Mosquito Control Plan

I. Introduction

The safest, most effective mosquito and arbovirus control programs are based on the practice of Integrated Pest Management (IPM). The basic theory behind IPM is to base control decisions such as target area, time of application, and control method on surveillance findings, and knowledge of the pest, and to apply the best and most appropriate control method(s) or pesticide(s) for each situation. By employing different control methods and pesticides, technicians can deal with various species of mosquitoes during all stages of their life cycle. IPM methodologies also decrease the development of pesticide resistance by minimizing usage of any one type of pesticide/mode of action, and by minimizing frequency and volume of application through appropriate targeting.

The way each IPM component is utilized should be tailored to best meet the particular public health needs of each affected locality. The application of pesticides for mosquito control should be a local decision based on local surveillance data and knowledge of local conditions (see Section E. below for recommended response levels). To be effective, control activities must be directed towards the specific target mosquito species (see chapter on mosquito surveillance for further details). Therefore, surveillance will be needed to identify local mosquito populations and the specific biology and habits of the target mosquitoes must be well understood. Information on the biology and behavior of some of the known and suspected WNV vectors is provided in Attachment 4.A.

A. General

In Virginia, mosquito control activities are the responsibility of the jurisdiction in which they are required. Section 32.1-187 of the *Code of Virginia* (1950), as amended, provides that counties, cities, and towns may create mosquito control districts. Because of the substantial threat posed by West Nile Virus (WNV) to humans and domestic and wild animals, localities are encouraged to provide additional support to active mosquito control districts, or to establish mosquito control programs in localities where such programs do not currently exist.

State and local government agencies should provide citizens with information for managing mosquitoes on their properties. As the first line of defense against mosquito-borne disease, Virginia citizens should eliminate or treat mosquito-breeding sites on their own property. Governmental agencies should undertake water management projects on local, state, and/or federal lands where practicable. These projects should include drainage maintenance of ditches and other man made structures that may collect temporary bodies of water, removal of artificial containers that may catch and hold rainwater, larvicidal treatments of habitats that cannot be drained, removed or otherwise changed and the stocking of mosquito eating fish into certain habitats. County or city governments should also enact and enforce ordinances pertaining to accumulations of artificial containers (e.g.,

tire piles, junk, stored materials, etc.) occur on private property, collect water, and serve as a source of local mosquito populations.

Adequate control of immature and adult mosquitoes may require the application of insecticides. The decision to initiate insecticide use should be based on an evaluation of its benefit by state and local authorities. When choosing insecticides, preference should be given to effective products or chemicals that are least toxic to humans and the environment. Commercial applicators that apply insecticides for mosquito control must be certified in Public Health Pest Control (Category-8) in accordance with the *Virginia Administrative Code*, sections: 2VAC20-51-10 through 2VAC20-51-90 (Regulations Governing Pesticide Applicator Certification). These regulations are available through the Virginia General Assembly website (http://leg1.state.va.us/000/lst/LS712906.HTM).

II. Objective

The objective of the mosquito control plan is to provide mosquito control guidelines for the reduction or prevention of WNV transmission to humans and their domestic animals by mosquito vectors.

III. Implementation Plan

A. Non Insecticidal Control

1. **Source Reduction** - The alteration or elimination of mosquito larval habitats is the most effective and economical method of providing long-term mosquito control. Through education and public information releases, state and local governments will provide technical assistance and encourage citizens to participate in source reduction through the removal of used tires, cleaning of rain gutters and bird baths, emptying unused swimming pools, draining or dumping other artificial water containers, unclogging ditches, punching holes in tires used as play ground equipment, and otherwise eliminating potential mosquito breeding sites around the home.

   State and local government agencies responsible for the maintenance of ditches, streams and stormwater basins on public land should remove tires and other refuse and otherwise maintain these areas in such a manner that they do not become mosquito larval habitats. Standing water in ditches along state roads should be reported to the Virginia Department of Transportation (Tel. 800-367-7623). Problems with mosquitoes breeding in storm water retention ponds should be brought to the attention of the locality's regulatory/maintenance agency such as the local Department of Public Works. In salt marshes, ditch plugs and other water control structures should be removed or modified to permit daily tidal inundation to occur. The daily tidal exchange eliminates mosquito breeding and

eventually restores the area to a productive salt marsh. Open Marsh Water Management, which includes the selective excavation of ponds, pond radials, and ditches, is effective in eliminating mosquito breeding sites and providing permanent habitat for mosquito-eating fish. **NOTE:** Many of these activities in wetlands will require coordination with, and permitting by the district office of the U.S. Army Corps of Engineers and/or the regional office of the Virginia Department of Environmental Quality. Army Corps of Engineers District Offices for Virginia are listed at www.usace.army.mil/where.html#State; regional DEQ offices are listed at in Appendix 6 . Many ditch maintenance activities are exempt from federal and state wetlands regulations, provided that the cross sectional area of the ditch is not modified. However, draining or excavating in wetland areas are regulated activities, and may require federal and/or state permits.

2. **Natural Predators -** Where appropriate, localities may introduce fish, such as mosquito fish (*Gambusia affinis*) into mosquito breeding habitats to control mosquitoes. Habitats where fish may be used to control mosquitoes include storm water retention ponds, stagnant ditches, backyard ornamental ponds and other man-made or artificial pools of water (residential/municipal). Other fish species, such as fathead minnows, freshwater killifish, certain species of sunfish and even the small fry of game fish (e.g., bass) may also be used to control mosquito larvae and pupae. Care should be taken to avoid stocking mosquito fish into areas that harbor game fish, as many larva-eating fish will also feed on game fish fry. County and city governments, or the mosquito control programs within these jurisdictions must obtain authorization from the Virginia Department of Game and Inland Fisheries (VDGIF) to collect and/or stock mosquito fish (Contact: Becky Wajda [pronounced Vida], Assistant Director, VDGIF Division of Wildlife Diversity; 804-367-8351). Jurisdictions having permits to use mosquito fish can obtain these fish for stocking from a hatchery operated by the York County, VA, Mosquito Control Program (contact James Rindfleisch at 757-890-3790).

