



CORE

Public Health Functions for BC

Evidence Review:

**Communicable Disease
(Vector-borne Disease
Management)**

**Population and Public Health
BC Ministry of Healthy Living and Sport**

This paper is a review of the scientific evidence for this core program. Core program evidence reviews may draw from a number of sources, including scientific studies circulated in the academic literature, and observational or anecdotal reports recorded in community-based publications. By bringing together multiple forms of evidence, these reviews aim to provide a proven context through which public health workers can focus their local and provincial objectives. This document should be seen as a guide to understanding the scientific and community-based research, rather than as a formula for achieving success. The evidence presented for a core program will inform the health authorities in developing their priorities, but these priorities will be tailored by local context.

This Evidence Review should be read in conjunction with the accompanying Model Core Program Paper.

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EXECUTIVE SUMMARY

Introduction

The annual number of cases of vector-borne illness in British Columbia has not been fully documented but it is expected to be significant. Mosquitoes and ticks are the most important biting arthropods that transmit disease in the province.

In order to lower the number of cases of arthropod-borne illness in the community and the costs of such cases to society, a modern comprehensive Vector Management Strategy is necessary.

The key elements include

- **Surveillance** – including virus in mosquitoes, birds, and humans and bacterial surveillance in ticks.
- **Integrated Vector Management** – including prevention, personal protection, and control.
- **Public Education Programs** – both for the public and for health and vector management officials.

Mosquito-borne Disease Management

Effective prevention of human West Nile viral infections depends on the careful development of comprehensive, integrated arboviral surveillance and vector mosquito management programs in areas where the virus occurs.

Ideally, mosquito vector management programs, sometimes called public health mosquito control programs, should be based on already existing nuisance mosquito management programs. With experienced and knowledgeable staff and readily available equipment and materials, a nuisance control program can easily be enlarged to include disease vector mosquito species.

A multidisciplinary team to conduct surveillance is required. Trained personnel conduct mosquito surveys to identify the species that are present, track the population levels during the spring and summer, and determine appropriate management alternatives. Health authorities monitor for viral activity in people and other hosts. Larvae should be found, sampled, and identified (at least to genus, usually to species) and recorded in a GIS mapping system. Adult mosquito surveillance should be carried out to determine species distribution and relative population densities using special mosquito traps. Vector species surveillance may involve the collection of live female mosquitoes for virus isolation. Coincident with mosquito surveillance, virus surveillance should be carried out.

Mosquito Control Methods

To control mosquitoes effectively and long-term, vector management officials need to use several complementary, integrated mosquito management techniques, including the following:

- **Sanitation** – removing the mosquito's food, water and shelter.
- **Habitat Disruption** – draining the water where mosquitoes breed, especially in backyard breeding sites.
- **Biological Control** – using bacteria, including *Bacillus thuringiensis israeliensis* and *Bacillus sphaericus*.
- **Mechanical Control** – maintaining window screens and altering building designs.

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- ***Personal Protection*** – wearing light-coloured, loose-fitting clothing, using repellents, and avoiding activities in areas when mosquitoes are active.
- ***Insecticide Application*** – using insecticides against larval and adult mosquitoes, including methoprene, chlorpyrifos and malathion.

Integrated mosquito management (IMM) is an ecologically-based strategy that relies heavily on natural mortality factors and seeks out control tactics that are compatible with or disrupt these factors as little as possible. IMM uses pesticides, but only after systematic monitoring of pest populations indicates a need. Ideally, an IMM program considers all available control methods and materials, including no action, and evaluates the interaction among various control practices, cultural practices, weather and habitat structure. Thus, this approach uses a combination of resource management techniques to control mosquito populations with decisions based on surveillance.

Tick-borne Disease Management

Avoidance of tick-infested areas and personal protection (using repellents and protective clothing) should be encouraged. Landscape alterations may significantly reduce tick populations in some cases. Widespread tick control is not recommended. Specific applications of acaricides may occasionally be warranted where large numbers of people must be present in an area when ticks are active and there is a perceived risk of disease transmission (e.g., scout jamboree in a recreational area known to be infested with tick vectors).

Vector-borne Disease Prevention Programs

Public Education

The Public Health Agency of Canada assessed the public education efforts of the Ontario Ministry of Health and Long-term Care regarding West Nile Virus through a survey of Hamilton residents. The Agency's findings were "both reassuring and instructive." The public education program included brochures and television, radio and newspaper advertisements dealing with personal protection and removing backyard larval breeding sites. The Ontario Ministry of Health and Long-term Care also posted fact sheets on its websites. Most of the respondents to the questionnaire indicated that they were aware of the West Nile Virus problem and were following, or planning to follow, provincial advice on personal protection and yard clean-up.

Mosquito Management Programs

From an economic viewpoint, the indirect and direct costs associated with mosquito-borne disease outweigh the costs associated with public health interventions, including vector surveillance and control. The current weight of scientific evidence indicates that human health risks from residential exposure to mosquito insecticides are low and are not likely to exceed levels of concern. Malathion, as used in mosquito control programs, does not pose an unreasonable risk to people, wildlife or the environment. Malathion degrades rapidly in the environment, especially in moist soil. It displays low toxicity to birds and mammals. Further, results indicate that, based on human health criteria, the risks from West Nile Virus exceed the risks from exposure to mosquito insecticides.

Conclusion

Integrated vector management programs—based on a careful assessment of surveillance data and an analysis of risk factors—can be used by public health authorities to break disease transmission cycles, whether the disease organisms involved are mosquito- or tick-borne organisms. Public education programs and personal protective measures are critical components in the defence against these diseases. Vector management is used when necessary to prevent the build-up of known disease vector populations. The judicious use of pesticides may be a necessary response when there is a risk of an incipient epidemic.

1.0 OVERVIEW/SETTING THE CONTEXT

In 2005, the British Columbia Ministry of Health released a policy framework to support the delivery of effective public health services. The *Framework for Core Functions in Public Health* identifies communicable disease as one of the 21 core programs that a health authority provides in a renewed and comprehensive public health system.

The process for developing performance improvement plans for each core program involves completion of an evidence review used to inform the development of a model core program paper. These resources are then utilized by the health authority in their performance improvement planning processes.

This evidence review was developed to identify the current state of the evidence-based on the research literature and accepted standards that have proven to be effective, especially at the health authority level. In addition, the evidence review identifies best practices and benchmarks where this information is available.

1.1 An Introduction to This Paper

The purpose of this evidence paper is to provide public health officials across BC with a comprehensive overview of major arthropod-borne diseases in BC and the evidence of effectiveness of public health interventions in their management. This document is intended to be a resource for all public health practitioners who are involved in vector-borne disease prevention and management.

Emphasis is placed on those mosquito- and tick-borne diseases that pose the greatest threat to people in BC.ⁱ More than 800 species of blood-sucking ticks and 3,000 species of mosquitoes inhabit the planet. They are the leading arthropod vectors of human disease.

This document is organized, in part, to facilitate evaluation of the evidence provided. The information given in this document is based on peer-reviewed publications and expert opinion, as noted in the text.

Some diseases, like influenza, are spread directly from person to person. Many others are carried by mosquitoes, ticks, and other arthropod vectors. Almost every type of blood-feeding arthropod can serve as a carrier or as an intermediate host for some kind of disease agent. Most of these diseases occur only in wildlife or domestic animals but some can be transmitted to man (zoonoses).

ⁱ Rodent-borne diseases are not covered in this evidence paper.

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1.1.1 Vector-borne Diseases in BC

Various mosquito and tick-borne diseases have been reported in BC over the years:

- McLintock¹ provided an overview of mosquito-borne encephalitis in Canada, discussing Western equine encephalitis (WEE), Eastern equine encephalitis (EEE), and St. Louis encephalitis (SLE). He mentioned WEE occurring in BC.
- Reisen and Monath² refer to WEE occurring in BC. Belton^{3,4} mentions human cases of WEE, transmitted by *Culex tarsalis* mosquitoes, in BC during the 1970s.
- The occurrence of California encephalitis in the East Kootenay region of BC in the late-1960s was reported by McLean et al.^{5,6}
- SLE antibodies have also been found in moose, bull snakes and snowshoe hares in Alberta and in birds and small mammals in British Columbia^{7,8}
- Lyme disease has been found in ticks collected from many areas of BC. Health authorities now believe that ticks that carry *Borrelia burgdorferi*, the agent that causes Lyme disease, may be present throughout the southern and interior areas of the province. To date, there have been over 50 laboratory-confirmed cases of Lyme disease. Of these, about 40 per cent had no record of travel outside of the province and are considered to have contracted the disease in BC. Five to seven cases of Lyme disease in humans are diagnosed per year in BC.ⁱⁱ
- West Nile Virus (WNV) has not been detected in BC, but has been found in adjacent jurisdictions (Alberta, Montana, Idaho, Washington, Oregon) and substantial numbers of cases have occurred in the recent past in Montana (2007) and in Idaho (2006). West Nile Virus presents the greatest risk of vector-borne disease in BC.

1.1.2 Impact of Vector-borne Disease in BC

There are a number of costs associated with vector-borne disease. These can include direct and indirect costs:

- **Direct** – medical care (immediate and long-term), travel, investigation of illness complaints, management interventions and legal actions.
- **Indirect costs** – loss of productivity, loss of business, emotional loss due to pain, loss of leisure time and death.

According to Zohrabian et al.,⁹ the cost of vector-borne disease prevention is usually less than the cost of vector control after an epidemic begins. Emergency control is more expensive and there is also the added cost to treat the disease cases that might otherwise have been prevented. They estimated the total cost of the WNV epidemic in Louisiana in 2002 to be \$20.1 million.ⁱⁱⁱ In addition, the cost of WNV to the American equine industry may be in the billions of dollars.

ⁱⁱ See the BCCDC website at

<http://www.bccdc.ca/resourcematerials/newsandalerts/healthalerts/2008HealthAlerts/LymeDiseaseBC.htm>.

ⁱⁱⁱ For current dollar values, see Bank of Canada's 10-year Currency Converter at <http://www.bankofcanada.ca/en/rates/exchform.html>.

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According to Villari et al.,¹⁰ the cost of a single case of Eastern Equine Encephalitis can range from about \$21,000 for a mild, transient illness. The cost could be as high as \$3 million for individuals who suffer permanent neurologic damage. Similarly, the lifetime cost of a single case of severe LaCrosse encephalitis is estimated to range from \$48,000 to as much as \$3.1 million.¹¹ These numbers fail to address the additional emotional cost to families of victims of mosquito-transmitted disease, the victim's severely changed quality of life, and similar issues.

Unfortunately, no studies of the costs associated with vector-borne disease in BC were available for this paper. Some cases of vector-borne disease (e.g., WNV) obviously are or will be costly, both to the persons involved and to the health system in BC.

1.1.3 Biting Arthropods that Transmit Disease in BC

Mosquitoes and ticks are the most important biting arthropods that transmit disease in BC. These two groups of arthropods probably have a greater influence on human health and well-being throughout the world than any other arthropod group, because of the important diseases that they transmit and the annoyance they cause.¹²

Mosquitoes also have direct effects on people. Mosquito bites may itch for days, causing restlessness, loss of sleep and serious nervous irritation. Their saliva contains proteins that are alien to the human body and repeated mosquito bites may result in sensitivity to it. Mosquitoes can also cause serious economic loss by restricting outdoor activities.

