed Skins	0	0	0	0	0	0	0	1	0	0	0	0
		Lost	0	1	0	0	0	1	0	1	-1	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	9	9	9	9	8	8	7	8	8	8	8
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	0	0	0	1	1	1	1	1
Set 2	Nymphs	Alive	10	10	10	9	9	9	9	9	9	9	9	9
		Dead	0	0	0	0	0	0	0	0	0	0	0	0
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0
		Lost	0	0	0	1	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	10	10	9	9	9	9	9	9	9	9	9
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0
Set 3	Nymphs	Alive	10	10	9	9	10	10	10	9	9	9	9	9
		Dead	0	0	0	0	0	0	0	0	0	0	0	0
		Shed Skins	0	0	0	0	0	0	0	0	0	0	0	0
		Lost	0	0	1	0	-1	0	0	1	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	10	10	9	9	10	10	10	9	9	9	9	9
		Fraction	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Skins	0	0	0	0	0	0	0	0	0	0	0	0

Table A10-1. Ants (Control Exposure Group, Wind Speed = 0 mph)

Date	Days	Set 1				Set 2				Set 3			
		Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
15-Mar-03	0	9	0	100	9	16	0	100	16	20	0	100	20
16-Mar-03	1	9	0	100	9	15	1	94	16	20	0	100	20
17-Mar-03	2	9	0	100	9	14	1	88	16	20	0	100	20
18-Mar-03	3	8	1	89	9	14	0	88	16	18	2	90	20
19-Mar-03	4	7	1	78	9	13	1	81	16	17	1	85	20
20-Mar-03	5	6	1	67	9	11	2	69	16	18	0	90	21
21-Mar-03	6	5	1	56	9	11	0	69	16	18	0	90	21
24-Mar-03	9	4	1	44	9	9	2	56	16	17	1	85	21
25-Mar-03	10	4	0	44	9	9	0	56.25	16	16	1	80	21
26-Mar-03	11	4	0	44	9	9	0	56.25	16	16	0	80	21
27-Mar-03	12	4	0	44	9	9	0	56.25	16	16	0	80	21
28-Mar-03	13	3	1	33	9	9	0	56.25	16	16	0	80	21
31-Mar-03	16	2	1	22	9	9	0	56.25	16	14	2	70	21
2-Apr-03	18	1	1	11	9	9	0	56.25	16	10	4	50	21
4-Apr-03	20	0	1	0	9	7	2	43.75	16	9	1	45	21
7-Apr-03	23	0	0	0	9	7	0	43.75	16	7	1	35	20
14-Apr-03	30	0	0	0	9	6	1	37.5	16	4	3	20	20
21-Apr-03	37	0	0	0	9	6	1	37.5	17	2	1	10.52632	19
24-Apr-03	40	0	0	0	9	6	0	37.5	17	2	0	10.52632	19
1-May-03	47	0	0	0	9	6	0	37.5	17	1	1	5.263158	19
8-May-03	54	0	0	0	9	6	0	37.5	17	1	0	5.263158	19
15-May-03	61	0	0	0	9	6	0	37.5	17	1	0	5.263158	19

Table A10-2. Ants (50 mg/m^3 Exposure Group, Wind Speed = 0 mph)

		Set 1				Set 2				Set 3			
Date	**Days**	**Alive**	**Dead**	**%Alive**	**No.**	**Alive**	**Dead**	**%Alive**	**No.**	**Alive**	**Dead**	**%Alive**	**No.**
16-Mar-03	0	12*	0	100	12	19	1	100	20	21†	0	100	21
17-Mar-03	1	11*	1	91.66667	12	17	3	89	21	19†	2	90.47619	21
18-Mar-03	2	12	0	100	13	13	3	68	20	17	2	80.95238	21
19-Mar-03	3	12	0	100	13	12	1	63	20	16	1	76.19048	21
20-Mar-03	4	11	0	91.66667	12	12	0	63	20	15	1	71.42857	21
21-Mar-03	5	11	0	91.66667	12	12	0	63	20	15†	0	71.42857	21
24-Mar-03	8	10	1	83.33333	12	12	0	63	20	15	0	71.42857	21
25-Mar-03	9	11	0	91.66667	13	12	0	63.15789	20	16	0	76.19048	22
26-Mar-03	10	10	0	83.33333	12	12	0	63.15789	20	14	0	66.66667	20
27-Mar-03	11	10	0	83.33333	12	12	0	63.15789	20	14	0	66.66667	20
28-Mar-03	12	9	1	75	12	12	0	63.15789	20	14	0	66.66667	20
31-Mar-03	15	0.403509‡	9‡	3.362573	12.40351	12	0	63.15789	20	14		66.66667	20
2-Apr-03	17	0‡				12	0	63.15789	20	11	2	52.38095	19†
Screen open, all ants escaped													
* 8 ants escaped, initial number reduced													
† Value adjusted, for consistency with other observations, 1 missing, total adjusted down													
‡ All specimens were dead. Apparent cause was excessive moisture possibly caused by warm weekend and vaporization and condensation of drinking water													

Table A10-3. Ants (100 mg/m^3 Exposure Group, Wind Speed = 0 mph)

Date	Days	Set 1				Set 2				Set 3			
		Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
17-Mar-03	0	20	0	100	20	20	0	100	20	20	0	100	20
18-Mar-03	1	20	0	100	20	20	0	100	20	19	1	95	20
19-Mar-03	2	20	0	100	20	20	0	100	20	19	0	95	20
20-Mar-03	3	19	1	95	20	19	0	100	19	17	1	89.47368	19
21-Mar-03	4	19	0	95	20	19	0	100	19	15	2	78.94737	19
24-Mar-03	7	18	1	90	20	14	5	74	19	14	1	73.68421	19
25-Mar-03	8	18	0	90	20	14	0	74	19	14	0	73.68421	19
26-Mar-03	9	18	0	90	20	13	1	68	19	14	0	73.68421	19
27-Mar-03	10	18	0	90	20	13	0	68	19	14	0	73.68421	19
28-Mar-03	11	18	0	90	20	10	3	53	19	14	0	73.68421	19
31-Mar-03	14	17	1	85	20	9	1	47	19	13	1	68.42105	19
2-Apr-03	16	17	0	85	20	8	1	42	19	8	5	42.10526	19
4-Apr-03	18	13	4	65	20	8	0	42	19	5	3	26.31579	19
7-Apr-03	21	13	0	65	20	8	0	42	19	5	0	26.31579	19
14-Apr-03	28	10	3	50	20	8	0	42	19	3	2	15.78947	19
21-Apr-03	35	7	3	35	20	7	1	37	19	3	0	15.78947	19
24-Apr-03	38	6	1	30	20	6	1	32	19	2	1	10.52632	19
1-May-03	45	6	0	30	20	5	0	28	18	2	0	10.52632	19
8-May-03	52	5	1	25	20	5	0	28	18	2	0	10.52632	19
15-May-03	59	5	0	25	20	4	1	22	18	1	1	5.263158	19

Table A10-4. Ants (400 mg/m^3 Exposure Group, Wind Speed = 0 mph)

		Set 1				Set 2				Set 3			
Date	**Days**	**Alive**	**Dead**	**%Alive**	**No.**	**Alive**	**Dead**	**%Alive**	**No.**	**Alive**	**Dead**	**%Alive**	**No.**
18-Mar-03	0	20	0	100	20	22	0	100	22	20	0	100	20
18-Mar-03	0.5	18	2	90	20	13	9	59	22	16	4	80	20
19-Mar-03	1	16	2	80	20	11	2	50	22	14	2	70	20
20-Mar-03	2	13	3	65	20	9	2	41	22	14	0	70	20
21-Mar-03	3	13	0	65	20	8	1	36	22	14	0	70	20
24-Mar-03	6	13	0	65	20	8	0	36.36364	22	13	1	65	20
25-Mar-03	7	13	0	65	20	8	0	36.36364	22	13	0	65	20
26-Mar-03	8	13	0	65	20	7	2	31.81818	23	13	0	65	20
27-Mar-03	9	13	0	65	20	7	0	31.81818	23	13	0	65	20
28-Mar-03	10	13	0	65	20	7	0	31.81818	23	13	0	65	20
31-Mar-03	13	11	2	55	20	7	0	31.81818	23	13	0	65	20
2-Apr-03	15	8	3	40	20	7	0	31.81818	23	13	0	65	20
4-Apr-03	17	8	0	40	20	6	1	27.27273	23	13	0	65	20
7-Apr-03	20	8	0	40	20	6	0	27.27273	23	13	0	65	20
14-Apr-03	27	6	2	30	20	5	1	22.72727	23	12	1	60	20
21-Apr-03	34	6	0	30	20	5	0	22.72727	23	12	0	60	20
24-Apr-03	37	6	0	30	20	5	0	22.72727	23	12	0	60	20
1-May-03	44	6	0	30	20	5	0	22.72727	23	8	4	40	20
8-May-03	51	6	0	30	20	5	0	22.72727	23	7	1	35	20
15-May-03	58	4	2	20	20	5	0	22.72727	23	6	1	30	20