3. **Avoidance of Adult Mosquitoes by the Public** - Through public service announcements and other means of outreach, citizens should be advised to install screens on windows and doors of homes and commercial buildings. They should also be advised to protect themselves by: avoiding outdoor areas during times when mosquito populations are actively feeding; wearing hats, socks, and loose fitting, light colored clothing with long pant legs and long sleeves when outdoors; and using mosquito repellents containing deet, and following safe repellent use practices (Attachment 4.B).

B. The Use of Insecticides - General

1. Notification: If it becomes necessary to use insecticide fogs/aerosols for area control of adult mosquitoes, local governments should provide residents with accurate and precise advance information on when and where these pesticides will be applied so that citizens who wish to avoid exposure may take cover and/or take action to protect pets and domestic animals including managed honeybee colonies, and aquaculture projects. Among various methods of informing the public, such as the media, one of the easiest ways to provide this advance notice is to establish a telephone hotline, publicize its number and record daily updates. Broad scale, aerosol/fog insecticide applications that cover areas that have not been surveyed or determined to have active mosquitoes, are not in keeping with prudent IPM practices. Targeted, focused and limited aerosol/fog application should be based on sound, scientific surveillance indicators.

2. Safe Use of Insecticides: A list of insecticide active ingredients registered for both larval and adult mosquito control in Virginia is provided in Attachment 4.C. The use of insecticides for mosquito control may be accompanied by risks to non-target organisms including humans. Direct toxicity is the primary concern, and may be reflected in fish or wildlife kills or in episodes of non-lethal effects that render exposed non-target organisms susceptible to other sources of morbidity or mortality. Pesticide application personnel, in particular, are at risk from direct toxic effects of insecticides, and proper precautions must always be taken when handling, mixing and applying pesticides. Equipment used for applying pesticides must be properly calibrated to dispense the pesticide according to label specifications. Whenever any pesticide is applied, the law requires that the directions outlined on the pesticide label be carefully followed. When choosing insecticides for mosquito control, governmental agencies and their contractors should give preference to those products that pose the least risk to humans and the environment. Environmentally friendly insecticides are generally the most effective in the long run because they help preserve many of the natural enemies that help regulate the size of mosquito populations. The relative risks (toxicity) associated with the currently registered mosquito control insecticides, both larvicides and adulticides are discussed in Attachment 4.C.

   NOTE: Any fish kills must be reported immediately upon discovery. During business hours contact the closest regional Department of Environmental Quality office; otherwise contact the Department of Emergency Management at 1-800-468-8892.

C. Use of Insecticides for Larval Control

1. Larval mosquito control targets immature mosquitoes in their aquatic habitat before they become flying, biting adults. In general, larval control is the most effective method of controlling some mosquito populations, has the least effect on non-target species, and is applied to the smallest area of the environment. For example, one can treat an acre of aquatic habitat to control mosquito larvae, but if one waits until the adults have emerged and dispersed, one may need to treat 500 acres to kill the adults that emerged from that acre of habitat. Localities may conduct their own larviciding activities, or contract with commercial pesticide applicators to conduct larviciding operations. Larvicides may be applied by hand, or with powered backpack mounted, vehicle mounted or aircraft mounted equipment. Aircraft application of larvicides is most practical when large areas of inaccessible terrain need to be treated quickly. The larvicides that can be used for mosquito control in Virginia include the following:

   a. Bacterial larvicides such as *Bacillus thuringiensis* var. *israelensis* (a toxin from a killed bacteria), and *Bacillus sphaericus* (a live bacterial spore) can be used successfully in a broad range of freshwater habitats, but are somewhat unpredictable in salt marsh habitats. *Bacillus thuringiensis* (***Bt***) based larvicides are sold in a variety of formulations (liquid, granule or briquet) under a wide variety of trade names such as: Mosquito Dunks®, VectoBac™, Aquabac™, Bti Briquets™. ***Bt*** based larvicides are quite effective against members of most mosquito genera, but may be slightly less effective on members of the *Culex* genus. *Bacillus sphaericus* (***Bs***) based larvicides are sold under the trade name VectoLex™. ***Bs*** is highly effective against species in the *Culex* genus, but are not effective against Asian tiger mosquitoes and several other species of Aedes mosquitoes. ***Bs*** works very well in polluted water, where it may be self-perpetuating. Bacterial larvicides are most effective when used against mosquitoes in the 1st through 3rd larval growth stages, but will not control late 4th stage or pupal stage mosquitoes.

   b. Biochemical larvicides contain an insect growth regulator called methoprene and are sold under the trade name Altosid®. Methoprene is an insect hormone mimic that prevents immature mosquitoes from developing into adults. Altosid® products are labeled for use in a wide variety of natural and artificial aquatic habitats and are effective for use in salt marshes. Altosid® is relatively target specific and will not harm many aquatic species such as amphibians or aquatic insects having incomplete metamorphosis (e.g., water bugs, damselflies, dragonflies). However, it may be slightly to moderately toxic to some fish species and is toxic to crustaceans such as shrimp or crab species

or aquatic insects with complete metamorphosis (e.g., flies, beetles). Altosid® may be somewhat toxic to birds which consume granules that land on dry ground. Altosid® is most effective when used against mosquitoes in the 1st through early 4th larval growth stages, but is not effective against late 4th larval stage or pupal stage mosquitoes.

c. Monomolecular surface film larvicide (trade name - Agnique®) is sprayed on water to prevent immature mosquitoes from attaching their siphon tubes to the water surface to breathe. Monomolecular surface films (MSFs) are often used when surveillance indicates that a large proportion of the immature mosquito population has reached the pupal stage which cannot be effectively controlled with microbial or biochemical larvicides. MSFs can be highly effective in puddles, ditches, and other artificial and natural habitats, and in polluted water. MSFs work best on small, sheltered bodies of water, but may be rendered ineffective (blown off the surface) in habitats exposed to excessive wind. Their effectiveness is also reduced in areas of heavy aquatic vegetation. MSFs are inert and will not pollute aquatic environments or harm aquatic organisms such as fish, amphibians, or crustaceans. However, MSFs can harm populations of small aquatic arthropods (e.g., spiders, water striders, etc.) that rely on water surface tension for locomotion or respiration.

