The Social Aspect of Mosquito Control: The City of Winnipeg

by

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A report submitted to the Department of Environment and Geography, University of Manitoba

In partial fulfilment of requirements for course ENVR 4500 (Honours Thesis Project)

April, 2019

Abstract:

The City of Winnipeg Insect Control Branch (ICB) is responsible for the control of mosquitoes within the City of Winnipeg. As a part of their integrated pest management plan, ICB will occasionally treat for mosquitoes with the use of aerial insecticides. Considering both the risks associated with mosquitoes and the insecticides used in their treatment, as well as the evolving face of Winnipeg, it is important to understand management decisions. Through thorough observation of 12 Insect Management Areas in the City of Winnipeg, several sets of factors pertaining to mosquito treatment and community profile were gathers. Once this information was gathered, several relationship were indicated. Firstly, this included a relationship between Mosquito Resiliency and Fogging Exposure, as well as Mosquito Population Levels and Fogging Exposure. Secondly, it appears that poorer neighbourhoods have higher Mosquito Resiliency than wealthier neighbourhoods. Thirdly, it appears that poorer and more diverse neighbourhoods have lower fogging exposure than wealthier neighbourhoods.

Acknowledgement:

I would like to acknowledge the guidance provided to me by my Advisor Dr. Steph McLachlan, who not only provided me with a huge amount of support over the several months of this project, but also allowed me access to a work space within the Environmental Conservation Lab. Secondly, I would like to Acknowledge Victoria Grima and the significant GIS work that she performed on my behalf, allowing me to work with spatial data. Finally, I would like to acknowledge the help of David Wade, Janet Rosin and all the rest of the management at the City of Winnipeg Insect Control Branch who helped me acquire tons of data.

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Introduction and Background:

The City of Winnipeg Insect Control Branch (ICB) is responsible for the management of various urban pests, including mosquitoes. Through their use of an integrated pest management (IPM) system, ICB targets mosquitoes both at the larval stage (termed larviciding) and the adult stage (termed both adulticiding and fogging). Larviciding is the most significant component of the program, involving the application of two biological agents: a granular product containing the bacterium *Bacillus thiringiensis* var. *israelensis* (Bti); and both granular and liquid forms of the agent methoprene. In total, ICB's larviciding program is responsible for the treatment of more than 33,000 hectares worth of standing water area within and adjacent to the boundary of the City of Winnipeg. Although, based upon their IPM practice, ICB will avoid fogging whenever possible, when larviciding fails to adequately control nuisance mosquito populations, aerial fogging becomes an option. The conditions for fogging are outlaid in ICB's Adulticiding Factor Analysis (AFA) Guidelines. The AFA level can either be low, medium or high and is based upon a variety of factors including precipitation levels and other climatic conditions, soil moisture, larviciding efficacy, current size and life stage of mosquito populations and adult nuisance mosquito counts gathered from the City of Winnipeg's 28 New Jersey Light Traps (NJLTs). Fogging is only considered when the AFA level is high (City of Winnipeg, 2018)

When the implementation of fogging is deemed necessary, ICB begins the application of Ultra Low Volume (ULV) aerial pesticides to all public streets, back lanes, golf courses, significantly-sized parks and cemeteries, all of which is determined based upon the City of Winnipeg 51 Insect Management Areas (IMAs). Traditionally, ICB has utilized the organophosphate Malathion for their aerial fogging treatments, but as of 2017 have switched over to the use of the pyrethroid Deltamethrin (tradename DeltaGard), although it worthwhile to note that the City of Winnipeg has not yet fogged with the new insecticide. Any resident of Winnipeg can opt-out of the nuisance fogging program by applying for a 90 metre buffer zone adjacent to their dwelling. Buffer zones are respected by ICB except in the instance of a health emergency declaration by the Provincial Chief Medical Health Officer, where all buffer zones will be disregarded for the emergency period (City of Winnipeg, 2018).

The City of Winnipeg's mosquito control program has historically been controversial, having garnered its fair share of media coverage over the last several decades. Based upon rhetoric used in much of this reporting, one could not be faulted for their assumption of a full-blown conflict between proponents and opponents of the City of Winnipeg's mosquito control program. One author in the magazine *Maclean's* even goes so far as to mockingly compare ICB's mosquito control program to a military intervention (Bergman, 2002). Issues raised in the media often include strong opinions for and against the use of Malathion (Walmsley, 1982; *CBC News,* 2015), the frequency with which the City of Winnipeg applies Malathion (*The Gazette*, 1991) and disagreement around private citizens applying for buffer zones (Gage, 1986; White 2010)

Clearly, ICB's use of Malathion is at the forefront of much of this controversy. In their report commissioned for the United States Department of Health and Human Services, Wilson *et al* (2003) discuss Malathion at length. Malathion is an organophosphate with a wide variety of applications, which functions through the molecule's inhibition of the enzyme acetylcholinesterase, which is vital in the breakdown of the neurotransmitter acetylcholine. While Malathion is toxic to humans, it generally has little to no health implications associated with concentrations below what is considered severe exposure. The only individuals likely to experience these high concentrations are those who handle and apply the chemical. Additionally, Wilson *et al* (2003) note that the International Agency for Research on Cancer (IARC) has deemed Malathion unclassifiable as a carcinogenic, although it appears in the decade since the publishing of their article that IARC has reversed this consideration, now classifying Malathion as a Group 2A probably carcinogen (IARC, 2015). Regardless of toxicity or carcinogenic potential, a portion of Malathion applied in the City of Winnipeg landscape. In their study of chemical deposition over a two year period, Farenhorst, Andronak & McQueen (2015) calculated that between 1.2% and 5.1% of Malathion applied by the City of Winnipeg ends-up as bulk deposition in the municipal landscape.

Even when considering the application of ICB's new "reduced risk" Malathion-substitute deltamethrin (City of Winnipeg, 2018), there is still some level of risk associated with application. In their study of a wide range of pyrethriod insecticides, Veit *et al* (2015) found evidence linking the exposure of young children to deltamethrin with impacted neural development up until the age of six. This is particularly concerning when considering that deltamethrin appears to accumulate in human breast milk, as highlighted by Bouwman, Serenda & Meinhardt's (2006) discovery of deltamethrin and other insecticides in the breast milk of a group of women living within a malarial-endemic zone of South Africa.

At the same time, it is also important to consider that aerial fogging is not without purpose. Mosquitoes pose a variety of problems to many groups of people and it is reasonable to expect mosquito harm to be mitigated. One of the major issues associated with mosquitoes is their transmission of pathogens and increasingly, the impact of climate change on the distribution of species. Hotez, Murray & Buekens (2014) note the emergence of mosquito-borne diseases often associated with developing nations throughout the relatively poor American Gulf Coast.

