Government of Northwest Territories
Gouvernement des Territoires du Nord-Ouest

An Overview of the West Nile Virus and California Serogroup of Vector Competent Mosquito Species in the Northwest Territories from 2004-2018

Taz Stuart, M.Sc., P.Biol.

TDTS Consulting

2020

Manuscript Report No. 286

ABSTRACT

In 2004, with the threat of West Nile virus occurring in Canada and the United States, the Government Northwest Territories (GNWT) began adult female mosquito monitoring for the threat of West Nile virus (WNv) capable carrying mosquito species. The GNWT Department of Environment and Natural Resources (ENR) distributed Centres for Disease Control (CDC) ultraviolet light and carbon dioxide producing traps in targeted locations to determine if there were vector competent mosquitoes to WNv present in the Northwest Territories (NWT). This is a summary of the annual mosquito species identification data with particular emphasis on those known to be WNv and California Serogroup virus (CSGv) vectors. Maintenance and expansion of testing for mosquito borne virus presence is provided as currently there have been no positive WNv mosquito pools in the NWT since 2004. In addition, this manuscript provides a basis for future vector and disease detection in these new mosquito species records being detected in the NWT's.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

In 2004, with the threat of West Nile virus (WNv) occurring in Canada and the United States, the Government Northwest Territories (GNWT) Department of Environment and Natural Resources (ENR) began adult mosquito monitoring for the threat of WNv capable carrying mosquito species. The GNWT distributed Centre for Disease Control (CDC) ultraviolet light and carbon dioxide producing traps in target locations in the NWT to determine if there were adult female vector competent mosquitoes present. This overview paper is a summary of the annual adult female mosquito species identification data with a particular emphasis on those known to be WNv and California serogroup virus vectors. All adult female mosquito identifications were based on the mosquito identification keys of Wood et al. 1979, Darsie and Ward 2005, Thielman and Hunter 2007. We have not reviewed, in this document, the individual mosquito species capabilities as vectors as this has been reviewed in the literature by other mosquito authors and are available online or in print in mosquito, vector and epidemiological journals. Recommended review articles include: Eldridge 1990, Griot et al. 1993, Bernard and Kramer. 2001, Rasool et al. 2012, and Drebot, 2015.

Methodology

For each adult mosquito monitoring year, a total of four (4) Center for Disease Control (CDC) UV Carbon Dioxide light traps were placed at the same two locations in Fort Smith and Yellowknife. The placement and collection of adult female mosquitoes occurred weekly and the CDC mosquito trap start and end dates varied year to year based on environmental and seasonal weather variations. Approximately every June and early September was the initial start and end dates. Mosquitoes were collected and then placed into freezers to be stored until the end of the monitoring collection season. Each site then sent the full seasons collections for identification and pooling for WNv testing. Only *Culex spp. t*hat was identified through the identification process at TDTS Consulting was submitted for viral testing. The results of each year's identification and viral testing were provided to the GWNT.

Mosquito Data Results 2004-2018

In 2004, the first year of monitoring for adult female mosquitoes in Yellowknife and Fort Smith occurred from the adult mosquito monitoring CDC light traps. Precipitation levels were above normal but temperatures overall were below normal based on Environment Canada's 30 year over year average (Environment Canada, 2019). In this first year, the CDC traps captured 12,532 mosquitoes over 35 trap nights. This is an average catch of 358 mosquitoes per trap night. Of these 12,532 mosquitoes, 66 were *Culex (Cx.) tarsalis*, which is a new species record for the NWT and is very competent vector for

transmitting WNv (Turell et al. 2005, Chen et al. 2012). From the other mosquitoes captured that can carry the CSGv (e.g. Jamestown Canyon and snowshoe hare virus), seven species were found: *Cx. restuans, Ochlerotatus (Oc.) communis*, *Oc. excrucians*, *Culiseata (Cs.) inornata*, *Coquillettidia (Cq.) perturbans*, *Aedes (Ae.) cinereus* and *Oc. canadensis*. *Oc. communis* was the most commonly trapped of these species, with 7,051 individuals identified. Table 1 provides the list of potential CSGv carrying mosquitoes in the NWT. Next was *Oc. excrucians* with 1,293 individuals. The final four species were in a lower prevalence of 97 *Cq. perturbans*, 39 *Oc. canadensis*, three *Ae. cinereus* and three *Cs. inornata*.