In extreme cases, they have caused deaths of domestic animals, apparently due to the loss of blood or anaphylactic shock. Unprotected people in some areas of BC that are heavily-infested with mosquitoes may suffer tremendous anxiety while outdoors. Indirectly, both ticks and mosquitoes may cause disease through the organisms that they transmit while biting people.

1.1.4 Conclusion

Arthropod-borne illness is a significant risk in BC. The annual number of cases of vector-borne illness in BC has not been fully documented, but it is expected to be significant; even those vector-borne illnesses that are reportable to public health (e.g., Lyme disease) are under-reported for a variety of reasons, including physician lack of awareness. There is a clear gap in our knowledge of the annual number of cases of each disease and their respective costs.

In order to lower the number of cases of arthropod-borne illness in the community and the costs of such cases to society, a modern comprehensive Vector Management Strategy is necessary. Three key elements to a Vector Management Strategy are discussed in this document:

- ***Surveillance*** – including virus in mosquitoes, birds, and humans and bacterial surveillance in ticks.
- ***Integrated Vector Management*** – including prevention, personal protection, and control.
- ***Public Education Programs*** – both for the public and for health and vector management officials.

2.0 DESCRIPTIONS OF KEY ARTHROPOD-BORNE DISEASES

This section discusses the major mosquito- and tick-borne diseases known to occur in BC.

2.1 Mosquito-borne Diseases

There are over 2,500 different species of mosquitoes throughout the world. About 200 species occur in North America, with about 80 species occurring in Canada.¹³ Several of these mosquitoes are important vectors of disease in Canada. Belton¹⁴ lists the mosquito species that are present in BC.

2.1.1 West Nile Virus

West Nile Virus (WNV) moved into Ontario from New York state in 2001 and has, over the past five years, spread across most of southern Canada.¹⁵ For greater detail on this mosquito-borne disease, see the following organizations' websites:

- The U.S. Centers for Disease Control and Prevention (CDC): <http://www.cdc.gov/ncidod/dvbid/westnile/index.htm> .
- Health Canada: <http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/diseases-maladies/wnv-vno-eng.php>.
- HealthLink BC: <http://www.healthlinkbc.ca/healthfiles/pdf/hfile88.pdf>.
- The Public Health Agency of Canada: <http://www.phac-aspc.gc.ca/wn-no/index-eng.php>.

For frequently asked questions and answers about WNV, see the document, *West Nile Virus in BC, Questions and Answers - 2004 Season*.¹⁶ A thorough review of WNV was also published by the CDC.¹⁵

Disease Name

West Nile Virus was first identified in the West Nile region of Uganda, Africa in 1937, and after that, in Eastern Europe in the 1990s. It was first reported in North America in New York City in 1999. Since then, it has been identified in most of the United States and many parts of Canada. WNV has been a medical challenge in Canada since it was first found in Ontario in 2001.

In 2005, endemic WNV activity was observed in central and western Canada including Ontario, Quebec, Manitoba, Saskatchewan and Alberta.^{iv}

Viral activity levels were higher across Canada in 2005 compared with 2004 but less than the activity levels observed during the dramatic expansion of previous years. The increased number of deaths from WNV in Canada in 2005 as compared with 2004 was thought to be due to hotter weather and a related increase in infected mosquitoes. As of October 29, 2005, there were 172 confirmed human cases (12 fatal). In 2004, there were 16 cases (2 fatal). In 2003, there were 1,319 cases (12 fatal). In 2002, there were 340 cases (20 fatal).¹⁷

^{iv} See the full report at <http://www.bccdc.org/content.php?item=203>.

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The CDC reported similar incidences in 2004 and 2005 (2,344 and 2,775 cases respectively), a 4-fold decrease from 9,862 cases in 2003. Despite more moderate activity levels, the virus appeared earlier in Oregon in 2005 than it did in 2004 and spread as far north as Washington State, a region that had been without detectable virus activity since 2002. South of the 60th parallel, BC remains the only area of western North America without evidence of infection in avian, mosquito or human populations.

Causative Agent

West Nile Virus belongs to a group of viruses called Flaviviruses. This group includes about 70 viruses, half of which are associated with human disease. Some are mosquito-transmitted, while others are tick-transmitted. Others have no known arthropod host. The Flaviviruses include those that cause West Nile Virus, Yellow Fever, Dengue, Japanese Encephalitis and Tick-borne Encephalitis.

Besides humans, WNV has been known to infect horses, birds, cats, domestic rabbits, chipmunks, gray squirrels, striped skunks and bats. There have been no documented cases of one animal infecting another animal, or of an animal infecting a human.

Biting Arthropod Vector

West Nile Virus is transmitted mainly by mosquitoes. WNV has been isolated from more than 40 different mosquito species in North America, including 10 species occurring in Canada. The most important species involved in disease transmission in Canada include *Culex tarsalis*, *Culex restuans* and *Culex pipiens*. *Culex tarsalis* and *Culex pipiens* are found in BC but fortunately, these species are less common than the nuisance mosquito species. People can become infected if they are bitten by mosquitoes that have previously bitten infected birds. Even when WNV has been identified in an area, most mosquitoes do not carry the virus.

There are other less common ways that WNV may be spread, including blood transfusions, organ transplantation, transplacental transfer and breastfeeding. There is also some evidence that poultry workers exposed to a WNV outbreak among turkeys may have become infected with the virus, possibly through fecal matter.

Vector Control

Successful mosquito management requires an integrated approach, discussed in detail in Section 3. Mosquito traps are monitored throughout the summer to help provide regular, ongoing information on the risk of WNV.

The control of the mosquito vectors of WNV is discussed in several recent documents, including:

- *Epidemic/Epizootic West Nile Virus in the United States: Guidelines for Surveillance, Prevention, and Control.*¹⁸
- *Municipal Mosquito Control Guidelines* by Health Canada.¹⁹

2.1.2 Western Equine Encephalitis

Some arthropod-borne viral infections attack the central nervous system and cause inflammation of the brain, or encephalitis. In Canada, there are three major kinds of mosquito-borne encephalitis: western equine encephalitis (WEE); eastern equine encephalitis (EEE); and St. Louis encephalitis (SLE).²⁰ These diseases are usually transmitted between animal populations by mosquitoes and occasionally to people. Each of these diseases is discussed in the sections that follow.

Disease Name

Western equine encephalitis is a mosquito-borne, viral infection that affects the central nervous system of humans and horses, sometimes causing irreversible damage,²¹ commonly referred to as “sleeping sickness”.^v

Western equine encephalitis was, until the arrival of WNV in North America, the most important mosquito-borne disease in Canada. Localized outbreaks have occurred in BC several times during the past 75 years.

Causative Agent

The WEE virus belongs to the genus Alphavirus, in the family Togaviridae.²²

Biting Arthropod Vector

Culex tarsalis and *Culex pipiens* are the two most common mosquito-borne virus vectors in Canada. *Culex tarsalis* and *Ochlerotatus* (= *Aedes*) *dorsalis* are the main mosquito vectors for WEE virus, especially in western Canada.

Vector Control

Outbreaks of WEE can be predicted, usually allowing sufficient lead time (up to 7-10 days) to organize an emergency mosquito management program that is aimed at breaking the mosquito virus cycle.²³ Typically, this program will be limited to a mosquito adulticiding program. However, if time and resources permit, it may be supplemented by a mosquito larviciding program.

To successfully predict a disease outbreak, several variables must be monitored, including the following:²¹

- Local weather conditions as they relate to mosquito abundance and activity.
- Mosquito vector abundance as determined by standard mosquito collection methods.
- Incidence of virus in collected mosquitoes.
- Incidence of viral antibodies in sentinel chicken flocks.
- Incidence of horse cases within the province and in neighbouring states and provinces.
- Incidence of the disease in humans.

^v For detailed information on this disease, see <http://emedicine.medscape.com/article/233568-overview> (Accessed December 28, 2005).

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The last two variables have little predictive value. Horse cases may be low because most of the horses were vaccinated against the disease. As well, by the time human cases are diagnosed and confirmed, it is usually too late to control the mosquito vectors.

2.1.3 St. Louis Encephalitis

St. Louis encephalitis (SLE) is a rare and sporadic but important mosquito-borne disease in BC.^{vi}

Disease Name

St. Louis encephalitis was first recognized as a clinical disease in 1933 during an epidemic in the central United States that was centred on St. Louis, Missouri.²⁴ Localized outbreaks occur fairly often in the United States but rarely in Canada. Most cases in western Canada are travel-related. Very few cases are ever reported in the Pacific Northwest region of the United States.

Several reviews of SLE have been published in response to a widespread epidemic of this disease that occurred throughout eastern North America, including southern Ontario, in 1975.^{25,26,27,28,29} The 1979 review of the outbreak in southern Ontario by Mahdy, Spence and Joshua²⁶ is most relevant to Canada.

In 1975, 66 human cases of SLE (including 5 fatalities) were reported in southern Ontario.^{30,31} Single cases were reported in Quebec³² and Manitoba.³³ An additional four cases were detected in southern Ontario during 1976.³⁴

Since 1976, there have been no reported cases in Canada. In serological surveys of residents of southern Ontario, made within 12 months of the 1975 epidemic, only about 0.8 percent of those tested had antibodies to SLE (as detected by haemagglutination inhibition (HAI) tests³⁵).

In addition, neutralizing antibodies were found in residents of Saskatchewan¹, Alberta³⁶, and British Columbia⁷. These findings suggest that the SLE outbreak of 1975 was much more widespread than originally believed.

Causative Agent

St. Louis encephalitis is an RNA virus that is related to Japanese encephalitis, West Nile and Murray Valley virus.³⁷ Monoclonal antibody and neutralization tests may be required to confirm the presence of SLE antibodies.³⁸ Six strains of SLE virus are recognized.³⁹ The strains vary in their virulence.⁴⁰

The SLE virus is a member of the family *Togaviridae* and genus *Flavivirus*. The virus is thought to occur naturally in birds. It is transmitted among birds and between birds and other animals by blood-feeding mosquitoes.

The SLE virus is not known to cause disease in birds and, once infected, individual birds are immune to further infection. Significant quantities of the virus are evident in birds 1-2 days following infection, with viral levels falling rapidly 1-3 days later.

^{vi} Detailed information about this disease is available on the CDC website at <http://www.cdc.gov/sle/>.

Biting Arthropod Vector

Culex pipiens is the main urban vector of the SLE virus in Canada. *Culex tarsalis* is the main vector of SLE virus in rural areas of Canada, especially in the western provinces. Both species are potential vectors of SLE in BC.