Even in more northern States, shorter and warmer winters will likely mean the appearance of previously foreign mosquito-borne illnesses to these areas (Greer & Fisman, 2008). In Canada, a changing climate could mean an increase in risk for Malaria, an infectious disease with currently negligible risk in the country (Berring-Ford *et al*, 2009), while a new species of West Nile Virus vector mosquito could appear in Southern Manitoba (Hongoh, Berrang-Ford, Scott & Lindsay, 2012). Additionally, the impact of nuisance mosquitoes should not be overlooked. In their examination of Madison, Wisconsin, Dickinson & Paskewtiz (2012) found that local residents were much more willing to support funding a nuisance mosquito control program as opposed to a West Nile Virus program.

Due in large part to the controversy surrounding the mosquito control program, the all-encompassing nature of mosquito control and the non-zero risk associated with both mosquitoes and the insecticides utilized in their treatment, it is only reasonable that the program is understood in the context of the community in which it serves. The City of Winnipeg is growing, with a population likely to exceed 900,000 inhabitants by the year 2040. The City of Winnipeg is likely to become much more diverse, with a population increase largely driven by immigration (City of Winnipeg, 2016). At the same time, the Indigenous population of the City will likely increase as the Manitoba-wide proportion of Indigenous individuals will increase to 20% of the population by 2036 (Statistics Canada, 2015). In the context of Winnipeg, there appears to be very little research into the community implication of the mosquito control program. One of the only studies that appears to exist is a Master's Thesis completed by Henderson (2003) in which she examined the knowledge of mosquito control on a neighbourhood scale and conducted a survey sampling the opinion of Winnipeg residents around the mosquito control program, only which 43% of individuals fully supported.

Outside the context of the City of Winnipeg, there have been some other interesting examples of research into the relationship between communities and mosquito populations. In their examination of various neighbourhoods in the American city of Baltimore LaDeau, Leisnham, Beihler & Bodner (2013) found higher pupal mosquito levels in poorer neighbourhoods as opposed to wealthier ones. This could partially be explained by another study in which Dowling *et al* (2013) examined varying class knowledge around mosquitoes in nearby Washington, D.C. and found that wealthier neighbourhoods had a better understanding around the relationship between standing water and mosquito propagation. Finally, in their examination of swimming pools in Bakersfield, California following the collapse of the housing market, Reisen, Takahashi, Carrol & Quiring (2008) found that the large amount of abandoned homes in the area coincided with a 276% spike in West Nile Virus as mosquito populations thrived.

Methods:

The purpose of this experiment was to observe a widely diverse set of areas within the City of Winnipeg in order to try and understand the relationships between the municipality's mosquito control program and the various communities within and if possible, make broad connections and comments on these said relationships. In order to complete this experiment, three Insect Management Areas (IMAs) were selected from each of the four quadrants comprising the City of Winnipeg (based upon ICB's definition, see: [https://www.winnipeg.ca/publicworks/ insectcontrol/mosquitoes/trapcount.stm](https://www.winnipeg.ca/publicworks/insectcontrol/mosquitoes/trapcount.stm)). In the northwest IMAs 2, 3 & 8 were selected; in the southeast IMAs 11, 12, & 17 were selected; in the southwest IMAs 21, 26 & 30 were selected; and in the northwest IMAs 38, 41 & 46 were selected (See *Figure 1* in the Appendix). For each of the 12 study IMAs both Treatment Factors (*Table 1* in Appendix) and Profile Factors (*Table 2* in Appendix) would be collected over the 2007 – 2018 period. The Treatment Factors included fogging exposure, mosquito resiliency and mosquito population size, while the Profile Factors included program opinion, community heterogeneity, level of poverty and spatial cover. For each of these seven factors, an approximation was calculated (See *Tables 1 & 2* in the Appendix).

To calculate Fogging Exposure, the cumulative instances of fogging were collected from ICB's online News Release Portal (See https://winnipeg.ca/publicworks/insectcontrol/news/default.stm). For each of the 12 years of the study period, any media release titled "Adult Nuisance Mosquito Control Program" was combed through, with any completion of treatment within any of the 12 IMAs being noted. Each day fogging was attempted, a news release would be published outlaying the IMAs that ICB was predicted to complete that following night. Generally, these publications were clear as to which IMAs were and were not treat and the date in which these treatment occurred, although this was not always the case. There were several instances of unclear treatments and for the sake of this experiment, they were treated as not having occurred. IMAs 2, 3, 8, 11, 12, 17 & 46 each had one instance of fogging disregarded for a lack of clarity. Once all instances of fogging were noted, each IMAs count was cumulated.

To calculate both Mosquito Population Levels and Mosquito Resiliency, ICB provided access to raw NJLT mosquito count data encompassing the 12 year study period. Based upon the City of Winnipeg's 2018 NJLT locations, each IMA was assigned a light trap within its physical boundaries, with two exceptions (See *Table 3* in the Appendix). For IMA 46, the nearby "*Grey St*" NJLT in IMA 6 was utilized for the entire study period, while the "*Huppe Bay*" NJLT in IMA 15 was substituted for IMA 12 for the period 2007 – 2014. Other than these two exceptions, each IMA's NJLT was located within its boundaries for the whole study period.

To measure the Mosquito Population Level, each assigned NJLT's entire collection of mosquito counts were cumulated. Although the total number of trap days varied slightly (ranging from 1182 – 1203), this was deemed insignificant enough not to bother warranting any form of standardization. To measure Mosquito Resiliency, several "recovery rates" were calculated for each IMA based upon NJLT counts and instances of fogging. Any time ICB had fogged one of the study IMAs, a count would be performed beginning on the subsequent day (as NJLT are collected in the morning and fogging occurs at night), noting the number of days required for NJLT mosquito counts to return within 90% of their pre-treatment population levels (i.e. the count that had been taken the morning of the day in which fogging occurred), assuming the population recovered. This experiment functioned under the assumption that mosquito levels would in-fact decrease following treatment. Based upon this information, two types of Recovery Rates would be calculated: one which considered all instances of post-treatment mosquito populations returning to within 90% of their pre-treatment levels (Termed: Complete Recovery Rate) and one which considered all instances of this failing to occur, whether because of ICB fogging an IMA before the mosquito population had recovered or because mosquito count information was absent during certain dates (Termed Incomplete Recovery Rate). There were several instances for most of the IMAs where it was clear that an IMA was fogged but the date in which it occurred uncertain, so these instances were ignored for the sake of this measurement. From these two recovery rates both an average Complete Recovery Rate and an average Combine Recovery Rate (which was an average of both Complete and Incomplete Recovery Rates) were calculated for each IMA.