Table 1. List of CSGv carrying mosquito species. Those species that are not present in the NWT are identified with an asterisk (*).

Aedes	*Coquillettidia*	*Culiseata*	*Culex*	*Ochlerotatus*
Ae. cinerus	*An. punctipennis**	*Cs. inornate*	*Cx. restuans*	*Oc. canadensis*
*Ae. albopictus**	*An. walker**		*Cs. melanura**	*Oc. cantator*
Ae. communis	*Cq. perturbans*			*Oc. excrucians*
Ae. vexans				*Oc. sticticus*
				Oc. stimulans
				Oc. sollicitans
				Oc. triseriatus

In 2005 trapping efforts were increased, with CDC traps being operated for 109 nights. Precipitation levels in this year were very conducive for nuisance and vector mosquitoes as precipitation was well above normal for the NWT (Environment Canada, 2019). The total adult mosquito catch from all trap nights is 59,869 mosquitoes, with an average catch of 549 per trap night. Two *Cx.* species were identified in 2005 with 444 being *Cx. tarsalis*, and one *Cx. territans*. The seven species of adult mosquitoes known to be carriers of the California group of viruses were found in 2005. These included the six from 2004, which are *Oc. communis*, *Oc. excrucians*, *Cs. inornata*, *Cq. perturbans*, *Ae. cinereus*, and *Oc. canadensis*. The most common of these seven species was once again *Oc. communis* with 33,396 adult mosquitoes identified. Next was *Oc. excrucians* with 3,384 individuals, *Oc. canadensis* with 780 individuals, then *Cq. perturbans* with 483 mosquitoes identified. The final three species consisted of 90 *Ae. vexans*, 30 *Ae. cinereus* and 23 *Cs. inornata*.

Due to logistical constraints within the GNWT, there were no adult female mosquito monitoring or identifications completed during the years of 2006-2010 in Yellowknife and Fort Smith.

In 2011, the adult female mosquito monitoring program was restarted and due to a very dry year, precipitation wise, as compared to the 30 year average from Environment Canada's weather data (Environment Canada, 2019), only 2,162 mosquitoes were trapped in CDC traps over 23 trap nights. That is an average catch of 94 mosquitoes per trap night. Five *Cx. tarsalis* were identified from the 2,162 mosquitoes caught. The adult mosquitoes that are potential vectors of the California group of viruses; there were nine *Oc. canadensis*

captured, 373 *Cq. perturbans*, 15 *Oc. sticticus*, 12 *Ae. cinereus*, one *Ae. vexans*, 60 *Oc. excrucians*, and 597 *Oc. communis*.

In 2012, due to another fairly dry summer season (Environment Canada, 2019), only 3,479 mosquitoes were captured over 22 trap nights. The average catch per trap night is 158 mosquitoes. Of the 3,479 mosquitoes identified only two were *Cx. tarsalis*. From the vectors of the California group of viruses, 73 were *Oc. canadensis*, 718 *Cq. perturbans*, 16 *Oc. sticticus*, 11 *Ae. cinereus*, two *Ae. vexans*, 109 *Oc. excrucians*, 1,618 *Oc. communis* and six *Cs. inornata*. It is important to note that this year was the same year as the largest anthrax outbreak in the NWT (New 2014).

In 2013 the mosquito catch jumped to 13,920 adult mosquitoes captured from 56 trap nights. This year saw an increase in precipitation which increased the overall trap counts (Environment Canada, 2019). This increase in precipitation brought the overall average catch per trap night up to 249 mosquitoes. Of the 13,920 mosquitoes captured, eight were *Cx. tarsalis*. From California group of viruses, 17 were *Oc. canadensis*, 273 *Cq. perturbans*, 26 *Oc. sticticus*, 84 *Ae. cinereus*, 225 *Ae. vexans*, 1,676 *Oc. excrucians*, 1,108 *Oc. communis* and five *Cs. inornata*.

