

British Columbia Mosquitoes as Vectors of West Nile Virus

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West Nile Virus (WNV) is transmitted between birds and mammals and maintained in endemic areas by mosquitoes (Diptera: Culicidae). It is occasionally found in reptiles and amphibia. Bird-biting species in the culicine group (*Culex*, *Culiseta*, *Aedes/Ochlerotatus*) evidently amplify the virus in endemic areas of Africa, S. Europe and W. Asia, and since 1999 in N. America. Mosquitoes develop in water, many of them, including most *Anopheles*, *Culex* and *Culiseta* species, have several generations a year, and almost all of these overwinter as mated but unfed adult females. WNV has been identified in a few males and overwintering females and it may therefore pass from adult ovary to egg.

The virus has been isolated from over 80 species of mosquito world wide since its discovery in the West Nile district of Uganda in 1937. It may multiply to a greater or lesser extent in the body cavity of infected mosquitoes and the virus must then migrate to their salivary glands ready to be injected into a host, if and when the mosquito takes a second blood meal. This, together with the biology of the species, leads to a scale of 'vector competence'.

Turell *et al.* (2005) ranked 25 potential WNV vectors with ratings from ++++ to 0 competence, and the Center for Disease Control lists another 27 North American species known to carry the virus (positive, indicated with a P in my table below) (CDC 2004, 2005). We have about 50 different species of mosquitoes in BC (Belton 1983) and I arbitrarily rated those included by CDC following Turell's criteria (taking into account their biology and ability to transmit other viruses), with a question mark for the species Turell *et al.* (2005) did not rate. I include the competent virus vector *Aedes togoi*, not yet studied in detail, but which is found commonly in rockpools around Georgia Strait and on Gulf Islands here and in WA. At the time of writing (May 2007), WNV has not been identified in any resident host in our Province.

Potential Vectors in BC	Positive (P)	Competence (+)	Feeding preference, biology
<i>Culex tarsalis</i>	P	++++	Birds, mammals ³
<i>Cx. pipiens</i>	P	+++	Mostly birds ³
<i>Cx. territans</i>	P	0?	Mostly amphibia ³
<i>Culiseta impatiens</i>	P	0?	Mostly mammals ⁵
<i>Cs. incidens</i>	P	++?	Mostly mammals ³
<i>Cs. inornata</i>	P	+++	Birds, mammals ³
<i>Cs. morsitans</i>	P	++?	Mostly birds ¹
<i>Aedes cinereus</i>	P	+	Birds? Mammals ¹
<i>Ae. vexans</i> [•]	P	++	Mostly mammals ¹
<i>Aedes (Ochlerotatus) canadensis</i>	P	++	General feeder ¹
<i>Ae. (Oc.) dorsalis</i>	P	+++	Mammals, occasionally birds ¹
<i>Ae. (Oc.) fitchii</i>	P	0?	Mostly mammals ¹
<i>Ae. (Oc.) hendersoni</i> [*]		+++?	Birds? mammals ¹
<i>Ae. (Oc.) melanimon</i>	P	+++	Mammals, occasionally birds ¹
<i>Ae. (Oc.) provocans</i>	P	0?	Mostly mammals ¹
<i>Ae. (Oc.) sierrensis</i>		+	Mammals ⁴
<i>Ae. (Oc.) sticticus</i>	P	+	Mammals ¹
<i>Ae. (Oc.) togoi</i>		++++?	Birds, mammals ⁴
<i>Mansonia (Coquillettidia) perturbans</i>	P	+	Birds, mammals ²
<i>Anopheles punctipennis</i>	P	+	Mammals, birds ³
<i>An. earlei</i>	P	+	Mammals, birds ³

¹ Eggs overwinter, one or two generations / year.

³ Females overwinter, several generations / year.

⁵ Females overwinter, one generation / year.

