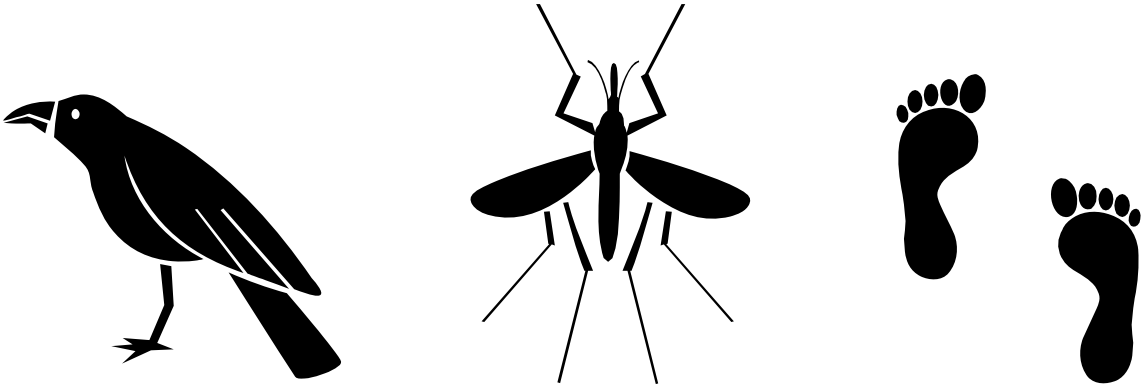
West Nile Virus Activity in British Columbia: 2009 Surveillance Program Results



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Executive Summary

Locally acquired West Nile Virus (WNV) was detected in BC for the first time in 2009. In August, two human cases living in the same household were reported positive for WNV infection (non-neurological symptoms) – the first case was reported on August 19. Both were exposed to the virus while traveling in the South Okanagan. The first positive mosquito pool was confirmed on August 21, and an additional 9 pools of *Culex tarsalis* mosquitoes were identified from traps in the South Okanagan. Three horses were identified with WNV infection in early September (the first 2 reports were received September 10); two horses from the South Okanagan and one in the Fraser Valley. The Fraser Valley horse was the only positive indicator outside of the South Okanagan in 2009. As in 2008, there was low WNV activity in the rest of Canada, and BC's cases were the first human cases reported in Canada in 2009 (Table 1). In addition, one travel-related human non-neurological infection was diagnosed in a BC resident in September 2009.

There were relatively few human cases of WNV in the United States in 2009 (Table 1), however, Washington State had its highest recorded level of activity with 341 positive mosquito pools, 22 birds, 71 horses and 36 human cases identified.

Table 1: Human WNV Infections in North America, 2004-2009

	2004	**2005**	**2006**	**2007**	**2008**	**2009**
Canada	20	239	127	2353	36	8
United States	2344	2949	4052	3404	1301	515

Sources: (PHAC, 2009a and CDC, 2009)

Annual corvid collections have steadily decreased over the last 7 years, suggesting a waning public interest and/or changes in local surveillance activity. Collections were sparse in areas bordering US states with WNV activity, except in the Fraser Valley. The number of dead birds reported online (398) was more than twice the number sent in for testing (144 province-wide). Online reports have also been steadily declining year over year. Receipt of corvid specimens from the field took up to 24 days with a median of 5 days.

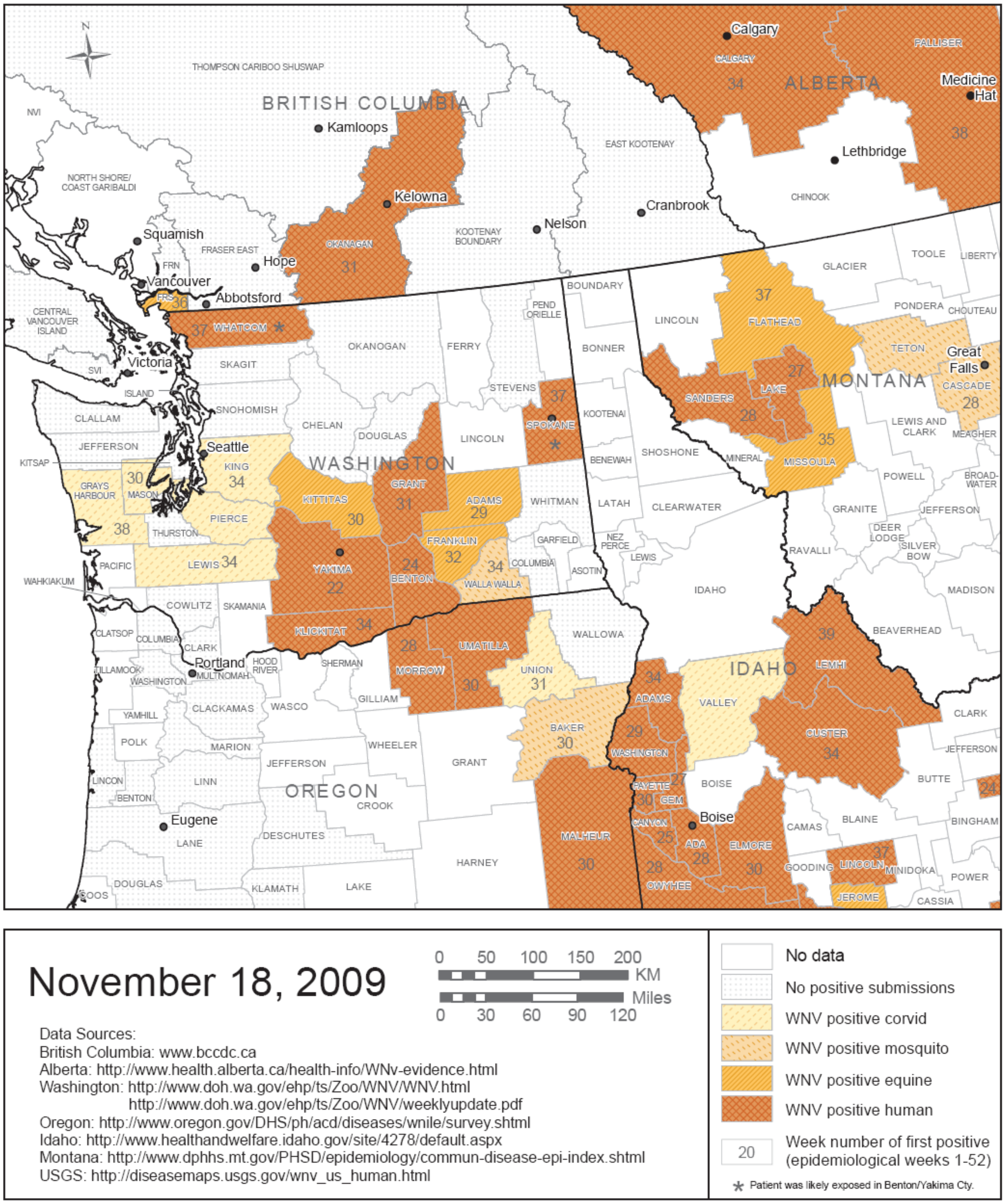
Overall the number of mosquitoes trapped was down from last year. However, the number of *Culex* species was significantly higher in 2009 than 2008. After the positive human infections were detected in BC, 4 additional traps were placed in the Okanagan to enhance surveillance in that area.

BC Centre for Disease Control (BCCDC) did not issue any routine WNV press releases this year, but did field media calls for interviews. A joint media announcement and briefing with the Interior Health Authority (IH) was held in late August to announce the province's first locally acquired cases.

Work has continued with GIS-based reporting and monitoring, and a third refined version of the raster-based map for determining and expressing risk with significant resolution has been developed. The province's positive human cases, mosquito pools and equine cases have served to validate the map.

The value of surveillance for 2009 had been affirmed by the four Health Authorities (HAs) that attended a planning meeting held in November, 2008. Similarly, surveillance for 2010 was discussed at our fall meeting in November, 2009, and the plan for the future is to continue targeted surveillance for WNV, with a view to modifying mosquito trap locations as needed.

Figure 1: West Nile Virus Activity in the Pacific Northwest, 2009



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Surveillance Planning Sessions

On November 18, 2008, a surveillance planning session was held with WNV coordinators and medical health officers (MHOs) at BCCDC. The health authorities discussed their priorities for mosquito and corvid surveillance, and mosquito control for the 2009 season at that time. In April 2009, BCCDC hosted their annual BC Vector-Borne Disease Committee Meeting (formerly the Provincial WNV Meeting), which included attendees from the HAs, municipalities, colleagues in animal health, and other stakeholders. Past surveillance results were reviewed, and guest speakers presented on WNV surveillance in Washington, vector borne diseases and climate change.

Surveillance Activities

Active surveillance activities for WNV focus on 2 targets – corvids and mosquitoes. Passive surveillance includes humans, horses and potentially other species that could be infected and reported. The objectives for WNV surveillance are two-fold:

1. To monitor WNV activity in various species in BC in order to:
    a. Predict increased risk to human health
    b. Inform public health decisions
    c. Guide communication strategies
    d. Monitor the effectiveness of control measures

2. To optimize mosquito control decision-making by identifying:
    a. The geographic and temporal distribution of potential vector species in BC
    b. Mosquito development sites

Human surveillance involves several stakeholders including BCCDC Epidemiology and Laboratory Services, Canadian Blood Services (CBS), BC Transplant Society and the physicians of BC. Physician requests for WNV testing received by BCCDC labs are tracked. Data sharing protocols with CBS have been developed to ensure prompt deferral of blood collected from suspected WNV-infected persons and to allow BCCDC to monitor asymptomatic infections identified through screening of the blood supply. From May to November, all organs intended for transplant are screened by BCCDC labs prior to transplanting. In the low risk period (December through April) only organs from donors with a travel risk are screened.

In accordance with established practice, information on any probable human cases was communicated in 2009 to the requesting physician as well as to the appropriate HA to enable administration of a case questionnaire to collect information on symptoms, travel history and likely mode of transmission. Cases are classified as either West Nile non-Neurological Syndrome (WN-non-NS) or West Nile Neurological Syndrome (WNNS) according to both self-reported symptoms and clinical information collected from the patient's physician. Cases are further categorized as probable or confirmed depending

on the laboratory test performed. Case definitions can be found at http://www.phac-aspc.gc.ca/wnv-vwn/hmncasedef_e.html.

The human testing algorithm entails screening acute serum samples for Flavivirus EIA – IgM and IgG. Convalescent sera are requested and tested in parallel with the acute sample for both IgM and IgG. Hemagglutinin Inhibition testing is performed on positive IgM and/or IgG samples, as required. WNV IgG avidity was also done as as required. All probable positive cases are referred to the National Microbiology Laboratory (Winnipeg) for confirmatory plaque-reduction neutralization testing (PRNT). Cerebral spinal fluid (CSF), plasma and samples from organ transplant donors are tested by reverse transcriptase-polymerase chain reaction (PCR). All submissions of cerebral spinal fluid from patients admitted to hospital for encephalitis/meningoencephalitis (regardless of test requested) are also tested for WNV by PCR.

BCCDC works with the Animal Health Centre (AHC), Animal Health Branch, BC Ministry of Agriculture and Lands (MAL) in the reporting of animal cases of WNV. Work is ongoing to improve monitoring and reporting of animal infections between animal health and public health. Additionally, a recommendation has gone forward to make WNV in animals reportable to public health under the Public Health Act Communicable Disease Regulation.

As per established protocols, corvid surveillance was achieved in 2009 through two mechanisms:

- Samples of dead corvids from IH, Fraser Health Authority (FH) and Vancouver Island Health Authority (VIHA) were submitted each week during the 2009 surveillance season for WNV testing. HAs collected birds in a number of different ways - some employed city parks department staff, others used the SPCA as a collection point and some hired designated staff to respond to public calls and collect birds for testing. This testing was performed at the AHC in Abbotsford, using a commercially available dipstick test (VEC test) for initial screening and PCR as required for confirmation.
- In addition to birds tested, an on-line form was available again in 2009 at the BCCDC website (http://westnile.bccdc.ca) for the public to report sightings of dead corvids. The intent is that dead corvids sighted by the public and reported through the online form in 2009 are separate from those picked up for testing. The locations of birds tested and reported online were used to create corvid density maps for regions of the province with sufficient data (https://maps.bccdc.org). These can be used as baseline values against which to assess corvid mortality, a potential indicator that virus has been introduced into an area.

Mosquito surveillance has been focused annually on WNV testing, identification and distribution of adult mosquitoes. Based on several years of baseline data, the start of mosquito surveillance activities was June 1st. Also, in 2009, Northern Health (NH) and Vancouver Coastal Health (VCH) chose not to participate in mosquito sampling, while IH and VIHA reduced their trap site locations. FH retained all their existing trap sites.

These decisions were based upon a risk assessment of the respective areas. Some traps were operated in more than one location on 2 different days of the week. Traps were run overnight and the catches sent in coolers to BCCDC for identification and WNV testing. In addition to the traps operated by the HAs, a member of the WNV team at BCCDC operated 16 traps in the South Okanagan, in partnership with the Osoyoos Indian Band, as part of a research project. Mosquitoes from these traps were submitted in the same way for identification and testing at BCCDC.

The BCCDC laboratory separated mosquito submissions into sex and taxonomic groupings: 1) *Aedes,* 2) *Anopheles,* 3) *Coquillettidia,* 4) *Culiseta* and 5) *Culex*. Mosquitoes were sorted on a chill table (to prevent denaturation of any viral RNA) and identified to genus or, in the case of *Culex*, to species. If a trap failed to capture any mosquitoes, the information (i.e. trap malfunctioned, no mosquitoes trapped or trap was not run) was faxed to the lab and recorded. Beginning in 2006, only female *Culex* mosquitoes were tested for the virus in groups of up to 50 mosquitoes per pool, by PCR. The remaining mosquitoes were identified but not tested. When traps contained more than 500 mosquitoes, the entire sample was sorted to selectively pick out all the female *Culex* mosquitoes for PCR testing. Five hundred mosquitoes from large volume traps were initially identified and reported; the remainder was saved for identification at the end of the season. A fraction of the remainder (½, ¼, ⅛, etc.) was identified and the total number for each genus in the trap extrapolated.

Surveillance for WNV in horses is passive. That is, there is no active program to look for infection or test the sero-prevalence of WNV antibodies in horses. Instead, serologic specimens from horses suspected of being infected with the virus are collected by the attending veterinarians and submitted for WNV testing. Specimens are tested using the IgM enzyme-linked immunosorbent assay (ELISA, also called enzyme immunoassay, or EIA), and rarely, serum neutralization tests. WNV is often fatal in horses. Horses that die or are euthanized after exhibiting neurological symptoms, and are submitted for diagnostic necropsy to the Animal Health Centre may be tested for WNV by immunohistochemistry.

Ongoing, prospective, cumulative temperature degree-day maps were used to help forecast higher risk areas for WNV. Degree day assessments can assist in predicting the number of generations of mosquitoes expected in a given area and the speed of virus replication.

Mosquito, bird, geographic and temperature data were integrated using an interactive online mapping tool (https://maps.bccdc.org/). This was developed to assist stakeholders with geo-spatial risk assessment to help target appropriate mosquito control activities. Larval data, collected by independent mosquito control contractors are included in this mapping tool for use by HAs when making mosquito control decisions. Unlike adult surveillance data, larval data are not available for viewing by the public.

Those involved in WNV surveillance activities included BCCDC Epidemiology and Laboratories, CBS staff; MAL staff, HA staff, federal, provincial, municipal and regional government staff, mosquito control contractors, academic centres, wildlife biologists and communications personnel. All were included in monthly teleconferences to discuss emerging surveillance issues. Surveillance results from BC, across Canada and the United States were summarized in a routine surveillance report distributed to BC stakeholders, including members of the surveillance group, infectious disease physicians, medical microbiologists and those involved in the provision of blood products and transfusion services.