In 2014 we saw yet another year with increased precipitation levels that equated to an overall increase of adult mosquitoes trapped in the CDC light traps (Environment Canada, 2019). Overall, 36,274 mosquitoes were trapped in CDC traps in NWT in 2014. The traps were operated for 67 nights, with an average catch per trap night of 541 mosquitoes. 40 *Cx. tarsalis* female adults were captured and identified from the 2014 catch. From the potential carriers of the California group of viruses, there were 40 *Oc. canadensis*, 926 *Cq. perturbans*, 1,558 *Oc. sticticus*, 340 *Ae. cinereus*, 142 *Ae. vexans*, 3,015 *Oc. excrucians*, 6,365 *Oc. communis* and 29 *Cs. inornata*.

In 2015, the CDC traps were operated for 60 trap nights. There was an overall decrease in precipitation levels as compared to the previous year (Environment Canada, 2019) and the total CDC trap catch was down to 10,791 mosquitoes. The average catch per trap night was 180 mosquitoes. Of the 10,791 mosquitoes caught, 61 were *Cx. tarsalis*. From the potential carriers of the California group of viruses, there were 120 *Oc. canadensis*, 1,992 *Cq. perturbans*, 263 *Oc. sticticus*, 67 *Ae. cinereus*, 13 *Ae. vexans*, 463 *Oc. excrucians*, 609 *Oc. communis* and 39 *Cs. inornata*.

In 2016 we saw an increase in the overall precipitation levels (Environment Canada, 2019) as 27,004 mosquitoes were captured in the CDC traps over 65 trap nights. This

results in an average catch per trap night of 415 mosquitoes. Two Culex species were identified from 2016s catch: *Cx. tarsalis* and *Cx. restuans*. This was the first record catch of *Cx. restuans*. From these, four *Cx. tarsalis* were identified and only one *Cx. restuans*. The potential carriers of the California group of viruses, 184 were *Oc. canadensis*, 814 *Cq. perturbans*, 662 *Oc. sticticus*, 247 *Ae. cinereus*, 128 *Ae. vexans*, 2,597 *Oc. excrucians*, 1,843 *Oc. communis* and 116 *Cs. inornata*.

In 2017, precipitation levels were near normal (Environment Canada, 2019) and 16,960 mosquitoes were captured and identified over 48 trap nights from the CDC light traps. The average catch per trap night is 353 mosquitoes. In total, 15 *Cx. tarsalis* were identified. From the potential vectors of the California group of viruses, 84 were *Oc. canadensis*, 440 *Cq. perturbans*, 124 *Oc. sticticus*, eight *Ae. cinereus*, 1,952 *Oc. excrucians*, 1,730 *Oc. communis* and five *Cs. inornata*.

The precipitation levels in the NWT during 2018 were above normal levels (Environment Canada, 2019) and many areas experienced high levels of adult mosquito activity like 2004. The CDC light traps captured 48,549 mosquitoes in 2018 due to the high levels of precipitation. Adult mosquitoes were captured over 33 trap nights, with an average catch amount of 1,471 mosquitoes. Only two were *Cx. tarsalis* as wet conditions are not the preferred type of environmental conditions to assist in increasing *Cx. tarsalis* numbers. *Culex* mosquitoes breed in hot and dry conditions for their numbers increase especially after two consecutive seasons of hot and dry weather conditions (Stuart and Curry 2009 unpublished). From the potential carriers of the California serogroup of viruses, 147 were *Oc. canadensis*, 873 *Cq. perturbans*, 754 *Oc. sticticus*, 91 *Ae. cinereus*, 97 *Ae. vexans*, 7,304 *Oc. excrucians*, 7,440 *Oc. communis* and 17 *Cs. inornata*.

Between the years of 2004 and 2018 several species have been identified that had not previously been found in the NWT. These included *Cx. restuans*, *Cx. tarsalis*, *Oc. campestris*, *Oc. dorsalis*, *Oc. cataphylla* , *Oc. nigromaculis*, *Cs. minnesotae*, *Oc. sticticus*, and *Oc. spencerii*. Figure 1 identifies the year of the new mosquito species records for the 2004-2018 monitoring years. Some of these species were primarily found in a single year, such as *Cx. restuans*, while others were identified from several years' catches. *Oc. campestris* is an example of the first species that may have been present but not seen over many years from our data analysis. 599 were identified in 2004, and the species was not seen again until 2015, when only one individual *Oc. campestris* was found. From our data we are identifying that *Oc. campestris* is endemic in the NWT.

