PUBLIC HEALTH RESPONSES TO WEST NILE VIRUS: THE ROLE OF RISK PERCEPTIONS AND BEHAVIORAL UNCERTAINTY IN RISK COMMUNICATION AND POLICY

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES
( Resource Management and Environmental Studies)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

April 2009

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ABSTRACT

Emerging and re-emerging infectious diseases provide a challenge to public health in that the frequency, location, duration, and severity of the disease and outbreak are not always readily identifiable. In the absence of such information, the need to understand what drives risk perceptions, risk trade-offs, and heterogeneity in population behaviors becomes important in designing effective and appropriate risk communications, public health messages, and interventions. In this thesis, four studies are described that examine risk perceptions, risk trade-offs, and behavioral uncertainties as they relate to West Nile virus (WNV) prevention and control strategies. In Chapter 2, the health belief model was used to examine the influence of health beliefs and demographics on health behaviors recommended to reduce the risk of WNV. Results showed that health beliefs and subsequent behaviors varied based on the perceived risk and disease context. Respondents were more likely to engage in recommended health behaviors if they received timely information, understood the benefits of a particular behavior, and lived in areas exposed to WNV. Chapter 3 explored behavioral and demographic risk factors associated with risk perceptions of WNV and WNV interventions. Unique associations were found which merit further study to understand the extent of their relationships. In Chapter 4, risk trade-offs of WNV interventions were examined between laypeople and health experts using multi-criteria decision analyses. Laypeople perceived some WNV interventions to be more effective than health experts reported them to be. Health experts were most concerned about the effectiveness of such interventions. This showed that laypeople were more willing to make risk trade-offs given the scenario. In Chapter 5, probabilistic modeling techniques were used to characterize variability and uncertainty in population, environmental, pesticide, and exposure characteristics. By modeling a realistic mosquito abatement campaign, we found that children under 6 are potentially at risk of exposure to malathion levels that exceed standards set by Canadian and US regulatory agencies. Together, these studies highlight the importance of targeted programs and risk communications to specific sub-populations bridging knowledge gaps. Though the findings are specific to WNV, their implications are far-reaching and useful in preparing for other emerging and re-emerging diseases.

Keywords: West Nile virus, West Nile virus interventions, emerging and re-emerging infectious disease, risk perception, risk trade-offs, risk factors, risk communication, probabilistic models, malathion, spatial and temporal variability, behavioral uncertainty, population heterogeneity, multi-criteria decision analysis, health belief model.
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GLOSSARY

I have tried to maintain continuity between the terminologies used in the different chapters. Due to the large number of technical terms used in this thesis, a short glossary is provided below.

**Accumulation (in the environment):** The potential accumulation of malathion in the environment, due to environmental half-lives, over the duration of a mosquito abatement program using adulticiding. If the second (and subsequent) spray events occur before malathion residues are completely cleared from the environment this can potentially lead to increased human exposure levels.

**Adulticiding:** The application of pesticides by ground or air to the environment to kill and control adult mosquitoes. It is usually considered as the last effort to control West Nile virus outbreaks.

**DEET:** N, N-diethyl-meta-toluamide. It is an active ingredient in many insect repellents.

**Deterministic models:** Models using single point estimates for parameters. Such models produce the same output for a given data point each time.

**Emerging infectious disease:** Previously unidentified diseases among humans (e.g. SARS, Avian Influenza).

**Health belief model:** A theoretical framework used in health communication theory. Examines why people engage in health related behaviors through six domains believed to influence individual health seeking behaviors: (1) perceived susceptibility, (2) perceived severity, (3) perceived benefits, (4) perceived barriers, (5) cues to action, and (6) self-efficacy.

**Health experts:** In this thesis it refers to health experts working in the field of communicable diseases in Canada with a focus on WNV.

**Laypeople:** The general public. In this thesis it refers to respondents to the Multi-criteria decision analysis survey who do not have technical WNV expertise.

**Larviciding:** The use of pesticides to control mosquito populations in their larval stage.
**Lowest Observed Adverse Effect Level (LOAEL):** Lowest dose of a tested substance to have a harmful effect.

**Malathion:** An organophosphate. A pesticide used in agriculture, for residential purposes, pest control, and for public health mosquito abatement programs.

**Multi-criteria decision analysis:** A tool that blends elements from economics, psychology, and ethics. It can be used to examine how trade-offs are made within dynamic and complex systems.

**No Observed Adverse Effect Level (NOAEL):** Highest tested dose of a substance reported to have no harmful effect.

**Probabilistic models:** Models that use parameter values drawn from probability distributions for different instantiations of an evaluation. This approach can be used to represent both uncertainty and within population variability.

**Re-emerging infectious diseases:** Previously identified diseases whose geographical distribution and/or incidence is changing or increasing (e.g. West Nile virus).

**Reference dose (RfD):** The US Environmental Protection Agency defines the reference dose as the reference estimate of the daily exposure to human populations that is unlikely to result in adverse human health effects. It is the ratio of the NOAEL to the multiplication of all the uncertainty factors.

**Risk factors:** Characteristics that may influence one’s level of perceived risk (e.g. Gender, age, education, geographical location).

**Risk perception:** How people will react to and characterize a particular health risk with regards to its nature, magnitude, and consequences.

**Risk trade-offs:** Trade-offs between various risks leading to a decision and/or action.

**Social amplification of risk:** The amplification of perceived risk beyond levels assessed by technical experts. Created by the format and frequency by which stories are delivered to the public. In the case of WNV, there was a large amount of media coverage despite its low relative risk in comparison to other diseases.
**Stochastic models:** Probabilistic models that draw parameter values from distributions for each time step in an instantiation. These models can be used to simulate inter-temporal variability.

**Uncertainty Factor:** Represents factors of uncertainty for between species data extrapolation, population heterogeneity, and other unknown factors in the NOAEL or LOAEL.

**West Nile virus:** A vector-borne disease belonging to the Flaviviridae family. It is maintained through an avian and mosquito transmission cycle. Humans and other mammals are incidental hosts.
ACKNOWLEDGEMENTS

First and foremost I would like to thank my supervisor Dr. Hadi Dowlatabadi. Thank you for your mentorship, encouragement, support, and guidance. You pushed me to discover places I did not know I was capable of going. Thank you also to Drs. Kay Teschke and Ray Copes for your time, helpful suggestions, guidance, and support. Thank you to Dr. Bonnie Henry and the BCCDC WNV team for facilitating this study, helping me to understand how the system works, and the practical implications of this research. The faculty, staff, and students from the Bridge Program and the Institute for Resources, Environment and Sustainability made the interdisciplinary nature of this work extremely fulfilling. The Centre for Health and Environment Research hosted the study website. Thank you to Christie Hurrell for helping to design and maintain the website. The Social Sciences and Humanities Research Council, the Bridge Program at the University of British Columbia, the BC Centre for Disease Control, Carnegie Mellon University, National Science Foundation, and the Exxon-Mobil Education Foundation provided financial support for this work.

Thank you to my parents for their love, support, encouragement, and continuous supply of nutritious and delicious foods during the writing phase. Many others also helped make this journey memorable. I would especially like to thank: Colin Bates, Neil Bellack, Zosia Brown, Steph Glube, Rebecca Goulding, Alex Hughes, Regina Matthew, Gillian Moran, Conor Reynolds, Alison Ritchie, Shelagh Szabo, Charlie Wilson, Meghan Winters, and Josh Young for their support, welcomed distractions, outdoor adventures, and good conversations. A special thank to my youngest friend Nigel Young for reminding me how fun it is to learn something new everyday. And to Jersey who kept me company while I wrote.
To my parents and Bubula
CO-AUTHORSHIP STATEMENT

Chapter 2: Influences of demographics, exposures, and health beliefs on behaviors related to West Nile virus.
I had the idea for this study, designed and oversaw the administration of the questionnaire, carried out the data analysis and prepared and revised the manuscript. Drs. Hadi Dowlatabadi, Kay Teschke, and Ray Copes contributed to the conceptual development and methods used in this chapter. They also provided comments on the manuscript draft. Dr. Bonnie Henry was instrumental in gaining support from participating provinces and assisted with questionnaire revisions. Laura MacDougall assisted with questionnaire revisions and ensuring questionnaire continuity. Mieke Fraser helped create the GIS maps with data that I provided.

Chapter 4: Multi-criteria decision analyses and re-emerging infectious disease: a case study of West Nile virus.
I had the idea for this study, designed and administered the questionnaire, carried out the data analysis and prepared and revised the manuscript. Dr. Hadi Dowlatabadi contributed to the methods and provided comments for revisions.

I would like to acknowledge Dr. Bonnie Henry’s contribution to questionnaire revisions and applicability. She was also instrumental in gaining support from participating provinces and assisted in recruiting health experts to partake in the questionnaire. I would also like to acknowledge Dr. Kay Teschke for her comments on the initial draft, they contributed to the readability and clarity of the manuscript.

Chapter 5: A model for Probabilistic Assessment of Malathion Spray Exposures (PAMSE) in British Columbia, Canada
This paper was the result of many meetings with members of the West Nile virus team at BC Centre for Disease Control. Dr Hadi Dowlatabadi and I came up with the idea for the study. I conducted the literature review, compiled all parameter descriptions, and modeled the population characteristics of PAMSE. Dr. Hadi Dowlatabadi created the code for the remaining portions of the PAMSE model with my assistance. I checked and refined the model, interpreted the results, and prepared the manuscript. Dr. Elizabeth Casman assisted in the literature review and provided comments on the initial draft of the manuscript.
1 Chapter 1: General introduction
1.1 Emerging and re-emerging infectious diseases

In the past decade we have witnessed the emergence and rapid spread of SARS from China to Hong Kong to Canada and elsewhere (Peiris, Yuen et al. 2003), new strains of avian influenza and their jump to humans, and emergence of diseases like the West Nile virus in new geographical regions (Subbarao and Katz 2000; Granwehr, Lillibridge et al. 2004).

The evolution and diffusion of emerging and re-emerging infectious diseases are products of many interacting factors. The exact interaction of factors tend to be disease specific, but usually involve: genetic, biological, social, political and economic determinants (Morens and Folkers 2004). The increase in the prevalence and incidence of such diseases is unprecedented and accompanied by uncertainty. There is scientific uncertainty in the frequency, location, duration, and severity of the disease. There is also uncertainty in appropriate interventions, and their implications on vulnerable populations and ecosystems (Cohen 2000; Morens and Folkers 2004). Given these uncertainties it is difficult to plan the appropriate risk communications, public health messages, and interventions needed to prevent disease outbreaks and minimize adverse health outcomes.

1.2 The role of risk factors and perceptions

Public perceptions of factors leading to risks and the subjective assessment of the level of these risks determine behaviors, attitudes, and actions. Risk perception can be defined as an individual’s attitudes and judgments pertaining to a particular risk (Slovic 1987; Slovic 2000). It is subjective construct and is influenced by the magnitude of risk, underlying factors, and information available (Leiss and Chociolk 1994). Research has shown that the perceived level of risk is higher when the hazard is: technological, involuntary, uncontrollable, unfamiliar, and exhibits a large mortality toll. For example, it has been shown that, in general, people underestimate common and controllable risks and overestimate the risks from rare and infrequent and uncontrollable events (Slovic, Fischhoff et al. 1980). Gender, age, education, geographic location, and being parents of young children have also been shown to influence risk perceptions (Savage 1993; Flynn, Slovic et al. 1994; Dosman, Wiktor et al. 2001; Krewski, Lemyre et al. 2006). Through systematic examination of risk perceptions in relation to an uncertain disease threat we can begin to understand and predict public responses (Slovic 1987). This will allow for good risk communication practices and appropriate public health program planning.
Given the uncertain nature of emerging and re-emerging infectious diseases there are likely to be gaps between expert knowledge and public understanding of risk factors and the level/magnitude of the risk. This consequently affects risk perceptions. Those charged with making public health decisions are faced with complex and uncertain scenarios under which to make decisions to protect the population and ecological health of their jurisdiction (Clemen and Reilly 2001). At times they may also make choices in response to public concern. The public, on the other hand, can make individual choices that can reduce (or increase) their risk of illness. Each decision is subjective and based on individual risk trade-offs. Decision makers will make trade-offs based on scientific knowledge, uncertainty, multiple objectives, efficacy of decisions, and variations in stakeholder perspectives and preferences (Keeney and Raiffa 1976; Fischhoff 1995). While laypeople often base risk trade-offs and choices on risk perceptions, intuition, and past experiences (Fischhoff 1995). Traditionally, trade-offs among various stakeholders (including laypeople) have not been incorporated into public health risk communication planning. However, for risk communication strategies to be effective experts need to be aware of possible knowledge gaps between themselves and the public and how this gap can be minimized (Powell and Leiss 1997). To do this we need to understand how these groups perceive risks and how they make risk trade-offs given a particular health-risk/intervention-option challenge.

### 1.3 Use of risk assessments in decision making

Risk assessments, used by regulators, are traditionally carried out using the red book methodology where scientists formulate problems, initiate risk assessments, and distribute the findings to risk managers for action. Through this process, the risks and uncertainties of particular hazards are examined using dose-response relationships and exposure assessments (NRC 1993; Paustenbach 2002). In the absence of public health specific methodology, decisions may be based on traditional risk assessments. However, such risk assessments are not tailored towards specific problems, and often do not take spatial and inter-individual and behavioral variability into consideration. By incorporating such uncertainties we can develop behaviorally realistic risk assessments allowing us to increase our understanding of the problem and emphasize areas where more effective public health programs can be designed and implemented (Dowdle and Hopkins 1998). This will consequently provide opportunities for risk reduction, risk communication, and risk management resulting in
more effective programmatic decisions reflecting the interdisciplinary nature of public health problems (Morgan and Henrion 1990).

### 1.4 System overview

The re-emergence of West Nile virus (WNV) was chosen to systematically examine determinants of risk perceptions, the level of perceived risk, risk and decision trade-offs, and behavioral uncertainties. West Nile virus was chosen for several reasons. There is scientific uncertainty in the frequency, location, duration of outbreaks, severity of illness in those infected, and no cure (Gubler 2007). Despite its low relative risk in comparison to other diseases, West Nile virus has also received a large amount of media attention (Nicol, Hurrel et al. 2008). This has led to the social amplification of risk and to a high level of public concern and reaction. This combination puts an emphasis on timely risk communication. It also highlights the need for a systematic assessment of risk perceptions, risk trade-offs and uncertainties. The BC Centre for Disease Control was also keen to be prepared in the event that WNV emerged in British Columbia.

### 1.5 Overview of West Nile virus

#### 1.5.1 Virus

West Nile virus, a vector borne disease, was first isolated in 1937 from the West Nile province of Uganda. It belongs to the Flaviviridae family, which also includes viruses causing dengue, yellow fever, Japanese encephalitis, and tick-borne encephalitis (Burke and Monath 2001). Numerous other incidences of infection and outbreaks in Israel, Egypt, Romania and Russia helped to further characterize the disease (Figure 1.1) (Hayes 2001). It is maintained by an enzootic cycle through avian and mosquito transmission cycles. Humans and other mammals acquire WNV infection predominately through mosquito bites, but are considered dead-end hosts (Hayes 2001). Blood transfusions, transplants, breast milk, and intrauterine transmission have also been documented as causes of infection (Kramer, Li et al. 2007).

West Nile virus was first detected in 1999 in North America with an outbreak in New York City (CDC 1999; Mostashari, Bunning et al. 2001). The North American strain of the virus is closely related to strains in the Mediterranean region and, more specifically, to a strain discovered in Israel in 1998 (Lanciotti, Roehrig et al. 1999). Though the mechanism of its emergence into North
America is uncertain, it has steadily spread across the continent. It was first identified in Canada in 2001 with the first human case reported in 2002 (Weir and Shapiro 2004). Canada has experienced two large outbreak years, in 2003 and 2007 with 1481 and 2374 confirmed human WNV clinical cases respectively. The majority of cases were concentrated in Alberta, Saskatchewan, and Manitoba (Figure 1.2). The true size of the outbreaks remains unknown as a high proportion of seroconverted individuals experience mild or no symptoms at all and were not attended by health professionals.

1.5.2 Vector
Since 1999, 62 mosquito species have been identified as WNV vectors through positive mosquito pools in the United States (Centers for Disease Control and Prevention 2007). In Canada, 10 infected mosquito species have been identified, of which *Culex pipiens*, *Culex restuans*, and *Culex tarsalis* are the most common (Public Health Agency of Canada 2006). The range of *Culex pipiens* and *Culex tarsalis* extends into British Columbia. *Culex pipiens* are found in the urbanized areas of the lower mainland, the Fraser Valley, and the South and Central regions of Vancouver island; *Culex tarsalis* are found in most regions of the province and act as the main vector for WNV in the Prairie provinces (BCCDC 2006). The virus is believed to be passed on between seasons through overwintering female mosquitoes, continued transmission between mosquitoes and birds in warmer climates, through the chronic infection of birds, and through migratory birds (Reisen and Brault 2007). Though mammals are considered dead-end hosts, equine infections may have a role in nonviremic transmission of the virus (Higgs, Schneider et al. 2005).

1.5.3 Avian host population
While WNV infection has been detected in 317 bird species, the most commonly observed infected birds are Corvids (Crow, Blue Jay, and Ravens) (CDC 2007). They are susceptible to infection and mortality and are, therefore, good indicator species (Michigan Department of Natural Resources 2007). The majority of birds die within 3 weeks of infection. The actual burden and impact of the virus on bird populations remains relatively unknown (LaDeau, Kilpatrick et al. 2007), though it is believed that some bird species are capable of clearing the infection (Reisen, Fang et al. 2005).

1.5.4 Human host population
The majority of human infections are asymptomatic (60-80%). As a result, reported human cases are only the tip of the iceberg (Figure 1.3). Of those infection, the majority present with West Nile
fever symptoms after 2-14 days (incubation period) (Mostashari, Bunning et al. 2001). General symptoms are flu like and include: fever, headache, malaise, myalgia, fatigue, skin rash, lymphadenopathy, vomiting, and diarrhea (Hayes and Gubler 2006). Less than 1% of all infected individuals develop severe neuroinvasive diseases (West Nile meningitis, West Nile encephalitis, and acute flaccid paralysis) (Kramer, Li et al. 2007). Historically, most patients with West Nile fever fully recover, with the duration of ailments ranging from days to months. Less than 0.1% of total infections (approximately 10% of those with severe neuroinvasive disease) result in fatalities (Reimann and Zielinski-Gutierrez 2007). Those over the age of 50 are at a higher risk of WNV infection and developing encephalitis, with the risk increasing for those over 75 (Granwehr, Lillibridge et al. 2004). Diabetes and immunosupression have also been found to increase vulnerability to WNV infection and complications (Nash, Mostashari et al. 2001; Campbell, Marfin et al. 2002).

1.6 Public health capacity and interventions
Public health capacity can be broadly defined as measures taken by public health officials to protect the health of the population. It is not restricted to interventions aimed at limiting infectious and other diseases but can include protection against intentional and unintentional injuries, environmental hazards, emergency preparedness and access to health care. Measures taken can vary depending on the task. They can include: surveillance; priority setting; program planning; implementation and monitoring, program evaluation; advocacy; policy; funding, and education (Canadian Public Health Association 2005). Public health capacity is fundamental to any health program. Yet it is embedded within a complex social and institutional framework, which influences programmatic decisions (Tol and Dowlatabadi 2001). Therefore, decisions are highly dependent on current regulations and guidelines, funding, and the political agenda (Figure 1.4). In lieu of describing the complex relationship, public health capacity is used in this thesis as it pertains to controlling and preventing WNV infection. This can take several forms: surveillance, public education promoting personal protective (health) behaviors, source reduction, and pesticide use for larviciding and adulticiding. Such measures encompass actions and responses that can be taken at both the individual level and/or at the societal (government) level. West Nile virus vaccine development was not examined, as there is currently no human vaccine available. Intervention methods will be further discussed in subsequent chapters but are briefly described below:
**SURVEILLANCE:** Active and passive surveillance systems are integral to monitoring the presence, prevalence, and progression of the disease cycle. They are critical in early detection, and provide timely information for the launch of possible interventions.

**PUBLIC EDUCATION:** Education aims to increase awareness of risk factors promoting individual behavior change that will reduce exposure and susceptibility to WNV. In Canada, public health officials recommend five preventative measures: (1) using insect repellents with DEET (N, N-diethyl-meta-toluamide), (2) avoiding outdoor areas during peak mosquito activity (dusk to dawn), (3) wearing protective clothing, (4) having screens on windows and doors, and (5) eliminating standing water (source reduction) to reduce the risk of WNV infection (Public Health Agency of Canada 2006; BCCDC 2008).

**SOURCE REDUCTION:** Source reduction reduces mosquito larvae habitats (such as standing or collected water on both private and public lands).

**LARVICIDING AND ADULTICIDING:** Both techniques rely on the use of pesticides to control mosquito populations in their larval and adult stages respectively (Rose 2001).

### 1.7 Thesis objective

The primary objective of this thesis is a systematic examination of risk perception determinants, level of perceived risk, risk and decision trade-offs, and behavioral uncertainties as they relate to the control and prevention of WNV. A secondary objective was to consider the implications of the findings for risk communication strategies and public health messages.

An *Integrated Assessment (IA)* approach was used in this dissertation, whereby research gaps were identified and the methodology was driven by the nature of uncertainties in the problem and their importance in evaluating the relative merits of potential interventions (Dowlatabadi and Morgan 1993). The advantage of using such an approach is that it can: put a problem into a broader perspective, explore options and alternatives as to how to manage the problem, identify sources of uncertainty, and translate sources of uncertainty into measures of risk to assist with decision-making (Rotmans and van Asselt 2003).
1.8 Overview of thesis chapters

There are four questions addressed in this thesis through individual chapters. They examine the role of risk perceptions on individual behavior engagement, risk trade-offs in decision-making, uncertainties in risk assessments, and the influence of risk factors on risk perceptions associated with individual and societal level interventions used to control and prevent WNV.

The main purpose of each chapter is briefly described below:

*CHAPTER 2:* Using the health belief model, the influence of health beliefs and demographics were examined in relation to individual behaviors recommended to reduce the risk of WNV.

*CHAPTER 3:* The influence of demographic and behavioral risk factors on risk perceptions related to WNV versus those of individual and societal preventative interventions were explored.

*CHAPTER 4:* Multi-criteria decision analyses were used to examine risk trade-offs and decisions between laypeople and health experts in the context of WNV risks and interventions.

*CHAPTER 5:* Scientific uncertainty and population and behavioral variability were included in a probabilistic model to examine potential pesticide exposures following adulticiding campaigns used in the prevention and control of WNV.
1.9 Thesis study provinces

Chapters 2, 3, and 4 are based on data collected in British Columbia, Alberta, and Manitoba, Canada. These provinces were selected to provide a range of WNV activity. To date, British Columbia has had no locally acquired cases of WNV; there have been an increasing number of human cases in Manitoba and Alberta since 2003 and 2004 respectively (Figure 1.5) (Alberta Health and Wellness 2008; BCCDC 2008; Manitoba Health 2008). These provinces were also keen to be involved and endorsed the project.

1.10 Study website

A website was set up for this study as a place where survey respondents could go for more information and to facilitate information sharing and result dissemination. The website is hosted by the Centre for Health and Environment Research (CHER) and can be found at:

www.cher.ubc.ca/westnile

The UBC Behavioral Research Ethics Board Certificate of Approval for this thesis can be found in Appendix A.
Figure 1.1. Timeline of the key aspects of the discovery and spread of West Nile virus into North America

Sources: (Hayes 2001; Weir and Shapiro 2004; Gubler 2007; Public Health Agency of Canada 2008)
Figure 1.2. Human West Nile virus clinical cases in Canada for 2003 and 2007

Adapted from (Public Health Agency of Canada 2007a)
Figure 1.3. Visualization of human infections with West Nile virus

<1% West Nile neuroinvasive disease

~20-40% West Nile fever

~60-80% Asymptomatic
Figure 1.4. Conceptual framework for examining the social dimension of West Nile virus risk in humans in this thesis.
Figure 1.5. Study provinces and cumulative number of human West Nile virus cases (2003-2007)
1.11 References


Michigan Department of Natural Resources. (2007). "West Nile virus. Available at: [http://www.michigan.gov/dnr/0,1607,7-153-10370_12150_12220-99070--,00.html](http://www.michigan.gov/dnr/0,1607,7-153-10370_12150_12220-99070--,00.html)"


Chapter 2: Influences of demographics, exposure, and health beliefs on behaviors related to West Nile virus

A version of this chapter will be submitted for publication.

2.1 Introduction

To prevent undesired health outcomes, we need to understand how the public perceives risks from diseases, examine current health behaviors, and determine what additional information is required for the adoption of healthy behaviors (Covello 2003). One aspect of this is perceived risk: how people will react to and characterize a particular health risk with regards to its nature and magnitude. One’s level of perceived risk of a particular hazard is developed over time and influenced by numerous factors including: (1) the hazard and the degree to which it is understood, (2) dread of the hazard, (3) the population at risk, (4) temporal and spatial variations, and (5) risk management, communication, and social amplification of the risk (Leiss and Chociolko 1994). These 5 factors will be further described in relation to re-emerging infectious diseases.²

Firstly, the hazard is based on the degree to which it is understood by the individual and can be interpreted as the potential frequency of disease outbreaks, the duration of potential exposure, and scientific uncertainty in understanding the seasonal and regional spread of the virus. Secondly, dread of the infection is both a function of one’s understanding of the hazard and one’s personal experience with the disease or similar infectious diseases, and the incidence of disease in one’s personal network. Thirdly, the make-up of the population at risk will influence risk perception, especially if children are involved. For example, having young children may increase one’s sensitivity to not only to the disease but also to preventative measures (Leiss and Chociolko 1994). Fourthly, variations in time (seasonal) and space (spatial proximity to outbreaks) influence when and where one's perceived risk may be elevated or attenuated (Poortinga, Cox et al. 2008).

Finally, risk management and risk communication are key elements to the level of perceived risks. This process, however, is not always reflected in risk communications or subsequent media derived messages (R.Copes, Personal Communication, January 2009). In an ideal situation, they can manage and disseminate information addressing scientific risks and public risk perceptions in a timely manner, thereby preventing risk vacuums and risk misinformation (Powell and Leiss 1997). The information used in risk communication is often based upon technical risks as provided by experts. Though experts and the public tend to agree on the outcome of a particular risk their definitions of risk differ (Fischhoff 1995). Studies have shown that, in general, people underestimate common and controllable risks and overestimate the risks from rare infrequent and uncontrollable events.

² For the purposes of this thesis, re-emerging infectious diseases refer to previously identified diseases whose geographic distribution and/or incidence is changing/increasing (Morens and Folkers 2004).
The role of risk communication and types of information disseminated, therefore, becomes critical in addressing risk perceptions and preventing misconceptions. Information is traditionally communicated to the public through press releases captured by the media. The format and frequency by which stories are delivered to the public can lead to social amplification and/or desensitization of perceived risk (Pidgeon, Kasperson et al. 2003). This phenomenon was highlighted in a newspaper content analysis of West Nile virus (WNV) in relation to Cryptococcus gattii; the study found that WNV received five times more news coverage despite a lower morbidity and mortality rate between 2001 and 2006 (Nicol, Hurrell et al. 2008). Alternatively a risk vacuum can be created when timely information is not communicated to the public. During the 1995 mad cow disease outbreak, in Britain, a risk vacuum was observed owing to a lack of risk communication. This led to public outrage and panic upon realization that the disease could be acquired from eating contaminated beef (Powell and Leiss 1997).

In order to better communicate the risks and benefits associated with a particular hazard, we need to understand the perceived benefits and barriers associated with mitigation activities among populations at risk (Leiss and Chociolko 1994). Research in the field of risk perception has predominantly focused on psychometric work or Cultural Theory (Pidgeon, Kasperson et al. 2003). However, the literature on risk communication and radon exposure has highlighted the importance of systematically understanding risk behaviors in an effort to design more effective risk communication campaigns (Harrison and Hoberg 1994; Johnson, Fisher et al. 1995; Morgan, Fischhoff et al. 2002). By using health communication theory to investigate re-emerging infectious diseases, we can ensure that risk communication and educational messages are designed to promote effective and intended health behavior changes. One theoretical framework used in health communication theory is the health belief model. It was developed in the 1950s to allow researchers to understand why people engage in health related behaviors by identifying characteristics that allowed or prevented specific health behaviors. The model assumes that an individual will engage in a health related behavior as long as they feel capable of successfully carrying out the behavior and if they perceive it can help them avoid a negative health condition. Central to the model are six main domains which are believed to most influence an individuals' health seeking behavior: (1) perceived susceptibility, (2) perceived severity, (3) perceived benefits, (4) perceived barriers, (5) cues to action, and (6) self-efficacy (Figure 2.1) (Glanz, Rimer et al. 2002; U.S. Department of Health and Human

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3 Cryptococcus gattii is an environmental yeast which can cause cryptococcosis. In BC, it has been responsible for 8 deaths and over 150 hospitalizations (Nicol, Hurrell et al. 2008).
The health belief model has been used for a variety of health concerns including cancer screening and infectious diseases such as tuberculosis, HIV/AIDS, influenza, and measles (Glanz, Rimer et al. 2002; Aquino, Fyfe et al. 2004).

West Nile virus is one example, of a re-emerging infectious disease, that can be used to examine the dynamics between risk perceptions and risk communication strategies to promote healthy behavior changes. West Nile virus is a good system to study because there is scientific uncertainty in the frequency, location, duration of outbreaks, severity of disease, and no cure (Gubler 2007). It has also been accompanied by large amount of media coverage resulting in the social amplification of risk (Nicol, Hurrell et al. 2008). This combination puts an emphasis on communication of risks in a timely and appropriate fashion to reduce the risk of infection, thereby amplifying the need to understand risk perceptions driving individual health actions.

West Nile virus was first detected in New York City in the summer of 1999. In Canada, it was first identified in 2001 with the first human case reported in 2002 (Weir and Shapiro 2004). Since its emergence it has steadily spread across North America (CDC 1999; Mostashari, Bunning et al. 2001). Canada has experienced two large outbreak years, in 2003 and 2007 with 1481 and 2374 human WNV clinical cases respectively (Figure 2.2) (Public Health Agency of Canada 2007; Public Health Agency of Canada 2007a). The majority of these cases were concentrated in Alberta, Manitoba, and Saskatchewan. The true size of the outbreaks remain unknown owing to the difficulty in ascertaining the number of mild and asymptomatic cases commonly produced by this mosquito-borne flavivirus that go unreported.

One method of reducing the risk of WNV infection is through individual personal protective (health) behaviors. In Canada, public health officials recommend five preventative measures for individuals: (1) using insect repellents with DEET (N, N-diethyl-meta-toluamide), (2) avoiding outdoor areas during peak mosquito activity (dusk to dawn), (3) wearing protective clothing, (4) having screens on windows and doors, and (5) eliminating standing water (source reduction) to reduce the risk of WNV infection (Public Health Agency of Canada 2006; BCCDC 2008). These activities are promoted through public education campaigns and press releases on an ongoing basis when WNV is a threat.

Knowledge, attitude, and behavior surveys of WNV have been conducted since 1999 in an attempt to better understand personal protective behaviors (Herrington 2003; Aquino, Fyfe et al. 2004;
A high proportion of studied populations are aware of WNV, with television cited as the most common source of information (Aquino, Fyfe et al. 2004; Averett, Neuberger et al. 2005; Wilson, Varia et al. 2005; Fox, Averett et al. 2006). Being outdoors between dusk and dawn or in mosquito prone areas, not wearing long sleeved shirts and pants, and not wearing mosquito repellent have all been shown to independently increase one’s risk of WNV infection (McCarthy, Hadler et al. 2001; Mostashari, Bunning et al. 2001). Though the results of such studies have indicated the importance of personal protective behaviors, their true efficacy and drivers of engagement remain largely unknown (Averett, Neuberger et al. 2005). Risk perceptions, risk exposure, beliefs, and lifestyles associated with higher risks of acquiring WNV have also not been well characterized (Mostashari, Bunning et al. 2001; Loeb, Elliot et al. 2005).

The health belief model was used in one of the aforementioned studies to understand the effectiveness of personal protection behaviors in preventing WNV. It was carried out as a precautionary planning measure in British Columbia, a region that has experienced no locally acquired human cases (BCCDC 2003; BCCDC 2007). Results showed that individuals’ negative perception towards DEET, desire to participate in outdoor activities at dusk and the effort required to remove standing water were the biggest barriers to participating in risk reducing health behaviors (Aquino, Fyfe et al. 2004). Other studies investigating behaviors in relation to WNV infection in Canada were carried out only at the onset of disease emergence, between 2002 and 2003 (Aquino, Fyfe et al. 2004; Wilson, Varia et al. 2005; Schellenberg, Anderson et al. 2006). No subsequent studies have been conducted to examine current risk perceptions or variations in perceptions across areas in Canada with varying levels of WNV exposure. However, we know that risk perceptions are both disease and context dependent and inevitably change over time within and between communities as the prevalence of the disease changes and as new information becomes available (Loewenstein and Mather 1990). For example, a study on radon identified misconceptions preventing homeowners from testing radon levels. As a result of this misconception, alternative and subsequently successful, communication brochures addressing the misconceptions were developed explaining the nature of radon and remediation strategies (Morgan, Fischhoff et al. 2002).

By systematically characterizing perceived risks in relation to health behaviors recommended to reduce the risk of WNV infection, we can examine whether educational health messages should be

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4 British Columbia reported 20 and 18 cases in 2003 and 2007 respectively, all attributed to out of province exposure. This reflects the high level of activity elsewhere in Canada (BCCDC 2003; BCCDC 2007).
specifically tailored to communities and disease contexts. This will allow for the creation of more effective public health interventions and risk communication and education campaigns than has been possible to date. The purpose of this study was to examine health beliefs, their impact on health behaviors recommended to prevent WNV infection, and their implications for risk communication. A sub-objective is to determine how health behaviors are impacted by potential WNV exposure and demographics. This was achieved by examining the following questions and hypotheses:

1. What health beliefs influence behaviors that are recommended to reduce the risk of WNV?
   \( H_0 \): Health beliefs (as outlined in the health belief model) do not individually influence behaviors recommended to reduce the risk of WNV.
   \( H_1 \): Health beliefs (as outlined in the health belief model) individually influence behaviors recommended to reduce the risk of WNV.

2. Do these behaviors differ based on potential WNV exposure and demographics?
   \( H_0 \): Individuals do not engage in personal protective behaviors because of their demographics and differential experience with WNV (based on provinces where WNV is endemic).
   \( H_1 \): Individuals engage in personal protective behaviors because of their demographics and differential experience with WNV (based on provinces where WNV is endemic).

3. What are the implications of findings for risk communication and educational messages?

2.2 Methods

A 32-item draft questionnaire was developed in collaboration with the BC Centre for Disease Control using the health belief model (Appendix B). In order to have instrumental continuity, the questionnaire was designed to replicate questions from a previous health belief model survey conducted in 2003 (Aquino, Fyfe et al. 2004). Our questionnaire had additional questions to characterize risk perceptions and lifestyle characteristics associated with WNV and WNV interventions (Chapter 3). Twenty-three of the items were specific to West Nile virus (of which 18 were from the 2003 survey), and 9 questions pertained to demographic factors. Multiple questions
with various scales (binary, categorical, and Likert) were designed to gauge the six health belief model domains in relation to personal protective behaviors used to prevent mosquito bites and WNV (Table 2.1). The questionnaire was pilot tested among a convenience sample (n=15) and vetted by a group of health experts and decision makers from the BC centre for Disease Control (n=7), revised, and prepared for implementation.

A randomized list of telephone numbers with full listed addresses was extracted from the residential telephone listings in British Columbia (BC), Alberta (AB) and Manitoba (MB) through ASDE Survey Sampler Inc, a firm that updates its databases bi-annually. Letters of invitation were mailed to potential participants; this was followed up a week later by a telephone call. West Coast Research carried out all the telephone interviews. Up to 4 telephone calls were made. Of these one was in the evening, one during the daytime, one during the weekend and one at random. As an incentive, participant’s names were entered into a random draw to win one of 2 iPods. At this point if a verbal consent was obtained from an adult (≥19 years of age), a telephone interview proceeded. Telephone interviews, of approximately 30 minutes duration, were conducted from July 18 through September 24, 2007. Interviewing stopped when at least 350 participants were recruited per exposure group. Potential exposure to WNV was classified by province of residence: BC with no locally acquired cases of WNV versus AB and MB with locally acquired cases of WNV (Figure 2.3). The sample size was determined to observe a difference in personal protective behaviors between the 2 exposure groups using Epi Info™ statcalc function, 95% confidence interval and 80% power (CDC 2005).

Data were double entered by Elan Data Makers. SPSS version 11.0 was used to clean and analyze the data. Descriptive analyses included counts for categorical variables; mean, median and inter-quartile ranges for Likert scale data; and median, mean, and standard deviations for continuous variables. All variables were visualized using box plots and histograms.

The outcome variables of interest were the five Public Health Agency of Canada recommended personal protective behaviors: (1) avoidance of the outdoors between dusk and dawn, (2) insect repellent use with DEET, (3) wearing protective clothing, (4) use of screens on windows and doors, and (5) source reduction. Outcome variables were self-reported on a Likert scale and aggregated into a dichotomous variable (occasionally or more frequently vs. never or don’t know) based on bimodal distributions and to allow for more meaningful analyses. Less than 5% of the total sample included “don’t know” responses, however, they were dispersed among the respondents and
outcomes (Table 2.2). In order to maintain the maximum number of observations they were included in the analyses.

Indicator variables were created to represent each of the health belief model domains (Table 2.3). Measures of association (chi square and spearman’s correlation) were calculated to examine associations between health behaviors (outcome variables) and 1) health belief model indicator variables, and 2) demographic variables.

Multivariable logistic regression models were created for each outcome variable (5 models total) based on a priori knowledge and the results of the bivariate analyses (p<0.05). All models initially included all health belief model indicator variables. Additional independent variables in all models included gender, age, and potential exposure (presence of WNV in the province of residence). Model parameters were assessed and refined using significance levels, potential relationship with the outcome, and Hosmer-Lemeshow goodness of fit statistics. Residuals were examined to evaluate model fit.

Sensitivity analyses based on an alternate dichotomization of the outcome variable (half the time or more frequently vs. never/don’t know) were carried out to test whether there was a difference between models when the response “occasionally” was included in the opposite category (e.g. with never and don’t know).

2.3 Results

2.3.1 Description of population
A total of 3891 households were randomly selected from residential listings in BC, AB, and MB. Nine hundred and twenty nine (24%) phone numbers were excluded because they were either not in service, the wrong number, or never called. Twenty four percent (N=709) agreed to participate in the survey. Manitoba (MB) had the highest response rate (26%, n=181), followed by AB (24%, n=177) and then BC (23%, n=351). The median age of respondents was between 45 and 54 years; 3% were aged 19-24 years, 11% were aged 25-34 years, 16% were aged 35-44 years, 23% were aged 45-54 years, 24% were aged 55-64 years, 15% were aged 65-74 years and 8% were aged over 75 years. Majority of respondents were female (61%) and had university or technical degrees (65%) (Table 2.4).
Of those who responded to the survey, 68% reported that mosquitoes and mosquito bites bothered them enough to take actions to prevent bites. Ninety two percent of respondents reported having used a mosquito repellent at some point in the past. A statistically significant difference was observed between province of residence and Public Health Agency of Canada recommended insect repellent use; 70.4% of respondents in areas potentially exposed to WNV (AB, MB) used recommended insect repellents compared to 38.5% in areas of no exposure (Spearman’s correlation = 0.321, p<0.001). This difference is likely due to the large presence of nuisance mosquitoes in Alberta and Manitoba (P.Curry, Personal Communication, January 2009). Respondents used insect repellents with DEET most frequently (34% used it often or always). Lemon eucalyptus oil or soybean oil products were rarely used (91% and 95% had never used the products respectively). When asked about the health and environmental effects of insect repellents with DEET, participants were divided. Thirty two percent felt that insect repellents with DEET were safe for their health, while 29% disagreed. When asked whether repellents with DEET would have detrimental environmental effects, a tri-modal distribution was observed: respondents agreed (33%), disagreed (19%), or stated that they did not know (38%), 10% reported being neutral. The main reasons for not using mosquito repellents included: no need for them (82%), health effects (68%), not liking the feeling (62%), and environmental effects (57%).

The main source of WNV information was obtained from the television, followed by newspaper and the radio (Table 2.1). On average, respondents in areas potentially exposed to WNV received information from a greater variety of sources. The majority of respondents in both exposure groups reported that they had enough information to engage in risk reduction activities (58% in BC vs. 70% in AB and MB). Almost all respondents knew that WNV was transmitted to humans through mosquito bites. However, only 52% knew that those over 50 years of age are at an increased risk of infection, and 70% of respondents incorrectly believed that there was an effective treatment for WNV (Table 2.1).

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5 The Public Health Agency of Canada recommends using insect repellents containing DEET, lemon eucalyptus oil, or soybean oil
6 Soybean oil is new to Canada and not sold widely.
2.3.2 Health behaviors
To reduce the risk of getting bitten by mosquitoes, 87% of respondents reported that they often or always used screens on windows and doors, 63% removed standing water, 42% wore long sleeved shirts and pants, 35% used insect repellents, and 29% avoided going outdoors between dusk and dawn (Table 2.4). Overall, 98% of respondents engaged in at least one personal protective measure to prevent mosquito bites. Though these actions are recommended for WNV prevention they can only be used as a proxy in this paper, as our survey did not distinguish between actions taken for WNV prevention versus nuisance mosquitoes.

2.3.3 Health beliefs
In areas with potential WNV exposure, 79% reported living in areas with medium or high mosquito activity in comparison to areas with no exposure (42%). Similarly, 82% of those in areas with potential WNV exposure reported engaging in recreational activities in areas with medium or high mosquito activity (60% in areas with no exposure). This reflects the high level of mosquito activity in areas with WNV activity. On average, respondents in areas with potential WNV exposure demonstrated an increased level of knowledge and self-efficacy and felt more susceptible to WNV than those in areas with no exposure (Table 2.2). This group was also more aware of the benefits associated with health behaviors used to prevent mosquito bites and WNV. As expected, those in potentially exposed areas perceived greater benefits of using insect repellents with DEET. This group also reported higher perceived barriers to insect repellents with DEET than respondents living in areas without WNV activity.

2.3.4 Relationship between health beliefs and health behaviors
Multivariable logistic regression analyses were used to examine the 5 recommended personal protective (health) behaviors to prevent mosquito bites and WNV. All models were controlled for gender, age, and presence of WNV. For a detailed description of each model please see table 2.5.