Surveillance Results

Results at a Glance

Table 2: Summary of BC Surveillance Statistics, 2009

	Human[1]	Corvids Submitted[1]	Corvids Sighted[1]	Mosquito Pools[2]	Horse
# Tested	379	144	398	2482	
# Positive	3 (*1)	0		10	3

1. Surveillance started on June 1st.
2. A pool may contain up to 50 mosquitoes that are tested at one time.

* The number of cases in brackets denotes the number of cases considered to be travel-related. For example, 6 (*2) would indicate a total of 6 probable cases, 2 of which are travel-related.

Surveillance of WNV in Humans

Epidemiology of Human Infections

In 2009, 379 human specimens were tested by Laboratory Services at BCCDC. Three human infections were reported in BC in 2009; 2 locally acquired and one travel-related.

The two locally acquired cases were members of the same household. Both cases reported non-neurological symptoms and had travelled to the South Okanagan region during their likely exposure period where they recalled being bitten by mosquitoes.

The travel-related case reported non-neurological symptoms and had travelled to Saskatchewan during their exposure period.

Protecting the Blood Supply from WNV – Testing at CBS

CBS performs year-round WNV nucleic acid testing on every donation. Although routine screening is performed in mini-pools (MP) of six specimens, more sensitive, single unit (SU) testing is selectively done for blood donations collected from regions of higher WNV risk (Busch et al. 2005). CBS uses two criteria for implementing SU testing: either a positive donor test result or an incidence of public health-reported symptomatic WNV in a health region over a two week period exceeding either 1:1000 in rural areas or 1:2500 in urban settings. SU testing is then implemented for a minimum of one-week for all donor clinics in proximity to an affected region. WNV testing reverts to routine MP screening if neither criterion is met over the ensuing one-week period.

In BC, CBS, BCCDC and BC Ministry of Health Services (MOHS) continued their close co-operation in WNV planning, preparation and surveillance. A comprehensive WNV Action Plan is updated each year; the 2009 edition is available at www.pbco.ca.

Between June 1 and October 16, the BCCDC provided daily reports of WNV test requests received by the centre to the CBS BC and Yukon Centre. This enables rapid identification of donors who may have recently given potentially WNV infectious blood, so that a product recall can be carried out as quickly as possible and when necessary, to defer donors for a 56 day period to prevent them from donating while potentially infectious. CBS was advised of 578 WNV test requests received by BCCDC; 43 of 578 (7.4%) were determined to originate from 35 registered CBS blood donors.

One of these donors had donated a whole blood unit 30 days prior to undergoing WNV testing at BCCDC; this donor was not one of the three confirmed human WNV cases reported in BC in 2009. A recall of in-date products was done; the red blood cells were discarded and the plasma sent for fractionation was also discarded. The platelet unit was not in-date and so was not recalled; no transfusion transmitted infection was reported.

Blood Donor WNV Screening in British Columbia

CBS, BC and Yukon Centre provided BCCDC with aggregate, regional blood donor WNV testing updates for BC collections throughout the WNV season. This reporting provides the most geographically comprehensive and timely ongoing human WNV surveillance data available to public health. Between June 6 and September 18, 2009, there were 33,689 collections of blood in BC. There were no positive WNV screening test results from any blood donation in British Columbia in 2009.

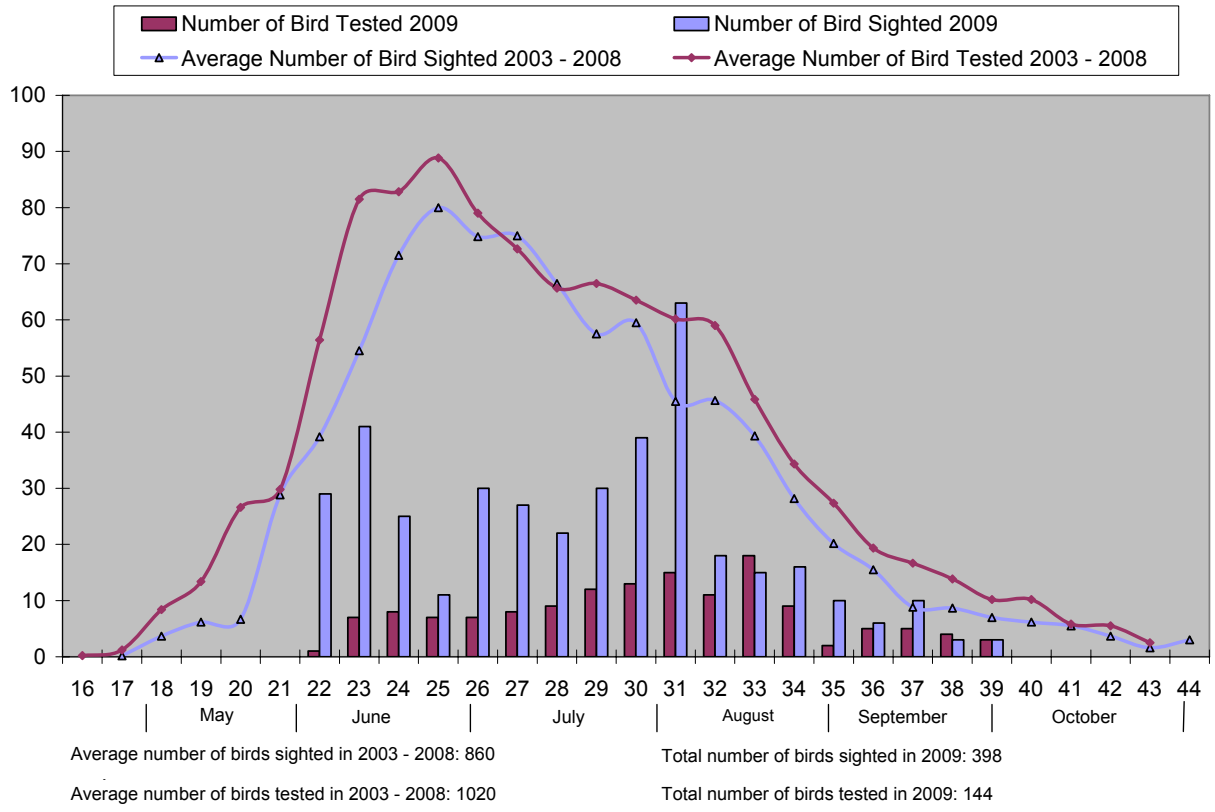
Blood Donor WNV Screening and Transfusion-Transmitted WNV Surveillance across Canada

Neither CBS nor Héma-Québec identified any WNV positive donors during 2009. As in the previous 6 years, no case of suspected transfusion-transmitted WNV was reported in Canada during 2009.

Surveillance of WNV in Corvids

During the 2009 surveillance season, 144 corvids were collected and tested (Figure 2). This is the 5th year that corvid collections have decreased. Waning public interest and changes in surveillance program participation may explain this decline, as NH and VCH did not participate in corvid surveillance in 2009. Even after local WNV activities were detected in early August, the number of corvids tested or sighted did not increase. There was a spike in the number of birds tested and sighted during the 3 weeks following a FH news release on July 21 (week 29). Of the birds submitted, 95.4% were tested which indicates that for the most part, appropriate specimens are being submitted for testing.

Figure 2: Comparison of Birds Sighted and Tested, 2003-2009



FH submitted the most corvids for testing in 2009. The number submitted from FH in 2009 was comparable to that observed in 2008, yet remains lower than what was submitted between 2003 and 2007. The number of corvids submitted from VIHA decreased significantly in 2009 compared to the 2008. IH again submitted few corvids, similar to the 2008 surveillance season.

Table 3: Comparison of Birds Tested by HA, 2005 – 2009

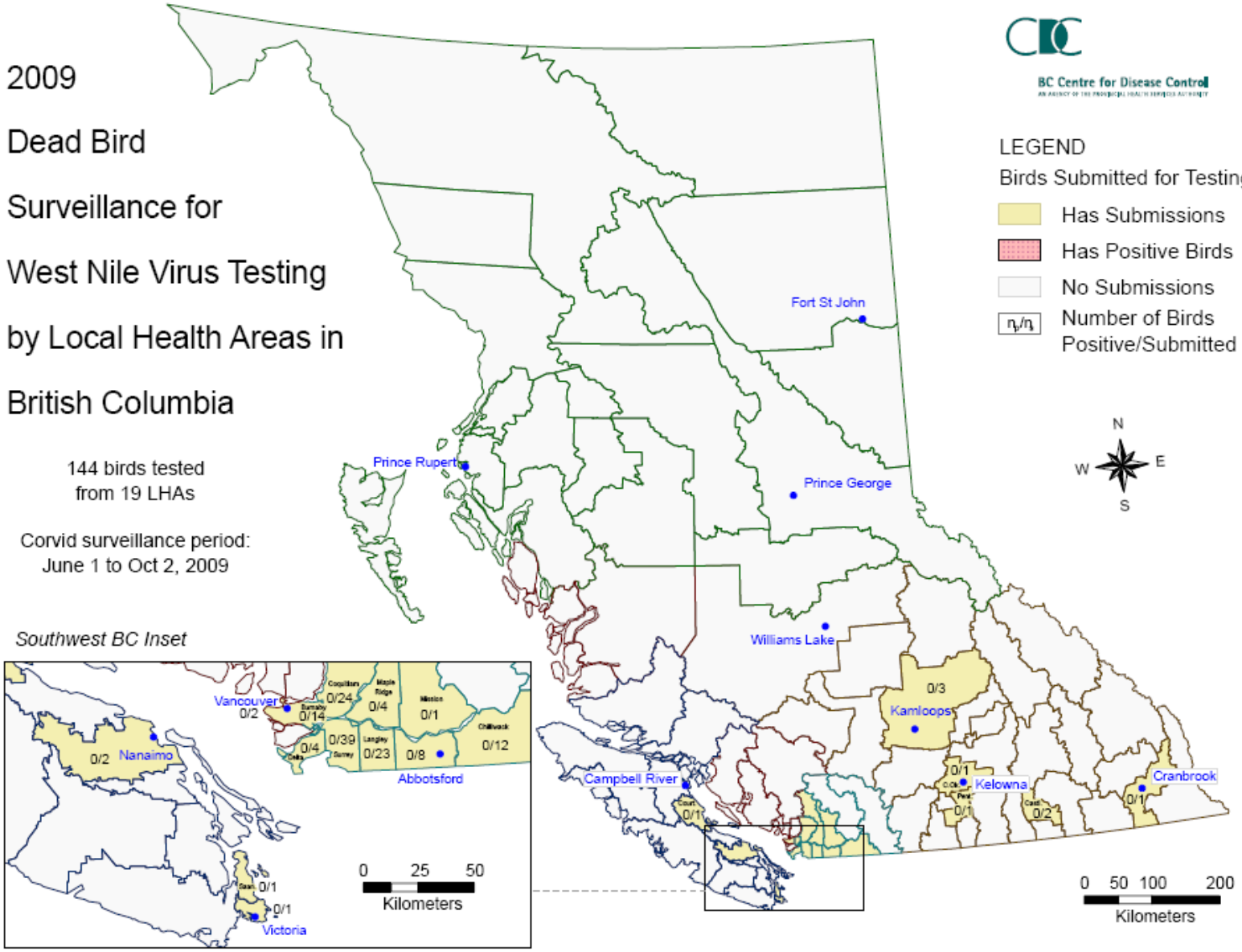
HA	2005	2006	2007	2008	2009
IH	195	93	72	2	8
FH	364	355	349	132	129
VCH	248	146	174	14	2*
VIHA	201	148	98	57	5
NH	50	61	47	0	0
Total	**1058**	**803**	**740**	**205**	**144**

** These 2 birds were found in Vancouver, but submitted by a wildlife rescue association, not VCH*

The spatial distribution of dead corvid submissions was patchy in 2009 (Figure 3). Only 19 Local Health Areas (LHAs) submitted specimens for testing. The lack of corvid submission program in both NH and VCH, a limited program in IH, and reduced public interest likely contributed to the low coverage observed in 2009. There was a slight improvement in coverage in IH from 2008 to 2009, however no corvids were submitted for testing or reported online from the South Okanagan where WNV was circulating. There were other LHAs in the Okanagan that submitted corvids, however too few specimens were tested to detect WNV. There was a drop in the number of LHAs submitting birds from VIHA in 2009, with reportedly very few calls being received from the public. There was good coverage of corvid submissions from FH in 2009 with only 2 LHAs not represented, and the number tested dropped only slightly from previous years.

There is concern that corvids should be collected from areas which neighbor WNV positive regions, since corvid surveillance enables quick detection of the new arrival of WNV to a region. Those regions include Washington, Idaho, Montana and now in BC; the South Okanagan and Fraser Valley. Some rural areas in BC have low corvid and human densities that limit the effectiveness of passive corvid surveillance and favour other methods of environmental surveillance such as mosquito sampling.

Figure 3: Geographic Distribution of Corvid Test Results, 2009



Lag Times for Corvid Submission and Testing

In 2009, the median number of days between corvid collection dates and the dates the AHC received the submissions was 5 days. This is the same as 2008 and very similar to the previous 5 years. The maximum transit lag decreased from 54 days in 2008 to 24 days in 2009, the lowest time reported in the previous 5 years. This demonstrates that HAs promptly sent dead birds to the AHC lab, which is important for timely testing and reporting. The majority of corvid samples were tested on the same day as they were received by the AHC lab.

Table 4: Lag Times for Submission of Corvid Specimens, 2005-2009

HSDA	Median Transit Lag Time (days)					Max Transit Lag (days)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
EK	7	9	4	2	3	44	48	0	2	3
KB	5	6	4	NA	10	14	35	7	NA	10
OK	5	3	4	NA	9	28	12	7	NA	10
TCS	6	3	6	38	14	39	84	11	38	15
FRE	2	3	3	3	5	12	8	11	18	11
FRN	4	3	4	4	6	32	33	22	26	19
FRS	3	5	3	5	5	10	9	7	13	18
RICH	6	7	6	6	NA	10	17	4	22	NA
VAN	5	7	5	10	23*	14	23	25	10	24*
NSCG	4	7	9	NA	NA	46	17	8	NA	NA
SVI	3	4	6	12	5	32	18	7	54	7
CVI	4	6	17	6	3	14	12	2	33	3
NVI	5	7	13	9	4	12	29	5	19	4
NW	3	2	2	NA	NA	7	13	0	NA	NA
NI	2	5	3	NA	NA	33	20	0	NA	NA
NE	6	5	7	NA	NA	29	50	0	NA	NA
Total	**4.0**	**4.0**	**4.0**	**5.0**	**5.0**	**46**	**84**	**25**	**54**	**24**

Note: - NA means no birds submitted this year.

- Transit Lag represents # of days between when a bird is found and received by AHC; including frozen storage before shipping.

- 1st five numbers are column medians; 2nd five are column maximums.

- In 2009, NH and VCH did not submit dead corvids for testing. These 2 HAs are excluded from this analysis.

** 2 birds were found in Vancouver, but submitted by a 3rd party, other than VCH.*

Surveillance of WNV in Mosquitoes

Many regions use the collection of mosquitoes and testing for infection as the cornerstone of their WNV program and as part of arbovirus surveillance. Random sampling in potentially active areas may give an early warning of the arrival of the virus before other animals become sick, but sampling in known endemically infected areas can offer vector population estimates and some insight into risk for the upcoming season. In addition to information about the spread of the virus, an active mosquito surveillance program can identify which species are present, which can lead to assessment about the type of habitat producing that species.

In BC, there was a total of 1,536 submissions from miniature CO_2-baited (dry ice), CDC mosquito light traps in 2009, resulting in 2,482 pools tested. A total of 182,063 mosquitoes were collected from these trap locations. We saw lower numbers of nuisance species of *Aedes* all across the province this year. The provincial average of *Culex* per trap night was 33.0 (all *Culex* species, including males). This was significantly higher than last year's average *Culex* count. The increase of 12.7 mosquitoes per trap night over last year was partly due to research traps being added to the surveillance totals. These were placed in locations that were known to have *Culex tarsalis*, but there was also a dramatic increase in *Cx. tarsalis* numbers in the Lower Mainland.

