

SASKATCHEWAN MOSQUITOES AND WEST NILE VIRUS

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West Nile virus and wild birds

West Nile virus (WN) is a virus of wild birds, transmitted from bird to bird primarily by mosquitoes. Native to southern Europe, the Middle East and Africa, the virus arrived in North America in 1999 and spread quickly across the continent. Over 225 species of birds have been reported as infected with WN; some of these species, such as members of the crow family, suffer severe disease and often die from WN infection, while others appear to tolerate infection without becoming ill. The American Crow, Black-billed Magpie, Blue Jay and Common Raven, are used as indicator species because their high and rapid death rates allow the spread of the virus to be monitored.

West Nile virus and mosquitoes

Some species of mosquito feed almost exclusively on birds, some feed mainly on mammals, and a few feed readily on both birds and mammals. During spring and summer, bird-feeding species of mosquito spread WN from bird to bird, and there is a gradual increase, or amplification, in the amount of virus circulating in birds and mosquitoes from the beginning to the end of the mosquito season. Mosquitoes thus act as 'vectors' of the virus, moving it between individual animals. Mosquito species that feed on both birds and mammals, and which often feed more than once as adult females, are capable of feeding first on an infected bird and then on a mammal, thereby passing the virus from the bird to the mammal. Even though the virus does not grow well in mammals and there is seldom enough virus in a mammal's blood stream to infect mosquitoes that feed on them, some mammals, including horses and humans, can become ill from WN infection.

Many mosquitoes, including most *Anopheles*, *Culex* and *Culiseta* species, have several generations a year, and almost all of them over-winter as mated but unfed adult females.

Although mosquitoes generally become infected by taking blood from an infected bird, the presence of the virus in a few over-wintering females that had not taken their first blood meal suggests that the virus can pass directly from the female mosquito to the eggs. If a mosquito infected with WN is able to pass WN to its eggs, then at least some of the adult mosquitoes that develop from those eggs will be infected and able to infect birds or mammals when they seek their first blood meal. The virus may multiply to a greater or lesser extent in infected mosquitoes between blood meals and this, together with the biology of the species, make some species more competent vectors, or virus carriers, than others.

Capacity of Saskatchewan mosquitoes as vectors of West Nile virus

In North America, 49 species of mosquitoes have been shown to carry WN. *Culex* species have been the mosquitoes most commonly infected with WN.⁵ Physiological and ecological characteristics of *Culex* species support the role of these mosquitoes in maintaining WN in nature. Seventeen species of Saskatchewan mosquitoes, belonging to the genera *Culex*, *Culiseta*, *Aedes*, *Ochlerotatus*, *Anopheles*, and *Coquillettidia*, have been shown to be infected with WN in other states or provinces. However, only a few of these species appear to have a high capacity as vectors that transmit the virus from bird to bird or from bird to mammal with regularity (Table 1)

Table 1. Vectorial capacity* of WN positive mosquitoes known to occur in Saskatchewan^{1,4,9}
(Cx.=Culex; Cs.=Culiseta; Ae.=Aedes; Och.=Ochlerotatus; Ano.=Anopheles; Coq.=Coquillitidia)