d. Surface Oils (Mineral Oils) (sold under trade names such as BVA Oils™ or Golden Bear Oil™) are sprayed as a layer on top of water to suffocate and drown larval and pupal mosquitoes. Surface oils are less affected by wind than monomolecular surface films and are effective in habitats with heavy emergent vegetation. Oils are mostly used when immature mosquito larvae have developed to a stage beyond which other larvicides will control them. Unlike monomolecular surface films, oils are not inert and so they may affect some non-target aquatic organisms. Use of oils on water in environmentally sensitive areas should be avoided. Where possible, the use of oils should be limited to artificial containers, puddles, ditches, and other un-natural habitats.

e. Chemical Larvicides: An organophosphate insecticide called Temephos is the only chemical insecticide sold for control of mosquito larvae. Temephos is sold under the trade name Abate®. Abate® can be effective in the treatment of puddles, artificial containers (tire piles), and polluted waters high in organic content. Abate®is very effective for controlling-mosquito larvae, but might also impact fish, amphibians, aquatic arthropods and other aquatic organisms. Therefore, its use should be avoided in

environmentally sensitive areas and limited to artificial containers, puddles and other un-natural habitats.

Misuse of chemical insecticides such as Abate® in semi-permanent, artificial and natural habitats (e.g., storm water settlement ponds, semi permanent ponds and wetlands) may impact important predators and natural enemies in the habitat. Elimination of the natural enemies that helped keep the initial mosquito population in check, facilitates a resurgence and re-colonization of that habitat by mosquitoes and can lead to a dependence on the continued use of larvicides in that habitat..

D. Use of Insecticides for Adult Mosquito Control

1. **Techniques of Adult Mosquito Control -** Adult control consists of two different methodologies. One methodology is known as "the application of "Ultra Low Volume (ULV) aerosols" and/or "fogging". The other methodology is known as the application of "barrier treatments".

2. **Aerosol or Fog Applications for Adult Mosquito Control** – Aerosols/fogs applications are the most widely used method of adult mosquito control and involve a volumetric treatment of air by the dispersal of very fine aerosolized droplets that are light enough to float on the air and be carried over a large area. These small droplets (generally ranging from 1 to 40 microns in size) float on air currents and intoxicate the flying mosquitoes that are impacted by them. Fogs/aerosols are dispensed in very low doses (ounces per acre) and do not leave any significant residual pesticide layers on surfaces within treated areas. Aerosols and fogs generally only kill mosquitoes that are in flight because mosquitoes that are resting in sheltered areas are not impacted by sufficient numbers of droplets to get a toxic insecticide dose.

    a. Ultra Low Volume (ULV) fogs and aerosols are generated with dispensing machines that physically split a liquid insecticide into very small droplets of a relatively uniform size (narrow size range). Most ULV machines can be set to produce droplets of a particular size within the 1 to 50 micron size range. The production of ULV aerosols/fogs does not require that the liquid insecticide concentrate be mixed with a carrier liquid such as oil or water, so a very small volume (ultra low volume) of liquid insecticide can be converted into a fog/aerosol of relatively pure insecticide and be dispensed over a wide area.

    b. Thermal fogs are generated with thermal fogging machines that heat the liquid insecticide during the process of breaking it into small droplets. Thermal fog droplet sizes may range from 1 to 50

microns, with a large portion of the droplets being in the 10 to 15 micron (visible) size range. Droplets within this size range scatter light and therefore appear as a white cloud. Insecticides dispensed by thermal foggers must be mixed with a carrier liquid such as oil, so thermal fog applications require more liquid volume per the quantity of insecticide dispensed.

c. Fogs and aerosols are essentially the same thing, but vary slightly in definition. A fog is a visible aerosol because it consists of a large portion of small droplets in the 10 to 15 micron, visible size range. An aerosol is a general term that describes air borne droplets in a variety of sizes from visible, fog-sized, droplets to larger, less visible droplet sizes in the 15 to 40 micron size range. A fog is an aerosol, but an aerosol is not necessarily a fog. The difference between these two terms is technical and for practical purposes, most personnel involved in mosquito control refer to aerosols generated by both ULV machines and thermal foggers as fogs, and refer to both types of machines as foggers. Aerosol droplets in the 40 to 100 micron size range do not float in the air for very long, and can leave a wet residual layer on any solid surfaces they encounter. These larger sized droplets are considered to be a mist.

d. Application of mosquito adulticide aerosols/fogs should be considered and evaluated on a case-by-case basis. Mosquito control response levels (see Section E., Level I-b through V, below) based on local levels of vector mosquito activity and arboviral activity may aid in determining when to apply adulticides. However, this judgment can only be made based on local surveillance data and knowledge of local conditions (e.g., human population density, detected levels of arboviral activity, target mosquito species, mosquito population density, layout of local roads or other geographical features, weather forecast, prevailing wind directions, etc.). Mosquito aerosol and fog applications should be made using properly maintained and calibrated ULV machines and foggers. Adulticide aerosol/fog applications may be made by equipment that is hand held, or mounted on backpacks, all terrain vehicles, trucks, or on fixed-wing or rotary-wing aircraft.

e. Aerial applications of mosquito control insecticides are useful for rapidly treating large areas that cannot be easily accessed or covered in a timely manner by ground based spraying equipment. Due to the speed of coverage, the large area that can be treated, and the uniformity of the coverage, aerial applications are more effective in controlling mosquitoes than ground-based

applications. Aerial applications may be recommended when there is a widespread and imminent threat from mosquitoes infected with WNV (see Section E., Response Level V, below). Depending on the configuration and size of the area to be sprayed, one may need to consider the advantages and drawbacks of using either fixed-wing or rotary-wing aircraft for dispersing insecticides.