² Larvae overwinter, one generation / year

⁴ Eggs and larvae overwinter, several generations / year

^{*} Biology very similar to P +++ *Ae. triseriatus* in eastern N. America.

[•] Though common and a competent vector, *Ae. vexans* has never been found with significant amounts of WNV in Canada. Mortality of birds and infection of horses will probably be our first notification of WNV in the Province. Nevertheless humans sharing the habitat of any of the species listed above might expect bites from them in a normal season and we should be prepared to confirm the mosquitoes' distribution and verify their blood feeding habits before then. Traps are being set out across the Province and picture keys to the genera of immature and adult mosquitoes of BC are available from the British Columbia Centre for Disease Control (BCCDC) where tests for viral RNA in the more competent mosquito species are being done.

Names of the genera of mosquitoes follow Wood *et al.* (1979).

Biology and Distribution

++++ *Culex tarsalis* is a native species, widely distributed in ditches and permanent and semipermanent pools in grassland and open woodland in the southern third of the Province. Specimens have recently been found in southern Vancouver Island. It is a proven virus vector, implicated in our human cases of Western Equine Encephalomyelitis (WEE) in the 1970's. They are present and bite mostly in the early morning and evening all summer. All our *Culex* and *Anopheles* species and most *Culiseta* overwinter as mated females and emerge in early spring for blood meals.

+++ *Cx. pipiens* was probably introduced to the west coast of North America in the late 1800's. Since the 1920's it has spread across the south of the Province and into Vancouver Island and is now one of the commonest mosquitoes in artificial containers (e.g. rain barrels and paddling pools) drainage ditches and storm sewers, particularly those contaminated with organic matter. It feeds primarily on birds but comes indoors to bite on warm summer nights, often making itself heard in the bedroom. It is a proven vector of WNV, WEE and St Louis Encephalitis (SLE). It was found in Prince George in 2004 and may be widely distributed in the southern half of the Province.

++++ *Cx. restuans*, which may not be indigenous, is an important amplifying vector of WNV. There are unconfirmed records of a female from Esquimalt and others from northern ID, but adults could be misidentified *Cx. pipiens*. Larvae, which have never been found in BC, are unmistakable. It is less 'domestic' than *Cx. pipiens*, but larvae can be found in artificial containers around homes, as well as other sites with some organic content. Primarily a bird feeder, females will also feed on reptiles and mammals.

Cx. territans is widely distributed in BC but has nowhere been seen or persuaded to bite a mammal. It is occasionally infected, perhaps from a bird or reptile but its preferred hosts are amphibians.

Culiseta impatiens, also widely distributed, is a human biter early in the season. Primarily a woodland species, it is long-lived, with just one generation a year. Its vector capacity and its host preferences later in the year are not known.

++ *Cs. incidens* is our commonest mosquito with many generations a year and very well adapted to domestic sites. It has recently been found with WNV (CDC 2005) and in laboratory tests it transmitted WNV and several other viruses (Reisen et al. 2006).

++ *Cs. inornata* is widely distributed across the western Provinces and into the arctic with several generations a year in the south of the Province. Egg rafts are laid in almost any slow moving or stagnant water but seldom in artificial containers and females are known to be competent vectors of WEE, feeding readily on birds and mammals. Its transmission rates were moderate in tests with WNV in CA but it is active earlier and later in the year than *Culex pipiens* and *tarsalis* both there and in BC.

++ *Cs. morsitans* is a widely distributed northern species. Most of its blood meals are from birds and it is known to bite mammals but its vector ability has not been investigated. It is our only member of the genus that overwinters in the egg stage.

+ *Aedes cinereus* is found throughout the Province and is known to bite humans even during the day. It is a late hatching species with several generations a year in southern BC. Its vector capacity is unknown.