Vector Control

Vectors of SLE can be controlled by following standard, integrated mosquito management practices (summarized in Section 3). Public health interventions involving large-scale aerial spraying for SLE vector management in Ontario in 1977 were described by Mahdy et al.²⁶

2.1.4 Malaria

Malaria is the most important mosquito-transmitted human disease throughout the world. In some developing countries, there is close to a 100 percent infection rate. Malaria is the leading cause of death in many countries, particularly for children.⁴¹ Fortunately, this disease is rare in temperate areas. The Canadian infectious disease surveillance system has reported an average of 538 malaria cases per year since 1990, and Statistics Canada reported an average of one death per year.⁴² Most cases diagnosed in BC involve travelers who have arrived or returned from countries where malaria is endemic.

Malaria was introduced into the United States in colonial days. It spread throughout the country as it was settled, being most common in the eastern, mid-western and southern states. In the early days, more than 100,000 cases were reported annually in North America. In recent years, only about 1,000 cases of malaria are reported annually in North America.

Over the past 40 years or so, there has been a resurgence of malaria in tropical and subtropical countries around the world. This has resulted from

- The termination of many malaria eradication programs in developing countries;
- The protozoans' evolving resistance to drugs;
- The mosquitoes' growing resistance to insecticides; and
- The creation of additional mosquito habitats around communities.

Most of the cases diagnosed in the United States and Canada are contracted overseas by North American travellers.^{43,44} Subsequent local transmission sometimes occurs in some southern states (e.g., migrant workers and nearby residents in California). Potentially, such transmission could occur in parts of southern Ontario and BC.

Disease Name

Malaria is a protozoan disease that is transmitted by certain mosquitoes. Infected mosquitoes inject the malaria parasite into the human bloodstream while blood-feeding. The parasite then reproduces asexually and ruptures blood cells. The parasite completes its sexual development in the next mosquito that has ingests blood from the infected human.

Causative Agent

The four protozoans that may be involved in malarial disease include *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae* and *Plasmodium ovale*.⁴⁵ The most common parasite is *Plasmodium vivax* and the most deadly is *Plasmodium falciparum*. The remaining two species, *Plasmodium malariae* and *Plasmodium ovale*, are less common and pose less danger to the victim. All of these parasites are transmitted from person to person by the bite of certain species of *Anopheles* mosquitoes.

Biting Arthropod Vector

There are more than 50 night-biting *Anopheles* species worldwide. In North America, there are at least 16 species of *Anopheles* present but only two species are known to be significant vectors of malaria: *Anopheles freeborni* and *Anopheles quadrimaculatus*. In BC, the following anopheline species are potential vectors of malaria (Dr. Peter Belton, personal communication): *Anopheles earlei*, *Anopheles freeborni*, and *Anopheles punctipennis*. Of these three species, *Anopheles freeborni* is the most likely species to be involved in malaria transmission in BC.⁴⁶

Vector Control

The need for control of malaria vectors in Canada is highly unlikely. It could only happen if someone, coming from abroad with an active case of malaria, were to be bitten by a local *Anopheles* mosquito. According to Dr. Robbin Lindsay (Public Health Agency, personal communication), malaria transmission within Canada would require the following series of events:

- Presence of a large population of infected reservoirs (infected travelers and immigrants).
- Substantive populations of *Anopheles* mosquitoes feeding on those individuals.
- Extended periods of warm weather (about 10 days with temperatures greater than 27°C) following mosquito feeding, for the protozoans to complete their development within the mosquitoes.
- Subsequent feeding of infective female *Anopheles* on susceptible human hosts.

Although it may be possible for all of these events to occur in some warmer areas of Canada (e.g., Windsor, southern BC), the probability is very low.

Instead of considering *Anopheles* control, it would be better to promote malaria prevention. Malaria prevention is everyone's responsibility.^{45,47}

- Educate international travelers to reduce their risk of exposure to malaria in the developing world.
- Encourage the travel industry to inform customers of the health risks they may face.
- Encourage pre-travel medical care.
- Educate physicians in assessing the health risks of travel.
- Encourage use of malaria prophylaxis before, during and after trips to risk areas.

2.1.5 Tularemia

Tularemia is a potentially serious infection that occurs naturally in Canada.^{vii}

Disease Name

Other names for tularemia include rabbit fever, deer-fly fever, Ohara disease, and Francis disease.⁴⁸

Causative Agent

Tularemia is caused by the bacterium *Francisella tularensis*. Animals acquire infection through tick, fly and mosquito bites and by contact with contaminated environments.¹²

Infected animals can transmit the infection to other animals by biting, scratching or by direct exposure to infected rodent waste or nesting materials contaminated with infected rodent waste.

Biting Arthropod Vector

Tularemia is transmitted to humans via ticks, flies, rodents and rabbits. Various authors emphasize the importance of the bites of various arthropods in the transmission of this disease.^{49,50} Mosquitoes, deer flies, horse flies, and stable flies—which may feed on small amounts of blood from several animals in succession—transmit the bacteria that cause tularemia by carrying these bacteria on their mouthparts from an infected host to an uninfected one. The insects themselves are not necessary steps in the life cycle of the bacteria.

Transmission may also occur mechanically, when hunters skin infected animals without due care. The most common means of transmission may be bacterial spread through the inoculation of skin, conjunctivae or oropharyngeal mucosa with infected blood or tissue while skinning, dressing or performing necropsies on animals.

Other modes of transmission include:

- Handling or ingestion of insufficiently cooked meat of infected rabbits or hares.
- Drinking contaminated water.
- Inhalation of dust from soil, grain or hay contaminated by infected rodents.
- Handling contaminated animal pelts.
- Bites of animals (cats, dogs, coyotes, skunks, hogs, squirrels) whose mouths have become contaminated from eating infected rabbits.

Vector Control

Prevention is the key to avoiding tularemia:¹²

- Handwashing, using soap and warm water, after handling wild or pet animals (live or dead) and after cleaning an animal cage or tank.

^{vii} For more detailed information, see the CDC website at: <http://www.bt.cdc.gov/agent/tularemia/index.asp> (Accessed January 25, 2006).

- Note any change in the behaviour of pets (especially rodents, rabbits and hares) or livestock, and consult a veterinarian if they develop unusual symptoms.
- Always wear gloves when disposing of dead animals (wild or domestic).
- Avoid tick bites while outdoors by wearing protective clothing when hiking in forested areas or when landscaping or doing lawn maintenance in areas with long grass.

2.2 Tick-borne Diseases

Ticks are among the most important of all arthropod vectors of disease. Worldwide, ticks are second only to mosquitoes in the number of diseases they transmit to humans. In North America, ticks are responsible for more human disease than any other group of arthropods.^{viii}

2.2.1 Lyme Disease

Lyme disease is one of several important tick-borne diseases.^{51,52} For greater detail on this disease, see the following organizations' websites:^{ix}

- Canadian Centre for Occupational Health and Safety, <http://www.ccohs.ca/oshanswers/diseases/lyme.html>.
- Ontario Health, <http://www.health.gov.on.ca/en/public/publications/disease/lyme.aspx>.
- Nova Scotia Health, <http://www.gov.ns.ca/hpp/cdpc/lyme.asp>.
- Manitoba Health, <http://www.gov.mb.ca/health/publichealth/cdc/fs/lyme.pdf>.

Disease Name

Other names sometimes used for Lyme disease include Lyme borreliosis, relapsing fever, Erythema chronicum migrans (ECM) with polyarthritis, Lyme arthritis, and tick-borne meningopolyneuritis.⁵¹

European physicians described a disease called erythema migrans (EM) in the early part of the 20th century. They associated this rash with the bite of ticks and postulated that it was caused by a tick-borne bacterium responsive to penicillin. EM was later diagnosed in a patient in Wisconsin in 1969 and successfully treated with antibiotics.

Causative Agent

Lyme disease is caused by the bacterium *Borrelia burgdorferi*, and is transmitted to humans by the bite of infected blacklegged ticks. Lyme disease was first recognized in the United States in 1975⁵³ following a mysterious outbreak of misdiagnosed juvenile rheumatoid arthritis, near the community of Lyme, Connecticut. Some of the people with Lyme disease became very sick, some were permanently disabled, and some died. The rural location of the Lyme outbreak and the onset of illness during summer and early fall suggested that the transmission of the disease was by an arthropod vector. They linked the presence of EM rash lesions to bites by ticks. They

^{viii} A good technical reference document on tick-borne disease is given at the Armed Forces Pest Management Board (US Department of Defense) website at <http://www.afpmb.org/pubs/tims/TG26/TG26.pdf>.

^{ix} Excellent coverage on Lyme disease is provided by the Public Health Agency of Canada (<http://www.phac-aspc.gc.ca/id-mi/lyme-fs-eng.php>) and the CDC in the United States (<http://www.cdc.gov/ncidod/dvbid/lyme/index.htm>).

also determined that early treatment with antibiotics not only shortened the duration of EM but also reduced the risk of subsequent arthritis.

In 1982, the etiologic agent of Lyme disease was discovered.⁵⁴ Burgdorfer isolated spirochetes (corkscrew-shaped bacteria) belonging to the genus *Borrelia* from the mid-guts of adult deer ticks, *Ixodes dammini* (referred to in this report as the blacklegged tick, *Ixodes scapularis*). Burgdorfer showed that these spirochetes reacted with immune serum from patients that had been diagnosed with Lyme disease. Microbiologists studied the bacterium's DNA and found that the bacterium had not been previously discovered.^x

Since the mid-1970s, Lyme disease has slowly spread across most of the United States and, to a much lesser extent, across southern Canada.⁵⁵⁻⁷¹ Considered a rapidly emerging disease, there are now approximately 15,000 new cases reported per year, mostly in the United States. In Canada, Ontario has the largest hot-spots for Lyme disease (centered on Point Pelee and, to a lesser degree, Thunder Bay). From 1981 to the end of 1998, a total of 280 human cases of Lyme disease were reported in Ontario. Of these cases, 127 patients had no history of out-of-province travel. Lunenburg County, Nova Scotia, is considered another hot-spot. There have also been scattered cases of Lyme disease in other regions of Canada, including southern BC.

Biting Arthropod Vector

Ixodes ticks are much smaller than the more common dog tick (*Dermacentor variabilis*).^{xi} In their larval and nymphal stages, they are no bigger than a pinhead. Adult ticks are slightly larger (about the size of a poppy seed). The nymphal ticks, which are most likely to feed on a person and are rarely noticed because of their small size, are usually involved in the transmission of Lyme disease.

The blacklegged deer tick (*Ixodes scapularis*) in eastern and central North America and its close relative the western blacklegged tick (*Ixodes pacificus*) on the Pacific Coast, are the two tick species most likely to transmit the Lyme disease spirochete to humans.^{xii}

Ixodes scapularis lives in grassy and wooded areas and normally feeds on small and large mammals (i.e., mice, shrews, birds, raccoons, cats, dogs, deer, horse and, occasionally, humans⁷²). Nymphs are most abundant during the spring and early summer, larvae during the summer and adults during the fall.

In those areas of North America where this disease is most prevalent, 10-65 percent of the *Ixodes scapularis* that are present may carry the spirochete. When an infected tick bites, the spirochete sometimes passes from the tick to the mammal being fed upon. The nymphal stage of the tick is more efficient than the adult tick in transmitting the spirochete.