Trap Coverage

Mosquito traps are used across North America for the surveillance of arbovirus, yet there is no standardized methodology to determine number and placement of traps. This dilemma probably stems from the fact there are many different vector species and each will behave in a different manner according to available habitat. The two primary vector species that drive WNV activity in Canada are *Culex pipiens* and *Cx. tarsalis*, and trap site selection is based primarily on the known geographic distribution of these vectors.

We have been monitoring mosquitoes in BC for WNV since 2003. We have focused testing to just female *Culex* species since 2006, and it was *Culex* species in traps from the South Okanagan that were first identified as positive. This section of the report reviews mosquito surveillance in 2009 and compares that with previous years.

Figure 4 depicts the locations of adult mosquito traps in 2009. Since adult mosquito surveillance began in 2003, the geographic coverage of traps has changed and the strategic placement of traps in mosquito rich environments has improved, reducing the number of low yield traps and providing better capture of high risk species like *Cx. pipiens* and *Cx. tarsalis* (Table 5). A more focused surveillance effort was undertaken this year, and sampling was reduced to the southern border of the province. As a result, the number of submissions was the 2nd lowest since trapping began in 2003.

Figure 4: Geographic Distribution of Mosquito Traps in BC, 2009

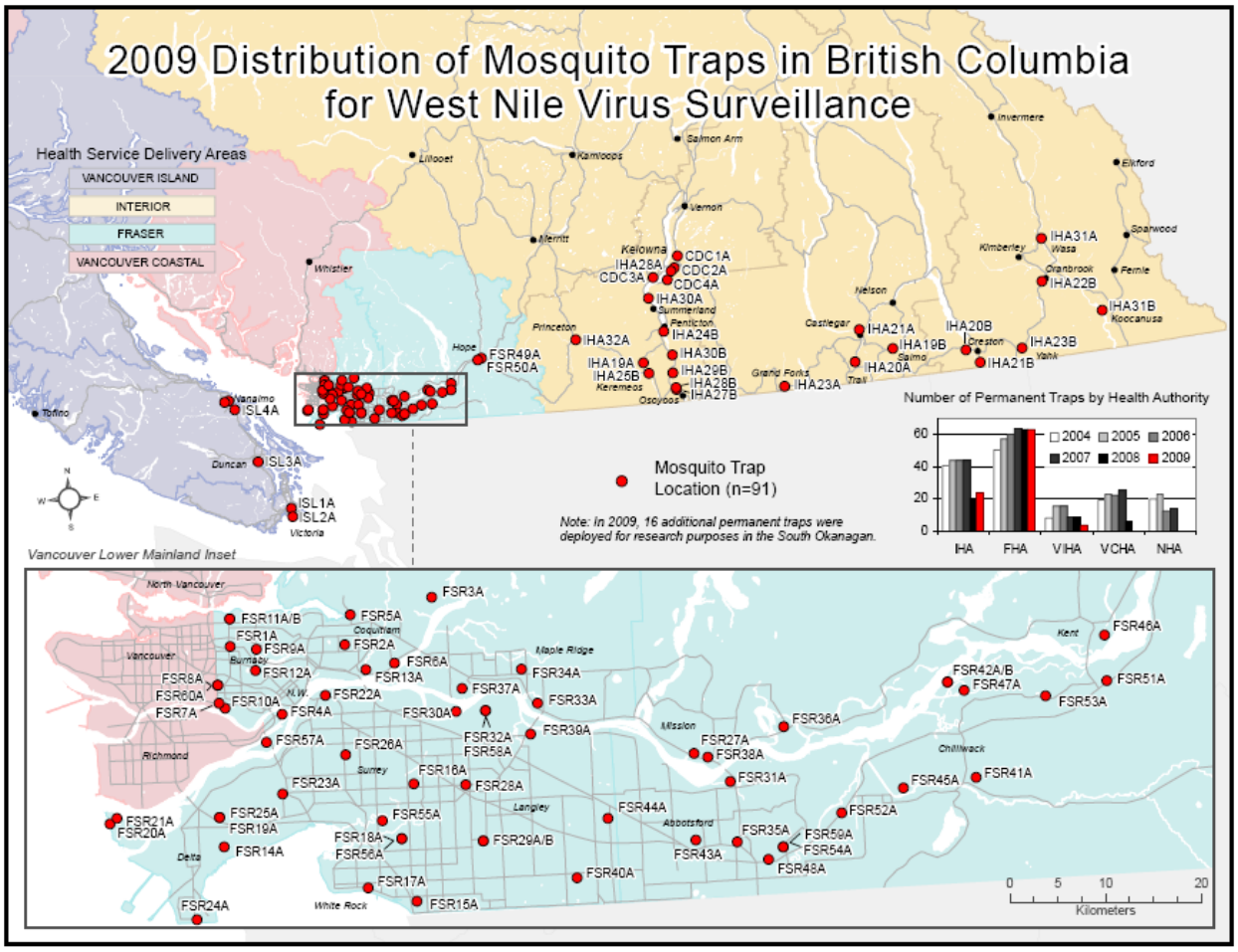


Table 5: Changes in Mosquito Trap Coverage, 2005-2009

Parameter	2005	2006	2007	2008	2009
# Permanent locations	189	148	155	98	91
# Mosquitoes	198,228	394,047	242,215	202,460	182,063
# Pools tested	6631	2329*	2568*	1873*	2482*
Submissions	2778	2287	2365	1471	1536
Ave # *Cx. tarsalis*^	1.9	4.8	3.5	1.4	11.8
Ave # *Cx. pipiens*^	5.1	8.6	14.3	10.5	21.1

** Only Culex species tested for WNV.*
^ Including male and female mosquitoes during the season. It is calculated by: Total number of Culex ÷ Total number of trap submissions = # per trap-night.

Geographic Distribution of Species

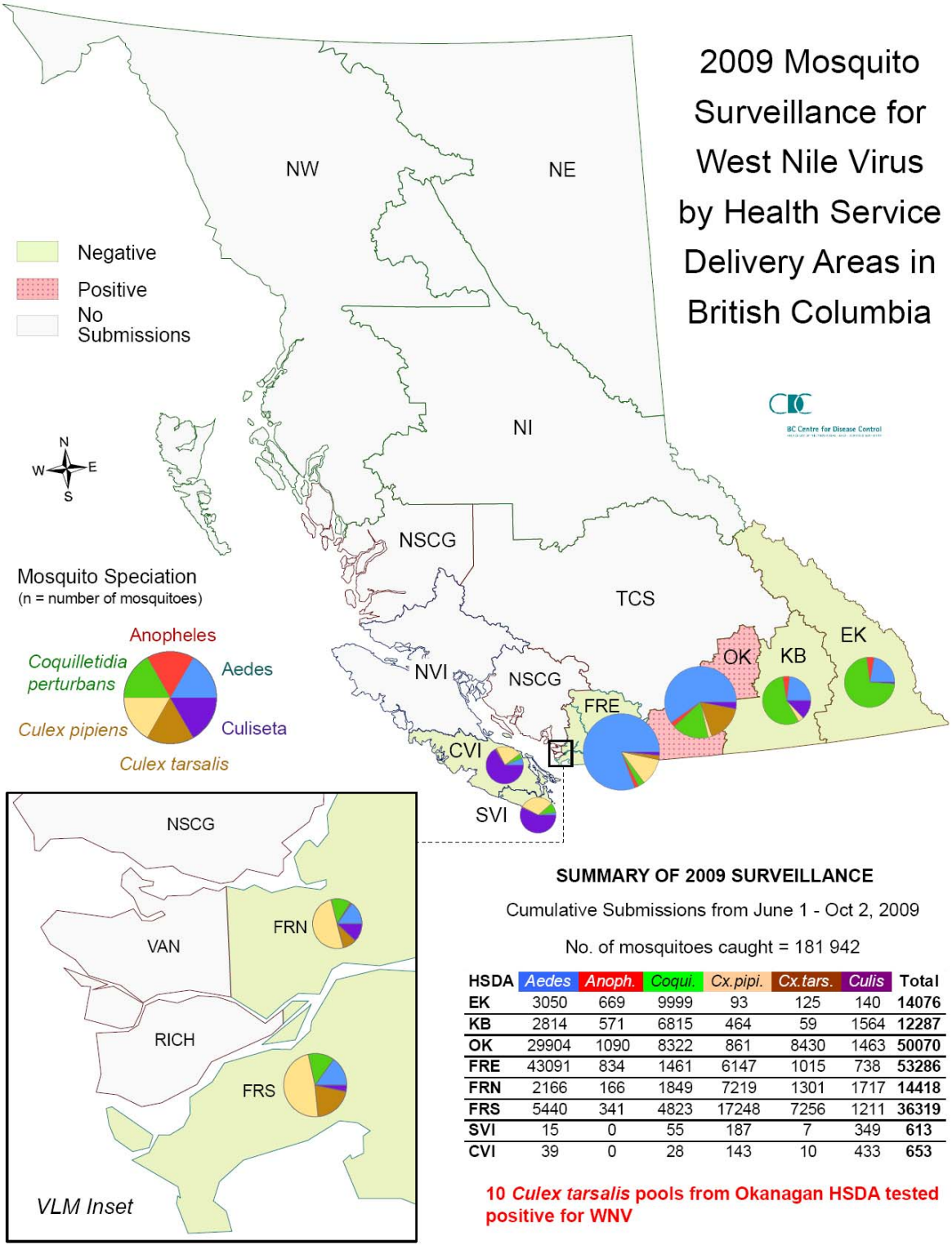
The most competent vectors of WNV are only occasionally found in NH and this has guided surveillance to focus on the southern reaches of the province. The most northerly WNV report in Canada is from Meadow Lake, Saskatchewan (approximately N54° 08').

Figure 5 illustrates the distribution of mosquitoes collected in 2009. The most northerly traps were near Mission Creek in Kelowna (N49° 50'), in the Okanagan, and at Wasa Lake (N49° 46') in the East Kootenays. A trap in Hope (N49° 22') was the furthest north for FH, and the trap near Nanaimo, in VIHA, was the 4th most northerly trap (N49° 123'). This restricted distribution of traps precludes any speculation about the distribution of mosquito species on a provincial scale as discussed in previous years.

The Effect of Rainfall and Snowpack on Mosquito Abundance

Environmental factors can be used to assist in predicting mosquito populations, and can be used to predict the potential for arboviral diseases. In BC, snow accumulation and melting of the snowpack affects the hydrology along the mountainous corridors as spring unfolds. Reisen et al (2008) recently proposed a model for conditions in California that are similar to BC. By the beginning of May, the subsequent melt of accumulated snow is a clue to the potential for standing water for early mosquito development. In Figure 6, the accumulated precipitation is illustrated (the colour scales vary with these 5 maps). Light green, orange, yellow or red colouration reflects below average moisture content, whereas dark green is average content and blue is above average (MOE 2009). Unlike the last 2 years, moisture accumulation was much lower in the southern portion of the province. Therefore, a drier year in 2009 presumably resulted in fewer mosquitoes being collected – the total number of mosquitoes collected was less than last year even with the greater number of trap submissions (see Table 5).

Figure 5: Geographic Distribution of Mosquito Species in BC, 2009



SUMMARY OF 2009 SURVEILLANCE

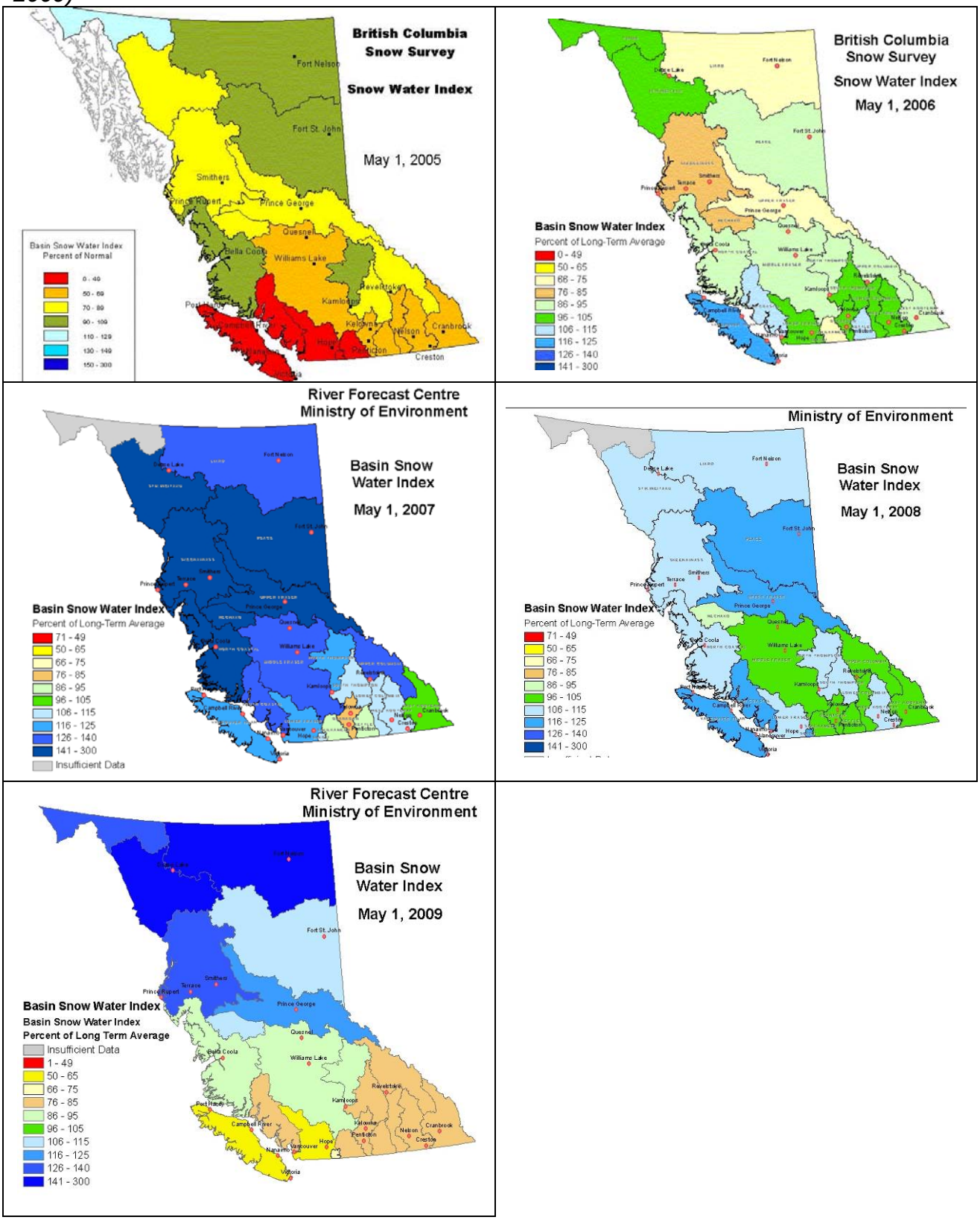
Cumulative Submissions from June 1 - Oct 2, 2009

No. of mosquitoes caught = 181 942

HSDA	*Aedes*	*Anoph.*	*Coqui.*	*Cx.pipi.*	*Cx.tars.*	*Culis*	Total
EK	3050	669	9999	93	125	140	**14076**
KB	2814	571	6815	464	59	1564	**12287**
OK	29904	1090	8322	861	8430	1463	**50070**
FRE	43091	834	1461	6147	1015	738	**53286**
FRN	2166	166	1849	7219	1301	1717	**14418**
FRS	5440	341	4823	17248	7256	1211	**36319**
SVI	15	0	55	187	7	349	**613**
CVI	39	0	28	143	10	433	**653**