Aerial applications of pesticides require much advanced planning to identify the areas that should be treated, identify the areas to be avoided, and to properly notify or warn populations and businesses (e.g. beekeepers, aquaculture farmers, food preparation facilities) within the proposed spray area. Properly certified applicators must be aboard each aircraft that is conducting aerial pesticide applications. State and local public health and other governmental agencies may establish pre-existing requirement contracts with commercial pesticide applicators that can be activated on a moments notice when wide-area mosquito control becomes necessary. When the potential for arthropod-vectored disease transmission is so high that mosquito control requirements exceed the capability of local and state resources to respond in a timely manner, the state may request assistance from the Federal Emergency Management Agency for emergency funding for contracting aerial mosquito control operations and/or may request assistance from the Department of Defense for aerial application of mosquito control pesticides by the U.S. Airforce.

f. Timing and conditions for adulticide aerosol/fog applications must be appropriate for treatments to be effective. Depending upon the target species, the greatest efficacy will be achieved when applications are made during periods when the target species is in flight. For example, *Culex pipiens*, a primary vector of WNV, is a nighttime biter, and applications should be made starting at dusk and continuing into the nighttime hours. The fogging of daytime flying mosquitoes can be problematic. Fog applications made during daylight hours are often ineffective because warm convective air currents rising from close to ground level will carry the fine aerosol/fog droplets up into the sky. Daylight fog applications can be effective only when there are no convective currents and this may occur during early morning hours, on overcast days, or in heavily shaded areas. Fogging applications should be made when air temperatures are above 50° F because mosquitoes will not fly at lower temperatures. It is preferable to make fogging applications when wind speeds are from 3 to 5 mph. To avoid poor pesticide coverage due to excessive pesticide drift and dilution, fog applications should not be made when wind speeds exceed 10 mph. Applications should not be made from

either ground vehicles or aircraft during periods of dead calm because the fog/aerosol will not be carried from the road or aerial spray swath into target areas.

3. **Barrier Treatments for Adult Mosquito Control –** Barrier treatments involve the application (spraying) of residual liquid pesticides on surface areas. A residual pesticide barrier applied to a surface can kill adult mosquitoes that subsequently land on the treated surfaces. Depending on the surface treated, and the occurrence of rain or other factors that might degrade a residual insecticide layer after treatment, residual barrier treatments may be effective for several days to several weeks after application. Barrier treatments are applied to foliage, vegetation, the eaves, ceilings and walls of houses, or any other place where adult mosquitoes are known to land and rest. Barrier treatments may be applied using a simple liquid insecticide sprayer with a fan nozzle, or may be applied using a ULV machine or thermal fogger set to dispense mist-sized droplets in the 40 to 100 micron size range. Portable ULV machines are best used to apply barrier treatments to plants and foliage because relatively small quantities of insecticide can be used to apply a uniform layer of insecticide on a large area of foliage.

4. **Insecticides Used for Adult Mosquito Control** – The products currently registered in Virginia for adult mosquito control include insecticides in the organophosphate, and synthetic pyrethroid classes as well as pyrethrins. Some of the commonly used insecticides currently registered for use as mosquito adulticides in Virginia are listed in Attachment 4.C. Each of these insecticides has advantages and drawbacks as well as label specifications that will influence which material is most appropriate for a given situation (Attachment 4.C). Considerations should always be made on the adverse impact to non-target species and potential for detrimental health effects on sectors of the human population. Localities seeking additional guidance on appropriate mosquito control pesticides should contact: the Virginia Cooperative Extension at Virginia Polytechnic Institute and State University, Blacksburg, Virginia, Tel. (540) 231-6543; Dr David Gaines, Public Health Entomologist for the VDH-Office of Epidemiology, Tel. (804) 786-6261; or Dr. Marvin Lawson, VDACS-Office of Pesticide Services, Tel. (804) 786-3534.

E. Recommended Response Levels for Mosquito Control Operations

1. **Level Ia** – Winter weather, low likelihood of WNV epizootic activity, and little or no adult mosquito vector activity present.

   Plan and organize mosquito control program elements for larval and adult control. Identify habitats where larval control measures can be applied. Scout and identify locations where drainage/source reduction activities

could be applied and identify areas that might require larvicidal control methods once the mosquito season commences. If resources are available, conduct ditching and other source reduction operations.

2. **Level Ib** – Mosquito breeding season, adult mosquito activity present, no current evidence of WNV epizootic activity.

   Where appropriate and resources permit, conduct ditching, drain cleaning, filling of ruts, and other habitat modification activities for source reduction. Conduct larval control of vector species in identified breeding habitats where source reduction (habitat modification) is not possible. Consider adult mosquito control where large primary vector populations are detected. Implement an education/media campaign to encourage citizens to eliminate container breeding habitats around their homes.

3. **Level II** - Mosquito larvae and adults present, initial evidence of WNV epizootic activity (limited to birds and/or mosquitoes).

   Where resources permit, conduct programs for larval control in key problem mosquito habitats, continue and enhance source reduction and public education programs. Target larval vector populations and consider use of adult vector control tactics in areas where WNV activity has been detected, and adult vector species have escaped larval control.

4. **Level III** – Moderate WNV epizootic activity in mosquitoes and birds with initial evidence of WNV in a horse or human.

   Continue, source reduction and public education programs and enhance larvicide programs to target vector breeding habitats in areas of increased WNV epizootic activity. Consider use of adult control tactics in areas where vector species have escaped larval control and where evidence of WNV has occurred. Plan an emergency mosquito control program to be ready if conditions ever reach a state where such operations are needed.

5. **Level IV** – Heavy WNV epizootic activity suggesting high risk of human infection (i.e., high dead and/or positive bird densities, high mosquito infection rates). Confirmed human or horse case, abundant adult bridge vectors.

   Conduct larval mosquito control and strongly consider use of adult mosquito control tactics targeted at vector populations. Increase control efforts in areas of potential human risk

6. **Level V** – Multiple human cases of WNV and conditions favoring further transmission to humans.

   Implement emergency larval control and strongly consider use of adult

mosquito control tactics. If outbreak is widespread, covers multiple jurisdictions, and mosquito populations originate from large habitats inaccessible to ground vehicles, consider conducting aerial application of larvicides and adulticides targeted to known and potential areas of vector mosquito activity.