^x The etiologic agent was given the name *Borrelia burgdorferi* in honour of its discovery by Burgdorfer.

^{xi} A blacklegged tick hatches from its egg as a light-tan, translucent larva (about the size of a period in newsprint), molts into a blackish nymph, and eventually molts a second time into a brick-red adult female (about the size of a sesame seed) or a black adult male (slightly smaller than the female).

^{xii} Note that Barker et al. (1992) isolated *Borrelia burgdorferi* from larval and nymphal *Ixodes dammini* (= *Ixodes scapularis*); and from nymphal and adult *Dermacentor variabilis*. An earlier study (Lindsay et al., 1991) did not isolate the spirochetes from the latter species.

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Borrelia burgdorferi invades the blood and tissues of various infected mammals and birds. The immature stages parasitize small mammals (e.g., white-footed mice, *Peromyscus leucopus*). The adult stage occurs on larger mammals (preferring the white-tailed deer, *Odocoileus virginianus*). There is a definite correlation between the number of white-tailed deer present in an endemic area and the incidence of Lyme disease.⁷³

The natural reservoir for *Borrelia burgdorferi* is thought to be the white-footed mouse. Ticks transfer the spirochetes to white-tailed deer, humans and other warm-blooded animals after a blood meal on an infected animal. In humans, dogs and many other animals, infection with *Borrelia burgdorferi* results in Lyme disease. In 1995, *Borrelia burgdorferi* was isolated from rabbit ticks, *Haemaphysalis leporispalustris*, in Alberta. The ticks were collected from an injured rabbit near Grand Prairie, Alberta.

In BC, many western blacklegged ticks have been collected from the southern part of the province and examined at the Provincial Laboratory. This tick is very common during the spring and early summer. It occurs on vegetation in warm, moist areas on Vancouver Island, the Gulf Islands, and along the mainland coast between the American border and Powell River. Its eastward range extends along the Fraser River to Yale and north to Boston Bar. *Borrelia burgdorferi* has been found in western blacklegged ticks collected from all areas checked, including Vancouver Island, the Gulf Islands, the Lower Mainland including the Fraser Valley, and the Sechelt Peninsula.^{xiii} However, the infection rates of *Ixodes pacificus* are much lower than those of *Ixodes scapularis*, ranging from 0.3-1.0 percent in BC.

To date, there have been about 54 confirmed cases of Lyme disease in BC. Most of the cases contracted their disease in Lyme-endemic parts of the world, particularly Europe. Less than half of the reported cases had no history of travel and likely contracted Lyme disease locally. These people were exposed in the central Interior, southern Okanagan, southeastern BC, Vancouver Island, the Lower Mainland, or the Gulf Islands (as far north as Cortez Island).

Vector Control

In addition to the use of pesticides, tick management is another option to control this vector.⁷⁴ Many tick management guides are available online.^{xiv} The various components are outlined in the sections that follow.

Sanitation

The number of ticks in endemic residential areas may be reduced by removing leaf litter, brush piles and woodpiles around houses and at the edges of yards. This is especially true with larger properties that include woodlots or are immediately adjacent to woodlots and with properties that have heavy plantings of ornamental shrubs and trees. Such a clean-up may also reduce the amount of suitable habitat for deer, rodents and ticks.

^{xiii} Note that *Borrelia burgdorferi* was also found in *Ixodes angustus* collected from mice in BC.

^{xiv} For example, see the Tick Management Handbook, produced by Connecticut Health, at <http://www.ct.gov/caes/lib/caes/documents/publications/bulletins/b1010.pdf>.

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Habitat Modification

Mow grass along trails, around buildings and in camping areas. In cottage areas, remove brush along trails or other areas of high human activity. In landscape shrubbery and other areas of the yard where close-cutting is not possible, the use of an approved insecticide will reduce tick populations.

Host Management

Community-based interventions to reduce deer populations or to kill ticks on deer and rodents have not been extensively implemented but may be effective in reducing community-wide risk of Lyme disease. The effectiveness of deer feeding stations equipped with insecticide applicators to kill ticks on deer and of other baited devices to kill ticks on rodents is currently under evaluation in the United States.

A treatment sometimes recommended in the United States is the use of a product called “Damminix”. This product consists of cardboard tubes containing cotton balls that have been dipped in insecticide (permethrin). These tubes are placed around the property in the wooded areas and below shrubs. Mice find the cotton and bring it back to their burrows to be used as nesting material, with the result being a decrease in the number of ticks in the area. After two years, the tick populations may rise again as other small animals that do not gather cotton become hosts to the ticks. Therefore, Damminix alone is not sufficient.

Bite Prevention

The Infectious Diseases Society of America *Practice Guidelines for Lyme Disease*⁷⁵ state that prevention remains the best approach for management of Lyme disease. The CDC recommend the following ways of preventing tick bites and Lyme disease:

- Avoid tick-infested areas, especially in May, June and July.
- Wear light-coloured clothing so that ticks can be spotted more easily.
- Tuck pant legs into socks or boots and shirt into pants or tape the area where pants and socks meet so that ticks cannot crawl under clothing.
- Spray insect repellent containing DEET on clothes and on exposed skin other than the face, or treat clothes (especially pants, socks and shoes) with permethrin, which kills ticks on contact.
- Wear a hat and a long-sleeved shirt for added protection.
- Walk in the center of trails to avoid overhanging grass and brush.
- After being outdoors, remove clothing and wash and dry it at a high temperature.
- Inspect body carefully and remove attached ticks with tweezers, grasping the tick as close to the skin surface as possible and pulling straight back with a slow steady force; avoid crushing the tick's body. In some areas, ticks (saved in a sealed container) can be submitted for identification.
- In households with pets, infestations are likely to occur in those areas where pets spend a great deal of time, such as shady sites.

Public Information Program

Lyme disease has been recognized for nearly 25 years. Since then, public awareness about the disease has increased but so has fear and misunderstanding. Therefore, people need to learn the facts in order to better understand how Lyme disease can be prevented and cured. As with any vector-borne disease, a public education program is an extremely important means of minimizing the fear, risk and spread of Lyme disease.

2.2.2 Rocky Mountain Spotted Fever

Rocky Mountain spotted fever (RMSF) is the most common fatal tick-borne disease in North America.^{xv}

Disease Name

Despite the name, this disease occurs most often in the eastern two-thirds of North America.¹² This wide-ranging disease has several names, including tick fever, tick-borne typhus fever, black fever, black measles, New World spotted fever and Mexican spotted fever. RMSF, like all rickettsial infections, is classified as a zoonosis. Ticks are the natural hosts, serving as both reservoirs and vectors of the rickettsial organism.

Causative Agent

Rickettsia rickettsii usually infects members of the tick family Ixodidae (hard ticks). These ticks have four stages in their life cycle: egg, larva, nymph and adult. After the eggs hatch, each stage must feed once to develop into the next stage. Both male and female ticks will bite.

Rickettsiae are transmitted to a vertebrate host through saliva while a tick is feeding. It usually takes about six hours of attachment and feeding before the rickettsiae are transmitted to the host. The risk of exposure to a tick carrying *Rickettsia rickettsii* is low.

In general, about 1-3 percent of the tick population carries *Rickettsia rickettsii*, even in areas where the majority of human cases are reported. Ticks can also become infected with *Rickettsia rickettsii* while feeding on blood from the host in either the larval, nymphal or adult stage. After an immature tick develops into the next stage, *Rickettsia rickettsii* may be transmitted to a second host during the feeding process. Furthermore, male ticks may transfer *Rickettsia rickettsii* to female ticks through body fluids or spermatozoa during the mating process. Once infected, a tick can carry the pathogen for life. A female tick can also transmit *Rickettsia rickettsii* to her eggs in a process called transovarial transmission.

Biting Arthropod Vector

Ticks transmit the organism to vertebrates primarily by their bite. Less commonly, infections may occur following exposure to crushed tick tissues, fluids or tick feces.

^{xv} For more detailed information, see the CDC website at http://www.cdc.gov/ticks/diseases/rocky_mountain_spotted_fever/.

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In Canada, two tick species may transmit this disease: the American dog tick (*Dermacentor variabilis*) may be involved east of the Rockies and the Rocky Mountain wood tick (*Dermacentor andersoni*) may be involved in BC.

The life cycle of the Rocky Mountain wood tick may be up to 2-3 years. The adult ticks feed primarily on large mammals. The larvae and nymphs feed on small rodents.

Vector Control

Ticks on private property, especially backyards, can be controlled with acaricides-insecticides, such as permethrin. Pets should be regularly inspected for ticks in order to keep them tick-free.

2.2.3 Tick-borne Relapsing Fever

Disease Name

Tick-borne relapsing fever was first recognized in North America in 1915.^{xvi} Tick-borne relapsing fever is caused by many species of *Borrelia* and is transmitted to humans by the soft *Ornithodoros* ticks. It is referred to as “endemic tick-borne relapsing fever” to distinguish it from “epidemic louse-borne relapsing fever”, which is caused by *Borrelia recurrentis* and is transmitted to humans by the body louse *Pediculus corporis*.

Causative Agent

Tick-borne relapsing fever is caused by a spirochete, *Borrelia hermsii*. It was first isolated in Canada in 1998, from the blood of three people from southern BC (West Kootenay, Okanagan Valley). Over the years, there have been approximately 40 documented cases; however, because of the possibility of misdiagnoses, this figure may under-represent the true number of cases.

Biting Arthropod Vector

The tick *Ornithodoros hermsi* is the known vector of *Borrelia hermsii* in eastern Washington and northern Idaho. Most human cases of tick-borne relapsing fever have been associated with log cabins or houses containing rodent nests (particularly of chipmunks and pine squirrels) and *Ornithodoros hermsi* ticks. This species of tick is active at night. Because it feeds rapidly and its bite is relatively painless, it may go unnoticed.

Vector Control

Thoroughly inspect cabins for rodents and nests. Promptly remove nests and treat the cabins with insecticides to kill any remaining ticks. Rodent-proof cabins to prevent subsequent rodent entry. Practice good sanitation procedures when handling rodent nests.

^{xvi} For more detailed information, see the CDC website at <http://www.cdc.gov/ncidod/dvbid/RelapsingFever/index.htm>.

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2.2.4 Colorado Tick Fever

Disease Name

Colorado tick fever (CTF), or mountain fever, is an acute viral dengue-like illness caused by a Coltivirus in the family Reoviridae. First described in 1850, CTF is the only common tick-transmitted viral disease in North America, occurring in areas above 1525 m in the mountains of Alberta and British Columbia in Canada.

Causative Agent

The causative agent, an RNA virus formerly classified as an Orbivirus of the family Reoviridae, is limited to *D. andersoni*. The International Committee on Taxonomy of Viruses has reclassified the agent of Colorado tick fever as a Coltivirus (still in the family of Reoviridae).

Biting Arthropod Vector

D. andersoni, which occurs in BC, is the key vector.

Vector Control

No actual control is recommended. Rather, the use of protective clothing and repellents are usually recommended.