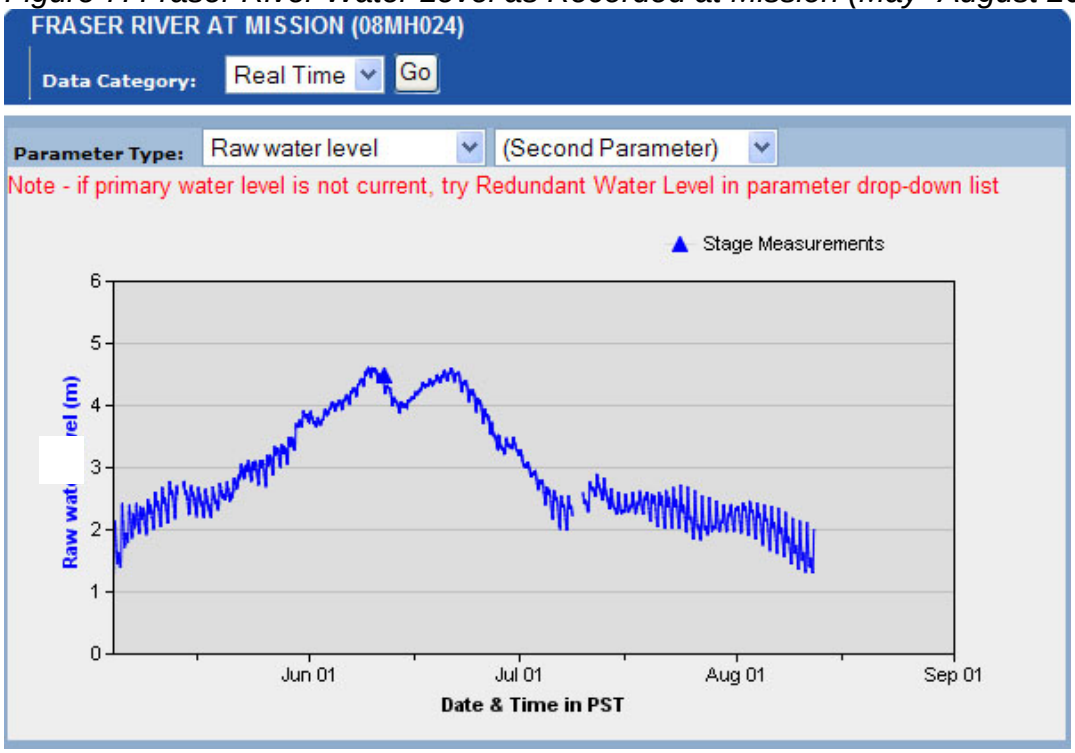
10 *Culex tarsalis* pools from Okanagan HSDA tested positive for WNV

Figure 6: Ministry of Environment Basin Snow Water Index Maps 2005 to 2009 (MOE 2009)



In 2007, the Fraser River peaked at about 6.0 meters and flooding was a concern. In 2008, the river remained at about 5.8 meters from the end of May to the middle of June, a longer period of time than in 2007 and this created more habitat for mosquito development. However, in 2009 the Fraser River level at the Mission gauge (Figure 7) remained at normal levels from May to the end of August, with a peak at 4.6 meters, so there was no threat of flooding this year.

Figure 7: Fraser River Water Level as Recorded at Mission (May- August 2009)



(Environment Canada, 2009)

Climate Data – Growing Degree Day Calculations

Temperature plays a key part in WNV biology, ecology and epidemiology. WNV amplification and rate of mosquito development occurs more rapidly with warmer temperatures, resulting in development of multiple generations of *Culex* spp. mosquitoes during the season. Warmer temperatures are also favourable for increased mosquito biting activity, thereby increasing the risk of transmission to humans.

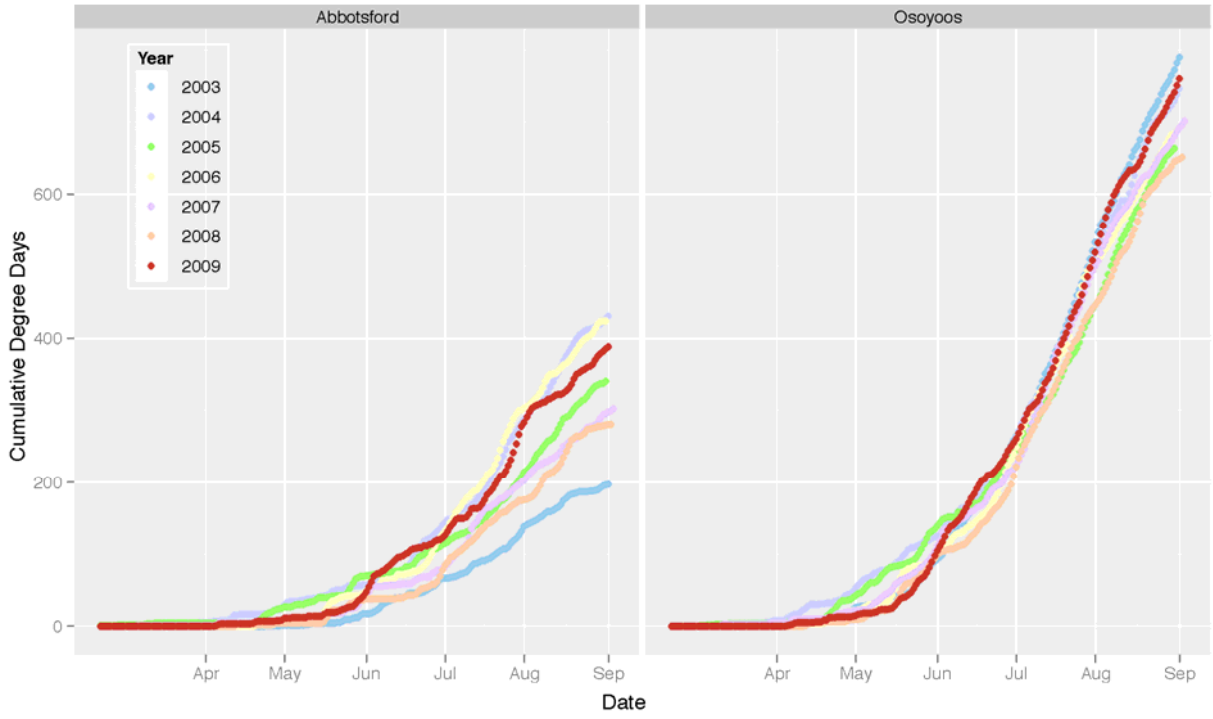
A base 16^{o}C growing degree day model was developed for *Cx. tarsalis* mosquito forecasting. The concept of growing degree days involves the amount of accumulated heat required for mosquitoes to complete their growth and development. Growing degree days were monitored on a weekly basis for select BC communities from various parts of the province. All communities experienced increased accumulated degree days this year compared to last year and the 30 year average. In particular, southern BC experienced very warm temperatures and rapid accumulation of heat starting in mid-May and continuing through to the end of August in 2009 (see Table 6).

Table 6: Accumulated Growing Degree Days for Select Communities up to August 31st

August 31st	2009	2008	2007	2006	2005	2004	2003	30YR
Cranbrook	368	366	442	423	307	360	476	276
Creston	519	414	607	554	446	517	620	351
Osoyoos	750	649	687	687	680	809	786	540
Kamloops	696	580	579	657	575	704	662	475
Abbotsford	385	280	295	342	340	430	360	222
Vancouver	289	204	221	239	245	329	275	170
Victoria	255	189	207	237	239	296	263	153
Prince George	252	185	189	237	184	264	196	139

Note: Degree day calculations beyond August 31st are not meaningful for WNV risk prediction as newly emerged Culex will likely enter diapause (a state where they do not seek a blood meal) by this time, and therefore the effect of temperature on mosquito development and viral replication after this time does not contribute to WNV risk.

Figure 8: Accumulated Growing Degree Days up to August 31st for Abbotsford and Osoyoos Weather Stations 2003-2009



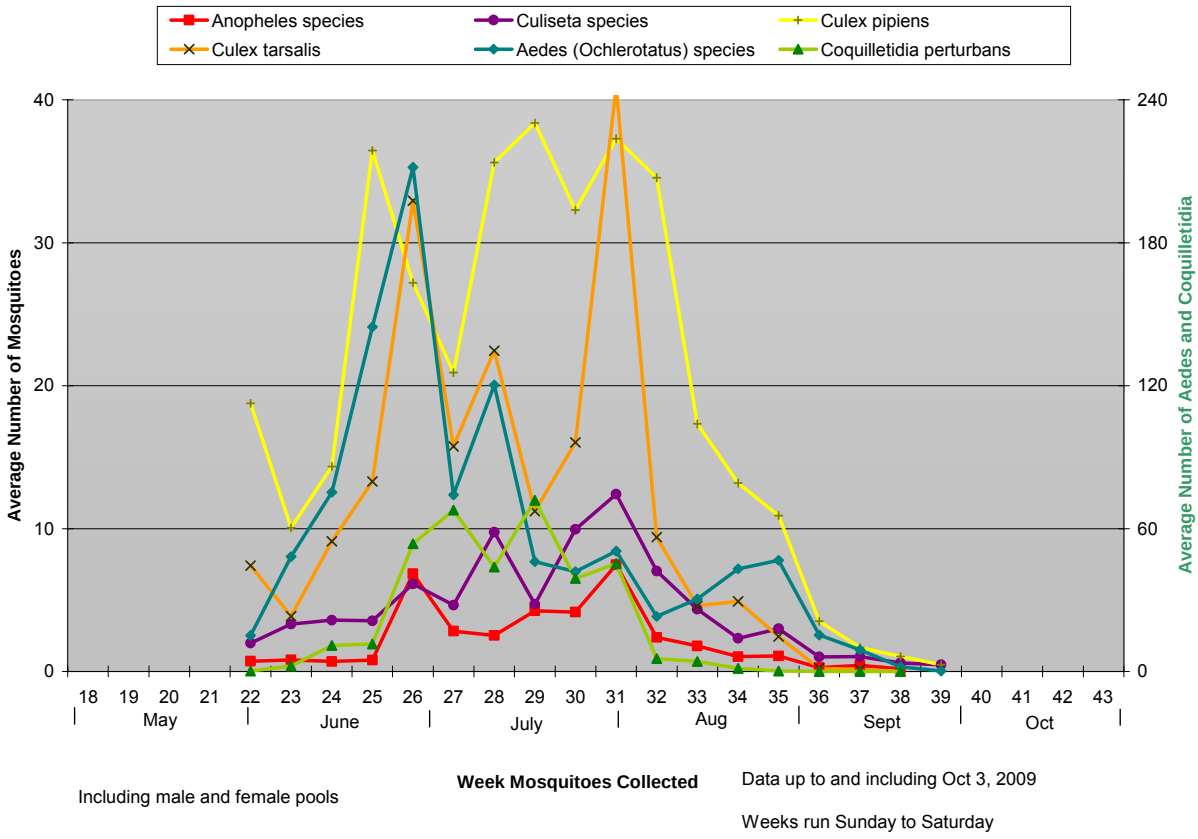
Temporal Distribution of Mosquitoes

Over the last 5 years, trap deployment has begun as early as the beginning of May to as late as the end of October. This window of surveillance can serve 2 basic functions: to give a record of populations as they progress through the season and to give an advanced estimate of risk of WNV infection based on the number of infected vector specimens during the most active time of the year. Surveillance has now confirmed that WNV will appear when vector species are most active.

In 2009, FH conducted surveillance from the beginning of June, VIHA began surveillance at the end of June and IH started deployment of traps at the beginning of July. The 3 HAs conducting mosquito surveillance ended their surveillance by the beginning of October. This surveillance period is when WNV infection is most prevalent in other jurisdictions. Figure 9 illustrates the changes of species groups in BC over the time for all traps. Caution should be used trying to compare 2008 and 2009 to other years because the sampling is heavily biased by the larger proportion of traps being used in the Lower Mainland, rather than across the entire province (Figure 4).

Aedes were the most common genus collected in 2009 surveillance for BC, as has been the case in every year of this program. *Coquillettidia perturbans* is usually the 2nd most common species collected, but this year there was nearly the same amount of *Cx. pipiens* due to the large numbers in the Fraser South (FRS) Health Service Delivery Area (HSDA). *Cx. pipiens* exploits the many storm water catch basins, and this may be the reason it is so commonly collected in this region. *Cx. tarsalis* was the next most numerous mosquito, followed by *Culiseta* and *Anopheles*. *Culex territans* was the least common - only 2 specimens were identified.

Figure 9: Average Number of Mosquito Species Trapped per Week, 2009



Most *Aedes* overwinter as eggs and their numbers will depend on moisture accumulation and snowmelt. This year, *Aedes* numbers peaked about one month after

the Fraser River crested in the Lower Mainland. Normal river levels resulted in fewer *Aedes* in the Eastern Fraser Valley than the past 2 years. *Coquillettidia perturbans* overwinter as larvae, and the adult population always seems to peak around the 2nd to 3rd week of July in BC. This trend has been repeated ever since surveillance began in 2003. Most of the other species of mosquitoes in BC overwinter as adults and their success in our northern latitude depends on spring and summer temperature. With the exception of Cranbrook region, the province was nearly as warm as 2003 when we had the worst forest fire season. The warm weather also seemed to benefit *Cx. pipiens* and *Cx. tarsalis*; they both were very abundant in the surveillance program.

Timing of WNV Emergence: Canada, BC and the Pacific Northwest

The first positive results for WNV in other regions of close proximity, or similar latitude where WNV is endemic has been considered a useful indicator for when the virus might appear in BC. In Canada, Alberta was not conducting mosquito surveillance, but positive mosquitoes were found in Saskatchewan by the end of July, Manitoba by the middle of August and Ontario by the end of August (Table 7). In the US, Washington had positive mosquito pools by the beginning of June (Table 8), and likely was the source of WNV for the Okanagan Valley in BC. The early appearance in the state possibly provided sufficient viral buildup to allow the disease to spread north into BC.

Table 7: First Recorded Dates of Positive Mosquitoes in Canada

Year	AB	SK	MN	ON	QC
2009		25-Jul	16-Aug	23-Aug	
2008		8-Aug	25-Jul	4-Jul	
2007	15-Jul	20-Jun	5-Jun	15-Jul	
2006	18-Jul	17-Jul	4-Jun	5-Jul	10-Aug
2005	7-Aug	28-Jul	15-Jul	26-Jul	3-Aug
2004	10-Aug	13-Aug	28-Jul	3-Aug	19-Aug
2003	23-Jul	12-Aug	25-Jul	23-Jul	29-Jul
2002			15-Aug	16-Jul	16-Aug
2001				22-Oct	

Sources: PHAC, 2009b

Table 8: Earliest Positive Surveillance Findings in Washington

Year	**Washington State**
2009	Week 22 (May 31-Jun 3), mosquitoes
2008	Wk 29 (Jul 16), mosquitoes
2007	Wk 33 (Aug 12-18), horse
2006	Wk 29 (July 16-22), human
2005	Wk 34 (Aug 21-27), mosquito
2004	None
2003	None
2002	October, bird

(Washington state department of health, 2009)

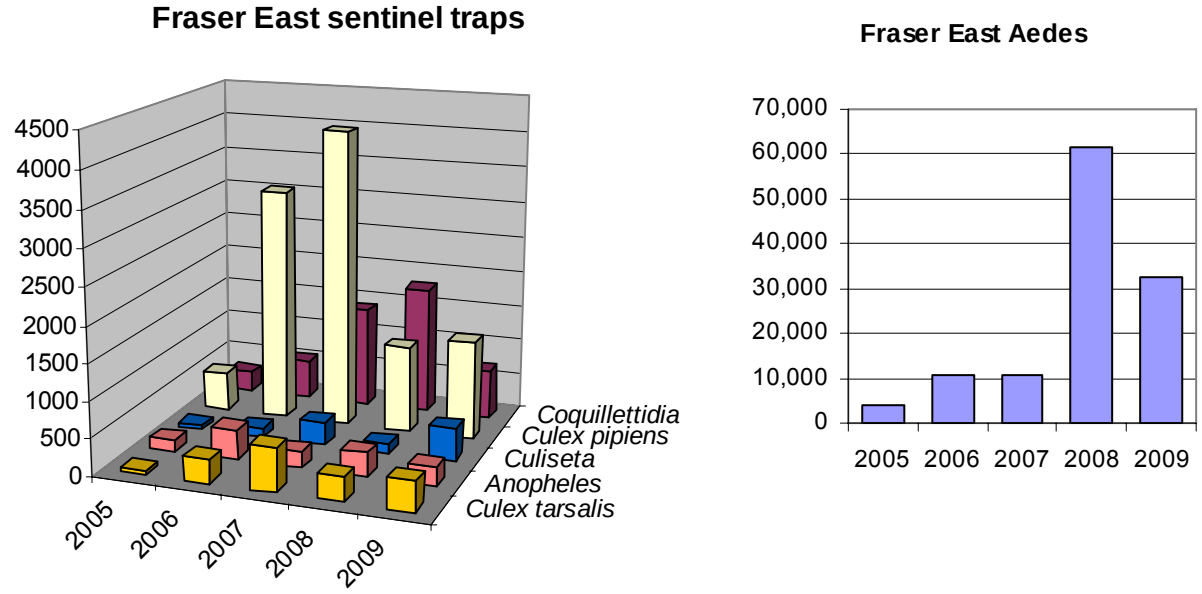
Relative Abundance of Mosquito Species Compared with Previous Years

There have been changes in many mosquito trapping locations in order to focus on higher risk areas. Therefore, the best way to compare mosquito species abundance for different years is to compare only traps that have been in the same general locations. Fortunately, some have been in the same general locations for 5 years. The information is presented as total catch from these traps for each year.