Known and Suspected Mosquito Vectors of West Nile Virus

Culex pipiens

Among the more common mosquito pests in Virginia, *Culex pipiens* is found in urban and suburban communities as well as on rural premises. It breeds in underground storm sewer catch basins; artificial containers; gutters; polluted ground pools; bird baths; discarded tires; animal waste lagoons; farm animal wallows; clogged, grass choked ditches; in effluent from sewage treatment plants; and in other sites that are slightly to very eutrophic or polluted with organic wastes. This mosquito is a nighttime flyer that will invade houses where it will hide in corners and in dark places during the day. This mosquito feeds principally on birds, but will feed on humans, particularly when inside a house. *Culex pipiens* over-winters as adult mosquitoes, hiding in culverts, under houses, and inside outbuildings. In the spring, eggs are laid on top of water, in suitable habitats. The eggs hatch into larvae that mature rapidly when water temperature and nutrient levels are relatively high. *Culex pipiens* females may travel up to 3/4 of a mile in a single night in search of a blood meal, but generally are found within ½ mile of their breeding habitat. *Culex pipiens* is the most important primary vector for WNV (amplifies WNV in the bird population). *Cx. pipiens* were the most common field collected mosquito to be found carrying WNV in during 1999, 2000 and 2001. For example, in 2001 there were five times as many *Cx. pipiens* that tested positive for WNV as Cx. restuans; *Cx. restuans* were the second most common field collected mosquito to test positive for WNV. *Cx. pipiens* are generally not readily trapped in large numbers with CDC traps, so low numbers in a CDC trap do not necessarily indicate low numbers in the environment. Their populations are best monitored with gravid traps baited with an appropriate infusion bait.

Culex restuans

Among the more common mosquitoes in Virginia, *Culex restuans* is found in most of the same breeding habitats as *Cx. pipiens*. *Cx. restuans* becomes active in the early spring and is the most common *Culex* species found during the springtime. *Cx. restuans* becomes less common during the warm summer months when *Cx. pipiens* is most active. *Cx. restuans* is a night biter that feeds exclusively on birds. Laboratory trials show them to be moderately competent WNV vectors, but they are probably the second most important primary vectors that amplify WNV in the bird population and they were the second most common field collected mosquito species to test positive for WNV during the 1999, 2000 and 2001 seasons. *Cx. restuans* are more readily trapped with properly baited gravid traps than CDC traps. Low numbers in a CDC trap do not necessarily indicate low numbers in the environment.

Culex salinarius

This species was identified as the most likely bridge vector for human WNV cases on Staten Island, NY in 2000. It is the third most common mosquito species to test positive for WNV. *Cx. salinarius* breeds in temporary flood-pools on the margins of freshwater, brackish or saltwater marshes. It may also be found breeding in any grass choked, stagnant puddle, or in large artificial containers containing a mixture of water and grassy organic matter or other vegetation. It can be found anywhere in Virginia and can be among the most abundant species in

some areas during the summer. It is attracted to CO2 baited CDC traps and is often caught in large numbers in coastal communities. *Cx. salinarius* is a nighttime flyer that may invade houses. It feeds readily on both birds and large mammals including humans. The flight range of *Cx. salinarius* is approximately 2-3 miles. It overwinters as an adult in rodent burrows, culverts or other sheltered areas, and may become active even during the winter months on nights when the air temperature is high enough to allow flight (e.g., >50°F).

Ochlerotatus triseriatus

This mosquito known as the "eastern tree hole mosquito" is found throughout Virginia. *Oc. triseriatus* favors laying eggs in tree holes (holes in stumps or tree trunks that hold water), but also breeds in artificial containers that are in shady locations and are polluted with some tree debris (leaves, etc.). It is often found in association with tire piles. *Oc. triseriatus* feeds during the day and its flight activity generally ends at dusk. *Oc. triseriatus* typically does not travel more than about 500 ft from its breeding habitat, so if tree hole mosquitoes are an identified problem, their breeding habitat is generally going to be close by. *Oc. triseriatus* has been identified as a moderately efficient WNV vector in the laboratory, but field data in 2000 and 2001 have shown it to be the fifth most common mosquito species found carrying WNV. *Oc. triseriatus* is the most important vector of LaCross Encephalitis. *Oc. triseriatus* are not readily trapped with CDC traps, so detection of low numbers with a CDC trap may mean that there are many more in the environment.

Ochlerotatus japonicus

This mosquito was first discovered in the United States in New York in 1998. Since that time it has been discovered throughout the states of Connecticut, New Jersey, and Pennsylvania. More recently it was discovered in central and western Maryland, Washington D.C., and northern Virginia and has been found in counties along the Shenandoah Valley and Blue Ridge mountains as far southwest as Roanoke Virginia. *Oc. japonicus* is associated with rock pools (holes in rock outcrops that hold water), but it breeds equally well in all forms of artificial containers. It can be found sharing its breeding habitat with *Oc. triseriatus* and like that species, becomes active relatively early in the season. Little is known about *Oc. japonicus*' flight range, or its feeding preferences, but it will bite humans. It was the sixth most common field collected mosquito to be found carrying WNV in 2001. In laboratory trials it has been shown to be a highly efficient vector of WNV. *Oc. japonicus* are not readily trapped with CDC traps, so detection of low numbers with a CDC trap may mean that there are many more in the environment..

Aedes albopictus

This mosquito is a container breeder that is found throughout Virginia and is easily the most common urban, suburban and rural nuisance mosquito associated with artificial breeding habitats. *Ae. albopictus* feeds during the day and its flight activity generally ends at dusk. However, it will enter homes at dusk, and once inside, will bite during the night even in darkness. *Ae. albopictus* does not become active until mid spring (mid May) and is most common during the summer months. This mosquito favors laying eggs in artificial containers that are in shady locations and are polluted with some tree debris (leaves, etc.), but it will also

breed in tree holes and rock pools. It is often found sharing larval habitats with *Oc. triseriatus* and *Oc. japonicus*. *Ae. albopictus* does not frequently travel more than about 500 ft from its breeding habitat, so if tiger mosquitoes are an identified problem, their breeding habitat is going to be close by. Populations of this mosquito are usually greatest around bushes and foliage nearest to the breeding habitat. *Ae. albopictus* has been identified as one of the most efficient WNV vectors in the laboratory, but its role in field transmission is still unclear. *Ae. albopictus* may also be an important vector of LaCross Encephalitis. *Ae. albopictus* are not readily trapped with CDC traps, so detection of low numbers with a CDC trap may indicate that there are many more in the environment.