3.0 MOSQUITO-BORNE DISEASE MANAGEMENT

Effective prevention of human West Nile viral infections depends on the careful development of comprehensive, integrated arboviral surveillance and vector mosquito management programs in areas where the virus occurs.^{76 xvii}

The 1999 New York epidemic demonstrated that, without sustained vector mosquito control in urban areas, even the world's most affluent cities are at risk for epidemic arboviral disease. The goal of these disease management programs should be to implement mosquito control early enough to prevent or decrease the risk of human infection with a mosquito-borne virus.

Ideally, mosquito vector management programs, sometimes called public health mosquito control programs, should be based on already existing nuisance mosquito management programs. With experienced and knowledgeable staff and readily available equipment and materials, a nuisance control program can easily be enlarged to include disease vector mosquito species.

The objectives of nuisance and public health mosquito control programs differ. The objective of nuisance mosquito control programs is to reduce mosquito annoyance to an acceptable level. The reduction of vector mosquito species may be an added benefit. The objective of public health mosquito control, on the other hand, is to prevent transmission of mosquito-borne diseases to humans. Populations of nuisance mosquitoes may also be reduced but that is not the primary objective.

Unfortunately, in many areas, there is insufficient local demand for ongoing nuisance mosquito management programs because there is no serious nuisance mosquito problem, the local population is too small, or the per capita costs are too high. In such cases, a public health intervention is required. Vector mosquitoes must then be controlled using licensed mosquito control contractors.

Mosquitoes can be controlled at two stages of their life cycle. Mosquitoes have four distinct stages during their life cycle: egg, larva, pupa and adult. The adult stage is free-flying, whereas the other immature stages are aquatic. The length of time that a mosquito takes to complete its life cycle varies according to food availability, weather conditions and the species of mosquito involved. Under favourable conditions, some mosquitoes can complete their entire life cycle in only 8-10 days. Mosquito larvae and adults are most susceptible to control measures.

Mosquitoes are monitored and managed during the larval and adult stages. A variety of methods, materials and equipment is used in monitoring and management. These approaches and tools are outlined briefly in the sections that follow. For greater detail, refer to the key references provided in these sections.

^{xvii} See also a joint statement by the United States CDC and the Environmental Protection Agency on integrated mosquito management at <http://www.epa.gov/pesticides/health/mosquitoes/mosquitojoint.htm>. Information on mosquito control programs can also be obtained from the American Mosquito Control Association website at <http://www.mosquito.org>.

A comprehensive document on this topic entitled *Municipal Mosquito Control Guidelines*¹⁹ was prepared for Health Canada and should be referred to by municipal officials establishing an integrated mosquito management program in their jurisdictions.

3.1 Surveillance

A multidisciplinary team approach is required.¹⁸ Trained personnel conduct mosquito surveys to identify the species that are present, track the population levels during the spring and summer, and determine appropriate management alternatives. Health authorities monitor for viral activity in people and other hosts.

3.1.1 Larval Mosquito Surveillance

Larvae should be found, sampled and identified (at least to genus, usually to species) and recorded in a GIS mapping system. A mosquito vector control program should target the main vector mosquito species.

The first step in surveillance is to do sampling to identify and map where these mosquitoes are found. Sample forms for recording information about individual breeding sites are provided in an Ontario Ministry of the Environment document^{xviii} and in the *Municipal Mosquito Control Guidelines*¹⁹. Larval breeding sites are classified as high, medium or low risk in a GIS format. Notes describing natural features, human influences and adjacent fisheries should be recorded.

Areas that do not have significant populations of vector mosquito species need not be targeted for control (in a nuisance mosquito control program, all sites with significant numbers of larvae would be targeted). Whereas most species of mosquito are a nuisance to people, very few are actually considered a health risk: *Culex tarsalis* and *Culex pipiens* for West Nile Virus and St. Louis encephalitis, *Culex tarsalis* and *O dorsalis* for Western equine encephalitis, and *A freeborni*, *A earlei* and *A puntipennis* for malaria.

Once the mapping of mosquitoes within a jurisdiction is complete, the mosquito management officials should undertake a risk assessment of the different sites and develop prescriptions for action should a public health risk be identified.

3.1.2 Adult Mosquito Surveillance

Adult mosquito surveillance should be carried out to determine species distribution and relative population densities using special mosquito traps. Protocols that should be followed and forms that can be used are provided in the *Municipal Mosquito Control Guidelines*.¹⁹ Vector species surveillance may involve the collection of live female mosquitoes for virus isolation.

^{xviii} See the Ontario Ministry of the Environment website at <http://www.ene.gov.on.ca/gp/5049e01.pdf> (Accessed February 1, 2006).

3.1.3 Virus Surveillance

Coincident with mosquito surveillance, virus surveillance should be carried out. Virus surveillance involves three main components:

- Health care providers should be advised to watch for symptoms of infection and order diagnostic tests on probable human cases.⁷⁷
- A monitoring and virus testing program for susceptible birds should be implemented (e.g., crows should be collected and tested for WNV).
- Key adult mosquito vectors should be sampled and tested for the presence of virus.

With WNV, computer-mapping of clusters of dead birds correlates with human cases 83 percent of the time. In half of those cases, dead bird hot spots were identified a full month before the first human infections (R. Carney, Coordinator, California West Nile Virus Dead Bird Surveillance Program, personal communication, February 2006).

With WEE and SLE surveillance, sentinel chicken flocks can be set out and blood samples taken during the late summer months as an early warning system.⁷⁸ They can be used to determine the onset of, and increase in, virus in the bird population. However, sentinel flocks in WNV surveillance have limited value.

Monitoring human cases alone is inadequate when dealing with mosquito-borne disease.^{18,79} Using epidemiological techniques to monitor equine and avian cases is very important to determine early trends and to allow reasonable response times for vector management activities. Reporting networks for bird and mammal cases involve veterinarians, laboratories, wildlife agencies, agriculture agencies and organizations, and the general public. These reporting systems require proactive and ongoing effort to implement and maintain. Provincial health agencies must collaborate with these partners to establish, maintain and analyze these databases.

3.2 Mosquito Control Methods

To control mosquitoes effectively and for the long-term, vector management officials need to use several complementary, integrated mosquito management techniques,¹⁹ including:

- **Sanitation** – removing the mosquito’s food, water and shelter.
- **Habitat Disruption** – draining the water where mosquitoes breed, especially in backyard breeding sites. Any alterations of natural water bodies requires prior consultations with environment and fisheries officials.
- **Biological Control** – using bacteria, including *Bacillus thuringiensis israeliensis* and *Bacillus sphaericus*.^{xix}
- **Mechanical Control** – maintaining window screens and altering building designs.
- **Personal Protection** – wearing light-coloured, loose-fitting clothing, using repellents, and avoiding activities in areas when mosquitoes are active.

^{xix} A Health Canada fact sheet on *Bacillus thuringiensis israeliensis* is available at <http://www.hc-sc.gc.ca/cps-spc/pubs/pest/fact-fiche/bti/index-eng.php>. The US Environmental Protection Agency has a fact sheet on *Bacillus sphaericus* at http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_128128.htm.

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- ***Insecticide Application*** – using insecticides against larval and adult mosquitoes, including methoprene, chlorpyrifos and malathion.^{xx}

3.2.1 Personal Protection from Bites

There are many simple things that individuals can do to protect themselves from mosquito-borne viruses. Preventive measures can cut the risk of infection substantially. People should be advised to:

- Destroy potential mosquito breeding sites around the home. People should try to identify and eliminate development sites on their property, including emptying saucers under flower pots, changing water in bird baths regularly (at least once a week), unclogging rain gutters, and removing used tires and other debris where rainwater may collect.
- Install mosquito screens on windows.
- If in a mosquito-infested area, remain in well-screened or completely enclosed, air-conditioned areas when possible.
- Consider staying indoors at dawn, dusk and in the early evening, which are peak mosquito-biting times.
- Wear protective clothing. Avoid dark-coloured clothing as it tends to attract mosquitoes. When in mosquito-infested areas, wear full-length pant legs and long sleeves to act as barriers against mosquito biting.⁸⁰
- Use mosquito repellent. Mosquito-borne viruses have been found in both daytime and dusk-to-dawn biting mosquitoes. For this reason, the application of a mosquito repellent containing DEET to areas of exposed skin is recommended when one must be in mosquito-infested areas during periods of peak mosquito activity.

A key element of personal protection is the regular use of repellents by people who are routinely exposed to high levels of vector mosquitoes. The simple logic that “if you are not bitten, you will not become infected” must be impressed on those people whose activities bring them into frequent contact with vector mosquitoes.

There is good evidence that people can substantially reduce their risk of becoming infected with WNV if they use personal protective measures. Loeb et al.,⁸¹ in a study carried out around Oakville, Ontario, showed that following two of the above measures can cut West Nile infection risk by 50 per cent. Coincident with the advice to use a repellent, people should be told to follow the directions given on the repellent label. The percentage of DEET in repellents should not exceed 30 percent for adults or 10 percent for children. DEET should not be used on children under 6 months of age.

Some common “repellents” that have been proven not to work include bug zappers, audible mosquito repellents (gadgets that emit sound waves to deter mosquitoes), and citrosa plants.⁸²⁻⁸⁵

^{xx} Health Canada facts sheets on these insecticides are available as follows: methoprene (<http://www.hc-sc.gc.ca/cps-spc/pubs/pest/fact-fiche/methoprene/index-eng.php>); chlorpyrifos (<http://www.hc-sc.gc.ca/cps-spc/pubs/pest/fact-fiche/chlorpyrifos/index-eng.php>); and malathion (<http://www.hc-sc.gc.ca/cps-spc/pubs/pest/fact-fiche/malathion/index-eng.php>).

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For more information about DEET (N,N-diethyl-m-toluamide), access Health Canada's fact sheet *Safety Tips on Using Personal Insect Repellents*,⁸⁶ Fradin,⁸⁵ and Fradin and Day⁸⁷. For information on public perceptions of personal protection, see the study by Herrington.⁸⁸

3.2.2 Insecticides

A variety of mosquito larvicides and adulticides are approved for use in Canada. A full listing of these products is available from the Pest Management Regulatory Agency (PMRA) website (<http://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php>), using the ELSE search tool.

All of the insecticides used in Canada are also used in the United States. Information on the insecticides used in the United States for mosquito management (many more than are used in Canada), is available from the following websites:

- National Center for Zoonotic, Vector-Borne, and Enteric Diseases: <http://www.cdc.gov/ncidod/dvbid/westnile/index.htm>.
- National Institute for Occupational Safety & Health: <http://www.cdc.gov/niosh/topics/pesticides/>.
- CDC Health Topic: Pesticides: <http://www.cdc.gov/health/pesticides.htm>.
- National Pesticide Information Center: <http://npic.orst.edu/>

Persons controlling mosquitoes in BC must be certified pesticide applicators, as per the BC *Integrated Pest Management Act*. A pesticide use permit is also required.^{xxi}

Larvicides

Currently, the mosquito larvicides of choice, especially for mosquito vectors, are the microbial insecticides *Bacillus thuringiensis israeliensis* (or BTI) and *Bacillus sphaericus* (BS), and the insect growth regulator methoprene. Each specific product has strict label precautions and use conditions. Fisheries and wildlife officials and natural resources biologists should be involved in planning vector control measures whenever fragile ecosystems could be impacted by mosquito control practices.