Table A10-5. Ants (800 mg/m^3 Exposure Group, Wind Speed = 0 mph)

		Set 1				Set 2				Set 3			
Date	**Days**	**Alive**	**Dead**	**%Alive**	**No.**	**Alive**	**Dead**	**%Alive**	**No.**	**Alive**	**Dead**	**%Alive**	**No.**
18-Mar-03	0	19	0	100	19	21	0	100	21	16	0	100	16
19-Mar-03	1	15	4	78.94737	19	17	4	81	21	9	7	56.25	16
20-Mar-03	2	12	3	63.15789	19	17	0	81	21	9	0	56.25	16
21-Mar-03	3	12	0	63	19	17		81	21	9		56.25	16
24-Mar-03	6	5	7	26	19	16	1	76	21	9	0	56.25	16
25-Mar-03	7	4	1	21.05263	19	16	0	76.19048	21	9	0	56.25	16
26-Mar-03	8	4	0	21.05263	19	15	1	71.42857	21	8	1	50	16
27-Mar-03	9	4	0	21.05263	19	15	0	71.42857	21	7	1	43.75	16
28-Mar-03	10	4	0	21.05263	19	11	4	52.38095	21	6	1	37.5	16
31-Mar-03	13	0.296627				7	4	33.33333	21	6	0	37.5	16
2-Apr-03	15	0				7	0	33.33333	21	5	1	31.25	16
4-Apr-03	17					7	0	33.33333	21	5	0	31.25	16
7-Apr-03	20					6	1	28.57143	21	5	0	31.25	16
14-Apr-03	27					3	3	14.28571	21	4	1	25	16
21-Apr-03	34					3	0	14.28571	21	2	2	12.5	16
24-Apr-03	37					3	0	14.28571	21	2	0	12.5	16
1-May-03	44					2	1	9.52381	21	0	2	0	16
8-May-03	51					2	0	9.52381	21	0	0	0	16
15-May-03	58					2	0	9.52381	21	0	0	0	16

Table A10-6. Ants (Control Exposure Group, Wind Speed = 2 mph)

Date	Days	Set 1				Set 2				Set 3			
		Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
21-May-03	0	15	0	100	15	15	0	100	15	15	0	100	15
22-May-03	1	15	0	100	15	15	0	100	15	15	0	100	15
23-May-03	2	14	1	93.33333	15	15	0	100	15	15	0	100	15
25-May-03	4	14	0	93	15	15	0	100	15	15	0	100	15
27-May-03	6	14	0	93	15	15	0	100	15	15	0	100	15
29-May-03	8	14	0	93	15	15	0	100	15	14	1	93.33333	15
2-Jun-03	12	14	0	93	15	15	0	100	15	14	0	93.33333	15
4-Jun-03	14	13	1	87	15	15	0	100	15	14	0	93.33333	15
6-Jun-03	16	13	0	87	15	15	0	100	15	14	0	93.33333	15
9-Jun-03	19	8	4	57	14	15	0	100	15	13	1	86.66667	15
11-Jun-03	21	8	0	57	14	15	0	100	15	11	2	73.33333	15
13-Jun-03	23	8	0	57	14	14	1	93.33333	15	11	0	73.33333	15
16-Jun-03	26	6	2	43	14	14	0	93.33333	15	11	0	73.33333	15
18-Jun-03	28	6	0	43	14	14	0	93.33333	15	11	0	73.33333	15
20-Jun-03	30	6	0	43	14	12	1	80	14	11	0	73.33333	15
23-Jun-03	33	6	0	43	14	11	1	73.33333	14	11	0	73.33333	15
27-Jun-03	37	6	0	43	14	10	1	66.66667	14	11	0	73.33333	15
2-Jul-03	42	6	0	43	14	10	1	66.66667	15	9	2	60	15
9-Jul-03	49	5	1	36	14	1	9	6.666667	15	0	9	0	15

Table A10-7. Ants (100 mg/m^3 Exposure Group, Wind Speed = 2 mph)

Date	Days	Set 1				Set 2				Set 3			
		Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
21-May-03	0	15	0	100	15	15	0	100	15	15	0	100	15
23-May-03	2	14	1	93.33333	15	15	0	100	15	15	0	100	15
25-May-03	4	14	0	93	15	14	1	93	15	14	1	93.33333	15
27-May-03	6	13	1	87	15	14	0	93	15	14	0	93.33333	15
29-May-03	8	12	1	80	15	14	0	93.33333	15	14	0	93.33333	15
2-Jun-03	12	12	0	80	15	14	0	93.33333	15	14	0	93.33333	15
4-Jun-03	14	12	0	80	15	14	0	93.33333	15	13	0	92.85714	14
6-Jun-03	16	11	1	73.33333	15	13	1	86.66667	15	13	0	92.85714	14
9-Jun-03	19	9	2	60	15	12	1	80	15	13	0	92.85714	14
11-Jun-03	21	9	0	60	15	11	1	73.33333	15	12	1	85.71429	14
13-Jun-03	23	6	0	40	12	10	1	66.66667	15	10	2	71.42857	14
16-Jun-03	26	5	1	33.33333	12	10	0	66.66667	15	9	1	64.28571	14
18-Jun-03	28	5	0	33.33333	12	10	0	66.66667	15	9	0	64.28571	14
20-Jun-03	30	5	0	33.33333	12	10	0	66.66667	15	9	0	64.28571	14
23-Jun-03	33	4	1	26.66667	12	10	0	66.66667	15	9	0	64.28571	14
27-Jun-03	37	4	0	26.66667	12	10	0	66.66667	15	9	0	64.28571	14
2-Jul-03	42	3	1	20	12	6	4	40	15	8	1	57.14286	14
9-Jul-03	49	0	3	0	12	0	6	0	15	6	2	42.85714	14

Table A10-8. Ants (200 mg/m^3 Exposure Group, Wind Speed = 2 mph)

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
22-May-03	0	15	0	100	15	15	0	100	15	15	0	100	15
23-May-03	1	13	2	86.66667	15	13	2	87	15	13	2	86.66667	15
25-May-03	3	12	1	80	15	8	5	53	15	13	0	86.66667	15
27-May-03	5	12	0	80	15	7	1	47	15	13	0	86.66667	15
29-May-03	7	12	0	80	15	7	0	47	15	12	1	80	15
2-Jun-03	11	12	0	80	15	4	3	26.66667	15	12	0	80	15
4-Jun-03	13	11	1	73.33333	15	4	0	26.66667	15	12	0	80	15
6-Jun-03	15	11	0	73.33333	15	4	0	26.66667	15	11	1	73.33333	15
9-Jun-03	18	3	7	21.42857	14	1	3	6.666667	15	4	7	26.66667	15
11-Jun-03	20	3	0	21.42857	14	1	0	6.666667	15	2	2	13.33333	15
13-Jun-03	22	2	1	14.28571	14	1	0	6.666667	15	0	2	0	15
16-Jun-03	25	2	0	14.28571	14	1	0	6.666667	15	0	0	0	15
18-Jun-03	27	2	0	14.28571	14	1	0	6.666667	15	0	0	0	15
20-Jun-03	29	1	1	7.142857	14	1		6.666667	15			0	15
23-Jun-03	32	1	0	7.142857	14	1		6.666667	15			0	15
27-Jun-03	36	1		7.142857	14	0	1	0	15			0	15
2-Jul-03	41	0	1	0	14	0		0	15			0	15

Table A10-9. Ants (400 mg/m^3 Exposure Group, Wind Speed = 2 mph)