Ochlerotatus atropalpus,

This mosquito, known as the "rock pool mosquito" breed mostly in rock pools (holes in rock outcrops that hold water), but have been known to occasionally breed in artificial containers, away from the rocky stream or river habitats where they are usually found. Like most other container breeding mosquito species, this mosquito feeds during daylight hours and does not venture far from its breeding habitat. They are known to bite humans and can be persistent biters near their habitat. Laboratory trials have shown *Oc. atropalpus* a to have one of the highest WNV vector competencies, but due to their limited distribution (mostly in places where rock pools occur) few have been captured and tested, and none have been found carrying WNV.

Aedes vexans

This mosquito is a floodwater breeder found throughout Virginia. It breeds in a great variety of temporary flood-pools, usually in woodlands or grassy sites (fields, ditches), and can be produced in large numbers in these habitats. Eggs are laid in moist depressions, especially those containing moist organic debris, and hatch when they are flooded by water. Eggs may hatch during the same season in which they were laid, or may also sit for several seasons until stimulated to hatch by floodwater. Several generations of this mosquito can occur each year. *Ae. vexans* has a flight range of 5 to 10 miles and feeds during dusk and after dark. Laboratory studies have shown it to be relatively inefficient as a WNV vector, but this mosquito can occur in large numbers and was suspected of being an important WNV bridge vector to horses and humans in New Jersey in 2000.

Ochlerotatus sollicitans

This mosquito is a saltmarsh breeder found primarily in coastal Virginia, but may occur anywhere in the state where water habitats and salinity levels are adequate. It is a fierce aggressive biter that can be produced in large numbers in saltmarsh habitats. *Oc. sollicitans* has a flight range of 5 to 10 miles, but may travel 40 or more miles. It takes feeding flights during dusk and after dark and is strongly attracted to lights, so it may migrate from salt marshes toward nearby towns. However, it will feed at any time during the day when its resting sites are invaded. Laboratory studies have shown it to be a moderately efficient WNV vector, but field studies have also shown that this mosquito feeds mainly on large animals and only a small proportion of its blood meals come from birds. Thus, only a low proportion might be infected with WNV. However, this mosquito can occur in huge numbers and care should be taken to avoid excessive exposure to them.

Other Mosquito Species

As the transmission of WNV is new in the United States, our knowledge of its vectors here is incomplete. During the 2001 season, 24 species of mosquitoes were found in the field carrying West Nile virus; 22 of those species are found in Virginia (see Table 1 below). About a dozen species of mosquitoes have been tested in the laboratory for their WNV vector competence (ability to become infected with, and transmit WNV). Those species that occur in Virginia and have high or moderate WNV vector competence have been described above. Other tested species have shown only low vector competence or no ability at all to become infected with and transmit WNV. Several other mosquito species in the *Ochlerotatus* genus have demonstrated potential to be WNV vectors in the laboratory and/or field. These include floodwater and salt marsh species. Thus far, the only floodwater species besides *Ae. vexans* to show potential as WNV vectors are *Oc. canadensis*, and *Oc. trivittatus*; a number of each of these mosquito species collected from the field in over the past three years in Northeastern United States, were carrying WNV. Other mosquito species that may serve as WNV vectors are likely to be discovered. Based on further surveillance information from other states and from Virginia's mosquito surveillance program, other species will be added to the known and suspected list as their vector potential is discovered.

Table 1: Field collected mosquito species found to be carrying West Nile virus (WNV) in the United States in 2001 and 2002 (carrying WNV does not necessarily mean that the mosquito was infected with, or had the ability to transmit the virus while feeding).

Rank	Total Positive Pools Found	Species	WNV Vector Competence	Vector Status *
1	1,286	*Culex pipiens*	Moderate	Primary & Bridge vector
2	346	*Culex restuans*	Moderate	Primary vector
3	141	*Culex salinarius*	High	Bridge & Primary vector
4	73	*Ochlerotatus triseriatus*	Moderate	Bridge vector
5	57	*Aedes vexans*	Low	Bridge vector
6	48	*Aedes albopictus*	High	Bridge vector
7	36	*Anopheles punctipennis*	Unknown	Bridge vector **?**
8	35	*Ochlerotatus jap. japonicus*	High	Bridge vector
9	22	*Culiseta melanura*	Unknown	Primary vector **??**
10	22	*Anopheles quadrimaculatus*	Unknown	Bridge vector **?**
11	19	*Culex erraticus*	Unknown	Bridge vector
12	15	*Coquillettidia perturbans*	Low	Bridge vector
13	14	*Ochlerotatus trivittatus*	Unknown	Bridge vector **?**
14	8	*Ochlerotatus sollicitans*	Moderate	Bridge vector
15	6	*Ochlerotatus taeniorhynchus*	Low	Bridge vector
16	6	*Ochlerotatus can. canadensis*	Unknown	Bridge vector **?**
17	6	*Psorophora columbiae*	Unknown	Bridge vector **?**
18	4	*Anopheles barberi*	Unknown	Bridge vector **?**
19	2	*Aedes aegypty*	Moderate	Bridge vector
20	2	*Orthopodomyia signifera*	Unknown	Unknown **?**
21	1	*Aedes cinereus*	Unknown	Bridge vector **?**
22	1	*Anopheles walkeri*	Unknown	Bridge vector **?**
23	1	*Culex territans*	Unknown	Unknown **?**
24	1	*Culiseta inornata*	Unknown	Unknown **?**
25	1	*Ochlerotatus atlanticus*	Unknown	Bridge vector **?**
26	1	*Ochlerotatus cantator*	Unknown	Bridge vector **?**
22	1	*Psorophora ciliata*	Unknown	Bridge vector **?**
24	1	*Uranotaenia sapphirina*	Unknown	Unknown **?**

***** Primary vectors feed on birds and maintain WNV in bird population; Bridge vectors feed on numerous animal species including horses, humans and birds and serve as a bridge for the virus to move from bird to mammal.