Fraser Health Authority

There are 6 traps that have been in the same general locations in the eastern Fraser Valley for the last 5 years. In this region there is a mix of urban and rural habitat for mosquitoes. The Fraser River is the prominent feature that affects mosquito biology, where multiple islands can flood creating large mosquito development sites. As previously noted under “The Effect of Rainfall and Snowpack on Mosquito Abundance”, the sustained high river levels in 2008 probably resulted in large *Aedes* populations that year (Figure 10). Although the number of mosquitoes was reduced this year in Fraser East (FRE), *Aedes* was still the most common species group.

Figure 10: Species Abundance from 2005-2009 in Representative Light Traps, Fraser East HSDA (Aedes is shown in a separate graph)

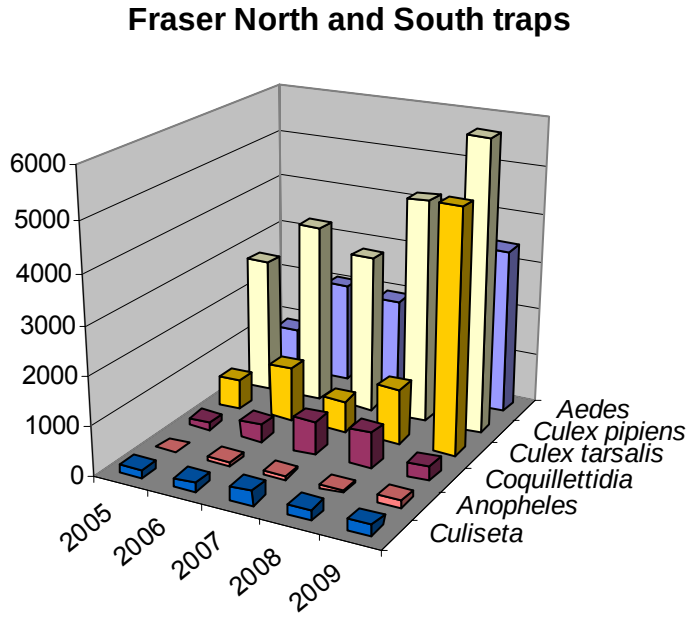


This year *Cx. pipiens* was the next most commonly encountered species of mosquitoes. This is different from last year when *Coquillettidia perturbans* was more common.

In 2009 we saw more *Culiseta* in the traps of FRE than the previous 4 years. They were present in larger numbers throughout the entire season with slight increase in week 29. *Cx. tarsalis* was the 5th most common species caught with the greatest number being caught during the last 3 weeks of July. *Anopheles* was the least common species group found in FRE and their numbers seem to be about the same as previous years. No *Cx. territans* were identified this year in FRE.

In Fraser North (FRN) and FRS, there are 8 trap sites that have been sampled at the same locations for the last 5 years. *Cx. pipiens* was the most common mosquito and its numbers have increased over the last 5 years. FRS had the greatest number with a consistent catch throughout the mosquito season. FRN conducted integrated pest management (IPM) for this species with catch basin treatments, and their populations did not peak until late in the season during week 32.

Figure 11: Species Abundance from 2005-2009 in Representative Light Traps, Fraser North and Fraser South HSDAs



Cx. tarsalis was the 2nd most abundant species in 2009, with the largest number seen over the last 5 years. This increase was primarily attributed to 3 traps in Delta but there was also some increase in traps from Surrey. An inquiry to Metro Vancouver about the cause uncovered an operation to increase the water table in Burns Bog. It was speculated that the raised water levels, in conjunction with warmer temperatures, may have increased suitable development sites, resulting in more adult *Cx. tarsalis*. This species is known to take advantage of open irrigation and drainage ditches. Being the primary vector for WNV in the Pacific Northwest, this increase in abundance does raise some concern about the potential for the spread of disease in this region.

Aedes was the 3rd most abundant genus caught in traps in 2009. The traps in FRS account for the greatest number of *Aedes* that were caught. The increase was most notable in one trap in Delta, which also had a large *Cx. tarsalis* catch this year.

Vancouver Island Health Authority

On Vancouver Island, there are 4 traps that have operated in the same general locations for the last 4 years, but this year a trap was operated in Nanaimo rather than Cumberland (Figure 4).

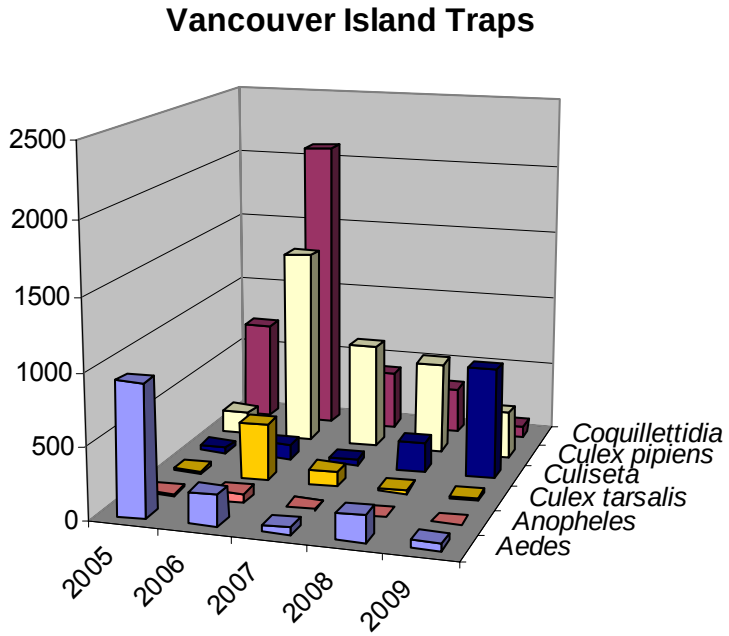
In 2009, *Culiseta* was the most common mosquito genus collected in VIHA. Both the Duncan and Victoria traps, which have been in the same general locations for the last 5 years had much greater numbers. *Culiseta incidens* is considered one of the most common mosquitoes in BC and can be found in artificial manmade containers, even

catch basins. This is likely the species being collected. It is found on the western side of the continent, but is only occasionally reported as testing positive for WNV.

Cx. pipiens was the 2nd most common mosquito collected in 2009, although the number was less than the last 3 years. In past years, the trap in Cumberland was situated close to the community sewage lagoon and it collected most of the *Cx. pipiens*, so the reduction is more a refection of trap location than overall abundance. The Saanich and Duncan traps collected about the same number as in previous years.

Coquillettidia was infrequently collected in 2009. Usually many more are collected from Swan Lake, but this year the number was about half of that caught in previous years. Apart from *Culiseta,* there were very few mosquitoes collected from VIHA this year. The dry May previously reported in Figure 6 for Vancouver Island is likely the reason very few mosquitoes were collected this year.

Figure 12: Species Abundance from 2005-2009 in Representative Light Traps, VIHA

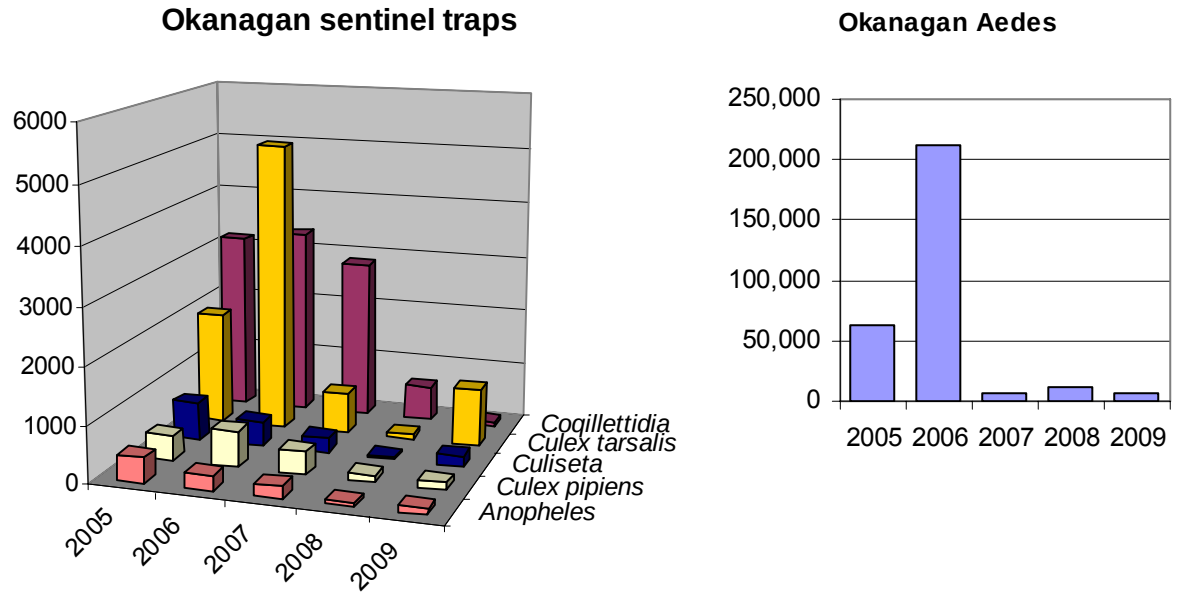


Interior Health Authority

The mosquito populations for this region of the province are significantly affected by snowmelt and river discharge. A below average moisture accumulation reported for the spring of 2009 (see Figure 6) resulted in a much lower overall mosquito population.

In the Okanagan region there were 6 traps that have been in the same general areas for the last 5 years. *Aedes* was the most common mosquito genus collected in traps in 2009. The total number has decreased since the Okanagan-Similkameen Regional District implemented an Integrated Mosquito Management Plan, beginning in 2006.

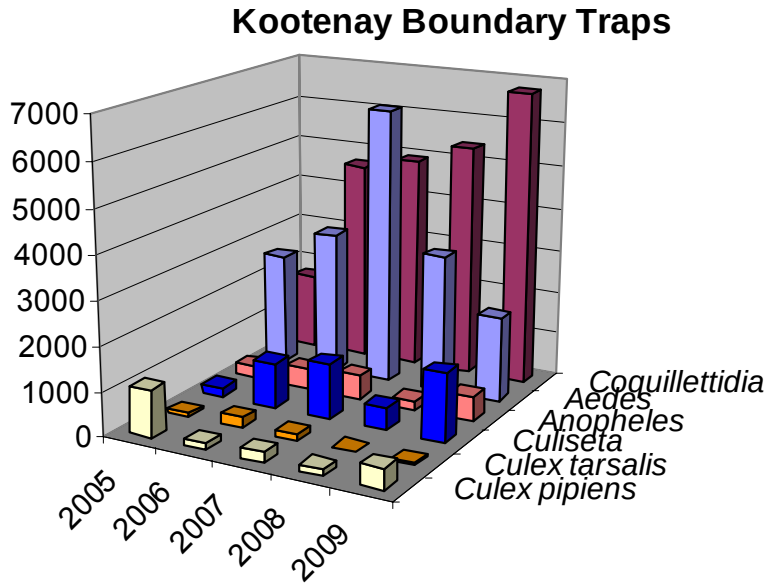
Figure 13: Species Abundance from 2005-2009 in Representative Light Traps, Okanagan HSDA (Aedes is shown in a separate graph).



Cx. tarsalis numbers were higher in 2009 than the previous 2 years, but still not as high as in 2005 and 2006. The *Cx. tarsalis* population was large enough that WNV was able to infect this species. With the virus now known to infect mosquitoes of this region, the population should be closely monitored so that numbers do not reach levels that were observed in 2006. In addition, if Washington State continues to see rapid spread of the virus, this HSDA should continue to support IPM for this species so that the impact of the virus is reduced.

In the Kootenay Boundary HSDA there are 4 trap sites that have generally been in the same locations for the last 5 years (Figure 14). *Coquillettidia* was the most common mosquito collected in the traps from this region. Many consider this as a bridge vector for WNV but it is not implicated as the primary vector to amplify the virus.

Figure 14: Species Abundance from 2005-2009 in Representative Light Traps, Kootenay Boundary HSDA

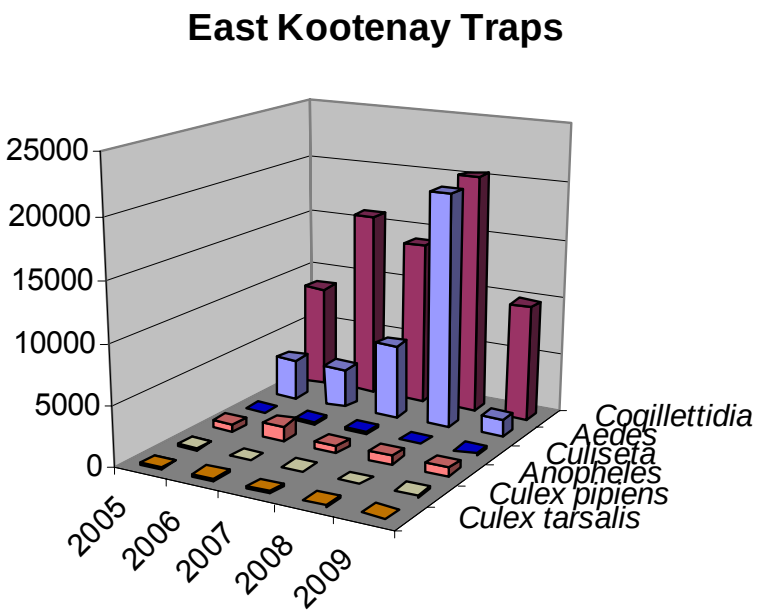


Castlegar and Trail are in a relatively narrow valley which the Columbia River flows through. The valley does not widen out until south of the US border in Northport, WA. No trap in 2009 from Kootenay Boundary caught more than 35 specimens of *Cx. tarsalis* over the entire season. Considering the general absence of vector species, this region still appears to have limited capacity for circulating the virus.

To the west in Grand Forks there is a wider valley which offers more opportunity for suitable manmade habitat for WNV vector species. In 2009, the trap at this location collected only 51 *Cx. pipiens* and no *Cx. tarsalis*. This region has run an IPM program for mosquitoes for many years, so this may be the reason they have so few mosquitoes.