Cues to action, information on when and how to engage in a specific health behavior, were independently associated with an increase in each of the five personal protective behaviors. Perceived susceptibility was also associated with all of the personal protective behaviors, however, its association was dependent on perceived susceptibility either at home or while engaging in
recreational activities. Perceived benefits and barriers to action were each associated with four personal protective behaviors. Perceived benefits of personal protective behaviors were associated with an increase in behaviors with an exception of screen use. Screen use was significantly associated with living in an area of perceived high susceptibility to infection (vs. low area), cues to action, community involvement, and likely driven by nuisance mosquitoes in Alberta and Manitoba resulting in a 14-fold increase in screen use due to the high proportion of screen use (Table 2.2).

Perceived barriers were associated with a reduction in personal protective behaviors with the exception of insect repellent use containing DEET where it resulted in a 15% increase in use (Table 2.5). Participating in recreational activities in areas of perceived medium or high mosquito activity, awareness of the benefits, cues to action, and potential exposure to WNV also increased insect repellent use containing DEET. Wearing long sleeved shirts and pants to prevent mosquito bites was significantly associated with engaging in recreational activities in an area of high-perceived susceptibility (vs. a low area), the cues to action, the benefits of action, being female, and having at least a university or technical degree.

The residuals of all models were within acceptable limits, did not exhibit heteroscedasticity, and no influential outliers were identified. All points had low leverage and cook distances. Multicollinearity of predictor variables were assessed through tolerance and variance inflation factor values, which were within acceptable ranges.

### 2.3.5 Sensitivity analyses

Similar results were obtained when the response “occasionally” was included with the never and don’t know group. Minor differences in predictive variables were observed for: DEET insect repellent use, wearing protective clothing, use of screens, and source reductions. The changes did not alter the overall model. In all cases one predictor was no longer significant.

### 2.4 Discussion

One hypothesis of this study was that those living in provinces where WNV is present (endemic areas) would be more likely to engage in personal protective behaviors. We found this to be true for

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7 Both leverage and the cooks distance are influence statistics which assess the influence of individual cases on the overall model (Field 2005).
insect repellent use with DEET, having screens on windows and doors, and avoiding the outdoors between peak mosquito hours of dusk to dawn. The same association was not seen for source reduction and wearing protective clothing. When we examined health beliefs in relation to health behaviors we found specific cues to action to be a significant predictor for all personal protective behaviors. Regardless of location, respondents who reported receiving information on a particular behavior through formal sources (e.g. television, newspaper, radio) or through informal sources (e.g. family, friends, neighbors) were more likely to engage in that specific behavior themselves. This is a natural extension of the health belief model. Though the importance of cues to action has been documented, it has not been systematically examined (Glanz, Rimer et al. 2002). This highlights the importance of specific behavioral information disseminated in a timely manner through media sources to which the public responds. As with other studies, respondents in our survey reported their main source of WNV information to be television (Aquino, Fyfe et al. 2004; Averett, Neuberger et al. 2005). However, the most common method for public health risk communication is through press releases. Television campaigns are rarely used due to their cost. In our study, over 50% of respondents did not know that there was no cure for WNV and could not correctly identify the age group at the greatest risk for WNV – an indicator that key aspects of disseminated messages to date have been ineffective. Despite such misconceptions, the majority of respondents reported engaging in a specific behavior due to formal and informal information sources. Given this variation in risk perceptions and misconceptions, perhaps it is time to rethink public health risk communication strategies and create innovative solutions that meet the needs and cost constraints of public health while creating effective messages that are able to reach at-risk populations.

Perceived benefits and barriers to action also play an important role. Even though a previous study on health beliefs did not find perceived benefits to be a significant predictor of personal protective behaviors (Aquino, Fyfe et al. 2004), one would expect that benefits related to particular action would likely promote its uptake. We found this construct to increase action between 47% and 87% for all health behaviors with the exception of screens. The latter is likely a function of the fact that screens likely result in a one-time benefit at the time of installation and may not have subsequent reported benefits.

Traditionally, the health belief model suggests that if one perceives there to be barriers to a particular action then they are less likely to engage in that action (Glanz, Rimer et al. 2002). Perceived barriers of the personal protective behaviors were significant in all outcomes with the exception of wearing
The direction of perceived barriers for the significant personal protective behaviors, however, was not consistent. As expected, respondents were less likely to engage in source reduction, use screens, and avoid outdoor areas between dusk and dawn if they perceived barriers to their implementation. This supports previous findings that perceived barriers hinder mosquito avoidance behavior and source reduction (Aquino, Fyfe et al. 2004). Aquino and colleagues also found that the same barriers (as in this study) led to a 50% reduction in the frequency of using DEET based insect repellents. In our study, we found that respondents, on average, were 15% more likely to use insect repellents with DEET than not use them despite reported barriers to use. Respondents used DEET based insect repellents despite reporting that they were worried about the effect of DEET products on their health and the environment. For example, 58% reported using DEET based insect repellents frequently yet 35% were worried about their health effects. More specifically, 21% of respondents used the product while worried about suffering adverse health effects. Similarly, 38% of respondents indicated they didn’t know whether DEET products had negative environmental effects but still used them. This shows that even though respondents perceived barriers they were willing to use insect repellents with DEET – perhaps an indication of their effectiveness and public health importance. Unfortunately, the survey was not designed to examine why this phenomenon occurred.

Perceived susceptibility is perhaps the cornerstone of the health belief model in that if one does not perceive a risk it is unlikely any action will be taken to counteract the risk. Traditionally, perceived susceptibility has been examined in the general sense (Glanz, Rimer et al. 2002). However, we found that perceived susceptibility was not only behavior dependent but also driven by whether one felt susceptible at home or while engaging in recreational activities. This is likely a result of nuisance mosquitoes during the evenings at home or while outside for recreational activities, and not due to the perceived risk of WNV. Though such mosquitoes are usually considered a nuisance, they may be carriers of WNV later in the summer season. Understanding where individuals feel most susceptible to mosquito bites is key to tailoring educational and risk messages to specific activities and locations. For example, flyers could be developed emphasizing the importance of screens and avoiding patios at dawn and dusk for residential areas. Where as flyers could accompany recreational activity brochures and bulletin boards promoting insect repellent use, wearing protective clothing, and source reduction.

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8 Wearing of pants, in particular, may also hint at the respondents’ desire to reduce the risk of acquiring Lyme disease - an aspect that was not included in our survey.
The social amplification of risk has been documented in the case of WNV (Nicol, Hurrell et al. 2008). It was thought that as WNV risk and media coverage increased over the summer we would observe an increased response rate. As predicted, the response rate increased as the number of WNV cases in the country increased (Table 2.6), with the highest response rates occurring in August. Though likely a function of social amplification of risk, it could also be a function of the popularity of vacationing during the month of August. The latter could lend itself to more people being willing to complete a questionnaire. When we examined study month, it was only a significant predictor of insect repellent use (with DEET) and not in the expected direction. Respondents who completed the survey in August were 54% less likely to use insect repellents with DEET than those who completed the survey in July (Table 2.5). There are several hypotheses for this. One might hypothesize that this is the vacation phenomenon and the likelihood that people may vacation outside of their normal habitat and, therefore, not in need of insect repellents. Alternatively, early in the mosquito season individuals may be more bothered by mosquito bites and, therefore, more likely to use insect repellent with DEET. This could also be related to an unusually high level of mosquito activity in July 2007 when *Culex tarsalis* are most active (P.Curry, Personal Communication, January 2009); however, July, August and September are all considered to be peak mosquito months (Manitoba Health 2007). Our survey was not designed to be stratified by month, as a result the questions were in reference to the summer in general and not to the specific time the survey was completed. It is likely a function of the survey design and its limitations as month lost its predictive power in the sensitivity analyses. Additionally, our survey was coincidentally carried out 2007, a year which had the highest number of human WNV infections to date in Canada. As a result respondents were more likely to be aware of WNV and more likely to have heightened risk perceptions. It would be interesting to design time series studies of WNV and other re-emerging infectious diseases to examine the temporal component of risk perceptions – as they will inevitably vary as the disease becomes more established. Such a study would assist with understanding at what threshold of risk individuals engage in personal protective behaviors and whether this changes between diseases and as the disease rate varies.

There were additional limitations associated with our study. First, respondents to the questionnaire may have exhibited memory recall bias – leading to random over or under reporting of answers. This was hopefully minimized through the timing of the survey. We implemented the survey in July, August, and September – months with high levels of mosquito activity and WNV risk. Second, our sampling frame excluded those without listed telephone numbers and those who use only cellular telephones. This would have likely excluded the younger demographic group – increasingly reliant
on only cellular telephones. Therefore, results may not be generalizable outside the study sample. Thirdly, though our survey asked questions about nuisance mosquitoes and WNV, but it was not able to tease out actions taken to only prevent mosquito bites versus actions taken to reduce the risk of WNV.

Despite limitations, this study demonstrates that by understanding risk perceptions that encourage behavior change versus misconceptions preventing behavior changes we can develop educational messages that match the informational needs of the populations at risk. This has implications not only for WNV public health campaigns but also for other re-emerging infectious diseases that are faced with scientific uncertainty. In understanding individual perceptions, targeted messages can be designed for a variety of scenarios and sub-populations to promote behavior change (Bennett and Calman 2001). Such messages must then be assessed for their clarity and appropriateness to ensure that misconceptions are not further propagated.

## 2.5 Conclusions

By examining WNV as a system we saw that perceptions and subsequent activities varied based on perceived risk and disease context. Respondents engaged in specific actions if they received formal or informal information on the specific behavior and understood the benefits. They were also willing to engage in actions that brought comfort (from mosquito bites) despite perceived risks and potential adverse effects. In addition, these actions may vary depending on experience and social exposure to a particular disease. Misconceptions surrounding WNV infection and treatment were also identified. Approximately half of respondents could not correctly identify the age group at risk for WNV infection and whether there was a treatment. Correcting these misconceptions are central to disease prevention. By understanding what leads individuals to engage in action and misconceptions that prevent recommended health behaviors we can develop more effective public health messages and risk communications. They need to be innovative and address the diversity of risk perceptions and regional variations of exposure for a particular disease. They need to encourage and promote actions intended for the community and its population. They need to be assessed for clarity and appropriateness. These steps may require unique and new approaches to traditional press releases and emphasize the importance of using popular media sources. This underscores the importance for research on the specific dynamics of re-emerging infectious diseases and risk
perceptions under scientific uncertainty. Such research will allow us to better understand and create public health risk communication campaigns for future new and re-emerging diseases.
Figure 2.1. Interplay of health belief model components

Adapted from: (Glanz, Rimer et al. 2002)
Figure 2.2. Number of reported human West Nile virus cases in Canada by year

Compiled from several data sources:
Figure 2.3. Cumulative human West Nile virus cases (2003-2007) and geographical location of survey respondents
<table>
<thead>
<tr>
<th>Health Belief Questions</th>
<th>Categories</th>
<th>BC No WNV</th>
<th>AB &amp; MB WNV in province</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 In general, do you live in a high, medium or low mosquito area?</td>
<td>Low</td>
<td>58.4 (205)</td>
<td>20.9 (75)</td>
<td>39.5 (280)</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>21.7 (76)</td>
<td>32.7 (117)</td>
<td>27.2 (193)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>19.9 (70)</td>
<td>46.4 (166)</td>
<td>33.3 (236)</td>
</tr>
<tr>
<td>2 In general, do you participate in recreational activities in a high, medium or low</td>
<td>Low</td>
<td>40.1 (140)</td>
<td>18.4 (66)</td>
<td>29.1 (206)</td>
</tr>
<tr>
<td>mosquito area?</td>
<td>Medium</td>
<td>26.9 (94)</td>
<td>29.9 (107)</td>
<td>28.4 (201)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>33.0 (115)</td>
<td>51.7 (185)</td>
<td>42.4 (300)</td>
</tr>
<tr>
<td>3 For a person who has contracted West Nile virus, how likely do you think it is that</td>
<td>Very unlikely</td>
<td>6.2 (22)</td>
<td>5.1 (18)</td>
<td>5.7 (40)</td>
</tr>
<tr>
<td>they will become seriously ill or die?</td>
<td>Unlikely</td>
<td>26.2 (91)</td>
<td>30.1 (107)</td>
<td>28.2 (198)</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>6.9 (24)</td>
<td>8.7 (31)</td>
<td>7.8 (55)</td>
</tr>
<tr>
<td></td>
<td>Likely</td>
<td>23.3 (81)</td>
<td>30.6 (109)</td>
<td>27 (190)</td>
</tr>
<tr>
<td></td>
<td>Very likely</td>
<td>6.1 (21)</td>
<td>5.6 (20)</td>
<td>5.8 (41)</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>31.1 (108)</td>
<td>19.9 (71)</td>
<td>25.5 (179)</td>
</tr>
<tr>
<td>4 You can get West Nile virus from mosquito bites</td>
<td>Strongly disagree</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Disagree</td>
<td>0.9 (3)</td>
<td>-</td>
<td>0.4 (3)</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>0.3 (1)</td>
<td>-</td>
<td>0.1 (1)</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>20.7 (72)</td>
<td>12.6 (45)</td>
<td>16.6 (117)</td>
</tr>
<tr>
<td></td>
<td>Strongly agree</td>
<td>76.9 (267)</td>
<td>86.8 (309)</td>
<td>81.9 (576)</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>1.2 (4)</td>
<td>0.6 (2)</td>
<td>0.9 (6)</td>
</tr>
<tr>
<td>5 There is an effective treatment for people who have contracted West Nile virus?</td>
<td>Strongly disagree</td>
<td>2.0 (7)</td>
<td>4.5 (16)</td>
<td>3.3 (23)</td>
</tr>
<tr>
<td></td>
<td>Disagree</td>
<td>17.0 (59)</td>
<td>18.6 (66)</td>
<td>17.8 (125)</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>0.3 (1)</td>
<td>2.5 (9)</td>
<td>1.4 (10)</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>24.5 (85)</td>
<td>31.8 (113)</td>
<td>28.2 (198)</td>
</tr>
<tr>
<td></td>
<td>Strongly agree</td>
<td>0.9 (3)</td>
<td>2.0 (7)</td>
<td>1.4 (10)</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>55.3 (192)</td>
<td>40.6 (144)</td>
<td>47.9 (336)</td>
</tr>
<tr>
<td>6 What age category do you consider to be at the greatest risk of becoming seriously</td>
<td>Children (0-12 yrs)</td>
<td>29.9 (103)</td>
<td>23.7 (84)</td>
<td>26.7 (187)</td>
</tr>
<tr>
<td>ill or dying when infected with West Nile virus?</td>
<td>Teens (13-19 yrs)</td>
<td>0.6 (2)</td>
<td>1.1 (4)</td>
<td>0.9 (6)</td>
</tr>
<tr>
<td></td>
<td>Adults (20-49 yrs)</td>
<td>0.9 (3)</td>
<td>0.3 (1)</td>
<td>0.6 (4)</td>
</tr>
<tr>
<td></td>
<td>Adults (&gt; 50 yrs)</td>
<td>44.6 (154)</td>
<td>58.9 (209)</td>
<td>51.9 (363)</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>24.1 (83)</td>
<td>16.1 (57)</td>
<td>20.0 (140)</td>
</tr>
<tr>
<td>7 Do you receive information about West Nile virus from the following sources?</td>
<td>TV</td>
<td>79.9 (270)</td>
<td>88.3 (308)</td>
<td>84.1 (578)</td>
</tr>
<tr>
<td></td>
<td>Newspaper</td>
<td>76.2 (253)</td>
<td>85.8 (290)</td>
<td>81.0 (543)</td>
</tr>
<tr>
<td></td>
<td>Radio</td>
<td>49.5 (163)</td>
<td>74.0 (242)</td>
<td>61.7 (405)</td>
</tr>
<tr>
<td></td>
<td>Friends</td>
<td>39.5 (126)</td>
<td>53.6 (173)</td>
<td>46.6 (229)</td>
</tr>
<tr>
<td></td>
<td>Family</td>
<td>36.1 (116)</td>
<td>49.7 (161)</td>
<td>42.9 (277)</td>
</tr>
<tr>
<td></td>
<td>Brochure</td>
<td>25.4 (80)</td>
<td>43.9 (138)</td>
<td>34.7 (218)</td>
</tr>
<tr>
<td>Health Belief Questions</td>
<td>BC No WNV</td>
<td>AB &amp; MB WNV in province</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>-------------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Public Health</td>
<td>14.4 (46)</td>
<td>30.0 (97)</td>
<td>22.2 (143)</td>
<td></td>
</tr>
<tr>
<td>Avoiding going outside during the peak mosquito hours of dusk to dawn helps reduce the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>risk of being infected with West Nile virus infection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>0.3 (1)</td>
<td>0.1 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>4.7 (16)</td>
<td>2.8 (10)</td>
<td>3.7 (26)</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>2.6 (9)</td>
<td>1.4 (5)</td>
<td>2.0 (14)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>58.9 (202)</td>
<td>59.8 (211)</td>
<td>59.3 (413)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>31.5 (108)</td>
<td>125 (35.4)</td>
<td>33.5 (233)</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>2.0 (7)</td>
<td>0.6 (2)</td>
<td>1.3 (9)</td>
<td></td>
</tr>
<tr>
<td>I go outdoors during peak mosquito hours of dusk to dawn because of the activities in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>which I am involved (social gathering, organized sports, physical activities, leisure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>activity, walking the dog, my occupation, etc…)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>1.1 (4)</td>
<td>3.9 (14)</td>
<td>2.5 (18)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>14.9 (52)</td>
<td>20.1 (72)</td>
<td>17.5 (124)</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>3.7 (13)</td>
<td>3.4 (12)</td>
<td>3.5 (25)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>56.3 (197)</td>
<td>55.3 (198)</td>
<td>55.8 (395)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>23.4 (82)</td>
<td>17.3 (62/)</td>
<td>20.3 (144)</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>0.6 (2)</td>
<td>-</td>
<td>0.3 (2)</td>
<td></td>
</tr>
<tr>
<td>Information I got about West Nile virus has influenced me to avoid going outdoors</td>
<td>30.6 (106)</td>
<td>17.5 (62)</td>
<td>24.0 (168)</td>
<td></td>
</tr>
<tr>
<td>during the peak mosquito hours of dusk to dawn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>1.3 (4)</td>
<td>4.2 (15)</td>
<td>4.6 (32)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>44.5 (154)</td>
<td>40.7 (144)</td>
<td>42.6 (298)</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>5.5 (19)</td>
<td>7.9 (28)</td>
<td>6.7 (47)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>15.6 (54)</td>
<td>25.4 (90)</td>
<td>20.6 (144)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>3.8 (13)</td>
<td>8.2 (29)</td>
<td>6.0 (42)</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>-</td>
<td>0.3 (1)</td>
<td>0.1 (1)</td>
<td></td>
</tr>
<tr>
<td>I know of neighbors/friends/family who avoid going outdoors between the hours of dusk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and dawn to avoid mosquito bites</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>4.9 (17)</td>
<td>4.2 (15)</td>
<td>4.6 (32)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>15.1 (52)</td>
<td>14.1 (50)</td>
<td>14.6 (102)</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>0.9 (3)</td>
<td>3.4 (12)</td>
<td>2.1 (15)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>20.3 (70)</td>
<td>36.3 (129)</td>
<td>28.5 (199)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>2.9 (10)</td>
<td>3.9 (14)</td>
<td>3.4 (24)</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>55.8 (192)</td>
<td>38.0 (135)</td>
<td>46.8 (327)</td>
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<tr>
<td>Applying a mosquito repellent containing DEET helps reduce the risk of being infected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with West Nile virus infection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>1.2 (4)</td>
<td>0.3 (1)</td>
<td>0.7 (5)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>2.9 (10)</td>
<td>1.1 (4)</td>
<td>2.0 (14)</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>7.0 (24)</td>
<td>2.0 (7)</td>
<td>4.4 (31)</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>47.5 (164)</td>
<td>51.4 (183)</td>
<td>49.5 (347)</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>30.4 (105)</td>
<td>42.1 (150)</td>
<td>36.4 (255)</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>11.0 (38)</td>
<td>3.1 (11)</td>
<td>7.0 (49)</td>
<td></td>
</tr>
<tr>
<td>Mosquito repellents with DEET are safe for your health</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>11.4 (31)</td>
<td>1.2 (4)</td>
<td>5.8 (35)</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>30.4 (83)</td>
<td>28.5 (95)</td>
<td>29.4 (178)</td>
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<td>Health Belief Questions</td>
<td>Categories</td>
<td>BC No WNV</td>
<td>AB &amp; MB WNV in province</td>
<td>All</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------------</td>
<td>-----------------------------</td>
<td>-----------</td>
<td>--------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
</tr>
<tr>
<td>14 Mosquito repellents with DEET are bad for the environment</td>
<td>Agree</td>
<td>21.6 (59)</td>
<td>39.6 (132)</td>
<td>31.5 (191)</td>
</tr>
<tr>
<td></td>
<td>Strongly agree</td>
<td>1.5 (4)</td>
<td>2.4 (8)</td>
<td>2.0 (12)</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>27.1 (74)</td>
<td>16.8 (56)</td>
<td>21.5 (130)</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>2.6 (7)</td>
<td>1.8 (6)</td>
<td>2.2 (13)</td>
</tr>
<tr>
<td></td>
<td>Disagree</td>
<td>10.6 (29)</td>
<td>22.1 (73)</td>
<td>16.9 (102)</td>
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<td>10.3 (28)</td>
<td>10.6 (35)</td>
<td>10.4 (63)</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>28.9 (79)</td>
<td>30.6 (101)</td>
<td>29.9 (180)</td>
</tr>
<tr>
<td></td>
<td>Strongly agree</td>
<td>4.8 (13)</td>
<td>0.9 (3)</td>
<td>2.7 (16)</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>42.9 (117)</td>
<td>33.9 (112)</td>
<td>38.0 (229)</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>1.5 (4)</td>
<td>1.2 (4)</td>
<td>1.3 (8)</td>
</tr>
<tr>
<td></td>
<td>Disagree</td>
<td>29.8 (81)</td>
<td>36.0 (119)</td>
<td>33.2 (200)</td>
</tr>
<tr>
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<td>13.0 (43)</td>
<td>13.1 (79)</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>23.5 (64)</td>
<td>33.8 (112)</td>
<td>29.2 (176)</td>
</tr>
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<td>Strongly agree</td>
<td>2.6 (7)</td>
<td>4.2 (14)</td>
<td>3.5 (21)</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>29.4 (80)</td>
<td>11.8 (39)</td>
<td>19.7 (119)</td>
</tr>
<tr>
<td>15 Mosquito repellents with DEET are expensive</td>
<td>Strongly disagree</td>
<td>1.3 (8)</td>
<td>0.3 (1)</td>
<td>1.3 (8)</td>
</tr>
<tr>
<td></td>
<td>Disagree</td>
<td>33.2 (200)</td>
<td>3.9 (13)</td>
<td>3.8 (23)</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>13.1 (79)</td>
<td>2.4 (8)</td>
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<td>29.2 (176)</td>
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<td>16 Mosquito repellents with DEET are convenient to use</td>
<td>Strongly disagree</td>
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<td>45.0 (149)</td>
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<td>17 Mosquito repellents with DEET are unpleasant when applied (greasy, sticky, bad smell, etc.)</td>
<td>Strongly disagree</td>
<td>33.8 (117)</td>
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<td>0.1 (1)</td>
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<td>18 Information I got about West Nile virus has influenced me to use mosquito repellent</td>
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<td>AB &amp; MB WNV in province</td>
<td>All (%)</td>
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<td>20 Wearing long sleeved shirts or other protective clothing outdoors helps reduce the</td>
<td>Agree</td>
<td>32.3 (111)</td>
<td>54.5 (193)</td>
<td>43.6 (304)</td>
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<td>20 risk of being infected with West Nile virus infection</td>
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<td>8.8 (31)</td>
<td>6.6 (46)</td>
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<td>30.5 (108)</td>
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<td>21 Wearing long sleeved clothing and pants is too uncomfortable/hot in the summer time</td>
<td>Disagree</td>
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<td>29.1 (104)</td>
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<td>6.6 (46)</td>
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<td>21 Don’t know</td>
<td>-</td>
<td>0.3 (1)</td>
<td>0.1 (1)</td>
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<tr>
<td>25 I know of neighbors/friends/family who wear long sleeved clothing and pants when</td>
<td>Strongly disagree</td>
<td>3.5 (12)</td>
<td>2.0 (7)</td>
<td>2.7 (19)</td>
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<tr>
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<td>AB &amp; MB WNV in province (%(n))</td>
<td>All (%(n))</td>
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<td><strong>26  Putting screens on windows/doors of your home helps reduce the risk of being infected with West Nile virus infection</strong></td>
<td>Agree</td>
<td>25.9 (89)</td>
<td>43.2 (153)</td>
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<td>Strongly disagree</td>
<td>-</td>
<td>0.6 (2)</td>
<td>0.3 (2)</td>
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<td>Disagree</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td><strong>27  Putting screens on the windows/doors of my house is time consuming</strong></td>
<td>Strongly disagree</td>
<td>31.2 (107)</td>
<td>36.8 (130)</td>
<td>34.1 (237)</td>
</tr>
<tr>
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<td>Disagree</td>
<td>40.2 (138)</td>
<td>46.2 (163)</td>
<td>43.2 (301)</td>
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<td>2.0 (7)</td>
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<td>Strongly agree</td>
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<td>Strongly agree</td>
<td>-</td>
<td>0.3 (1)</td>
<td>0.1 (1)</td>
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<td>9.6 (34)</td>
<td>12.8 (89)</td>
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<tr>
<td><strong>28  Putting screens on the windows/doors of my house is too physically demanding</strong></td>
<td>Strongly disagree</td>
<td>28.7 (98)</td>
<td>31.1 (110)</td>
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<td>Strongly agree</td>
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<td>Don’t know</td>
<td>15.2 (52)</td>
<td>9.9 (35)</td>
<td>12.5 (87)</td>
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<tr>
<td><strong>29  Putting screens on the windows/doors of my house is too expensive</strong></td>
<td>Strongly disagree</td>
<td>42.0 (144)</td>
<td>40.4 (143)</td>
<td>41.2 (287)</td>
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<td>43.4 (149)</td>
<td>49.2 (174)</td>
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<td>Don’t know</td>
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<td>1.1 (4)</td>
<td>1.3 (9)</td>
</tr>
<tr>
<td><strong>30  I do not have control over putting screens on the windows/doors of my house (e.g. I’m a tenant, due to building regulations, building design doesn’t allow it, etc.)</strong></td>
<td>Strongly disagree</td>
<td>42.0 (144)</td>
<td>40.4 (143)</td>
<td>41.2 (287)</td>
</tr>
<tr>
<td></td>
<td>Disagree</td>
<td>43.4 (149)</td>
<td>49.2 (174)</td>
<td>46.3 (323)</td>
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<td>4.2 (15)</td>
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<td>AB &amp; MB WNV in province</td>
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<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
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<td>31 Putting screens on the windows/doors of my house is too tedious to keep intact</td>
<td>Strongly disagree</td>
<td>23.0 (79)</td>
<td>23.4 (83)</td>
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<td>60.5 (423)</td>
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<td>Strongly agree</td>
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<td>Don’t know</td>
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<td>32 Putting screens on the windows/doors of my house is too difficult</td>
<td>Strongly disagree</td>
<td>31.4 (108)</td>
<td>35.9 (127)</td>
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<td>Strongly agree</td>
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<td>33 Putting screens on the windows/doors of my house is not needed</td>
<td>Strongly disagree</td>
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<td>62.3 (221)</td>
<td>48.4 (340)</td>
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<td>43.2 (150)</td>
<td>30.7 (109)</td>
<td>36.9 (259)</td>
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<td>Strongly agree</td>
<td>10.1 (35)</td>
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<td>0.3 (1)</td>
<td>0.3 (2)</td>
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<td>25.9 (92)</td>
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<td>-</td>
<td>0.1 (1)</td>
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<td>Strongly agree</td>
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<td>3.8 (25)</td>
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<td>22.3 (80)</td>
<td>22.1 (156)</td>
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<td>Disagree</td>
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<td>44.1 (158)</td>
<td>39.9 (282)</td>
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<td>17.0 (61)</td>
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<td>-</td>
<td>0.1 (1)</td>
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<td>42 Information I got about West Nile virus has influenced me to remove standing water</td>
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<td>16.6 (59)</td>
<td>20.2 (140)</td>
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<td>from places where water collects</td>
<td>Disagree</td>
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<td>22.0 (78)</td>
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<td>34.6 (123)</td>
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<td>AB &amp; MB</td>
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<td>----------------------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>-----</td>
<td>---------</td>
<td>-----</td>
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<td>I know of neighbors/friends/family who have remove standing water from places where water collects</td>
<td>Strongly disagree</td>
<td>3.2 (11)</td>
<td>2.3 (8)</td>
<td>2.7 (19)</td>
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<td>37.6 (263)</td>
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<td>11.3 (40)</td>
<td>9.7 (68)</td>
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<td>Don't know</td>
<td>49.7 (171)</td>
<td>36.3 (129)</td>
<td>42.9 (300)</td>
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</table>

All responses are given in both % share and number (n) of respondents as not all respondents completed all questions.
Please note the numbering scheme here does not correlate to questionnaire number in Appendix A.
Table 2.2 Description and distribution of outcome variables by exposure group

<table>
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<tr>
<th>Health Behavior Outcomes</th>
<th>Categories</th>
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<th>WNV in province</th>
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</tr>
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<td></td>
<td></td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
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<tr>
<td>How often do you use the following to reduce the risk of being bitten by mosquito bites:</td>
<td></td>
<td></td>
<td></td>
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<td>A Avoid doing things outdoors where mosquitoes are a nuisance</td>
<td>Never</td>
<td>47.1 (165)</td>
<td>28.0 (100)</td>
<td>37.5 (265)</td>
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<td>Occasionally</td>
<td>28.0 (98)</td>
<td>29.7 (106)</td>
<td>28.9 (204)</td>
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<tr>
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<td>Half the time</td>
<td>6.9 (24)</td>
<td>7.6 (27)</td>
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<tr>
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<td>Often</td>
<td>12.9 (45)</td>
<td>24.6 (88)</td>
<td>18.8 (133)</td>
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<td>Always</td>
<td>4.9 (17)</td>
<td>10.1 (36)</td>
<td>7.5 (53)</td>
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<td>Don’t know</td>
<td>0.3 (1)</td>
<td>-</td>
<td>0.1 (1)</td>
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<tr>
<td>B Use a mosquito repellent with DEET (for example: Off!, Muskol)</td>
<td>Never</td>
<td>52.8 (162)</td>
<td>25.9 (90)</td>
<td>38.5 (252)</td>
</tr>
<tr>
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<td>Occasionally</td>
<td>15.0 (46)</td>
<td>17.5 (61)</td>
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<td>Half the time</td>
<td>4.9 (15)</td>
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<td>20.1 (70)</td>
<td>15.7 (103)</td>
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<td>2.6 (9)</td>
<td>3.4 (22)</td>
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<tr>
<td>C Wear long sleeved clothing and pants</td>
<td>Never</td>
<td>36.3 (127)</td>
<td>20.9 (75)</td>
<td>28.5 (202)</td>
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<td>18.6 (65)</td>
<td>22.3 (80)</td>
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<td>26.9 (94)</td>
<td>33.5 (120)</td>
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<td>0.3 (2)</td>
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<td>D Put screens on the windows/doors in my house</td>
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<td>-</td>
<td>1.8 (13)</td>
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<td>2.0 (7)</td>
<td>6.1 (43)</td>
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<td>80.9 (573)</td>
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<td>E Remove standing water from places where water collects</td>
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<td>6.1 (20)</td>
<td>6.9 (45)</td>
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<td>Half the time</td>
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<td>13.3 (86)</td>
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<td>1.2 (4)</td>
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All responses are given in both % share and number (n) of respondents as not all respondents completed all questions.
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<th>Health Belief Question (Table 2.2) &amp; Calculation</th>
<th>Possible Range</th>
<th>No WNV (SD)</th>
<th>WNV in province (SD)</th>
<th>All (SD)</th>
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<td>2.25 (0.78)</td>
<td>1.64 (0.80)</td>
<td>1.94 (0.85)</td>
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<td>2.33 (0.77)</td>
<td>1.92 (0.85)</td>
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<td>Severity</td>
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<td>0-5</td>
<td>2.42 (1.58)</td>
<td>2.03 (1.69)</td>
<td>2.23 (1.65)</td>
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<td>Recoded:</td>
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<td>1.92 (0.66)</td>
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<td>1.80 (0.69)</td>
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<td>Σ (4, 5, 6)</td>
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<td>2.39 (2.02)</td>
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<td>Benefits to action</td>
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<td>4.26 (0.71)</td>
<td>4.11 (0.93)</td>
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<td>3.62 (1.11)</td>
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<td>14.06 (4.35)</td>
<td>12.03 (5.66)</td>
<td>13.14 (5.08)</td>
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<td>3.77 (2.43)</td>
<td>4.72 (2.64)</td>
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<td>Benefits to action</td>
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<td>0-5</td>
<td>4.08 (0.91)</td>
<td>3.98 (0.88)</td>
<td>4.03 (0.90)</td>
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<tr>
<td>Barriers to action</td>
<td>Σ (21, 22, 23)</td>
<td>0-13</td>
<td>7.92 (1.94)</td>
<td>7.42 (2.08)</td>
<td>7.67 (2.03)</td>
</tr>
<tr>
<td>Cues to action (specific)</td>
<td>Σ (24, 25)</td>
<td>0-10</td>
<td>5.20 (2.46)</td>
<td>3.97 (2.38)</td>
<td>4.59 (2.50)</td>
</tr>
<tr>
<td><strong>Screens Domains</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefits to action</td>
<td>26</td>
<td>0-5</td>
<td>4.78 (0.45)</td>
<td>4.65 (0.48)</td>
<td>4.72 (0.47)</td>
</tr>
<tr>
<td>Barriers to action</td>
<td>Σ (27, 28, 29, 30, 31, 32, 33)</td>
<td>0-23</td>
<td>11.62 (3.79)</td>
<td>11.96 (4.42)</td>
<td>11.78 (4.11)</td>
</tr>
<tr>
<td>Cues to action (specific)</td>
<td>Σ (34, 35)</td>
<td>0-10</td>
<td>6.35 (2.10)</td>
<td>4.76 (2.59)</td>
<td>5.57 (2.49)</td>
</tr>
<tr>
<td><strong>Source reduction Domains</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefits to action</td>
<td>36</td>
<td>0-5</td>
<td>4.45 (0.75)</td>
<td>4.46 (0.72)</td>
<td>4.46 (0.74)</td>
</tr>
<tr>
<td>Barriers to action</td>
<td>Σ (37, 38, 39, 40, 41)</td>
<td>0-17</td>
<td>10.00 (3.37)</td>
<td>10.06 (3.64)</td>
<td>10.03 (3.50)</td>
</tr>
<tr>
<td>Cues to action (specific)</td>
<td>Σ (42, 43)</td>
<td>0-10</td>
<td>5.57 (2.60)</td>
<td>4.81 (2.72)</td>
<td>5.20 (2.68)</td>
</tr>
</tbody>
</table>
Table 2.4. Distribution of selected demographic characteristics by province

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>BC (n=351)</th>
<th>AB &amp; MB (n=358)</th>
<th>All % (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No WNV % (n)</td>
<td>WNV in province % (n)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>38.3 (134)</td>
<td>40.6 (145)</td>
<td>39.5 (279)</td>
</tr>
<tr>
<td>Female</td>
<td>61.7 (216)</td>
<td>59.4 (212)</td>
<td>60.5 (428)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;44 years</td>
<td>27.2 (95)</td>
<td>33.1 (118)</td>
<td>30.2 (213)</td>
</tr>
<tr>
<td>≥45 years</td>
<td>72.8 (254)</td>
<td>66.9 (238)</td>
<td>69.8 (492)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School or less</td>
<td>36.1 (125)</td>
<td>32.2 (114)</td>
<td>34.1 (239)</td>
</tr>
<tr>
<td>University/technical and higher</td>
<td>63.9 (221)</td>
<td>67.8 (240)</td>
<td>65.9 (461)</td>
</tr>
<tr>
<td>Month</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>29.4 (102)</td>
<td>29.8 (106)</td>
<td>29.5 (208)</td>
</tr>
<tr>
<td>August</td>
<td>38.3 (133)</td>
<td>45.8 (163)</td>
<td>42.0 (296)</td>
</tr>
<tr>
<td>September</td>
<td>32.5 (113)</td>
<td>24.4 (87)</td>
<td>28.4 (200)</td>
</tr>
<tr>
<td>Residential type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single family</td>
<td>74.9 (263)</td>
<td>82.7 (296)</td>
<td>78.8 (559)</td>
</tr>
<tr>
<td>Other</td>
<td>25.1 (88)</td>
<td>17.3 (62)</td>
<td>21.2 (150)</td>
</tr>
<tr>
<td>Community Involvement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>81.2 (281)</td>
<td>74.6 (246)</td>
<td>77.9 (545)</td>
</tr>
<tr>
<td>Yes</td>
<td>18.8 (65)</td>
<td>25.4 (90)</td>
<td>22.1 (155)</td>
</tr>
</tbody>
</table>

All responses are given in both % share and number (n) of respondents as not all respondents completed all questions.
### Table 2.5. Adjusted odds ratios, 95% confidence intervals and p-values for logistic regression models assessing self-reported personal protective behaviors

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Avoidance at dawn/dusk (n=682)</th>
<th>Use of insect repellent with DEET (n=582)</th>
<th>Protective clothing (n=684)</th>
<th>Use of screens (n=659)</th>
<th>Source reduction (n=496)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95 CI</td>
<td>p-value</td>
<td>OR</td>
<td>95 CI</td>
</tr>
<tr>
<td>Susceptibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Home Law)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home Med</td>
<td>1.42</td>
<td>0.90-2.25</td>
<td>0.131</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Home High</td>
<td>2.14</td>
<td>1.34-3.41</td>
<td>0.001</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Susceptibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Recreation Law)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation Med</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation High</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.74</td>
<td>1.55-4.85</td>
</tr>
<tr>
<td>Benefits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barriers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cues to action</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific</td>
<td>1.23</td>
<td>1.13-1.34</td>
<td>&lt;0.001</td>
<td>1.27</td>
<td>1.16-1.40</td>
</tr>
<tr>
<td>Self efficacy</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gender(\gamma)</td>
<td>1.56</td>
<td>1.08-2.26</td>
<td>0.019</td>
<td>0.77</td>
<td>0.49-1.22</td>
</tr>
<tr>
<td>Age(\gamma)</td>
<td>0.99</td>
<td>0.66-1.48</td>
<td>0.968</td>
<td>1.10</td>
<td>0.68-1.77</td>
</tr>
<tr>
<td>Presence WNV(\gamma)</td>
<td>1.47</td>
<td>0.99-2.18</td>
<td>0.058</td>
<td>1.66</td>
<td>1.06-2.59</td>
</tr>
<tr>
<td>Education(\gamma)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Involvement(\gamma)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Month</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(July)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>0.46</td>
<td>0.27-0.78</td>
</tr>
<tr>
<td>September</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>0.83</td>
<td>0.46-1.50</td>
</tr>
</tbody>
</table>

- Not significant; removed from model
- Not hypothesized for this health behavior, therefore not offered in model.
\(\gamma\) Reference values are as follows: Gender (male) vs. female; Education (high school or less) vs. university and/or technical; Presence WNV (no) vs. yes; Involvement (no) vs. yes.
\(\gamma\) Brackets indicate reference values
All models had Hosmer-Lemeshow p-values > 0.05
Table 2.6. West Nile virus human cases in 2007 and survey response rates in study provinces

<table>
<thead>
<tr>
<th>Month</th>
<th>British Columbia</th>
<th>Alberta</th>
<th>Manitoba</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cases</td>
<td>Response Rate</td>
<td>Cases</td>
</tr>
<tr>
<td>July</td>
<td>1*</td>
<td>29%</td>
<td>44</td>
</tr>
<tr>
<td>August</td>
<td>27*</td>
<td>38%</td>
<td>249</td>
</tr>
<tr>
<td>September</td>
<td>1*</td>
<td>33%</td>
<td>19</td>
</tr>
</tbody>
</table>

* Travel related cases

Sources: (BCCDC 2007; Alberta Health and Wellness 2008; Manitoba Health 2008a)
2.6 References


BCCDC (2008). How do I protect myself? 
http://www.bccdc.org/content.php?item=204&PHPSESSID=af72a0677e9e406a02c7fd51c8b1c66d6 Last accessed August 2008.


Chapter 3: Exploring public risk perceptions of West Nile virus and West Nile virus interventions: Demographic and behavioral factors

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A version of this chapter will be submitted for publication.

Elmich, N. “Exploring public risk perceptions of West Nile virus and West Nile virus interventions: Demographic and behavioral factors."
3.1 Introduction

To better regulate risks and develop targeted health communication systems we need to understand determinants of risk perceptions. Factors with the potential to drive risk perceptions have been well studied. For example, people underestimate risks when they are considered natural, voluntary, controllable, and familiar (Slovic 1987; Glickman and Gough 1990; Leiss and Chociolko 1994; Morgan, Fischhoff et al. 2002). Beyond these factors, we know that risk perceptions are also based on individual characteristics and experience with the hazard (Slovic, Fischhoff et al. 1990). Associations between risk perceptions and gender, age, and formal educational attainment are well known. In general, women tend to consider the risk to be of a greater magnitude and more problematic (Stern, Dietz et al. 1993; Slovic 2000). Those who are younger and/or have had fewer years of formal education tend to perceive risks as greater (Savage 1993). Risk perceptions can also vary based on geographical location and disease context and familiarity (Dosman, Wiktor et al. 2001; Krewski, Lemyre et al. 2007). Having young children may also increase parent’s sensitivity to not only the disease but also to preventative measures and subsequently risk perceptions (Leiss and Chociolko 1994).

The systematic understanding of risk behaviors in relation to environmental health hazards has been well studied and led to the development of more effective risk communication strategies (Slovic 2000; Morgan, Fischhoff et al. 2002). In public health, a mental models approach to understanding HIV/AIDS led to the development of more effective messages addressing specific risks, how they are created, and how they are controlled (Morgan, Fischhoff et al. 2002). West Nile virus (WNV) provides an interesting example to further examine risk perceptions, as there are risks and trade-offs associated with both the virus and intervention strategies. Systematically assessing such risk perceptions in relation to the level of the intervention and to demographic and behavioral factors can be useful in targeting public health messages.

West Nile virus is a re-emerging infectious disease, which has spread across North America since its emergence in New York City in the summer of 1999 (Glaser 2004; Weir and Shapiro 2004). Only between 20-40% of infected humans developed West Nile fever symptoms, with less than 1% developing severe neuroinvasive diseases such as West Nile meningitis, West Nile encephalitis, and acute flaccid paralysis (Mostashari, Bunning et al. 2001; Kramer, Li et al. 2007). The main risk factor
for infection and severe neuroinvasive disease is age. Those over the age of 50 are at a higher risk of WNV infection, with the risk increasing for those over 75 (Granwehr, Lillibridge et al. 2004).