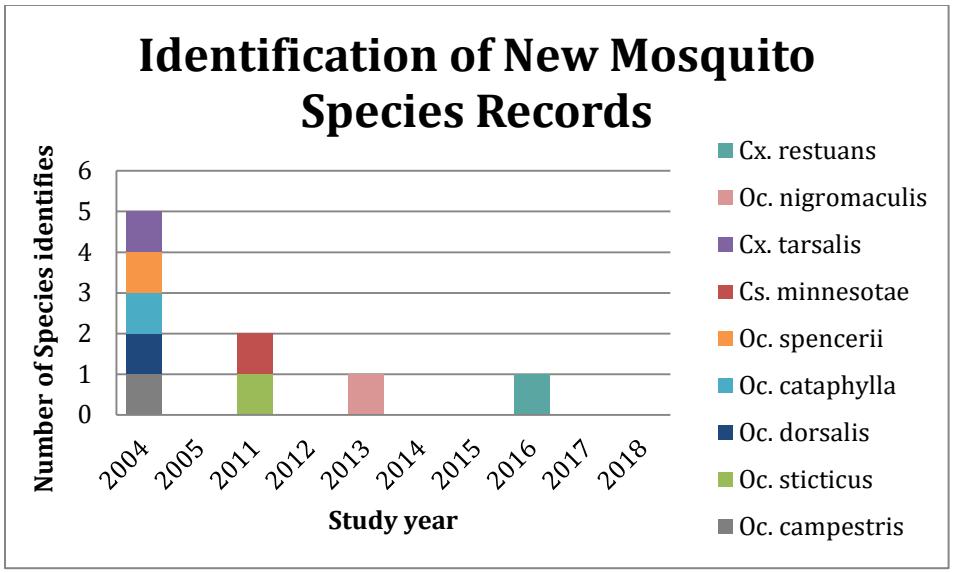

Figure 1. The year in which a mosquito species was captured and identified for the first time in the NWT.

CDC light trap identifications were examined for the years 2004, 2005, and from 2011-2018. From this analysis and the identification of these nine new mosquito species records, the number captured of these new mosquito species records has varied year to year quite dramatically. Figure 2 shows the variation of captured female mosquitoes from 2004-2018 which identifies a maximum total number captured in CDC light traps of 16,912 captured female mosquitoes in 2005 and a minimum of 22 captured female mosquitoes in 2012. By comparison, 2005 was well above average moisture year and 2012 was an extremely dry year (Environment Canada, 2019). As mosquitoes require water to complete their lifecycle, these weather events affected overall mosquito numbers captured in the CDC light traps. Removing the large spike in total number of identified mosquitoes captured in CDC light traps and focusing on 2011-2018, there appears to be a general trend of increasing mosquito numbers within the newly identified mosquito species records. However, 2014 stands out as a potential outlier. This trend is shown in Figure 3 with the data from 2011-2018.

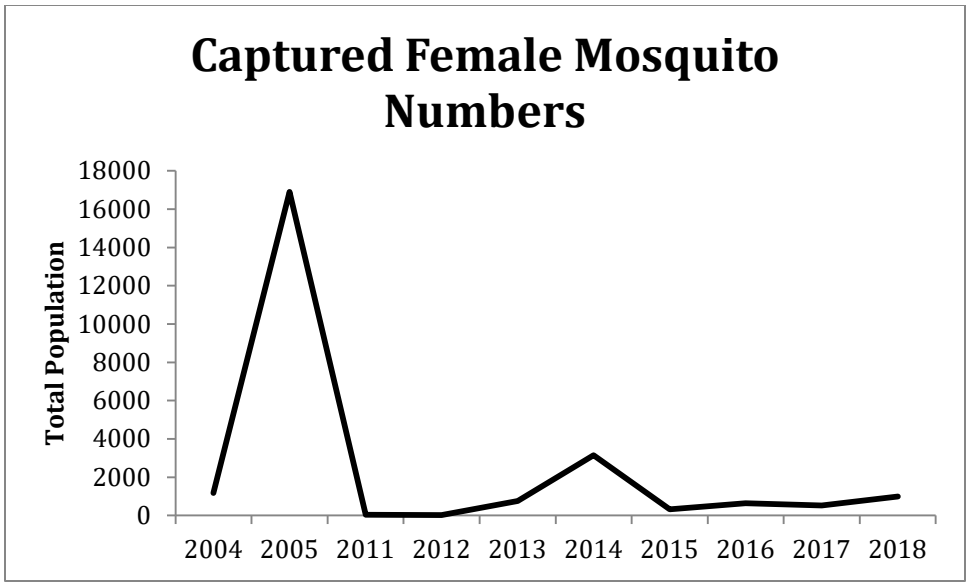

Figure 2. The total yearly identified mosquitoes of all nine newly identified mosquitoes species records.