Species	Ecozone or Ecoregion	Host Preference	Vector	Role	Vectorial Capacity
			Bird-to-bird	Bird-to-mammal	
<i>Cx. tarsalis</i> ** (2)	prairie/parkland	Birds, mammals	++	+++	+++
<i>Cx. restitans</i> ** (2)	prairie/parkland	Mostly birds	+++	++	++
<i>Cx. territans</i> (2)	prairie/parkland/boreal	Frogs, reptiles?			
<i>Cs. inornata</i> ** (2)	prairie/parkland/boreal	Mostly mammals, occasionally birds		++	++
<i>Ae. vexans</i> (3)	prairie/parkland	Mammals		++	++
<i>Ae. cinereus</i> (3)	Parkland/boreal	Mammals, birds?			
<i>Och. canadensis</i> (3)	parkland	Mammals, general feeder			+
<i>Och. dorsalis</i> (3)	prairie/parkland	Mammals, occasionally birds		++	++
<i>Och. fitchii</i> (3)	prairie/parkland/boreal	Mammals			
<i>Och. nigromaculis</i> (3)	prairie	Mammals			
<i>Och. provocans</i> (3)	parkland/boreal	Mammals			
<i>Och. sticticus</i> (3)	prairie/parkland	Mammals			
<i>Ano. Earlei</i> (2)	prairie/parkland/boreal	Mammals			
<i>Ano. walkert</i> (4)	prairie/parkland/boreal				
<i>Cs. morsitans</i> (2)	parkland/boreal	Birds, mammals			
<i>Coq. perturbans</i> (5)	parkland/boreal	Birds, mammals, general feeder			+

* Vectorial capacity includes vector competence and also adjusts for population size, feeding habits, lifespan, etc. Vector competence refers to the ability of a species to transmit a pathogen.

** WN virus isolations obtained in 2003 from Saskatchewan

1 Vectorial capacity is rated as follows: 0=inefficient, +=efficient, +++=moderately efficient and ++++=extremely efficient. If cell is blank, vectorial competence is unknown.

2 Females overwinter, several generations per year

3 Eggs overwinter, one or two generations per year

4 Eggs overwinter, several generations per year

5 Larvae overwinter, one generation per year

Culex tarsalis is believed to be the principal transmitter of WN to humans in Saskatchewan due to its multivoltine reproduction (multiple generations per season), regular habit of taking more than one blood meal, and willingness to feed on both birds and mammals. This last trait makes it Saskatchewan's most important "bridge" vector, moving WN outside its normal bird-to-bird cycle of infection to one including people.

There is evidence in some *Culex* species, including *Culex tarsalis*, of vertical transmission from parent to offspring as evidenced by infected males (males do not take blood meals). Such transmission through eggs may explain how WN infects so many vector mosquitoes so rapidly during the mosquito season (*Culex tarsalis* has several generations a year), and also how the virus may survive the winter (*Culex tarsalis* overwinters as a mated adult female).

Culex restuans is a competent bird-to-bird and bird-to-mammal vector for WN, but it has not been a common species of mosquito in Saskatchewan over the last decade. Historical records of *Culex restuans* show only a sporadic occurrence of this species, with low numbers collected at Weyburn, Outlook, Saskatoon and Melfort. However, a survey of water-filled tires and catch basins in 2003 revealed that this species is probably more widespread than previously thought, particularly in parkland areas. This species and *Culex tarsalis* are probably the principal species infecting and amplifying the virus in birds. *Culex restuans* seems to prefer bird hosts, and feeds only occasionally on mammals, snakes and turtles. Thus its role as a vector of infection for humans is small.

Another species of *Culex*, *Culex pipiens*, is the species suspected of being the main vector in many urban areas of southeastern Canada and the United States. This species has not been recorded in Saskatchewan. The distribution of *Culex pipiens* includes

southern Ontario and Quebec as well as southern B.C. (Belton, P. 2004. pers.comm.).

Culiseta inornata may be a significant transmitter of WN from birds to horses late in the summer season (Lindsay, R. 2003. pers. comm.). However, its preference for the blood of larger mammals and its reluctance to take more than one blood meal make virus transmission by this species to humans or other animals relatively rare.

WN infection in *Ochlerotatus dorsalis* and *Aedes vexans* has been less frequent than in *Culex* spp. or in *Culiseta inornata*, but these species are usually more abundant than *Culex tarsalis*.

They are capable of transmitting WN from birds to mammals and thus may be the source of some human infections. Selected *Aedes* and *Ochlerotatus* species probably serve as bridge vectors transmitting WN from the *Culex*/bird cycle to humans and horses.^{2,14,15,16} *Aedes vexans* is Saskatchewan's most common mosquito pest for humans, but it rarely feeds on birds and thus rarely becomes infected with WN. *Ochlerotatus nigromaculis* is a grassland species restricted to the southern parts of Saskatchewan, south of the Trans-Canada Highway. It breeds in shallow pasture depressions and weedy ditches. The first adults are encountered in July and a second generation is possible in September if conditions are favourable. It is a severe biter and can take multiple blood meals.