The risk of WNV infection can be reduced through individual and societal level interventions. In Canada, public health officials recommend five preventative measures for individuals: (1) using insect repellents with DEET (N, N-diethyl-meta-toluamide), (2) avoiding outdoor areas during peak mosquito activity (dusk to dawn), (3) wearing protective clothing, (4) having screens on windows and doors, and (5) eliminating standing water (source reduction) to reduce the risk of WNV infection (PHAC 2006; BCCDC 2008). These activities are promoted through public education campaigns and press releases on an ongoing basis when WNV is a threat. At the societal (municipal) level, larviciding and adulticiding may be used to further prevent the risk of WNV infection.

Though such preventative measures often limit the risk of WNV infection, some may also pose additional health risks. There have been conflicting studies on the safety of DEET based products among children. A number of studies have shown adverse toxic effects from DEET based insect repellents among children (CDC 1989; Lipscomb, Kramer et al. 1992; Nevin 2004). While one study found no evidence of increased risk in children (Koren, Matsui et al. 2003). There are also concerns over the potential human risks associated with pesticides used in adulticiding. The young are at a greater risk of adverse effects. (Fitz 2003) - an issue which has receive some media attention (Globe Editorial 2008). Probabilistic modeling of potential exposures can be used to demonstrate that children may be at risk of exceeding reference doses set by the Canadian Pest Management Regulatory Agency and the United States Environmental Protection Agency (Chapter 5). These observations highlight the challenging risk trade-offs inherent in dealing with WNV and similar vector borne diseases – the elderly are at the greatest risk if the disease is unchecked, while children are at greatest risk from the interventions to reduce the spread of disease.

Being a re-emerging infectious disease, and mistakenly conflated with climate change (Riedel 2004), WNV has received significant media attention, resulting in the social amplification of risk (Nicol, Hurrell et al. 2008). This amplification, in combination with disease experience, has led to heightened levels of risk awareness. This has triggered changes in the willingness to accept certain risks. For example, in Saskatchewan, an 80% increase in support of an adulticiding program was reported following a season of WNV activity (Schellenberg, Anderson et al. 2006). Similarly, in Chapters 2 it was found that those who lived in areas with WNV activity were more likely to engage in recommended health preventative measures.
Given the concern over the safety of insect repellents with DEET and pesticides used in adulticiding, the social amplification of risk, and the social dimension of risk trade-offs the purpose of this study was to explore the impact of demographic and behavioral factors on risk perceptions related to exposures to, and sickness from individual and societal level interventions used to control and prevent WNV infection. This was achieved by asking the following questions and hypotheses:

1. What demographic and behavioral factors influence risk perceptions related to WNV, exposure to and sickness from pesticides (societal intervention) and insect repellents with DEET (individual intervention)?
   \[ H_0: \text{Risk perceptions of WNV and WNV interventions are not influenced by demographics.} \]
   \[ H_1: \text{Risk perceptions of WNV and WNV interventions are influenced by demographics.} \]

2. Is there a proportion of the population that worries about all risks from disease to insect repellents with DEET to pesticide exposure? If yes, do their behavior patterns lead to a different risk profile than other members of the public?
   \[ H_0: \text{Individuals do not systematically worry about all risks related to WNV.} \]
   \[ H_1: \text{Individuals systematically worry about all risks related to WNV.} \]

### 3.2 Methods

A randomized telephone survey examining health beliefs and behaviors in relation to WNV was carried out between July and October 2007 (Chapter 2). A companion survey eliciting activity levels and risk trade-offs, using online and mail surveys, was carried out for those who participated in the telephone survey (Chapter 4). Both surveys were part of larger study examining risk perceptions, health behaviors, and risk trade-offs is relation to WNV in three Canadian provinces with different levels of WNV activity.

Data obtained from both survey sources were merged using unique identifiers. All variables used were categorical. Descriptive analyses included counts and cross-tabulations. Variables were
visualized using box plots and histograms. SPSS statistical software version 11.0 was used for all analyses.

This paper examines survey elements pertaining to risk perceptions and fears related to WNV and WNV interventions and their relationship to six risk factors (independent variables): (1) gender, (2) age (at risk for WNV vs. not at risk), (3) having children under 14, (4) exposure to WNV (province of residence), (5) household location (urban vs. rural), and (6) outdoor activity level (active vs. non-active). The first five outcome variables were self-reported while activity level was collected based on self-reported frequency of outdoor activity on weekdays and weekend days. Outdoor activity levels were aggregated into active (2 or more hours outdoors on a given day) and inactive (less than 2 hours outdoors on a given day) for all respondents. Sensitivity analyses based on an alternate dichotomization of outdoor activity levels (very active = 4 or more hours outdoors vs. less active = 4 or less hours outdoors) was carried out to test the appropriateness of the outdoor activity level categorization in this study.

Risk perceptions were described using 7 variables. Five variables reflected perceptions related to exposure and sickness from pesticides, insect repellents using DEET, and insect bites (Table 3.1). A sixth variable aggregated these responses to designate those who perceived a high level of risk from all aforementioned factors. The seventh variable reflected perceived risk of getting sick from WNV.

Bivariate relationships between demographic and behavioral factors and risk perceptions were examined using Pearsons chi-square ($\chi^2$) test. Odds ratios and cross-tabulations were examined to interpret any effects. Multivariable logistic regression analyses were created for outcome variables based on the results of bivariate analyses. As this study is exploring various risk perceptions, variables shown to have a weak association ($p<0.20$) with the outcome of interest were initially considered for multivariable logistic models. Gender, age, and potential exposure (presence of WNV in the province of residence) were controlled for in all models. Model parameters were assessed and refined using significance levels, potential relationship with the outcome, and the Hosmer-Lemeshow goodness of fit statistic. Residuals were examined to evaluate model fit.
3.3 Results

3.3.1 Description of population
Of those who completed the health belief and behavior survey (N=709), 463 also completed the companion online/mail survey examining activity levels and risk trade-offs (Chapters 2 and 4). Five participants were excluded due to multiple online entries and 17 participants were excluded because they did not answer the outcomes of interest. The final sample size was 441, of which 222 lived in British Columbia, 108 in Alberta, and 111 in Manitoba. Majority of respondents were female, over the age of 45, and had obtained a university degree. Table 3.2 provides a summary of the demographic characteristics.

3.3.2 Demographic and behavioral risk factors
Risk factor variables were selected to reflect population attributes with a potential to influence risk perceptions. Seventy three percent of respondents reported living in urban areas. The majority of respondents (86%) were considered to be active (≥ 2 hours of activity outdoors) on a given weekday or weekend day. Less than one quarter of the sample reported having children under the age of 14 (Table 3.2).

3.3.3 Risk perceptions
Five questions were asked to ascertain risk perceptions associated with exposure to and sickness from pesticide use (for controlling mosquito populations), insect repellents with DEET, and insect bites. The highest proportion of respondents were somewhat or very concerned about getting sick from exposure to pesticides. This was followed by getting sick from insect bites, exposure to approved pesticides, getting sick from insect repellents with DEET and finally exposure to insect repellents with DEET (Table 3.1). Of those who were concerned, 27% were concerned about the risk from all sources of exposure and sickness and are subsequently called worryers. Only 6.2% of respondents felt that they themselves or someone they knew would be at risk of WNV infection. In Alberta and Manitoba, provinces with WNV, the percentage was slightly higher at 10%.

When risk perceptions associated with exposure to pesticides (societal level actions) were examined in relation to concern about exposure to insect repellents with DEET (individual level action), it was found that 43.5% of respondents were worried about the risk from both and societal actions while
30.3% were concerned about neither (p<0.05) (Table 3.3). Similarly, 50.7% of respondents were concerned about getting sick from exposure to pesticides and insect repellents with DEET, while 27.6% were worried about getting sick from neither (Table 3.3). Interestingly, 8% of respondents were not worried about exposure to pesticides but concerned about exposure to insect repellents with DEET. When this proportion was examined by province of residence, it ranged from 5.5% in British Columbia to 9.3% in Alberta and peaked to 11.7% among respondents from Manitoba (p<0.05), where adulticiding is regularly used to control and prevent both nuisance mosquitoes and WNV. Though not statistically significant, of the 8% who were not worried about exposure to pesticides but concerned about exposure to insect repellents with DEET, 42.9% also reported never using insect repellents containing DEET. All else being equal, this sub-population is at high risk of acquiring WNV and should be the target of risk reduction messages that either address concern about health effects of insect repellents with DEET or provide advice on how to avoid mosquito bites.

3.3.4 Relationship between risk factors and risk perceptions
As expected gender was independently associated with several risk perceptions (p<0.05). In bivariate analyses, on average, women were 53% more likely to be concerned about exposures to pesticides; 200% more likely to be concerned about exposure to insect repellents containing DEET; 85% more concerned about getting sick from insect bites; 66% more concerned about getting sick from pesticide exposure; and 94% more concerned than men about getting sick from insect repellents containing DEET (Table 3.4).

Surprisingly, those who were 45 years of age or older were less concerned about getting sick from insect bites and pesticide exposure (38% and 48% less concerned than those <45 years of age). Those with children under 14 years of age were significantly concerned about getting sick from exposure to insect repellents containing DEET (75% more concerned than those without children).

As expected, exposure to WNV was significantly associated with several risk perceptions. On average, those who lived in Alberta and Manitoba and had been exposed to WNV were less concerned about exposure to and getting sick from exposure to pesticides and insect repellents with DEET. However, they were twice as concerned as those living in British Columbia about getting sick from an insect bite and were approximately 4-times as concerned that they or someone they knew would get sick from WNV (Table 3.4). Respondents who reported living in urban areas were,
on average, less concerned about exposure to and sickness from exposure to pesticides and insect repellents containing DEET. A visual representation of the perceived risks of disease versus intervention can be seen in Figure 3.1.

Outdoor activity levels were not significantly associated with any of the risk characteristics examined in this study. A sensitivity analysis of the binary categorization was carried out to ensure appropriateness of the variable. When a more stringent definition of an active individual was used (i.e., ≥ 4 hours of outdoor activity on a given day), 56% of respondents were considered to be active. However, this 30% reduction in the size of the active group did not change the results of the bivariate analyses. This will be further examined in the discussion.

Multivariable logistic regression analyses were carried out for 6 risk perception outcome variables (risk questions 1-6 in Table 3.1). Variables with a moderate association (p<0.20) were initially included in the multivariable logistic regressions. All models were controlled for gender, age, and presence of WNV in province of residence. Other predictor variables were only maintained in the model if they were statistically significant (p<0.05).

When gender, age, and presence of WNV were controlled, “having children under 14” was no longer a significant predictor of risk perceptions associated with WNV and interventions. Living in urban areas maintained its association with perceived risks from interventions; respondents living in urban areas were less likely to be concerned about the risks from pesticides and insect repellents with DEET (Table 3.5). Gender remained a significant predictor in 4 models; women were more concerned about exposure to and illness from pesticides, illness from insect repellents with DEET and also insect bites. Age was only significant in one model; those aged 45 and over were 50% less likely to be concerned about getting sick from pesticide exposures. Living in a province exposed to WNV was significant in two models: respondents in Alberta and Manitoba were 49% less concerned about exposures to pesticides and twice as concerned about getting sick from insect bites than respondents living in British Columbia.

The residuals of the models were within acceptable limits, did not exhibit heteroscedasticity, and no influential outliers were identified. Multicollinearity was also assessed through tolerance and variance inflation factor values – all were found to be within acceptable ranges.
3.4 Discussion

The purpose of this paper was to examine factors that can determine risk perceptions related to WNV and exposure to and sickness from insect repellents with DEET (individual WNV intervention) and pesticides (societal WNV interventions) used in controlling and preventing the spread of WNV. It was hypothesized that risk perceptions of WNV and WNV interventions would be influenced by demographics. In this study, unique associations between demographic and behavioral risk factors and risk perceptions of WNV and preventative interventions were found. Each risk factor will be examined in detail below.

GENDER: As with previous studies we found that gender was a significant predictor of perceived risk. On average, women were more concerned of risks associated with exposure to and sickness from exposure to pesticides, DEET based insect repellents, and getting sick from mosquito bites.

AGE: Although anyone can be infected by WNV, those over 50 are at an increased risk of infection leading to lasting and significant illness. We, therefore, expected this group to perceive a greater risk of illness. Surprisingly we did not find this in our study. We found that, when gender, potential exposure to WNV (province of residence) and household location were controlled for, those aged 45 and older were 50% less likely to be concerned about getting sick from exposures to pesticides. This alludes to the social dimension of WNV risk trade-offs. Perhaps those at risk of WNV infection are less concerned about the potential adverse effects of pesticides used to control and prevent WNV in a community. Unfortunately, in order to maintain data continuity, age was collected using standardized categories preventing us from examining those over the age of 50 and specifically at risk of WNV. Additionally, less than 7% of respondents in this survey were over 75 years of age, and not all had complete responses due to the telephone and Internet format used. Given the low response rate in the >75 year age group and no rationale for examining the >65 age group, an age cut-off of > 45 years was used. This age cut-off has been previously used to examine behavioral risks associated with WNV, and was also in Chapter 2 (Gujral, Zielinski-Gutierrez et al. 2007). The social dimension of risk trade-offs surrounding age and WNV should be further examined as it may have implications successful WNV programming and communication.

CHILDREN UNDER 14: Given the potential adverse risks associated with pesticides used in adulticiding programs and the controversy over the safety of insect repellents with DEET we hypothesized that parents of children under 14 would perceive higher risks than those without
children. Parental risk perceptions have previously been examined in relation to childhood vaccinations (Spier 2001; Raithatha, Holland et al. 2003). However, their role in re-emerging and emerging infectious diseases are also important as they may drive or hinder recommended health behaviors (McClain, Bernhard et al. 2005) or in this case, lobby against interventions such as adulticiding. When the effects of other variables were taken into account, we did not find any significant associations between being a parent and risk perceptions related to WNV or interventions. However, in bivariate analyses we found that those with children were 75% more concerned about getting sick from exposure to insect repellents containing DEET. Given the controversy over the safety of DEET based insect repellents among children this association should be further explored as it in no-doubt plays a role in effective protection against WNV and other vector borne diseases.

**PRESENCE OF WNV:** In Chapter 2 it was found that those who lived in areas exposed to WNV and had experience with the disease were more likely to engage in personal protective behavior. In this study, respondents living in Alberta and Manitoba (and exposed to WNV) were less concerned about exposure to pesticides, but twice as concerned as respondents in British Columbia about getting from insect bites, and almost 4 times as concerned about getting sick from WNV. This builds on the findings of previous and subsequent chapters and highlights the importance of disease context and experience (Chapters 2 and 4).

**LOCATION:** Geographical location has been shown to influence risk perceptions (Krewski, Lemyre et al. 2006). This characteristic was further explored by considering risk perceptions in relation to urban vs. rural household locations. It was found that those who reported living in urban areas were less likely to be concerned about exposures to and sickness from exposure to pesticides and insect repellents with DEET. This is of particular interest to public health message development as *Culex pipiens*, a highly efficient WNV vector, targets urban and suburban areas.

**OUTDOOR ACTIVITY:** Outdoor activity levels have not been previously examined in relation to risk perceptions. It was expected that those who appreciate and enjoy spending time outdoors would still be willing to do so while assuming certain risks. This association was not found in this study; however, this is likely due to limited data collection. The data suggests that 86% of our respondents were active and participated in outdoor recreational activities for 2 or more hours on a given day. When alternate categorizations were used, 56% of respondents participated in 4 or more hours of outdoor activity on a given day. This is likely to be an overestimation of the true level of
outdoor activity and an artifact of the survey instrument. Similar to other healthy habits, questions eliciting frequency of activity often result in overestimation by respondents (Montoye, Kemmper et al. 1996). In order to better capture outdoor activity levels, a 24-hour activity log or a 3-day activity log should be administered either by mail or Internet. Questions used in this survey were developed to reflect risk perceptions pertaining to WNV. In hindsight, standardized questionnaires (such as the International Physical Activity Questionnaire) should have been used to elicit responses. This would have allowed for comparison with other activity surveys. The use of standardized questions over 24 hours or 3 days would provide a better proxy for estimation of outdoor activity levels increasing accuracy and improving the basis for grouping respondents into active and non-active groups.

WORRIERS: It was hypothesized that individuals may systematically worry about all risks related to WNV. Twenty seven percent of the respondents were worriers – they were concerned about all the risks from disease to insect repellents with DEET to pesticide exposure. However, demographic and behavioral factors examined in this study were not predictive of this state-of-mind. This issue should be further examined with a greater variety of risk perception questions, hazards, and risk characteristics. Determining whether there are demographic risk factors that describe this group can be helpful in targeting future public messages to ensure that this groups level if concern is not over amplified.

It was also found that 8% of all respondents, and more specifically 11.7% of respondents in Manitoba, were concerned about exposure to insect repellents with DEET but not pesticide exposure. Pesticide use, especially through adulticiding, can impose a false sense security on individuals whereby individuals feel protected because of societal levels actions. However, their actual risk of WNV infection may or may not be reduced through adulticiding. Though this is not statistical significance it does have practical importance. The concern over insect repellent use containing DEET is worrisome because it may lead to an increased risk of WNV infection given that a large proportion of this group did not use insect repellents with DEET. Unfortunately due to the sampling design of the survey, and subsequent small sample sizes within each province, further associations could not be examined. The issue of individual versus societal responses to WNV should be further examined using both quantitative and qualitative methods to understand what responses are most acceptable and effective.
Due to the nature of the survey, its length, and the need to maintain continuity with past-administered surveys we could ask very few new questions exploring the dynamic relationship between risk perceptions and risk factors. Given that the telephone interview lasted between 30-45 minutes, additional risk perception questions using different techniques could not be asked. This would have allowed for increased data accuracy, and the opportunity to examine additional risk factors and metrics. Similarly, due to the length of the survey respondents were not asked to make comparisons between the risks offered in the questionnaire. This study was exploratory in nature and intended to examine the potential relationships between risk factors and risk perceptions as they relate to WNV and WNV interventions. It provides a foundation for future research examining determinants of risk perceptions in relation to re-emerging and emerging infectious diseases and other health issues which rely on both individual engagement of health behaviors and a public (societal) response.

In this study, variations in individual risk perceptions have been identified. These differences should be further studied using mental models to determine why differences exist, what messages need to be developed and how they should be delivered. By understanding these risk perception differences, public health and risk communication messages can be developed which can address differences and potential biases among sub-populations. Such messages can then be delivered through identified, appropriate, and effective channels. This approach would allow risk information to be delivered in a manner applicable to the target audience resulting using effective communication tools (Bennett and Calman 2001). Risk perception also has a broader role within re-emerging and emerging infectious disease. Systematically understanding the underlying factors over time will allow us to communicate efficiently and ensure that the target audience does not misestimate or overestimate the actual risks from the disease. Given that re-emerging and emerging infectious diseases often appear without much warning it is important to characterize risk perceptions for a variety of diseases over time. This will enable public health to adapt lessons learnt to new situations. This study has given us insight on how to further explore such issues.

### 3.5 Conclusion

Research has shown that gender, age, education, and geographical location can be important determinants of risk perceptions. In this paper, demographic and behavioral variables were examined in relation to risk perceptions of WNV versus those of preventative interventions.
Gender, age, household location (urban vs. rural) and experience with WNV were found to have associations with various examined risk perceptions. Variations between risk perceptions associated with individual level and societal level interventions, used to prevent and control WNV, were also identified. The role of risk factors in developing public health and risk communication messages is well documented in environmental health hazards and should be further examined using mental models in the context of re-emerging and emerging infectious diseases to provide insight on how people may react to adopting behaviors. By understanding factors that may influence risk perceptions and trade-offs of the disease versus interventions and between types of interventions, messages can be developed to target specific behaviors and preventative strategies. Even in the absence of mental models, identification of vulnerable sub-populations (e.g., those rejecting insect repellents with DEET as a risk reduction measure) can lead to messages targeted at promoting other acceptable personal risk reduction strategies. This would increase the effectiveness of prevention measures prior to an outbreak of the disease in question.
## Table 3.1. Distribution and description of risk perception questions

<table>
<thead>
<tr>
<th>Risk Perception Questions</th>
<th>Categories</th>
<th>BC (n=222)</th>
<th>AB &amp; MB (n=219)</th>
<th>All (n=441)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Being exposed to an approved pesticide for controlling mosquitoes</td>
<td>Little or no concern</td>
<td>29.9 (66)</td>
<td>46.6 (102)</td>
<td>38.2 (168)</td>
</tr>
<tr>
<td></td>
<td>Somewhat/very concerned</td>
<td>70.1 (155)</td>
<td>53.4 (117)</td>
<td>61.8 (272)</td>
</tr>
<tr>
<td>2  Being exposed to an insect repellent with DEET</td>
<td>Little or no concern</td>
<td>45.5 (100)</td>
<td>51.6 (113)</td>
<td>48.5 (213)</td>
</tr>
<tr>
<td></td>
<td>Somewhat/very concerned</td>
<td>54.5 (120)</td>
<td>48.4 (106)</td>
<td>51.5 (226)</td>
</tr>
<tr>
<td>3  Getting sick from an insect bite</td>
<td>Little or no concern</td>
<td>42.5 (94)</td>
<td>26.9 (59)</td>
<td>34.8 (153)</td>
</tr>
<tr>
<td></td>
<td>Somewhat/very concerned</td>
<td>57.5 (127)</td>
<td>73.1 (160)</td>
<td>65.2 (287)</td>
</tr>
<tr>
<td>4  Getting sick from exposure to pesticides</td>
<td>Little or no concern</td>
<td>25.5 (56)</td>
<td>34.7 (76)</td>
<td>30.1 (132)</td>
</tr>
<tr>
<td></td>
<td>Somewhat/very concerned</td>
<td>74.5 (164)</td>
<td>65.3 (143)</td>
<td>69.9 (307)</td>
</tr>
<tr>
<td>5  Getting sick from using an insect repellent with DEET</td>
<td>Little or no concern</td>
<td>45.5 (100)</td>
<td>48.4 (106)</td>
<td>46.9 (206)</td>
</tr>
<tr>
<td></td>
<td>Somewhat/very concerned</td>
<td>54.5 (120)</td>
<td>51.6 (113)</td>
<td>53.1 (233)</td>
</tr>
<tr>
<td>6  Somewhat or very concerned on all risk questions (1-5)</td>
<td>Not concerned on some/all risk questions</td>
<td>71.5 (158)</td>
<td>74.4 (163)</td>
<td>73.0 (321)</td>
</tr>
<tr>
<td></td>
<td>Concerned all on risk questions</td>
<td>28.5 (63)</td>
<td>25.6 (56)</td>
<td>27.0 (119)</td>
</tr>
<tr>
<td>7  How likely do you think that you or someone in your immediate family will get sick from WNV in the next 12 months?</td>
<td>Unlikely/very unlikely</td>
<td>97.2 (206)</td>
<td>90.0 (171)</td>
<td>93.8 (377)</td>
</tr>
<tr>
<td></td>
<td>Likely/very likely</td>
<td>2.8 (6)</td>
<td>10.0 (19)</td>
<td>6.2 (25)</td>
</tr>
</tbody>
</table>

All responses are given in both % share and number (n) of respondents as not all respondents completed all questions.
Table 3.2. Distribution of potential risk characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>BC (n=222) No Exposure</th>
<th>AB &amp; MB (n=219) Exposure</th>
<th>All (n=441)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% (n)</td>
<td>% (n)</td>
<td>% (n)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>40.7 (90)</td>
<td>41.6 (91)</td>
<td>41.1 (181)</td>
</tr>
<tr>
<td>Female</td>
<td>59.3 (131)</td>
<td>58.4 (128)</td>
<td>58.9 (259)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;44 years</td>
<td>25.9 (57)</td>
<td>31.2 (68)</td>
<td>28.5 (125)</td>
</tr>
<tr>
<td>≥45 years</td>
<td>74.1 (163)</td>
<td>68.8 (150)</td>
<td>71.5 (313)</td>
</tr>
<tr>
<td><strong>Children under 14</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>79.5 (175)</td>
<td>76.3 (167)</td>
<td>77.9 (342)</td>
</tr>
<tr>
<td>Yes</td>
<td>20.5 (45)</td>
<td>23.7 (52)</td>
<td>22.1 (97)</td>
</tr>
<tr>
<td><strong>Household location</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>65.8 (146)</td>
<td>79.5 (174)</td>
<td>72.6 (320)</td>
</tr>
<tr>
<td>Rural</td>
<td>34.2 (76)</td>
<td>20.5 (45)</td>
<td>27.4 (121)</td>
</tr>
<tr>
<td><strong>Activity Level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not active</td>
<td>17.6 (39)</td>
<td>11.0 (24)</td>
<td>14.3 (63)</td>
</tr>
<tr>
<td>Active</td>
<td>82.4 (183)</td>
<td>89.0 (195)</td>
<td>85.7 (378)</td>
</tr>
</tbody>
</table>

All responses are given in both % share and number (n) of respondents as not all respondents completed all questions.
Table 3.3. Two by two matrices for risk perceptions surrounding pesticides (societal level action) versus insect repellents with DEET (individual level action)

<table>
<thead>
<tr>
<th>Individual level action</th>
<th>Societal level action</th>
<th>Concern about exposure to pesticides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Concern about exposure to insect repellent with DEET</td>
<td>Yes</td>
<td>191 (43.5)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>80 (18.2)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>271 (61.7)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Individual level action</th>
<th>Societal level action</th>
<th>Concern about sickness from pesticides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Concern about sickness from insect repellent with DEET</td>
<td>Yes</td>
<td>222 (50.7)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>84 (19.2)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>306 (69.9)</td>
</tr>
</tbody>
</table>
### Table 3.4 Unadjusted odds ratios, 95% confidence intervals and p-values for risk characteristics in relation to risk perceptions

<table>
<thead>
<tr>
<th>Risk Perceptions</th>
<th>Exposure to pesticides (n=437-440)</th>
<th>Exposure to insect repellent with DEET (n=437-439)</th>
<th>Sick from insect bites (n=437-439)</th>
<th>Sick from pesticides (n=437-440)</th>
<th>Sick from insect repellent with DEET (n=437-440)</th>
<th>Worry (n=437-440)</th>
<th>WNV risk (n=400-402)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td>OR 1.53 (CI 0.94-2.67) p 0.033</td>
<td>OR 2.10 (CI 1.43-3.10) p &lt;0.001</td>
<td>OR 1.85 (CI 1.24-2.75) p 0.003</td>
<td>OR 1.66 (CI 1.10-2.016) p 0.016</td>
<td>OR 1.94 (CI 1.32-2.001) p 0.014</td>
<td>OR 1.45 (CI 0.94-0.95) p 0.11</td>
<td>OR 1.11 (CI 0.49-0.803) p 0.01</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>OR 0.77 (CI 0.50-0.82) p 0.012</td>
<td>OR 0.86 (CI 0.56-0.459) p 0.042</td>
<td>OR 0.52 (CI 0.32-0.010) p 0.016</td>
<td>OR 0.68 (CI 0.47-0.072) p 0.018</td>
<td>OR 0.88 (CI 0.56-0.592) p 0.014</td>
<td>OR 1.54 (CI 0.56-0.404) p 0.01</td>
<td>OR 1.40 (CI 0.20-0.514) p 0.01</td>
</tr>
<tr>
<td><strong>Children</strong></td>
<td>OR 1.52 (CI 0.94-1.12) p 0.089</td>
<td>OR 1.52 (CI 0.96-2.46) p 0.072</td>
<td>OR 1.49 (CI 0.89-2.133) p 0.018</td>
<td>OR 1.75 (CI 1.10-2.018) p 0.018</td>
<td>OR 1.53 (CI 0.94-0.087) p 0.014</td>
<td>OR 0.69 (CI 0.23-0.514) p 0.01</td>
<td>OR 0.20 (CI 0.08-0.514) p 0.01</td>
</tr>
<tr>
<td><strong>Presence of WNV</strong></td>
<td>OR 0.49 (CI 0.33-0.72) p &lt;0.001</td>
<td>OR 0.78 (CI 0.54-1.14) p 0.018</td>
<td>OR 2.0 (CI 1.35-3.00) p 0.001</td>
<td>OR 0.64 (CI 0.43-0.97) p 0.035</td>
<td>OR 0.89 (CI 0.61-0.536) p 0.018</td>
<td>OR 0.86 (CI 0.57-0.488) p 0.01</td>
<td>OR 3.82 (CI 1.49-9.77) p 0.005</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>OR 0.60 (CI 0.38-0.94) p 0.026</td>
<td>OR 0.64 (CI 0.42-0.98) p 0.039</td>
<td>OR 1.41 (CI 0.91-2.17) p 0.121</td>
<td>OR 0.58 (CI 0.36-0.95) p 0.030</td>
<td>OR 0.64 (CI 0.42-0.97) p 0.037</td>
<td>OR 0.79 (CI 0.50-0.305) p 0.078</td>
<td>OR 0.34 (CI 0.571) p 0.01</td>
</tr>
<tr>
<td><strong>Activity level</strong></td>
<td>OR 0.66 (CI 0.37-1.18) p 0.059</td>
<td>OR 0.96 (CI 0.56-0.877) p 0.243</td>
<td>OR 1.38 (CI 0.80-2.39) p 0.243</td>
<td>OR 1.19 (CI 0.67-2.11) p 0.542</td>
<td>OR 1.11 (CI 0.65-0.695) p 0.243</td>
<td>OR 1.35 (CI 0.72-0.353) p 0.86</td>
<td>OR 0.28 (CI 0.788) p 0.01</td>
</tr>
</tbody>
</table>

Reference values are as follows, brackets () indicate reference values:
- Gender: (male) vs. female
- Age: (<45) vs. ≥ 45 years of age
- Children: (no children) vs. children under 14
- WNV: (presence of WNV in province of residence) vs. no presence of WNV in province
- Location: (Rural) vs. Urban
- Activity level: (< 2 hours of outdoor activity) vs. > 2 hours of outdoor activity on a given day
Figure 3.1. Visual representation of demographic and behavioral factors that had a significant association with perceived risk of illness and intervention in bivariate analyses.
Table 3.5 Adjusted odds ratios, 95% confidence intervals, and p values for multivariable logistic regression models.

<table>
<thead>
<tr>
<th>Risk Perceptions</th>
<th>Exposure to pesticides (n=436)</th>
<th>Exposure to insect repellent with DEET (n=435)</th>
<th>Sick from insect bites (n=435)</th>
<th>Sick from pesticides (n=435)</th>
<th>Sick from insect repellent with DEET (n=435)</th>
<th>Worry (n=436)</th>
<th>WNV risk (n=436)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR 95 CI p</td>
<td>OR 95 CI p</td>
<td>OR 95 CI p</td>
<td>OR 95 CI p</td>
<td>OR 95 CI p</td>
<td>OR 95 CI p</td>
<td>OR 95 CI p</td>
</tr>
<tr>
<td>Gender</td>
<td>2.1 0.97- 2.19</td>
<td>1.77 1.17- 0.001</td>
<td>2.66 2.38</td>
<td>2.74 1.85</td>
<td>2.19 1.40</td>
<td>0.067</td>
<td>0.135</td>
</tr>
<tr>
<td>Age</td>
<td>0.88 0.57- 1.36</td>
<td>0.70 0.44- 0.138</td>
<td>1.12 0.83</td>
<td>0.94 0.69</td>
<td>1.51 0.94</td>
<td>0.001</td>
<td>0.805</td>
</tr>
<tr>
<td>Children</td>
<td>x x x</td>
<td>x x x x</td>
<td>- - -</td>
<td>- - -</td>
<td>- - -</td>
<td>- - -</td>
<td>- - -</td>
</tr>
<tr>
<td>WNV</td>
<td>0.84 0.57- 0.372</td>
<td>1.37- 0.001</td>
<td>0.95 0.65- 0.810</td>
<td>0.89 0.58- 0.582</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>0.63 0.39- 0.053</td>
<td>0.40- 0.043</td>
<td>0.54 0.32- 0.017</td>
<td>0.93 x x</td>
<td>x x x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity level</td>
<td>x x x</td>
<td>x x x x</td>
<td>x x x x</td>
<td>x x x x</td>
<td>x x x x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Not significant; removed from model
- Reference values are as follows, brackets ( ) indicate reference values
  - Gender: (male) vs. female
  - Age: (<45) vs. > 45 years of age
  - Children: (no children) vs. children under 14
  - WNV: (presence of WNV in province of residence) vs. no presence of WNV in province
  - Location: (Rural) vs. Urban
  - Activity level: (≤ 2 hours of outdoor activity) vs. > 2 hours of outdoor activity on a given day
3.6 References

BCCDC (2008). How do I protect myself?  


4 Chapter 4: Multi-criteria decision analyses and re-emerging infectious disease: A case study of West Nile virus\textsuperscript{10}

\textsuperscript{10} A version of this chapter will be submitted for publication. Elmich, N and H. Dowlatabadi. “Multi-criteria decision analyses and re-emerging infectious diseases: A case study of West Nile virus.”
4.1 Introduction

Policy decisions are complex, often involve inherent uncertainty, and are sometimes made in response to perceived public concern (Clemen and Reilly 2001). They are not only based on technical facts but also risks and values, and must balance numerous factors (Bennett and Calman 2001; Belton and Steward 2002). Judgments are made to address scientific uncertainty, multiple objectives, efficacy of decisions, and variations in stakeholder perspectives and preferences (Keeney and Raiffa 1976; Clemen and Reilly 2001). Such decision trade-offs, when made by experts, are often based on risks derived from scientific knowledge and statistical probabilities. The public, on the other hand, bases risk perceptions and decisions on intuition and past experiences (Fischhoff 1995; Powell and Leiss 1997). Through good risk communication practices the gap in knowledge between scientific risk assessments and public risk perceptions can be reduced (Powell and Leiss 1997). For this to occur, public and expert risk perceptions and decision trade-offs with regards to a particular problem must be understood.

Perceived risk and decision trade-offs will naturally change as risk levels increase. Perceived risk of a particular hazard is a subjective measure developed over time and driven by numerous factors: (1) the hazard and the degree to which it is understood, (2) dread of the hazard, (3) the population at risk, (4) temporal and spatial variations, and (5) risk management and communication (Fischhoff, Slovic et al. 1978; Slovic 1987; Leiss and Chociolko 1994). However, the dynamic relationship between the type of hazard and level of perceived risk is difficult to ascertain. Certain risks will evoke a predictable and measurable response (decision) while others exhibit sporadic, hard to explain, fluctuations (Glickman and Gough 1990; Leiss and Chociolko 1994). Driving this dynamic process is adaptation: how people adapt their expectations and values over time as new information and technologies become available (Loewenstein and Mather 1990; Bornik and Dowlatahadi 2008).

Age, sex, education, geographical location, and being parents of young children have also been shown to influence risk perceptions (Flynn, Slovic et al. 1994; Leiss and Chociolko 1994; Slovic 1999; Krewski, Lemyre et al. 2006). These are significant factors that may have a role in how risk communication strategies are developed.

In public health, further decision trade-offs are required to secure and allocate funds towards specific diseases, populations in need, and intervention strategies (Baltussen and Niessen 2006). Yet programmatic decisions and risk trade-offs protecting the publics’ health must still be made and
subsequently communicated to the public. Decisions about re-emerging infectious diseases are further complicated by their inherent uncertainty and unknown disease range and activity. In the absence of disease predictability and given budgetary constraints, it is vital to understand how decision trade-offs are made and how resources should be allocated given perceived risk levels.

Traditionally, public health decisions have relied on evidence-based epidemiological studies and to a lesser extent on public knowledge, attitude, and behavior surveys. Such studies are both time and cost intensive and cannot usually capture the complex nature of decision trade-offs. Multi-criteria decision analysis is a tool, blending elements from economics, ethics and psychology, which can be used to examine how trade-offs are made within dynamic and complex systems (Keeney and Raiffa 1976; Clemen and Reilly 2001; Baron 2008). It works by comparing and contrasting potential decisions against one another using a number of implicit and explicit trade-offs. It has traditionally been used to improve solution strategies for complex problems with heterogeneous stakeholders (e.g., hazardous site remediation, water and energy projects). Multi-criteria decision analysis is often implemented using focus groups or multi stakeholder meetings (Linkov, Satterstrom et al. 2006). Despite its potential usefulness in creating transparent frameworks for public health decisions, few such applications exist to date (Baltussen, Stolk et al. 2006; Baltussen, ten Asbroek et al. 2007).

One system that may benefit from multi-criteria decision analysis is in a re-emerging infectious disease setting, as trade-offs of risks and benefits among various public and personal interventions are inevitable. West Nile virus (WNV), a re-emerging vector-borne disease, was identified in New York City in 1999 and has since established itself in North America. It was first detected in Canada in 2001, with the first documented human case in 2002 (Weir and Shapiro 2004). Despite its well-studied presence in North America, the determinants of its range, virulence and severity are still not fully understood. Furthermore, the virus is unlikely to be eliminated given the complex nature of its co-evolution with its many hosts (Gubler 2007). Given this threat to public health, it is necessary to plan interventions to prevent infection and control potential outbreaks. It is also important to understand the associations between perceived risk and both the disease itself and the interventions to prevent it. The challenge lies in finding an “acceptable” compromise between these risks (Fischhoff, Lichtenstein et al. 1981; Krewski, Somers et al. 1987; Krewski 1993; Slovic 1999). This understanding will lead to effective public health decisions and risk communication strategies (Leiss 2001; Morgan, Fischhoff et al. 2002).

For the purposes of this thesis, re-emerging infectious diseases refer to previously identified diseases whose geographic distribution and/or incidence is changing/increasing (Morens and Folkers 2004).
West Nile virus prevention and control programs in Canada are varied in nature and scope by region. They are limited by annual budgetary allocations and have changed over the years as more information has become available and as the risk in specific areas has changed. Yet, we do not know how people perceive WNV and associated interventions. There are risks, costs, and uncertainties associated with interventions designed and implemented to prevent and control disease propagation, all of which need to be balanced against one another in order to make acceptable risk decisions (Fischhoff, Lichtenstein et al. 1981). West Nile virus interventions may include the following (Table 4.1):

- **Surveillance** systems have the potential to monitor the presence, prevalence, and progression of the disease cycle. They are critical in early detection, and provide timely information for the launch of possible interventions.
- **Public Education** aims to increase awareness of risk factors promoting behavior change that reduce individual exposure or susceptibility to WNV. Personal risk reduction measures are numerous, but most frequently include staying indoors during peak mosquito hours and use of mosquito repellents.
- **Source Reduction** targets mosquito breeding grounds (such as standing or collected water) on both private and public lands.
- **Larviciding** and **Adulticiding** rely on the use of pesticides to control mosquito populations in their larval and adult stages respectively (Rose 2001).

The choice of interventions will depend on the decision makers’ perceptions of the effectiveness, risks and costs of the intervention, the threat of the virus, and the extent of the disease as well as the acceptability of the intervention by the public. Despite their potential effectiveness, interventions can pose risks to some or all of the population and to ecosystems. For example, larviciding and adulticiding rely on the use of pesticides that are harmful to both the vector and many other organisms. Larviciding is often undertaken as a nuisance mosquito control measure regardless of WNV activity, while adulticiding is often used as a last resort to control the extent of an outbreak. The effectiveness of such interventions critically depends on timely monitoring, detection, and implementation; if introduced too late, they may not break the circle of transmission. Finally, the persistence of pesticides and their byproducts in the environment may pose further risks long after the outbreak has subsided due to seasonality of the vectors (Chapter 5). This creates trade-offs between risks from the unfettered circulation of the virus and from interventions to limit its presence and transmission. The uncertainty of the “acceptable” strategy is exacerbated when
interventions have limited risk reduction capacity, and exposure to the virus has a low probability of severe adverse health effects – both of which are the case with WNV.

Decision trade-offs are part of public health, including WNV program planning. By understanding how the public values such trade-offs, there is a potential to target public health programs and risk communication campaigns more effectively. The purpose of this study is to examine such trade-offs and their implications for WNV program planning and risk communication strategies. A sub-objective is to determine if public communication about WNV risk reduction needs to be tailored to specific target audiences. A methodology employing two surveys, one of the public and one of experts, both based on a multi-criteria decision analysis framework, allowed us to address the following questions and hypotheses:

1. What WNV programmatic decisions would laypeople make given a set of performance criteria? Are there demographic differences in these decisions? What WNV programmatic decisions would health experts make given a set of performance criteria?
   - $H_0$: Laypeople and health experts perceive the same risks from interventions.
   - $H_1$: Laypeople and health experts perceive risks differently from interventions.

2. Do these decisions differ between actual and hypothetical risk levels?
   - $H_0$: Laypeople will all perceive the same risks from WNV interventions regardless of demographics and experience with the actual risks.
   - $H_1$: Laypeople will perceive the risks from WNV interventions to be different based on demographics and experience with the actual risks.

3. What are the implications of findings for public health programs and risk communication?

4.2 Methods

Multi-criteria decision analysis surveys of laypeople and health experts were carried out to determine their preferences for interventions aimed at controlling WNV. Questions elicited quantitative judgments of perceived risks and benefits associated with particular interventions (Appendix C). This was part of a larger study between July and September 2007 examining risk perceptions and health behaviors in relation to WNV in three Canadian provinces with different levels of WNV
activity: British Columbia, Alberta, and Manitoba (Chapter 2). To date, British Columbia has had no locally acquired cases; there has been an increasing number of human cases in Manitoba and Alberta since 2003 and 2004 respectively (Alberta Health and Wellness 2008; BCCDC 2008; Manitoba Health 2008). The three provinces have employed various types and levels of interventions (Table 4.1).

**LAYPEOPLE RECRUITMENT:** To be eligible, participants had to have completed an earlier health behavior survey described in Chapter 2. Potential participants were asked whether they would like to complete the multi-criteria decision analysis survey online or by mail. The online survey link was e-mailed to participants while the paper survey was mailed with a self addressed and stamped return envelope. The online and paper surveys were identical. Up to four e-mail reminders were sent to participants who chose to complete the survey online. However, due to cost constraints no mail reminders were sent out.

**HEALTH EXPERT RECRUITMENT:** Health experts working in the field of communicable diseases in Canada were invited to participate in the survey either online or by mail. Invitations were sent through list-serves and e-mails to identified individuals.

In collaboration with experts at the British Columbia Centre for Disease Control, a set of five intervention options to prevent and control WNV were selected for study (Table 4.2). Each was to be evaluated based on five performance criteria to reflect decision trade-offs frequently considered in program planning: monetary cost; environmental consequences; effectiveness; ease and speed of implementation; and public acceptance. Survey participants were asked to consider each performance criterion and rank the five intervention options using a 5-point Likert scale ranging from least to most. The participant’s confidence in their responses within each performance criterion was elicited through a separate Likert scale question. Finally, participants were asked to rank the importance of each of performance criteria evaluations given three hypothetical risk scenarios: low risk – when there is no presence of WNV in the community; medium risk – when there are birds and mosquitoes in the community that have been shown to carry WNV but no humans have presented with illness; high risk – when people in the community have become sick.