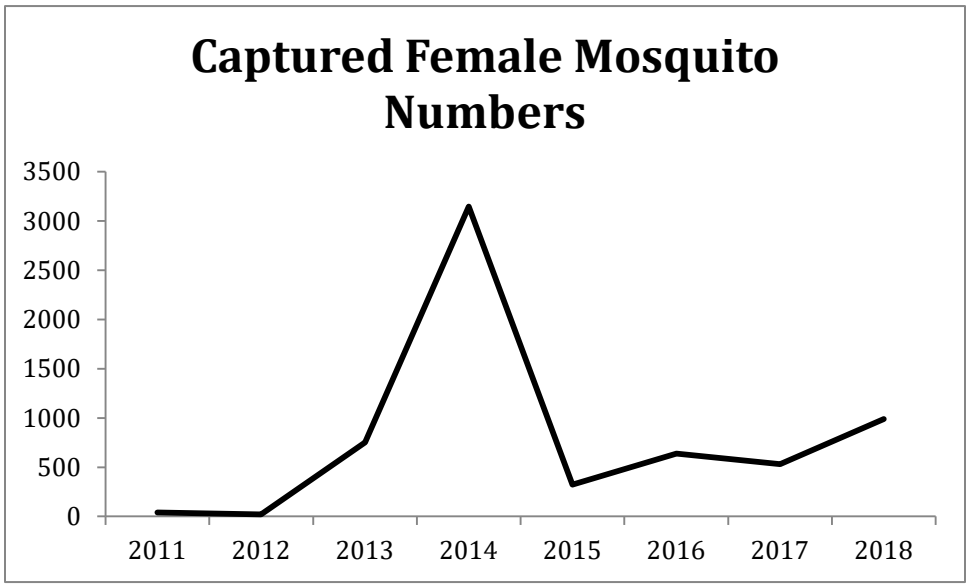

Figure 3. From 2011-2018 the yearly total identified mosquitoes captured from the nine newly identified mosquito species records.

Cx. tarsalis has been found in every surveillance year since monitoring began for adult female mosquitoes in 2004. Over this this time period, *Cx. tarsalis* has been found in varying numbers over each year such as in 2004, where 66 *Cx. tarsalis* were identified. This jumped to 444 in 2005; five *Cx. tarsalis* were found in 2011; two in 2012, eight in 2013, 40 in 2014, 61 in 2015, four in 2016, 15 in 2017 and only two in 2018. From our data we are identifying that *Cx. tarsalis* is endemic in the NWT.

Oc. dorsalis were present in many surveillance years beginning in 2004. In 2004, 239 *Oc. dorsalis* were identified. No *Oc. dorsalis* were found in 2005, 2011, and 2012, with the species reappearing in the CDC light traps in 2013. 427 *Oc. dorsalis* were identified in 2013, 1,521 in 2014, 56 in 2015, 260 in 2016, 305 in 2017 and 194 in 2018. From our data we are identifying that *Oc. dorsalis* is endemic in the NWT.

Oc. cataphylla were identified periodically throughout the surveillance years. In 2004, 267 *Oc. cataphylla* were identified, with numbers greatly increasing to 16,468 *Oc. cataphylla* adult females identified in 2005. The species was not observed again until 2016, with only 33 individuals found. Low numbers of *Oc. cataphylla* continued over the next two years, with 14 identified in 2017 and 12 identified in 2018. From our data we are identifying that *Oc. cataphylla* is endemic in the NWT.

Oc. nigromaculis was identified from NWT CDC traps in only two of the ten years of surveillance. In 2013, 113 *Oc. nigromaculis* were identified. Only one other individual was found the following year in 2014. Based on two consecutive years of its presence, we are identifying that *Oc. nigromaculis* is likely endemic in the NWT.