To calculate both Level of Poverty and Community Heterogeneity for each IMA, census data was gathered from City of Winnipeg's custom Statistics Canada neighbourhood-by-neighbourhood 2011 census portal (See https://winnipeg.ca/census/2011/). For each of the 12 study IMAs, six statistics were gathered for each of the composite neighbourhoods (See *Table 4* in Appendix). Three of statistics were grouped together as "Population Statistics" and were meant to approximate community heterogeneity, while the other three were grouped together as "Household Statistics" and were meant to approximate levels of poverty. Population Statistics included Percentage of Aboriginal Ancestry, Percentage of Recent Immigrant and Percentage of Visible Minorities, while Household Statistics included Median Household Income, Percentage of Rented Dwelling Tenure and Percentage of Dwelling Condition: Major Repairs Needed. Since the statistical information was provided on a neighbourhood scale, each IMA's composite neighbourhoods' information was gathered and each of the six statistics in each IMA was given a weighted average. Once this was complete, each IMAs six statistics were given a ranking out of twelve based relative to one another. Then, each IMAs Population and Household Statistics were added together, giving each IMA a ranking out of 36. Finally, each of these total Population and Household statistics were ranked once more out of 12.

To calculate program opinion, the cumulative number of buffer were calculated for each IMA. In order to acquire this information, a Freedom of Information and Protection of Privacy Act (FIPPA) request had to be submitted to the City of Winnipeg. Initially, ICB was unwilling to provide buffer zone information on a practical scale, for fear of infringing upon citizen privacy, so the request had to be made. Although, even with the FIPPA request, the City of Winnipeg was still unwilling to provide access to buffer zone information on an individual neighbourhood or IMA scale, instead opting to provide buffer zone counts for coupled, and at times tripled, neighbourhoods and IMAs. Fortunately, it worked out that many of the neighbourhood pairs could be combined together to encompass an entire IMA. Through this method, buffer zone counts were able to be amassed for 9 out of 12 of the study IMAs, which included IMAs 2, 3, 8, 11, 12, 17, 26, 41 & 46. Then, in order to account for the varying number of households in each IMA, the number of household were calculated for each composite neighbourhood (in a similar vein to Household and Population Statistics) based upon the City of Winnipeg 2011 census data and the number of buffer zones were standardized based upon the number of households in IMA 2 (A ratio of 8135/n). Once this was accomplished, a standardized cumulative count of buffer zones was created.

To calculate the Park/Open Space and Industrial Cover, City of Winnipeg Spatial Data was acquired from the University of Manitoba GIS Library. The data for Park/Open Space Cover consisted of all Park Categories Zonings, which included: Park and Open Space, Stormwater Retention Basin and Greenfield – Future Park. The data for Industrial Cover consisted of all Manufacturing Zonings, including Light, General and Heavy. Then using ArcGIS, each composite neighbourhood's Industrial and Park/Open Space Cover was calculated. In order to do this, a new field 'Area' was created, with a double field type in the attribute table of the Neighbourhood shapefile and the geometry was calculated in square metres. Each composite neighbourhood was exported as a shapefile and the geoprocessing "clip" tool was used to select the portion of Industrial or Park/Open Space Cover than fell within the neighbourhood. This information was exported and each IMA's composite neighbourhood's Industrial and Park/Open Space cover were calculated and added together. Once this was done, the proportion of each IMA was calculated based on the spatial cover and the entire area of the IMA (See *Table 5* in Appendix).

Once all of the Treatment and Profile Factors were calculated, three outcomes were measured. Firstly, all factors relating explicitly to mosquito control were examined for any unusual values as to determine any IMAs with extreme values. This included the entire set of Treatment Factors, as well as Program Opinion, since cumulative buffer zones are intrinsically tied to mosquito management.

Secondly, a ranking of variables was compiled for each of the Treatment Factors, including both average recovery rates. In order to accomplish this, all IMAs were given a rank out of twelve for each of their entire set of factors. Then, grouping each factor's rankings into quadrants, each quadrant was assigned a colour, with subsequently higher quadrants darkening in tone (i.e. Quadrant 1, being comprised of ranks 1 – 3 would be the lightest in tone, while Quadrant 4, being comprised of ranks 10 – 12, would be the darkest in tone). For each Treatment Factor, the IMAs comprising the top and bottom quadrants would be gathered and compared with their respective Profile Factors.

Finally, an examination was undertaken to assess the strength of relationships between Fogging Exposure (Cumulative Instances of Fogging) and the other Treatment Factors. Three Regression plots were assembled: Cumulative Mosquito Count vs. Cumulative Instances of Fogging; Average Complete Recovery Rate vs. Cumulative Instances of Fogging; and Average Combined Recovery Rate vs. Cumulative Instances of Fogging. For these each of these three relationships, a P-Value and R^2 were calculated.

<u>Results</u>

After compiling all data, there were found to be a few noteworthy outliers. Firstly, with respect to Cumulative Mosquito Count (*Figure 1*), IMA 26 had a significantly larger cumulative count of 53,744 mosquitoes as compared to that of the second highest IMA 2, which had a cumulative count of 28,116 mosquitoes. Secondly, while neither the average Complete nor Combined Recovery Rates (*Figure 3*) possessed any apparently extreme values, it is noteworthy to highlight