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12 Due to a low level of Internet access in Manitoba (S. Roberecki, Personal Communication, May 2007), a mailed survey option was offered to all participants.
from WNV. The questionnaire was pilot tested among a convenience sample (n=15) to ensure comprehension and flow, revised, and implemented.

The online survey software, SurveyMonkey, was used to collect data (SurveyMonkey 1999). Data were extracted, cleaned, and analyzed using SPSS version 11.0. Descriptive analyses included counts for categorical variables; means, medians and inter-quartile ranges for Likert scale data; and medians, means, and standard deviations for continuous variables. In order to calculate a multi-criteria preference score for each intervention, a weighted additive model was used, with weighting by rank of the importance of the performance criterion and the participant’s confidence in their rankings for each criterion. (Table 4.2):

\[
\text{Intervention Preference Score} = \\
(C_1 \times (R_{C_1} \times F_{C_1/100})) + (V_1 \times (R_{V_1} \times F_{V_1/100})) + (E_1 \times (R_{E_1} \times F_{E_1/100})) + (S_1 \times (R_{S_1} \times F_{S_1/100})) + (P_1 \times (R_{P_1} \times F_{P_1/100}))
\]

Where \( C_1 \) = rank of the intervention (I) within the monetary cost criterion  
\( V_1 \) = rank of the intervention (I) within the environmental consequences criterion  
\( E_1 \) = rank of the intervention (I) within the effectiveness criterion  
\( S_1 \) = rank of the intervention (I) within the ease and speed of implementation criterion  
\( P_1 \) = rank of the intervention (I) within the public acceptance criterion  
\( R_{\pi} \) = rank of the importance of the performance criterion (\( \pi \)) for a given risk scenario  
\( F_{\pi} \) = confidence of the participant in their answer for this performance criterion (\( \pi \)), on a Likert scale from 1 to 5

Matrices were only created for respondents with complete answers. Matrices were aggregated to calculate mean values and mean ranks for each intervention, criterion, province, and risk scenario. Demographic differences for gender, age, education, and household location were only evaluated for laypeople responses using two-tailed independent sample t-tests.

### 4.3 Results

#### 4.3.1 Description of laypeople

Of those who completed the health behavior survey (N=709), 458 also completed the multi-criteria decision-analysis survey. The response rate, given completion of the health behavior survey, was 65% (British Columbia=67%, Alberta=64%, Manitoba=64%). The majority of participants in
British Columbia and Alberta chose to complete the survey online (56% and 60% respectively), while 53% chose to complete the survey by mail in Manitoba. Majority of respondents were female, over the age of 45, and had obtained a university degree. Table 4.3 summarizes the demographic characteristics of the participants.

4.3.2 Description of health experts
Fifty-seven public health experts completed the survey, of which 44 were from British Columbia. Since this group was a convenience sample derived from e-mail list-serves, a response rate could not be calculated. The health expert group was highly educated with almost all respondents reporting at least a university degree. Just under half were female and a similar fraction were under the age of 45 (Table 4.3).

4.3.3 Description of public and expert rankings
The performance criteria can be divided into three categories: costs, benefits, and processes. The costs (monetary, environmental) of interventions showed comparable characteristics. Costs were ranked highest for adulticiding followed by larviciding for both the public and health officials (Table 4.4). Benefit-based performance criteria (effectiveness, ease and speed of implementation) also behaved similarly for both groups. Source reduction and larviciding were both ranked as being more effective and easier to implement than other interventions. Finally, there was little difference in public acceptance (a process) across interventions with the exception of adulticiding and choosing to “do nothing,” which both groups ranked less favorably. The survey allowed respondents to indicate their level of confidence in their judgments. The majority of respondents (both members of the public and health officials) were confident in their answers (laypeople: \( \bar{x} = 3.7 \pm 0.70 \); health experts: \( \bar{x} = 4.0 \pm 0.66 \)).

When respondents were asked the importance of the performance criteria for each risk scenario, laypeople gave different trade-offs compared to health experts (Table 4.5). Among laypeople, with rising risk levels, the importance of monetary costs, environmental consequences, and public acceptance decreased while the importance of effectiveness and ease and speed of implementation increased. This indicates that when health is in danger, laypeople are willing to make trade-offs to ensure effectiveness and implementation speed of preventative programs. There were no such trade-offs for health experts. Their concern was with the effectiveness of interventions.
4.3.4 Performance matrices for laypeople
Table 4.6 provides the intervention preferences by risk scenario stratified by the participant group and within laypeople, stratified by province. In British Columbia, where WNV is not present, there were only small differences in intervention preference by risk scenario. In Alberta and Manitoba where WNV is present, intervention preferences were identical for all risk scenarios. Larviciding was the preferred intervention option in all provinces and in both participant groups. This was followed by source reduction. Alberta and Manitoba diverged at this point in the overall rankings (Table 4.6). Manitoba participants, a province with nuisance mosquitoes and many WNV cases in 2007, ranked adulticiding third followed by educational programs. Participants in Alberta, a province that does not conduct adulticiding, ranked educational programs higher than adulticiding.

There were three statistically significant differences in intervention preference scores for demographic variables: (1) males scored no program, larviciding, and adulticiding higher than females, (2) those under 45 years had a higher mean score for adulticiding than those 45 and older, and (3) those with a high school education or less scored educational programs higher than those with university and or technical degrees (Table 4.7).

4.3.5 Performance matrices for health experts
Public health official performance matrices were also created for each risk scenario. In all risk scenarios, the most preferred intervention for health experts was larviciding – the same as laypeople. From this point on the health expert rankings diverged given risk levels. As the hypothetical risk level increased, the preference score for adulticiding decreased while it increased for source reduction. Even though the rankings were similar in some instances, there were statistically significant differences in the mean preference scores between laypeople and health experts (Table 4.6). Experts, on average, ranked active mosquito control interventions higher than laypeople.

4.4 Discussion
The purpose of this study was to examine decision trade-offs and their implications for WNV program planning and risk communication between laypeople and health experts. We hypothesized that laypeople and health experts perceive risks differently from interventions. We found that
laypeople were more sensitive to trade-offs in performance criteria, while health experts were most concerned about the effectiveness of interventions.

**LARVICIDING**: Both groups preferred this option for the control and prevention of WNV. It had a favorable ranking on all performance criteria and ranked highly in effectiveness. It is already in use for dealing with nuisance mosquitoes in many areas, often without the explicit knowledge of the general public.

**EDUCATION**: Even though the aggregate rankings for educational programs were identical between laypeople and health experts, there were significant differences within evaluation criteria. Health experts had significantly higher mean preference scores for educational programs in medium and high-risk scenarios. Both groups considered education to be the most publicly accepted intervention. However, health experts ranked it highly on effectiveness and ease of implementation while the general public ranked those two criteria poorly. Additionally, respondents with a high school education or less ranked public education programs significantly more favorably than those with university and or technical degrees. This could be a function of three causes: (1) those with higher levels of education may have increased access to information through the Internet or other media, (2) the readability and appropriateness of information disseminated, and/or (3) an understanding threshold among sub-populations at which point information fatigue is observed. These findings highlight gaps between sub-populations of the general public as well as between the public and health experts. Risk communication should tailor messages for sub-populations aimed at explaining the expected effectiveness of interventions. This will allow the public to see the relative efficacy of different implemented programs and to support them appropriately. Such targeted risk information would benefit sub-populations and avoid information fatigue.

**SOURCE REDUCTION**: Laypeople and health experts both ranked the performance criteria for source reduction similarly. It ranked highly on effectiveness and public acceptance. Both groups also perceived it to be relatively difficult to implement.

**NO WNV PROGRAM**: Health experts ranked a “do nothing” approach significantly higher than the public who expect some form of active intervention. This difference is likely due to the social amplification of risk. Despite its low relative risk in comparison to other diseases, WNV receives a large amount of media attention (Nicol, Hurrell et al. 2008). The increased publicity and awareness likely leads laypeople to seek action. Health experts would ideally not be influenced by this
phenomenon. Building on the public acceptance of tradeoffs could minimize the difference seen in these perceptions. Presumably communications outlining the limited risks from WNV combined with limited efficacy and potential risks of various interventions would garner public support for a “do nothing” approach when appropriate.

**ADULTICIDING:** A difference was also seen in the rankings for adulticiding. Health experts, who responded to our survey, ranked adulticiding significantly higher in a low risk scenario. Though never explicitly studied, observations of adulticiding programs in relation to outbreaks suggest that by the time an adulticiding program is implemented the transmission cycle of the virus is well underway and the number of human cases have already begun to decrease due to other factors. For example, during the 2003 outbreak in Fort Collins it was argued that adulticiding should have been implemented sooner (Nasci 2004). More recently, it has been suggested that there is a lag time in early warning systems that prevent access to timely information and results in a delay in response time (R. Nasci, Personal Communication, January 2009). While some health experts believe that adulticiding should only be considered in a high-risk scenario when a human outbreak is well underway as a last effort to protect the public (R. Copes, Personal Communication, January 2009). Regardless of the reason, health experts are privy to this information while the public is not – this is a critical gap in knowledge and risk communication. By creating public messages on adulticiding the perceptions of the public can be brought into line with those of health officials and scientists. This would perhaps eliminate the public clamor for adulticiding after an outbreak as this strategy has limited efficacy, polarizes the public, and may impose a large environmental burden.

Of interest, is that parents of children under the age 14 did not rank interventions differently. The presence of children is known to increase risk perceptions in relation to particular hazards (Leiss and Chociolko 1994). Even though WNV does not pose a great risk for the young, conventional adulticiding programs have the potential to expose young children to concentrations of pesticides above the Canadian Pest Management Regulatory Agency and US Environmental Protection Agency recommended amounts (Chapter 5). This indicates that parents of young children are either not concerned or unaware of the potential risks at hand. This is another instance of the need for better risk communication.

In this study, we had the luxury of being able to examine differences in ranking of intervention preferences between participants from areas where WNV is present and not present, due to variations in WNV prevalence across Canada. It is known that increased familiarity with the risk and
increased exposure (to the disease) affects risk perceptions (Dosman, Wiktor et al. 2001). As such we had hypothesized that those who lived in provinces where WNV was endemic would perceive the risks from interventions differently. In British Columbia, a province with no locally acquired WNV cases, we saw ranking variations across hypothetical risk levels – probably influenced by media coverage of WNV outbreaks elsewhere and the social amplification of risk (Covello, Peters et al. 2001; Nicol, Hurrell et al. 2008).

In areas with disease experience we saw that perceived risks for hypothetical risk scenarios reflected the local disease and intervention context. Regional adaptations to WNV in Alberta and Manitoba reflected programmatic decisions and unofficial policies. Alberta has opted not to use adulticiding for mosquito abatement purposes whereas Manitoba frequently undergoes adulticiding campaigns for both nuisance and WNV mosquito control (A. Furnell, Personal Communication, April 2008). Such policy decisions increase experience with specific interventions resulting in “acceptance” of some interventions and the value changes implicit in that realization. As with other studies, our results show that experience with interventions is a better predictor of preferences than hypothetical risk scenarios (Loewenstein and Mather 1990). West Nile virus programs and risk communication strategies would benefit from incorporating lessons learnt from areas with experience with various interventions. This will allow for targeted public health programs and risk communication strategies.

Unfortunately, due to the forced ranking system used in the survey instrument we were unable to observe the relationship between combinations of demographic risk factors and decision trade-offs or the extent to which demographic factors described the differences in views between laypeople and health experts. Despite the shortcomings of a forced ranking system, it provides us with an estimation of trade-offs and a starting point for policy discussions and the design of future more in-depth assessments of risk trade-offs surrounding re-emerging infectious diseases. Such research would complement our study by identifying important risk factors in driving decision trade-offs. There were also additional limitations with the sampling frames for both laypeople and health experts. The laypeople sample frame consisted of only listed telephone numbers with full addresses. This excludes the portion of the population that uses only cellular telephones, which is increasing and contains a younger demographic group. However, the study population consisted of mostly females and from urban areas, consistent with other risk perception surveys using a random telephone sample to obtain the sampling frame (Aquino, Fyfe et al. 2004). Health experts were recruited through a convenience sample and though recruitment was extended across Canada, the
majority of respondents were from British Columbia. As a consequence the view of health experts derived in this study cannot be generalized to the rest of Canada.

This is the first study to examine similarities and difference in decisions between laypeople and health experts given WNV risk. Results reveal key differences between evaluation criteria and intervention strategy selection of the public versus those of experts. Laypeople perceived some interventions, for example adulticiding, to be more effective than health experts reported them to be. Laypeople were more willing to make risk trade-offs given WNV risk. Conversely, health experts in our study considered it difficult to implement and with limited effectiveness. This gap in knowledge combined with the social amplification of risk could lead laypeople to have an expectation on their part for the implementation of such interventions while health authorities can be reluctant to act. Within laypeople, there are further differences associated with demographic factors. By understanding the differences of views between laypeople and health experts we can begin to develop and implement educational programs and risk communication messages which address such gaps. This in turn will reduce the information disparity between public opinion and health experts resulting in accord over acceptable interventions. This will allow for the implementation of more effective interventions that limit the overall risk from West Nile virus and other re-emerging infectious diseases.

### 4.5 Conclusions

All too often public opinions and decision-making processes are disconnected and exacerbated by poor risk communication for re-emerging infectious diseases with scientific uncertainty. Despite differences in perceived values between laypeople and experts, leaders should consider public opinions when balancing risks, forming trade-offs, and communicating risks (Leiss 2001). Multi-criteria decision analyses may be of value to public health and risk communication as it provides a structured approach for eliciting perceived values and desired decision outcomes (Kammen and Hassenzahl 1999).

The findings presented here underscore the willingness of the public to consider different evaluation criteria and trade-offs among these depending on perceived risk levels and the characteristics for

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13 It should be noted that not all health experts might have this view. This statement only reflects the answers of health experts who completed the multi-criteria decision analysis survey.
each intervention. Too often only one dimension, of a decision or series of decisions, is represented within communication plans. However, addressing misconceptions and counterbalancing benefits with a realistic presentation of efficacy and potential costs is likely to lead to more sustainable public support for appropriate health interventions (Covello, Peters et al. 2001).

In order to make “acceptable” decisions, risks from the disease in question and possible interventions must be understood and balanced. Multi-criteria decision analyses are not traditionally used in public health but they create a transparent forum by which decision trade-offs can be examined. The results may shed light on what risks the public is willing to assume. Through its application in this study, we have gained a better understanding of risk trade-offs among laypeople in three Canadian provinces and a group of health experts. Laypeople want action and are more sensitive to trade-offs than health experts who are most concerned about the effectiveness of programs. This was emphasized by trade-off differences in adulticiding. Through risk communication we can educate the public on the limited effectiveness bridging the gap between current perceptions leading to more effective WNV program planning.
Table 4.1. Comparison of West Nile Virus interventions across study provinces for 2007

<table>
<thead>
<tr>
<th>Interventions</th>
<th>Intervention Description</th>
<th>Province</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Do Nothing</td>
<td>No WNV program, prefer to allocate funds to another health program.</td>
<td>BC</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AB</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MB</td>
<td>-</td>
</tr>
<tr>
<td>Surveillance*</td>
<td>Can include combination of mosquito, corvid, and human surveillance.</td>
<td>BC</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AB</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MB</td>
<td>✓</td>
</tr>
<tr>
<td>Education</td>
<td>Public education to prevent mosquito bites.</td>
<td>BC</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AB</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MB</td>
<td>✓</td>
</tr>
<tr>
<td>Source</td>
<td>Reducing mosquito habitats such as standing water to prevent mosquitoes from breeding.</td>
<td>BC</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AB</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MB</td>
<td>✓</td>
</tr>
<tr>
<td>Reduction</td>
<td>Applying pesticides to kill mosquitoes in their larval stage.</td>
<td>BC</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AB</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MB</td>
<td>✓</td>
</tr>
<tr>
<td>Adulticiding**</td>
<td>Applying pesticides to kill mosquitoes in their adult stage once they are flying around.</td>
<td>BC</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AB</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MB</td>
<td>✓</td>
</tr>
</tbody>
</table>

* Surveillance was not included as an intervention option in the multi-criteria decision analysis survey as it is ongoing and imperative to surveillance epidemiology and reporting of communicable diseases

** Adulticiding pesticide permits were obtained in British Columbia in the event of an outbreak, but have not been required to date.
Table 4.2. Schematic of performance matrix

<table>
<thead>
<tr>
<th>Interventions</th>
<th>Performance Criteria (π)</th>
<th>Cost (C)</th>
<th>Environmental Consequences (V)</th>
<th>Benefits</th>
<th>Process</th>
<th>Preference Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Program (NO)</td>
<td>Cost</td>
<td>C_NO</td>
<td>V_NO * Rwgt_V</td>
<td>E_NO</td>
<td>S_NO</td>
<td>P_NO * Rwgt_P</td>
</tr>
<tr>
<td>Education (EDU)</td>
<td></td>
<td>C_EDU</td>
<td>V_EDU * Rwgt_V</td>
<td>E_EDU</td>
<td>S_EDU</td>
<td>P_EDU * Rwgt_P</td>
</tr>
<tr>
<td>Source Reduction (H₂O)</td>
<td></td>
<td>C_H20</td>
<td>V_H20 * Rwgt_V</td>
<td>E_H20</td>
<td>S_H20</td>
<td>P_H20 * Rwgt_P</td>
</tr>
<tr>
<td>Larviciding (LAR)</td>
<td></td>
<td>C_LAR</td>
<td>V_LAR * Rwgt_V</td>
<td>E_LAR</td>
<td>S_LAR</td>
<td>P_LAR * Rwgt_P</td>
</tr>
<tr>
<td>Adulticiding (ADU)</td>
<td></td>
<td>C_ADU</td>
<td>V_ADU * Rwgt_V</td>
<td>E_ADU</td>
<td>S_ADU</td>
<td>P_ADU * Rwgt_P</td>
</tr>
</tbody>
</table>

* Risk scenario(R) with confidence level (F) in π

\[
W_{gtc} = \frac{R_c \cdot F_c}{100}
\]

\[
W_{gtv} = \frac{R_v \cdot F_v}{100}
\]

\[
W_{gtE} = \frac{R_E \cdot F_E}{100}
\]

\[
W_{gtS} = \frac{R_S \cdot F_S}{100}
\]

\[
W_{gtP} = \frac{R_P \cdot F_P}{100}
\]

* Please note that weights were created for each hypothetical risk scenario: low risk, medium risk, and high risk.
Table 4.3. Summary of demographics for participant groups (laypeople, health experts)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Laypeople No WNV BC (n=230)</th>
<th>Laypeople WNV Present AB (n=114)</th>
<th>Laypeople WNV Present MB (n=114)</th>
<th>Health experts (n=57)</th>
<th>Canada Census</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
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<td>n=113</td>
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<td>&lt;45 years</td>
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<td>35.1</td>
<td>26.5</td>
<td>44.9</td>
<td>28.1*</td>
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<td>≥ 45 years</td>
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<td>Education</td>
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<td>High school or less</td>
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<td>49.3</td>
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<td>20.0</td>
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</tr>
</tbody>
</table>

* Age percentages do not equal 100 because those < 19 were excluded

Census Canada percentages adapted from: (Statistics Canada 2001; Statistics Canada 2006)

All responses are given in both % share and number (n) of respondents as not all respondents completed all questions.
Table 4.4 Distribution of intervention rankings for each performance criterion, for laypeople (P) and health experts (E)

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Rank</th>
<th>Monetary Cost</th>
<th>Environmental Consequences</th>
<th>Effectiveness</th>
<th>Benefits</th>
<th>Ease &amp; Speed</th>
<th>Public Acceptance</th>
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<td>E</td>
<td>P</td>
<td>E</td>
<td>P</td>
<td>E</td>
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<td>54.4</td>
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<td>-</td>
</tr>
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<td>1.5</td>
<td>3.5</td>
<td>4.1</td>
<td>5.3</td>
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<td>-</td>
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<td>3.1</td>
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<td>35.1</td>
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<td>14.0</td>
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<td>1.8</td>
<td>1.3</td>
<td>-</td>
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<td>12.3</td>
<td>13.8</td>
<td>8.8</td>
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</tbody>
</table>

*Rankings are for each performance criteria where: 1 = least expensive, least environmental consequences, least effective, slowest, least accepted; 5 = most expensive, most environmental concern, most effective, quickest, and most accepted; na = missing;

All responses are given in both % share and number (n) of respondents as not all respondents completed all questions.
Table 3.5 Distribution of individual performance criteria rankings for each hypothetical risk scenario, for laypeople (P) and health experts (E)

<table>
<thead>
<tr>
<th>Performance Objectives</th>
<th>Rank*</th>
<th>Laypeople</th>
<th></th>
<th>Health experts</th>
<th></th>
</tr>
</thead>
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<td></td>
<td></td>
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<td>Medium</td>
<td>High</td>
<td>Low</td>
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<td>38.2 (175)</td>
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<td>21.6 (99)</td>
<td>16.6 (76)</td>
<td>24.6 (14)</td>
</tr>
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<td>13.3 (61)</td>
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<td>24.6 (14)</td>
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<td>2.8 (13)</td>
<td>12.3 (7)</td>
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<td>4.4 (20)</td>
<td>3.9 (18)</td>
<td>10.5 (6)</td>
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<tr>
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<td>12.3 (7)</td>
</tr>
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<td>10.0 (46)</td>
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<td>17.5 (10)</td>
</tr>
<tr>
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<td>23.8 (109)</td>
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<td>28.1 (16)</td>
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<td>15.9 (73)</td>
<td>15.9 (73)</td>
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</table>

*Where 1 = least important, 5 = most important, na = missing
All responses are given in both % share and number (n) of respondents as not all respondents completed all questions.
Table 4.6. Mean preference score and ranks for West Nile virus interventions for laypeople and health experts across hypothetical risk scenarios, by participant group and location.

Where 1 = least preferred and 5 = most preferred intervention

<table>
<thead>
<tr>
<th>Interventions</th>
<th>Laypeople No WNV</th>
<th>Laypeople WNV present</th>
<th>Provinces Combined</th>
<th>Health Experts</th>
<th>t-test</th>
</tr>
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<td>MB</td>
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<td></td>
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<td>15.14</td>
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* p < 0.05; t-test between performance scores for provinces combined vs. health experts
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SD = Standard Deviation, SE = Standard Error, t-stat = t-statistic

*p<0.05, ** p < 0.01
4.6 References


5 Chapter 5: A model for Probabilistic Assessment of Malathion Spray Exposures (PAMSE) in British Columbia, Canada\textsuperscript{14}

\textsuperscript{14} A version of this chapter will be submitted for publication. Elmieh, N., Dowlatbadi, H., and E. Casman. “A model for Probabilistic Assessment of Malathion Spray Exposures (PAMSE) in British Columbia, Canada.
5.1 Introduction

West Nile virus (WNV) was first detected in New York City in the summer of 1999 and in 2001 in Canada (Weir and Shapiro 2004). It has since spread steadily across North America (CDC 1999; Mostashari, Bunning et al. 2001). Despite its well-studied presence in North America, the determinants of its range, virulence and severity are still not fully understood. Furthermore, the virus is unlikely to be eliminated given the complex nature of its co-evolution with its many hosts (Gubler 2007). This has lead to significant public health efforts to understand and monitor the virus, its hosts, and vectors in order to prevent potential outbreaks. One method of managing and reducing the risk to humans is through adulticiding: the application of pesticides by ground or air to the environment to kill and control adult mosquitoes. Adulticiding is part of a multi-pronged approach that also includes surveillance, education, source reduction and larviciding. Adulticiding is usually the last effort to control WNV outbreak, undertaken only after local surveillance has identified infected adult mosquitoes and an increase in the number of human cases. The true efficacy of adulticiding remains unknown and is critically dependant on effective monitoring, detection and implementation. Despite these challenges, various indices and vectors have been developed to assist with the decision to employ adulticiding (Nasci 2004). The effectiveness of adulticiding depends on timely monitoring, detection and implementation. If adulticiding is introduced too late, it is unlikely to break the circle of transmission. In addition to its questionable efficacy, there are concerns that the health risks associated with pesticide exposure can exceed those of WNV (Elmieh, Dowlatabadi et al 2005). This concern has also been the source of controversy and popular press coverage (Globe Editorial 2008).

Pesticide regulatory decisions are made using risk assessments aimed at quantifying probability exposures to hazardous materials among individuals and populations. Through this process, the risks and uncertainties of particular hazards are examined using dose-response relationships and exposure assessments (NRC 1993; Paustenbach 2002). Risk assessments can be deterministic, probabilistic, or a hybrid of these. Deterministic models use single point estimates and do not account for variability and uncertainty in the system. Such models will produce the same output for a given data point each time. Probabilistic models incorporate variability and uncertainty in to data points by using probability distributions. Probabilistic models are advantageous as they can provide a more comprehensive picture of the risk and uncertainties in the risk estimates (Williams, James et
As a result they can provide opportunities for risk reduction, risk communication, and risk management resulting in more effective programmatic decisions reflecting the interdisciplinary nature of public health problems (Morgan and Henrion 1990).

Pesticides are regulated by the Environmental Protection Agency in the United States and the Pest Management Regulatory Agency in Canada. The agencies carry out risk assessments to determine the acceptability of a proposed pesticide for registration and use. Levels of exposure from inhalation, dermal, and ingestion exposure to the pesticide are estimated using exposure scenarios for people of different ages and animal toxicity studies. Potential adverse human health effects and safe exposure levels are derived through animal toxicity studies using standard methods (Williams, James et al. 2000; USEPA 2007a). The definitions are:

- No Observed Adverse Effect Level (NOAEL) is the highest tested dose of a substance reported to have no harmful effect.
- Lowest Observed Adverse Effect Level (LOAEL) is the lowest dose of a tested substance to have a harmful effect.
- Uncertainty Factor (UF) represents factors of uncertainty for between species data extrapolation, population heterogeneity, and other unknown factors in NOAEL or LOAEL.
- Reference Dose (RfD) is a reference estimate of the daily exposure to human populations that is unlikely to result in adverse human health effects. It is the ratio of no-observed adverse effect level (NOAEL) to the multiplication of all the uncertainty factors.

Though risk assessments account for uncertainty in data points and between species they are traditionally deterministic (USEPA 2001). In the case of pesticides and mosquito abatement programs, the regulatory agencies do not take into account uncertainty surrounding spatial and temporal variations in exposure and the potential accumulation of pesticides in the environment (Dubus, Brown et al. 2003). The current risk assessment framework used to establish the regulations for pesticide application rates assumes a single exposure to pesticides and an environmental half-life of one day.

15 Probabilistic and stochastic models are sometimes used interchangeably. Though they both incorporate variability and uncertainty in data points, stochastic models are fundamentally different in that they also introduce variability in time (Dubus, Brown et al. 2003). For example, models using explicit representations of the impact of weather on exposure are stochastic because of the time varying nature of atmospheric processes.
Three published risk assessments have been carried out examining pesticides used for the control and prevention of WNV in a public health setting (Peterson, Macedo et al. 2006; Gosselin, Valcke et al. 2008; Valcke, Gosselin et al. 2008). Two are deterministic in nature and one is a hybrid of probabilistic and deterministic techniques (Table 5.1). In one deterministic model, Peterson and colleagues found no toxicological concern for malathion exposure and concluded that the risk of WNV infection outweighs that of malathion (Peterson, Macedo et al. 2006). The National Institute of Public Health in Quebec also examined the risks using two models. One was deterministic and the other used probabilistic definitions for some parameters. In both Quebec studies toxicological concern from malathion exposure was found, especially among toddlers (Gosselin, Valcke et al. 2008; Valcke, Gosselin et al. 2008). The differences in results of these three models lie in parameter definitions and probability density functions of certain parameters.

Even though deterministic models tend to incorporate conservatism into their assumptions, the deterministic models by Peterson and colleagues (2006) and Gosselin and colleagues (2008) did not take variability and uncertainty in data points into account. While Valcke and colleagues incorporated this into their model, they did not include interindividual and spatial variability (Valcke, Gosselin et al. 2008). Both sources of variability are fundamental to risk assessments. Variations in body characteristics (e.g. height and weight) within a population will affect pesticide exposure levels (Sander and Oberg 2006). While incorporating spatial variability will alter pesticide concentrations in the environment (van Alphen and Stoorvogel 2002). Without taking such variability into account, risk characterizations may misestimate the risk. This puts in question the applicability of such deterministic models to actual public health mosquito abatement programs, which often require repeated applications over a period of time to reduce the mosquito population and human risk. Behaviorally realistic probabilistic models can better characterize variability and uncertainty in risks and may allow for better risk management of public health decisions (Dowdle and Hopkins 1998).

The pest management regulatory agency in Canada has only registered malathion for public health mosquito control (Elmieh, Dowlatabadi et al. 2005). Malathion, an organophosphate, was first registered for use in Canada in 1953, and in the United States in 1956 for a variety of uses including agriculture (food and non food), residential uses (lawn and garden), pest control and for public health programs (USEPA 2000; National Pesticide Information Center 2001; Pest Management 16 There are currently 6 pesticides registered for mosquito abatement programs in the United States: permethrin, pyrethrins, resmethrin, phenothrin, malathion, and naled 17 In emergency public health situations pyrethrin may be used for mosquito abatement programs in Canada (BCCDC 2007).
Malathion is highly functional as a pesticide due to its high toxicity among insects and low toxicity among other species. Once exposed, malathion is broken down into malaoxon, which exhibits greater toxicity and is potentially carcinogenic (Agency for Toxic Substances and Disease Registry 2000; National Pesticide Information Center 2001). Insects lack the carboxylesterase necessary for detoxification of the chemical (Aldridge 1996). Fish and some aquatic invertebrates are also susceptible to acute adverse effects from malathion, as shown by the death of 99% of Long Island’s fall lobster landings in 1999 (Sibbald 2001; De Guise, Maratea et al. 2004). Mammals and humans use carboxylesterase to remove one or both of the ethyl groups. This prevents the formation of the active inhibitor and leads to the elimination of the by-products through urine within a few days of exposure (Agency for Toxic Substances and Disease Registry 2003). The effectiveness of carboxylesterase may be limited and inhibited in the presence of synergists used to activate malathion and other impurities often found with pesticides (Aldridge 1996).

Once in the environment, malathion has the potential to accumulate. Literature shows that malathion has an environmental half-life ranging from 0.5 a day in dry soil and up to 19 days in water (Pest Management Regulatory Agency 2003). The longer half-life of malathion in water has led to the creation of buffer zones and spray drift requirements (USEPA 2000a). Though the buffer zones protect natural bodies of water, they do not take into account natural forms of precipitation, evapotranspiration, and watered lawns and gardens that may be present in spray areas. This unaccounted form of moisture can lead to longer half-lives of malathion and the potential to accumulate in the environment. Despite this risk, current risk assessments only use deterministic half-lives in calculating malathion exposure thereby excluding the impact of plant surface and soil moisture in their calculations and potential pesticide exposure levels. Some deterministic models do examine cumulative dose, however, this does not take into account the potential accumulation of malathion in the environment, based on half-life, over the duration of a spray campaign. Previous WNV outbreaks we taught us that in order to effectively target adult mosquitoes we need to consider a campaign that lasts at least one month with applications every 4 or 5 days. Therefore, the combination of environmental half-life and the timing and frequency of spray events become important in determining cumulative pesticide exposure and the cumulative concentration of its metabolites in humans and the environment.
Exposure among humans can occur through three routes:

- Dermal contact (e.g. contact contaminated surfaces such as plants, soils, pavements, and toys/playground equipment).
- Ingestion (e.g. consumption of contaminated fruits and vegetables, accidental soil ingestion, and hand to mouth activities).
- Inhalation (e.g. vaporized particles).

Once exposed the major health impact of malathion in humans is its interference with the nervous system. As such it can indirectly effect other organs and human body functions usually associated with respiratory, cardiovascular, gastrointestinal, and the ocular systems. Most commonly, the adverse effects are acute in nature and include difficulty in breathing, tightness in the chest, vomiting, cramps, diarrhea, blurred vision, salivation, sweating, headache, dizziness, loss of consciousness, and in severe circumstances death (Agency for Toxic Substances and Disease Registry 2003). Impacts of exposure in children are of special concern due to their lower body weight and their developmental stage. Children are also likely to be at a higher risk of exposure because of the duration and patterns of activity outdoors (Fitz 2003; USEPA 2007).

Given the potential for adverse human health impacts it is crucial to model exposure and doses received with care. The uncertainty in cumulative exposure levels and its accumulation in the environment must be explicitly examined in relation to standards set by regulatory agencies. The purpose of this paper is to develop a probabilistic model incorporating system uncertainties into estimating the probability distribution of malathion exposure in a public health mosquito abatement spray campaign. The hypotheses are as follows:

- $H_0$: Traditional risk assessments (and uncertainty factors) provide an adequate method for assuring that the public is not exposed to malathion above guidelines in public health adulticiding programs.
- $H_1$: Traditional risk assessments are not adequate for public health adulticiding programs, and need to include scientific uncertainty in environmental characteristics and population and behavioral variability into parameter definitions to allow for a more realistic assessment of exposure levels.
5.2 Methods

5.2.1 Model overview
The Probabilistic Assessment of Malathion Spray Exposures (PAMSE) model was developed to capture the impacts of parametric and structural uncertainties in determinants of exposure. The stochastic model was built using Analytica® a software modeling environment with graphical representation of parameter dependencies and model structures (Lumina Decision Systems 2007). Probabilistic variables and distributions were defined to describe: the environmental factors defining malathion concentrations; the distribution of weight and body surface area characterizing different age groups in the population; and, the patterns of activity that bring individuals into potential contact with the pesticide. The full probability distributions for the key variables are propagated throughout model equations to calculate explicit probability distributions for doses received by exposure pathway and age. Existing literature was used, where possible, to model: distributions, uncertainties, population characteristics, and exposure pathways.

The model was run with a sample size of 10,000 runs using a Knuth randomization scheme and median latin hypercube sampling methodology. Each run provides a probability distribution for each variable of interest. The main output of the simulation was the probability distribution of exposure (mg/kg-day) for each represented age group and associated body characteristics (e.g. weight, height, surface area). The 40-day simulation allowed for the explicit identification of “who” exceeded the reference dose (RfD) and what percentage of the total population within each age group they represented. Model outcomes could also be evaluated with greater specificity for each day of the campaign, exposure pathway, and behavioral characteristics.

Our model takes into account human acute exposure (1 day) and its potential for bioaccumulation and sub-chronic exposure for up to 32 days. The model does not take into account the pharmacokinetics of malathion, the effects of malaoxon, or occupational and accidental exposures to malathion. The proceeding sub-sections will describe methodology pertaining to model variables, uncertainties, and key assumptions in three modules (Figure 5.1):

- Population characteristics
- Environmental and pesticide characteristics
- Exposure pathways

For a full description of the code used to define the variables, their distributions, and mathematical equations please see Appendix D.
5.2.2 Population characteristics

Four aspects of the population were specified in order to characterize interindividual variability in activity patterns, exposure and dose received: age, weight, height, and surface area. The population was divided into five age groups: <2, 2-6, 7-14, 15-65, and >65 years. The age categories were chosen as indices to reflect differences in activity patterns, physiology and potential exposure levels. Population distributions were calculated using Statistic Canada Community Profiles for British Columbia (Statistics Canada 2006).

Annual mean and standard deviations of weight and height data for all ages were obtained from the National Health and Nutrition Examination Survey (NHANES), covering the period 1988 to 1994. These were used to construct age-group specific weight and height distributions for the population in the model (Table 5.2) (CDC 2004).\(^1\)

Surface area distributions were calculated for each age group in order to estimate exposure through trans-dermal and ingestion through hand to mouth transfer. Two different equations were used to calculate the surface area, one for children under 30kg and one for children and adults over 30 kg (Table 5.2) (Mosteller 1987; Elert 2001).

If weight of individual \(i < 30\) kg:
\[
SA_i = (W_i + 4)/30
\]

If weight of individual \(i \geq 30\) kg:
\[
SA_i = (H_i * W_i)/3600^{1/2}
\]

Where:
- \(SA_i\): Surface area (\(m^2\)) for individual \((i)\)
- \(W_i\): Weight (kg) for individual \((i)\)
- \(H_i\): Height (cm) for individual \((i)\)

Surface area distributions were used to calculate the fraction of exposed skin for dermal exposure.

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\(^1\)NHANES is a national program in the United States. It conducts both physical examinations and interviews to assess the health and nutrition status of children and adults in the United States. (CDC 2005)
The surface area of each simulated individual was calculated to determine hand to mouth events and exposure to malathion via ingestion (described in section 5.2.4).

5.2.3 Environmental and pesticide characteristics

To model malathion exposure several environmental and pesticide characteristics and the variability and uncertainty in their distributions were defined for:

- Spray method
- Dispersion and deposition
- Spatial Environment
- Frequency and duration of spray events
- Potential for accumulation in the environment

The following equation was used to derive the amount of malathion available in the environment and available for uptake by the individual \((i)\). Each variable will be elaborated in subsequent subsections.

\[
C_{x,y,t} = \left( (AR_{x',y'} \times D_{x,y}) + F_{st} \right) / S_{x,y}
\]

Where:

- \(C_{x,y,t}\) Environmental concentration of malathion (mg/m\(^2\)) available for uptake at spatial grid location \((x,y)\), at time \((t)\) accounting for multiple spray events \((s)\)
- \(AR_{x',y'}\) Application rate of malathion for where the pesticide is released \(x',y'\) (g a.i/ha \(\Rightarrow\) mg/m\(^2\)). Value is user defined and dependent on application method.
- \(D_{x,y}\) Mass fraction of AR that remains (after drifts into and out of this virtual box) aloft over plot identified by its \(x,y\) coordinates. This determines air borne concentration of the pesticide as well as mass that is eventually deposited on available surfaces on that plot.
- \(F_{st}\) Fraction of malathion still active in the environment from a previous spray events \((s)\) at time \((t)\). This accounts for spray frequency, and half-life of malathion in the environment.
- \(S_{x,y}\) Fraction surface area available for deposition in plot \(x,y\). This accounts for foliage, building and other surfaces in the immediate environment where exposures through transdermal and ingestion pathways are being calculated. The area over which deposition can take place is expressed as a multiple of the projected area of the plot.
SPRAY METHOD: In this model, the user defines whether the mosquito abatement campaign will be conducted using ground or aerial ultra low volume (ULV) spray mechanisms determining the application rate (Figure 5.1). We used a uniform probability distribution ranging from a minimum of 26.0 g a.i./ha to a maximum of 60.8 g a.i./ha for ground ULV spraying, and a deterministic value of 233 g a.i/ha for aerial spraying to reflect the Pest Management Regulatory Agency registered and recommended rates (Table 5.3).\textsuperscript{19}

The user also determines whether the whole town or half the town is sprayed in order to explore scenarios where individual households are allowed to opt out of the spray campaign.

PESTICIDE DISPERSION AND DEPOSITION: Due to national security concerns the US Environmental Protection agency models were not available to us. We, therefore, developed simple spatial dispersion and deposition models for both ground and aerial ULV spraying.

For ground ULV spray campaigns we assumed foggers were truck-mounted at 1.5m, and driven down each street perpendicular to the prevailing wind direction. The spray application rate was assumed to be continuous, with a typical dispersion plume. The spray truck was assumed to traverse a series of parallel streets, each one block apart (70m in this model).

Published data suggests that between 1-5\% of the application rate can be deposited as far away as 490m from the source (USEPA 1997; Teske, Thistle et al. 2000). Using this information, we assumed that between 70 to 90\% of the intended application with a mode of 82\% landed in the intended 0-70m area. Using a box model, with a mass balance, we allocated a distribution of up to 30\% drift beyond each grid cell for up to 490m using the following scheme:

<table>
<thead>
<tr>
<th>m</th>
<th>Distance from point of spray</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>m =0</td>
<td>0-70m</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>m =1</td>
<td>70-140m</td>
<td>$\beta (1-\alpha)$</td>
</tr>
<tr>
<td>m =2</td>
<td>140-210m</td>
<td>$\beta (1-\beta (1-\alpha))$</td>
</tr>
<tr>
<td>m =3</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>m =6</td>
<td>420-490m</td>
<td>$1- \sum_{m=0}^{6} D_m$</td>
</tr>
</tbody>
</table>

\textsuperscript{19} g a.i./ha = grams active ingredient / hectare
Where:

- $D_{x,y}$: Mass fraction of application rate that is deposited and drifts to and away from a plot within spatial grid at location $(x,y)$
- $m$: Measured distance downwind from spray release point where malathion is deposited and drifts to and away from
- $\alpha$: Fraction of malathion mass landing within intended 0-70m area. Drawn from triangular probability distribution with minimum of 0.70, mode of 0.82, and maximum of 0.94.
- $\beta$: Fraction of remaining mass of malathion aloft and drifting to next grid cell. Drawn from normal probability distribution with $\chi = 0.18$ and $SD = 0.04$

The box model allowed us to estimate the probability distribution of total deposition at a given point, in a typical urban grid, from sources both close and up to seven blocks away. The deposition rate in each single-family plot was the sum of the intended deposition plus the amount of drifted pesticide. A visual representation of a cross-section of the spatial grid and potential for drift overlap can be seen in Figure 5.2.

Similar deposition patterns were simulated for aerial ULV applications whereby a substantial fraction of deposition occurred directly beneath the swath of the airplane with downwind drift. The standard swath width for aerial applications is 150m with an observed drift of 300m from the edge of the swath approximating 35% of the application rate (USEPA 1997). Therefore, 65% of the intended application rate was assumed to land in the area immediately below the aircraft swath width. The same basic model formulation as the ground ULV deposition was used to determine the percent deposition distribution directly under the swath. The remaining swaths (up to 1200m downwind) were treated in a mass balance box diffusion model and allocated to neighboring swaths until the whole of the city had been modeled.20

In the alternate (user-defined scenario) where only half the town is sprayed, the area was divided into two equal halves. The area upwind was sprayed as before (ground or aerial). The remainder of the town only received malathion that had drifted beyond the intended application area.