Of the other species shown in Table 1, virus transmission by most woodland *Ochlerotatus* and *Aedes* species rarely occurs due to their reluctance to take more than one blood meal during their lifetime. *Ochlerotatus sticticus*, a species associated with *Aedes vexans*, is a floodwater species that is only abundant in localized areas that flood over extensive areas. *Ochlerotatus canadensis*, *Ochlerotatus fitchii*, *Ochlerotatus provocans* and *Aedes cinereus* are mammal-feeding, woodland species that are sometimes



Figure 1. *Culex tarsalis*. This “elegant”, medium-sized species is relatively easy to identify. The females have rounded abdomens, not pointed as in *Ochlerotatus* and *Aedes* species. *Culex tarsalis* also has a broad median white band on the proboscis and conspicuous apical and basal rings on the segments of the legs / Ralph Underwood

common and have a widespread distribution in the province. They are most abundant in the northern parklands and boreal forest transition zone. *Aedes cinereus* is not encountered in prairie regions. *Anopheles earlei* and *Anopheles walkeri* are widespread species in parkland and forested areas that can have several generations per year. *Culiseta impatiens* is a relatively rare northern forest species that prefers shaded pools in coniferous forest areas. *Culiseta morsitans* is found in the aspen parkland area and southern boreal forest areas, often breeding in habitats containing sedges. Unlike the other species of *Culiseta*, this species over-winters in the egg stage and not as adult females. *Coquillettidia perturbans* is a cattail marsh mosquito, but is rarely encountered in Saskatchewan.

Biology of *Culex tarsalis*

The main mosquito vector or transmitter of WN to humans in Saskatchewan appears

to be *Culex tarsalis* (Figure 1). This species is also the main vector of two other important disease-causing viruses that are known to occur from time to time in Saskatchewan: Western Equine Encephalitis virus and St. Louis Encephalitis virus.

Culex tarsalis over-winters as adult females that hibernate in skunk and badger burrows, basements, cellars, caves and buildings that provide some protection from the cold.^{10,21} Adults emerge from hibernation from early to late April in southern Saskatchewan when the outside temperatures start to exceed the temperatures where they are hibernating.¹⁰ *Culex tarsalis* may have several generations per year, with eggs laid in floating egg rafts throughout the spring and summer. Development of the first generation in the water is relatively slow and is dependent on water temperature. Adults from this first generation usually appear during the middle

Table 2. Week of First Occurrence of 1st, 2nd and 3rd Generation *Culex tarsalis* in Saskatchewan 2003

Grassland Ecoregion (n=10)	Gen 1	Gen 2	Gen 3
Mean	June 16–June 22	July 7–July 13	July 28–August 3
Range	June 9–June 22	June 30–July 27	July 14–Aug. 10
Parkland Ecoregion (n=19)			
Mean	July 7–July 13	July 28–Aug. 3	Aug. 18–Aug. 24
Range	June 23–July 20	July 21–Aug. 17	July 21–Aug. 31
Boreal Transition Ecoregion (n=7)			
Mean	July 7–July 13	July 28–Aug. 3	Aug. 4 – Aug. 10
Range	June 23–July 27	July 21–Aug. 17	Aug. 4 – Aug. 10

of June in southern prairie areas and near the end of June in more northerly parkland areas. Larger numbers of *Culex tarsalis* start to appear with the emergence of the second generation adults in July and, depending on weather, numbers can build up to substantial populations by late summer. Three generations per season are usual for this species in southern areas while two per season are usual in the parklands. In 2003, high mean daily temperatures and a long frost-free period resulted in four generations of *Culex tarsalis* in southern prairie areas and three in the parkland and boreal transition areas (Table 2). *Culex tarsalis* adults have been caught in sampling traps in September, but these are usually inseminated females getting ready for hibernation. Most females of this last generation do not take a blood meal.