Figure 1: Cumulative Mosquito Count

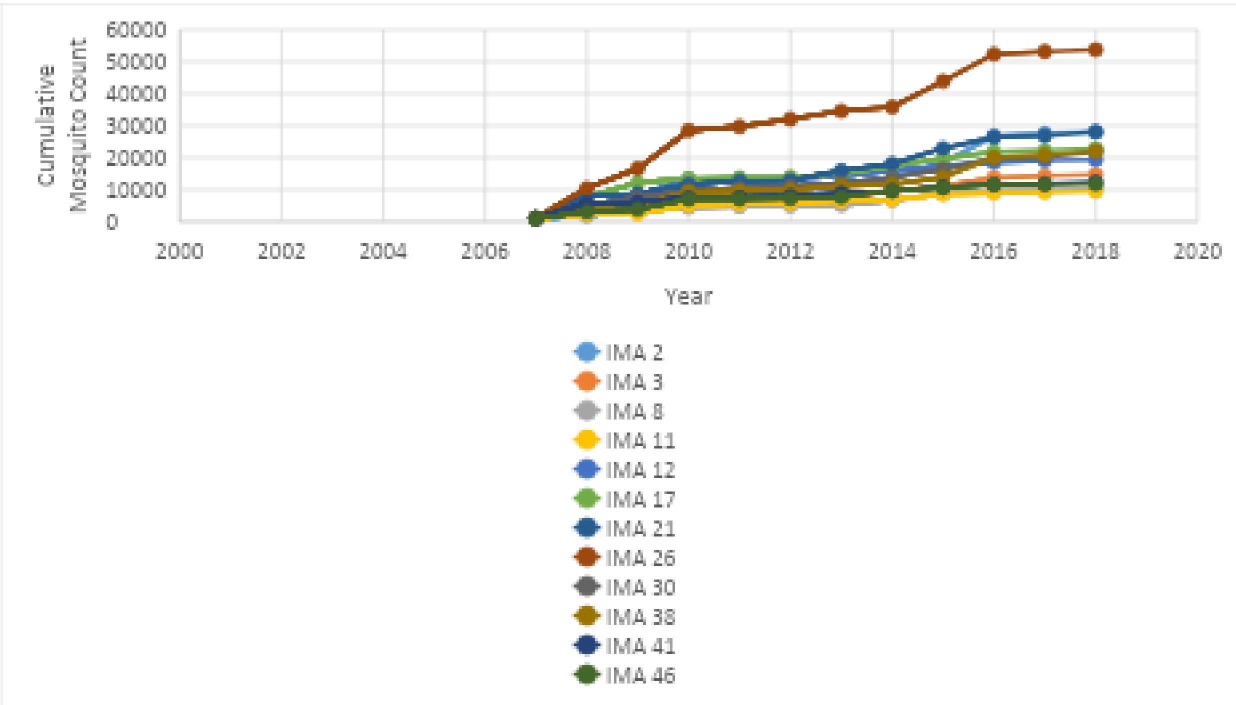
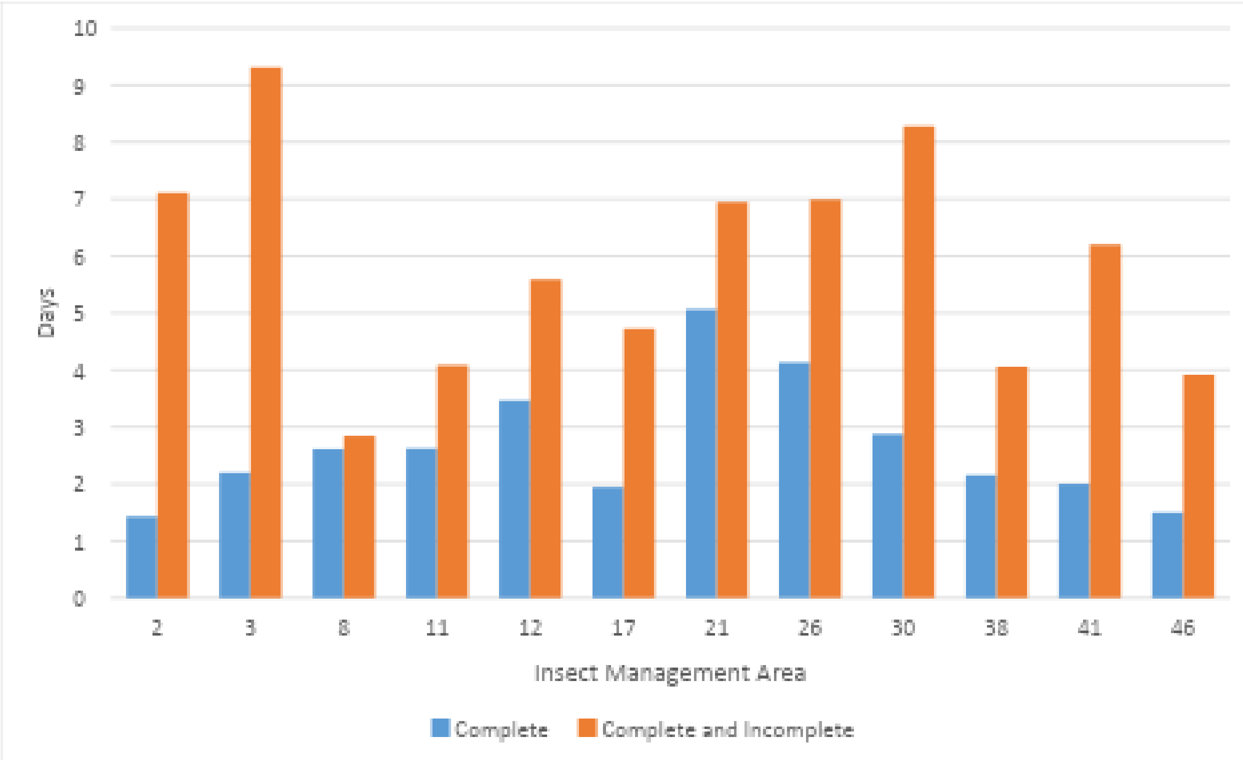


Figure 2: Average Complete and Complete/Incomplete Recovery Rates



that there often appears to be a serious discrepancy between the Complete and Combined values in terms of relative size. For example, while IMA 2 and 3 have among the lowest Average Complete Recovery Rates (1.42 and 2.20 days respectively), they also have among the highest average Combined Recovery Rates (7.11 and 9.31 days). Thirdly, with respect to Cumulative Buffer Zones (*Figure 4*), there were two noteworthy extremes. Firstly was IMA 41, which possessed a standardized cumulative count of 1289 buffer zones, while IMA 11 possessed a standardized cumulative count of 895 buffer zones. These two IMAs stood in comparison to the thirdly ranked IMA 26 with a standardized cumulative count of 319 buffer zones. Finally, although the Instances of Fogging (*Figure 3*) really lacked any extreme values relative to the sample, it is worthwhile to note that the highest ranked IMA 26 (29 instances of fogging) also had the highest cumulative mosquito count, while the lowest ranked IMA 41 (13 instances of fogging) had the highest number of cumulative buffer zones.

With respect to the variable rankings, there appears to be little difference between the Profile Factors of both the highest and lowest IMAs for all Treatment Factors, although there are several differences worth noting. In the case of average Complete Recovery Rate, both the Program Opinion (Cumulative Buffer Zones) and Household Statistics appear to be higher in IMAs with higher Mosquito resiliency (i.e. areas with fast Recvoery Rates). In the case of Combined Recovery Rate, higher ranked IMAs appear to have slightly higher Household Factors while lower ranked IMAs appear to have slightly higher cumulative buffer zones. In the case of Fogging Exposure, lower ranked neighbourhoods appear to have both higher Population and Household Factors.