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20 Note, this means that some of the pesticide can drift away from the modeled region.
**SPATIAL ENVIRONMENT:** Ingestion and trans-dermal exposures occur through contact with pesticides deposited on various surfaces in the environment. Within each residential plot we assumed a well-mixed environment with unbiased deposition rates on various surfaces. The deposition surfaces in a given residential plot were then determined on a plot-by-plot basis using a simple model of the landscape. Each plot was described to have a building, trees and shrubs, paved surfaces and the balance of grass the horizontal surfaces were assigned to be grass. The size of buildings, area of shrubbery and trees, and paved surfaces were randomly sampled from distributions describing a typical North American neighborhood dominated by single-family housing. This permitted calculation of deposition concentrations on available surfaces that varied from plot to plot, even when the total pesticide load deposited on plots were the same. The details of how each plot’s surface areas were estimated can be found in Table 5.4 and used the following equation:

\[ S_{x,y} = \sum_l A_l I_l \]

Where:
- \( S_{x,y} \) is the surface area available for deposition in plot \( x,y \). Fraction of actual area where malathion can be deposited >> area of the plot
- \( l \) designates land cover type: pavement, building, turf and tree
- \( A_l \) is the fraction of plot area covered by material type \( l \)
- \( I_l \) is the area index for material type \( l \)

**LENGTH AND FREQUENCY OF SPRAY CAMPAIGN:** In order for adult mosquito abatement programs to be effective numerous spray events must occur within a given time period to ensure adult mosquitoes are killed. Three or four applications are typical, but as many as 8 spray applications may be warranted in certain situations (Shapiro and Micucci 2003). Such spray events tend to occur on a 4 day cycle (Doyle 2004). Therefore, a spray campaign may last up to 32 days depending on the number of spray applications required. In this model, the user defined the frequency of the spray campaign, which determined the length of the potential exposure period.

**HALF-LIFE AND ACCUMULATION:** Traditionally, risk assessment models use a 24-hour point value for the half-life. We know that malathion generally breaks down into metabolites and is excreted from the human body within a few days, and that its environmental half-life can range from
0.5 days in soil to 19 days in water (Agency for Toxic Substances and Disease Registry 2003; Pest Management Regulatory Agency 2003). Therefore, the half-life of malathion in the environment is highly dependent on the local ecology, weather conditions and whether homeowners/renters water their gardens. This leads to a wide range of potential half-lives depending on local conditions (Figure 5.3). To address this, we used the following equation and allowed the user to select either a discrete environmental half-life value (0.5, 1, 2, 4, 8, 16) based on their local environment and climate or choose a lognormal distribution (µ=0.7, sigma=2.8; µ=1, sigma=2.5) representing various microclimates in the spray zone:

\[ f_t = \left(\frac{1}{2}\right)^{t/\tau} \]

Where:
- \( f_t \) Fraction of the pesticide in the environment at \( t \) days after the spray event.
- \( \tau \) Half-life of the pesticide

Given constant spray application rates in \( s \) spray campaigns. The cumulative fraction of active pesticide in the environment can be calculated as:

\[ F_t = \sum_s f_{s,t} \]

Where:
- \( f_{s,t} \) Fraction of from spray event \( s \) remaining at time \( t \).

It would be tempting to assume that a shorter lifetime is warranted if application campaigns could be timed to coincide with dry conditions, but that is exactly when keen gardeners are least likely to resist watering. Furthermore, the microenvironment of the underside of blades of grass is invariably humid due to evapotranspiration. This is particularly important as a potential source of exposure for children playing outside. The probability density function for a given spray day in the PAMSE model is presented in Figure 5.4.

We modeled each spray event to begin at dusk when mosquito activity is greatest. We assumed that residents received notification of the spray event and remained indoors for the night. It was assumed that airborne malathion could filtrate indoors; a triangular distribution was defined for airborne malathion expected to drift indoors with a mode of 30%. The first exposure to malathion
in the outdoor environment was modeled to take place 12 hours (morning) after the spray event. Malthion residue in the environment, and available for uptake, was calculated at 12 hours and on a 24 hour basis thereafter for up to 30 days after the spray event.

Depending on the spray schedule and environmental half-life chosen by the user the environmental concentration available for exposure can vary.

5.2.4 Exposure pathways
Exposure to malathion can occur through three pathways (dermal, inhalation, ingestion). Each Pathway was modeled using the following general equation:

\[ PD_{i,j,t} = \sum_{x,y,s} (C_{x,y,t} \times E_{i,x,y,t} \times U_j) / W_i \]

Where:
- \( PD_{i,j,t} \): Potential Dose (mg/kg/day) for individual (i) through exposure pathway (j) at time (t)
- \( C_{x,y,t} \): Environmental Concentration of malathion (mg/m\(^2\) or mg/m\(^3\) based on exposure pathway) available for potential uptake at spatial grid location (x,y), at time (t) accounting for multiple spray events (s)
- \( E_{i,j,x,y,t} \): Exposure to malathion for an individual accounting for age, body characteristics, and activity patterns of the individual (i), by exposure pathway (j), at a spatial grid location (x,y) at time (t). Units dependent on exposure pathway.
- \( U_j \): Potential uptake fraction of malathion for particular exposure pathway (j)
- \( W_i \): Weight (kg) of individual (i)

The sum of all exposure pathways, divided by the weight of individual (i) was modeled and used to estimate the probability density of total dose received for the whole population. The total dose and pathway specific doses of all individuals in the model were compared to the animal toxicity NOAEL endpoint values and the Target MOE values from both the Pest Management Regulatory Agency and the US Environmental Protection Agency to identify and quantify sub-populations exceeding the set safety thresholds. The PAMSE framework also provides a reverse assessment, using rank-order correlation, thereby allowing the user to determine parameters critical in causing over-exposure. This can be used to target risk reduction messaging in the event of an adulticiding campaign and to identify areas for further research.
DERMAL EXPOSURE: Dermal exposure was assumed to take place outdoors where contact with contaminated surfaces and extraction and absorption of the pesticide can occur. We calculated potential dermal exposure based on the age of the person, time spent outdoors on a given day, type of activities and expected fraction of exposed skin. Each age group was associated with their own probability density functions for each of these factors. Figure 5.5 presents two iterations of the number of hours spent outdoors engaged in activity by age group for a given day. The rate of absorption through skin was also sampled from a probability density function informed by the literature. Modeled activities and their frequency varied by age and day and included: playing outdoors, in transit, gardening with gloves, gardening without gloves, and resting outdoors. Activity levels and hand to mouth events by age group defined the number of times exposed skin areas would come into contact with the pesticide (Table 5.5).

\[
PD_{\text{Dermal},i,t} = (C_{x,y,t} \times T_{it} \times ESA_{it} \times X_{\text{dermal}} \times U_{\text{dermal}}) / W_i
\]

Where:
- \(PD_{\text{Dermal},i,t}\) Potential dermal dose (mg/kg/day) of individual \(i\) at time \(t\)
- \(C_{x,y,t}\) Environmental Concentration of malathion available for potential uptake (mg/m\(^2\)) at spatial grid location \((x,y)\), at time \(t\) including residues from previous spray events \((s)\)
- \(T_{it}\) Number of touches per day with contaminated surfaces for individual \(i\) per day at time \(t\)
- \(ESA_{it}\) Exposed surface area of skin (m\(^2\)) for individual \(i\) at time \(t\)
- \(X_{\text{dermal}}\) Fraction of malathion that is extractable from surface
- \(U_{\text{dermal}}\) Fraction of malathion absorbed through dermal contact
- \(W_i\) Weight (kg) of individual \(i\)

INGESTION EXPOSURE: Potential ingestion exposure was modeled to account for hand to mouth events, eating wild berries from bushes, eating unwashed produce from home gardens, and accidentally ingesting grass and/or soil while outside. Variation in frequency, distribution, and transferable amount available for ingestion was modeled for each age group (Table 5.6). The total ingested dose was corrected for a user-defined percentage of the population eating produce from their home garden(s). This percentage was translated into a random draw of dwellings in the model.
$PD_{\text{Ingestion}}_{i,t} = \left( C_{x,y,t} \times G_{i,t}^{2/3} \right) / W_i$

Where:
- $PD_{\text{Ingestion}}_{i,t}$ Potential dose ingested (mg/kg/day) of individual ($i$) at time ($t$)
- $C_{x,y,t}$ Environmental Concentration of malathion available for potential uptake (mg/m$^3$) at spatial grid location ($x,y$), at time ($t$) including residues from previous spray events ($s$)
- $G_{i,t}$ Amount of produce consumed (m$^2$/day) by individual ($i$) at time ($t$) * user defined percentage consumed from home garden
- $W_i$ Weight (kg) of individual ($i$)

**INHALATION EXPOSURE:** Potential inhaled exposure was calculated using: (1) amount of malathion airborne at a given location, (2) the exposure period, (3) the rate of inhalation, and (4) the absorption rate. For ground ULV spraying the maximum height of the fogging plume was assumed to be 15m (minimum = 5m, mode = 7m) with a perpendicular wind causing the pesticide to drift downwind from the spray nozzle. Data suggest that a spray plume can remain aloft for between 30 minutes and 6 hours and that between 14-95% can be absorbed (Segawa, Sitts et al. 1991). It was assumed that approximately 30% of airborne malathion would drift indoors with a distribution ranging from 10% to 100%. Deterministic, age specific, inhalation rates were obtained from the US Environmental Protection Agency for respiration rates and to calculate the potential inhalation exposure at a given location within the grid (Table 5.7).

$PD_{\text{Inhalation}}_{i,t} = \left( C_{x,y,t} / Z_{xy} \right) \times \text{IN}_{\text{Inhalation}} \times V_{\text{Inhalation}}_{i,t} \times B_{\text{Inhalation}} \times P_{\text{Inhalation}}_{i,t} / W_i$

Where:
- $PD_{\text{Inhalation}}_{i,t}$ Potential dose inhaled (mg/day/day) of individual ($i$) at time ($t$)
- $C_{x,y,t}$ Environmental Concentration of malathion available for potential uptake (mg/m$^3$) at spatial grid location ($x,y$), at time ($t$)
- $Z_{xy}$ Height (m) of the pesticide bloom over plot ($x,y$) during the time it is airborne.
- $\text{IN}_{\text{Inhalation}}$ Fraction of malathion infiltrating indoors
- $V_{\text{Inhalation}}_{i,t}$ Volume of air inhaled (m$^3$/hour) by individual ($i$) at time ($t$)
- $B_{\text{Inhalation}}$ Fraction of malathion absorbed through inhalation
- $P_{\text{Inhalation}}_{i,t}$ Period of time individual ($i$) is exposed to malation (hours/day) at time ($t$)
- $W_i$ Weight (kg) of individual ($i$)
TOTAL COMBINED EXPOSURE DOSE: The three exposure (dermal, ingestion, and inhalation) pathways were combined to provide a total combined exposure dose accounting for all previously mentioned variables, their ranges, and uncertainties associated with them.

5.3 Results

The model was run with a random sample size of 10000 runs using a Knuth randomization scheme and the median latin hypercube sampling methodology. Exposure pathways and the overall exposure from all pathways are presented below using the following user input assumptions:

- **Environmental half-life:** lognormal distribution (median = 1, geometric SD = 2.5)
- **Spray schedule:** 4 spray events
- **Area sprayed:** whole area
- **Spray method:** ground ultra low volume fogging
- **Percentage population that eat from garden:** 10%

**DERMAL EXPOSURE:** The maximum dermal exposure occurred in conjunction with the spray events among all age groups. A decrease in the dermal exposures was seen after a spray event, though levels remained elevated for the duration of the spray campaign representing a small amount of accumulation in the environment leading to increasing potential exposures with subsequent spray events. Dermal exposures were most pronounced for children between the ages of 2 and 6 (toddlers, who would most likely and frequently, be touching items in the environment) (Figure 5.6). Less than 1% of children under 6 exceeded the reference dose (RfD) (Table 5.8).

**INGESTION EXPOSURE:** As with dermal exposure, we see increased ingestion exposure levels in parallel with spray events. This cumulated over the spray campaign. Children between 2 and 6 years old had the highest estimated dose of ingestion exposure (Figure 5.7). The modeled ingestion exposure levels were below the reference dose (RfD) for all age groups (Table 5.8).

**INHALATION EXPOSURE:** A spike in the total inhaled dose was observed in the total daily inhalation dose corresponding with the spray schedule and subsequent 24 hours (Figure 5.8). Children under 6 were seen to be at the greatest risk of inhalation exposure with a mean exposure level of 0.003 mg/kg/day with exposure levels ranging from 0.000018 to 0.013 mg/kg/day (Figure 5.9). When this distribution of potential inhalation exposures was compared to the reference dose (RfD), 3.9% of children under 6 exceeded the reference dose (RfD) of both agencies on the day of
the spray and subsequent 24 hours (Table 5.8).

**COMBINED TOTAL EXPOSURE:** Combining all exposure pathways we estimate that up to 7.5% of children under the age of 6 can exceed the reference dose (RfD) as set by the Pest Management Regulatory Agency in Canada (Table 5.8). The total combined exposure distribution ranged from:

- 0.000056-0.021 mg/kg/day for children under 2
- 0.000096-0.015 mg/kg/day for children between 2-6

The US Environmental Protection Agency uncertainty factors are 10-fold lower, as a result no exceedances were observed. This difference between PMRA and US EPA may reflect a greater degree of risk aversion on the part of PMRA, or it may reflect an inadequate margin of safety in the United States.

**ACCUMULATION IN THE ENVIRONMENT:** Though most of the exposure to malathion occurred on the day of the spray event, we saw evidence for the potential accumulation of malathion in the environment (from previous spray events) leading to increased potential exposures with subsequent spray events among children between the ages of 2 and 5 (Figure 5.10). Unlike children less than 2, their potential exposure did not return to zero between spray events and as a result increased over the duration of the spray campaign.

**PARAMETER IMPORTANCE ANALYSIS:** The absolute rank-order correlation was used to determine the contribution of each parameter to the overall output (combined total exposure). The environmental half-life parameter had the greatest contribution to the overall combined total exposure for each age group.

### 5.4 Discussion

The purpose of this paper was to examine malathion exposure using probabilistic modeling in a public health mosquito abatement setting. Traditionally risk assessments have used deterministic models with point estimates (USEPA 2001) to assess the dose of pesticides received in the population. Through the explicit inclusion of variability and uncertainty into the spatial, temporal,
and population aspects of a risk assessment we found that children under the age of 6 were potentially at risk of exceeding the reference dose as set by the Pest Management Regulatory Agency and the US Environmental Protection Agency. We saw greater overall exceedances using the Pest Management Regulatory Agency due to their higher uncertainty factors. The largest contributor to this exceedance was inhalation followed by dermal exposure. This excess exposure among children raises concerns about the potential harm to their developing organs. It is also unknown whether their system is as efficient in breaking down malathion, and whether it bioaccumulates in their systems (Fitz 2003). The potential for young children to be exposed to pesticide levels above the recommended reference dose, specified by the Pest Management Regulatory Agency in Canada, should be taken into consideration when planning adulticiding programs and reflected in public health messages. For example, messages should implicitly highlight the importance of young children remaining indoors during the spray event and to minimize outdoor activities on the day following a spray event. It also suggests that children’s outdoor activity environment should be kept as dry as possible in order to accelerate the environmental breakdown of malathion.

Risk assessments examining pesticides for mosquito abatement programs have conventionally used a half-life for pesticides equivalent to 24 hours (USEPA 2001; Peterson, Macedo et al. 2006). This does not take into account the variable decay rate of many pesticides once in the environment and in various micro-climatic conditions. Malathion has a much higher half-life in the presence of water. This has implications for many environments in British Columbia and elsewhere where spray areas can be moist due to rainfall, dew, and irrigation of gardens and lawns. By incorporating a distribution of half-lives, we observe an accumulation in the environment and increasing dose effects in dermal and ingestion exposures. In lieu of overlooking the possibility of accumulation in the environment, the environmental half-life could be used to target the specifics of public health messages and outreach programs beyond staying indoors. This would reduce exposure levels indirectly. Public health campaigns and messages could, therefore, be used to maximize decay rates by promoting and scheduling watering of lawns and gardens appropriately. This would ensure that the soil and vegetation is dry thus providing the necessary environment for malathion to be broken down faster than when in the presence of water residue.

This model is unique in that it incorporates variability and factors of uncertainty relevant to human exposure and public health mosquito abatement programs through the use of probability distributions for most parameters. The uncertainties in the model can be grouped into two categories: environmental and behavioral. The environmental uncertainties pertain to the amount of
malathion and frequency with which its used as well as its dispersion, deposition, and its potential to accumulate on surfaces in the spatial environment modeled. Depending on the probability distribution of each parameter source (the uncertainty in the discrete values), human exposures will vary and potentially exceed set standards. Data points for environmental uncertainties were generated through available data when possible and expert assumptions that allowed the model to more accurately predict potential exposures related to public health decisions involving malathion. The inclusion of indoor penetration of airborne malathion led us to see exceedances above inhalation guidelines for children under the age of 6 immediately following the spray-event. Similarly, the inclusion of a distribution of environmental half-lives led us to see exceedances above the combined exposure pathway guidelines due to pesticide accumulation in the environment and subsequent dermal and ingestion exposures. The parameter importance analysis also identified that the definition of environmental half-life had the greatest contribution to the final output.

The framework presented in the PAMSE model is sufficiently generic to permit inclusion of pyrethrin and other pesticides used in public health mosquito abatement programs. However, such analysis is not presented here due to a lack of published environmental fate data on pyrethrins. Actual data points for pesticide application, dispersion, deposition and accumulation in the environment for various pesticides would allow us to validate this model, refine it to accurately characterize environmental concentrations, and expand it to include other pesticides used in public health programs.

Population heterogeneity is naturally occurring and as a result we see interindividual variability across populations, places, and time. Heterogeneity in populations can result in portions of the population being subjected to exposure levels above and below reference exposure points even when these have had generous uncertainty margins built into their estimation (Paustenbach 2002). However, to date, heterogeneity in population exposure and dose has not traditionally been part of risk assessments. To account for this, we created age specific probability distributions for weight, height, and activity ranges. This allowed the model to differentiate between individuals and activities that may expose individuals to additional pesticide exposures. By accounting for population heterogeneity we saw exceedances above the reference dose (RfD) previously undetected in risk assessments. Though our model is not validated, it shows that by incorporating population heterogeneity there are potential sub populations that may be at risk of exceeding current standards. With behavioral activity data this aspect of the model can be validated and explored to determine the role of population heterogeneity in exposure levels.
This also raises the need for assessing the importance of behavioral parameters. Potential exposures to malathion, and other pesticides, can vary substantially depending on the details of such parameters. For example, if those who are avid gardeners do so without gloves for prolonged periods of time they are at a considerably higher risk of absorbing pesticides. Those who work outdoors and in contact with the natural environment may also be at a higher risk of excess exposures – similar to that of occupational exposures. The consideration of such details can be of assistance to public health in identifying and modeling the risks for sub-populations. This could be then be used to develop risk communication and public health messages targeted towards specific groups at an increased risk of exposure.

Though only one scenario has been presented in this paper, flexibility is one of this model’s strengths. It can be manipulated to the specifics of a certain situation (for example, various climatic conditions can be modeled through user defined environmental half-lives). It can be used to assess a variety of circumstances to provide quantitative insights for informed decisions in the event of a WNV outbreak. By incorporating uncertainty, this model provides decision makers with the opportunity to examine and judge the probability that exposure targets have been overestimated or underestimated for the population given the disease and pesticide exposure context.

### 5.5 Conclusion

By characterizing data variability and uncertainty and their distributions, we see that malathion spraying in compliance with Canadian guidelines can still leave more than 7% of children under the age of 6 at risk of excessive exposure to malathion (pathways combined) above the reference dose (RfD). Just under 4% of children can potentially exceed inhalation guidelines in both Canada and the US for inhalation exposure. Through a realistic modeling scenario, intended specifically for mosquito abatement programs using malathion, we see that potentially children are at risk of exceeding guidelines and at risk of potential adverse health effects. This puts an unnecessary burden on children – who are not at risk of WNV infection.

Traditionally risk assessments use an environmental half-life of 24 hours. However, we found that a more realistic distribution of environmental half-lives has a large effect on the decay rate and malathion accumulation in the environment. This exacerbates the combined total exposure,
especially among children under 6, over a campaign period. Though this model has not been validated, the findings can be of practical importance to public health. For example, in the event of an adulticiding campaign using malathion, the insights from this model can be used inform to target public health messages to maximize the decay rate by keeping children indoors for at least six hours after the fogging events and ensuring that their outdoor activity areas are as dry as possible. Behavioral parameters definitions presented in this model should be further explored to determine whether there are other specific sub-populations (e.g. gardeners) that may be at an increased risk of exposure. This model also provides a framework by which to assess a variety of circumstances and provide quantitative insights for informed decisions in pesticide control measures to limit vector-borne diseases.
Table 5.1. Overview of models examining human exposures to pesticides used in West Nile virus mosquito abatement programs

<table>
<thead>
<tr>
<th>Model parameters</th>
<th>Available Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticides considered</td>
<td>PAMSE</td>
</tr>
<tr>
<td>Malathion</td>
<td>Malathion</td>
</tr>
<tr>
<td>Malathion</td>
<td></td>
</tr>
<tr>
<td>Naled</td>
<td></td>
</tr>
<tr>
<td>Permethrin</td>
<td></td>
</tr>
<tr>
<td>Resmethrin</td>
<td></td>
</tr>
<tr>
<td>Phenothrin</td>
<td></td>
</tr>
<tr>
<td>Pyrethrins</td>
<td></td>
</tr>
<tr>
<td>Piperonyl butoxide*</td>
<td></td>
</tr>
<tr>
<td>Spray events</td>
<td>Up to 8</td>
</tr>
<tr>
<td>Half-life</td>
<td>Probabilistic</td>
</tr>
<tr>
<td>Environmental deposition</td>
<td>Probabilistic</td>
</tr>
<tr>
<td>Population characteristics</td>
<td>Probabilistic</td>
</tr>
<tr>
<td>Weather</td>
<td>-</td>
</tr>
</tbody>
</table>

*Piperonyl butoxide is a synergist which accompanies pesticides

Sources: (Peterson, Macedo et al. 2006; Gosselin, Valcke et al. 2008; Valcke, Gosselin et al. 2008)
A variable node in this model represents one or more related variables.
Table 5.2. Overview of population characteristic parameter descriptions in PAMSE and by Peterson and colleagues (2006)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Peterson et al</th>
<th>PAMSE MODEL</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age groups</td>
<td>0.5-1.5 years 2-3 years 5-6 years 10-12 years &gt;12 years</td>
<td>&lt; 2 years 2-6 years 7-14 years 15-65 years &gt;65 years</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Weight characteristics</td>
<td>Mean body weight from USEPA</td>
<td>Weight distributions for each age group from NHANES</td>
<td>(CDC 2004)</td>
</tr>
<tr>
<td>Height characteristics</td>
<td>-</td>
<td>Height distributions for each age group from NHANES</td>
<td></td>
</tr>
<tr>
<td>Surface area calculations</td>
<td>Sum of surface areas for face (head/2) + hand + arm + feet + leg. Assumed minimally clothed. Source unknown.</td>
<td>Distributions based on weight and height data from NHANES for each person represented in the probabilistic samples: &lt; 30 kg: (Weight + 4) / 30 ≥ 30 kg: (Height x Weight)/3600)1/2</td>
<td>(Mosteller 1987; Elert 2001)</td>
</tr>
<tr>
<td>Surface area</td>
<td>Sum of surface areas for face (head/2) + hand + arm + feet + leg. Assumed minimally clothed</td>
<td>By age based on fraction of skin exposed. Total available surface area = surface area by age * fraction skin exposed</td>
<td>Expert Judgment</td>
</tr>
</tbody>
</table>

lognormal= lognormal distribution with \( \mu = \text{median} \); sigma= geometric standard deviation

normal= normal distribution with \( \mu = \text{mean} \); SD=standard deviation
Table 5.3. Overview of general model parameters in PAMSE and by Peterson and colleagues (2006)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Peterson et al</th>
<th>PAMSE MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basics</strong></td>
<td></td>
<td>Parameter definition</td>
</tr>
<tr>
<td>Model type</td>
<td>Deterministic</td>
<td>Probabilistic</td>
</tr>
<tr>
<td>Pesticides considered</td>
<td>Malathion</td>
<td>Malathion</td>
</tr>
<tr>
<td></td>
<td>Naled</td>
<td>Malathion</td>
</tr>
<tr>
<td></td>
<td>Permethrin</td>
<td>Malathion</td>
</tr>
<tr>
<td></td>
<td>Resmethrin</td>
<td>Malathion</td>
</tr>
<tr>
<td></td>
<td>Phenothrin</td>
<td>Malathion</td>
</tr>
<tr>
<td></td>
<td>Pyrethrins</td>
<td>Malathion</td>
</tr>
<tr>
<td></td>
<td>Piperonyl butoxide*</td>
<td></td>
</tr>
<tr>
<td><strong>Malathion Acute Endpoints</strong></td>
<td></td>
<td>Adult NOAEL: 25 mg/kg/day</td>
</tr>
<tr>
<td>Dermal</td>
<td>NOAEL: 50 mg/kg/day</td>
<td>Adult NOAEL: 25 mg/kg/day</td>
</tr>
<tr>
<td>Ingestion</td>
<td>Adults: 300</td>
<td>Children NOAEL: 5 mg/kg/day</td>
</tr>
<tr>
<td>Inhalation</td>
<td>Children: 1000</td>
<td>Adult NOAEL: 25.8 mg/kg/day</td>
</tr>
<tr>
<td></td>
<td>Adults: 1000</td>
<td>Children NOAEL: 5 mg/kg/day</td>
</tr>
<tr>
<td></td>
<td>Children: 1000</td>
<td>Adult NOAEL: 25.8 mg/kg/day</td>
</tr>
<tr>
<td></td>
<td>Children: 1000</td>
<td>Children NOAEL: 5 mg/kg/day</td>
</tr>
<tr>
<td><strong>Malathion sub-chronic Endpoints</strong></td>
<td></td>
<td>Adult NOAEL: 25 mg/kg/day</td>
</tr>
<tr>
<td>Dermal</td>
<td>NOAEL: 2.4 mg/kg/day</td>
<td>Adult NOAEL: 25 mg/kg/day</td>
</tr>
<tr>
<td>Ingestion</td>
<td>Adults: 300</td>
<td>Children NOAEL: 5 mg/kg/day</td>
</tr>
<tr>
<td>Inhalation</td>
<td>Children: 1000</td>
<td>Adult NOAEL: 25.8 mg/kg/day</td>
</tr>
<tr>
<td></td>
<td>Adults: 1000</td>
<td>Children NOAEL: 5 mg/kg/day</td>
</tr>
<tr>
<td></td>
<td>Children: 1000</td>
<td>Adult NOAEL: 25.8 mg/kg/day</td>
</tr>
<tr>
<td></td>
<td>Children: 1000</td>
<td>Children NOAEL: 5 mg/kg/day</td>
</tr>
<tr>
<td><strong>Uncertainty Factor</strong></td>
<td></td>
<td>Adults: 300</td>
</tr>
<tr>
<td>Dermal</td>
<td>100</td>
<td>Children: 1000</td>
</tr>
<tr>
<td>Ingestion</td>
<td>Adults: 1000</td>
<td>Children: 1000</td>
</tr>
<tr>
<td>Inhalation</td>
<td>Adults: 1000</td>
<td>Children: 1000</td>
</tr>
<tr>
<td></td>
<td>Children: 1000</td>
<td>Adult NOAEL: 25.8 mg/kg/day</td>
</tr>
<tr>
<td></td>
<td>Children: 1000</td>
<td>Children NOAEL: 5 mg/kg/day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adults: 1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adults: 1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 1000</td>
</tr>
</tbody>
</table>

* Piperonyl butoxide is a synergist which accompanies pesticides

**Uncertainty factor incorporates factors of uncertainty for between species data extrapolation, population heterogeneity, and other unknown factors.

NOAEL: no observed adverse effect level
Figure 5.2. Cross-section of spray deposition and dispersion across one block in the PAMSE spatial grid at a given point in time assuming that the spray direction is perpendicular to picture, there is no wind, and that the fogging truck moving along 0 and 70m marks.
Table 5.4. Overview of temporal and spatial parameter descriptions in PAMSE and by Peterson and colleagues (2006)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Peterson et al</th>
<th>Parameter definition</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spray specifics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray method</td>
<td>Ground ULV</td>
<td>Ground or Aerial ULV</td>
<td>User defined</td>
</tr>
<tr>
<td>Application rate</td>
<td>Ground: 63.9 g a.i./ha</td>
<td>Ground: 26.0-60.8 g a.i./ha*</td>
<td>(Pest Management Regulatory Agency 2003)</td>
</tr>
<tr>
<td></td>
<td>Aerial: n/a</td>
<td>Aerial: 233 g a.i./ha**</td>
<td>User defined, discrete values ranging from: 0.5 - 19 days Lognormal distributions</td>
</tr>
<tr>
<td>Half-life</td>
<td>Surface: 6.5 days</td>
<td>User defined, discrete values ranging from: 0.5 - 19 days Lognormal distributions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil: 1 day</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>1 day</td>
<td>1 day</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Sub chronic</td>
<td>90 days</td>
<td>Up to 32 days</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Spray events</td>
<td>10 events</td>
<td>User defined up to 8 events</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Spray cycle</td>
<td>3 and 10 day cycle</td>
<td>4 day cycle</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Time of spray</td>
<td>2100hr</td>
<td>Dusk</td>
<td></td>
</tr>
<tr>
<td>Weather data</td>
<td>Albany, NY</td>
<td>N/A</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td></td>
<td>Salem, MA</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Spatial resolution</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spatial grid</td>
<td>Cartesian</td>
<td>Cartesian. Grid for structures and roads: Plot sizes of 20m x 30 m 1m x 5m for streets and alleys</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Ground: Release 1.5m with plume height in a triangular distribution with a minimum of 5m, peak of 7m and maximum of 15m</td>
<td>(Teske, Thistle et al. 2000)</td>
</tr>
<tr>
<td>Spray release point</td>
<td>Ground: 1.5m</td>
<td>Aerial: Height: 100m Swath: 150m</td>
<td>Expert Judgment; Global Leaf Area Index (LAI) survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Deposition</strong></td>
<td>ISCST3 model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receptors at 7.6m and 91.4m</td>
<td></td>
<td>Deposition surface characteristics</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Receptors at 1.5m height 1 hour average deposition measured at 7.6m and 91.4m of source</td>
<td>Probabilistic samples for each plot from a uniform distribution with bounds of: Building: 15-25% Foliage: 10-30% Pavement: 15-25% Turf: Remainder of plot</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dispersion</strong></td>
<td>AERMOD tier 1 air dispersion model, version 1. Concentrations measured at 7.6m and 91.4m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground</td>
<td>1-5% deposited up to 490m downwind</td>
<td>Ground: (Moore, Dukes et al. 1993; Tietze, Hester et al. 1994); Expert Judgment</td>
<td></td>
</tr>
<tr>
<td>Aerial</td>
<td>35% deposited up to 1200m downwind</td>
<td>Aerial: USEPA Standard Operating Procedures for Residential Exposure Assessments: (USEPA 2000b); Expert Judgment</td>
<td></td>
</tr>
</tbody>
</table>

* grams active ingredient per hectare
** maximum allowable application rate in the presence of vehicles
Figure 5.3. Percent malathion concentration in the environment for three possible malathion half-life scenarios over 4 spray events in the PAMSE model
Figure 5.4. Probability distribution function of deposited malathion at a given location
Figure 5.5. Two iterations of hours of outdoor activity by age group
Table 5.5. Overview of dermal exposure parameter descriptions in PAMSE and by Peterson and colleagues (2006)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Parameter definition</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dermal Exposure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure</td>
<td>Assumed exposure 10 times higher than flagger scenario from pesticide handler data</td>
<td>-</td>
</tr>
<tr>
<td>Fraction pesticide extractable</td>
<td>Turf: 0.013, Foliage: 0.05, 5%</td>
<td>(USEPA 2000b)</td>
</tr>
<tr>
<td>Absorption</td>
<td>Activities assumed: playing outdoors, in transit, gardening with and without gloves, and resting.</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Activity levels</td>
<td>Distributions for number of touches/hour for each activity by each age group to determine number of times per day that exposed skin is expected to come in contact with potentially contaminated surfaces</td>
<td></td>
</tr>
</tbody>
</table>
| Hours of activity                | > 2 years: lognormal ($\mu=0.4$, $\sigma=2$)  
2-6 years: lognormal ($\mu=1$, $\sigma=1.5$)  
7-14 years: lognormal ($\mu=1$, $\sigma=1.5$)  
15-65 years: lognormal ($\mu=0.4$, $\sigma=3$)  
>65 years: lognormal ($\mu=1$, $\sigma=2$)  | Expert Judgment |
| Activity locations               | 67% of time outdoors on turf, remainder of time spent near foliage                                                                                                                                                | Expert Judgment   |
| Contact rate (number of touches/hour) based on activity type | Playing/active outdoors: normal($\mu=100$, $SD=20$)  
In transit: normal($\mu=10$, $SD=2$)  
Gardening with gloves = 2  
Gardening without gloves: normal($\mu=100$, $SD=20$)  
Resting: normal($\mu=5$, $SD=1$)  | Expert Judgment |
| Contact multiplier               | = hours of activity x activity types x contact rate  
Number of times per day that exposed skin is expected to come in contact with surfaced potentially contaminated with pesticides.                                                                                   | -                 |

lognormal = lognormal distribution with $\mu$ = median; $\sigma$ = geometric standard deviation
normal = normal distribution with $\mu$ = mean; $SD$ = standard deviation
Table 5.6. Overview of ingestion exposure parameter descriptions in PAMSE model and by Peterson and colleagues (2006)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Peterson et al</th>
<th>PAMSE MODEL</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ingestion Exposure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand to mouth events</td>
<td>For infants and children</td>
<td>Distributions by age per hour:</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 2 years: normal (μ = 20, SD = 4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-6 years: normal (μ = 20, SD = 4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7-14 years: normal (μ = 5, SD = 1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥15 years: normal (μ = 0.3, SD = 0.005)</td>
<td></td>
</tr>
<tr>
<td>Surface area</td>
<td>Infants: 0.007m²</td>
<td>Based on normalized surface areas (m²) distributions by age</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td></td>
<td>2-3 years: 0.035m²</td>
<td>Distribution:</td>
<td></td>
</tr>
<tr>
<td>Absorption rate</td>
<td>50% available through saliva extraction on spray days</td>
<td>Normal(μ = 0.5, SD = 0.1)</td>
<td>USEPA 2000b</td>
</tr>
<tr>
<td>Garden ingestion</td>
<td>Acute: Assumed tomato eaten day after spray without washing. Subchronic: tomato and lettuce consumption. Used 3-day average food consumption.</td>
<td>User defined percent consumption of household from garden.</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Grass/turf</td>
<td>Assumed 20% dislodged and available</td>
<td>Distributions (cm²/day):</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td></td>
<td>20.5 events/hr for 4 hrs/day</td>
<td>&lt; 2 years: normal (μ = 14.9, SD = 14.6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-6 years: normal (μ = 20.6, SD = 13.3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7-14 years: normal (μ = 0.08, SD = 1.4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥15 years: normal (μ = 0, SD = 0)</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>Ingestion rates:</td>
<td>Incidental soil ingestion distributions (mg/day)</td>
<td>USEPA 2000b</td>
</tr>
<tr>
<td></td>
<td>Adults: 50 mg/day</td>
<td>Adults: lognormal (μ = 211, sigma = 3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children: 100 mg/day</td>
<td>Children: lognormal (μ = 81, sigma = 4.56)</td>
<td></td>
</tr>
</tbody>
</table>

lognormal = lognormal distribution with μ = median; sigma = geometric standard deviation
normal = normal distribution with μ = mean; SD = standard deviation
Table 5.7. Overview of inhalation exposure parameter descriptions in PAMSE model and by Peterson and colleagues (2006)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Peterson et al</th>
<th>PAMSE MODEL</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inhalation Exposure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airborne concentration</td>
<td>Concentration of active ingredient at height 1.5, 7.6 from source</td>
<td>Determined based on environmental concentrations and drift. Maximum plume height for ground spraying at 15m and at 35m for aerial spraying.</td>
<td>Expert Judgment</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>Adults: 1.5m$^3$/hr</td>
<td>Deterministic values used based on US Environmental Protection Agency values</td>
<td>(USEPA 2000b)</td>
</tr>
<tr>
<td></td>
<td>Children (including infants): 1.2m$^3$/hr</td>
<td>&lt; 2 years: 0.25 m$^3$/hr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Note: respiratory rates indicative of moderate physical activity</td>
<td>2-6 years: 0.36 m$^3$/hr</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7-14 years: 0.4 m$^3$/hr</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 15 years: 0.55 m$^3$/hr</td>
<td></td>
</tr>
<tr>
<td>Duration of exposure</td>
<td>6 hours</td>
<td>Between 30 minutes and 6 hours with following distribution: lognormal ($\mu=1$, $\sigma=1.5$)</td>
<td>(USEPA 2000b)</td>
</tr>
<tr>
<td>Exposure location</td>
<td>Outside, 7.6m from emission for 6 hour period</td>
<td>Dependent on activity</td>
<td>-</td>
</tr>
<tr>
<td>Indoor penetration</td>
<td>-</td>
<td>Triangular distribution with min = 0.1, max=1, mode =0.30</td>
<td>Expert Judgement</td>
</tr>
<tr>
<td>Absorption rate of chemical</td>
<td>-</td>
<td>Uniform distribution ranging from 14% to 95%</td>
<td>(Segawa, Sitts et al. 1991)</td>
</tr>
</tbody>
</table>

lognormal= lognormal distribution with $\mu$= median; sigma= geometric standard deviation
Figure 5.6. Mean dermal exposure to malathion by age group
Table 5.8. Uncertainty factors and percent maximum potential exceedance by exposure pathway

<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>NOAEL (mg/kg/day)</th>
<th>Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Uncertainty factors</td>
<td>% Exceedance</td>
</tr>
<tr>
<td><strong>Dermal</strong></td>
<td></td>
<td>Adults: 25</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 5</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Ingestion</strong></td>
<td></td>
<td>Adults: 25</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 5</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Inhalation</strong></td>
<td></td>
<td>Adults: 25.8</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 5</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Combined</strong></td>
<td></td>
<td>Adults: 25</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 5</td>
<td>1000</td>
</tr>
</tbody>
</table>
Figure 5.7. Mean ingestion exposure to malathion by age group
Figure 5.8. Mean inhalation exposure to malathion by age group
Figure 5.9. Distribution of potential inhalation exposures to malathion for children under 6
Figure 5.10. Potential exceedances (%) over Pest Management Regulatory Agencies target reference dose (RfD) by age group for the duration of a spray campaign.
5.6 References


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Chapter 6: General summary
6.1 Summary of thesis objectives

The objective of this thesis was to systematically examine risk perceptions, risk trade-offs and uncertainty as they related to behaviors and decisions for the prevention and control of West Nile virus (WNV). In Chapter 2, health beliefs and demographics related to adopting health behaviors were examined. Chapter 3 examined whether demographic and behavioral risk factors were associated with risk perceptions of WNV and those of WNV interventions. In Chapter 4, multi-criteria decision analyses were used to understand the risk trade-offs between stakeholders (laypeople and health experts) in WNV program planning. We explicitly examined scientific uncertainty and population variability in pesticide exposures using probabilistic modeling techniques in Chapter 5. Throughout all the chapters, the implications of the findings on risk communication and public health planning were also considered.

6.2 Summary of study findings

The major findings of Chapter 2, “Influences of demographics, exposure, and health beliefs on behaviors related to West Nile virus”, were that:

- Health beliefs and behavioral activities changed depending on both perceived risk and disease context.
- Misconceptions exist about WNV. Half the respondents were unable to identify the age group at risk of WNV infection and that there is no treatment for infection.
- Respondents were more likely to engage in recommended health behaviors if they received timely formal and informal information (cues to action), understood the benefits of a particular health behavior (benefits of action), and lived in areas that had been exposed to WNV.
- The health belief model was extended to examine the role of specific information in cues to action. Results showed that specific information sources have a potential role in promoting behavior change.
- Respondents were also willing to use insect repellents with DEET despite perceived barriers and concerns. This warrants further research.

The major findings of Chapter 3, “Exploring public risk perceptions of West Nile virus and West Nile virus interventions: Demographic and behavioral risk factors”, were that:
• There are unique associations between demographic and behavioral risk factors and risk perceptions of WNV infection and risks posed by WNV intervention strategies. Women were more likely to be independently concerned about all risk trade-offs. Those with WNV experience were less concerned about exposure to pesticides, and more concerned about getting sick from insect bites and WNV infection. Surprisingly, respondents living in urban areas were less likely to be concerned about exposures to and sick from exposures to pesticides and insect repellents with DEET. Both groups were expected to perceive greater risks from WNV.

• A small portion of respondents were concerned about exposure to insect repellents with DEET (individual response) but not to pesticide exposure (societal response). Though not statistically significant, this observation should be further examined using quantitative and qualitative studies to understand whether individuals who rely on societal responses are more (or less) at risk of WNV infection.

• Further research using mental models should be carried out to explore the differences observed in risk perceptions as they relate to emerging and re-emerging infectious diseases, and the adoption of recommended health behaviors.

In Chapter 4, “Multi-criteria decision analyses and re-emerging infectious disease: A case study of West Nile virus”, we found that:

• Laypeople perceived some interventions, e.g. adulticiding, to be more effective than health experts reported them to be. Thus, there could be an expectation on their part for such interventions while health authorities can be reluctant to act.

• This shows that laypeople were more sensitive to risk trade-offs, while health experts were most concerned about the effectiveness of interventions.

• Knowledge gaps were identified between laypeople and health experts. Interestingly, those with the lowest educational attainment had a higher faith in the effectiveness of education campaigns than those with higher education and health professionals. Furthermore, we found that laypeople lacked information on the efficacy of interventions while health experts were particularly aware of the limited effectiveness of adulticiding in mitigating human outbreaks.

• Actual risk is a better predictor of risk perceptions and decision trade-offs than hypothetical risk scenarios.
Chapter 5, “A model for Probabilistic Assessment of Malathion Spray Exposures (PAMSE) in British Columbia”, showed us that:

- By using probabilistic modeling techniques, we were able to explicitly characterize variability and uncertainty in: the half-life of pesticides, their dispersion and deposition in the environment, uptake through inhalation, contact and ingestion and the ultimate dose received by age, body mass and size. By modeling a realistic mosquito abatement campaign (spatially and temporally) we found that children under 6 are at risk of exposure to malathion at levels that exceed the guidelines specified by the Canadian Pest Management Regulatory Agency and the US Environmental Protection Agency.
- This chapter highlighted the asymmetric distribution of risks and the importance of characterizing variability and uncertainty in risk assessments especially pertaining to heterogeneity in population physiology, behavior and the environment.

6.3 Policy implications of research

An important factor in conducting this research was the implication of findings on risk communication and public health programming. Though the findings are specific to WNV program planning, the implications are far reaching and can be useful in preparing for other emerging and re-emerging infectious diseases. Throughout all the chapters, a common implication was the importance of tailoring risk communication and educational campaigns in ways that are innovative and heterogeneous. They need to address the diversity of risk perceptions and regional variations of exposure to a particular disease. Further research should be carried out to determine what messages are most acceptable and effective. This will enable community and sub-population specific messages thereby promoting and encouraging healthy behavioral actions.