In the spring, small numbers of *Culex tarsalis* larvae usually can be found in shallow, permanent and semi-permanent ponds, irrigated areas and weedy roadside ditches, often in association with *Culiseta inornata*.^{7, 19,20} However, as populations build during the summer, larvae may be found in temporary water bodies, including artificial containers, water-filled hoof prints

near livestock watering sites, bird baths, used tires, and foul water in corrals and around feedlots.^{7, 20}

Culex tarsalis has a wide distribution throughout the prairie areas of Saskatchewan with its northern limit being the aspen parkland and boreal transition ecoregions. The species is more numerous south of a line running in a northwesterly direction from Yorkton through Saskatoon, North Battleford and Lloydminster. However, if climatic conditions are favourable during the summer, its numbers may be large even in parkland and forest fringe areas by early August. Historically, southeastern Saskatchewan has had consistently higher numbers of *Culex tarsalis* than have other regions, due mainly to higher heat units for development, relatively high precipitation levels, and higher wetland densities in the southeast. This traditional distribution appears to be changing, however, perhaps due to the impacts of climate change (i.e. warmer winters, warmer minimum daily temperature, greater accumulations of heat units required for development and longer frost-free periods). In 2003, *Culex tarsalis* was found at 46 locations throughout the province and as far north as Spiritwood and

Meadow Lake. Although overall populations were low, *Culex tarsalis* was more numerous in southern grassland ecoregions than in the parkland or boreal transition ecoregions. The range of average counts in New Jersey mosquito traps placed in 34 different communities in July and August 2003 were 16.8 to 56.6 for grassland habitat and 6.4 to 29.9 for parkland habitat.

In Saskatoon and Regina, *Culex tarsalis* is present each summer, but in varying numbers. For example, in Regina, *Culex tarsalis* made up approximately 0.1 percent of the total mosquito population captured during 2002, and from 1994-2002 *Culex tarsalis* levels have averaged about 0.01 percent of the total mosquitoes trapped. In 1993, however, *Culex tarsalis* comprised 5.6 percent of the total seasonal catch.⁹

This species can become a significant part of the total mosquito population later in the

summer. Table 3 shows the midsummer *Culex tarsalis* populations from five selected localities in 2003. Populations varied from 1.3 – 11.8 percent of the total mosquitoes caught during the mid-June to mid-September period. Although these numbers represent the entire period, there are specific weeks in August when *Culex tarsalis* numbers reached as high as 67 percent of the total in Leader, 39 percent in Maple Creek, 48 percent in Rowan’s Ravine, 9 percent in Melfort and 15 percent in Lloydminster. Furthermore, New Jersey light traps do not catch as high a proportion of *Culex* species as do CDC Traps baited with CO₂. When using catch numbers from these types of traps the numbers and proportions of *Culex tarsalis* rise sharply (Table 4). The risk of a person being bitten by a WN infected *Culex tarsalis*, when this species is abundant and virus is present in local wild birds, is quite high, with the period of greatest risk being mid-July to mid-August.

Table 3. Mid-summer mosquito abundance in southern Saskatchewan in 2003, with New Jersey light traps (total number of *Culex tarsalis* and all other species females caught during the season and the percent of *Culex tarsalis* of the total)

Location	Leader	Maple Creek	Rowan’s Ravine	Melfort	Lloydminster	All traps
Period operated	June 16- Sept. 21	June 9 – Sept. 28	June 16 – Sept. 14	June 16 – Aug. 14	June 16 – Sept. 21	
<i>Culex tarsalis</i>	94	65	203	16	110	488
Total mosquitoes	1085	667	1716	1223	1968	6659
% of Total	8.7	9.7	11.8	1.3	5.6	7.3