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
22-May-03	0	15	0	100	15	15	0	100	15	15	0	100	15
23-May-03	1	15	0	100	15	15	0	100	15	15	0	100	15
25-May-03	3	14	1	93.33333	15	14	1	93	15	15	0	100	15
27-May-03	5	14	0	93	15	14	0	93	15	14	1	93.33333	15
29-May-03	7	10	4	67	15	14	0	93	15	11	3	73.33333	15
2-Jun-03	11	8	2	53.33333	15	12	2	80	15	11	0	73.33333	15
4-Jun-03	13	3	5	20	15	11	1	73.33333	15	11	0	73.33333	15
6-Jun-03	15	2	1	13.33333	15	7	4	46.66667	15	10	1	66.66667	15
9-Jun-03	18	0	2	0	15	0	7	0	15	0	10	0	15
11-Jun-03	20	0	0	0	15	0	0	0	15	0	0	0	15

Table A10-10. Ants (800 mg/m^3 Exposure Group, Wind Speed = 2 mph)

Date	Days	Set 1				Set 2				Set 3			
		Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
22-May-03	0	15	0	100	15	15	0	100	15	15	0	100	15
23-May-03	1	15	0	100	15	14	1	93	15	15	0	100	15
25-May-03	3	15	0	100	15	14	0	93	15	15	0	100	15
27-May-03	5	14	1	93	15	9	5	60	15	15	0	100	15
29-May-03	7	14	0	93	15	8	1	53	15	15	0	100	15
2-Jun-03	11	13	1	86.66667	15	8	0	53.33333	15	15	0	100	15
4-Jun-03	13	12	1	80	15	5	1	38.46154	13	10	5	66.66667	15
6-Jun-03	15	12	0	80	15	4	0	33.33333	12	9	1	60	15
9-Jun-03	18	0	12	0	15	0	4	0	12	0	9	0	15
11-Jun-03	20	0	0	0	15	0	0	0	12	0	0	0	15

Table A10-11. Ants (Control Exposure Group, Wind Speed = 4 mph [8 mph in tunnel])

Date	Days	Set 1				Set 2				Set 3			
		Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
15-Jul-03	0	15	0	100.00	15	15	0	100.00	15	13	0	100.00	13
16-Jul-03	1	15	0	100.00	15	15	0	100.00	15	13	0	100.00	13
17-Jul-03	2	15	0	100.00	15	15	0	100.00	15	13	0	100.00	13
18-Jul-03	3	15	0	100.00	15	14	1	93.33	15	13	0	100.00	13
21-Jul-03	6	15	0	100.00	15	10	4	66.67	15	12	1	92.31	13
23-Jul-03	8	14	1	93.33	15	7	4	46.67	16	11	1	84.62	13
27-Jul-03	12	6	4	40.00	11	6	1	40.00	16	6	5	46.15	13
29-Jul-03	14	5	1	33.33	11	2	4	13.33	16	2	0	15.38	9
1-Aug-03	17	5	0	33.33	11	2	0	13.33	16	2	0	15.38	9
5-Aug-03	21	5	0	33.33	11	2	0	13.33	16	2	0	15.38	9
11-Aug-03	27	3	2	20.00	11	1	1	6.67	16	2	0	15.38	9
13-Aug-03	29	3	0	20.00	11	1	0	6.67	16	2	0	15.38	9
18-Aug-03	34	3	0	20.00	11	1	0	6.67	16	2	0	15.38	9
25-Aug-03	41	2	1	13.33	11	2	1	13.33	18	2	0	15.38	9
2-Sep-03	49	1	1	6.67	11	0	0	0.00	16	0	2	0.00	9
8-Sep-03	55	1	0	6.67	11	0	0	0.00	16	0	0	0.00	9
15-Sep-03		0	1	0.00	11	0	0	0.00	16	0	0	0.00	9

Table A10-12. Ants (50 mg/m^3 Exposure Group, Wind Speed = 4 mph [8 mph in tunnel])

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
16-Jul-03	0	6	0	100.00	6	14	0	100.00	14	14	0	100.00	14
17-Jul-03	1	5	1	83.33	6	11	3	78.57	14	14	0	100.00	14
18-Jul-03	2	5	0	83.33	6	10	1	71.43	14	12	2	85.71	14
21-Jul-03	5	5	0	83.33	6	7	3	50.00	14	6	6	42.86	14
23-Jul-03	7	5	0	83.33	6	5	2	35.71	14	5	1	35.71	14
27-Jul-03	11	4	1	66.67	6	3	2	21.43	14	1	4	7.14	14
29-Jul-03	13	2	2	33.33	6	2	1	14.29	14	1	0	7.14	14
1-Aug-03	16	2	0	33.33	6	1	1	7.14	14	1	0	7.14	14
5-Aug-03	20	2	0	33.33	6	1	0	7.14	14	1	0	7.14	14
11-Aug-03	26	1	1	16.67	6	1	0	7.14	14	1	0	7.14	14
13-Aug-03	28	1	0	16.67	6	1	0	7.14	14	1	0	7.14	14
18-Aug-03	33	1	0	16.67	6	1	0	7.14	14	0	1	0.00	14
25-Aug-03	40	0	1	0.00	6	0	1	0.00	14	0	0	0.00	14
2-Sep-03	48	0	0	0.00	6	0	0	0.00	14	0	0	0.00	14
8-Sep-03	54	0	0	0.00	6	0	0	0.00	14	0	0	0.00	14
15-Sep-03	61	0	0	0.00	6	0	0	0.00	14	0	0	0.00	14

Table A10-13. Ants (100 mg/m^3 Exposure Group, Wind Speed = 4 mph [8 mph in tunnel])

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
17-Jul-03	0	15	0	100	15	16	0	100	16	15	0	100	15
17-Jul-03	0	15	0	100	15	15	1	94	16	14	1	93.33333	15
18-Jul-03	1	12	3	80	15	13	2	81	16	11	3	73.33333	15
21-Jul-03	4	9	3	60	15	7	6	44	16	7	4	46.66667	15
23-Jul-03	6	8	1	53	15	7	0	44	16	6	1	40	15
27-Jul-03	10	5	3	33.33333	15	5	2	31.25	16	2	3	13.33333	14
29-Jul-03	12	3	2	20	15	5	0	31.25	16	2	0	13.33333	14
1-Aug-03	15	3	0	20	15	4	1	25	16	1	1	6.666667	14
5-Aug-03	19	2	1	13.33333	15	4	0	25	16	1	0	6.666667	14
11-Aug-03	25	2	0	13.33333	15	4	0	25	16	0	1	0	14
13-Aug-03	27	2	0	13.33333	15	4	0	25	16	0	0	0	14
18-Aug-03	32	2	0	13.33333	15	4	0	25	16	0	0	0	14
25-Aug-03	39	2	0	13.33333	15	4	0	25	16	0	0	0	14
2-Sep-03	47	2	0	13.33333	15	4	0	25	16	0	0	0	14
8-Sep-03	53	2	0	13.33333	15	4	0	25	16	0	0	0	14
15-Sep-03	60	2	0	13.33333	15	4	0	25	16	0	0	0	14

Table A10-14. Ants (200 mg/m^3 Exposure Group, Wind Speed = 4 mph [8 mph in tunnel])

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
18-Jul-03	0	15	0	100	15	15	0	100	15	15	0	100	15
18-Jul-03	0	12	3	80	15	15	0	100	15	13	2	86.66667	15
21-Jul-03	3	11	1	73.33333	15	12	3	80	15	9	4	60	15
23-Jul-03	5	8	3	53	15	10	2	67	15	6	3	40	15
27-Jul-03	9	5	3	33	15	2	8	13	15	0	6	0	15
29-Jul-03	11	4	1	26.66667	15	0	2	0	15	0	0	0	15
1-Aug-03	14	4	0	26.66667	15	0	0	0	15	0	0	0	15
5-Aug-03	18	4	6	26.66667	21	0	0	0	15	0	0	0	15
11-Aug-03	24	3	1	20	21	0	0	0	15	0	0	0	15
13-Aug-03	26	1	2	6.666667	21	0	0	0	15	0	0	0	15
18-Aug-03	31	0	1	0	21	0	0	0	15	0	0	0	15
25-Aug-03	38	0	0	0	21	0	0	0	15	0	0	0	15
2-Sep-03	46	0	0	0	21	0	0	0	15	0	0	0	15
8-Sep-03	52	0	0	0	21	0	0	0	15	0	0	0	15
15-Sep-03	59	0	0	0	21	0	0	0	15	0	0	0	15