There are 4 traps that have been operated in the same general area of the East Kootenays for the last 5 years. From these traps, *Coquillettidia perturbans* is the most common mosquito collected (Figure 15). Two of these traps are in the Creston Valley where extensive marshlands can account for their development. Usually they have produced up to one half of the total *Coquillettidia perturbans* collected in the traps of the IH region. This year the number collected was much less than 2008. The dry conditions do not seem to favour the development of this species. *Aedes* numbers were at the lowest seen in the last 5 years. Of the primary WNV vector species collected, only around 100 of each *Culex* species were collected for the entire season.

Figure 15: Species Abundance from 2005-2009 in Representative Light Traps, East Kootenay HSDA



Summary

Sentinel traps are a very useful tool in determining changes in mosquito populations from year to year. An active surveillance program is used across North America to predict the risk of an impending outbreak. For example, Manitoba uses surveillance information as part of a strategy to determine when WNV may cause a major epidemic. In this program they use mosquito population information to make recommendations for pre-emptive mosquito control to reduce the impact of this virus. Without any active surveillance, Manitoba would not be able to react until after the risk has passed, since people are usually not confirmed infected until weeks after the virus appears.

Physical conditions such as precipitation play an important role in assessing the potential for developing mosquito populations. Precipitation is one factor used in Winnipeg for their Adulticide Factor Analysis (AFA) and in California's Mosquito-Borne Virus Surveillance & Response Plan. In BC we see a dramatic increase in *Aedes* populations when rain and melting snowpack causes unusually high runoff. Watching the provincial river forecast report can help predict trends early in the season. Developing a similar predictive model for parts of BC might be useful now that we know the virus has been found in the South Okanagan.

Early season temperature accumulation can give an indication of the activity of *Culex* species, which overwinter as adults. This year we had an extremely warm summer and relatively large *Cx. tarsalis* populations.

The HAs have focused surveillance this year by reducing the period of sampling to the most likely part of the season when WNV would appear. Also, the trapping locations

were reduced and focused (particularly in IH) along the Canada/US border. As pointed out, some positive indicators were found in Washington State, in close proximity to VIHA and FH at some point over the last 5 years.

The BC Mosquito Control Subcommittee recommends that a strategy be in place for separating some *Aedes* to species where *Aedes togoi* and *Aedes dorsalis* are found. This could be a consideration for surveillance in subsequent years if the number of samples is reduced. Speciation could occur any time after *Culex* have been sorted and tested.

A continued focus on trapping and testing for the primary vector species, *Cx. pipiens* and *Cx. tarsalis*, is a good practice to reduce cost and maximize efficiency of surveillance. If WNV is known to be circulating, consideration could be given to using gravid traps in regions known to have *Cx. pipiens*, in order to maximize the chances of getting a blood-fed female. (There is evidence that *Cx. pipiens* is drawn to gravid traps.)

Lag Times for Mosquito Submissions

The time it takes for a sample to go from the field to the laboratory is important for the timely reporting of WNV results back to the HAs, and for maximum detection of the virus. This year there was only a one day median turnaround time (Table 9). The maximum delay from collection to submission was only 9 days. This is primarily attributed to statutory holidays when we ask the field staff to hold samples in freezers until after the holiday, rather than having them delayed, without adequate temperature control, at a courier's storage facility when BCCDC staff are unable to accept submissions.

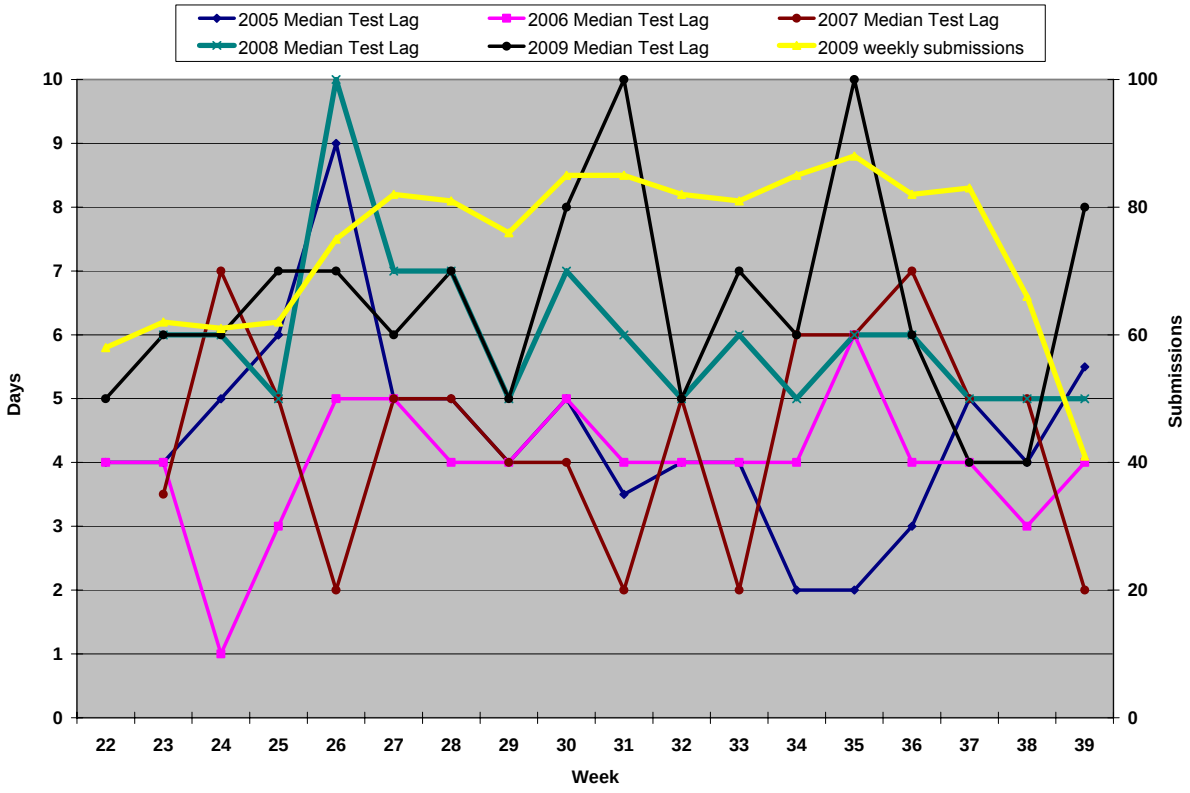
Table 9: Mosquito Lag Time for Sample Submission, 2005-2009

	Median of Submission					Maximum of Submission				
HSDA	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
EK	2	2	3	1	2	13	5	13	2	3
KB	2	1	2	2	2	6	2	4	3	2
OK	1	1	1	2	2	9	4	3	3	6
TCS	1	2	1	NA	NA	5	7	5	NA	NA
FRE	2	1	1	1	1	8	4	32	7	5
FRN	1	1	1	1	1	6	4	1	4	5
FRS	1	1	1	1	1	16	4	8	5	4
SVI	1	1	1	2	2	11	2	6	7	9
CVI	1	1	1	2	2	6	7	7	7	9
NVI	2	2	1	1	NA	3	3	7	5	NA
All	**1**	**1**	**1**	**1**	**1**	**24**	**16**	**56**	**7**	**9**

Note: All numbers are in days. Includes time in frozen storage before shipping. Each row refers to annual medians (first 5 columns) and maximums (2nd 5 columns) across the province.

BCCDC laboratories received about 85 samples per week during July and August and 70 to 80 during other times of the season. BCCDC Labs processed these samples in about 7 days, except partway through the season when samples from the research traps in the Okanagan were submitted in bunches rather than on a weekly basis (Figure 16).

Figure 16: Change in Laboratory Lag Time for Mosquito Identification and Testing



What's Up and Coming with Mosquitoes in 2010?

In FH and IH a larviciding Pest Management Plan (PMP) to reduce the risk from WNV was advertised and ready for use in 2009. Only areas in IH did pre-emptive control of potential WNV vector mosquitoes under these plans. In the South Okanagan, where WNV appeared this year, the Regional District of the Okanagan-Similkameen treated mosquito development sites. Without any mosquito control, the number of infections may have been higher if mosquito populations were left unchecked. If future, more aggressive action such as adult control is considered a necessity, then an amendment to this PMP should be done early in the spring of 2010 before the summer mosquito season.

Most of the positive mosquito pools in the South Okanagan were from a research program that sampled 2 times a week and included 6 times as many traps as currently used in WNV surveillance for that region. One of the positive pools came from a surveillance trap operated by IH. Since the virus was recovered from this area, consideration has been given to operating more traps in this region for the next few years to see if WNV has become endemic and is spreading.

Surveillance of WNV in Horses

In the first half of September 2009, two horses with appropriate clinical signs and confirmed laboratory results were reported with WNV infection in the South Okanagan, and one was reported in the Fraser Valley. None of the 3 infected horses had travelled off of their resident farms during the incubation period of WNV infection (3 to 14 days), which indicates that these infections were locally acquired.

Communication with MAL is ongoing related to the veterinary reporting process for WNV infections in horses.

Geographic Information Systems – Applications to WNV

Geographic information systems (GIS) mapping and analysis has been an integral tool for WNV surveillance and planning in BC. Data from a variety of sources (health-related events, field sampling, municipal infrastructure, environmental, etc.) and technologies (global positioning systems, remote sensing, databases, etc.) can be integrated in a GIS for visualization and analysis. In addition to the weekly summary maps posted on the WNV website, the BCCDC has developed:

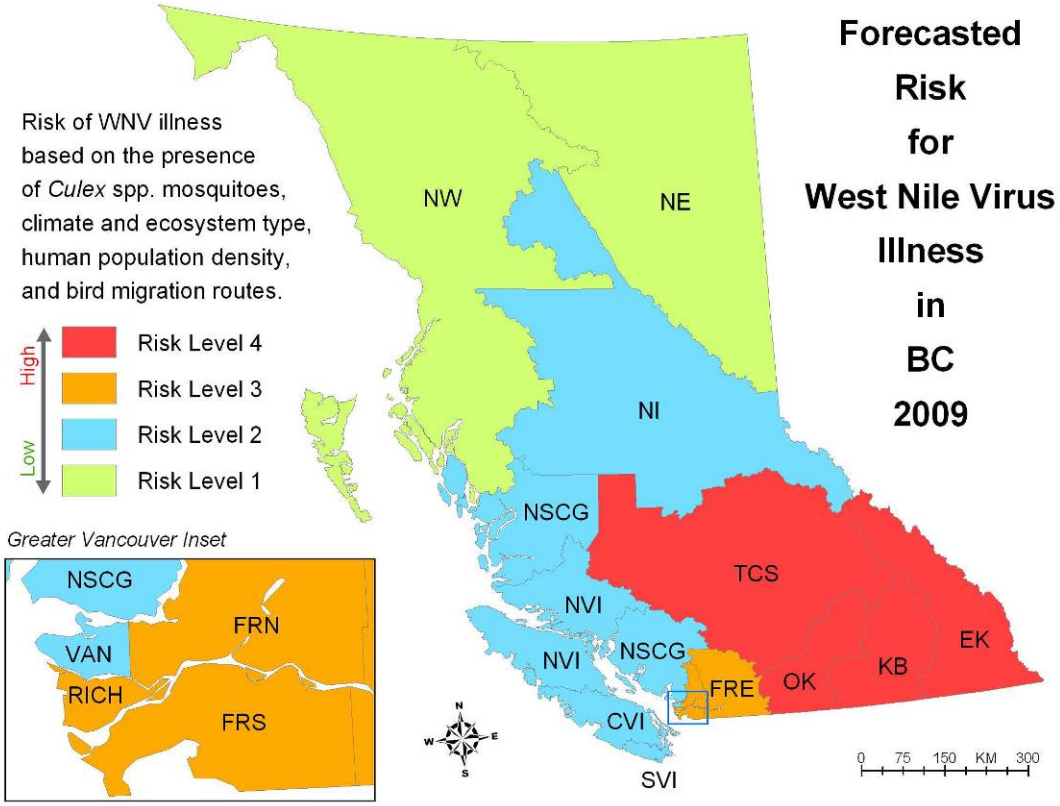
- an interactive web-based GIS mapping system for public health officials and members of the public to view WNV surveillance data in spatial format,
- a growing degree day model to forecast *Cx. tarsalis* mosquito development during the surveillance season,
- density maps of dead corvid sightings and submissions for WNV testing to detect hotspots of corvid die-offs,
- an assessment on the feasibility of adult mosquito control in select BC communities, and
- forecasted WNV risk models based on mosquito, temperature, geographic and environmental factors to inform WNV preparedness, surveillance and response.

Please refer to http://www.bccdc.ca/westnile and http://maps.bccdc.ca for all WNV mapping related content.

Raster GIS-based Risk Model for WNV

Creating risk maps based on known environmental and ecological drivers of disease occurrence is one tool that can be used to guide provincial health programming for zoonotic diseases such as WNV. The previous risk model was based on surveillance and ecological data summarized at the HSDA geopolitical unit (Figure 17). Assigning levels of forecasted risk by HSDA have been useful for the allocation of program funding since health care services are delivered and managed at this geographic level. However, a major limitation of this approach is the homogeneous rating of risk within the entire HSDA whereby all geographical areas within the HSDA are classified as having the same level of WNV risk, when in fact there is much variability in ecology, climate, human development, etc. A solution to this problem is to perform a spatial risk assessment of WNV using a raster or cell-based approach via GIS modeling to yield a specific, community level assessment of risk across BC. The raster GIS approach enables the representation of data as unique individual cells, and the collection of these cells in geographic space produces a continuous surface with varying data values of the phenomenon of interest.

Figure 17: Forecasted risk for West Nile virus illness in British Columbia by HSDA, 2009



GIS data layers relevant to WNV ecology and epidemiology with full provincial coverage were inputted into the models: *Culex* mosquito distribution, temperature, degrees latitude, agricultural land, human population density, and corvid density. Precipitation was not included in the model because its influence on mosquito abundance and WNV epidemiology remains too complex and uncertain (Pecoraro *et al*. 2007). The cell size of analysis (minimum mapping unit) for the raster GIS-based model was 2 km x 2 km which was determined by the spatial resolution of the base 16^{o}C degree days model developed by Tachiiri *et al*. (2006).