Figure 3: Instances of Fogging

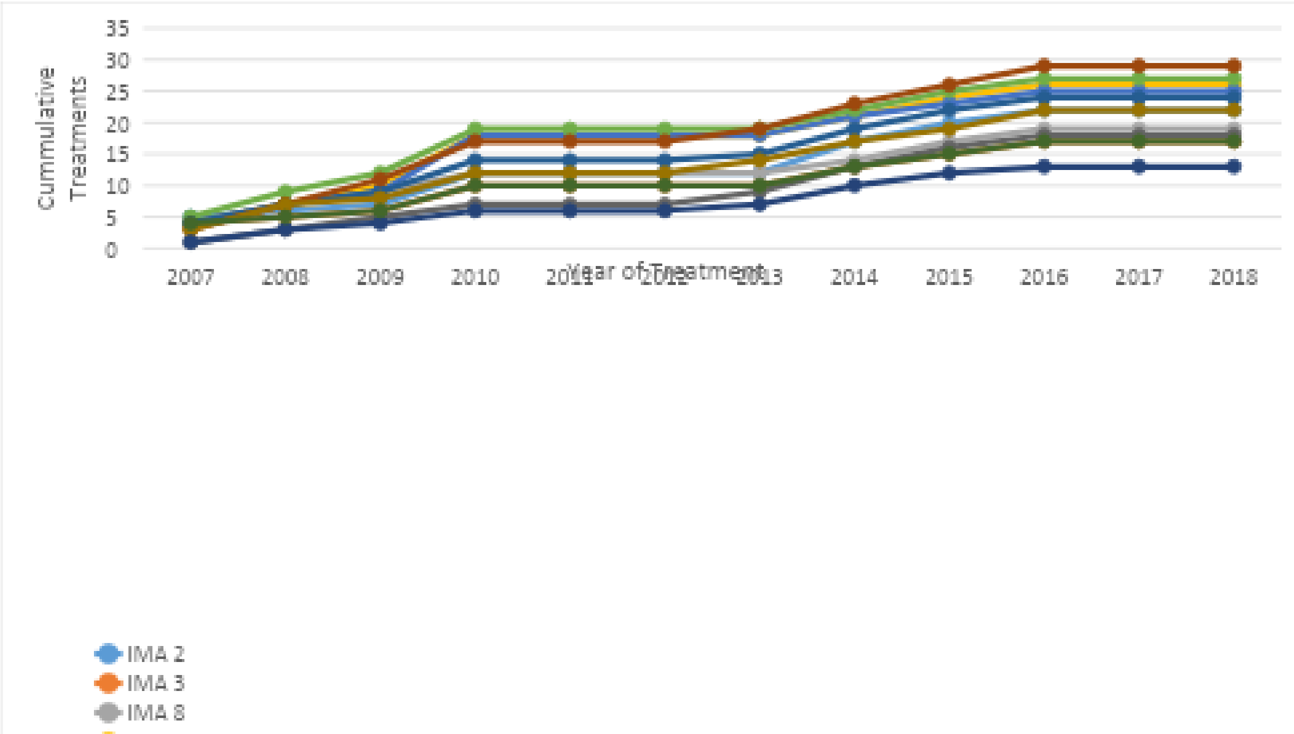


Figure 4: Cumulative Buffer Zones, Standardized to IMA 2 Household Population (2011)

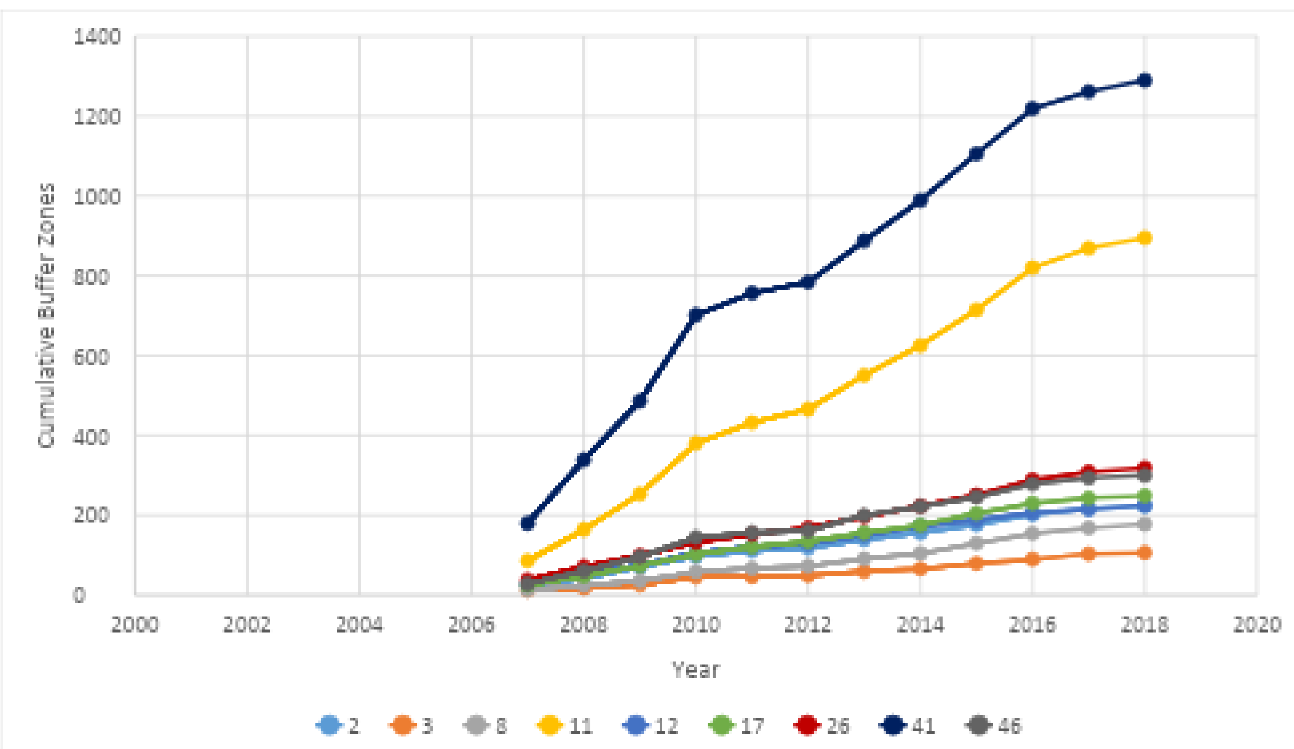


Figure 5: Quadrants

Treatment		Buffers	Population	Household	Park/Open	Industrial
Q4		Q3	Q4	Q4	Q4	Q4
Q3		Q2	Q3	Q3	Q3	Q3
Q2		Q1	Q2	Q2	Q2	Q2
Q1			Q1	Q1	Q1	Q1