Using Insect Repellents Safely

The U.S. Centers for Disease Control recommend the following precautions when using insect repellents containing DEET as the active ingredient:

- Repellents should be applied only to exposed skin and/or clothing (as directed on the product label). Do not use under clothing.
- Make sure product is labeled for use on skin or clothing, not such things as tents or bed nets. Adults should not use products containing greater than 50% DEET on skin. Do not use products containing greater than 10% DEET on children.
- Higher concentrations of DEET (up to 50%) give the longest period of protection. Lower concentrations give shorter periods of protection. Use of DEET in concentrations greater than 50% will not increase the level of mosquito repellency or the length of the protection period.
- Never use repellents over cuts, wounds, or irritated skin.
- Don't apply to eyes and mouth, and apply sparingly around ears. When using sprays do not spray directly onto face; spray on hands first and then apply to face.
- Do not allow children to handle repellents, and do not apply to children's hands. When using on children, apply to your own hands and then put it on the child.
- Do not spray in enclosed areas. Avoid breathing a repellent spray, and do not use repellents near food.
- Use just enough repellent to cover exposed skin and/or clothing. Heavy application and saturation is unnecessary for effectiveness; if biting insects do not respond to a thin film of repellent, apply a bit more.
- After returning indoors, wash treated skin with soap and water or bathe. This is particularly important when repellents are used repeatedly in a day or on consecutive days. Also, wash treated clothing before wearing it again.
- If you suspect that you or your child is reacting to an insect repellent, discontinue use, wash treated skin and then call your local poison control center. If/when you go to a doctor, take the repellent with you.

You and your doctor can get specific medical information about the active ingredients in repellents and other pesticides by calling the National Pesticide Telecommunications Network (NPTN) at 1-800-858-7378. NPTN operates 9:30 a.m. to 7:30 p.m. (Eastern Time) seven days a week.

Pesticides Registered in Virginia Commonly Used to Control Mosquitoes

Larvicides: Insecticides applied to bodies of water identified as mosquito breeding areas to kill mosquitoes during the larval or pupal stages.

- ***Bacillus thuringiensis israelensis (Bti)***. Spores of this naturally occurring soil bacterium contain a pure toxin which disrupts the gut of mosquitoes and primitive fly species by binding to receptor cells present. It has little effect in other insect species. Bti will not affect mosquito larvae that have developed past the late 4th instar, or are in the pupal stage of development. Bti is not toxic to birds, mammals or fish and is practically non toxic to amphibians.

  Bacillus thuringiensis israelensis (Vectobac formulation*) has an oral LD_{50}* (rats) of >5000 mg/kg, and a dermal LD_{50}* (rabbits) of >2500 mg/kg.

- ***Bacillus sphaericus***. A naturally occurring bacterium also contains a toxin that disrupts the gut of mosquito larvae by binding to receptor cells found in certain species of mosquitoes. *B. sphaericus* will not affect mosquito larvae that have developed past the late 4th instar, or are in the pupal stage of development. *B. sphaericus* is not toxic to mammals or other animal groups. Data on toxicity to other arthropods is unavailable.
- ***B. sphaericus*** is very effective against *Culex* mosquito species found in water with high organic content.

  Bacillus sphaericus (Vectolex formulation*) has an oral LD_{50}* (rats) of >5000 mg/kg, and a dermal LD_{50}* (rabbits) of >2000 mg/kg.

- **Methoprene**. (Altosid). An insect growth regulator that prevents the normal maturation of insect larvae. Methoprene will not affect mosquito larvae that are developed past the late 4th instar, or are in the pupal stage of development. Methoprene has little effect on mammals, snails, frogs, mosquito fish, or on aquatic insects from orders with incomplete metamorphosis (e.g., will not affect mayflies, stoneflies, dragonflies, or damselflies, but may affect aquatic beetles and true flies). Methoprene may be slightly toxic to birds and slightly to moderately toxic to some species of fish. It may be highly toxic to aquatic to freshwater and estuarine invertebrates such as crabs or shrimp.

  Methoprene (technical grade) has an oral LD_{50}* (rats) of >5000 mg/kg, and a dermal LD_{50}* (rabbits) of >2000 mg/kg.

- **Temephos**. (Abate). An organophosphate insecticide that has a low to moderate mammalian toxicity. Temephos is highly effective against all mosquito larval stages but will not easily kill mosquito pupae. Temephos

can be highly toxic to some bird species and to some aquatic organisms such as certain fish species, freshwater insects, and other invertebrates (e.g., shrimp, crabs, mollusks).

Temephos (technical grade) has a variable oral LD_{50}* in rats that could be as low as 1226 mg/kg, and a dermal LD_{50}* (rabbits) of 1155 mg/kg.

- **Monomolecular Films (**Agnique**)**. Chemicals which spread a thin film on the surface of the water and make it difficult for mosquito larvae, pupae or emerging adults to break through or attach to the water's surface, causing them to drown. Typically films remain active for 10-14 days on standing water.

- **Surface Oils**. Similar to monomolecular films, oils form a coating on top of water to drown larvae, pupae and emerging adult mosquitoes. Oils do not pose a risk to human health. However, they may be toxic to amphibians, fish and other aquatic organisms if misapplied.

Adulticides: Insecticides, typically applied with ultra low volume (ULV) spray equipment, that dispenses the pesticide as a fine fog to kill adult mosquitoes. ULV releases a few ounces per acre of treated area, and is released as tiny particles (generally <50 micron sized droplets) of insecticide solution that drift in the air. Insecticides can only be used for fogging applications if they are labeled for that purpose. Adulticides may also be applied as a liquid surface spray or applied as a ULV mist (larger droplet sizes of >50 microns) to leave a toxic residual "barrier treatment" on surfaces (walls, ceilings, eaves and shrub or ivy foliage) where mosquitoes land and rest. Insecticides can only be used for barrier treatments if they are labeled for that purpose.