Detailed guidance on the use of mosquito larvicides is given in *Municipal Mosquito Control Guidelines*,¹⁹ and in an Ontario Ministry of the Environment document.^{xxii} The latter document includes detailed advice on the treatment with methoprene and *Bacillus sphaericus* of urban catch basins that may be breeding larval *Culex* mosquitoes.

^{xxi} The permit required for the control of WNV vectors can be consulted at <http://www.healthservices.gov.bc.ca/pho/pdf/wnv/permitconso.pdf> (Accessed February 1, 2006). A listing of insecticides is included with this document. See also <http://www.healthservices.gov.bc.ca/pho/wnv.html> under consolidated pesticide permit (unofficial, accessed February 1, 2006) and the Ministry of Environment document, entitled *Integrated Pest Management Act and Regulation - Mosquito Management Sector Review Paper* (http://www.env.gov.bc.ca/epd/ipmp/regs/pdf/mosquito_review.pdf). The insecticides commonly used are listed in an online BC Centre for Disease Control document located at <http://www.healthservices.gov.bc.ca/pho/pdf/WNV/permitconso.pdf> (accessed February 19, 2006).

^{xxii} See the Ontario Ministry of the Environment website at <http://www.ene.gov.on.ca/gp/5049e01.pdf> (Accessed February 1, 2006).

Adulticides

Integrated mosquito management programs endeavour to prevent large flights or swarms of mosquitoes through all the measures described previously. However, many factors may necessitate use of adulticides (e.g., heavy rains, flooding, high tides, strong winds, environmental constraints, inaccessible larval habitats, missed breeding sites, budget shortfalls, absent employees, or equipment failures). An incipient outbreak of mosquito-borne disease may also force the use of mosquito adulticiding.

The mosquito adulticide of choice in Canada for ground and aerial spraying is malathion ULV. Several products are available. For ground spraying only, ULV products containing pyrethrins and piperonyl butoxide may be also used.

Detailed guidance on the use of ULV insecticides for adult mosquito vector control are given in a training CD-rom prepared by R.A. Ellis (2000) for Ontario's Ministry of the Environment. The Ministry of the Environment also has a document on best practices to follow when applying ULV insecticides for vector control entitled *Best Practices for the Application of Malathion by Ultra Low Volume Equipment for Control of Adult Mosquitoes in West Nile Virus Control Programs*.⁸⁹

In BC, two types of mosquito adulticides are allowed for WNV vector control: malathion and pyrethrins. On contact with the mosquito, both work to quickly "knock down" the adult female as it flies into the ULV mist. Neither pesticide persists in the natural environment. Both materials break down within hours or days of application.

Many studies have shown that the aerial ULV application of insecticide can reduce adult mosquito density. Reducing the mosquito density reduces the risk of infection. Most of the studies showed that malathion ULV was effective in reducing vector mosquito populations. These studies have been summarized in a report entitled *Use of Malathion ULV for West Nile Vector Management*.⁹⁰

Carney (personal communication, February 2006) showed that California's intensified mosquito control efforts may have saved lives in 2005.^{xxiii} Using computerized mapping, this study compared two sections of Sacramento County that were subject to aerial spraying (using pyrethrum ULV) with two similar neighbourhoods that were not sprayed. Two weeks after the spraying began, the level of infected mosquitoes was dramatically reduced (greater than 95 percent reduction) and there were no further human cases in the two sprayed zones, whereas infections continued in the two untreated areas, eventually accounting for 20 percent of the county's total WNV cases.

^{xxiii} For a summary of the study, see http://www.cdc.gov/ncidod/dvbid/westnile/conf/February_2006.htm.

3.3 Public Education

Public education is an important and multifaceted component of a vector management program. Messages must be appropriate to the target audiences. The audiences include everyone from lay people to medical professionals, the young and the old, members of the news media, and officials at every level of government.

Programs should also provide up-to-date information about mosquito-borne disease through toll-free information lines, press releases, online government websites, press releases, advertisements, and door-to-door outreach in selected locations. An advertisement might take the form of a fact sheet, describing the disease and the risk to the public.^{xxiv} In some communities, the information may need to be written in English and another language.

Public education should focus on ways to reduce mosquito breeding and to protect against mosquito bites.⁹¹ The public should be encouraged to help with virus surveillance by reporting dead birds to the appropriate local authorities, especially, in the case of WNV, dead birds of the crow family.

Public education should also have a component that encourages municipalities to carry out the preparatory work that will allow them to initiate mosquito vector control measures, if and when necessary. Regional health authorities should work with municipalities to plan the most appropriate measures to control the mosquito vectors that carry disease.

Public education efforts must be stepped up if an increase in the intensity of virus activity is detected by bird- or mosquito-based surveillance systems within a jurisdiction. Provincial medical officials must also keep physicians informed of changes in case definitions, routes of transmission, and treatment regimes. Developing guidelines and fact sheets for physicians on clinical features and treatment and personal protection guides for the public are ways in which the provincial health agency can provide important services to the medical community and the public.

Adulticide applications are quite visible and may contribute to public apprehension. The public should be provided with balanced information on the materials that are used in adulticiding and the precautions that they may follow during and after an adulticiding program in their community. The public should always be advised of when and where adulticiding is planned.

The public education program on WNV should be assessed on a regular basis to determine its strengths and weaknesses. Several relevant assessment models are available.^{92,93}

^{xxiv} Examples of fact sheets can be found on Health Canada's website at http://www.hc-sc.gc.ca/iyh-vsv/diseases-maladies/wnv-vno_e.html and HealthLink BC's website at <http://www.healthlinkbc.ca/healthfiles/hfile88.stm>.

3.4 Conclusion

Integrated mosquito management (IMM) is an ecologically-based strategy that relies heavily on natural mortality factors and seeks out control tactics that are compatible with or disrupt these factors as little as possible. IMM uses pesticides, but only after systematic monitoring of pest populations indicates a need. Ideally, an IMM program considers all available control methods and materials, including no action, and evaluates the interaction among various control practices, cultural practices, weather and habitat structure. Thus, this approach uses a combination of resource management techniques to control mosquito populations with decisions based on surveillance.

4.0 TICK-BORNE DISEASE MANAGEMENT

The best currently available method for preventing infections from tick bites is to avoid vector tick exposure.⁹⁴ If exposure to ticks is unavoidable, the risk of infection can be reduced by using both protective clothing and tick repellents, checking the entire body for ticks daily, and promptly removing attached ticks. Large-area spraying should only be done under certain conditions.

4.1 Surveillance

Surveys of potential or known tick habitats can be carried out on a periodic basis.⁹⁵ Such surveys may reveal the presence of high-level tick infestations and trigger the application of management procedures. Several monitoring techniques have been developed for American dog ticks, including the following:

- Examination of small animal hosts trapped at selected sampling sites.
- Examination of survey personnel.
- Sampling for questing ticks using a drag cloth.⁹⁶

Daily inspection for attached ticks is also critically important. Animal studies suggest that transmission of *Borrelia burgdorferi* from infected ticks usually requires at least 24 hours and often as long as 48 hours.^{97,98} As a result, daily inspection and prompt removal of ticks can prevent transmission.

Particular attention should be given to children and to exposed, hairy areas of the body where ticks often attach (e.g., head, nape of neck). Ticks should not be squeezed during removal. The preferred technique requires firm application of fine tweezers as close to the skin as possible and removal of the tick straight backwards without rotation. Fingers should not be used to remove ticks. If this is unavoidable, gloves should be worn and/or exposed skin should be washed with soap and water immediately after removal of any ticks found.

4.2 Use of Repellents and Insecticides

Personal protection is the first line of defence against tick-borne illnesses.^{67,99} It includes:

- The avoidance of tick-infested habitats.
- The use of personal protective measures, such as repellents and protective clothing.
- Checking for and removing attached ticks.

Wear appropriate clothing and use a repellent containing DEET when walking or working in areas where ticks may be present, especially during the months from May to November. Tuck pant legs into socks or boots.

Protective clothing, such as long-sleeved shirts and long pants that are tight at the wrists and ankles (or tucked into work gloves or socks), can act as an effective barrier. Light-coloured clothing can also aid in the detection of ticks that have not yet attached. A hat should be worn in

areas where contact with vegetation cannot be avoided (e.g., dense woods, high grasses or thickets).

Permethrin (a synthetic pyrethroid) is available as a spray in some stores for application to companion animals and to certain fabrics (e.g., tent screens). It must not be applied directly to skin surfaces. Permethrin kills ticks on contact.

The BC Ministry of Health has a fact sheet on personal protection from tick bites.¹⁰⁰

4.2.1 Repellents

Insect repellents, containing about 30 percent N,N-diethyl-m-toluamide (DEET), will deter ticks. Note that DEET does not seem to be as effective against ticks as it is against mosquitoes. The effectiveness of DEET against black-legged ticks has not been fully evaluated. Frequent application (every 1-2 hours) may be required for optimal efficacy. Repellents are less effective with heavy sweating or wetting. Container instructions must be followed.

4.2.2 Targeted Use of Acaricides

Permethrin (a synthetic pyrethroid) kills ticks on contact. Permethrin is an acaricide-insecticide that is available as a spray for application to pets and certain fabrics (e.g., tent screens). When DEET-based repellents are applied in combination with permethrin-treated clothing, protection against bites of nearly 100 percent can be achieved^{85 xxv}.

Because ticks are most abundant in localized areas (e.g., along animal trails), widespread spraying of acaricides is not usually recommended.¹⁰¹ Large-area applications should only be used when and where necessary. Usually, only one spring or fall application, plus one early summer application, to wood-grass interfaces (where ticks are most abundant) is all that is necessary.

4.3 Landscape Modification

To reduce tick habitat, property owners should be encouraged to clean up their yards, especially leaf litter along the margins of grassy and wooded areas prone to shelter ticks and rodents.¹⁰² Wood chips can be used as a barrier strip to separate “areas to avoid” from “areas to use”.

4.4 Conclusion

Avoidance of tick-infested areas and personal protection (using repellents and protective clothing) should be encouraged. Landscape alterations may significantly reduce tick populations in some cases. Widespread tick control is not recommended. Specific applications of acaricides may occasionally be warranted where large numbers of people must be present in an area when ticks are active and there is a perceived risk of disease transmission (e.g., scout jamboree in a recreational area known to be infested with tick vectors).

^{xxv} For a complete listing of products available for tick control, see the Pest Management Regulatory Agency ELSE website and search for products used for tick control (<http://www.pmr-arla.gc.ca/english/main/search-e.html>).

5.0 VECTOR-BORNE DISEASE PREVENTION PROGRAMS

5.1 Communicating Vector-borne Disease Prevention to the Public

See Section 3.3 for information on public education measures.