Table A10-15. Ants (400 mg/m^3 Exposure Group, Wind Speed = 4 mph [8 mph in tunnel])

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
19-Jul-03	0	15	0	100	15	15	0	100	15	14	0	100	14
21-Jul-03	2	0	15	0	15	9	6	60	15	8	6	57.14286	14
23-Jul-03	4	0	0	0	15	14	0	93	20	7	1	50	14
27-Jul-03	8	0	0	0	15	6	3	40	15	4	3	28.57143	14
29-Jul-03	10	0	0	0	15	5	1	33	15	2	2	14.28571	14
1-Aug-03	13	0	0	0	15	4	1	26.66667	15	2	0	14.28571	14
5-Aug-03	17	0	0	0	15	2	0	13.33333	13	2	0	14.28571	14
11-Aug-03	23	0	0	0	15	1	0	6.666667	12	2	0	14.28571	14
13-Aug-03	25	0	0	0	15	1	0	6.666667	12	2	0	14.28571	14
18-Aug-03	30	0	0	0	15	0	1	0	12	2	0	14.28571	14
25-Aug-03	37	0	0	0	15	0	0	0	12	2	0	14.28571	14
2-Sep-03	45	0	0	0	15	0	0	0	12	2	0	14.28571	14
8-Sep-03	51	0	0	0	15	0	0	0	12	2	0	14.28571	14
15-Sep-03	58	0	0	0	15	0	0	0	12	2	0	14.28571	14

Table A10-16. Ants (50 mg/m^3 Control Exposure Group, Wind Speed = 8 mph [16 mph in tunnel])

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
15-Jul-03	0	15	0	100	15	15	0	100	15	15	5	100	20
16-Jul-03	1	15	0	100	15	15	0	100	15	10	1	66.66667	16
17-Jul-03	2	15	0	100	15	14	1	93	15	9	1	60	16
18-Jul-03	3	15	0	100	15	14	0	93	15	9	0	60	16
21-Jul-03	6	14	1	93	15	14	0	93	15	9	0	60	16
23-Jul-03	8	13	1	86.66667	15	14	0	93.33333	15	9	0	60	16
27-Jul-03	12	12	1	80	15	3	0	20	4	3	6	20	16
29-Jul-03	14	5	1	33.33333	9	3	0	20	4	3	0	20	16
1-Aug-03	17	1	4	6.666667	9	2	0	13.33333	3	3	0	20	16
5-Aug-03	21	0	1	0	9	2	0	13.33333	3	2	1	13.33333	16
11-Aug-03	27	0	0	0	9	1	1	6.666667	3	2	0	13.33333	16
13-Aug-03	29	0	0	0	9	0	0	0	2	2	0	13.33333	16
18-Aug-03	34	0	0	0	9	0	0	0	2	2	0	13.33333	16
25-Aug-03	41	0	0	0	9	0	0	0	2	2	0	13.33333	16
2-Sep-03	49	0	0	0	9	0	0	0	2	2	0	13.33333	16
8-Sep-03	55	0	0	0	9	0	0	0	2	2	0	13.33333	16

Table A10-17. Ants (50 mg/m^3 Exposure Group, Wind Speed = 8 mph [16 mph in tunnel])

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
16-Jul-03	0	10	0	100	10	15	0	100	15	10	0	100	10
17-Jul-03	1	9	1	90	10	15	0	100	15	7	3	70	10
18-Jul-03	2	9	0	90	10	14	1	93	15	7	0	70	10
21-Jul-03	5	6	3	60	10	13	1	87	15	5	2	50	10
23-Jul-03	7	6	0	60	10	12	1	80	15	2	3	20	10
27-Jul-03	11	0	0	0	4	5	7	33.33333	15	0	2	0	10
29-Jul-03	13	0	0	0	4	0	5	0	15	0	0	0	10
1-Aug-03	16	0	0	0	4	0	0	0	15	0	0	0	10
5-Aug-03	20	0	0	0	4	0	0	0	15	0	0	0	10
11-Aug-03	26	0	0	0	4	0	0	0	15	0	0	0	10
13-Aug-03	28	0	0	0	4	0	0	0	15	0	0	0	10
18-Aug-03	33	0	0	0	4	0	0	0	15	0	0	0	10
25-Aug-03	40	0	0	0	4	0	0	0	15	0	0	0	10
2-Sep-03	48	0	0	0	4	0	0	0	15	0	0	0	10
8-Sep-03	54	0	0	0	4	0	0	0	15	0	0	0	10
15-Sep-03	61	0	0	0	4	0	0	0	15	0	0	0	10

Table A10-18. Ants (100 mg/m^3 Exposure Group, Wind Speed = 8 mph [16 mph in tunnel])

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
17-Jul-03	0	15	0	100.00	15	15	0	100	15	15	0	100	15
17-Jul-03	0	12	3	80.00	15	13	2	86.67	15	14	1	93.33	15
18-Jul-03	1	12	0	80.00	15	13	0	86.67	15	14	0	93.33	15
21-Jul-03	4	9	3	60.00	15	11	2	73.33	15	9	5	60.00	15
23-Jul-03	6	8	1	53.33	15	7	4	46.67	15	6	3	40.00	15
27-Jul-03	10	3	5	20.00	15	8	3	53.33	19	0	6	0.00	15
29-Jul-03	12	3	0	20.00	15	5	2	33.33	18	0	6	0.00	21
1-Aug-03	15	3	0	20.00	15	5	0	33.33	18	0	0	0.00	21
5-Aug-03	19	3	0	20.00	15	5	0	33.33	18	0	0	0.00	21
11-Aug-03	25	3	0	20.00	15	5	0	33.33	18	0	0	0.00	21
13-Aug-03	27	3	0	20.00	15	5	0	33.33	18	0	0	0.00	21
18-Aug-03	32	3	0	20.00	15	5	0	33.33	18	0	0	0.00	21
25-Aug-03	39	1	2	6.67	15	5	0	33.33	18	0	0	0.00	21
2-Sep-03	47	1	0	6.67	15	5	0	33.33	18	0	0	0.00	21
8-Sep-03	53	1	0	6.67	15	5	0	33.33	18	0	0	0.00	21
15-Sep-03	60	1	0	6.67	15	4	0	26.67	17	0	0	0.00	21

Table A10-19. Ants (200 mg/m^3 Exposure Group, Wind Speed = 8 mph [16 mph in tunnel])

		Set 1				Set 2				Set 3			
Date	Days	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
18-Jul-03	0	15	0	100	15	15	0	100	15	15	0	100	15
18-Jul-03	0	11	4	73.33333	15	13	2	87	15	11	4	73.33333	15
21-Jul-03	3	7	4	46.66667	15	12	1	80	15	6	5	40	15
23-Jul-03	5	5	2	33	15	6	6	40	15	6	0	40	15
27-Jul-03	9	3	2	20	15	6	0	40	15	3	3	20	15
29-Jul-03	11	0	3	0	15	6	0	40	15	3	0	20	15
1-Aug-03	14	0	0	0	15	5	1	33.33333	15	3	0	20	15
5-Aug-03	18	0	0	0	15	1	4	6.666667	15	2	1	13.33333	15
11-Aug-03	24	0	0	0	15	0	1	0	15	0	2	0	15
13-Aug-03	26	0	0	0	15	0	0	0	15	0	0	0	15
18-Aug-03	31	0	0	0	15	0	0	0	15	0	0	0	15
25-Aug-03	38	0	0	0	15	0	0	0	15	0	0	0	15
2-Sep-03	46	0	0	0	15	0	0	0	15	0	0	0	15
8-Sep-03	52	0	0	0	15	0	0	0	15	0	0	0	15
15-Sep-03	59	0	0	0	15	0	0	0	15	0	0	0	15

Table A10-20. Ants (400 mg/m^3 Exposure Group, Wind Speed = 8 mph [16 mph in tunnel])