Organophosphate Insecticides – Because organophosphates are neurotoxins that readily affect mammalian nervous systems (cholinesterase inhibitors), exposure to high doses can over-stimulate the nervous system and cause convulsions, respiratory paralysis and death. Most organophosphates are toxic to fish and aquatic invertebrates and are highly toxic to honeybees.

- **Malathion**. An organophosphate insecticide applied by truck-mounted or aircraft-mounted ULV sprayers at a maximum rate of 0.23 pounds (2.5 fluid ounces) of active ingredient per acre. Malathion has a relatively low toxicity to humans and other mammals, is moderately toxic to birds and has a wide range of toxicities to different fish species. It is highly toxic to amphibians and aquatic invertebrates, and should not be applied over water with ground fogging equipment. Malathion is highly toxic to honeybees and should not be applied at times and locations where bees are foraging.

Malathion (e.g., Fyfanon ULV formulation) has an oral LD_{50}* (rats) of 2830 mg/kg; a dermal LD_{50}* (rats) of 2000 mg/kg; and an inhalation LC_{50}** (rats) of >5000 mg/m^3 (4 hour exposure).

- **Naled** (dibrom) can be applied by truck-mounted or aircraft-mounted ULV sprayers at a maximum rate of 0.05 pounds (0.8 ounces) of active ingredient per acre by air and 0.33 ounce per acre by ground equipment. Naled is moderately toxic to humans and other mammals, and moderately to highly toxic to birds. It may also be moderately to highly toxic to fish and highly toxic to aquatic invertebrates and should not be applied over water with ground fogging equipment. Naled is highly toxic to honeybees and should not be applied at times and locations where bees are foraging. Naled is also highly corrosive and will damage the paint on cars or other objects that are too close to the sprayer.

  Naled (e.g., Trumpet EC formulation*) has an oral LD_{50}* (rats; female) of 180 mg/kg; a dermal LD_{50}* (rats; female) of 360 mg/kg, and an inhalation LC_{50}** (rats) of 1520 mg/m^3 (6 hour exposure).

Pyrethroid Insecticides - Due to their toxicity to fish, many of these products have restrictions which prohibit the direct application of these products to open water or within 100 feet of lakes streams, rivers or bays. Pyrethroids are also highly toxic to honeybees and care must be taken not to spray in areas and at times when honeybees are foraging.

- **Permethrin** can be applied by backpack, truck, or aircraft mounted foggers at a maximum rate of 0.0036 pounds (0.057 ounces) of active ingredient per acre. Some permethrin formulations are labeled for use as barrier treatments. Permethrin is practically non-toxic to birds and has a low mammalian toxicity. Permethrin is highly toxic to fish and aquatic invertebrates (crabs, mollusks) and should not be applied where surface water is present or where air movement favors drift towards aquatic environments. Permethrin is extremely toxic to honeybees and should not be applied at times and locations where bees are foraging.

  Permethrin (e.g., Aqua-Resilin formulation*) has an oral LD_{50}* (rats) of 1000 mg/kg; a dermal LD_{50}* (rabbits) of >5000 mg/kg, and an inhalation LC_{50}** (rats) of 2870 mg/m^3 (4 hour exposure).

- **Resmethrin** can be applied by backpack, truck, or aircraft mounted foggers at a maximum rate of 0.0035 pounds (0.056 ounces) of active ingredient per acre. Resmethrin is practically non-toxic to birds and has a low mammalian toxicity. Resmethrin is very is highly toxic to fish and aquatic invertebrates and should not be applied where surface water is present or where air movement favors drift towards aquatic environments. Resmethrin is highly toxic to honeybees and should not be applied at times and locations where bees are foraging.

Resmethrin (e.g., Scourge formulation*) has an oral LD_{50}* (rats) of 2700 mg/kg; a dermal LD_{50}* (rabbits) of >2000 mg/kg, and an inhalation LC_{50}** (rats) of 2640 mg/m^3 (4 hour exposure).

- **Sumethrin** can be applied by backpack, truck, or aircraft mounted foggers at a maximum rate of 0.0036 pounds (0.057 ounces) of active ingredient per acre. Sumithrin has a moderate toxicity to aquatic invertebrates and is very highly toxic to fish and should not be applied where surface water is present or where air movement favors drift towards aquatic environments. Data on toxicity to birds and bees was unavailable.

  Sumethrin (Anvil formulation*) has an oral LD_{50}* (rats) of >5000 mg/kg; a dermal LD_{50}* (rabbits) of >2000 mg/kg, and an inhalation LC_{50}** (rats) of 4570 mg/m^3 (4 hour exposure).

* LD_{50} = The lethal dosage of pesticide that would kill 50% of test animals (usually rats), expressed as milligrams of pesticide per kilogram of the animals body weight. The lower the value for an LD_{50}, the more toxic the pesticide will be. The LD_{50} for oral or dermal toxicity can vary from one insecticide formulation to another (e.g., two different formulations of the same insecticide could vary significantly, and pure technical grade material might be less toxic than some formulations of lower concentration). Although the effects of an insecticide would not be the same for humans as for rats, test rats are used as a rough equivalent for the pesticide's effects on mammals or humans. Translated to humans, an oral LD_{50} of 5000 mg/kg (5 grams/kg) would mean that a human weighing roughly 100 kg (220 lbs) would have to consume 500 grams (1 pound) of pesticide to suffer a 50% mortality rate. An oral LD_{50} of >5000 mg/kg is generally not considered to be very toxic. Table salt is not generally considered to be toxic, however, a 100 kg human who consumed 500 grams of table salt would suffer considerable or possibly lethal toxic effects.

** LC_{50} = The lethal concentration of pesticide that would kill 50% of test animals (usually rats) after a specified amount of time breathing this concentration. The LC_{50} for inhalation is usually expressed as milligrams of pesticide per cubic meter of air.