5.2 Effectiveness of Public Education

There are a number of papers that look at the effectiveness of public education in vector-borne disease management. The Public Health Agency of Canada (PHAC) assessed the public education efforts of the Ontario Ministry of Health and Long-term Care regarding WNV through a survey of Hamilton residents.⁹³ PHAC's findings were "both reassuring and instructive."

The public education program included brochures and television, radio and newspaper advertisements dealing with personal protection and removing backyard larval breeding sites. The Ontario Ministry of Health and Long-term Care also posted fact sheets on its websites.¹⁰³

Most of the respondents to the survey indicated that they were aware of the WNV problem and were following, or planning to follow, provincial advice on personal protection and yard clean-up.

5.3 Mosquito Management Programs

Mosquito management requires an understanding of mosquito surveillance and integrated control options. It may involve the use of restricted-class insecticides and specialized application equipment. Some products may adversely impact human health and the environment if not used properly. In BC, persons involved in mosquito management must be certified to do so by the BC Ministry of Environment.

Certification involves, in part, taking and passing an approved mosquito and biting fly course. The course stresses an integrated pest management approach.^{xxvi}

5.4 Risk Analysis

Risk analysis includes risk assessment, risk characterization, risk communication, risk management and policy relating to risk. It also includes risks to human health and the environment, both built and natural. One can consider threats from physical, chemical and biological materials and from a variety of human activities as well as natural events.

^{xxvi} For further details on certification, see the BC Ministry of Environment website at http://www.env.gov.bc.ca/epd/ipmp/pest_certification/certif_main.htm.

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Economic data about epidemics are essential for estimating the costs and benefits of strengthening and maintaining prevention and control programs, improving existing surveillance systems, and introducing other proposed interventions.^{xxvii}

The insecticides used in Canada for the control of mosquito larvae and adults have all been carefully assessed for efficacy, toxicology and environmental impact by Health Canada's Pest Management Regulatory Agency (PMRA). PMRA has deemed their use in mosquito control programs to be a safe practice when used according to label precautions and directions.^{xxviii}

The U.S. Environmental Protection Agency's overall risk assessment of malathion is posted on their website.¹⁰⁴ Regarding public health uses of malathion (including ULV applications for mosquito vector control), the Agency concluded that:

Risk estimates for combined dermal and inhalation exposure (adult margin of exposure (MOE) = 5600; toddler MOE = 2200) for exposure to turf after aerial ULV applications are significantly greater than the target MOE of 100 and are not of concern for residential bystander inhalation and dermal exposure. Ground ULV truck fogger applications result in combined dermal and inhalation exposure MOEs of 22000 for adults and 7700 for toddlers. These values are significantly greater than the target MOE of 100 and are not of risk concern.

Similar conclusions were reached by Health Canada's PMRA.¹⁰⁵

5.5 Effectiveness of Spraying

Some people question the effectiveness of insecticide spraying for vector control. However, this matter has been studied extensively over the years by various government and university researchers, both in Canada and the United States.¹⁰⁶⁻¹⁰⁹ Although there are some experts who question the value of mosquito adulticiding, most researchers agree that the use of a mosquito adulticide is a valuable tool in breaking the virus transmission cycle.

A full review of the effectiveness of malathion ULV for controlling vector mosquitoes was prepared for the BC Centre for Disease Control.⁹⁰ Ground ULV applications usually provide about 95 percent control in open areas and up to 70 percent control in protected areas (e.g., in dense vegetation). If large-area applications are necessary, aerial ULV applications give a more uniform and thorough coverage of the area to be protected than ground-based applications because they are not limited by the need for a close network of roads or by obstructions on the ground.

Vector populations can rebound through new emergences and infiltration from outside the treated zones. From a disease control point-of-view, this means that multiple applications of an adulticide, spaced about 4-7 days apart, may be needed to break the virus transmission chain.

^{xxvii} For more information, refer to Appendix 4 of *A Framework for Core Functions in Public Health: Resource Document* (Available from http://www.hls.gov.bc.ca/publications/year/2005/core_functions.pdf).

^{xxviii} A number of assessments of mosquito control products are available from PMRA's website (<http://www.pmra-arla.gc.ca/english/consum/mosquito-e.html>). The US Environmental Protection Agency has a similar website, dealing with the products used in that country (<http://www.epa.gov/pesticides/health/mosquitoes/control.htm>).

Most of the case studies that were reviewed support the use of adulticiding as a tool in mosquito vector control. Although every study was unique, most of the researchers concluded that mosquito adulticiding can be a valuable tool in reducing vector populations.⁹¹

5.5.1 Risk of Malathion Use versus Risk of West Nile Virus Cases

Environmentalists usually condemn attempts to control the vectors of disease by spraying insecticide, saying that the detrimental health effects of spraying outweigh the relatively few lives that may be saved, and that there are more environmentally friendly ways of controlling mosquitoes.

Malathion can be used for public health mosquito control programs without posing unreasonable risks to the general population when applied according to the label directions and precautions. The exposure and risks to both adults and children posed by ULV aerial and ground applications of malathion has been estimated.

Because of the very small amount of active ingredient released per hectare of ground, the estimates found that, for all scenarios considered, exposures were several times below an amount that might pose a health concern. These estimates assumed that a toddler would ingest some soil and grass in addition to skin and inhalation exposure. However, at high doses, malathion, like other organophosphates, can over-stimulate the nervous system, causing nausea, dizziness or confusion. Severe high-dose poisoning with any organophosphate can cause convulsions, respiratory paralysis and death.

5.5.2 Mosquito Spraying and Pesticide Levels in Humans

Public health officials weigh the risk of mosquito-borne diseases against the risk of human exposure to pesticides sprayed to control mosquitoes. Response to outbreaks of mosquito-borne diseases has focused on vector control through habitat reduction and application of insecticides that kill mosquito larvae. However, in certain situations, public health officials control adult mosquito populations by spraying ultra-low volume (ULV) insecticides, such as malathion and pyrethrins. These ULV applications generate aerosols of fine droplets of insecticide that stay aloft and kill mosquitoes on contact while minimizing the risk of exposure to persons, wildlife and the environment.

Few field studies have been done on the impact on human health of insecticides used in Canada for mosquito control. However, in the United States, several studies have assessed human exposure to ULV insecticides, permethrin and d-phenothrin, used in emergency, large-scale mosquito control activities. The findings of these studies indicated ULV applications did not result in substantial insecticide exposure to humans.

For example, the United States CDC examined the potential health dangers of exposure to mosquito spraying for WNV control in Mississippi. Officials interviewed and took urine samples from 192 residents of four cities in Mississippi. Two of the cities used truck foggers for mosquito control. The CDC concluded that local mosquito control activities did not lead to increased pesticide levels.

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The use of pesticides to fight the spread of WNV has been controversial but it has been a central aspect in disease prevention. The study allayed some fears about increasing insecticide use in the face of an outbreak. The doses that are sprayed for mosquito control purposes are calibrated to be just enough to kill mosquitoes and to be safe for humans.

5.5.3 Theoretical Risk Assessment for West Nile Virus versus Insecticide Use

A human-health risk assessment for WNV and the insecticides used in mosquito management was reported in 2006 by Peterson, Macedo and Davis.¹¹⁰ The objective of their study was to use worst-case risk assessment methodologies to evaluate human-health risks for WNV and the insecticides most commonly used to control adult mosquitoes. They evaluated documented health effects from WNV infection and determined the potential population risks based on reported frequencies. They determined potential acute (1-day) and sub-chronic (90-day) multi-route residential exposures from each insecticide for several human subgroups during a disease outbreak scenario. They then compared potential insecticide exposures to toxicological and regulatory effect levels. Risk quotients (RQs, the ratio of exposure to toxicological effect) were < 1.0 for all subgroups. Acute RQs ranged from 0.0004 to 0.4726; sub-chronic RQs ranged from 0.00014 to 0.2074. Their results and the current weight of scientific evidence indicate that human-health risks from residential exposure to mosquito insecticides are low and are not likely to exceed levels of concern. Further, their results indicate that, based on human-health criteria, the risks from WNV exceed the risks from exposure to mosquito insecticides.

5.5.4 Economic Considerations

Zohrabian et al.¹¹¹ examined the economic impact of WNV in Louisiana during 2002. A total of 329 persons with WNV disease were reported in Louisiana, with illness onsets from June to November. Among these, 204 had illnesses involving the central nervous system; 24 died (Louisiana Office of Public Health, unpublished data). They collected data from hospitals, a patient questionnaire and public offices. Hospital charges were converted to economic costs by using Medicare cost-to-charge ratios.

The estimated cost of the Louisiana epidemic was \$20.1 million from June 2002 to February 2003, including a \$10.9 million cost of illness (\$4.4 million medical and \$6.5 million non-medical costs) and a \$9.2 million cost of public health response. These data indicate a substantial short-term cost of the WNV disease epidemic in Louisiana.

In one of its fact sheets on WEE, the US CDC¹¹² presented the following estimates:

- Total case costs range from \$US 21,000 for transiently infected individuals to \$US 3 million for severely infected individuals.
- Insecticide applications can cost as much as \$US 1.4 million, depending on the insecticide, delivery system, and the size of area treated.

Vanderhoof et al.,¹¹³ of the New York University Stern School of Business, estimated that Lyme disease costs Americans about \$US 1 billion per year. This includes unnecessary or inappropriate medical care, lost productivity, legal fees and other direct/indirect expenses.

Additionally, the human toll can be high. Patients can have ongoing problems resulting in emotional distress, permanent physical damage and a significant disruption of their lifestyle (e.g., job loss, divorce, loss of friends or family).

5.5.5 Legal Issues

Group action suits have been launched against the Province of Ontario regarding WNV infections.^{xxix} A \$75 million lawsuit by 40 families of WNV victims who believe the Ontario government should have done more to warn the public of the dangers of the disease was launched in the wake of the 2002 outbreak in southern Ontario. The province could be held accountable for negligence in its handling of the West Nile outbreak. This seems to be a precedent-setting case where victims of public health errors are suing for negligence. This matter is still before the courts.

In Ontario, the *Occupational Health and Safety Act* creates duties for employers, including the need to consider the potential for exposure of outdoor workers to WNV and the measures that should be taken to prevent exposure and possible infection.^{xxx} According to the authors of these web page,

...any company, organization or public entity that owns or occupies land that may serve as a breeding ground for mosquitoes may have certain obligations to persons entering onto the property and neighbouring residents to minimize the risk associated with the proliferation of mosquitoes and the virus.

5.6 **Conclusion**

Malathion, as used in mosquito control programs, does not pose an unreasonable risk to people, wildlife or the environment. Malathion degrades rapidly in the environment, especially in moist soil. It displays low toxicity to birds and mammals. However, malathion is highly toxic to some insects, including beneficial insects such as honeybees. For that reason, the Pest Management Regulatory Agency has established specific precautions on the label to reduce such risks.

The direct costs of an arthropod-borne disease include a combination of personal and public expenditures on both the prevention and treatment of the mosquito-borne disease. Personal expenditures may include individual or family spending on repellents and insecticides, doctors' fees, drugs, transport to health facilities, and support for the patient and, sometimes, an accompanying family member, during hospital stays. It may also involve the treatment and/or loss of a companion animal and the associated costs.