Figure 6: Mosquito Population Level

IMA	Rank
26	12
2	11
21	10
46	3
8	2
11	1

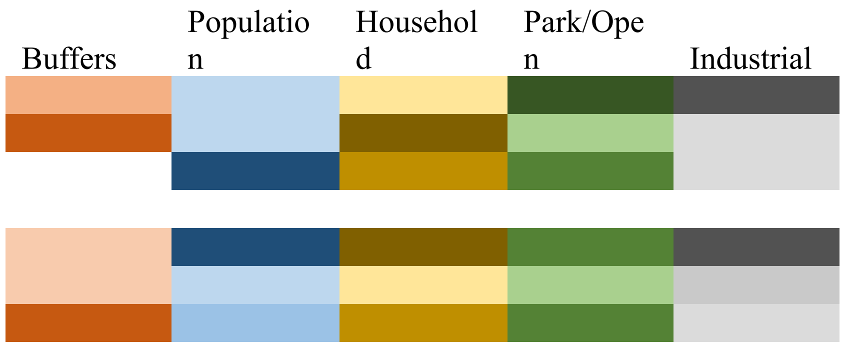


Figure 7: Mosquito Resiliency (Complete Recovery Rate)

IMA	Rank
2	12
46	11
17	10
12	3
26	2
21	1

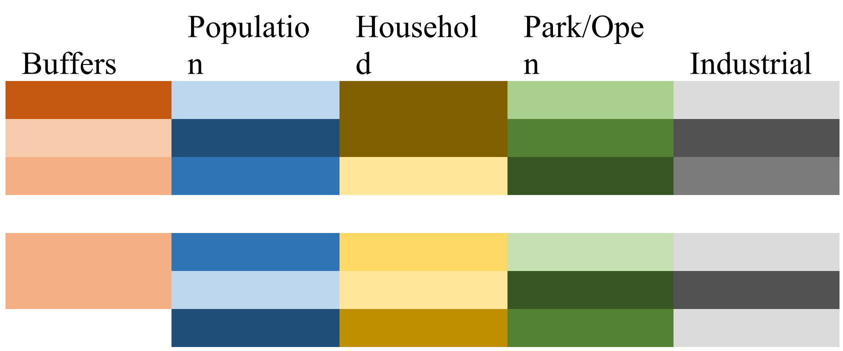


Figure 8: Mosquito Resiliency (Combined Recovery Rate)

IMA	Rank
8	12
46	11
38	10
2	3
30	2
3	1

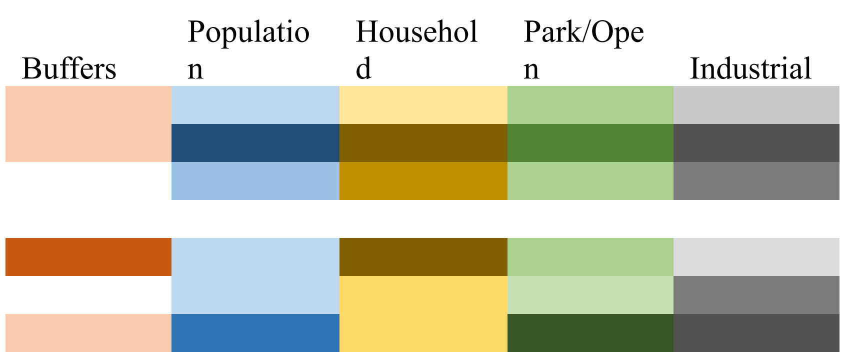


Figure 9: Fogging Exposure (Instances of Fogging)