Date	Days	Set 1				Set 2				Set 3			
		Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.	Alive	Dead	%Alive	No.
19-Jul-03	0	15	0	100	15	15	0	100	15	15	0	100	15
21-Jul-03	2	0	15	0	15	0	15	0	15	3	12	20	15
23-Jul-03	4	0	0	0	15	0	0	0	15	3	0	20	15
27-Jul-03	8	0	0	0	15	0	0	0	15	0	3	0	15
29-Jul-03	10	0	0	0	15	0	0	0	15	0	0	0	15
1-Aug-03	13	0	0	0	15	0	0	0	15	0	0	0	15
5-Aug-03	17	0	0	0	15	0	0	0	15	0	0	0	15
11-Aug-03	23	0	0	0	15	0	0	0	15	0	0	0	15
13-Aug-03	25	0	0	0	15	0	0	0	15	0	0	0	15
18-Aug-03	30	0	0	0	15	0	0	0	15	0	0	0	15
25-Aug-03	37	0	0	0	15	0	0	0	15	0	0	0	15
2-Sep-03	45	0	0	0	15	0	0	0	15	0	0	0	15
8-Sep-03	51	0	0	0	15	0	0	0	15	0	0	0	15
15-Sep-03	58	0	0	0	15	0	0	0	15	0	0	0	15

Table A11-1. Beetle First Instar (Control Group Exposed AM of 21 May 2003)

Observations of Beetle Larvae Survival for Exposure on May 21-22 2003						
			0	**3**	**5**	**7**
Size		**Date**	**6-Jun-03**	**9-Jun-03**	**11-Jun-03**	**13-Jun-03**
		Alive	30	29	29	29
	Grubs	Dead	0	1	0	0
		Alive	0	0	0	0
	New pupae	Dead	0	0	0	0
		Adult	0	0	0	0
	New Adults	Dead A	0	0	0	0
		Tot Alive	30	29	29	29
		Fraction	1.000	0.967	0.967	0.967
Set 1	Summary	Total	30	30	30	30
		Alive	30	29	28	26
	Grubs	Dead	0	0	1	2
		Pupae	0	0	0	0
	New pupae	Dead P	0	0	0	0
		Adult	0	0	0	0
	New Adults	Dead A	0	0	0	0
		Tot Alive	30	29	28	26
		Fraction	1.000	0.967	0.933	0.929
Set 2	Summary	Total	30	29	29	29
		Alive	30	30	30	29
	Grubs	Dead	0	0	0	1
		Pupae	0	0	0	0
	New pupae	Dead P	0	0	0	0
		Adult	0	0	0	0
	New Adults	Dead A	0	0	0	0
		Tot Alive	30	30	30	29
		Fraction	1	1	1	0.966667
Set 3	Summary	Total	30	30	30	30
		Alive	30	30	28	27
	Grubs	Dead	0	0	0	1
		Pupae	0	0	0	0
	New pupae	Dead P	0	0	0	0
		Adult	0	0	0	0
	New Adults	Dead A	0	0	0	0
		Tot Alive	30	30	28	27
		Fraction	1	1	0.933333	0.900
Set 4	Summary	Total	30	30	28	28

Table A11-2. Beetle First Instar (50 mg/m^3 Group Exposed AM of 21 May 2003)

Observations of Beetle Larvae Survival for Exposure on May 21-22 2003											
			0	**1**	**2**	**6**	**9**	**12**	**19**	**21**	**23**
Size		**Date**	**21-May-03**	**22-May-03**	**23-May-03**	**27-May-03**	**30-May-03**	**2-Jun-03**	**9-Jun-03**	**11-Jun-03**	**13-Jun-03**
Set 1	Grubs	Alive	31	30	29	19	14	13	13	13	13
		Dead	0	1	0	10	5	1	0	0	0
	New pupae	Pupae	0	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	31	30	29	19	14	13	13	13	13
		Fraction	1.000	0.968	0.935	0.613	0.452	0.419	0.419	0.419	0.419
		Total	31	31	30	30	30	30	30	30	30
Set 2	Grubs	Alive	30	30	30	19	11	9	9	9	9
		Dead	0	0	0	11	8	2	0	0	0
	New pupae	Pupae	0	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	30	30	19	11	9	9	9	9
		Fraction	1.000	1.000	1.000	0.633	0.367	0.300	0.300	0.300	0.300
		Total	30	30	30	30	30	30	30	30	30
Set 3	Grubs	Alive	30	30	30	23	14	14	14	13	13
		Dead	0	0	0	7	8	0	0	1	1
	New pupae	Pupae	0	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	30	30	23	14	14	14	13	13
		Fraction	1.000	1.000	1.000	0.767	0.467	0.467	0.467	0.433	0.433
		Total	30	30	30	30	29	29	29	29	30

Table A11-3. Beetle First Instar (100 mg/m^3 Group Exposed PM of 21 May 2003)

Observations of Beetle Larvae Survival for Exposure on May 21-22 2003											
			0	**1**	**2**	**6**	**9**	**12**	**19**	**21**	**23**
Size		**Date**	**21-May-03**	**22-May-03**	**23-May-03**	**27-May-03**	**30-May-03**	**2-Jun-03**	**9-Jun-03**	**11-Jun-03**	**13-Jun-03**
Set 1	Grubs	Alive	30	29	28	23	22	21	20	19	19
		Dead	0	1	1	4	2	1	1	1	0
	New pupae	Pupae	0	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	29	28	23	22	21	20	19	19
		Fraction	1.000	0.967	0.933	0.767	0.733	0.700	0.667	0.633	0.633
		Total	30	30	30	29	30	30	30	30	30
Set 2	Grubs	Alive									
		Dead	30	30	28	19	16	8	7	7	7
	New pupae	Pupae	0	0	2	9	3	8	1	0	0
		Dead P	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	0	0	0		0	0	0	0	0
		Fraction	30	30	28	19	16	8	7	7	7
		Total	1.000	1.000	0.933	0.633	0.533	0.267	0.233	0.233	0.233
Set 3	Grubs	Alive	30	30	30	30	30	30	30	30	30
		Dead	30	29	29	29	25	23	23	23	23
	New pupae	Pupae	0	1	0	0	3	2	0	0	0
		Dead P	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	0	0	0	0	0	0	0	0	0
		Fraction	30	29	29	29	25	23	23	23	23
		Total	1.000	0.967	0.967	0.967	0.833	0.767	0.767	0.767	0.767

Table A11-4. Beetle First Instar (200 mg/m^3 Group Exposed AM of 22 May 2003)

Observations of Beetle Larvae Survival for Exposure on May 21-22 2003										
			0	**1**	**5**	**8**	**11**	**18**	**20**	**22**
Size		**Date**	**22-May-03**	**23-May-03**	**27-May-03**	**30-May-03**	**2-Jun-03**	**9-Jun-03**	**11-Jun-03**	**13-Jun-03**
Set 1	Grubs	Alive	30	30	24	23	21	18	18	17
		Dead	0	0	6	1	2	3	0	1
	New pupae	Pupae	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	30	24	23	21	18	18	17
		Fraction	1.000	1.000	0.800	0.767	0.700	0.600	0.600	0.567
		Total	30	30	30	30	30	30	30	30
Set 2	Grubs	Alive	30	28	25	14	10	9	9	9
		Dead	0	2	3	10	4	1	0	0
	New pupae	Pupae	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	28	25	14	10	9	9	9
		Fraction	1.000	0.933	0.833	0.467	0.333	0.300	0.300	0.300
		Total	30	30	30	29	29	29	29	29
Set 3	Grubs	Alive	30	28	25	9	8	9	9	9
		Dead	0	2	3	15	1	1	1	0
	New pupae	Pupae	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	28	25	9	8	9	9	9
		Fraction	1.000	0.933	0.833	0.300	0.267	0.300	0.300	0.300
		Total	30	30	30	29	29	31	32	32

Table A11-5. Beetle First Instar (800 mg/m^3 Group Exposed PM of 22 May 2003)