Chapter 4 was the first use of multi-criteria decision analyses in emerging and re-emerging infectious disease research and highlights the possible role of this technique in environmental health issues. We found that laypeople and health experts were willing to make different risk trade-offs. This gap in knowledge of risks between laypeople and health experts highlights the need to address risk trade-offs and room for improvement in risk communication. Again, risk messages should be tailor-made and targeted towards specific sub-populations. This would provide necessary information on the relative efficacy of various interventions while avoiding information fatigue. Differences in trade-
offs also identified the need to disseminate information on the limited effectiveness of adulticiding programs, once human cases of WNV have been detected. Bringing health professionals and the public in accord over acceptable interventions is critical in the timely and effective management of WNV and acceptable-risk decisions.

The concept of tailoring messages and reducing bias in risk perceptions can also be applied to other emerging and re-emerging infectious diseases to help with knowledge translation. Systematically examining the specific dynamics and temporality of such diseases in relation to risk perceptions using mental models will facilitate the identification of appropriate messages and program interventions and how they may change over time as new information becomes available. This in turn will help create more acceptable and effective messages for at risk sub-populations prior to an outbreak or epidemic.

The explicit characterization of intra-population and behavioral variability and spatial-temporal uncertainty showed us that adulticiding programs using malathion could potentially be exposing up to 7.5% of children under 6 at risk of exposure levels beyond recommended guidelines. This translates into potential adverse health effects for children due to their lower body weight and developmental stage (Fitz 2003). This also puts in question the applicability of deterministic risk assessment models (which use single point estimates) for uses beyond those intended – i.e., such models were not designed for examining population exposures to repeated adulticiding programs. It also highlights the need for behaviorally realistic models for decision-making. This is of particular importance to public health, where such models can allow us to increase our understanding of the problem and emphasize areas where more effective programs can be designed and implemented (Dowdle and Hopkins 1998).

6.4 Limitations and future research

There are several shortcomings in this dissertation that are worthy of mention here. They are aspects that I would change if I could start again, and can highlight as potentially rewarding avenues for future research.
A major objective in the design and administration of the survey was to maintain continuity with a 2003 BC Centre for Disease Control survey examining risk perceptions using the health belief model (Aquino, Fyfe et al. 2004). There are both advantages and disadvantages to this approach.

- This continuity will allow for comparative analyses. Though the comparative analysis in British Columbia is outside of the scope of this thesis, it will provide an interesting comparison of how risk perceptions of residents in British Columbia have changed – if at all. By maintaining continuity, we have enabled future pre and post WNV infection analyses if and when WNV does become endemic to British Columbia. We can also examine risk perceptions over time in the study provinces to determine the extent of social amplification of risk and/or information fatigue.

- Unfortunately, due to the need to maintain continuity we were unable to further explore many concepts. The influence of risk factors on risk perceptions and trade-offs had to be examined using a minimal number of questions due to length of the survey. We could ask very few new questions and were, therefore, unable to completely explore various question types and metrics. However, despite this limitation we found interesting correlations between risk factors and risk perceptions. We examined individual versus societal measures towards preventing and controlling WNV (Chapter 3), unfortunately due to the survey design there was not adequate power to further investigate initial findings. The concept of “worriers” to all types of risk was also explored in chapter 3, but did not find significant associations. Though exploratory, chapter 3 provides a foundation for future work and highlights variations in risk perceptions. Mental models should be used to help understand why there are differences in risk perceptions, what messages would be most effective, and how they should be delivered. The findings of such mental models would help with designing and targeting effective public health and risk communications. Future work should also be expanded beyond WNV to examining risk characteristics and risk perceptions specific to an array of emerging and re-emerging infectious diseases. The findings would be invaluable to public health planning of such diseases, especially given the uncertainty surrounding them.

The health belief model is useful in identifying health beliefs that promote or deter individuals from engaging in recommended health behaviors. Through the application of the health belief model (Chapter 2) we discovered disease misconceptions and found that those without disease specific experience and exposure to the disease were less likely to engage in actions and less likely to understand the benefits of the health behaviors. Though the health belief model allowed us to
identify such perceptions and misconceptions, it does not provide direction for effective communication strategies to address such beliefs. This warrants further research using alternative health communication strategies such as the theory of planned behavior, the trans-theoretical model, and stages of change model to determine at what stage of health behavior adoption those without disease experience are (Glanz, Rimer et al. 2002). This would assist in the development of risk communication messages and public health programs to address misconceptions and for promoting behavior change in areas naive to emerging and re-emerging infectious diseases.

Through the PAMSE model (Chapter 5) we discovered the importance of parameter definitions. We found that variations in the definitions of behaviorally and scientifically realistic parameters could alter the model and lead to substantial estimates of exposures. This is of particular concern for sub-populations who may already be susceptible or for those who engage in unperceiving risky behaviors (e.g. gardening without gloves). The framework developed in PAMSE can be expanded to establish various scenarios of behavioral complexity that would allow the user to choose what is realistic for their target population. The collection of primary data on behavioral activities related to pesticide exposures could then validate such scenarios. The current model can also be validated in the event of adulticiding in British Columbia with malathion. PAMSE can also be expanded to incorporate additional pesticides used in the United States as well as the risks of WNV infection. This would provide a probabilistic risk-risk comparison similar to deterministic models presented by Peterson and colleagues (Peterson, Macedo et al. 2006).

6.5 Thesis contribution

The collection of chapters presented in this thesis contribute to literature in the field of West Nile virus, risk perception, risk trade-offs, planning public health programs under uncertainty, risk communication, and risk assessments. Collaboration with BC Centre for Disease Control and their associations with the Public Health Agency of Canada will ensure in the rapid use and dissemination of the findings.

The study website (www.cher.ubc.ca/westnile) will also facilitate information sharing and help disseminate the results and outcomes to survey respondents and other interest groups.
6.6 References


Appendices
Appendix A: Ethics certificate

CERTIFICATE OF APPROVAL - AMENDMENT & RENEWAL

INSTITUTION/ WHERE RESEARCH WILL BE CARRIED OUT:

IC: UBC
4108 East Mall
Vancouver, BC
Canada

PROJECT TITLE:
Risk Perceptions towards Host-Nile Virus

FINAL DATE:
July 31, 2008

CERTIFICATE EXPIRY DATE:
July 31, 2008

AMENDMENT(S)  | APPROVAL AND AMENDMENT APPROVAL DATE:
--- | ---
1 | June 14, 2007
2 | June 14, 2007
3 | June 14, 2007
4 | June 14, 2007
5 | June 14, 2007
6 | June 14, 2007
7 | June 14, 2007
8 | June 14, 2007
9 | June 14, 2007
10 | June 14, 2007

The application for continuing ethical review and the amendment(s) for the above-named project have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

[Approval signed by the Behavioral Research Ethics Board]

The following are the members of the Behavioral Research Ethics Board:

- Dr. Peter Donders, Chair
- Dr. John MacFarlane, Associate Chair
- Dr. Karen Neugarten, Associate Chair
- Dr. Linda Fisk, Associate Chair
Appendix B: Health behavior survey
Hello, my name is _________________________ and I am calling on behalf of the University of British Columbia.

I am following up on the letter that was sent to your home last week. We are conducting a survey on issues related to West Nile virus. I would now like to randomly select an adult from your home to interview.

S1. Can I please speak to an adult (> 19 years old) in your home, this can include yourself?

□ Yes  □ No

When would be a good time to call back so that I may speak with

Date/time

S1A. Did you receive the letter of introduction that was sent a week ago?

□ Yes  □ No  □ Don’t know

If YES proceed with below
If NO or DON’T KNOW please review consent letter

You have just been randomly selected to participate in a short survey on issues related to West Nile virus. The purpose of our study is to find out what things people are doing to protect themselves from infection with West Nile virus and why they do these things.

There are two parts to this research. First, I would like to learn what you think about mosquitoes, West Nile virus, and the things that you do to prevent getting bitten by mosquitoes. This part of the survey will take about 15 minutes to complete by phone.

Then, we would like to ask you to complete a few additional questions on where you spend your time outdoors during the summer months and how you would make decisions around preventing and controlling West Nile virus infection. This part of the survey will take between 5-10 minutes to complete. You have the option of completing the second part either by computer or by mail. Your complete set of answers will help us make sure that people engaged in different activities are aware of the most effective ways of reducing their risk of being infected by West Nile virus.

To compensate you for your time, your name will be entered into a random draw to win one of 2 iPods. By participating you are also making an important contribution to West Nile virus control and prevention programs. We will be happy to share the results of the survey with you, should you be interested.
Please remember, all of the information you provide will be strictly confidential, neither you nor your answers will be identifiable in any reports as a result of this study. You are welcome to refuse to answer any of the questions.

S2. Would you be willing to participate in both parts of this study?
   □ Yes Proceed to S3
   □ No Skip to Demographics and thank them for their time (END CALL)

S3. Do you have access to the internet?
   □ Yes Proceed to S4
   □ No Skip to S6

S4. Would you be willing to respond to the second part of the survey through a secure on-line survey? To do so, we will require your e-mail address so that we can e-mail you a link to our on-line survey. Your e-mail will not be used for any other purposes.
   □ Yes Proceed to S5
   □ No Skip to S6
   □ Refused Skip to S6

S5. Can I please have your name and e-mail address so that we can send you the web link for the survey?
   First Name:
   Last Name:
   Email address:
   Email address:
   Repeat aloud and re-enter e-mail address
   Ask if participant has any questions.
   START SURVEY

S6. Would you rather complete the second part of the survey by regular mail? [We can send the second part of the questionnaire via Canada Post, along with a pre-paid return envelope]
   □ Yes Proceed to S7
   □ No Skip to Demographics and thank them for their time (END CALL)
   □ Refused Skip to Demographics and thank them for their time (END CALL)

S7. Can I please have your name and mailing address so that we can mail you a copy of the second part of the survey?
   First Name:
   Last Name:
   Street Address:
   City:
   Province [enter province]:
   Postal Code:
   Ask if participant has any questions.
   START SURVEY
SECTION 1: HEALTH BEHAVIOR MODEL

SECTION 1A: MOSQUITO RELATED BEHAVIOUR

Please be aware that some of the questions will sound the same. It is important that we complete each question. Thank you for your patience and agreement to participate.

I am going to begin by asking you a few questions about mosquitoes.

1. A high mosquito area has many mosquitoes around almost every day or evening and people get bitten if outdoors for 30 minutes or less.

A medium mosquito area has some mosquitoes around some days or evenings and people who spend time outdoors get bitten at least once per week.

A low mosquito area has almost no mosquitoes and people who spend time outdoors rarely get bitten.

1a. In general, do you live in a high, medium or low mosquito area?

<table>
<thead>
<tr>
<th>High mosquito area</th>
<th>Medium mosquito area</th>
<th>Low mosquito area</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

1b. In general, do you work in a high, medium or low mosquito area?

<table>
<thead>
<tr>
<th>High mosquito area</th>
<th>Medium mosquito area</th>
<th>Low mosquito area</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

1c. In general, do you participate in recreational activities in a high, medium or low mosquito area?

<table>
<thead>
<tr>
<th>High mosquito area</th>
<th>Medium mosquito area</th>
<th>Low mosquito area</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

2. Please tell me if you strongly agree, agree, are neutral, disagree, strongly disagree with the following statement. If you don’t know, that is also an option.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

2. Mosquitoes and mosquito bites bother me enough that I take actions to stop getting bitten

3. Have you ever used a mosquito repellent? (a mosquito repellent is a product that you spray or rub on your skin and clothes to keep mosquitoes away)

严格执行 Q3a

□ Yes Proceed to Q3a

□ No skip to Q4
3a. I’m going to read a list of mosquito repellents. Please tell me if you have been applying any of the following mosquito repellents always, often, half the time, occasionally, or never this summer to avoid getting mosquito bites.

<table>
<thead>
<tr>
<th>repellent</th>
<th>Always</th>
<th>Often</th>
<th>Half the time</th>
<th>Occasionally</th>
<th>Never</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a-1. A product with DEET (for example: Off!, Muskol)</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3a-2. Lemon eucalyptus products (for example: Repel Lemon Eucalyptus, Off! Botanicals)</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3a-3. Soybean oil</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3a-4. Citronella (for example: Buzz away, Green Ban)</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3a-5. Lavender oil</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3a-6. Other (please specify):</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

3b. I’m going to read a list of statements about mosquito repellents with DEET that people put on their bodies. Please tell me whether you strongly agree, agree, are neutral, disagree or strongly disagree with the following statements. If you don’t know, that is also an option.

Mosquito repellents with DEET are:

<table>
<thead>
<tr>
<th>statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>3b-1. Safe for your health</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3b-2. Bad for the environment</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3b-3. Expensive</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3b-4. Convenient to use</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>3b-5. Unpleasant when applied (greasy, sticky, bad smell, etc.)</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

4. What are the reasons you do not use mosquito repellent(s)?
Please read all possible responses

<table>
<thead>
<tr>
<th>reason</th>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>4a. I don’t think they work</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4b. I don’t need them</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4c. I am allergic to them</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4d. I am worried about the effects they may have on my health</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4e. I worry about the effect they might have on the environment</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4f. I don’t like the feel or smell of mosquito repellents</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4g. I don’t have the time to apply mosquito repellent</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4h. They are too expensive</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4i. I forget to put them on</td>
<td>1</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>4j. Other (please describe)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Apart from mosquito repellents, how often do you do other things to reduce the risk of being bitten by mosquitoes? Please tell me if you do the following actions always, often, half the time, occasionally or never.

<table>
<thead>
<tr>
<th>Action</th>
<th>Always</th>
<th>Often</th>
<th>Half the time</th>
<th>Occasionally</th>
<th>Never</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>5a. Avoid doing things outdoors where mosquitoes are a nuisance</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>5b. Avoid going outside during the peak mosquito hours of dusk to dawn when possible</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>5c. Wear long sleeved clothing and pants</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>5d. Use bug lights/candles</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>5e. Use pesticides on home/lawn</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>5f. Put screens on the windows/doors in my house</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>5g. Remove standing water from places where water collects</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

6. Mosquitoes are most active from dusk (evening) to dawn (early morning). In the summer, how often would you spend time outdoors during this active period?

- □ 6-7 days/week
- □ 4-6 days/week
- □ 2-4 days/week
- □ Less than 2 days a week
- □ Never

For the next 4 questions please tell me if you strongly agree, agree, are neutral, disagree or strongly disagree with the statements that I’m going to read. If you don’t know, that is also an option.

7. Please tell me if you strongly agree, agree, are neutral, disagree, or strongly disagree with the following statement. If you don’t know, that is also an option.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>I go outdoors during peak mosquito hours of dusk because of the activities in which I am involved (social gatherings, organized sports, physical activities, leisure activity, walking the dog, my occupation, etc…)</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

8. Now I’m going to read a list of statements about controlling mosquito populations. Please tell me whether you strongly agree, agree, are neutral, disagree or strongly disagree with the following statements. If you don’t know, that is also an option.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removing standing water from places where water collects is:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8a. Time consuming</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>8b. Too physically demanding</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>8c. Not important if my municipal government has a mosquito control program</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>8d. I do not know how to remove standing water from places where water collects</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>8e. I do not have any items that collect standing water</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>
Now I’m going to read a list of statements about wearing long sleeved clothing and pants to avoid mosquito bites.

Please tell me whether you strongly agree, agree, are neutral, disagree or strongly disagree with the following statements. If you don’t know, that is also an option.

<table>
<thead>
<tr>
<th>Wearing long sleeved clothing and pants is:</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>9a. Too uncomfortable/hot in the summer time</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>9b. Not effective against avoiding mosquito bites</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>9c. Not fashionable</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

And finally, I’m going to read a list of statements about putting screens on the windows and doors of your homes to avoid mosquito bites.

Please tell me whether you strongly agree, agree, are neutral, disagree or strongly disagree with the following statements. If you don’t know, that is also an option.

<table>
<thead>
<tr>
<th>Putting screens on the windows/doors of my house is:</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>10a. Time consuming</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>10b. Too physically demanding</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>10c. Too expensive</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>10d. I do not have control over this (e.g. I’m a tenant, building design and/or regulations, etc…)</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>10e. Tedious to keep intact</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>10f. Too difficult</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>10g. Not needed</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

The next five statements try to capture your concerns about different approaches towards reducing the risk being bitten by mosquitoes and West Nile virus. Please tell me whether you are very concerned, concerned, not concerned or whether you have no opinion for each of the following statements.

<table>
<thead>
<tr>
<th>The next five statements try to capture your concerns about different approaches towards reducing the risk being bitten by mosquitoes and West Nile virus. Please tell me whether you are very concerned, concerned, not concerned or whether you have no opinion for each of the following statements.</th>
<th>Very concerned</th>
<th>Somewhat concerned</th>
<th>Not at all concerned</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>11a. Being exposed to an approved pesticide for controlling mosquitoes</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>11b. Being exposed to an insect repellent with DEET</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>11c. Getting sick from an insect bite</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>11d. Getting sick from exposure to pesticides</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>11e. Getting sick from using an insect repellent with DEET</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
12. Has the neighbourhood you currently live in ever been sprayed, while you’ve lived there, with a pesticide to kill insects?

- □ Yes  Proceed to Q12a
- □ No  Skip to SECTION 1B (Q13)
- □ Not Sure  Skip to SECTION 1B (Q13)

12a. Did you take any of the following actions to avoid exposure to the pesticides sprayed in your neighborhood?

*Please read all possible responses, if answer is yes, then circle answer(s) below.*

- 12a-1. Remain indoors for 1-2 hours after spray has occurred
- 12a-2. Remain indoors for the entire night after spray has occurred
- 12a-3. Keep children inside the day following the spraying
- 12a-4. Close windows while spraying is occurring
- 12a-5. Bring children’s toys into the house prior to spraying
- 12a-6. Wash children’s toys after spray has occurred
- 12a-7. Wash garden fruits/vegetables prior to consumption (including wild berries) after spraying has occurred
- 12a-8. Participate in a campaign against spraying
- 12a-9. Petition to have property removed from spraying
- 12a-10. Stayed with friends/family or at a hotel outside of the spray zone
- 12a-11. Other (please describe):

SECTION 1B: Knowledge and beliefs (around WNV)

This next section is going to be asking you questions about West Nile virus infection.

13. Before getting the letter in the mail about this study, had you heard about West Nile virus?

- □ Yes  Proceed to Q14
- □ No  Skip to Q23
- □ Not Sure

14. Where do you receive information on West Nile virus?

*Please read all possible responses.*

If answer is YES please ask participant “What was the key message that you received from the <information source> (i.e. Pamphlet/brochure)” and fill in column accordingly.

<table>
<thead>
<tr>
<th>Information provided</th>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>14a. Pamphlets/brochure</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14b. TV</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14c. Newspaper</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14d. Radio</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14e. Internet</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14f. From my doctors office</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14g. Public health</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14h. Friends</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14i. Family</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>14j. Other (please describe):</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

14k. Haven’t received any information on West Nile virus  1
For the next 5 questions please tell me if you strongly agree, agree, are neutral, disagree or strongly disagree with the statements that I’m going to read. If you don’t know, that is also an option.

## 15.

**Please tell me if you strongly agree, agree, are neutral, disagree, or strongly disagree with the following statements. If you don’t know, that is also an option.**

Information I got about West Nile virus has influenced me to:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>15a. Use mosquito repellant</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>15b. Remove standing water from places where water collects</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>15c. Avoid going outdoors during the peak mosquito hours of dusk to dawn</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>15d. Wear long sleeved clothing and pants</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>15e. Put screens on the windows and doors of my home</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

## 16.

**Please tell me whether you strongly agree, agree, are neutral, disagree, or strongly disagree with the following statements. If you don’t know, that is also an option.**

The following action will help reduce the risk of being infected with West Nile virus infection:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>16a. Wearing long sleeved shirts or other protective clothing outdoors</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>16b. Avoiding going outside during the peak mosquito hours of dusk to dawn</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>16c. Washing hands regularly</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>16d. Applying a mosquito repellant containing DEET</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>16e. Applying another mosquito repellant</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>16f. Wearing a mask</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>16g. Removing standing water from places where water collects</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>16h. Using a bug zapper</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>16i. Putting screens on windowsdoors of your home</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

## 17.

**Please tell me whether you strongly agree, agree, are neutral, disagree, or strongly disagree with the following statements. If you don’t know, that is also an option.**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>17a. I have enough information to engage in all desired West Nile virus risk reduction activities</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>17b. I talk to my neighbours/friends/family about West Nile virus</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>17c. Most of my neighbours/friends/family are engaged in activities which may reduce the risk of West Nile virus</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

I know of neighbors/friends/family who engage in the following activities to specifically avoid mosquito bites:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>17d. Put on mosquito repellent when they go out</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>17e. Remove standing water from places where water collects</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>17f. Wear long sleeved clothing and pants when outdoors</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>17g. Have screens on windows and doors of their home</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>17h. Avoid going outdoors between the hours of dusk and dawn to avoid mosquito bites</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>
18. Please tell me if you strongly agree, agree, are neutral, disagree, or strongly disagree with the following statements. If you don’t know, that is also an option.

I’m going to read a list of ways people can get a disease, please tell me if you think you can get West Nile virus this way.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>18a. Mosquito bites</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>18b. Blood transfusions</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>18c. Sexual contact with someone who has an active case of West Nile virus</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>18d. Organ transplants</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>18e. Being in the same room with someone who has an active case of West Nile virus</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>18f. Drinking water infected with West Nile virus</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>18g. Contact with dead birds</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>18h. Shaking hands with someone who has an active case of West Nile virus</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

19. Please tell me whether you strongly agree, agree, are neutral, disagree, or strongly disagree with the following statement. If you don’t know, that is also an option.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is an effective treatment for people who have contracted West Nile virus?</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

20. What age category do you consider to be at the greatest risk of becoming seriously ill or dying when infected with West Nile virus?

*Only one response, please circle participants response below*

<table>
<thead>
<tr>
<th>Age Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children (0-12 years)</td>
<td>1</td>
</tr>
<tr>
<td>Teenagers (13-19 years)</td>
<td>2</td>
</tr>
<tr>
<td>Adults (20-49 years)</td>
<td>3</td>
</tr>
<tr>
<td>Adults (&gt; 50 years)</td>
<td>4</td>
</tr>
<tr>
<td>Don’t know</td>
<td>5</td>
</tr>
</tbody>
</table>

21. Please tell me if you think the following statements are very likely, likely, neutral, unlikely, very unlikely, or whether you don’t know.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Very likely</th>
<th>Likely</th>
<th>Neutral</th>
<th>Unlikely</th>
<th>Very unlikely</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>21a. How likely do you think it is to be bitten by a mosquito that has West Nile virus</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>21b. How likely do you think it is that you or someone in your immediate family will get sick from West Nile virus during the next 12 months</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>21c. For a person who has contracted West Nile virus, how likely do you think it is that they will become seriously ill or die?</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>
22. **PLEASE NOTE this question will change depending on the province**

**AB and MB:** Did the presence of West Nile virus in your area influence your behavior to take additional measures to decrease the risk of West Nile virus?
- [ ] Yes
- [ ] No
- [ ] Don’t know

**BC:** Would the presence of West Nile virus in your area influence your behavior to take additional measures to decrease the risk of West Nile virus?
- [ ] Yes
- [ ] No
- [ ] Don’t know

23. Have you lived or traveled to areas where mosquito borne diseases were a concern in the PAST 3 YEARS? *(This can include Malaria, Dengue, St.Louis encephalitis, West Nile virus, etc…)*
- [ ] Yes
- [ ] No
- [ ] Not sure

### SECTION 2: DEMOGRAPHICS

I’m almost at the end of the interview. I just have a few more questions to ask about you and your family’s background. These are standard questions used only for statistical purposes. Please remember that all the information collected in this survey is strictly confidential and will only be used for statistical purposes. Neither you nor answers will be identifiable.

24. Please record participants sex based on voice
- [ ] Male
- [ ] Female

25. What age category do you fall into?
*Please read age ranges and circle participants answer.*

<table>
<thead>
<tr>
<th>Age Category</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>19-24 years</td>
<td></td>
</tr>
<tr>
<td>25-34 years</td>
<td></td>
</tr>
<tr>
<td>35-44 years</td>
<td></td>
</tr>
<tr>
<td>45-54 years</td>
<td></td>
</tr>
<tr>
<td>55-64 years</td>
<td></td>
</tr>
<tr>
<td>65 -74 years</td>
<td></td>
</tr>
<tr>
<td>&gt;75 years</td>
<td></td>
</tr>
<tr>
<td>No answer</td>
<td>9</td>
</tr>
</tbody>
</table>

26. What is the highest level of formal education that you have completed?
*Please circle participants answer.*

<table>
<thead>
<tr>
<th>Education Level</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary school</td>
<td>1</td>
</tr>
<tr>
<td>Secondary school</td>
<td>2</td>
</tr>
<tr>
<td>Technical or vocational</td>
<td>3</td>
</tr>
<tr>
<td>University/college</td>
<td>4</td>
</tr>
<tr>
<td>Post-graduate degree</td>
<td>5</td>
</tr>
<tr>
<td>No answer degree</td>
<td>9</td>
</tr>
</tbody>
</table>

27. What city do you live in?___________
28. What type of residence do you live in?

*Please circle participants answer.*

<table>
<thead>
<tr>
<th>Type of Residence</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single family dwelling</td>
<td>1</td>
</tr>
<tr>
<td>Multiple family dwelling</td>
<td>2</td>
</tr>
<tr>
<td>Apartment building</td>
<td>3</td>
</tr>
<tr>
<td>Other (please describe)</td>
<td>4</td>
</tr>
<tr>
<td>No answer</td>
<td>9</td>
</tr>
</tbody>
</table>

29. How many people (other than yourself) live in your household?

____________ number individuals

☐ Refuse to answer

What are the age categories of the individuals in your household??

*Please write down number of individuals for each age category*

<table>
<thead>
<tr>
<th>Age Category</th>
<th># Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2 years</td>
<td></td>
</tr>
<tr>
<td>2-6 years</td>
<td></td>
</tr>
<tr>
<td>7-14 years</td>
<td></td>
</tr>
<tr>
<td>15-18 years</td>
<td></td>
</tr>
<tr>
<td>19-24 years</td>
<td></td>
</tr>
<tr>
<td>25-34 years</td>
<td></td>
</tr>
<tr>
<td>35-44 years</td>
<td></td>
</tr>
<tr>
<td>45-54 years</td>
<td></td>
</tr>
<tr>
<td>55-64 years</td>
<td></td>
</tr>
<tr>
<td>65-74 years</td>
<td></td>
</tr>
<tr>
<td>&gt; 75 years</td>
<td></td>
</tr>
<tr>
<td>Refuse to answer</td>
<td></td>
</tr>
</tbody>
</table>

30. Are you active in the community through an advocacy group or other community action group (examples of such groups can include environmental groups, non-governmental organizations, political groups, or local community groups)?

☐ Yes  Proceed to Q30a

☐ No

☐ Don’t know  Skip to Q31

☐ Refuse to answer

30a. Please indicate your level of involvement with each group: *Only one response, please circle participant’s response below*

<table>
<thead>
<tr>
<th>Level of Involvement</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donate money</td>
<td>1</td>
</tr>
<tr>
<td>Active member</td>
<td>2</td>
</tr>
<tr>
<td>Group leader</td>
<td>3</td>
</tr>
<tr>
<td>Other (please describe)</td>
<td>4</td>
</tr>
</tbody>
</table>
31. This is the end of the survey. Thank you for taking the time to complete this survey. Your answers are greatly appreciated. Would you like a copy of the report summarizing the results of this survey?

☐ Yes
☐ No

32. Would you like this document sent to the same mailing address or e-mail address as provided at the start of the survey?

☐ Yes
☐ No  Please provide address below

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Before I hang up, do you have any questions?

THANK PARTICIPANT AGAIN
Appendix C: Multi-criteria decision analysis survey
West Nile Virus Survey Part 2

Thank you for agreeing to fill out the second part of the West Nile virus survey.

As you know, this survey is a follow-up to a survey you completed by phone (carried out by the University of British Columbia). This part of the survey is looking at where people spend their time outdoors during the summer months and how people make decisions around West Nile virus control and prevention measures.

Your answers will help us make better decisions around West Nile virus control and prevention. This survey should take between 5-10 minutes to complete. Please note there are questions on both sides of the page.

All of your answers will be kept strictly confidential. There are no right or wrong answers. By completing questions in the survey, we will assume that you have given your consent for us to use your responses in preparation of reports in which neither you nor your answers will be identifiable. If you have any questions, please contact us at 604-822-0945 or by e-mail wnvstudy@ires.ubc.ca

Please do not leave any questions blank. If you decide you don't want to answer a question please choose "prefer not to answer."

Once you are done, please pop the survey in the enclosed stamped addressed reply envelope and drop it off in the mail.

Thanks you for your interest!

Sincerely,

Negar Elmieh, MS, MPH
SECTION 1: Activity Log
This section is going to ask you about the number of hours you spend outdoors within an **urban setting (city, town)** and the number of hours you spend outdoors in **rural or natural environments**.

1. Let’s start with an **urban setting (city, town)**. How many hours, on average, do you spend outdoors within an urban setting (city, town) during a typical weekday and weekend day in the summer?

Activities in an urban setting can include: your occupation, regular activities such as scheduled physical activity and irregular activities such as gardening, playing outside, walking, eating dinner on the porch etc.

*Please assume a typical summer day. Please select appropriate number of hours for both Weekday and Weekend days:*

<table>
<thead>
<tr>
<th></th>
<th>Less than 1 hour</th>
<th>1-2 hours</th>
<th>2-4 hours</th>
<th>4-6 hours</th>
<th>More than 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Weekend day</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

2. Let's move onto **rural or natural environments**. How many hours, on average, do you spend outdoors in rural or natural environments during a typical weekday and weekend day in the summer?

Activities in rural or natural environments can include: your occupation, hiking, camping, and picnics away from your neighborhood/community.

*Please assume a typical summer day. Please select appropriate number of hours for both Weekday and Weekend days:*

<table>
<thead>
<tr>
<th></th>
<th>Less than 1 hour</th>
<th>1-2 hours</th>
<th>2-4 hours</th>
<th>4-6 hours</th>
<th>More than 6 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Weekend day</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

3. Do you consider where you live to be an urban setting or a rural setting?
   - □ Urban (town, city)
   - □ Rural
   - □ Other (please specify): ______________________________________________________
SECTION 2: Activity log for children

IF YOU DO NOT HAVE CHILDREN UNDER THE AGE OF 14 PLEASE SKIP TO SECTION 3 (page 5)

This section is going to estimate the levels of outdoor activity for children under the age of 14 within an **urban setting (city, town)** and in **rural or natural environments** during a typical weekday and weekend day in the summer.

Please recall that:

Activities within an **urban setting (city, town)** can include: regular activities such as scheduled physical activity and irregular activities such as gardening, playing outside, walking, eating dinner on the porch etc.

Activities in **rural or natural environments** can include activities such as hiking, camping, and picnics away from your neighborhood/city. If you live in a rural area it is possible that your children may spend no time within an urban setting.

4. Do you have children under the age of 2?
   □ Yes  (Please proceed to question 4a)
   □ No    (Please skip to question 5)
   □ Prefer not to answer (Please skip to question 5)

4a. **CHILDREN UNDER 2:**

   How many hours, on average, does your child under the age of 2 spend outdoors within an urban setting (city, town) and in rural or natural environments during a typical weekday and weekend day in the summer? Please assume a typical summer day. Please note, if you have more than one child under the age of 2 please choose one child to estimate hours for.

   **Please select appropriate number of hours for both Weekday and Weekend day in urban and rural areas. If not applicable please select N/A:**

<table>
<thead>
<tr>
<th></th>
<th>Less than 1 hour</th>
<th>1-2 hours</th>
<th>2-4 hours</th>
<th>4-6 hours</th>
<th>More than 6 hours</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday – Urban setting</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Weekend day – Urban setting</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Weekday – Rural/natural environment</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Weekend day – Rural/natural environment</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
5. Do you have children between the ages of 2 and 6?
- ☐ Yes  (Please proceed to question 5a)
- ☐ No  (Please skip to question 6)
- ☐ Prefer not to answer (Please skip to question 6)

5a. **CHILDREN BETWEEN 2-6:**
How many hours, on average, does your child between the ages of 2-6 spend outdoors within an urban setting (city, town) and in rural or natural environments during a typical weekday and weekend day in the summer? Please assume a typical summer day. Please note, if you have more than one child between 2-6 please choose one child to estimate hours for.

*Please select appropriate number of hours for both Weekday and Weekend day in urban and rural areas. If not applicable please select N/A:*

<table>
<thead>
<tr>
<th></th>
<th>Less than 1 hour</th>
<th>1-2 hours</th>
<th>2-4 hours</th>
<th>4-6 hours</th>
<th>More than 6 hours</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday – Urban setting</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Weekend day – Urban setting</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Weekday – Rural/natural environment</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Weekend day – Rural/natural environment</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

6. Do you have children between the ages of 7 and 14?
- ☐ Yes  *(Proceed to question 6a)*
- ☐ No  *(Please skip to Section 3)*
- ☐ Prefer not to answer *(Please skip to Section 3)*

6a. **CHILDREN BETWEEN 7-14:**
How many hours, on average, does your child between the ages of 7-14 spend outdoors within an urban setting (city, town) and in rural or natural environments during a typical weekday and weekend day in the summer? Please assume a typical summer day. Please note, if you have more than one child between 7-14 please choose one child to estimate hours for.
Please select appropriate number of hours for both Weekday and Weekend day in urban and rural areas. If not applicable please select N/A:

<table>
<thead>
<tr>
<th></th>
<th>Less than 1 hour</th>
<th>1-2 hours</th>
<th>2-4 hours</th>
<th>4-6 hours</th>
<th>More than 6 hours</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday – Urban setting</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Weekend day – Urban setting</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Weekday – Rural/natural environment</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Weekend day – Rural/natural environment</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

SECTION 3: Public health options to reduce West Nile virus

This section is going to ask you about criteria used to evaluate West Nile virus programs. In order to learn whether you believe different interventions are warranted under different circumstances we'd like you to imagine three different risk scenarios: Low risk, medium risk and high risk.

For each risk scenario we would like you to consider five evaluation criteria (cost, effectiveness, public acceptance, speed and ease of implementation, and environmental consequences).

Please rank these criteria from most important (1) to least important (5).

7. Please rank the following 5 criteria from most important (1) to least important (5) for a program to reduce West Nile virus in your community in a low risk scenario.

**Low risk** is when there is no presence of West Nile virus in your community.

*Please write the rank next to each criteria. Please make sure that each rank (1-5) is only used once.*

<table>
<thead>
<tr>
<th>Criteria – Low risk</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>Effectiveness</td>
<td></td>
</tr>
<tr>
<td>Public acceptance</td>
<td></td>
</tr>
<tr>
<td>Ease and speed of implementation</td>
<td></td>
</tr>
<tr>
<td>Environmental consequences</td>
<td></td>
</tr>
</tbody>
</table>
8. Now please imagine a medium risk scenario:

**Medium risk** is when there are birds and mosquitoes in your community that have been shown to carry West Nile virus but no humans have become sick. Please rank the criteria again from most important (1) to least important (5).

Please write the rank next to each criteria. Please make sure that each rank (1-5) is only used once.

<table>
<thead>
<tr>
<th>Criteria – Medium risk</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>Effectiveness</td>
<td></td>
</tr>
<tr>
<td>Public acceptance</td>
<td></td>
</tr>
<tr>
<td>Ease and speed of implementation</td>
<td></td>
</tr>
<tr>
<td>Environmental consequences</td>
<td></td>
</tr>
</tbody>
</table>

9. Now please imagine a high risk scenario:

**High risk** is when people in your community have become sick from West Nile virus. Please rank the criteria again from most important (1) to least important (5).

Please write the rank next to each criteria. Please make sure that each rank (1-5) is only used once.

<table>
<thead>
<tr>
<th>Criteria – High risk</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>Effectiveness</td>
<td></td>
</tr>
<tr>
<td>Public acceptance</td>
<td></td>
</tr>
<tr>
<td>Ease and speed of implementation</td>
<td></td>
</tr>
<tr>
<td>Environmental consequences</td>
<td></td>
</tr>
</tbody>
</table>

SECTION 4: Public health options to reduce West Nile virus (continued)

Now I’d like you to consider 5 options that can be used to reduce the risk of West Nile virus:

1) No West Nile virus program (prefer to allocate funds to another health program)
2) Public education to prevent mosquito bites
3) Reducing mosquito habitats such as standing water to prevent them from breeding
4) Applying pesticides to kill mosquitoes in their larval stage
5) Applying pesticides to kill mosquitoes in their adult stage once they are flying around.

The next section is going to ask you about these 5 options.
10. Please imagine a theoretical pot of money (for example, $10,000); what percentage would you give to each option to reduce the risk of West Nile virus?

*Please write a percent next to each option. Please make sure that your total percentage adds to a 100%*

<table>
<thead>
<tr>
<th>Program Options</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No West Nile virus program (prefer to allocate funds to another health program)</td>
<td></td>
</tr>
<tr>
<td>Public education to prevent mosquito bites</td>
<td></td>
</tr>
<tr>
<td>Reducing mosquito habitats such as standing water to prevent them from breeding</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their larval stage</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their adult stage once they are flying around.</td>
<td></td>
</tr>
</tbody>
</table>

**Total Percent** (please add up)

11. If you chose to allocate funds to another health program in Question 10, please tell us which health programs you would choose to give funds to:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

☐ Not applicable

SECTION 5: Public health options to reduce West Nile virus (continued)

For this section, please consider the five individual criteria (cost, effectiveness, public acceptance, ease and speed of implementation, and environmental consequences) in these programs to reduce the risk of West Nile virus.

12. Please rank the *cost* of the following options from most expensive (1) to least expensive (5) in a program to reduce the risk of West Nile virus:

*Please rank each option for cost. Please make sure that each rank (1-5) is only used once.*

<table>
<thead>
<tr>
<th>Program Options</th>
<th>Rank: Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>No West Nile virus program (prefer to allocate funds to another health program)</td>
<td></td>
</tr>
<tr>
<td>Public education to prevent mosquito bites</td>
<td></td>
</tr>
<tr>
<td>Reducing mosquito habitats such as standing water to prevent them from breeding</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their larval stage</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their adult stage once they are flying around.</td>
<td></td>
</tr>
</tbody>
</table>
12a. How confident are you about your rankings of the costs associated with the various options (the question above)? Please select one level below:

<table>
<thead>
<tr>
<th>Very confident</th>
<th>Somewhat confident</th>
<th>Neutral</th>
<th>Not very confident</th>
<th>Not at all confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

13. Please rank the effectiveness of the following options from most effective (1) to least effective (5) in a program to reduce the risk of West Nile virus:

Please rank each option for effectiveness. Please make sure that each rank (1-5) is only used once.

<table>
<thead>
<tr>
<th>Program Options</th>
<th>Rank: Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>No West Nile virus program (prefer to allocate funds to another health program)</td>
<td></td>
</tr>
<tr>
<td>Public education to prevent mosquito bites</td>
<td></td>
</tr>
<tr>
<td>Reducing mosquito habitats such as standing water to prevent them from breeding</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their larval stage</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their adult stage once they are flying around.</td>
<td></td>
</tr>
</tbody>
</table>

13a. How confident are you about your rankings of the effectiveness associated with the various options (the question above)? Please select one level below:

<table>
<thead>
<tr>
<th>Very confident</th>
<th>Somewhat confident</th>
<th>Neutral</th>
<th>Not very confident</th>
<th>Not at all confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

14. Please rank the public acceptance of the following options from most accepted (1) to least accepted (5) in a program to reduce the risk of West Nile virus:

Please rank each option for public acceptance. Please make sure that each rank (1-5) is only used once.

<table>
<thead>
<tr>
<th>Program Options</th>
<th>Rank: Public Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>No West Nile virus program (prefer to allocate funds to another health program)</td>
<td></td>
</tr>
<tr>
<td>Public education to prevent mosquito bites</td>
<td></td>
</tr>
<tr>
<td>Reducing mosquito habitats such as standing water to prevent them from breeding</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their larval stage</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their adult stage once they are flying around.</td>
<td></td>
</tr>
</tbody>
</table>
14a. How confident are you about your rankings of the public acceptance associated with the various options (the question above)? *Please select one level below:*

<table>
<thead>
<tr>
<th>Very confident</th>
<th>Somewhat confident</th>
<th>Neutral</th>
<th>Not very confident</th>
<th>Not at all confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

15. Please rank the *ease and speed of implementation* the following options from quickest (1) to slowest (5) in a program to reduce the risk of West Nile virus:

*Please rank each option for ease and speed of implementation. Please make sure that each rank (1-5) is only used once.*

<table>
<thead>
<tr>
<th>Program Options</th>
<th>Rank: Ease and speed of implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No West Nile virus program (prefer to allocate funds to another health program)</td>
<td></td>
</tr>
<tr>
<td>Public education to prevent mosquito bites</td>
<td></td>
</tr>
<tr>
<td>Reducing mosquito habitats such as standing water to prevent them from breeding</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their larval stage</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their adult stage once they are flying around</td>
<td></td>
</tr>
</tbody>
</table>

15a. How confident are you about your rankings of the ease and speed of implementation associated with the various options (the question above)? *Please select one level below:*

<table>
<thead>
<tr>
<th>Very confident</th>
<th>Somewhat confident</th>
<th>Neutral</th>
<th>Not very confident</th>
<th>Not at all confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
16. Please rank the *environmental consequences* of the following options from most environmental concern (1) to least environmental concern (5) in a program to reduce the risk of West Nile virus:

*Please rank each option for environmental consequences. Please make sure that each rank (1-5) is only used once.*

<table>
<thead>
<tr>
<th>Options</th>
<th>Rank: Environmental consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>No West Nile virus program (prefer to allocate funds to another health program)</td>
<td></td>
</tr>
<tr>
<td>Public education to prevent mosquito bites</td>
<td></td>
</tr>
<tr>
<td>Reducing mosquito habitats such as standing water to prevent them from breeding</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their larval stage</td>
<td></td>
</tr>
<tr>
<td>Applying pesticides to kill mosquitoes in their adult stage once they are flying around</td>
<td></td>
</tr>
</tbody>
</table>

16a. How confident are you about your rankings of the environmental consequences associated with the various options (the question above)? *Please select one level below:*

<table>
<thead>
<tr>
<th>Very confident</th>
<th>Somewhat confident</th>
<th>Neutral</th>
<th>Not very confident</th>
<th>Not at all confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

**Thank You!**

This brings us to the end of our survey. Thank you for taking the time to complete this survey. Your answers are greatly appreciated.

Once data collection is complete, we will contact the winners of the study draw (for 2 iPODS). If you chose to receive the results of this study, you will receive a report once the study has finished.