++ *Ae. vexans* is a notorious early summer floodwater pest over the entire Province. With favourable early warm flooding, it may produce 2 generations a year. Females bite man and domestic mammals indiscriminately but seem to feed on birds less often. Most bite between dusk and dawn and are proven virus vectors. Despite being a common pest, it has never been found to contain significant amounts of WNV in Canada and it is unlikely to be a significant vector in the Province

++ *Ae. (Ochlerotatus) canadensis* is a fairly common species found in the late summer throughout the Province. In the south it may produce two generations a year and is a very general feeder on animals ranging from amphibia to mammals. They have not yet been found with virus in Canada.

+++ *Ae. (Oc) dorsalis* and *melanimon* are very similar species producing up to two generations a year in saline pools and flooded pastures in the interior of the Province. *Ae. dorsalis* is also found in coastal salt marshes around the Georgia Strait and south to CA. It is known to feed on birds occasionally. Both are confirmed vectors of other viruses

Ae. (Oc) fitchii is a widely distributed human pest of woodland and open pools often up to high altitudes in mid and late summer. Its vector ability is not known.

+++? *Ae. (Oc) hendersoni* is an uncommon tree cavity and shaded artificial container breeder known from Vernon to Kootenay Lake. It can be a significant local pest but its vector capacity is not known. It has been confused in the past with

Ae. (Oc) triseriatus, a proven vector with a +++ rating, that evidently can transmit WNV in eastern North America.

Ae. (Oc) provocans is an early man-biting snowmelt species collected mostly in the east of the Province. Its vector capacity has not been investigated.

+ *Ae. (Oc) sierrensis* can be a significant pest on the west coast and the south of the Province, biting during the day and entering houses. It develops in tree cavities and shaded artificial containers, overwintering in the larval stage or as eggs if the late summer is dry. Its WNV infection and transmission rates were low in California tests (Goddard *et al.* 2002). It has not been found with WNV in the wild and, because it seems not to bite birds, may not be an important virus vector.

+ *Ae. (Oc) sticticus* is, after *Ae. vexans*, our second most important flood-plain pest, hatching after extensive flooding or prolonged rainfall. It has been shown to transmit SLE in the laboratory (Hammon and Reeves 1943).

++++? *Ae. (Oc) togoi* could be as important a vector as the two other species introduced from Asia, *Ae. albopictus* and *Ae. (Oc) japonicus* established in the east. The last is now also established in western WA not far from our border. All 3 feed during the day on a variety of hosts. Fortunately our species has not spread inland from its favoured coastal rock pools but it is distributed widely around the Georgia Strait, the Gulf Islands and the Washington coast. In Asia, *Ae. togoi* is an important vector of Japanese Encephalitis, a virus of the same serotype, (B), as WNV. It breeds year round, overwintering as 4th stage larvae or eggs, feeds on birds and mammals and is often common enough to be a pest to seaside homeowners.

+ *Mansonia (Cq) perturbans* typically develops in permanent 'cat tail' marshes where the larvae and pupae attach to the air-filled roots of marsh plants and resist conventional control methods. It overwinters in the larval stage and is widely distributed in the southern half of the Province, there are records of it on Vancouver Island, in the Georgia Strait and in 2004 it was found near Prince George. Females bite birds and mammals readily day and night, enter houses and inflict a bite that is painful and long lasting on most victims. It is a proven virus vector in the east. Present but not tested for competence as a vector in CA.

+ *Anopheles punctipennis* can develop in almost any open water and is occasionally found in tree cavities and artificial containers. All three of our *Anopheles* species are potential virus vectors; this one is generally distributed in the southern half of the Province, *An. freeborni*, an efficient vector of human malaria, is restricted to dryer southern regions. *Anopheles punctipennis* is the only anophelene confirmed from Vancouver Island (Stephen *et al.* 2006).

+ *Anopheles earlei* extends much farther north than *An. punctipennis* but its biology is similar with several generations a year in the south. It probably feeds mainly on mammals and, often found in beaver lodges, has been called our national mosquito.

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For the latest information on West Nile virus in the Province, visit the BCCDC web site <<http://www.bccdc.org>>.