Observations of Beetle Larvae Survival for Exposure on May 21-22 2003										
			0	**1**	**5**	**8**	**11**	**18**	**20**	**22**
Size		**Date**	**22-May-03**	**23-May-03**	**27-May-03**	**30-May-03**	**2-Jun-03**	**9-Jun-03**	**11-Jun-03**	**13-Jun-03**
Set 1	Grubs	Alive	30	30	29	28	20	19	18	18
		Dead	0	0	1	1	8	1	2	0
	New pupae	Pupae	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	30	29	28	20	19	18	18
		Fraction	1.000	1.000	0.967	0.933	0.667	0.633	0.600	0.600
		Total	30	30	30	30	30	30	31	31
Set 2	Grubs	Alive	30	30	30	23	23	0	0	0
		Dead	0	0	0	7	1	8	0	0
	New pupae	Pupae	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	30	30	23	23	0	0	0
		Fraction	1.000	1.000	1.000	0.767	0.767	0.000	0.000	0.000
		Total	30	30	30	30	31	16	16	16
Set 3	Grubs	Alive	30	25	23	20	16	15	14	14
		Dead	0	4	2	3	4	2	1	0
	New pupae	Pupae	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0
	Summary	Tot Alive	30	25	23	20	16	15	14	14
		Fraction	1.000	0.833	0.767	0.667	0.533	0.500	0.467	0.467
		Total	30	29	29	29	29	30	30	30

Table A12-1. Beetle Larvae (Control Group Exposed PM of 12 Feb 2003)

Observations of Beetle Larvae Survival for Exposure on February 10-12, 2003												
			0	**1**	**6**	**9**	**13**	**19**	**22**	**28**	**33**	**37**
Size		**Date**	**9-Feb-03**	**12-Feb-03**	**18-Feb-03**	**21-Feb-03**	**25-Feb-03**	**3-Mar-03**	**6-Mar-03**	**12-Mar-03**	**17-Mar-03**	**21-Mar-03**
Mini	Grubs	Alive	400	338	330	323	313	312	306	284	273	275
		Dead	0	50	6	3	12	9	7	20	8	1
	New pupae	Alive	0	0	0	0	0	0	0	0	0	0
		Dead	0	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	400	338	330	323	313	312	306	284	273	275
		Fraction	1.000	0.845	0.825	0.808	0.783	0.780	0.765	0.710	0.683	0.688
		Total	400	388	386	382	384	392	393	391	388	391
Small	Grubs	Alive	400	374	350	115	105	113	111	109	96	84
		Dead	0	21	16	0	1	4	1	2		0
	New pupae	Pupae	0	0	0	0	0	0	0	0	13	4
		Dead P	0	0	0	0	0	0	0	0		0
	New Adults	Adult	0	0	0	0	0	0	0	0		0
		Dead A	0	0	0	0	0	0	0	0		0
	Summary	Tot Alive	400	374	350	115	105	113	111	109	109	101
		Fraction	1.000	0.935	0.875	0.827	0.755	0.813	0.799	0.784	0.784	0.727
		Total	400	395	387	152	143	155	154	154	154	146
Medium	Grubs	Alive	400	393	383	382	373	361	352	334	221	140
		Dead	0	14	17	1	7	12	9	11	8	2
	New pupae	Pupae	0	0	0	0	0	0	1	9	98	50
		Dead P	0	0	0	0	0	0	0	1	0	3
	New Adults	Adult	0	0	0	0	0	0	0	0	0	5
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	400	393	383	382	373	361	353	343	328	294
		Fraction	1	0.9825	0.9575	0.955	0.9325	0.9025	0.8825	0.8575	0.82	0.735
		Total	400	407	414	414	412	412	413	416	409	383
Large	Grubs	Alive	400	392	376	366	339	304	228	50	13	5
		Dead	0	3	6	0	2	0	10	9	7	1
	New pupae	Pupae	0	5	10	10	27	34	66	161	30	4
		Dead P	0	0	0	0	0	0	0	8	5	29
	New Adults	Adult	0	0	0	0	4	18	32	20	72	89
		Dead A	0	0	0	0	0	0	1	2	0	0
	Summary	Tot Alive	400	397	391	391	391	390	379	352	340	307
		Fraction	1	0.9925	0.9775	0.9775	0.9775	0.975	0.9475	0.88	0.85	0.7675
		Total	400	400	400	400	402	401	402	404	409	435

Table A12-2. Beetle Larvae (25 mg/m^3 Group Exposed PM of 12 Feb 2003)

Observations of Beetle Larvae Survival for Exposure on February 10-12, 2003												
			0	**1**	**6**	**9**	**13**	**19**	**22**	**28**	**33**	**37**
Size		**Date**	**9-Feb-03**	**12-Feb-03**	**18-Feb-03**	**21-Feb-03**	**25-Feb-03**	**3-Mar-03**	**6-Mar-03**	**12-Mar-03**	**17-Mar-03**	**21-Mar-03**
Mini	Grubs	Alive	300	259	249	237	229	232	230	217	208	199
		Dead	0	41	6	8	7	2	2	13	6	3
	New pupae	Alive	0	0	0	0	0	0	0	0	2	6
		Dead	0	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	300	259	249	237	229	232	230	217	210	207
		Fraction	1.000	0.863	0.830	0.790	0.763	0.773	0.767	0.723	0.700	0.690
		Total	300	300	296	292	291	296	296	296	295	295
Small	Grubs	Alive	300	275	265	255	249	247	236	245	215	194
		Dead	0	30	8	8	5	2	1	1	3	0
	New pupae	Pupae	0	0	0	0	0	0	0	1	27	15
		Dead P	0	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	300	275	265	255	249	247	236	246	243	237
		Fraction	1.000	0.917	0.883	0.850	0.830	0.823	0.787	0.820	0.810	0.790
		Total	300	305	303	301	300	300	290	301	301	295
Medium	Grubs	Alive	300	293	287	272	267	261	258	164	118	77
		Dead	0	8	7	11	2	5	4	10	0	2
	New pupae	Pupae	0	0	0	0	0	1	0	82	47	24
		Dead P	0	0	0	0	0	0	0	0	0	1
	New Adults	Adult	0	0	0	0	0	0	0	0	0	5
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	300	293	287	272	267	262	259	247	248	230
		Fraction	1.000	0.977	0.957	0.907	0.890	0.873	0.863	0.823	0.827	0.767
		Total	300	301	302	298	295	295	296	294	295	281
Large	Grubs	Alive	500	491	478	294	301	254	196	26	11	4
		Dead	0	5	0	5	4	3	2	10	4	3
	New pupae	Pupae	0	2	12	127	18	14	52	142	14	2
		Dead P	0	0	0	0	0		0	6	25	5
	New Adults	Adult	0	0	0	0	0	33	110	95	39	81
		Dead A	0	0	0	0	0		6	6	5	7
	Summary	Tot Alive	500	493	492	435	460	427	415	375	344	327
		Fraction	1.000	0.986	0.984	0.870	0.920	0.854	0.830	0.750	0.688	0.654
		Total	500	498	497	445	474	444	446	440	473	483

Table A12-3. Beetle Larvae (50 mg/m^3 Group Exposed AM of 13 Feb 2003)