Cs. minnesotae was not seen in CDC traps until 2011, but after that was found consistently, though often in low numbers over many consecutive years. In 2011, four *Cs. minnesotae* were identified. In 2012 this number dropped to one. 2013 saw numbers rise to 114, followed by 19 in 2014, 46 in 2015, 33 in 2016, 73 in 2017 and 28 in 2018. From our data we are identifying that *Cs. minnesotae* is in endemic in the NWT.

Oc. sticticus is another species that was not discovered until 2011 but then was identified in the CDC light trap collections every year after. In 2011, 15 *Oc. sticticus* were identified, followed by 16 in 2012, 26 in 2013, 1,558 in 2014, 158 in 2015, 339 in 2016, 124 in 2017 and 754 in 2018. From our data we are identifying that *Oc. stiticus* is endemic in the NWT.

The final new species in NWT is *Oc. spencerii*. This species was observed in 2004, with five individuals identified. It was not identified again until 2011, when 15 *Oc. spencerii* were found. This was followed by three in 2012, 30 in 2013, and eight in 2014. However, this species has not been found or seen in CDC traps since 2014. Even though it has not been captured in the CDC light traps it is our opinion that *Oc. spencerii* is endemic in the NWT.

Each season's identifications from the nine new mosquito species records have not been present each year. Figure 4 is a graphical representation of the proportion of the species captured each year to show the variability of these potential vector carrying zoonotic mosquitoes in the NWT. Only *Cx. tarsalis* has been present in every year of study. *Oc. sticticus and Cs. minnesotae* have been captured each year since their identification in 2011. The remaining four species have been sporadically captured throughout the ten study years.

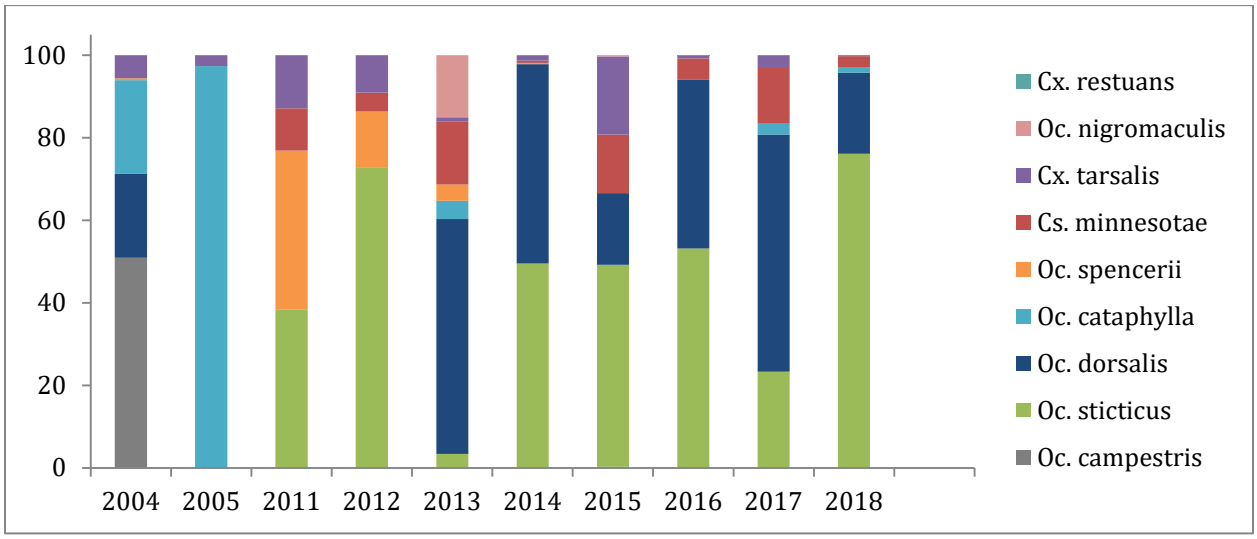

Figure 4. The total yearly captured female mosquito identifications broken down into the species proportions for the nine newly identified mosquito species records in the NWT.

Of those nine, two species, *Cx. tarsalis and Cx. restuans* have the capacity to carry zoonotic disease. *Cx. tarsalis* is the common vector for WNv in western Canada, and *Cx. restuans* is compatible with CSGv's.