IMA	Rank
26	12
17	11
11	10
3	3
46	2
41	1

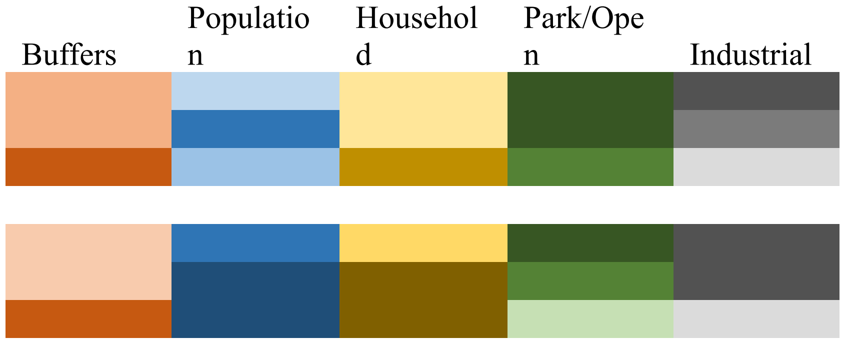


Figure 10: Cumulative Instances of Fogging vs. Cumulative Mosquito Count

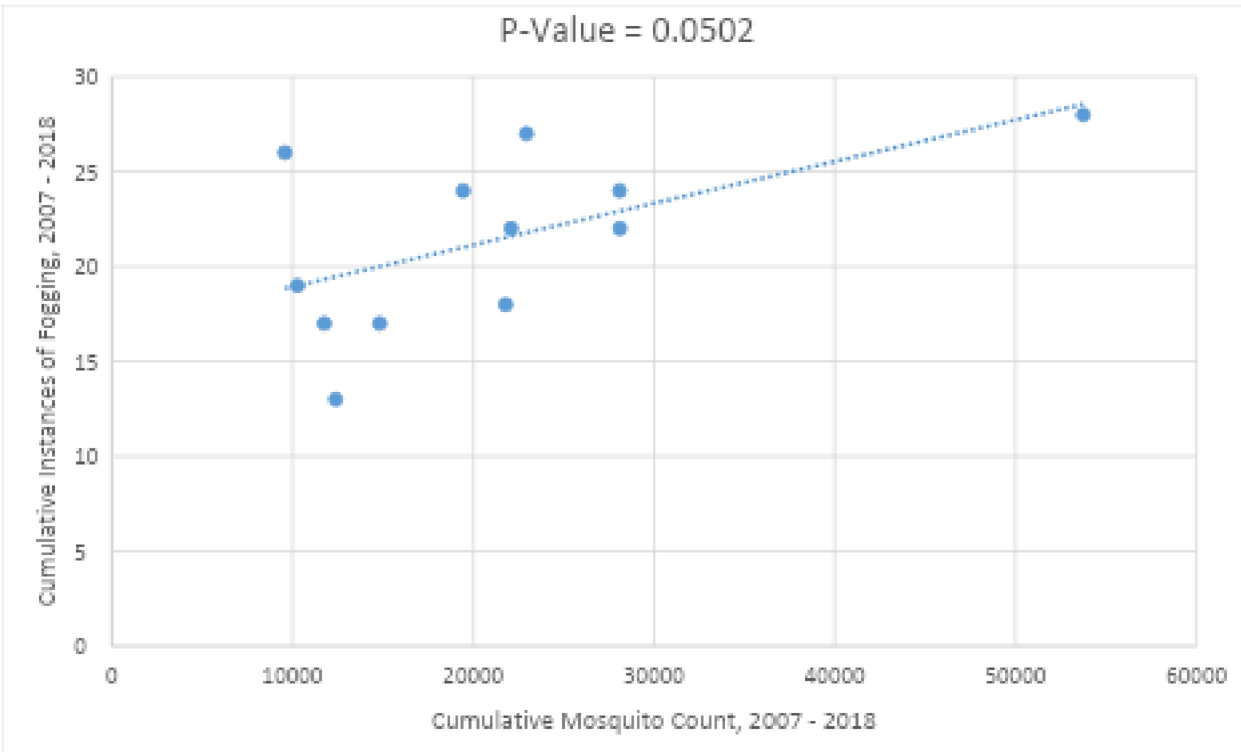


Figure 11: Average Complete Recovery Rate vs. Cumulative Fogging Treatment

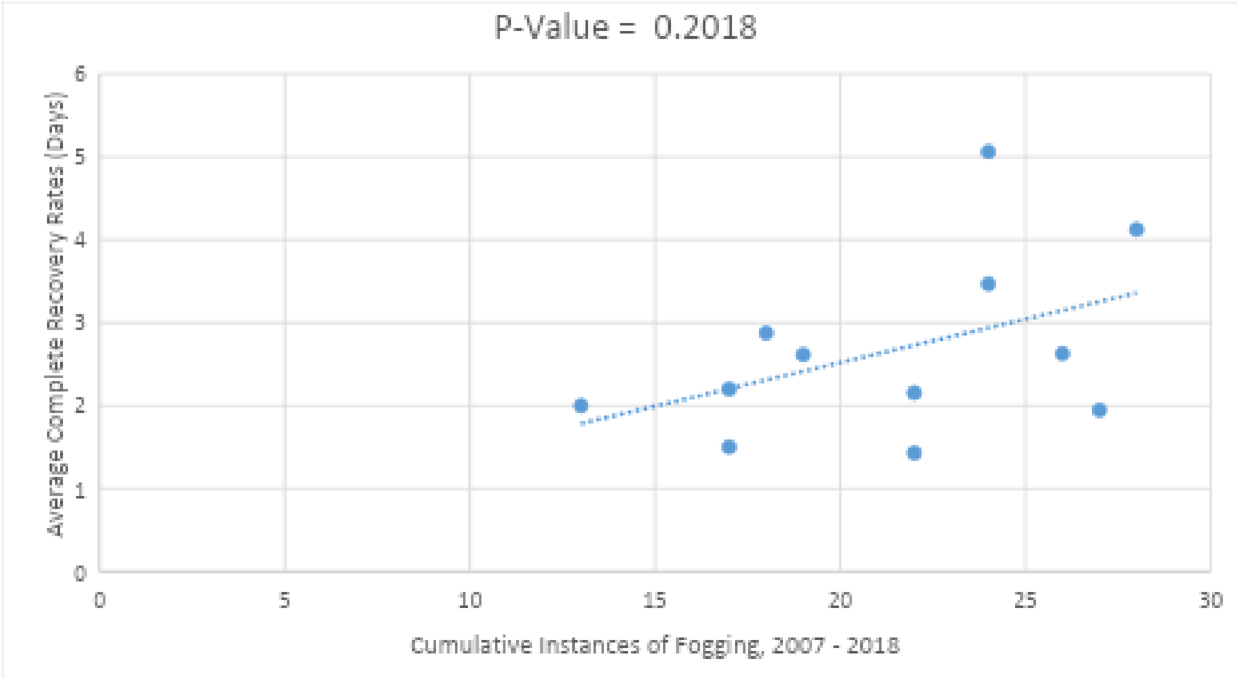
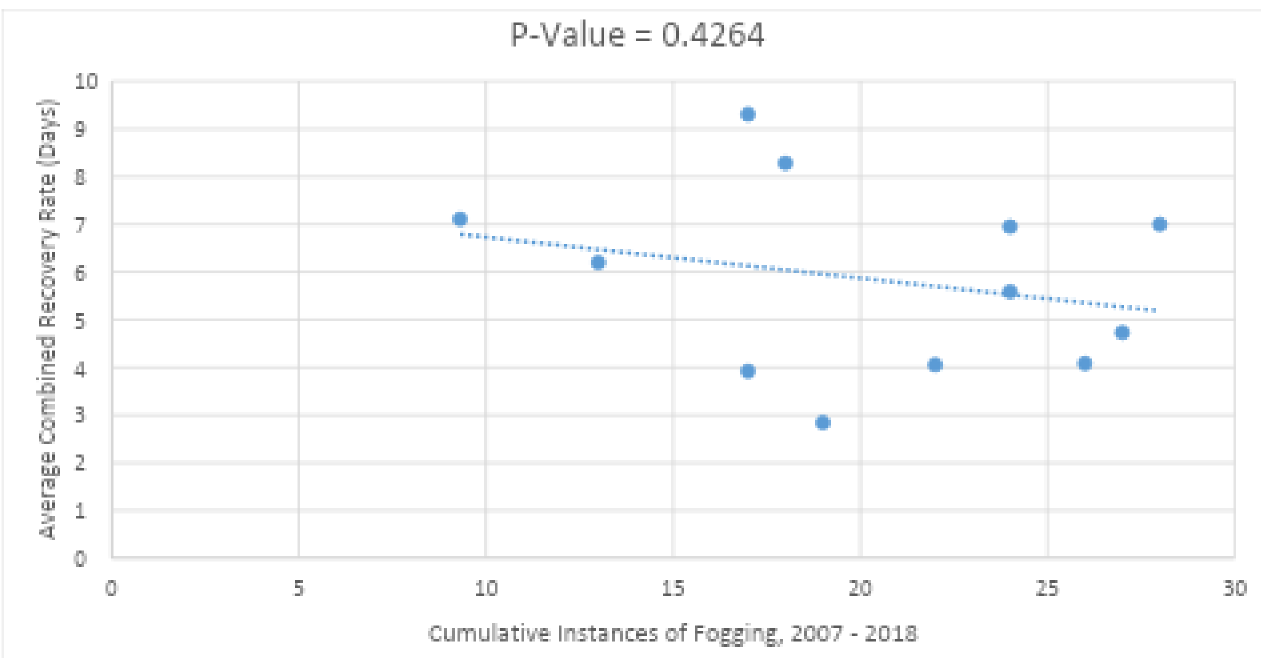