Observations of Beetle Larvae Survival for Exposure on Februrary 10-12, 2003												
			0	**1**	**6**	**11**	**13**	**18**	**25**	**27**	**32**	**36**
Size		**Date**	**9-Feb-03**	**14-Feb-03**	**19-Feb-03**	**24-Feb-03**	**26-Feb-03**	**3-Mar-03**	**10-Mar-03**	**12-Mar-03**	**17-Mar-03**	**21-Mar-03**
Mini	Grubs	Alive	300	226	212	207	205	189	188	184	180	181
		Dead	0	66	8	5	3	5	8	5	2	1
	New pupae	Pupae	0	0	0	0	0	0	0	0	0	0
		Dead P	0	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	0
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	300	226	212	207	205	189	188	184	180	181
		Fraction	1.000	0.753	0.707	0.690	0.683	0.630	0.627	0.613	0.600	0.603
		Total	300	292	286	286	287	276	283	284	282	284
		Date							**7-Mar-03**	**15-Mar-03**	**29**	
Small	Grubs	Alive	300	294	278	262	258	244	251	229	216	192
		Dead	0	13	9	16	4	4	1	6		2
	New pupae	Pupae	0	0	0	0	0	0	0	18	13	16
		Dead P	0	0	0	0	0	0	0	0		0
	New Adults	Adult	0	0	0	0	0	0	0	0		0
		Dead A	0	0	0	0	0	0	0	0		0
	Summary	Tot Alive	300	294	278	262	258	244	251	247	247	239
		Fraction	1.000	0.980	0.927	0.873	0.860	0.813	0.837	0.823	0.823	0.797
		Total	300	307	300	300	300	290	298	300	300	294
		Date					**20-->**	**5-Mar-03**	**7-Mar-03**	**15-Mar-03**		
Med	Grubs	Alive	300	297	292	278	278	271	269	151	102	71
		Dead	0	7	5	9	3	5	0	7	1	4
	New pupae	Pupae	0	0	0	0	0	1	1	111	47	15
		Dead P	0	0	0	0	0	0	0	0		0
	New Adults	Adult	0	0	0	0	0	0	0	0		11
		Dead A	0	0	0	0	0	0	0	0		0
	Summary	Tot Alive	300	297	292	278	278	272	271	264	262	246
		Fraction	1.000	0.990	0.973	0.927	0.927	0.907	0.903	0.880	0.873	0.820
		Total	300	304	304	299	302	301	300	300	299	287
		Date					**18-->**	**3-Mar-03**	**7-Mar-03**	**15-Mar-03**		
Large	Grubs	Alive	300	296	280	234	219	168	74	11	6	2
		Dead	0	1	5	1	0	0	2	2	2	0
	New pupae	Pupae	0	3	11	45	14	51	90	60	4	1
		Dead P	0	0	0	0	0	0	3	5		0
	New Adults	Adult	0	0	0	0	4	17	0	99	53	1
		Dead A	0	0	0	0	0	0	0	2		5
	Summary	Tot Alive	300	299	294	293	292	292	285	275	274	266
		Fraction	1.000	0.997	0.980	0.977	0.973	0.973	0.950	0.917	0.913	0.887
		Total	300	300	300	300	299	299	300	306	307	309

Table A12-4. Beetle Larvae (100 mg/m^3 Group Exposed PM of 13 Feb 2003)

Observations of Beetle Larvae Survival for Exposure on Februrary 10-12, 2003												
			0	**4**	**6**	**11**	**14**	**20**	**26**	**30**	**32**	**39**
Size		**Date**	**9-Feb-03**	**17-Feb-03**	**19-Feb-03**	**24-Feb-03**	**27-Feb-03**	**5-Mar-03**	**11-Mar-03**	**15-Mar-03**	**17-Mar-03**	**24-Mar-03**
Mini	Grubs	Alive	300	274	258	258	240	226	210	208	208	
		Dead	0	30	8	2	17	14	17	4	1	
	New pupae	Pupae	0	0	0	0	0	0	0			
		Dead P	0	0	0	0	0	0	0			
	New Adults	Adult	0	0	0	0	0	0	0			
		Dead A	0	0	0	0	0	0	0			
	Summary	Tot Alive	300	274	258	258	240	226	210	208	208	0
		Fraction	1.000	0.913	0.860	0.860	0.800	0.753	0.700	0.693	0.693	0.000
		Total	300	304	296	298	297	297	298	300	301	93
		Date			**20-Feb-03**				**11-Mar-03**			
Small	Grubs	Alive	300	277	262	244	238	246	231	204	195	143
		Dead	0	23	17	8	6	9	6	3	3	1
	New pupae	Pupae	0	0	0	0	0	0	1	20	9	41
		Dead P	0	0	0	0	0	0	0			0
	New Adults	Adult	0	0	0	0	0	0	0			9
		Dead A	0	0	0	0		0	0			0
	Summary	Tot Alive	300	277	262	244	238	246	232	225	225	214
		Fraction	1.000	0.923	0.873	0.813	0.793	0.820	0.773	0.750	0.750	0.713
		Total	300	300	302	292	292	309	301	297	300	290
Medium	Grubs	Alive	300	298	467	424						
		Dead	0	2	11	22						
	New pupae	Pupae	0	0	0	0						
		Dead P	0	0	0	0						
	New Adults	Adult	0	0	0	0						
		Dead A	0	0	0	0						
	Summary	Tot Alive	300	298	467	424	0	0	0	0	0	0
		Fraction	1.000	0.993	0.973	0.883	0.000	0.000	0.000	0.000	0.000	0.000
		Total	300	300	480	459	35	35	35	35	35	35
									10-Mar-03	**11-Mar-03**		
Large	Grubs	Alive	300	299	281	264	193	106	26	20	5	2
		Dead	0	0	1	1	1	7	2	1	1	0
	New pupae	Pupae	0	1	15	16	27	83	90	5	13	0
		Dead P	0	0	0	0	0	5	2	2	1	0
	New Adults	Adult	0	0	0	0	0	58	41	15	99	5
		Dead A	0	0	0	0		0	1	1	4	3
	Summary	Tot Alive	300	300	297	296	252	243	250	246	239	233
		Fraction	1.000	1.000	0.990	0.987	0.840	0.810	0.833	0.820	0.797	0.777
		Total	300	300	298	298	255	263	278	281	285	285

Table A12-5. Beetle Larvae (200 mg/m^3 Group Exposed AM of 14 Feb 2003)

Observations of Beetle Larvae Survival for Exposure on Februrary 10-12, 2003												
			0	**3**	**6**	**11**	**13**	**19**	**25**	**29**	**32**	**38**
Size		**Date**	**13-Feb-03**	**17-Feb-03**	**20-Feb-03**	**25-Feb-03**	**27-Feb-03**	**5-Mar-03**	**11-Mar-03**	**15-Mar-03**	**18-Mar-03**	**24-Mar-03**
Mini	Grubs	Alive	300	251	260	242	242	232	226	217	211	
		Dead	0	31	6	2	2	6	13	7	4	
	New pupae	Pupae	0	0	0	0	0	0	0	1	2	
		Dead P	0	0	0	0	0	0	0		0	
	New Adults	Adult	0	0	0	0	0	0	0		0	
		Dead A	0	0	0	0	0	0	0		0	
	Summary	Tot Alive	300	251	260	242	242	232	226	218	214	3
		Fraction	1.000	0.837	0.867	0.807	0.807	0.773	0.753	0.727	0.713	0.010
		Total	300	282	297	281	283	279	286	285	285	74
Small	Grubs	Alive	300	280	276	265	251	251	246	224	218	178
		Dead	0	20	3	7	15	3	4	1	1	1
	New pupae	Pupae	0	0	0	0	0	0	0	17	10	23
		Dead P	0	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	11
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	300	280	276	265	251	251	246	241	245	228
		Fraction	1.000	0.933	0.920	0.883	0.837	0.837	0.820	0.803	0.817	0.760
		Total	300	300	299	295	296	299	298	294	299	283
Medium	Grubs	Alive	300	288	287	278	271	269	258	224	218	113
		Dead L	0	9	3	9	6	3	7	3	1	3
	New pupae	Pupae	0	0	0	0	0	0	1	29	10	34
		Dead P	0	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	11
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	300	288	287	278	271	269	259	254	258	187
		Fraction	1.000	0.960	0.957	0.927	0.903	0.897	0.863	0.847	0.860	0.623
		Total	300	297	299	299	298	299	296	294	299	231
										16-Mar-03		
Large	Grubs	Alive	300	291	280	215	200	129	26	10	5	1
		Dead	0	1	1	3	4	6	2	1	0	0
	New pupae	Pupae	0	8	9	61	9	66	99	16	5	1
		Dead P	0	0	0	2	0	1	9	1	3	0
	New Adults	Adult	0	0	0	0	0	48	37	75	47	14
		Dead A	0	0	0	0	0	0	0	1	0	0
	Summary	Tot Alive	300	299	297	291	285	279	266	264	261	258
		Fraction	1.000	0.997	0.990	0.970	0.950	0.930	0.887	0.880	0.870	0.860
		Total	300	300	299	300	298	300	307	310	313	310

Table A12-6. Beetle Larvae (400 mg/m^3 Group Exposed PM of 14 Feb 2003)