Figure 5 provides the portion of female mosquitoes capable of carrying and possibly transmitting zoonotic viruses. The 2011, 2012 and 2015 seasons are at a very high proportion of the total female mosquitoes captured in the NWTs. As of this manuscript writing, the mosquito monitoring years of 2018 and 2019 have been viral tested for WNv and CSGv's and in both these years, the results were negative for WNv and CSGv.

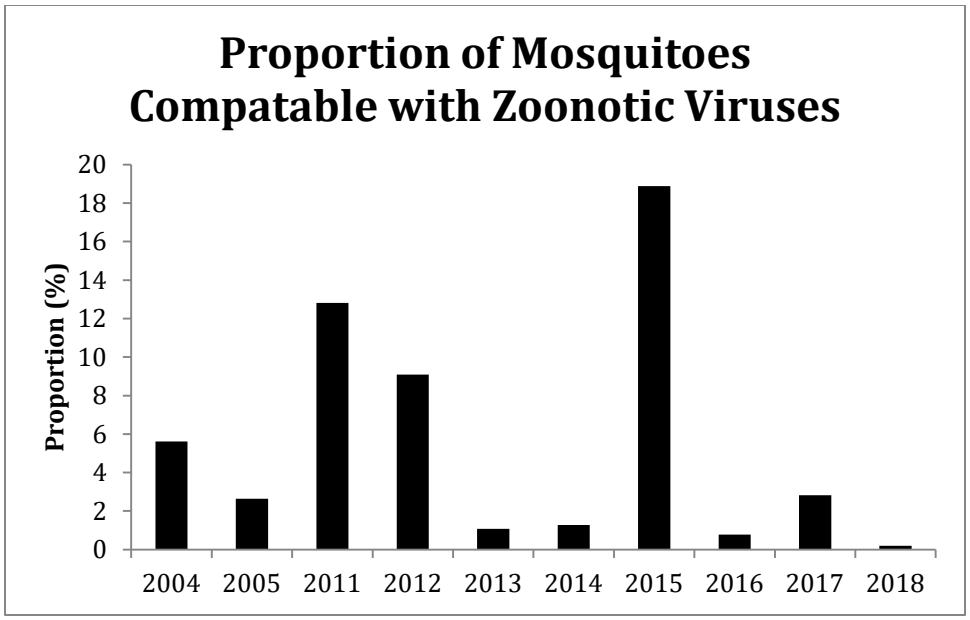

Figure 5. Proportion of mosquitoes captured each year that are capable of transmitting zoonotic disease. All seasons, except for 2016 are comprised of only *Cx. tarsalis.* In 2016, one female mosquito from *Cx. restuans* was captured.

DISCUSSION

With the vector competent mosquito species being newly discovered over ten years of monitoring adult mosquitoes, such as *Oc. Sticticus* in the NWT, the incidence and prevalence of other mosquito borne zoonoses can potentially be expected in the future. For example, there are epidemiological studies over the years (Drebot 2015) that have shown the presence of California serogroup virus in the animal and human population. The vector competent mosquitoes present in the NWT are *Ae. cinereus*, *Ae. vexans*, *Cq. perturbans*, *Cx. restuans*, *Cx. tarsalis*, *Cs. inornata*, *Oc. canadensis*, *Oc. excrucians* and *Oc. sticticus*. Ongoing environmental changes in the NWT may alter the current distribution of arthropods and vector borne zoonoses. As the world continues to warm, severe weather conditions and patterns, with additional precipitation and warmer than normal summer and winter seasons with the presence of vector capable species being present it is plausible that in time that the first human cases of WNv and/or California serogroup of virus's in humans will start being detected in the NWT. As of 2019, the NWT does not have any known WNv prevalence in the corvid population or in the *Cx. tarsalis* mosquitoes captured to date. The NWT is not currently on the Canadian WNv risk maps but maybe in the future as climate change increases the probability of new areas for WNv risk (Reisen et al. 2006) and possibly CSGv risk.