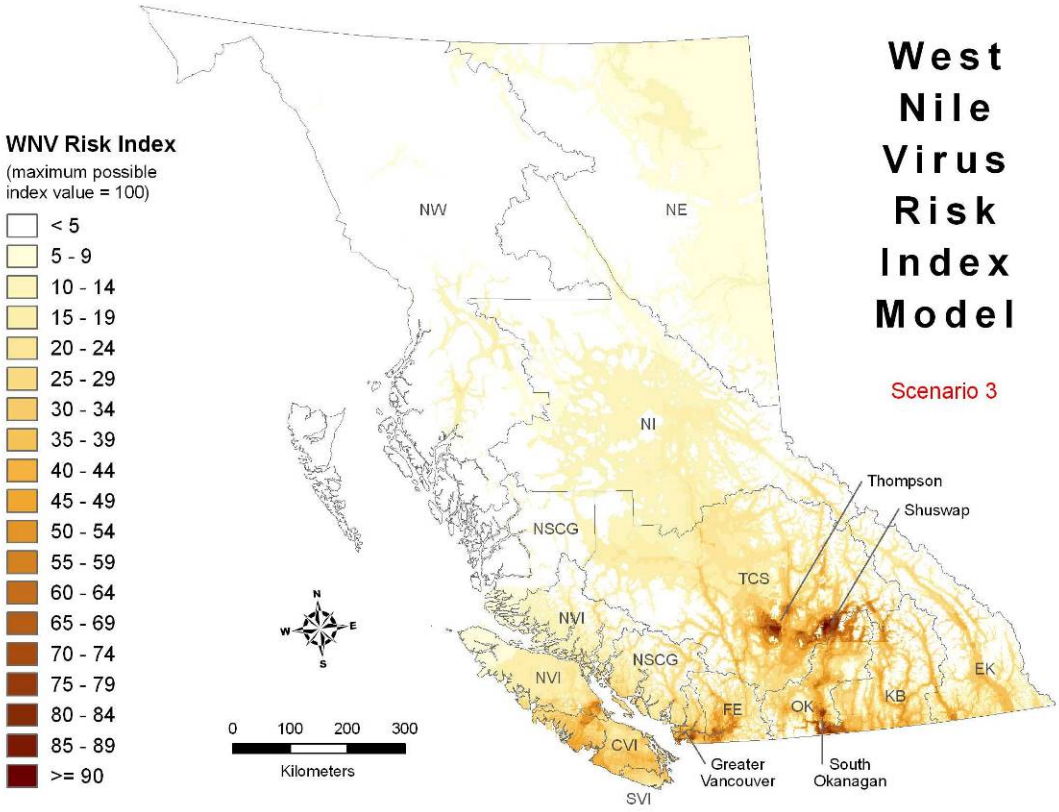
Three model scenarios, differing in the inclusion of input variables and weighting of values, were created. These model variables/GIS data layers were weighted according to their importance to WNV biology and epidemiology based on internal expertise, observations from other jurisdictions with similar ecology and occurrence of local WNV activity in BC during 2009. *Cx. tarsalis* and *Cx. pipiens* abundance were perceived to be the most important factors for WNV risk because transmission of the virus between infected birds and mosquitoes, and between mosquitoes and humans can only occur if the WNV competent mosquito species are present. The number of accumulated degree days (i.e. heat) was also weighted heavily because of its importance to mosquito development, virus amplification and mosquito biting activity. Degrees latitude represented the proximity to endemic WNV activity in the bordering southern states of

Washington, Idaho and Montana. Proximity to agricultural areas, density of human populations, and abundance of corvids were only included in the first model scenario because of the relative uncertainty related to these variables and WNV epidemiology in BC.

A summary of the input data variables used in the 3 risk model scenarios are described below in order of importance:

Scenario 1 (November 2008)	Scenario 2 (April 2009)	Scenario 3 (November 2009)
Cx. tarsalis	*Cx. tarsalis*	*Cx. tarsalis*
Cx. pipiens	*Cx. pipiens*	degree days
degree days	degree days	*Cx. pipiens*
agricultural land		latitude
latitude		
population density		
corvid density		

Figure 18: West Nile Virus risk index model scenario 3 for British Columbia.



Risk model scenario 3 (Figure 18) provides the best and most reliable risk forecast because the selection and weighting of input variables were directed by the ecological

characteristics of the South Okanagan and Fraser Valley (areas where WNV was identified in 2009). Consequently, risk model scenario 3 identified the South Okanagan and Greater Vancouver-Fraser Valley, as well as the Thompson-Shuswap region as the highest forecasted WNV risk areas in BC. These areas are characterized by medium to high mosquito abundance, warm spring and summer temperatures, lower latitudes, and agricultural areas proximal to urban populations (see Potential Causes of BC's First WNV Activity on page 40). In general, risk model scenarios 1 and 2 (not shown) also identified the same high risk areas as risk model scenario 3. However, risk model scenario 1 was previously considered less reliable because of its model complexity and uncertainty related to the inclusion of additional model variables, and risk model 2 did not explicitly address southern BC's proximity to endemic WNV activity in the bordering southern states of Washington, Idaho and Montana.

For the most part, the high risk areas identified correspond to the high risk zones that were previously classified by the HSDA approach. The main advantage of the raster GIS-based approach proposed here is that WNV risk can be identified at a finer, local spatial scale (4 km^2 cell). This is an important improvement upon the previous risk model since higher risk areas within an HSDA or even within a community can be identified. Resources for WNV surveillance in mosquitoes and dead birds, and preventative measures to reduce mosquito breeding habitat can then be focused on specific communities or even within certain neighbourhoods and recreational areas.

In conclusion, all 3 risk model scenarios identified the same WNV risk areas in BC, despite having different input data layers and weighting of variables. These high risk areas include the South Okanagan, Greater Vancouver-Fraser Valley, and Thompson-Shuswap regions. The models were validated by this year's detection of WNV in the South Okanagan and Fraser Valley, and further refinement of the models will be pursued as new data are collected and analyzed. In particular, risk model scenario 3 provides the best prediction for WNV risk in BC for the upcoming year.

Communications

Communication Objectives

- Inform British Columbians and visitors to the province of the potential risk associated with WNV and to provide awareness regarding using personal protective measures. Awareness is created through the distribution of resource materials (including brochures), radio and news releases, fact sheets, information bulletins and the BCCDC website.
- Inform stakeholders about specific strategies and responses by providing an up-to-date WNV resource plan and key messages.
- Provide up-to-date information on human WNV surveillance in BC through timely surveillance reports.
- Respond to issues/inquiries via provincial spokespersons (Provincial Health Officer [PHO], BCCDC, regional MHOs), HealthLinkBC and other correspondence as required.

Strategies

- Provincial coordination of communications/public information through regular BC WNV communication group teleconference meetings
- Series of press releases and informational support material distributed throughout summer months with targeted timelines and key messages
- BCCDC Web site – updated with timely and consistent materials for public and professional use
- Weekly conference calls between MHOs, BCCDC and other related professionals
- Cooperation with other provinces/territories and Health Canada in coordinating public information and education

Target Audiences

- Home and property owners in both rural and urban areas
- People aged 50 years and older
- Physicians
- Public health nurses/HealthLinkBC
- Local governments; provincial ministries, regional districts and municipalities
- General public who spend, or whose children spend a significant amount of time outdoors on a regular basis
- Agricultural industry (e.g. organic farmers, bee keepers)

2009 Communications Review

- Communication strategies, including the provision of public awareness, were a significant tool in responding to WNV in 2009, particularly as British Columbia confirmed its first indigenous human case of West Nile virus infection.
- The public awareness campaign emphasized personal protection and the campaign consisted of several components, such as:
    - Stakeholders across the province (e.g., parks, hospitals, tourist centers, veterinary offices, etc.) received brochures.
    - News releases and information bulletins were done on an as needed basis.
    - Inquiries were directed through BCCDC via provincial spokespersons.
    - Up-to-date information/resources including weekly reports were posted via the BCCDC website at www.bccdc.ca/westnile
- News releases issued in 2009 included:
    - First human West Nile Virus case in BC confirmed
    - B.C. confirms first West Nile Virus activity
- Media Activity
    - BCCDC received 28 media calls focused on West Nile Virus
    - A press conference was held on Saturday, August 22 when a positive mosquito pool was confirmed in the South Okanagan.

2009 Key Messages

- BC has a coordinated approach to the public health threat posed by WNV. The provincial plan is coordinated by BCCDC, and includes BC HAs, MHOs and local governments.
- Details of BC's WNV strategy have been developed by a provincial working group that includes public health inspectors, physicians, veterinarians, wildlife experts, entomologists, academics and pesticide officers. The multi-agency group has representation from BCCDC, HAs and the B.C. Ministries of Healthy Living and Sport, Environment, Agriculture and Lands and Community and Rural Development.
- The province's strategy for WNV includes:
    - Identification and mapping of mosquito breeding grounds to assist in mosquito control measures
    - Development and implementation of an IPM plan that uses the most appropriate methods to control mosquitoes in a given area
    - Purchase and placement of mosquito traps throughout BC
    - Testing of mosquitoes and dead crows for WNV infection
    - Reporting of dead corvid sightings through a web based system
    - Providing testing of human specimens for WNV through BCCDC
    - Public information to emphasize self protection measures that can be taken by individuals: source reduction to reduce mosquito breeding grounds and personal protective measures to reduce the risk of mosquito bites
    - Monitoring and testing to ensure safe blood, organ and tissue supply
    - Up to date summaries of WNV reporting and activity posted to the BCCDC web site

- The risk of becoming ill from WNV in BC is low, but preventive measures are important.

2010 Communication Strategy

- The 2010 WNV campaign resources remain similar to those used during 2009. The activities for 2010 include:
    - Series of press releases and informational support material distributed throughout summer months with targeted timelines and key messages:
        - A news release in June encouraging British Columbians to prepare for the WNV season
        - A News release in August focused on personal protection.
- Provincial coordination of communications/public information through regular BC WNV communication group teleconference meetings
- BCCDC web site – updated with timely and consistent materials for public and professional use
- Regular conference calls between MHOs, BCCDC and other related professionals
- Cooperation with other provinces/territories in coordinating public information and education

Media Inquiries

Media inquiries are handled by BCCDC (604-707-2412) and HA Communications offices.

Provincial Spokespersons

Regional MHOs are the primary spokespersons for their jurisdictions, with PHO and BCCDC supporting these efforts.

Educational Materials

Website

This summer a new BCCDC website was launched (www.bccdc.ca/westnile) which includes many improvements to the functionality and content of the site. The navigation structure of the website has changed, so we invite users to let us know if they cannot find what they are looking for.

WNV 101

Education is an important part of the BC WNV response plan. There are a variety of ways which WNV is brought to the attention of the public each year - most involve education through news media. An education tool BCCDC is currently developing in collaboration with FH and a Maple Ridge school is an optional teaching resource for BC teachers.

The package includes background information for the teacher, 5 lesson ideas with worksheets, and a resource list. The lessons will be focused on WNV with the option for students to research other zoonotic diseases within assignments. Topics covered within the package include; discussion of zoonotic diseases, WNV article review, the WNV transmission cycle, identification of mosquito habitat, personal protective measures for WNV, surveillance for WNV and testing methods for WNV. Hopefully the unit will encourage students to take responsibility for protecting themselves from disease, and show them that daily activities and personal behaviour can change the risk of contracting certain diseases. The skills required to find, interpret and apply public health information (charts, maps, health alerts) online will be practiced. In addition, the students will practice evaluation of media to identify sources of high quality information. This package was tested in a class this fall, and will be revised based on feedback and posted for download from the BCCDC website once finalized.

Discussion

Potential Causes of BC's First WNV Activity

The long awaited arrival of WNV in BC puts to rest the question of whether the province would ever have local WNV activity. This does however raise a series of new questions. How was the virus introduced into the province? Why did it finally occur in 2009, and not previously? Why was this year's activity primarily focused in the South Okanagan, and not elsewhere in the province?

WNV Introduction

BC's WNV activity in 2009 was likely initiated by introduction of the virus in the same year, given that the previous six years of WNV surveillance failed to detect a single instance of local WNV activity. Potential pathways for WNV introduction into BC include wind-borne mosquito dispersion, human-mediated mosquito transport by plane or boat (e.g. in tires), introduction of an infected bird by migration, commercial or clandestine importation of an infected bird and human introduction of the virus (Kilpatrick *et al.*, 2004, 2006). Given the location of the initial WNV activity, we feel that introduction likely occurred by either short-distance movement of local birds or mosquitoes from Washington State, or long-distance avian migration from southern areas where WNV is endemic. The Okanagan Valley extends south into Washington State where 36 human and 71 equine cases of WNV were detected in 2009 – a greater than ten-fold increase from previous years: http://www.doh.wa.gov/ehp/TS/Zoo/WNV/WNV.html This WNV activity in Washington State provides a significant viral source, one that is connected to BC by a natural corridor, which could facilitate viral introduction by local vector or reservoir movement. *Cx. tarsalis* has been shown in mark-recapture studies to move upwards of 14.5 km in a single trapping period (Bailey *et al.*, 1965), while other mosquito species can move up to 300 km on wind-currents (see Pedgley, 1983 for a review of wind-borne insect movement). Movement of avian reservoirs is another possible mechanism for the introduction of WNV into BC. Bird migration is thought to have played an important role in the initial westward movement of WNV in both the US and Canada (Gubler, 2007) and WNV antibodies have been detected in migratory birds here in BC. However, others suggest that short distance bird movement is a more likely explanation for the movement of WNV in North America (Rappole *et al.*, 2006) with local movement of crows (Ward *et al.*, 2006) or house sparrows (Rappole & Hubalek, 2003), suggested drivers of short-distance viral spread. The delayed arrival of WNV in BC, despite the presence of yearly migration through our province, provides indirect support for the role of local bird or mosquito movement, especially given Washington State's recent WNV activity. However, it is also possible that introduction of WNV into BC by migratory birds has occurred previously, but that the ecological and environmental circumstances in 2009 were for the first time suitable for WNV establishment and subsequent amplification of the virus to levels that could be detected by WNV surveillance.

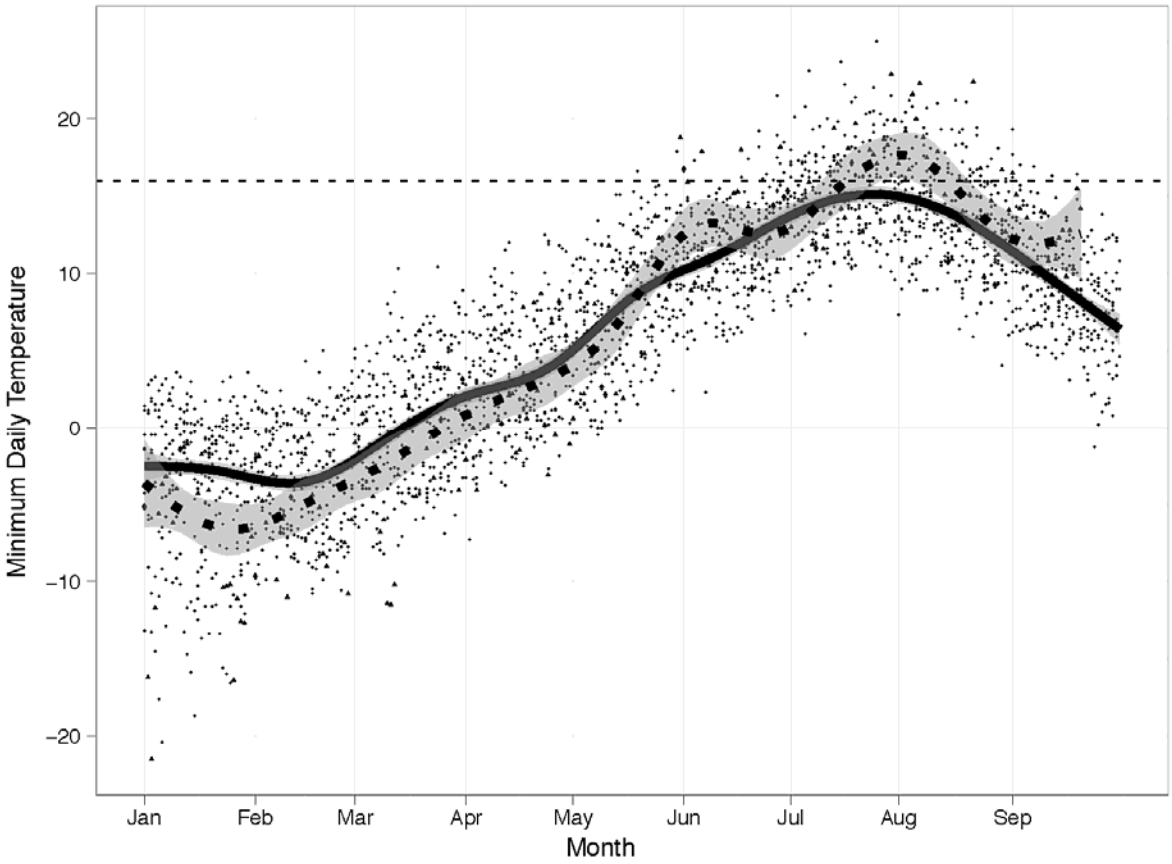
Why the Okanagan? Why 2009?