Observations of Beetle Larvae Survival for Exposure on Februrary 10-12, 2003												
			0	**3**	**6**	**11**	**13**	**19**	**25**	**30**	**32**	**38**
Size		**Date**	**13-Feb-03**	**17-Feb-03**	**20-Feb-03**	**25-Feb-03**	**27-Feb-03**	**5-Mar-03**	**11-Mar-03**	**16-Mar-03**	**18-Mar-03**	**24-Mar-03**
Mini	Grubs	Alive	300	259	248	244	240	233	208	201	198	
		Dead	0	32	11	4	3	7	25	4	3	
	New pupae	Pupae	0	0	0	0	0	0	0	1	0	
		Dead P	0	0	0	0	0	0	0	0	0	
	New Adults	Adult	0	0	0	0	0	0	0	0	0	
		Dead A	0	0	0	0	0	0	0	0	0	
	Summary	Tot Alive	300	259	248	244	240	233	208	202	199	1
		Fraction	1.000	0.863	0.827	0.813	0.800	0.777	0.693	0.673	0.663	0.003
		Total	300	291	291	291	290	290	290	288	288	90
Small	Grubs	Alive	300	264	258	243	237	232	227	206	195	142
		Dead	0	33	4	14	6	8	5	2	0	5
	New pupae	Pupae	0	0	0	0	0	0	1	19	6	37
		Dead P	0	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	0	15
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	300	264	258	243	237	232	228	226	221	205
		Fraction	1.000	0.983	0.967	0.940	0.913	0.920	0.907	0.857	0.863	0.793
		Total	300	297	295	294	294	297	298	298	293	282
Medium	Grubs	Alive	300	295	290	281	273	275	264	130	112	63
		Dead	0	5	5	8	6	6	2	3	4	2
	New pupae	Pupae	0	0	0	1	0	0	7	119	20	28
		Dead P	0	0	0	0	0	0	0	0	0	0
	New Adults	Adult	0	0	0	0	0	0	0	0	3	95
		Dead A	0	0	0	0	0	0	0	0	0	0
	Summary	Tot Alive	300	295	290	282	274	276	272	257	259	238
		Fraction	1.000	0.983	0.967	0.940	0.913	0.920	0.907	0.857	0.863	0.793
		Total	300	300	300	300	298	306	304	292	298	279
		Date							**12-Mar-03**	**26**	**0**	
Large	Grubs	Alive	200	196	185	132	122	77	15	4	4	1
		Dead	0	3	1	2	1	4	1	0	0	0
	New pupae	Pupae	0	4	10	50	9	43	59	9	0	0
		Dead P	0	0	0	0	0	3	7	2	0	2
	New Adults	Adult	0	0	0	0	0	42	44	37	25	13
		Dead A	0	0	0	0	0	0	3	1	0	0
	Summary	Tot Alive	200	200	199	196	195	190	177	172	172	167
		Fraction	1.000	1.000	0.995	0.980	0.975	0.950	0.885	0.860	0.860	0.835
		Total	200	203	203	202	202	207	215	216	216	215

Table A13-1. Beetle Adults (Control Exposure Group, March 2003)

Date	Days	Set 1			
		Alive	Dead	%Alive	No.
16-Mar-03	0	24	0	100	24
17-Mar-03	1	24	0	100	24
18-Mar-03	2	23	1	95.83333	24
19-Mar-03	3	23	0	96	24
20-Mar-03	4				
21-Mar-03	5				
22-Mar-03	6				
23-Mar-03	7				
24-Mar-03	8	21	2	88	24
25-Mar-03	9				
26-Mar-03	10	21	0	88	24
27-Mar-03	11	17	4	71	24
28-Mar-03	12				
29-Mar-03	13				
30-Mar-03	14				
31-Mar-03	15				
1-Apr-03	16				
2-Apr-03	17				
3-Apr-03	18				
4-Apr-03	19	2*	15*	8	24
5-Apr-03	20				
6-Apr-03	21				
7-Apr-03	22	0	2	0	24

* Mold in cage

Table A13-2. Beetle Adults (50 mg/m^3 Exposure Group, March 2003)

Date	Days	Set 1			
		Alive	Dead	%Alive	No.
16-Mar-03	0	24	0	100	24
17-Mar-03	1	24	0	100	24
18-Mar-03	2	24	0	100	24
19-Mar-03	3	23	1	96	24
20-Mar-03	4				
21-Mar-03	5				
22-Mar-03	6				
23-Mar-03	7				
24-Mar-03	8	16	7	67	24
25-Mar-03	9				
26-Mar-03	10	16	0	67	24
27-Mar-03	11	14	2	58	24
28-Mar-03	12				
29-Mar-03	13				
30-Mar-03	14				
31-Mar-03	15				
1-Apr-03	16				
2-Apr-03	17				
3-Apr-03	18				
4-Apr-03	19	11	3	46	24
5-Apr-03	20				
6-Apr-03	21				
7-Apr-03	22	10	1	42	24
8-Apr-03	23				
9-Apr-03	24				
10-Apr-03	25				
11-Apr-03	26				
12-Apr-03	27				
13-Apr-03	28				
14-Apr-03	29	3	7	13	24

Table A13-3. Beetle Adults (100 mg/m^3 Exposure Group, March 2003)

Date	Days	Set 1			
		Alive	Dead	%Alive	No.
17-Mar-03	0	22	0	100	22
18-Mar-03	1	21	1	95.45455	22
19-Mar-03	2	21	0	95.45455	22
20-Mar-03	3				
21-Mar-03	4				
22-Mar-03	5				
23-Mar-03	6	8	13	36	22
24-Mar-03	7				
25-Mar-03	8				
26-Mar-03	9	5	3	23	22
27-Mar-03	10	5		23	22
28-Mar-03	11				
29-Mar-03	12				
30-Mar-03	13				
31-Mar-03	14				
1-Apr-03	15				
2-Apr-03	16				
3-Apr-03	17				
4-Apr-03	18	1	4	5	22
5-Apr-03	19				
6-Apr-03	20				
7-Apr-03	21	0	1	0	22
8-Apr-03	22				
9-Apr-03	23				
10-Apr-03	24				
11-Apr-03	25				
12-Apr-03	26				
13-Apr-03	27				
14-Apr-03	28	0		0	22

Table A13-4. Beetle Adults (400 mg/m^3 Exposure Group, March 2003)

Date	Days	Set 1			
		Alive	Dead	%Alive	No.
18-Mar-03	0	24	0	100	24
19-Mar-03	1	24	0	100	24
20-Mar-03	2				
21-Mar-03	3				
22-Mar-03	4				
23-Mar-03	5	14	10	58	24
24-Mar-03	6				
25-Mar-03	7				
26-Mar-03	8	13	1	54	24
27-Mar-03	9	13	0	54	24
28-Mar-03	10				
29-Mar-03	11				
30-Mar-03	12				
31-Mar-03	13				
1-Apr-03	14				
2-Apr-03	15				
3-Apr-03	16				
4-Apr-03	17	7	6	29	24
5-Apr-03	18				
6-Apr-03	19				
7-Apr-03	20	6	1	25	24
8-Apr-03	21				
9-Apr-03	22				
10-Apr-03	23				
11-Apr-03	24				
12-Apr-03	25				
13-Apr-03	26				
14-Apr-03	27	2	4	8	24

Table A13-5. Beetle Adults (800 mg/m^3 Exposure Group, March 2003)

Date	Days	Set 1			
		Alive	Dead	%Alive	No.
18-Mar-03	0	24	0	100	24
19-Mar-03	1	24	0	100	24
20-Mar-03	2				
21-Mar-03	3				
22-Mar-03	4				
23-Mar-03	5				
24-Mar-03	6	10	14	42	24
25-Mar-03	7				
26-Mar-03	8	9	1	38	24
27-Mar-03	9	7	2	29	24
28-Mar-03	10				
29-Mar-03	11				
30-Mar-03	12				
31-Mar-03	13				
1-Apr-03	14				
2-Apr-03	15				
3-Apr-03	16				
4-Apr-03	17	4	3	17	24
5-Apr-03	18				
6-Apr-03	19				
7-Apr-03	20	3	1	13	24
8-Apr-03	21				
9-Apr-03	22				
10-Apr-03	23				
11-Apr-03	24				
12-Apr-03	25				
13-Apr-03	26				
14-Apr-03	27	2	1	8	24

Appendix B. Supporting Publication

The publication generated by this project (in addition to this final project report) is the following journal article:

Strenge, DL, CJ Driver, RS Herrington, and RS Zack. "Notes on the Life History of *Macaria curvata* (*Lepidoptera: Geometridae*) in Southcentral Washington State" The Pan-Pacific Entomologist 82(1):91-96 (2006).