RECOMMENDATIONS

Epidemiological research and continued adult female mosquito monitoring is needed to further evaluate the human health risk associated with endemic mosquito borne WNv, CSGv and other related potential arbovirus presence and transmission in the NWT. Evaluation of the presence of host reservoirs for both WNv, e.g. the corvids such as crows and for the CSGv viruses in such animals as squirrels, chipmunks, hares and various rodents for snowshoe hare viruses, or larger animals such as deer for Jamestown Canyon viruses, should be considered to evaluate any human risk from these natural occurring potential reservoirs in the NWT. The yearly set up of UV CDC light traps in the same locations is key in continuing the identification and testing of mosquitoes present in the NWT's.

LITERATURE CITED

Bernard, K.A. and Kramer, L.D. Viral Immunology. Volume 14 Issue 4. December 2001. Pages 319-338. http://doi.org/10.1089/088282401527165574

Chen, C., T. Epp, E. Jenkins, C. Waldner, P. Curry and C. Soos. 2012. Predicting Weekly Variation of *Culex tarsalis* (Diptera: Culicidae) West Nile Virus Infection in a Newly Endemic Region, the Canadian Prairies. Journal of Medical Entomology: 49(5). Pages 1,144–1,153. https://doi.org/10.1603/ME11221.

Eldridge, B. 1990. Evolutionary Relationships among California Serogroup Viruses (Bunyaviridae) and *Aedes* Mosquitoes (Diptera: Culicidae). Journal of Medical Entomology: 27(5). Pages 738–749.

Environment Canada. 2019. Climate Weather Historical Monthly Data for Station - Fort Smith Climate and Station - Yellowknife A from 2004 to 2018. https://climate.weather.gc.ca/historical_data/search_historic_data_stations_e.html?searchType=stnProv&timeframe=1&lstProvince=NT&optLimit=yearRange&StartYear=2004&EndYear=2018&Year=2020&Month=7&Day=6&selRowPerPage=25&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&startRow=101

Griot, C., F. Gonzalez-Scarano and N. Nathanson. 1993. Molecular Determinants of the Virulence and Infectivity of California Serogroup Bunyaviruses. Annual Review of Microbiology: 47(1). Pages 117-138.

Darsie, R.F. and R.A. Ward. 2005. Identification and Geographical Distribution of the Mosquitoes of North America, North of Mexico. Gainesville, FL., University Press of Florida.

Drebot, M. 2015. Emerging Mosquito-Borne Bunyaviruses in Canada. CCDR: 41(6). https://doi.org/10.14745/ccdr.v41i06a01

Maffei., B, J. Jones, S. Kauffman, B. Ebel, G. Dupuis, A. Ngo, K. Nicholas, D. Young, M. Shi, P. Kulasekera, V. Eidson, M. White, J. Stone and J. Kramer. 2000. NY State West Nile Virus Surveillance Team (2001). West Nile Virus Infection in Birds and Mosquitoes, New York State. Emerging Infectious Diseases, 7(4). Pages 679-685.

New, D. 2014. Epidemiology of Anthrax Outbreaks in Wood Bison (*Bison bison athabascae*) of The Mackenzie Bison Population. Master's Thesis. University of Saskatchewan.

Rasool, N., T. Benstead, M. Drebot and T. Hatchette. 2012. Jamestown Canyon Virus: A Potential Cause for Acute Inflammatory Polyneuropathy? Neurology: 78.

Reisen, W., Y. Fang and M. Vincent. 2006. Effects of Temperature on the Transmission of West Nile Virus by *Culex tarsalis* (Diptera: Culicidae). Journal of Medical Entomology: 43(2). Pages 309–317.

Stuart, T. and P. Curry. 2009. Personal Communication: Cx. tarsalis Seasonality and Distribution over Several Hot and Dry Summers in Manitoba. Email correspondence.

Thielman, A. and F. Hunter. 2007. A Photographic Key to Adult Female Mosquito Species of Canada (Diptera: Culicidae). Canadian Journal of Arthropod Identification: 4. Pages 1-117.

Turell, M., D. Dohm, M. Sardelis, M. O';Guinn, T. Andreadis T and J. Blow. 2005. An Update on the Potential of North American Mosquitoes (Diptera: Culicidae) to Transmit West Nile virus. Journal of Medical Entomology: 42. Pages 57–62.

Wood, D.M., P.T. Dang and R.A. Ellis. 1979. The Mosquitoes of Canada (Diptera: Culicidae): The Insects and Arachnids of Canada Part 17. Ottawa Canada. Agriculture Canada.