In addition to the significant WNV activity in Washington State, a variety of other factors also favoured the South Okanagan as the location of BC's initial WNV activity. In fact, provincial risk maps created by the BCCDC predicted that the South Okanagan has higher WNV risk than other areas in the province. Much of this is attributed to the hot climate of this area. Temperature is thought by many to be a limiting factor for WNV activity, and the South Okanagan is one of the hottest locations in Canada. The importance of temperature on WNV transmission stems primarily from the role that mosquitoes play in disease transmission. Temperature affects mosquito development rates, the frequency with which mosquitoes take blood meals, the length of the gonotrophic cycle, and their lifespan (Becker, 2008). Rates of viral development within the mosquito vector are also driven by temperature, and this positive association has important consequences for disease transmission as failure of the virus to replicate before mosquito death will halt amplification. Positive associations between temperature and viral transmission have been observed for both *Cx*. *pipiens* (Dohm *e*t *al.*, 2002) and *Cx. tarsalis* (Reisen *e*t *al.*, 2006).

The importance of temperature in WNV transmission may also explain why the virus was first detected in 2009, as the southern part of BC had above average temperatures this year. Daily minimum temperatures are likely the best reflection of temperatures present during the periods of the day when WNV vectors are most active, and hence may be particularly relevant to WNV transmission. The average minimum daily temperature in Osoyoos during July was 1^{o}C greater than the twenty-year average, while the average of daily minimum temperatures during August was almost 2^{o}C greater than the 20 year average. Furthermore, the first positive mosquito pool in the South Okanagan was detected approximately one week after a significant rainfall, and immediately following a significant warm period during which nightly temperatures were well above the 16 ^{o}C limit for optimal *Cx. tarsalis*-driven transmission (Figure 19). While this localized precipitation likely increased vector development sites, the ensuing period of extreme heat would have facilitated rapid viral amplification and subsequent transmission in avian and mosquito populations. The South Okanagan also experienced reduced stream and river flows in 2009, owing in part to both summer weather conditions and to reduced snowpack observed during the winter of 2008/2009 (BC Environment). Most rivers in the Okanagan basin showed 10-20 year low stream flows for much of the summer (BC Environment). These conditions may also have contributed to elevated *Cx. tarsalis* numbers observed in the South Okanagan in 2009, as it has been suggested that reduced stream flow can increase the number of isolated pools suitable for mosquito development (Landesman *e*t *al.*, 2007; Lafferty, 2009).

Figure 19: Observed minimum daily temperatures in Osoyoos: 2009 and 10-year averages.

Note: Shaded areas represent standard errors. Full line represents 10-year averages, while dotted line represents values observed in 2009. Horizontal dashed line indicates 16°C; the temperature above which optimal larval Cx. tarsalis development, adult activity and virus replication are thought to occur.



The landscape of the South Okanagan also contains characteristics that may facilitate WNV activity. The extensive agriculture in the Okanagan Valley has resulted in a lush irrigated landscape surrounded by desert scrubland. The clustering of human settlements along the rivers and lakes results in further spatial aggregation of humans, birds and mosquitoes that may facilitate viral amplification and spillover. Furthermore, the abundant agriculture and irrigation may provide an abundance of *Cx. tarsalis* habitat, as this species favours clear standing water as is often found in irrigated landscapes.

While the above causes are likely distal drivers of the observed WNV activity in 2009, the more proximal driver was likely the elevated numbers of *Cx. tarsalis* observed in the South Okanagan and in the Fraser Valley. Peaks in the abundance of this vector in late June have been observed previously in the province's interior region, however, several locations in 2009 showed an unprecedented increase in the number of *Cx. tarsalis* in early August, with maximum nightly trap counts as high as 800 individuals. This short

term explosion in *Cx. tarsalis* abundance occurred concurrently with the first detection of a positive mosquito pool, and with the estimated exposure date for the 2 human WNV cases. *Cx. tarsalis* is a bridge vector that feeds on both birds and mammals (Kent *et al.*, 2009), and the elevated abundance of this species in the latter part of the summer likely facilitated viral spillover from avian populations into human populations. The abundance of *Cx*. *pipiens*, while not showing such drastic increases, has been increasing steadily since 2003, reaching nearly 30 *Cx*. *pipiens* per trap-night in 2009 in the FH.

Summary

The exact causes of this initial WNV activity in the province are undoubtedly complex and difficult to ascertain. However, we believe that several key characteristics made the Okanagan uniquely susceptible to WNV in 2009. First, the significant WNV activity observed in Washington State provided a nearby source for short distance viral introduction. Second, weather conditions, specifically the above average temperatures and low stream flows, may have resulted in elevated *Cx. tarsalis* numbers, which in turn facilitated viral amplification and viral spillovers into human populations.

The Future of WNV in BC

Now that local WNV activity has for the first time been detected in BC, it is important to consider what we may expect with regard to the severity of WNV activity in 2010. While such predictions are obviously speculative given the importance of weather on the transmission cycle, examining how human case counts changed in the years following viral introduction into an area of North America may shed light on what we can expect regarding WNV activity in 2010.

The historic progression of WNV activity in Idaho, Illinois, California, Wyoming, South Dakota and to a lesser degree Alberta, is characterized by a three-year pattern with limited WNV activity during the introductory year, significant increases in human cases during the 2nd year, and an eventual reduction during the 3rd year. This pattern was first identified by Reisen and Brault (2007), who attribute this three year progression to 1) initial viral introduction and successful overwintering of the virus in mosquito vectors, 2) significant amplification and spillover the following year, and 3) acquisition of avian herd immunity and mosquito control efforts that limit activity in year three. Although this three-year pattern appears to hold for many areas of North America, it does not characterize the experiences of all jurisdictions, as historic WNV trends in Oregon show a slow build and less significant outbreak, while Washington State has had only sporadic minor WNV activity prior to this summer.

The importance of climatic triggers in driving WNV activity makes predictions difficult. As was discussed previously, the temperature conditions experienced in the South Okanagan in 2009 were uniquely warm. However, predictions that 2010 could be an El Niño year (US National Weather Service) indicate that temperature conditions could again be elevated in BC. Furthermore, the presence of a WNV positive horse in the Fraser Valley in early September indicates that the virus is now in close proximity to BC's primary urban centres where *Cx. pipiens* is a much more abundant species. This may signal a change from a primarily rural transmission driven by *Cx. tarsalis* (as observed in 2009), to a more urban transmission cycle driven by *Cx. pipiens*. Having said that, BC also has a relatively low abundance of both key WNV vectors compared to regions previously suffering severe WNV activity. Furthermore, the delayed introduction of the virus has allowed public health officials in BC to learn from the experience of other jurisdictions, and municipal pre-emptive larviciding may therefore reduce both the number of WNV vectors and the associated WNV risk.

It is difficult to accurately predict the intensity of WNV activity in BC in 2010. Regardless of the final outcome, WNV activity levels in 2010 will provide valuable insight into the nature of WNV expansion and transmission along its northern border. Significant WNV activity in 2010, despite a return to normal temperatures, would indirectly support the hypothesis that the prolonged absence of WNV in the province was primarily due to ineffective viral introduction. Conversely, a return to cooler weather conditions combined with a lack of WNV activity in 2010 would suggest that environmental and ecological conditions in this part of the Pacific Northwest are typically unsuitable for yearly WNV

establishment, amplification and transmission. Regardless, appropriate vigilance and surveillance by physicians and public health officials is required in the near future.

From the Literature

Surveillance

Gu et al., 2008:
Fundamental issues in mosquito surveillance for arboviral transmission.

Gu et al. examine key issues related to mosquito sampling design and estimation of transmission intensity. Two surveillance approaches are identified: targeted surveillance for the detection of virus in areas with low infection rates, and extensive surveillance for evaluation of risk exposures in areas with high levels of infection. Targeted surveillance is defined as "increasing mosquito sampling at sites where interactions between vector mosquitoes and reservoir hosts are favourable for a greater likelihood of arboviral transmission". In areas with low levels of WNV, the authors suggest using epidemiological intelligence to identify potential hot spots in which to focus targeted efforts in order to maximize the potential of early viral detection. Later in the season, when infection rates are elevated, the authors suggest expanding the extent of surveillance efforts in order to evaluate the range of arboviral transmission. The authors also state their preference for the use of Maximum Likelihood Estimates (MLE) of mosquito infection rates compared to the simpler MIR (ratio of # of positive pools to total mosquitoes collected). The Density of Infected Mosquitoes (DIM) (vector abundance X estimated infection rate) is suggested as the best risk indicator because it estimates the frequency of contact between humans and infected mosquitoes. Finally, the authors suggest that surveillance data be presented in a non-aggregated form in order to allow for "spatiotemporal tracking of transmission dynamics".

Syed and Leal, 2009
Acute olfactory response of *Culex* mosquitoes to a human- and bird-derived attractant

The authors have identified a compound from birds and humans that is found to stimulate the olfactory receptor neurons in the antenna of *Cx. quinquefasciatus*. Nonanal, a chemical compound collected from all ethnic groups tested (Latino, East Indian, White, African, Chinese) as well as birds (pigeons, chickens), produces the most potent stimulus in *Cx. quinquefasciatus* of all natural chemicals tested, with higher levels of nonanal producing stronger responses in mosquito antennae. Encephalitis Vector Survey (EVS) traps baited with nonanal alone did catch significantly more mosquitoes then non-baited traps, although the absolute number of mosquitoes captured in these traps was low (~15-20). Pairing nonanal with CO_2 revealed a synergistic reaction, as using both in combination captured significantly more mosquitoes then using either alone.

Clinical Studies

Sejvar et al., 2008.
Neurocognitive and functional outcomes in persons recovering from West Nile virus illness

The authors evaluated the neurocognitive and functional effects of WNV disease. A cohort of 54 patients was assessed using quality of life indices and neurocognitive performance measures. These patients were classified by disease syndrome for comparison; WNV fever, meningitis, and encephalitis. Three comparisons were undertaken: 1) between these comparison groups, 2) between the study cohort and controls with chronic fatigue syndrome, and 3) between the study cohort and a normative control population. Half of those with WNV fever reported reduced quality of life and diminished functional impairments, while 75% of those with meningitis or encephalitis reported similar symptoms. However, no differences were noted on objective neurocognitive tests of psychomotor speed, executive planning and reasoning, memory and attention. Overall, those with WNV syndrome responded similarly to controls on neurocognitive performance tests, with the exception of psychomotor speed. WNV participants also faired poorly on tests focusing on visual processing, executive function, and maintenance of vigilance. Difficulties with concentration, memory and fatigue were also common among members of the WNV cohort.

Panitzer et al., 2009.
West Nile virus infection in plasma of blood and plasma donors, United States.

This study compares the titers found in immune globulin-intravenous (IGIV) with the titer levels found in individuals with confirmed past WNV infection as a way to independently measure the percentage of the US population with previous WNV infection. According to the authors, the WNV neutralization titers found in IGIV released to the market began to increase only in 2003 (which actually represent the infection rate of 2002). During 2005-2008, the WNV neutralizing titers increased by 3.6 per year (r2=0.9793), with titers in 2008 IGIV ranging from 2.8 to 69.8; 40% of samples are above titer levels shown to be protective in animal models of WNV infection. Plasma from individuals with confirmed WNV infection had mean neutralization titers ~100x greater than the general IGIV samples tested, providing support for previous estimates of past WNV infection in the population at ~1%.

Climate and Landscape

Soverow et al., 2009:
Infectious disease in a warming world: How weather influenced West Nile virus in the United States (2001-2005)

An epidemiological study design called a “case-crossover” was used to study the effects of ambient temperature, humidity and precipitation on the incidence of WNV among

16,298 cases reported to the CDC between 2001 and 2005 from 17 US states. The study design used here compares climate conditions occurring the week of WNV infection to that of a randomly selected week either 4 weeks prior or 4 weeks after the week of infection. A 5°C increase in mean weekly maximum temperature was associated with a 32-50% increase in WNV incidence. Similar patterns were found for the cumulative temperature (14°C base) and mean weekly temperature. Every 20mm increase in the amount of cumulative precipitation resulted in a 4-8% increase in WNV incidence 1-2 weeks later. One or more day of >50mm precipitation increased WNV incidence by 33%. Progressively lower impacts were observed with the use of a lower threshold (e.g. 40mm, 30mm).

Biology and Transmission

Loss, et al., 2009a:
Avian host community structure and prevalence of West Nile virus in Chicago, Illinois

This study was designed to test 1) whether avian richness was negatively correlated with prevalence of infection in bird and mosquito populations, and 2) to examine what bird species display the highest WNV seroprevalence rates in the Chicago area. Transient point counts were done at a variety of sites to estimate species richness, and blood was collected from birds captured using mist nets. Mosquitoes were also collected every two weeks from these sites. Analysis was restricted to only birds breeding in the region. Antibodies were detected in 16 of 60 avian species, with decreasing seroprevalence from 2005 to 2006. Seroprevalence in morning doves, northern cardinals and house finches was greater than 10% in both years. Infection rates in *Culex* vectors were not related to avian richness, relative abundance of high seroprevalent birds or total seroprevalence. The authors suggest that antibody status is primarily driven by year effects. Birds from areas with higher *Culex* infection rates were more likely to test positive for WNV (Odds Ratio: 582.16).

Loss et al., 2009b:
Nestling passerines are not important hosts for amplification of West Nile virus in Chicago, Illinois.

It has been hypothesized that nesting birds play an important role in WNV transmission. The authors sampled nesting passerines in Chicago during intense WNV activity. Sampled nestlings were tested for the presence of WNV, as were *Cx. pipiens* in the area. Despite high mosquito infection rates, only one 8-day-old house wren was positive for WNV RNA, and only one 10-day-old mourning dove had positive WNV antibodies. Study results suggest that nestling passerines are unimportant to WNV transmission in the Chicago area.

Wheeler et al., 2009:
Differential impact of West Nile virus on California birds.

This paper examined whether the high virulence of the new WN02 strain has caused significant declines in the populations of susceptible birds. The impact of WNV on birds was examined by: 1) testing the seroprevalence of WNV in both free ranging and dead birds tested as part of California's Dead Bird Surveillance program, 2) laboratory based host-competence studies, and 3) through Bayesian analysis (Generalized Linear Mixed Models) of breeding bird survey data. Seroprevalence was greater in large bodied birds, while vectors apparently favoured scrub jays. Elevated WNV prevalence in corvids, loggerhead shrikes, and raptors may be due to oral infection resulting from predation. Herons were frequently infected, while infection in song sparrows was low. According to combined risk scores, the Orange-crowned warbler, American crow, Western Scrub jay, Black-crowned night heron, White-crowned sparrow and Cattle egret are the most competent reservoirs in California. Breeding bird survey results show that four or five corvids declined in at least one region. Yellow-billed magpies were especially affected by WNV in northern regions, reaching a 27 year low. House finches and house sparrows declined significantly in north but not south WNV areas. In general, the ability of invading WNV genotype to invade temperate climates is closely related to its ability to induce the elevated viremia required for effective infection of *Culex* vectors.

Future Surveillance and Intervention Activities

BCCDC staff met with the 4 southern HAs and the Ministry of Healthy Living and Sport on November 23, 2009 to discuss future surveillance and mosquito control plans. Over the past 7 years, BCCDC and the HAs have developed and refined surveillance techniques, and learned much from our collaborative experiences and the experiences of other jurisdictions in Canada and the US.

Surveillance activities and results for 2009 were reviewed, and the implementation and utility of a 3rd version of the raster-based risk map was discussed.

A representative from MAL discussed the process of reporting equine positives, and presented a draft form for reporting.

The value of corvid and mosquito surveillance was discussed, and input was received from the HAs on the degree of surveillance they could provide. There was also discussion about the value of pre-emptive larviciding by communities.

At the meeting it was generally agreed that:

- The newest risk model was a valuable tool for identifying where mosquito trapping should be focused and where pre-emptive larviciding should be a priority;
- Dead corvid online reporting could be supported;
- Corvid collection for testing could be supported in targeted areas;
- Mosquito trapping would continue in the same jurisdictions that carried it out in 2009, but with some modification of trap locations and an increased intensity in higher risk areas;
- Pre-emptive larviciding could be of value in targeted areas of BC; and
- Funding for local government activities is valuable and should continue;

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