In the meanwhile, if you have any questions and/or concerns please don't hesitate contact us at 604-822-0945 or via e-mail wnvstudy@ires.ubc.ca. Thanks again!
Appendix D: Analytica code for the PAMSE model
Software version 4.1.0

System Variables with non-default values:

- Time := Sequence(0, 30, 1)
  - Title: Time
  - Description: Dynamic simulation periods are specified in Time's definition. This is usually a list of numbers or labels, typically in some unit of time (days, weeks, months, etc.). Use the iDynamic() function in your variables to perform dynamic simulation.

- Samplesize := 10K
- Sampletype := 1
- Typechecking := 1
- Checking := 1
- Showhier := 1
- Saveoptions := 2
- Savevalues := 0
- Distresol := 1
- Randomtype := 2

{40000|Att_graphvaluerange Graph_pdf_valdim: 1,0,1,,10}

Attribute Source

Attribute Reference

Askattribute Recursive, Function, Yes
Askattribute Source, Function, Yes
Askattribute Source, Module, Yes
Askattribute Source, Variable, Yes
Model Wnv_exposure
Title: WNV Exposure
Description: Probability of being exposed to WNV
Author: Negar Elmieh
Date: Thu, Jun 10, 2004 1:41 PM
Saveauthor: NegarElmieh
Savedate: Jan 14, 2009 10:05 PM
Defaultsize: 48,24
Diagstate: 1,0,0,1,441,664,17
Fontstyle: Arial, 18
Fileinfo: 0, Model Wnv_exposure, 2, 2, 0, 0, \host\Shared Folders\PhD\West

- Nile virus\Chapter 4 - model\pamse model\Models\PAMSE_chapter version

n_stochastic.TXT
Pagesetup: (000300000048004800000002D80228FFE1FFE202F902460347052803

- FC000200000048004800000002D802280010000000640000000100030303000000

- 1270F0001000100000000000000006008001901900000000000000000000000

- 00000000000000000000000000000000000000000000000000000000000000000

Att_diagramprintsca: 100,1,1,1,1,1,537,1200,4,0

Formnode Halflife1
Title: Halflife
Definition: 0
Nodelocation: 208,328
Nodesize: 180,20
Original: Halflife

Formnode Schedule1
Title: Schedule
Definition: 0
Nodelocation: 208,376
Nodesize: 180,20
Original: Sprayschedule

Text Te1
Description: ~
Please choose scenario characteristics from list of choices below left ~
1) Half-life of malathion ~
2) Number of spraying events (each assumed to be separated by a 4 day interval.) ~
3) Fraction of area in region sprayed ~
4) Method of pesticide application ~
5) Fraction of population who regularly eat berries, lettuce and tomatoes from their garden ~

Then click on buttons to the right for summary model outputs.

Nodelocation: 496,160,0
Nodesize: 364,84
Nodeinfo: 1,0,0,1,0,0,1,,1
Nodecolor: -26215,-13105,-1
Nodefont: Palatino, 18

Formnode Spray_area2
Title: Spray Area
Definition: 0
Nodelocation: 208,424
Nodesize: 180,24
Original: Area_sprayed

Module Model1
Title: Model
Author: Hadi Dowlatabadi
Date: Tue, Jan 4, 2005 9:51 AM
Defaultsize: 48,24
Nodelocation: 488,368,0
Nodesize: 72,116
Diagstate: 1,0,-23,1152,659,17
Att__diagramprintsca: 100,1,1,1,1,1,1537,1

Module Population_weights_
Title: Population Characteristics: weight, height & age
Author: Negar Elmieh
Date: Fri, Dec 17, 2004 10:57 AM
Defaultsize: 48,24
Nodelocation: 168,368,1
Nodesize: 108,48
Diagstate: 1,92,227,675,472,17

Chance Wgt_4
Title: Weight dist. 15-65
Units: Kg
Description: Weight distribution ages 15-65
Definition: Normal( 76, 8 )
Nodelocation: 112,168,0
Nodesize: 100,24
Valuestate: 1,424,434,416,303,1,CDFP

Chance Wgt_1
Title: Weight dist. < 2
Units: Kg
Description: Weight for ages < 2
Definition: Normal( 8.3, 1.2 )
Nodelocation: 112,24,0
Nodesize: 100,24
Windstate: 2,106,59,476,224
Valuestate: 1,200,210,638,536,1,CDFP
Graphsetup: Graphtool:0~
Distresol:1~
Diststeps:1~
Cdfresol:1~
Cdfsteps:1~
Symbolsize:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:4~
Xmaximum:12~
Yminimum:0~
Ymaximum:1~
Zminimum:1~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Includexzero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,1,0,0,0]~
Probindex:[0.05,0.25,0.5,0.75,0.95]~

Chance Wgt_3
Title: Weight dist. 7-14
Units: Kg
Description: Weight distribution ages 7-14
Definition: Normal( 42, 8 )
Nodelocation: 112,120,0
Nodesize: 100,24
Valuestate: 1,232,242,734,545,1,CDFP

Chance Wgt_5
Title: Weigh dist. >65
Units: Kg
Description: Weight distributions over 65
Definition: Normal( 72, 5.4 )
Nodelocation: 112,216,0
Nodesize: 100,24
Valuestate: 1,184,194,707,400,1,PDFP

Chance Wgt_2
Title: Weight dist. 2-6
Units: Kg
Description: Weight distribution 1-6
Definition: Normal( 16.9, 3.3 )
Nodelocation: 112,72,0
Nodesize: 100,24
Valuestate: 1,321,284,707,400,1,CDFP

Chance Sa_1
Title: Surface Area < 2
Units: sq m
Description: Surface Area ages < 2
Definition: (Wgt_1 + 4)/30
Nodelocation: 552,24
Nodesize: 100,24
Valuestate: 1,443,166,416,303,1,PDFP

Chance Hgt_1
Title: Height dist. < 2
Units: cm
Description: Height distribution < 2
Definition: Normal( 71.7, 4 )
Nodelocation: 320,24
Nodesize: 100,24
Valuestate: 1,152,162,416,303,1,PDFP

Chance Hgt_2
Title: Height dist 2-6
Units: cm
Description: Height distribution ages 2-6
Definition: Normal( 104.9, 7.1 )
Nodelocation: 320,72,0
Nodesize: 100,24
Valuestate: 1,184,194,707,400,1,PDFP

Chance Sa_2
Title: Surface Area 2-6
Units: sq m
Description: Surface area ages 2-6
Definition: (wgt_2+4)/30
Nodelocation: 552,72,0
Nodesize: 100,24
Valuestate: 1,184,194,707,400,1,PDFP

Chance Hgt_3
Title: Height dist 7-14
Units: cm
Description: Height distribution ages 7-14
Definition: Normal( 145.7, 8.3 )
Nodelocation: 320,120
Nodesize: 100,24
Valuestate: 2,184,194,707,400,1,PDFP

Chance Sa_3
Title: Surface area 7-14
Units: sq m
Description: Surface areas for ages 7-14
Definition: if (wgt_3<30) then~
(wgt_3+4)/30~
else~
((hgt_3*wgt_3)/3600)^1/2
Nodelocation: 552,120,0
Nodesize: 100,24
Windstate: 1,248,258
Valuestate: 2,184,194,707,400,1,CDFP

Chance Hgt_4
Title: Height dist 15-65
Units: cm
Description: Height distribution ages 15-65
Definition: Normal( 169.2, 1 )
Nodelocation: 320,168
Nodesize: 100,24
Valuestate: 2,477,75,707,400,1,PDFP

Chance Sa_4
Title: Surface area 15-65
Units: sq m
Description: Surface areas ages 15-65
Definition: ((hgt_4*wgt_4)/3600)^1/2
Nodelocation: 552,168,0
Nodesize: 100,24
Valuestate: 2,477,75,707,400,1,PDFP

Chance Hgt_5
Title: Height dist > 65
Units: cm
Description: Height distributions over 65
Definition: Normal( 164.8, 2 )
Nodelocation: 320,216,0
Nodesize: 100,24
Valuestate: 1,184,194,707,400,1,PDFP

Chance Sa_5
Title: Surface area > 65
Units: sq m
Description: Surfaces areas ages over 65
Definition: ((hgt_5*wgt_5)/3600)^1/2
Nodelocation: 552,216,0
Nodesize: 100,24
Variable Weights
Title: Wt groups
Definition: Table(Age) (~
Wgt_1, Wgt_2, Wgt_3, Wgt_4, Wgt_5)
Nodelocation: 112, 288
Nodesize: 88, 24
Windstate: 1, 336, 377
Defnstate: 2, 386, 261, 416, 303, 0, MIDM
Valuestate: 2, 139, 1, 671, 649, 0, STAT
Graphsetup: Graph: tool: 0
Dist: resol: 5
Dist: steps: 1
Cdf: resol: 5
Cdf: steps: 1
Symbols: size: 6
Lins: tyle: 1
Frame: 1
Grid: 1
Ticks: 1
Mesh: 1
Scales: 1
Rotation: 45
Tilt: 0
Depth: 70
Frameauto: 1
Showkey: 1
X: minimum: 0
X: maximum: 2.5
Y: minimum: 0
Y: maximum: 20
Z: minimum: 1
Z: maximum: 5
X: intervals: 0
Y: intervals: 0
Include: xzero: 0
Include: yzero: 0
Include: zzero: 0
Statsselect: [1, 1, 1, 1, 0, 0, 0]
Probindex: [0.05, 0.25, 0.5, 0.75, 0.95]

Variable Skins
Title: Sa groups
Definition: Table(Age) (~
Sa_1, Sa_2, Sa_3, Sa_4, Sa_5)
Nodelocation: 552, 288
Nodesize: 88, 24
Defnstate: 2, 386, 261, 416, 303, 0, MIDM
Valuestate: 2, 139, 1, 671, 649, 0, STAT
Graphsetup: Graph: tool: 0
Dist: resol: 5
Dist: steps: 1
Cdf: resol: 5
Cdf: steps: 1
Symbols: size: 6
Lins: tyle: 1
Frame: 1
Grid: 1
Ticks: 1
Mesh: 1
Scales: 1
Rotation: 45
Tilt: 0
Depth: 70
Frameauto: 1
Showkey: 1
X: minimum: 0
X: maximum: 2.5
Y: minimum: 0
Y: maximum: 20
Z: minimum: 1
Z: maximum: 5
X: intervals: 0
Y: intervals: 0
Include: xzero: 0
Include: yzero: 0
Include: zzero: 0
Statsselect: [1, 1, 1, 1, 0, 0, 0]
Probindex: [0.05, 0.25, 0.5, 0.75, 0.95]

Variable Normalized_sa
Title: Normalized SA
Definition: Skins/m: ean(slice(skins, age, 1))
Nodelocation: 552, 368
Nodesize: 84, 24
Valuestate: 2, 72, 82, 765, 478, 1, PDFP

Close Population_weights__

Index Age
Title: Age
Definition: ['Less than 2', 'Aged 2 to 6', 'Aged 7 to 14', 'Aged 15 to 65', 'Aged 65+']
Nodelocation: 232, 24, 1
Nodesize: 56, 28
Windstate: 2, 678, 307, 476, 224
Valuestate: 1, 328, 338, 416, 303, 0, DEFA
Constant Population_makeup
Title: Demographic Structure
Definition: Table(Age)(\approx 9.96m,0.0688,0.0946,0.694,0.135)
Nodelocation: 456,24,0
Nodesize: 72,28

Module Inhalation
Title: Inhalation
Author: Negar Elmieh
Date: Fri, Dec 17, 2004 10:57 AM
Defaultsize: 48,24
Nodelocation: 448,400,0
Nodesize: 80,32
Diagstate: 1,1,448,245,17
Fontstyle: Helvetica, 14

Objective Inhaled_dose
Title: Inhaled Dose
Units: mg/kg/day
Definition: riskinhalex*(Inhaled_ab_rate*Airborne*Volinhaled*Xperiod)/\approx Weights
Nodelocation: 360,200,0
Nodesize: 68,28
Windstate: 1,232,242
Valuestate: 2,49,5,1152,659,1,PDFP
Graphsetup: Distresol:20~~
Diststeps:0
Reformval: [Time,Time,Undefined,Undefined,1]
Numberformat: 1,E,2,2,0,0
\{140000|Att_graphvaluerange: 1,\ldots,10\}
\{140000|Att_resultslicestate: [Age,2,Sys_localindex('STATISTICS'),1,Time,1]\}

Module Airborne_characterization
Title: Airborne characterization
Author: Hadi Dowlatabadi
Date: Thu, Dec 30, 2004 12:20 PM
Defaultsize: 72,24
Nodelocation: 360,296,0
Nodesize: 100,24
Diagstate: 1,1,7,448,245,17
Fontstyle: Helvetica, 14

Chance Dispersion_layer
Title: Dispersion layer
Units: m
Description: The fogging truck plume is esimtaed to be triangular(5,7,\sim\sim 15)m in height. ~
The plume from an aeroplane in assumed to be triangular(15,25,35)m in~~
height.
Definition: ifall spray_method_choice = 'Ground' then triangular(5,7,1~~
5) else~~
ifall spray_method_choice = 'Aerial' then triangular(15,25,35) else~~
triangular(5,7,15)
Nodelocation: 152,128
Nodesize: 72,24
Valuestate: 1,136,146,416,303,1,PDFP
Graphsetup: Graphtool:0~~
Distresol:1~~
Diststeps:1~~
Cdfresol:5~~
Cdfsteps:1~~
Symbolsize:6~~
Linestyle:1~~
Frame:1~~
Grid:1~~
Text Te3
Description: Assuming a wind speed of 2-5 kph, malathion drifts as far as 500m. This suggests the time aloft is of the order 30-180 minutes.

The application is via a fogger that creates a plume with a modal height of 7 meters and a likely maximum of 15 meters.

Indoor concentrations are assumed to be distributed as a Triangular(0.1, 0.3, 1) distribution.

Objective Airborne
Title: Airborne Malathion at a given location
Units: mg/m^3
Description: multiplier for application rate
Definition: ar*Riskinhalex/Dispersion_layer*Indoor_infiltration*(if Spray_method_choice = 'Ground' then Deposition_ground else Deposition_air)

Graphsetup: Graphtool:0
Distresol:10
Diststeps:1
Cdfresol:5
Cdfsteps:1
Symbolsize:6
Linestyle:1
Frame:1
Grid:1
Ticks:1
Mesh:1
Scales:1
Rotation:45
Tilt:0
Depth:70
Frameauto:1
Showkey:1
Xminimum:0
Xmaximum:100
Chance Indoor_infiltration
Title: Indoor infiltration
Definition: Triangular( .1, .3, 1 )
Nodelocation: 336,48
Nodelocation: 336,48
Windstate: 2,0,-23,1441,664
Valuestate: 2,0,-23,1441,664,0,STAT

Close Airborne_characteriz

Chance Xperiod
Title: Exposure period
Units: days
Description: The fog remains aloft for between 30 minutes and 6 hours. This is the duration of inhalation events during a 24 hour period.
Definition: Lognormal( 1, 1.5 )
Nodelocation: 152,136,0
Nodelocation: 152,136,0
Windstate: 2,0,-23,1441,664
Valuestate: 2,317,141,549,426,0,STAT

Chance Volinhaled
Title: Volume inhaled per hour
Units: m3/hour
Description: Distribution of breathing rates have been substituted with a deterministic volume of air inhaled per hour from EPA.
Definition: Table(Age)(~ 0.25,0.36,0.4,0.55,0.55)
Nodelocation: 152,200,0
Nodelocation: 152,200,0
Defnstate: 2,386,249,416,303,0,MIDM
Valuestate: 1,88,98,416,303,0,MIDM

Chance Inhaled_ab_rate
Title: Inhaled Absorption rate
Units: fraction
Description: It is commonly assumed that all pollution inhaled in air will be absorbed. Segan et al 1991 show that a range of fractions are absorbed from 14% to 95%.
Definition: uniform(.14, .95)
Nodelocation: 152,272,0
Nodelocation: 152,272,0

Objective Population_above_ac2
Title: Inhaled Dose > Target MOE
Units: %
Description: This expression will return a value larger than zero if A NY of the cases exceeds the acceptable risk level.
Definition: 100*Probability((inhaled_dose>(Animal_tox_derm2/Target_moe~ _dermal2)))
Nodelocation: 560,200,0
Nodelocation: 560,200,0
Valuestate: 2,213,31,810,532,0,MIDM
Graphsetup: Graphtool:0~
Distresol:1~
Diststems:1~
Variable Animal_tox_derm2
Title: Animal Toxic Endpoint
(ingestion)
Units: mg/kg
Definition: Table(Age)(
5,5,5,25.8,25.8)
Nodelocation: 512,96,0
Nnodesize: 48,32
Valuestate: 1,152,162,416,303,0,MIDM

Variable Target_moe_dermal2
Title: Target MOE
(ingestion)
Definition: Table(Age)(
1000,1000,1000,1000,1000)
Nodelocation: 608,96,0
Nnodesize: 48,32

Close Inhalation

Module Inhalation1
Title: Ingestion
Author: Negar Elmieh
Date: Fri, Dec 17, 2004 10:57 AM
Defaultsize: 48,24
Nodelocation: 448,312,0
Nnodesize: 80,32
Diagstate: 1,1,7,448,245,17
Fontstyle: Arial, 15

Alias Malathion_at_a_given
Title: Malathion at a given location
Definition: 1
Nodelocation: 192,120,1
Nnodesize: 64,29
Nodeinfo: 1,1,1,1,1,1,1,1,0,
Nodecolor: -6558,-13109,-1
Nodefont: Helvetica, 14
Original: Depositedmalathion
Objective Ingested_dose_table
Title: Ingested dose by route
Units: mg/kg/day
Definition: Table(Ingested_matter)(
Doseingestberries, Doseingesttomatoes, Ingestedlettuce, Ingestedgrass, Doseingestsoil, Handtomouthingestion)
Nodelocation: 344, 312, 1
Nodesize: 56, 24
Windstate: 2, 102, 90, 476, 224
Valuestate: 1, 238, 126, 696, 493, 0, STAT
Numberformat: 1, E, 2, 0, 0

Objective Total_ingested
Title: Total Ingested
Units: mg/kg/day
Description: Here the various pathways of ingestion exposure are summed and corrected for the fraction of the population expected to rely on their garden for berries, tomatoes, and lettuce.
Definition: sum(Ingested_dose_table * Gardeneaters, ingested_matter)
Nodelocation: 520, 312, 1
Nodesize: 48, 24
Windstate: 2, 102, 90, 476, 224
Valuestate: 2, 140, 48, 735, 548, 1, MEAN
Graphsetup: Graphtool: 0
Distresol: 1
Diststeps: 1
Cdfresol: 5
Cdfsteps: 1
Symbolsize: 6
Linestyle: 1
Frame: 1
Grid: 3
Ticks: 1
Mesh: 1
Scales: 1
Rotation: 45
Tilt: 0
Depth: 70
Frameauto: 1
Showkey: 1
Xminimum: 0
Xmaximum: 60
Yminimum: 0
Ymaximum: 1.5
Zminimum: 1
Zmaximum: 5
Xintervals: 6
Yintervals: 4
Includezero: 0
Includeyzero: 0
Includezzero: 0
Statsselect: [1, 1, 1, 1, 0, 0, 0]
Probindex: [5%, 25%, 50%, 75%, 95%]
Reformval: [Time, Age]
Numberformat: 1, E, 2, 2, 0, 0

Variable Animal_tox_ingestion
Title: Animal Toxic Endpoint (ingestion)
Units: mg/kg/day
Definition: Table(Age)(5, 5, 5, 25, 25)
Nodelocation: 664, 177, 1
Nodesize: 48, 40
Valuestate: 1, 264, 274, 563, 408, 1, MIDM

Variable Target_moe_ingestion
Title: Target MOE (~)
(ingestion)
Definition: Table(Age)(~
1000,1000,1000,300,300)
Nodelocation: 760,176,1
Nodesize: 48,24

Index Ingested_matter
Title: Ingested matter
Definition: ['Berries','Tomatoes','Lettuce','turf','soil','hand licking~~
g']
Nodelocation: 48,24,0
Nodesize: 48,24
Windstate: 1,408,418
Valuestate: 1,168,178,416,303,0,MIDM
{!40000[Att_previndexvalue: ['Berries','Tomatoes','Lettuce','turf','s~~
oil','hand licking']}

Index Feed_from_garden
Title: Feed from garden
Units: %
Definition: [10,25,50]
Nodelocation: 136,24,1
Nodesize: 52,24

Module Soil
Title: Soil
Author: Negar Elmieh
Date: Mon, Jan 10, 2005 1:04 PM
Defaultsize: 48,24
Nodelocation: 192,288,1
Nodesize: 48,24
Diagstate: 1,335,4,426,336,17

Chance Massofsoilingested
Title: Mass of soil ingested accidentally by children
Units: g/day
Description: Mass of accidental soil ingestion based on the Ti tracer ~~~
(highest estimate) distributional characteristics. The data from EPA ~~~
is reported in mg, hence the conversion factor of 10^-3 to convert to~~~
g.
Definition: Lognormal( 81, 4.56 )/1000
Nodelocation: 128,56
Nodesize: 72,40
Valuestate: 2,232,242,416,303,1,PDFP
Graphsetup: Graphtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsize:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:1~
Yminimum:0~
Ymaximum:1~
Zminimum:0~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Includezero:0~

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Variable Accidental_soil_ing
Title: Accidental soil ingestion exposure
Units: g/day
Description: soil density is assumed to be 1.5g/cm^3. The top 1 cm is scraped and ingested. Together with the estimated ingestion rate, this provides us with a surface area equivalent
Definition: Table(Age)(Massofsoilingested,Massofsoilingested,Massofsoilingestedad,Massofsoil~~ingestedad,Massofsoilingestedad)
Nodelocation: 208,152
Nodesize: 84,24
Windstate: 1,265,379
Defnstate: 1,569,430,416,303,0,MIDM
Valuestate: 2,552,319,475,294,1,MIDM

Chance Massofsoilingestedad
Title: Mass of soil ingested accidentally by adolescents & adults
Units: g/day
Description: Mass of accidental soil ingestion based on the Ti tracer (highest estimate) distributional characteristics. The published data are in mg/day, hence the conversion factor of 10e-3.
Definition: Lognormal(211,3)/1000
Nodelocation: 288,56
Nodesize: 72,40
Valuestate: 2,232,242,416,303,1,PDFP

Objective Doseingestsoil
Title: Dose Ingested through Soil
Units: mg/kg/day
Description: given a density of soil of 1.5g/cm^-3 and a cube of soil equal in mass to the accidental ingestion...~
mass of soil/density = volume
(Volume)^-3 = one dimension of the cube
(Volume)^2/3 = surface area
Surface Area*deposition rate=ingested
Definition: (((((Accidental_soil_ing/1.5)^(2/3))*Depositedmalathion)/~~
(Weights*(10^-4))))
Nodelocation: 208,224
Nodesize: 72,28
Windstate: 1,207,118
Valuestate: 1,62,45,126,798,1,STAT
Nodeformat: 1,E,2,2,0,0

Close Soil

Module Turf
Title: Turf
Author: Negar Elmieh
Date: Mon, Jan 10, 2005 1:04 PM
Defaultsize: 48,24
Nodelocation: 192,336,1
Nodesize: 48,24
Diagstate: 1,248,258,449,243,17

Chance Area_of_grass_ingest
Title: Area of grass ingested
Units: cm^2./day
Definition: dynamic(if ((weights > 8) and (weights < 20)) then triangu~~
lar(0,25,50) else 0,if ((weights > 8) and (weights < 20)) then triang~~
ular(0,25,50) else 0)
Nodelocation: 240,48
Nodesize: 72,32
Windstate: 1,413,151
Valuestate: 2,228,174,627,581,0,STAT
Graphsetup: Grahtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsize:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:1~
Yminimum:0~
Ymaximum:1~
Zminimum:0~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Includezero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,1,0,0,0]~
Probindex:[0,0.01,0.05,0.25,0.5,0.75,0.95,0.99,1]~

Reformval: [Undefined, Age, Undefined, Undefined, 1]
{"40000:Att_resultslicestate: [Time,2,Age,4,Sys_localindex('STATISTICS~~
'),1]}

Objective Ingestedgrass
Title: Dose ingested through grass
Units: mg/kg/day
Definition: \(((\text{Deposited malathion}) \times \text{Area of grass ingest}) / (10^4 \times \text{Weights})\)
Nodelocation: 240,144
Nodesize: 64,28
Windstate: 1,426,500
Valuestate: 1,554,426,416,303,1,STAT
Numberformat: 1,E,2,2,0,0

Close Turf

Module Berries
Title: Berries
Author: Negar Elmieh
Date: Mon, Jan 10, 2005 1:04 PM
Defaultsize: 48,24
Nodelocation: 192,240,1
Nodesize: 48,24
Diagstate: 1,433,40,350,248,17
Valuestate: 1,324,305,416,303,0,MIDM

Chance Mass_of_berry1
Title: Berry consumption
Units: g/day
Description: Each berry is assumed to weigh 5g
Definition: Table(Age)(Lognormal(1,1.25),Lognormal(6,1.25),Lognormal(8,1.25),Lognormal(8,1.25))
Nodelocation: 240,64
Nodesize: 72,28
Defnstate: 1,324,305,416,303,0,MIDM
Valuestate: 1,360,370,629,403,0,STAT

Objective Doseingestberries1
Title: Dose Ingested through berries
Units: mg/kg/day
Description: given a density of berry of 1g/cm^3 and a cube of soil equal in mass to the accidental ingestion...~
~~
\~mass of berries/density= volume~
(Volume)^-3 = one dimension of the cube~
(Volume)^2/3 = surface area~
Surface Area*deposition rate=ingested
Definition: \(((\text{Berry weight} \times \text{Mass of berries1})/1)^(2/3) \times \text{Deposited malathion}) / (\text{Weights} \times (10^4)))\)
Nodelocation: 176,152
Nodesize: 64,28
Valuestate: 1,62,45,1262,798,0,MIDM
Numberformat: 1,E,2,2,0,0

Chance Berry_weight
Title: berry weight
Units: g
Definition: normal(5,1)
Nodelocation: 96,64
Nodesize: 72,28

Close Berries

Module Lettuce
Title: Lettuce
Author: Negar Elmieh
Date: Mon, Jan 10, 2005 1:04 PM
Defaultsize: 48,24
Nodelocation: 192,384,1
Nodesize: 48,24
Diagstate: 1,603,323,449,243,17
Chance Area of lettuce
Title: Area of lettuce ingested
Units: cm^2/day
Description: Area of lettuce consumed daily
Definition: Table(Age)(~lognormal(15,1.25),lognormal(50,1.25),lognormal(75,1.5),lognormal(75,1.5),lognormal(75,1.5),lognormal(75,1.5))
Nodelocation: 216,48
Nodesize: 72,32
Valuestate: 1,232,242,416,303,1,PDFP
Graphsetup: Graphtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbols:6~
Linestyles:1~
Frames:1~
Grid:1~
Tics:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:1~
Yminimum:0~
Ymaximum:1~
Zminimum:0~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Includexzero:0~
Includeyzero:0~
Includezzero:0~
Statsselect: [1,1,1,1,1,0,0,0]~
Probindex: [0,0.01,0.05,0.25,0.5,0.75,0.95,0.99,1]~

Objective Ingested lettuce
Title: Dose ingested through lettuce
Units: mg/kg/day
Definition: (((Depositedmalathion*Area_of_lettuce))/((10^4)*Weights))~
Nodelocation: 216,144
Nodesize: 64,28
Winds: 1,408,446
Valuestate: 1,554,426,416,30,3,1,STAT
Numberformat: 1,E,2,2,0,0

Close Lettuce

Module Tomatoes
Title: Tomatoes
Author: Negar Elmieh
Date: Mon, Jan 10, 2005 1:04 PM
Defaultsize: 48,24
Nodelocation: 192,192,1
Nodesize: 48,24
Diagstate: 1,252,116,442,333,17

Chance Mass of berries
Title: tomato consumption
number
Units: g/day
Description: Each berry is assumed to weigh 5g
Definition: Table(Age)(~
Lognormal(0.16,1.25), Lognormal(0.32,1.25), Lognormal(0.5,1.25), Lognormal(0.5,1.25), Lognormal(0.5,1.25))

Objective Doseingesttomatoes
Title: Dose Ingested through tomatoes
Units: mg/kg/day
Description: given a density of tomato of 1g/cm^3 and a cube of soil equal in mass to the accidental ingestion...~

\[
\text{mass of tomato/density} = \text{volume} \\
(Volume)^{\frac{1}{3}} = \text{one dimension of the cube} \\
(Volume)^{\frac{2}{3}} = \text{surface area} \\
\text{Surface Area*deposition rate=ingested}
\]

Definition: \[\frac{(((\text{Berry_weight1}*\text{Mass_of_berries3})/1)^{(2/3)})*\text{Depositedm}}{(\text{Weights}*(10^4))}\]

Chance Berry_weight1
Title: tomato weight
Units: g
Definition: Normal( 100, 20 )

Close Tomatoes

Module Hand_to_mouth
Title: Hand to mouth
Author: Negar Elmieh
Date: Mon, Jan 10, 2005 1:04 PM
Defaultsize: 48,24

Alias Contact_hours1
Title: Contact hours
Definition: 1

Chance Hand_surface_area
Title: hand surface area
Units: m^2
Description: Surface area of hands
Definition: \[\text{normalized_sa*normal(20,2)/10000}\]

Graphsetup: Graphtool:0~
Distresol: 20~
Diststeps: 1~
Cdfresol: 5~
Cdfsteps: 1~
Symbolsize: 6~
Linestyle: 1~
Frame: 1~
Chance Saliva_extraction
Title: saliva extraction
Units: fraction
Definition: Normal( 0.5, 0.1 )
Nodelocation: 136,208
Nodesize: 68,32
Windstate: 2,102,90,476,22
Valuestate: 1,408,418,416,303,1
Graphsetup: Graphtool:0~
Distresol:1~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsizer:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:150~
Yminimum:0~
Ymaximum:0.4~
Zminimum:1~
Zmaximum:5~
Xintervals:0~
Yintervals:0~
Includexzero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,1,0,0,0]~
Probindex:[0.05,0.25,0.5,0.75,0.95]~

Chance Hand_to_mouth_events
Title: hand to mouth events per hour
Units: per hour
Definition: Table(Age)(~
Normal(20,4),Normal(20,4),Normal(5,1),Normal(0.3,5m),Normal(0.3,5m))
Nodelocation: 136,296
Nodesize: 68,32
Valuestate: 2,181,116,673,398,1
Graphsetup: Graphtool:0~
Distresol:1~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsizer:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:40~
Yminimum:0~
Ymaximum:0.1~
Zminimum:1~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Includexzero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,1,0,0,0]~
Variable Handtomouthingestion
Title: Hand to Mouth Exposure
Units: mg/day
Definition: (((((((Depositedmalathion*Hours_of_activity)*Hand_surface_area)*Hand_to_mouth_events)*Saliva_extraction)*Extractablebycontact))/~Weights)
Nodelocation: 296,200
Nodesize: 56,28
Windstate: 1,184,194
Valuestate: 1,274,189,484,420,0,MIDM
Reformval: [Time,Age]
Numberformat: 1,E,2,2,0,0

Alias Extractable_depositi
Title: Extractable deposition on skin
Definition: 1
Nodelocation: 296,104
Nodesize: 68,32
Nodecolor: -6558,-13109,-1
Original: Extractablebycontact

Close Hand_to_mouth

Objective Population_above_ac4
Title: Ingested Dose > Target MOE
Units: %
Description: This expression will return a value larger than zero if A
NY of the cases exceeds the acceptable risk level.
Definition: 100*Probability((Total_ingested>(Animal_tox_ingestion/Targ~
et_moe_ingestion)))
Nodelocation: 728,312,0
Nodesize: 88,24
Nodeinfo: 1,1,1,1,1,1,1,,0,
Valuestate: 1,133,160,825,672,1,MIDM
Graphsetup: Graphtool:0~
Distresol:1~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsize:6~
Linestyle:1~
Frame:2~
Grid:3~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:60~
Yminimum:0~
Ymaximum:1~
Zminimum:1~
Zmaximum:5~
Xintervals:0~
Yintervals:4~
Includezero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,0,0,0]~
Probindex:[0.05,0.25,0.5,0.75,0.95]~
Module Eat_produce_from_gar
Title: Eat produce from Garden or Store?
Author: Negar Elmieh
Date: Mon, Jan 10, 2005 1:04 PM
Defaultsize: 48,24
Nodelocation: 520,400,1
Nodesize: 76,24
Diagstate: 1,1,7,448,245,17

Chance Gardeneaters
Title: Fraction of population who eat from sprayed garden
Definition: if uniform(0,1) >Eat_from_garden/100 then eatstore else eatgard
Nodelocation: 216,48
Nodesize: 92,44
Windstate: 1,117,86
Valuestate: 1,184,194,416,303,1,CDFP

Variable Eat_from_garden
Title: Eat from garden?
Units: %
Definition: Choice(Feed_from_garden,1)
Nodelocation: 216,144
Nodesize: 80,28
Windstate: 1,738,594
Valuestate: 1,136,146,416,303,0,MIDM
Aliases: Formnode Eat_from_garden1

Variable Eatstore
Title: Eat produce from store
Definition: Table(Ingested_matter)(~
0,0,0,1,1,1)
Nodelocation: 48,80
Nodesize: 48,24

Variable Eatgard
Title: Eat produce from garden
Definition: Table(Ingested_matter)(~
1,1,1,1,1,1)
Nodelocation: 48,24
Nodesize: 48,24

Close Eat_produce_from_gar

Close Inhalation1

Module Inhalation2
Title: Dermal
Author: Negar Elmieh
Date: Fri, Dec 17, 2004 10:57 AM
Defaultsize: 48,24
Nodelocation: 448,224,0
Nodesize: 80,32
Diagstate: 1,0,-23,1152,659,17
Fontstyle: Helvetica, 14

Chance Extractable_foliage
Title: Extractable fraction (foliage)
Definition: Normal( 0.05, 10m )
Nodelocation: 408,88,1
Nodesize: 72,28
Windstate: 1,95,236
Valuestate: 1,129,306,416,303,1,PDFP
Graphsetup: Graphtool:0~
Distresol:1~
Diststeps:1~
Cdfresol:5~
Title: Extractable deposition on skin
Description: The toddler is assumed to spend 33% of time outdoors in the garden and the remainder on the turf.
Definition: (If (Uniform(0,1)<0.33) Then Extractable_foliage Else Extractable_turf)
Node location: 216, 160, 1
Node size: 72, 28
Wind state: 2, 102, 90, 476, 224
Value state: 2, 40, 50, 416, 303, 1, PDFP
Aliases: Alias Extractable_deposit
Graph setup: Graphtool: 0~
Dist resolution: 10~
Dist steps: 1~
Cdf resolution: 5~
Cdf steps: 1~
Symbol size: 6~
Line style: 1~
Frame: 1~
Grid: 1~
Ticks: 1~
Mesh: 1~
Scales: 1~
Rotation: 45~
Tilt: 0~
Depth: 70~
Frame auto: 1~
Show key: 1~
X minimum: 0~
X maximum: 0.08~
Y minimum: 0~
Y maximum: 40~
Z minimum: 1~
Z maximum: 1~
X intervals: 0~
Y intervals: 0~
Include x zero: 0~
Include y zero: 0~
Include z zero: 0~
Stats select: [1, 1, 1, 1, 0, 0, 0, 0]~
Prob index: [0.05, 0.25, 0.5, 0.75, 0.95]~
Variable Exp_skin_area
Title: Area of exposed skin
Units: sqm
Description: Fraction exposed of calculated skin areas. Perhaps a couple of incidental issues are worth considering:
1) If there are insects about and there is fear of infection, there would be less exposed skin area.
2) If the spray is applied at dusk, there is a good chance that the exposure to "big skin" is not on day 0, but from day 1 onwards.
3) That the spray event may promote more skin being exposed from day 1 onwards!
Definition: skins*exposed
Nodelocation: 408,232,0
Nodesize: 64,24
Windstate: 2,237,108,476,224
Valuestate: 2,40,50,416,303,1,CDFP
Reformval: [Undefined,Age,Undefined,Undefined,1]

Chance Exposed
Title: fraction of skin exposed
Units: fraction
Description: Fraction exposed of calculated skin areas. Perhaps a couple of incidental issues are worth considering:
1) If there are insects about and there is fear of infection, there would be less exposed skin area.
2) If the spray is applied at dusk, there is a good chance that the exposure to "big skin" is not on day 0, but from day 1 onwards.
3) That the spray event may promote more skin being exposed from day 1 onwards!
Definition: Table(Age)(Lognormal(0.03,2),Lognormal(0.06,1.96),Lognormal(0.065,2.1),Lognormal(0.1,2),Lognormal(0.1,1.3))
Nodelocation: 408,160,1
Nodesize: 72,28
Windstate: 2,102,90,476,224
Defnstate: 2,221,27,416,303,0,MIDM
Valuestate: 2,144,200,767,456,0,STAT

Chance Extractable_turf
Title: Extractable fraction (turf)
Units: fraction
Description: From EPA study
Definition: Normal( 0.013, 3m )
Nodelocation: 216,88,1
Nodesize: 76,28
Windstate: 1,135,347
Valuestate: 2,360,124,416,549,0,STAT

Chance Fraction_transferrable1
Title: Fraction transferrable from surfaces
Units: fraction
Description: The EPA study states 5% of deposition rate is transferred. This has been translated into a normal(.05,.01)
Definition: Normal( .05 , .01 )
Nodelocation: 216,240,1
Nodesize: 68,28
Valuestate: 1,360,370,416,303,0,STAT

Chance Contactrate
Title: Contact Rate
Units: Number/hour
Description: From Hadi's head
Definition: Table(Activity)(Normal(100,20),Normal(10,2),2,Normal(100,20),Normal(5,1))
Nodelocation: 88,384,0
Nodesize: 56,24
Windstate: 1,647,181
Defnstate: 2,274,200,715,429,0,MIDM
Valuestate: 2,168,178,854,593,0,STAT
Aliases: Alias Contact_hours1
Graphsetup: Graphtool:0~
Distresol:1~
Diststeps:0~
Cdfresol:5~
Cdfsteps:1~
Symbolsizet6~
Baroverlap:0~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:1~
Yminimum:0~
Ymaximum:1~
Zminimum:0~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Includezero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,0,0,0]~
Probindex:[0.05,0.25,0.5,0.75,0.95]~

Reformval: [Undefined,Activity,Undefined,Undefined,1]
{!40000|Att_resultslis:state: [Activity,3, Sys_localindex('STATISTICS')~~,1]}

Objective Dermal_dose
Title: Dermal Dose
Units: mg/kg/day
Description: This is the level of exposure to malathion through dermal~~ contact. The threshold of concern is 25mg/kg/day. The MOE for this e~~ exposure mode is 300. Therefore, exposure above 83 ug/kg/day would be ~~ of concern.

Definition: (((Contact_multiplier*Depositedmalathion)*Exp_skin_area~~ )*Fraction_transferra1)*Extractablebycontact)/Weights))
Nodelocation: 408,328
Nodesize: 52,24
Windstate: 2,102,90,476,224
Valuestate: 2,40,50,789,529,1,MIDM
Graphsetup: Graphtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsizet6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:100~
Alias Malathion_inside_imm
Title: Malathion inside immediate spray area
Definition: 1
Nodelocation: 464,424,0
Nodesize: 64,24
Nodecolor: -6558,-13109,-1
Original: Depositedmalathion

Alias Wt_groups
Title: Wt groups
Definition: 1
Nodelocation: 352,424,0
Nodesize: 48,24
Nodecolor: -6558,-13109,-1
Original: Weights

Objective Population_above_acc
Title: Dermal Dose > Target MOE
Units: %
Description: This expression will return a value larger than zero if A
NY of the cases exceeds the acceptable risk level.
Definition: 100*(Probability( Dermal_dose> (Animal_tox_derm/Target_moe
_dermal*times_moe)))
Nodelocation: 600,328
Nodesize: 88,28
Windstate: 2,102,90,476,224
Valuestate: 2,-23,1441,664,0,MIDM
Reformval: [Age,Time]
{"40000|Att_resultslicestate: [Times_moe,3,Time,1,Age,3]}

Variable Animal_tox_derm
Title: Animal Toxic Endpoint~ (Dermal)
Definition: Table(Age)(~ 5,5,5,25,25)
Nodelocation: 552,224
Nodesize: 48,32
Windstate: 2,102,90,476,224
Valuestate: 2,40,50,416,303,0,MIDM

Variable Target_moe_dermal
Title: Target MOE~ (Dermal)
Definition: Table(Age)(~ 1000,1000,1000,300,300)
Nodelocation: 648,224
Nodesize: 48,32
Windstate: 2,102,90,476,224
Defnstate: 2,40,50,416,303,0,MIDM
Valuestate: 2,40,50,416,303,0,MIDM

Variable Activity_pattern_by_
Title: Activity Pattern by age
Units: %
Definition: Table(Age,Activity)(
    30,30,0,0,40,~
    50,30,0,0,20,~
    50,30,0,0,20,~
    30,10,20,20,20,~
    0,20,20,20,40~
)
Nodelocation: 88,328,0
Nodesize: 48,28
Windstate: 2,0,-23,1440,663
Defnstate: 1,325,155,664,319,0,MIDM
Reformdef: [Age,Activity]

Index Activity
Title: Activity
Definition: ['Playing','Transit','Gardening with globves','Gardening w/o globves','Resting']
Nodelocation: 48,24,0
Nodesize: 48,24

Chance Hours_of_activity
Title: Hours of Activity
Description: Table(Age)(
    Lognormal(0.4,2),Lognormal(1,1.5),Lognormal(1,1.5),Lognormal(0.4,3),Lognormal(1,2))
Definition: Table(Age)(
    Hours_under_6, Hours_2to6, Hours_7_to_14, Hours_15_to_65, Hours_over_65)
Nodelocation: 88,272,0
Nodesize: 56,24
Windstate: 2,0,-23,1152,659
Defnstate: 2,40,50,416,303,0,MIDM
Valuestate: 2,0,-23,1152,659,1,SAMP
Graphsetup: {!40000|Att_graphvaluerange Hours_of_activity:1,,0,,,,,0,12}~
    {!40000|Att_contlinestyle Graph_pdf_valdim:6}~
    Distresol:10~
    {!40000|Att_contlinestyle Run:1}~
    {!40000|Att_graphindexrange Time:1,,0,,,,,0,30}
Reformdef: [Age,Activity]
Reformval: [Undefined,Age,Undefined,Undefined,1]
{!40000|Att_resultslicestate: [Run,49,Age,1,Time,5]}

Variable Contact_multiplier
Title: Contact Multiplier
Units: /day
Description: This is the number of times, per day, that the exposed skin is expected to come into contact with outdoor deposits of malathion and its metabolites.
Definition: sum(Activity_pattern_by_*Hours_of_activity*Contactrate, activity)/100
Nodelocation: 224,328,0
Nodesize: 48,24
Valuestate: 2,0,-23,1440,663,1,CDFP
Graphsetup: Distresol:20
Reformval: [Undefined,Age,Undefined,Undefined,1]
{!40000|Att_resultslicestate: [Time,6,Age,1,Sys_localindex('STEP'),1]}

Chance Hours_under_6
Title: Hours Under 2
Definition: dynamic(Lognormal(0.4,2), Lognormal(0.4,2))
Nodelocation: 312,40,1
Nodesize: 48,24
Windstate: 2,517,56,476,224
Valuestate: 2,0,-23,1441,664,1,SAMP
Graphsetup: {!40000|Att_contlinestyle Run:1}
Reformval: [Time,Undefined,2,Undefined,Undefined,0]
Chance Hours_2to6
Title: Hours 2 to 6
Definition: dynamic(Lognormal(1,1.5), Lognormal(1,1.5))
Nodelocation: 456,32,1
Nodesize: 48,24
Windstate: 2,517,56,476,224
Valuestate: 2,0,-23,1441,664,1,SAMP
Graphsetup: {!40000|Att_contlinestyle Run:1}
Reformval: [Time,Undefined,2,Undefined,Undefined,0]
{!40000|Att_resultslicestate: [Run,18,Time,1]}

Chance Hours_7_to_14
Title: Hours 7 to 14
Definition: dynamic(Lognormal(1,1.5), Lognormal(1,1.5))
Nodelocation: 568,32,1
Nodesize: 48,24
Windstate: 2,517,56,476,224
Valuestate: 2,0,-23,1441,664,1,SAMP
Graphsetup: {!40000|Att_contlinestyle Run:1}
Reformval: [Time,Undefined,2,Undefined,Undefined,0]
{!40000|Att_resultslicestate: [Run,18,Time,1]}

Chance Hours_15_to_65
Title: Hours 15 to 65
Definition: dynamic(Lognormal(0.75,1.99), Lognormal(0.75,1.99))
Nodelocation: 584,96,1
Nodesize: 48,24
Windstate: 2,517,56,476,224
Valuestate: 2,0,-23,1441,664,1,SAMP
Graphsetup: {!40000|Att_contlinestyle Run:1}
Reformval: [Time,Undefined,2,1,Undefined,0]
{!40000|Att_resultslicestate: [Run,18,Time,1]}

Chance Hours_over_65
Title: Hours over 65
Definition: dynamic(Lognormal(0.9,1.7), Lognormal(0.9,1.7))
Nodelocation: 688,64,1
Nodesize: 48,24
Windstate: 2,0,-23,1440,663
Valuestate: 2,0,-23,1441,664,1,SAMP
Graphsetup: {!40000|Att_contlinestyle Run:1}
Reformval: [Time,Undefined,2,1,Undefined,0]
{!40000|Att_resultslicestate: [Run,18,Time,1]}

Variable Va3
Definition: Dermal_dose/Animal_tox_derm
Nodelocation: 832,320,1
Nodesize: 48,24
Windstate: 2,102,90,476,224
Valuestate: 2,40,50,416,303,1,CDFP
Reformval: [Time,Age]
{!40000|Att_resultslicestate: [Time,2,Age,1,Sys_localindex('STEP'),1]~~}

Decision Times_moe
Title: times moe
Definition: [10,2,1,0.5]
Nodelocation: 792,216,1
Nodesize: 48,24
Windstate: 2,102,90,476,224
Valuestate: 2,40,50,416,303,0,MIDM

Close Inhalation2

Index Spray_method
Title: Spray Method
Units: g.a.i//ha
Description: Sparying Method
Objective Total_dose
Title: Total Dose
Units: mg/kg/day
Definition: Dermal_dose+Inhaled_dose+total_ingested
Nodelocation: 624,320,0
Nodelocation: 744,224,0
Variable Animal_tox_tot
Title: Animal Toxic Endpoint (sum)
Units: mg/kg/day
Definition: Table(Age)(~5,5,25,25)
Nodelocation: 744,224,0
Nodelocation: 848,224,0
Variable Target_moe_tot
Title: Target MOE (sum)
Definition: Table(Age)(~1000,1000,1000,300,300)
Nodelocation: 848,224,0
Objective Population_above_ac3
Title: Total Dose > Target MOE
Units: %

Description: This expression will return a value larger than zero if A

NY of the cases exceeds the acceptable risk level.