Table 4. Mid-summer mosquito abundance in southern Saskatchewan, 2003 with CDC traps and CO₂ (total number of *Culex tarsalis* and all other species females caught during the season and the percent of *Culex tarsalis* of the total)

Location	Assiniboia	Gull Lake	Dundurn	Melfort	Lloydminster	All traps
Period operated	Aug. 4 – Sept. 14	July 28 – Sept. 7	July 28 – Sept. 7	July 21 – Sept. 14	Aug. 11 – Sept. 14	
<i>Culex tarsalis</i>	81	68	146	42	127	464
Total mosquitoes	227	154	842	2370	250	3843
% of Total	35.7	44.2	17.3	1.8	5.6	12.1

Avoiding West Nile virus

Most mosquitoes, including *Culex tarsalis*, are very active at dusk and dawn. According to Hearle, *Culex tarsalis* is active at dusk, when it makes persistent efforts to enter houses in search of blood meals.¹¹ He reports that females are painful and persistent biters, and are easily disturbed. McLintock reports this species to bite readily even during the day and often to be troublesome to children.¹³ If you need to be outside when mosquitoes are active, wear light colored clothing with long-sleeved shirts or jackets, long pants and socks. Use mosquito netting on strollers to protect infants and toddlers, and use bug spray. All three *Culex* species in Saskatchewan can breed in containers and other areas with standing water right in your own back yard. Clean up and empty containers of standing water: old tires, flower pots, barrels, or tin cans. Empty and clean bird baths once a week and cover rain barrels with mesh or screen. Remove water that collects on pool covers, and check eaves and drains. Clear leaves and twigs from eaves-troughs, storm and roof gutters throughout the summer. Make sure drainage ditches are not clogged and fill in low depressions in lawn areas. Cut the lawn

frequently and clear out dense shrubbery where mosquitoes like to rest during the day. Finally, check window and door screens for holes; make sure they fit snugly into frames. For further information on WN virus and control of mosquitoes around your home, consult the Saskatchewan Health website at: www.health.gov.sk.ca or the Health Canada website at: <http://www.hc-sc.gc.ca>

Other mosquito-borne viruses in Saskatchewan

Saskatchewan mosquitoes are host to several viruses in addition to West Nile virus (Table 5) and these viruses were present in the province long before the arrival of WN. They include viruses important to human health, such as St. Louis and Western Equine encephalitis viruses, the less serious viruses of the group called the California encephalitis virus complex and some viruses that are not known to cause any human disease at all: Turlock, Hart Park Flanders and Cache Valley viruses.^{3, 17} Cache Valley virus is primarily a virus of mammals. The several strains of California encephalitis virus are found in squirrels and snowshoe hares, and primarily occur in the boreal forest and tundra.^{12, 18, 23}

Table 5. Mosquito-borne viruses from Saskatchewan^{1,2,3, 6,12, 14,15,16, 18, 22, 23} (Cx.=Culex; Cs.=Culiseta; Ae.=Aedes; Och.=Ochlerotatus; Ano.=Anopheles; Coq.=Coquillitidia)

Species	Habitat	West. Equine	St. Louis	Hart Park Flanders	Cache Valley	Turlock	California **
<i>Cx. tarsalis</i>	prairie	x	x	x		x	
<i>Cs. inornata</i>	prairie	x			X	x	x
<i>Ano. earlei</i>	prairie	x					
<i>Och. campestris</i>	prairie	x					
<i>Och. spencerii</i>	prairie	x					
<i>Och. flavescens</i>	prairie	x					
<i>Och. dorsalis</i>	prairie	x					
<i>Ae. vexans</i>	prairie	x					
<i>Och. implicatus</i>	woodland						x *
<i>Och. punctator</i>	woodland						x
<i>Och. excrucians</i>	woodland						x
<i>Och. cataphylla</i>	woodland						x
<i>Och. fitchii</i>	woodland						x

* mother-to-offspring transmission of virus ** Snowshoe Hare and/or Jamestown Canyon strains

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