^{xxix} See http://www.medicalpost.com/mpcontent/article.jsp?content=20050905_183559_4356 and <http://www.reko.ca/westnile.html> for a description of an individual suit against the Ontario government (Accessed February 2006).

^{xxx} These duties are discussed on the following two web pages: (1) <http://www.fasken.com/web/fmdwebsite.nsf/alldoc/37142feea1ddf78885256d4200684405?opendocument> and (2) [http://www.fasken.com/web/fmdwebsite.nsf/alldoc/e9b658e1e3d92e1785256d480068db15/\\$file/fmalert_jun03.pdf!openelement](http://www.fasken.com/web/fmdwebsite.nsf/alldoc/e9b658e1e3d92e1785256d480068db15/$file/fmalert_jun03.pdf!openelement) ; accessed 17 February 2006).

Public expenditures include spending by government on maintaining health facilities and health care infrastructure, public education, disease surveillance, publicly managed vector control and research.

The indirect costs of an arthropod-borne disease may include lost productivity or income associated with illness or death. This might be expressed as the cost of lost workdays or absenteeism from formal employment and the value of unpaid work done in the home by both men and women. If a patient dies, the indirect cost includes the discounted future lifetime earnings of that person.

From an economic viewpoint, the indirect and direct costs associated with mosquito-borne disease outweigh the costs associated with public health interventions, including vector surveillance and control.

6.0 CONCLUSION

Integrated vector management programs—based on a careful assessment of surveillance data and an analysis of risk factors—can be used by public health authorities to break disease transmission cycles, whether the disease organisms involved are mosquito- or tick-borne organisms. Public education programs and personal protective measures are critical components in the defence against these diseases. Vector management is used when necessary to prevent the build-up of known disease vector populations. The judicious use of pesticides may be a necessary response when there is a risk of an incipient epidemic.

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GLOSSARY

Antibodies: a Y-shaped protein on the surface of B cells that is secreted into the blood or lymph in response to an antigenic stimulus (e.g., a bacterium, virus, parasite, or transplanted organ) and that neutralizes the antigen by binding specifically to it; an immunoglobulin.

Adulticiding: The application of chemicals to kill adult mosquitoes by ground or aerial application, based on surveillance data, is an extremely important part of any integrated mosquito management program. Adulticides are typically applied as an ultra-low-volume (ULV) spray where small amounts of insecticide are dispersed either by truck-mounted equipment or from fixed-wing or rotary aircraft.

Arbovirus: a virus transmitted by an arthropod (short for arthropod-borne virus). 'Arboviruses' are a large group (more than 400) of enveloped RNA viruses which are transmitted primarily (but not exclusively) by arthropod vectors (mosquitoes, sand-flies, fleas, ticks, lice, etc). They were previously grouped together under the name 'Arboviruses' but "Arbovirus" is not a taxonomic classification. More recently, this disordered assemblage has been split into 4 bona fide virus families.

Arthropod: Any of numerous invertebrate animals of the phylum Arthropoda, including the insects, crustaceans, and arachnids; they are characterized by a chitinous exoskeleton and a segmented body to which jointed appendages are articulated in pairs. Arthropods account for more than 85% of all known animal species. Mosquitoes and ticks are arthropods.

Arthropod-borne disease: A disease transmitted by an arthropod (e.g., malaria is transmitted by certain anopheline mosquitoes).

Blood-feeding: some arthropods take blood, a behaviour known as 'blood-feeding'. The blood they ingest is known as a 'blood-meal'. They use the blood-meal to mature their eggs. Some biting arthropods also require a sugar source to meet their energy requirements for mating, locating their hosts, and oviposition.

Breeding place: any body of water which contains or produces mosquitoes. "Breeding place" has been finally established in the laws and regulations and in the scientific literature. Some workers prefer the term "mosquito source" as more descriptive.

Crow family: includes crows, ravens, magpies, nutcrackers and blue jays.

DEET: N,N-Diethyl-meta-Toluamide; a colorless, oily liquid that has a mild odor and is used as a mosquito and tick repellent.

Disease: A pathological condition of a part, organ, or system of an organism resulting from various causes, such as infection, genetic defect, or environmental stress, and characterized by an identifiable group of signs or symptoms. A condition in which bodily health is impaired;

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sickness; illness; a malady; an ailment; a condition which adversely affects survival. (An archaic form, "dis-ease", means discomfort).

ELISA: the Enzyme-Linked Immunosorbent Assay is a biochemical technique used in immunology to detect the presence of an antibody or an antigen in a sample. It uses two antibodies, one of which is specific to the antigen and the other of which is coupled to an enzyme. This second antibody gives the assay its "enzyme-linked" name, and will cause a chromogenic or fluorogenic substrate to produce a signal. Because the ELISA can be performed to evaluate either the presence of antigen or the presence of antibody in a sample, it is a useful tool both for determining serum antibody concentrations (e.g., WNV) and for detecting the presence of antigen.

Encephalitis: an inflammation of the brain that is caused by certain viruses transmitted by mosquitoes. Human cases of encephalitis range from unapparent or mild cases to very severe illnesses that can permanently damage the central nervous system or, in some instances, cause death. The viruses causing encephalitis are usually transmitted from bird to mosquito to bird and sometimes from bird to mosquito to human. When the incidence of any encephalitis virus increases in bird populations, it becomes more likely that humans and equines can become involved. In most cases, the human or equine host is a "dead-end host" for the virus, meaning that the disease probably will not be transmitted from these hosts because they cannot infect mosquitoes.

Epidemic: a disease that is common to or affecting many at the same time. An unusual spread of a disease within an area.

Flavivirus: any of a family (Flaviviridae) of single-stranded RNA viruses that are transmitted by ticks and mosquitoes and include the causative agents of dengue, Japanese B encephalitis, West Nile fever, and yellow fever.

Host: an individual infested by or upon which a parasite grows. An individual preyed upon. Regarding mosquitoes, the plants and animals from which they obtain nectar or blood. Regarding disease, the source of the disease organism.

Infection: invasion by and multiplication of pathogenic microorganisms in a body part or tissue, which may produce subsequent tissue injury and progress to overt disease through a variety of cellular or toxic mechanisms.

Integrated Pest Management: a process for managing pest populations that includes the following elements: planning and managing ecosystems to prevent organisms from becoming pests; identifying pest problems and potential pest problems; monitoring populations of pests and beneficial organisms, damage caused by pests and environmental conditions; using injury thresholds in making treatment decisions; suppressing pest populations to acceptable levels using strategies based on several considerations (i.e., biological, physical, cultural, mechanical, behavioural and chemical controls in appropriate combinations, environmental and human health protection; and evaluating the effectiveness of pest management treatments.

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Larvicide: a pesticide that is used to kill the larval stage of an insect. Mosquito larvicide refers to the insecticides that are used to control mosquito larvae. Larviciding is a general term for the process of killing mosquitoes by applying natural agents or commercial products designed to control larvae in aquatic habitats. Larvicide treatments can be applied from either the ground or air.

Mosquitoes: any of various two-winged insects of the family Culicidae; the female of most species is distinguished by a long proboscis for sucking blood. Some species are vectors of diseases such as WNV.

Parasite: Any organism that lives in or on another organism without benefiting the host organism; commonly refers to pathogens, most commonly in reference to protozoans and helminthes.

Pathogen: the organism that causes a disease.

Pyrethroid: a class of insecticides derived from the natural pyrethrins (e.g., permethrin).

Reservoir: the animals in which the pathogen lives and which serve as the source of the pathogen for the mosquitoes that transmit it. The animal hosts in which a disease-producing organism is usually found. Any host species that perpetuates a disease organism for a prolonged period and serves as a source of infection for the disease vector.

Resistance: the ability of an organism to develop strains that are impervious to specific threats to their existence. The malaria parasite has developed strains that are resistant to drugs such as chloroquine. The Anopheles mosquitoes of many tropical countries have developed strains that are resistant to many insecticides.

Rickettsiae: small, gram-negative bacteria that grow strictly in eukaryotic cells. Rickettsia rickettsii is the organism responsible for RMSF.

Risk: the potential for realization of unwanted, adverse consequences to human life, health, property, or the environment.

Risk assessment: the process of establishing information regarding acceptable levels of a risk and/or levels of risk for an individual, group, society, or the environment.

Rodent-borne viruses: these capable of causing illnesses and deaths in humans, are also present in much of southern Canada. Hantaviruses, which can cause fatal infections (pulmonary syndrome), are of particular public health concern because the deer mice that carry hantaviruses tend to invade dwellings and are present across Canada, including BC. Hantaviruses and related diseases are discussed in a separate evidence paper.

Sentinel flocks: chickens, quail, pheasant or other birds that are retained in outdoor cages in specific sampling areas and bled periodically to monitor arbovirus activity. These sentinel birds are raised in a mosquito-free environment and tested prior to placement to ensure that they have

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not been exposed to arboviral activity elsewhere. If the sentinel bird tests positive after being placed in an area, it is a sure sign of arbovirus activity in the area. To adequately sample large areas requires numerous sentinel flocks, so this method can be costly.

Source Reduction: the elimination of larval mosquito breeding sites; ranges from removing containers that collect water and simple drainage, using pumps or creating ditches, to actual filling of the site. A wide variety of equipment and materials may be used. Usually, a municipality will already have all the required gear to carry-out the work.

Spirochete: a corkscrew-shaped bacterium.

Surveillance: the collection, collation, analysis, and dissemination of observational data.

Susceptible hosts: the people and/or other animals that can be infected by the pathogen.

Ticks: any of numerous small bloodsucking parasitic arachnids of the family Ixodidae; many ticks transmit febrile diseases (e.g., Rocky Mountain spotted fever, Lyme disease).

Ultra-low Volume: the application of a pesticide, usually a more concentrated formulation, by spraying relatively small amounts over a large area (usually less than 1 litre of product per hectare). A method of insecticide distribution in which a small portion of the compound is fragmented into extremely fine droplets for aerial dispersal. Abbreviated as 'ULV'.

Vectors: the arthropod species that can transmit the pathogen, either mechanically or biologically, from its reservoirs to the susceptible hosts.

Vector-borne diseases: infections that are transmitted to humans and animals through blood-feeding arthropods, such as mosquitoes, ticks and fleas. Arthropods are the most important disease vectors. Several genera of arthropods play a role in human disease but mosquitoes and ticks are the most notable disease vectors. The most significant mode of vector-borne disease transmission is by biological transmission by blood-feeding arthropods. The pathogen multiplies within the arthropod vector and the pathogen is transmitted when the arthropod takes a blood meal. Mechanical transmission of disease agents may also occur when arthropods physically carry pathogens from one place or host to another on their body parts.

Virus: a microorganism composed of a piece of genetic material (RNA or DNA) surrounded by a protein coat. To replicate, a virus must infect a cell and direct its cellular machinery to produce new viruses.

Zoonoses: diseases of animals that can be transmitted to humans. Many zoonotic diseases require a biological vector (e.g., a mosquito, tick, flea, or mite) in order to be transmitted from the animal host to the human host.