Definition: 100*Probability((total_dose>(Animal_tox_tot/Target_moe_tot))

Nodelocation: 800,320,1
Nodesize: 92,24
Nodeinfo: 1,1,1,1,1,1,1,,0, Windstate: 2,102,90,476,224
Valuestate: 2,117,52,843,580,1,MIDM
Aliases: Formnode Total_dose_above_target_
Graphsetup: Graphtool:0~
Distresol:1~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsize:6~
Linestyle:1~
Frame:2~
Grid:3~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:30~
Yminimum:0~
Ymaximum:4~
Zminimum:1~
Zmaximum:5~
Xintervals:8~
Yintervals:4~
Includezzero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,0,0,0]~
Probindex:[0.05,0.25,0.5,0.75,0.95]~

Nodelocation: 48,24
Nodesize: 48,28
Index Spray_area
Title: Spray Area
Definition: ['Whole','Half']
Nodelocation: 48,24
Nodesize: 48,28

Index Total_dose_inputs
Title: Total Dose Inputs
Definition: Table(Self)~
Dep70_140,Dep140_210,Dep210_280,Dep280_350,Area_sprayed,Dep350_420,Dep420_490,Halflife,Sprayschedule,Resid24hr,Residovernight,Adep150,Adep150_300,Adep300_450,Adep450_600,Leaf_area_index_foli,Leaf_area_index_turf,Area_of_foliage,Area_of_structure,Area_of_paving,Area_index_of_struct,Wgt_4,Dispersion_layer,Xperiod,Volinhaled,Inhaled_ab_rate,Massofsoilingested,Massofsoilingestedad,Area_of_grass_ingest,Mass_of_berry1,Berry_weight1,Hand_surface_area,Saliva_extraction,Hand_to_mouth_events,Extractable_foliage,Extractable
bycontact,Exposed,Extractable_turf,Fraction_transferral1,Contactrate)
Indexvals: ['Deposition 70-140 m', 'Deposition 140-210 m', 'Deposition 210-280 m', 'Deposition 280-350 m', 'Area Sprayed', 'Deposition 350-420 m', 'Half life', 'Spray schedule', '24 hour residue', 'Morning after residue', 'Deposition 0-600m downwind', 'Deposition 600m-1200m downwind', 'Deposition 1200-1500m downwind', 'Leaf Area Index Foliage', 'Leaf Area Index Turf', 'area of trees', 'area of structures', 'area of pavement', 'area index of structures', 'Weight dist. 15-65', 'Weight dist. < 2', 'Weight dist. 7-14', 'Weight dist. >65', 'Height dist. 2-6', 'Surface Area < 2', 'Surface Area 2-6', 'Height dist 7-14', 'Surface area 7-14', 'Height dist 15-65', 'Surface area 15-65', 'Height dist > 65', 'Surface area > 65', 'Dispersion layer', 'Exposure period', 'Volume inhaled per hour', 'Inhaled Absorption rate', 'Mass of soil in gested accidentally by children', 'Mass of soil ingested accidentally by adolescents & adults', 'Area of grass ingested', 'Berry consumption number', 'Berry weight', 'Area of lettuce ingested', 'tomato consumption number', 'tomato weight', 'Area of grass ingested', 'Berry consumption number', 'Berry weight', 'Area of lettuce ingested', 'tomato consumption number', 'tomato weight', 'Hand surface area', 'saliva extraction', 'hand to mouth events per hour', 'Extractable fraction (foliage)', 'Extractable fraction (turf)', 'Fraction transferrable from surfaces', 'Contact hours']

Variable Total_dose_importance
Title: Key determinants of dose
Definition: Abs( RankCorrel( Total_dose_inputs, Total_dose ) )
Nodelocation: 624,400,1
Nodesize: 84,28
Valuestate: 1,72,82,1134,763,0,1,MIDM
Aliases: Formnode Total_dose_importance1
Nodelcolor: 19661,
Graphsetup: Graphtool:0-
Distresol:1-
Diststeps:1-
Cdfresol:5-
Cdfsteps:1-
Symbolsize:6-
Linestyle:1-
Frame:1-
Grid:1-
Ticks:1-
Mesh:1-
Scales:1-
Rotation:45-
Tilt:0-
Depth:70-
Chance Half_life
Title: half life
Units: days
Definition: \[0.5,1,2,3,4,8,16,\lognormal(0.7,2.8),\lognormal(2,2),\lognormal(1,2.5)]
Nodelocation: 312,424,0
Nodesize: 72,24
Windstate: 1,102,90
Valuestate: 1,276,116,862,489,0,STAT

Chance Frx2
Title: double spray
Definition: Dynamic(Spray2,(Spray2+(If (Spray2[Time-1]=1) Then (Frx2[Time-1]*Residovernight) Else (Frx2[Time-1]*Resid24hr))))
Nodelocation: 312,216
Nodesize: 72,24
Valuestate: 1,281,65,756,500,1,MIDM
Reformval: [Time,Half_life]
Variable Spray4
Definition: Table(Time)(~
1,0,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0)
Nodelocation: 80,264
Nodesize: 72,24

Variable Spray8
Definition: Table(Time)(~
1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0)
Nodelocation: 80,312
Nodesize: 72,24
Defnstate: 1,168,178,482,523,0,MIDM

Variable Spray1
Units: none
Description: spray schedule with single application
Definition: Table(Time)(~
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0)
Nodelocation: 80,168
Nodesize: 72,24

Chance Frx1
Title: single spray
Description: decay dynamics for single spray
Dynamic(Spray1,(Spray1+(Frx1[Time-1]*Exp((-(Ln(2)/Halflife))))))
Definition: Dynamic(Spray1,(If (Spray1[Time-1]=1) Then (Frx1[Time-1]*Residovernight) Else (Frx1[Time-1]*Resid24hr))))
Nodelocation: 312,168
Nodesize: 72,24
Windstate: 1,271,112
Valuestate: 1,356,237,646,427,0,MIDM
Reformval: [Time,Half_life]

Chance Frx4
Title: quad spray
Definition: Dynamic(Spray4,(Spray4+(If (Spray4[Time-1]=1) Then (Frx4[Time-1]*Residovernight) Else (Frx4[Time-1]*Resid24hr))))
Nodelocation: 312,264
Nodesize: 72,24
Valuestate: 1,104,114,756,500,1,MIDM
Reformval: [Time,Half_life]

Chance Frx8
Title: oct spray
Definition: Dynamic(Spray8,(Spray8+(If (Spray8[Time-1]=1) Then (Frx8[Time-1]*Residovernight) Else (Frx8[Time-1]*Resid24hr))))
Nodelocation: 312,312
Nodesize: 72,24
Valuestate: 1,301,156,830,641,1,DEFA
Reformval: [Time,Half_life]

Chance Halflife
Title: Half life
Units: days
Definition: Choice(Halflife,10)
Nodelocation: 312,24
Nodesize: 92,24
Windstate: 1,56,66
Valuestate: 1,376,386,416,303,0,MIDM
Aliases: Formnode Halflife1

Index Spray_models
Title: Spray Models
Definition: [1,2,4,8]
Nodelocation: 464,432
Nodesize: 72,24

Objective Spray_schedule
Title: Residue in the Environment
Definition: (If (Sprayschedule=1) Then Frx1 Else (If (Sprayschedule=2) Then Frx2 Else (If (Sprayschedule=4) Then Frx4 Else Frx8)))

Nodelocation: 576,192,1
Nodesize: 76,36
Windstate: 1,440,450
Valuestate: 1,131,146,1034,587,0,MIDM
Reformval: [Half_life,Time]
Numberformat: 1,%,4,1,0,0

Chance Sprayschedule
Title: Spray schedule
Units: events
Definition: Choice(Spray_models,3)
Nodelocation: 576,56
Nodesize: 92,24
Valuestate: 1,376,386,416,303,0,MIDM
Aliases: Formnode Schedule1

Objective Riskinhalex
Title: Risk of inhalation exposure
Definition: (If (Sprayschedule=1) Then Spray1 Else (If (Sprayschedule=2) Then Spray2 Else (If (Sprayschedule=4) Then Spray4 Else Spray8)))
Nodelocation: 576,264,1
Nodesize: 76,32
Windstate: 1,184,194
Defnstate: 1,168,179,504,643,0,MIDM
Valuestate: 1,72,82,618,716,1,MIDM

Objective Riskingestx
Title: Risk of ingestion/dermal exposure
Description: Spray is applied at dusk and the risk of dermal and ingestion is minimal until the following day.
Definition: 1
Nodelocation: 576,336,1
Nodesize: 76,36
Windstate: 1,152,162
Defnstate: 1,168,179,504,643,0,MIDM
Valuestate: 1,456,466,416,303,0,MIDM

Chance Resid24hr
Title: 24 hour residue
Definition: Exp(-((Ln(2)/Halflife))
Nodelocation: 392,88
Nodesize: 72,24
Windstate: 1,328,338
Valuestate: 1,456,466,416,303,0,MIDM

Chance Residovernight
Title: Morning after residue
Definition: Exp(-((Ln(2)*0.33)/Halflife))
Nodelocation: 232,88
Nodesize: 72,24
Windstate: 1,245,587
Valuestate: 1,472,482,416,303,0,MIDM

Chance Frx3
Title: Table 4
Description: decay dynamics for single spray
Dynamic(Spray1,(Spray1+(Frx1[Time-1]*Exp((-Ln(2)/Halflife)))))
Definition: Dynamic(Spray1,(If (Spray1[Time-1]=1) Then (Frx3[Time-1]*Residovernight) Else (Frx3[Time-1]*Resid24hr)))
Nodelocation: 80,32
Nodesize: 72,24
Valuestate: 1,356,237,856,520,0,MIDM
Reformval: [Half_life,Time]

Alias Va2
Title: Va1
Definition: 1
Nodelocation: 112,64,1
Nodesize: 48,24
Nodeinfo: 1,1,1,1,1,1,0,0,0,0
Original: Va1

Close Temporal_aggregation

Objective Depositedmalathion
Title: Deposited Malathion at a given location
Units: mg/m^2
Description: multiplier for application rate
Definition: if Spray_method_choice = 'Ground' then ar*Deposition_ground
*Spray_schedule else~
ar*Deposition_air*Spray_schedule
Nodelocation: 528,264,0
Nodesize: 64,28
Nodeinfo: 1,1,1,1,1,1,1,,0,
Windstate: 2,102,90,476,224
Defnstate: 2,304,52,416,303,0,MIDM
Valuestate: 2,0,23,1441,664,1,PDFP
Aliases: Alias Malathion_at_a_given, Alias Malathion_inside_imm
Graphsetup:{!40000|Att_graphvaluerange Depositedmalathion:1,,0,,,,,0,~~
3}~
{!40000|Att_contlinestyle Graph_pdf_valdim:6}~
Graphtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsze:6~
Linelstyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0~
Xmaximum:100~
Yminimum:0~
Ymaximum:2~
Zminimum:1~
Zmaximum:5~
Xintervals:0~
Yintervals:0~
Includezero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1, 1, 1, 1, 1, 0, 0, 0 ]~
Probindex:[0.05, 0.25, 0.5, 0.75, 0.95 ]~
{!40000|Att_contlinestyle Run:1}
Nodefont: Helvetica, 14
Reformval: [Time,Undefined,Undefined,Undefined,1,2]
{!40000|Att_resultslicestate: [Time,2,Sys_localindex('STEP'),1]}

Decision Ar
Title: Application Rate
Units: mg/m^2
Description: Aerial ULV 496.6 - 642.7 g a.i./ha - but the maximum rate~~
rate when bystanders and cars are present is only 233g ai/ha. We hav~~
e used this lower figure as the maximum of our application rate.~~
Ground ULV 26.0-60.8 g a.i./ha~
uniform(26,60.8)/10
Definition: ifall spray_method_choice = 'Ground' then uniform(26,60.8)~~
/10 else~
ifall spray_method_choice = 'Aerial' then uniform(150,233)/10 else~
uniform(26,60.8)/10
Nodelocation: 312,168,1
Module Area_index
Title: Model of deposition surfaces
Author: Hadi Dowlatabadi
Date: Wed, Jan 12, 2005 9:27 PM

Chance Leaf_area_index_foli
Title: Leaf Area Index Foliage
Units: m^2/m^2
Description: This beta distribution was specified to reflect data in the global LAI survey for tree cover in this region.
Definition: Beta(3, 2, 1.1, 8.8)

Chance Leaf_area_index_turf
Title: Leaf Area Index Turf
Units: m^2/m^2
Description: The building regulations of towns of approximately 50,000 inhabitants. Plot size 30x20m for single dwellings.
Max area of lot covered by building 25%.
Max allowable height of buildings 10m.
Paths and driveways Triangular(40,60, 80).
Range of arboreal cover 10-30%.
Remainder is assumed to be turf.
Definition: Beta(1.2, 3, 0.5, 5)

Decision Plotarea
Title: Plot area
Units: m^2
Description: The building regulations of towns of approximately 5,000 inhabitants. Plot size 30x20m for single dwellings.
Max area of lot covered by building 25%.
Max allowable height of buildings 10m.
Paths and driveways Triangular(40,60, 80).
Range of arboreal cover 10-30%.
Remainder is assumed to be turf.
Definition: 20*30
Description: This is the area of a given plot of land covered by trees~~

Definition: uniform(.1,.3)
Nodelocation: 352,32
Nodesize: 68,24
Windstate: 1,194,253

Chance Area_of_structure
Title: area of structures
Units: fraction
Description: Fraction of the plot covered by built structures. This is ~~~
limited to 25% in many municipalities in British Columbia (e.g., Chil~wack)
Definition: Triangular( 0.15, 0.2, 0.25 )
Nodelocation: 72,248
Nodesize: 68,24
Valuestate: 2,248,258,416,303,1,PDFP

Chance Area_of_paving
Title: area of pavement
Units: fraction
Definition: Triangular( .15, .2 , .25 )
Nodelocation: 232,104
Nodesize: 68,24
Valuestate: 2,152,162,416,303,0,STAT

Variable Area_of_turf
Title: Area of turf
Definition: (1-((Area_of_foliage-Area_of_structure)-Area_of_paving))
Nodelocation: 232,216
Nodesize: 68,24
Windstate: 2,371,297,476,224

Chance Area_index_of_struct
Title: Area index of structures
Units: m^2/m^2
Description: A structure has a height, a roof and sides. The surface a~~
rea of the structure is determined by the fraction of the plot area it~~
may occupy.~

A pitched roof is assumed, with a 30 deg pitch, and equivalent area 1~~
5% larger than the building footprint
Definition: (Area_of_structure)^.5*4*uniform(.3, .5)+1.15*Area_of_stru~~
cure
Nodelocation: 232,272
Nodesize: 68,24
Windstate: 2,376,40,476,224
Valuestate: 1,184,194,416,303,1,PDFP

Objective Cai
Title: inverse composite area index
Units: %
Description: This calculation determines the distribution of surface a~~
reas per projected surface area in our urban setting.~

This distribution can be used to calculate what fraction of applied pe~~
sticide is deposited on a unit area within the fogging zone, if all t~~
he material stayed within the intended spatial boundary.
Definition: 100/(Area_index_of_struct+Area_of_paving+(Area_of_turf*Lea~~
f_index_turf)+(Area_of_foliage*Leaf_area_index_foli))
Nodelocation: 472,248
Nodesize: 56,32
Windstate: 2,454,36,476,224
Valuestate: 1,293,49,639,531,1,CDFP
Graphsetup: Graphtool:0~
Distresol:100~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsize:6~
The spatial characteristics of this region is modeled after a typical town of 50,000 in British Columbia, following the regional building regulations and ecological/landcover characteristics.

Plot size for single family homes 20mx30m.
Max area covered by structures, 25%.
Max building height 10m.

The spatial grid over which these lots are organized includes streets & is 35x21m.
A town of 50,000, with 3 people per household, excluding a town center and non-residential buildings, will be 3500m square.

Module Spatial dispersion
Author: Negar Elmieh
Date: Nov 15, 2009 10:52 AM
Default size: 48,24
Node location: 360,408
Node size: 308,80
Node info: 1,0,0,1,0,0,1,,0,
Node font: Helvetica, 14

Close Area_index

Module Spatial aggregation
Title: Spatial aggregation
Author: Hadi Dowlatabadi
Date: Wed, Dec 29, 2004 8:05 PM
Default size: 72,24
Node location: 160,60,0
Node size: 112,36
Diag state: 1,13,8,953,643,17
Font style: Helvetica, 14

Chance Dep70-140
Title: Deposition
70-140 m
Units: %
Description: % of Application rate reaching this distance.
Definition: \((100 - \text{Dep0}\_70)\text{normal}(0.18, 0.04)\)
Nodelocation: 160,512
Nodesize: 76,24
Valuestate: 1,424,434,416,303,0,STAT

Chance Dep140\_210
Title: Deposition ~
140-210 m
Units: %
Description: % of Application rate reaching this distance.
Definition: \((100 - (\text{Dep0}\_70 + \text{Dep70}\_140))\text{normal}(0.18, 0.04)\)
Nodelocation: 160,472
Nodesize: 76,24
Valuestate: 1,456,466,416,303,1,PDFP

Chance Dep210\_280
Title: Deposition ~
210-280 m
Units: %
Description: % of Application rate reaching this distance.
Definition: \((100 - (\text{Dep0}\_70 + \text{Dep70}\_140 + \text{Dep140}\_210))\text{normal}(0.18, 0.04)\)
Nodelocation: 160,432
Nodesize: 76,24
Valuestate: 1,408,162,416,303,1,PDFP

Chance Dep280\_350
Title: Deposition ~
280-350 m
Units: %
Description: % of Application rate reaching this distance.
Definition: \((100 - (\text{Dep0}\_70 + \text{Dep70}\_140 + \text{Dep140}\_210 + \text{Dep210}\_280))\text{normal}(0.18, 0.04)\)
Nodelocation: 160,392
Nodesize: 76,24
Valuestate: 1,721,70,416,303,1,PDFP

Variable Depurbangrid45
Title: Deposition in 35m grid~
(Ground ULV)
Units: %
Definition: \(\text{dep0}\_70\text{cai}/100 + \text{Dep70}\_140 + \text{Dep140}\_210 + \text{Dep210}\_280 + \text{Dep280}\_350 + \text{Dep350}\_420 + \text{Dep420}\_490\)
Nodelocation: 448,512
Nodesize: 72,32
Windstate: 2,479,275,476,224
Valuestate: 1,553,158,677,584,1,CDFP
Graphsetup: Graphtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsize:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:20~
Xmaximum:60~
Yminimum:0~
Ymaximum:1~
Zminimum:1~
Text Te2
Description: We have assumed a spatial grid of roads 35 meters per half block. This defines the path of the fogging truck as being 0, 70, 140, 210, 280, 350, 420 and 490m from the point at the pesticide is released.

Published studies provide information on single pass deposition fractions over a variety of distances. These data suggest deposition rates between 1 and 5% of the application rate as far away as 490m away.

The area from 70 to 490 meters away is 6 times larger than the immediate spray area (0-70m). Deposition rates of 1-5% at that distance suggest local deposition between 70% and 94% of application rate [100%-x%], where x is 1% to 5%. Thus the local distribution of deposition is U(70%, 94%) and the drifted balance of applied pesticide is probabilistically assigned to various swaths from 70 to 490 meters away.

Variable: If only half the area
Title: Deposition pattern If half the area is sprayed
(Ground ULV)
Units: %
Description: distances 0-1750 are fogged. Distances up to 490m away from the boundary receive drifted pesticide.
Definition: If (Cross_spray_scale<1750) Then Depurbangrid45 Else If (Cross_spray_scale<1820) Then (Dep70_140+Dep140_210+Dep210_280+Dep280_350+Dep350_420+Dep420_490) Else If (Cross_spray_scale<1960) Then (Dep140_210+Dep210_280+Dep280_350+Dep350_420+Dep420_490) Else If (Cross_spray_scale<2100) Then (Dep210_280+Dep280_350+Dep350_420+Dep420_490) Else If (Cross_spray_scale<2240) Then (Dep280_350+Dep350_420+Dep420_490) Else If (Cross_spray_scale<2380) Then (Dep350_420+Dep420_490) Else If (Cross_spray_scale<2520) Then (Dep420_490) else 0

Text Te4
Description: WHAT IF ONLY 1/2 AREA IS TREATED?
If this is a town of 50,000 on a town that is square but with a lot of grid of 35mx21, it will be about 3500m on a side.

One half being fumigated means that 1750 will experience drifted deposition. The first row will be 70-140m away, the second, ... Finally, we assumed that homes more than 450m away from the border will...
Given the assumed grid structure we can assign exposure to each location.

**Title:** Scale perpendicular to drift

**Units:** m

**Description:** distances 0-1650 are fogged. distances 1650-2100 receive drifted pesticide. Beyond 2100 there is no incidental deposition.

**Definition:** Uniform(0, 3500)

**Objective Deposition**

**Title:** Deposition

**Definition:** (if area_sprayed = 'Whole' then Depurbangrid45 else if area_sprayed = 'Half' then If_only_half_the_are else Depurbangrid45/100)

**Chance Dep350_420**

**Title:** Deposition

**Units:** %

**Description:** % of Application rate reaching this distance.

**Definition:** (100-(Dep0_70+Dep70_140+Dep140_210+Dep210_280+Dep280_350))/normal(0.18,.04)

**Objective Comparing deposition**

**Title:** Comparison of Deposition Rates

**Units:** %

**Definition:** [Depurbangrid45, If_only_half_the_are]

**Indexvals:** ['Deposition in 35m grid', 'Deposition pattern If half the area is sprayed']
Chance Dep0_70
Title: Deposition ~
0-70 m
Units: %
Description: % of Application rate reaching this distance is being back calculated from the 1 to 5% deposited over an area beyond this distance that is 6 times larger. So, the maximum drift of 5% over 6 times larger area determines a lower bound of local deposition 100-30/6 = 70%.
The same is applied to determine the upper bound of local deposition (100% - 1% x 6 = 94%) ~
The remaining swaths then each take a share of whatever drifts off
Definition: Triangular( 70, 82, 94 )
Nodelocation: 160,560
Nodesize: 76,24

Close Spatial_aggregation

Module Spatial_aggregation1
Title: Spatial aggregation:~
Arial ULV
Author: Hadi Dowlatabadi
Date: Wed, Dec 29, 2004 8:05 PM
Defaultsize: 48,24
Nodelocation: 160,168,0
Nodesize: 112,36
Diagstate: 1,72,-15,939,652,17
Fontstyle: Helvetica, 14

Chance Adep150
Title: Deposition 0-150m Inside Swath
Units: %
Description: % of Application rate under the swath
Definition: Triangular( 50, 65, 80 )
Nodelocation: 208,544
Nodesize: 132,24
Windstate: 1,457,324
Valuestate: 1,200,210,522,303,1,CDFP
Graphsetup: Graphtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsize:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0.25~
Xmaximum:0.35~
Yminimum:0~
Ymaximum:20~
Zminimum:1~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Includexzero:0~
Includeyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,1,0,0,0]~
Probindex:[0.05,0.25,0.5,0.75,0.95]~

Chance Adep150_300
Title: Deposition ~
150-300m downwind
Units: %
Definition: ((100-Adep150)*Normal(0.35,0.08))
Nodelocation: 208,504
Nodesize: 132,24
Windstate: 1,745,290
Valuestate: 1,578,515,416,303,1,CDFP
Graphsetup: Graphtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsize:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0.4~
Xmaximum:0.8~
Yminimum:0~
Ymaximum:20~
Zminimum:1~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Includexzero:0~

219
Variable Fulltreatment
Title: Full treatment
Units: %
Description: Assuming drift up to 1200m away, on Average 35% of mass is deposited away from the swath flown.
Definition: Ca/100*
(If (Cross_spray_scale<150) Then Adep150 ~
Else (If (Cross_spray_scale<300) Then (Adep150+adep150_300) Else (If (Cross_spray_scale<450) Then (Adep150+adep150_300+adep300_450) ~
Else (if (cross_spray_scale<600) then (Adep150+Adep150_300+adep300_450+adep450_600)
Else if (cross_spray_scale<750) then ~(Adep150+Adep150_300+adep300_450+adep450_600+adep600_750)
Else if (cross_spray_scale<900) then ~(Adep150+Adep150_300+adep300_450+adep450_600+adep600_750+adep750_900)
Else if (cross_spray_scale<1050) then ~(Adep150+Adep150_300+adep300_450+adep450_600+adep600_750+adep750_900+adep900_1050)
Else ~(Adep150+Adep150_300+adep300_450+adep450_600+adep600_750+adep750_900+adep900_1050+adep1050_1200)
))))))
Nodelocation: 488,544
Nodessize: 72,28
Windstate: 1,607,241
Valuestate: 1,344,354,679,460,1,CDFP
Graphsetup: Graphtool:0
Distresol:10
Diststeps:1
Cdfresol:5
Cdfsteps:1
Symbolsize:6
Linestyle:1
Frame:1
Grid:1
Ticks:1
Mesh:1
Scales:1
Rotation:45
Tilt:0
Depth:70
Frameauto:1
Showkey:1
Xminimum:0.05
Xmaximum:0.3
Yminimum:0
Ymaximum:4000
Zminimum:1
Zmaximum:1
Xintervals:0
Yintervals:0
Includexzero:0
Includeyzero:0
Includezzero:0
Statsselect:[1,1,1,1,0,0,0]
Probindex:[0.05,0.25,0.5,0.75,0.95]

Text Te5
Description: The model uses EPA Standard Operating Procedures and observations for calibration.
Aircraft height = 100m
Swath width = 150m
Observed drift 300m from edge of swath = ~35%~
~
Thus we assume the area immediately below the swath receives ~65% of ~
intended application rate.~
~
We use the same basic formulation as the ground ULV. ~

Variable Partial treatment
Title: Partial Treatment
Units: %
Description: 1750 of 3500 gets drift. The drift plume is~
1200m from the 1750 boundary.
Definition: (If (Cross_spray_scale<1750) Then Fulltreatment Else ((Cai~~
/100)*((If (Cross_spray_scale<1900) Then (((Adep150_300+Adep300_450~~
)+Adep450_600)+Adep600_750)+Adep750_900)+Adep900_1050)+Adep1050_1200)~~
Else (If (Cross_spray_scale<2050) Then (((Adep300_450+Adep450_600)~~
+Adep600_750)+Adep750_900)+Adep900_1050)+Adep1050_1200) Else (If (Cro~~
ss_spray_scale<2200) Then (((Adep450_600+Adep600_750)+Adep750_900)+A~~
dep900_1050)+Adep1050_1200) Else (If (Cross_spray_scale<2350) Then (((~~
(Adep600_750)+Adep750_900)+Adep900_1050)+Adep1050_1200) Else (If (Cro~~
s_spray_scale<2500) Then (((Adep750_900)+Adep900_1050)+Adep1050_1200) E~~
lse ((If (Cross_spray_scale<2650) Then (Adep900_1050+Adep1050_1200) El~~
se Adep1050_1200))))))

Objective Deposition_air
Title: Deposition
Definition: ((If (Area_sprayed='Whole') Then Fulltreatment Else (If (A~~
rea_sprayed='Half') Then Partialtreatment Else Fulltreatment))/100)

Alias Scale_perpendicular
Title: Scale perpendicular to drift
Definition: 1

Chance Adeps
Title: Deposition~
450-600m downwind
Units: %
Description: % of Application rate reaching this distance.
Definition: (((100-((Adep150+Adep150_300)+Adep300_450))*Normal(0.35,0.0~~
8))

Text Te6
Description: WHAT IF ONLY 1/2 AREA IS TREATED?
If this is a town of 50,000 on a town that is square but with a lot g~~
rid of 35m21, it will be about 3500m on a side.~
One half being fumigated means that 1750 will experience drifted d~~
position. The first row will be 0-600m away, and so on. up to 1500 a~~
way.

Objective Deposition_air
Title: Deposition
Definition: ((If (Area_sprayed='Whole') Then Fulltreatment Else (If (A~~
rea_sprayed='Half') Then Partialtreatment Else Fulltreatment))/100)

Valuestate: 1,264,274,655,494,1,CDFP

Alias Scale_perpendicular
Title: Scale perpendicular to drift
Definition: 1

Valuestate: 1,264,274,655,494,1,CDFP
Objective Comparing areal depositions
Title: Full vs. Partial Areal Spray Deposition Fractions
Units: %
Definition: [Full treatment, Partial treatment]
Indexvals: ['Full treatment', 'Partial Treatment']
Nodelocation: 736,432
Nodesize: 60,36
Valuestate: 1,152,162,831,676,1,CDFP

Alias Area_sprayed2
Title: Area Sprayed
Definition: 1
Nodelocation: 728,608
Nodesize: 72,24
Original: Area_sprayed

Chance Adep300_450
Title: Deposition ~ 300-450m downwind
Units: %
Definition: ((100 - (Adep150 + Adep150_300)) * Normal(0.35, 0.08))
Nodelocation: 208,464
Nodesize: 132,24
Windstate: 1,731,367
Valuestate: 1,797,378,416,303,1,CDFP

Graphsetup: Graphtool:0~
Distresol:10~
Diststeps:1~
Cdfresol:5~
Cdfsteps:1~
Symbolsze:6~
Linestyle:1~
Frame:1~
Grid:1~
Ticks:1~
Mesh:1~
Scales:1~
Rotation:45~
Tilt:0~
Depth:70~
Frameauto:1~
Showkey:1~
Xminimum:0.4~
Xmaximum:0.8~
Yminimum:0~
Ymaximum:20~
Zminimum:1~
Zmaximum:1~
Xintervals:0~
Yintervals:0~
Yintervals:0~
Includefxzero:0~
Inclideyzero:0~
Includezzero:0~
Statsselect:[1,1,1,1,0,0,0]~
Probindex:[0.05,0.25,0.5,0.75,0.95]~

Chance Adep600_750
Title: Deposition ~ 600-750m downwind
Units: %
Definition: ((100 - (((Adep150 + Adep150_300) + Adep300_450) + Adep450_600)) * Normal(0.35, 0.08))
Nodelocation: 208,384
Nodesize: 132,24
Windstate: 1,657,475
Valuestate: 1,376,386,416,303,0,STAT
Chance Adep750_900
Title: Deposition
750-900m downwind
Units: %
Description: % of Application rate reaching this distance.
Definition: \( (100 - ((A_{dep150} + A_{dep150_300}) + A_{dep300_450} + A_{dep450_600}) + A_{dep600_750}) \times \text{Normal}(0.35, 0.08)) \)
Node location: 208,344
Node size: 132,24
Value state: 1,376,386,416,303,0, STAT

Chance Adep900_1050
Title: Deposition
900-1050m downwind
Units: %
Description: % of Application rate reaching this distance.
Definition: \( (100 - (((A_{dep150} + A_{dep150_300}) + A_{dep300_450}) + A_{dep450_600}) + A_{dep600_750} + A_{dep750_900}) \times \text{Normal}(0.35, 0.08)) \)
Node location: 208,304
Node size: 132,24
Wind state: 1,488,286
Value state: 1,376,386,416,303,0, STAT

Chance Adep1050_1200
Title: Deposition
1050-1200m downwind
Units: %
Description: % of Application rate reaching this distance.
Definition: \( (100 - (((((A_{dep150} + A_{dep150_300}) + A_{dep300_450}) + A_{dep450_600}) + A_{dep600_750}) + A_{dep750_900}) + A_{dep900_1050}) \times \text{Normal}(0.35, 0.08)) \)
Node location: 208,264
Node size: 132,24
Value state: 1,376,386,416,303,0, STAT

Close Spatial_aggregation

Close Spatial_dispersion

Module Spray_frequency
Title: Spray Frequency
Author: NegarElmieh
Date: Nov 15, 2008 10:52 AM
Default size: 72,32
Node location: 312,344,1
Node size: 88,28

Variable Va1
Node location: 160,80,1
Node size: 72,32
Node info: 1,1,1,1,1,1,0,0,0,0
Aliases: Alias Va2

Close Spray_frequency

Close Malation_in_the_envi

Close Environmental___pest

Close Model1

Formnode Total_dose__target
Title: Total Dose > Target MOE
Definition: 1
Node location: 784,392
Node size: 200,24
Node font: Helvetica, 14
Original: Population_above_ac3

Formnode Total_dose1
Function Gaussian(meanVec : numeric[I],covar : numeric[I,J]; I,J:IndexType)
Title: Gaussian
Description: A multi-variate Gaussian distribution based on a mean vector and covariance matrix. The covariance matrix must be symmetric and positive-definite. The mean vector is indexed by I. The covariance matrix is 2-D, indexed by I & J. Indexes I & J should be the same length.

Definition: var S := Decompose(covar,I,J);~
var U := ifall J then 0 else 0;~
var Z := Normal(U,1);~
sum(S*Z,J) + meanVec

Nodelocation: 104,56,1
Nodesize: 48,24
Windstate: 2,36,128,486,314
Paramnames: meanVec,covar,I,J

Function Dirichlet(alpha : Numeric[I]; I:IndexType)
Title: Dirichlet
Description: A Dirichlet distribution with parameters alpha_i>0.
Each sample of a Dirichlet distribution produces a random vector whose elements sum to 1. It is commonly used to represent second order probability information.

The Dirichlet distribution has a density given by

\[ k \prod_{i} x_i^{\alpha_i-1} \]

where k is a normalization factor equal to:

\[ k = \frac{\GammaFn(\text{sum}(\alpha,I))}{\text{Sum}(\GammaFn(\alpha),I)} \]

The parameters, alpha, can be interpreted as observation counts. The mean is given by the relative values of alpha (normalized to 1), but the variance narrows as the alphas get larger, just as your confidence in a distribution would narrow as you get more samples.

The Dirichlet lends itself to easy Bayesian updating. If you have a prior of alpha0, and you observe N
Definition: var a:=Gamma(alpha);~
a/sum(a,I)

Nodelocation: 232,56,1
Nodesize: 48,24
Windstate: 2,26,18,900,615
Paramnames: alpha,I

Function BiNormal(MeanVec : numeric[I]; Sdeviations : positive[I]; I:IndexType; correlationCoef : numeric atomic)
Title: BiNormal
Description: A 2-D Normal (or Bi-variate Gaussian) distribution with the indicated individual standard deviations (>0) and the indicated correlation coefficient. The index, I, must have exactly 2 elements, Sdeviations must be indexed by I.

Definition: if size(I)<>2 then ~
Error("Index to BiNormal must have 2 elements")~
else~

var s := product(Sdeviations,I) * correlationCoef;~
Index J:=CopyIndex(I);~
Gaussian( meanVec, if I<>J then s else Sdeviations^2 , I,J )

Nodelocation: 360,56,1
Nodesize: 48,24
Windstate: 2,2,24,525,540
Paramnames: MeanVec,Sdeviations,I,correlationCoef

Function SampleCovariance(X ; I,J,R : IndexType)
Title: Sample Covariance
Description: Returns a covariance matrix based on the sampled data, X, indexed by I and R. (I is the dimensionality of X, R corresponds to the samples). The result will be indexed by I and J -- supply J to be the same length as I.

~
Note that the mean is simply \[ \text{Average}(X,R) \], and doesn’t warrant a separate function.

**Definition:** \[ Z := X - \text{Average}(X,R) \]

\[ \text{sum}(Z^2[I=J,R]/(\text{size}(R)-1) \]

**Nodelocation:** 104,136,1
**Nodessize:** 48,24
**Windstate:** 2,26,277,476,304
**Paramnames:** X,I,J,R

**Function Multinomial(N:Positive ; theta:Positive  ; I : IndexType)  
Title: Multinomial  
Description:** Returns the Multinomial Distribution.

The multinomial distribution is a generalization of the Binomial distribution to \( N \) possible outcomes. For example, if you were to roll a fair die \( N \) times, an outcome would be the number of times each of the six numbers appears. Theta would be the probability of each outcome, and index \( I \) is the list of possible outcomes. If theta doesn’t sum to 1, it is normalized.

Each sample is a vector indexed by \( I \) indicating the number of times the corresponding outcome (die number) occurred during that sample point. Each sample will have the property that \( \text{sum}(result, I) = N \).

**Definition:**

\[ Z := n \]
\[ \text{var } k := \text{size}(I); \]
\[ \text{var } j := \text{cumulate}(1,1) \text{ in } I \text{ do begin} \]
\[ \text{Index } I2 := j..k; \]
\[ \text{var } \theta2 := \text{Slice}(\theta, I, I2); \text{ /* unnormalized sub-process */} \]
\[ \text{var } p := \theta2/\text{sum}(\theta2, I2); \]
\[ \text{var } xj := \text{Binomial}(Z, p[I2=j]); \]
\[ z := z - xj; \]
end

**Nodelocation:** 472,56,1
**Nodessize:** 48,24
**Windstate:** 2,56,42,476,522
**Paramnames:** N,theta,I

**Function Correlate_dists(dists : samp[I,Run] ; rankcorrs : numeric array[I,J] ; I ,J : IndexType )  
Title: Correlate Dists  
Description:** Reorders the samples in dists so as to match the desired rank correlations between distributions as closely as possible. Rankcorrs must be positive definite, and the diagonal should contain all ones.

The result will be distributions having the same margins as the original input, but with rank correlations close to those of the rankcorrs matrix.

**Definition:**

\[ \text{var } u := \text{Sample}(\text{Gaussian}(0, \text{rankcorrs}, I, J)); \]
\[ \text{var } dsort := \text{sortIndex}(\text{dists}, \text{Run}); \]
\[ \text{var } urank := \text{Rank}(u, \text{Run}); \]
\[ \text{dists}[\text{Run}=\text{dsort[Run=urank]}] \]

**Nodelocation:** 232,136,1
**Nodessize:** 48,24
**Windstate:** 2,315,33,494,399
**Paramnames:** dists,rankcorrs,I,J

**Function Correlate_with( S, referenceS : samp ; rankcorr : numeric )  
Title: Correlate With  
Description:** Reorders the samples of \( S \) so that the result is correlated with the reference sample with a rank correlation close to rankcorr.

**Example:** To generate a logNormal distribution that is highly correlated with Ch1, use, e.g.,:

\[ \text{Correlate_with( LogNormal(2,3), Ch1, 0.8 )} \]

**Definition:**

\[ \text{Index } q := 1..2; \]
\[ \text{var } u := \text{sample}(\text{binormal}(0, 1, q, \text{rankcorr })); \]
var rrank := Rank(referenceS, Run);
var u1sort := sortIndex(u[q=1], Run);
var u2rank := Rank(u[q=2], Run);
var ssort := sortIndex(S, Run);
S[Run=ssort[Run=u2rank[Run=u1sort[Run=rrank]]]]
Nodelocation: 352, 136, 1
Nodesize: 48, 24
Windstate: 2, 445, 194, 470, 272
Paramnames: S, referenceS, rankcorr

Close Multivariate_distrib

Close Wnv_exposure