Figure 12: Average Combined Recovery Rate vs. Cumulative Fogging Treatment



With respect to the correlation graphs, the relationship between Cumulative Mosquito Count and Cumulative Instances of Fogging was a positive relationship with an R^2 Value of 0.3312 and a P-value of 0.0502. The relationship between Average Complete Recovery Rate and Cumulative Instances of fogging was positive, with an R^2 Value of 0.2024 and P-value of 0.2018. The relationship between Average Combined Recovery Rate and Cumulative Instances of Fogging was slightly negative, with an R^2 Value of 0.0643 and a P-value of 0.4264

Discussion:

Following the examination of these several factors, there are some interesting relationships that appear. Firstly, there appears to be a relationships between the cumulative mosquito count (mosquito population) and the instances of fogging (fogging exposure). IMA 26, which is composed of various neighbourhoods in the Charleswood region of Winnipeg, had both the highest cumulative mosquito count and the highest instances of fogging. IMA 41, which is composed of several central city neighbourhoods, including Wolseley and the Winnipeg downtown area, had the lowest instances of fogging and among the lowest cumulative mosquito counts (12,394 mosquitoes in total). What makes this relationship more apparent is that both of these IMAs have among the highest cumulative buffer zones. While IMA 41 has significantly more buffer zones than IMA 26, IMA 26 still has the third most number of cumulative buffer zones (319). Additionally, after performing a regression on cumulative mosquito count and the instances of fogging (*Figure 10*), it appears that there is a relationship between the two and that it is statistically significant.

There also appears to be some kind of relationship between recovery rates and instances of fogging. IMA 26, the IMA with the highest fogging exposure, has among the longest Average Complete Recovery Rate (4.125 days), while IMA 41, the IMA with the lowest fogging exposure, has among the shortest Average Complete Recovery Rate (2 days). In the comparison between average recovery rate and instances of fogging (*Figure 11*), there appears to be a trend towards a relationship, even though the results are not statistically significant (P-Value of 0.2018). Additionally, even though the comparison between the cumulative instances of fogging and the average combined recovery rate (*Figure 12*) seem to be an indication that there is no relationship between instances of fogging and recovery rates, this could be better explained by the nature of metric, which appears to not have been all the precise.

Another noteworthy observation was that neighbourhoods with the highest mosquito resiliency (i.e. fastest recovery rates) appear to be poorer neighbourhoods than neighbourhoods with lower mosquito resiliency. With respect to the Complete Recovery Rate Ranking (*Figure 7*), the top quartile of IMAs is significantly darker in hue than the bottom quadrant of IMAs. With respect to the Combined Recovery Rate Ranking (*Figure 8*), although the difference in hue is not as pronounced as the Complete Recovery Rank Ranking, the top quartile of IMAs is still clearly darker than the bottom quartile of IMAs. Although the results of the Combined Recovery Rate have been less than precise, this is still somewhat of an indication of the relationship between poverty and mosquito resiliency. The relationship between poverty and mosquito resiliency is interesting when examining the Fogging Exposure Ranking (*Figure 9)*, as the bottom ranked IMAs are both significantly more poor and diverse than the highest ranked IMAs. It appears that while poorer neighbourhoods have higher mosquito resiliency, they are actually treated relatively less than other IMAs. This is an interesting management decision.

Finally, with respect to Spatial Cover, it appears that the metric had little impact on any of the Treatment Factors. In all four of the rankings (*Figures 6 – 9*) there were no discernable differences between the highest ranked and the lowest ranked IMAs for any of the study factors.

While it is likely spatial cover does have some impact on these Treatment Factors, the particular City of Winnipeg GIS information gathered for this experiment was likely not the best proxy, as for both Industrial Cover and Park/Open Space Cover, information was calculated based on City of Winnipeg zoning, which can encompass a broad variety of landscape used. Additionally, neither metric was able to account for commercial or other types of land cover which may be present in an area such as the Winnipeg downtown. This would be an interesting topic of examination for a follow-up study.

Conclusion:

The City of Winnipeg Insect Control Branch is responsible for the treatment of mosquitoes within the City of Winnipeg. When mosquito populations become problematic, the Insect Control Branch will treat for adult mosquitoes with the use of aerial insecticides. Due to the controversy around fogging and the risks associated with both mosquitoes and the insecticides used in their treatment, this study was conducted in order to better understand the relationships between management practices and the unique characteristics of each community. In order to accomplish, three Treatment Factors and four Profile factors were calculated and compared with one another, to try and better understand the relationships between them. In the end, it appeared that several relationship appeared among factors, including Fogging Exposure and Mosquito Resiliency, as well as Mosquito Population Levels and Fogging Exposure. Additionally, based upon the quadrant ranking system used in this experiment, it appears that poorer neighbourhoods have higher Mosquito Resiliency, while both poorer and more diverse neighbourhoods are fogged less than wealthier and more homogenous neighbourhood. Finally, it was shown that the GIS data used in this experiment, likely of its zoning nature, was less than useful in determining relationships between factors.

Appendix:

Table 1: Treatment Factors

Factor	Fogging Exposure	Mosquito Resiliency	Mosquito Population Size
Measurement	Instances of Fogging	Complete Recovery Rate Complete and Incomplete Recovery Rate	Cumulative Mosquito Count

Table 2: Profile Factors

Factor	Program Opinion	Community Heterogeneity	Neighbourhood Poverty	Spatial Cover
Measurement	Cumulative Buffer Zones	Population Statistics	Household Statistics	Park/Open Space Cover Industrial Cover

Table 3: New Jersey Light Traps

Insect Management Area	**New Jersey Light Trap**
2	Frasers Grove (2007 – 2018)
3	Kirlystone (2007 – 2018)
8	Transcona (2007 – 2014); Allenby (2015-2018)
11	Ferndale (2007 – 2018)
12/15	Huppe Bay (*IMA 15*; 2007 – 2014); Nipigon (*IMA 12*; 2015 – 2018)
17	Brixford (2007 – 2018)
21	King's Park (2007 – 2018)
26	Miramar (2007 – 2018)
30	River Heights (2007 – 2014); Wellington (2015); Renfrew (2016 – 2018)
38	Winchester (2007 – 2018)
41	Greenwood (2007); Dominion (2007); Lipton (2007 – 2009); Basswood (2010 – 2018)
41/6	Grey St (*IMA 6*; 2007 – 2018)

Table 4: Household and Population Statistics

Factors	IMA 2	R.	IMA 3	R.	IMA 8	R.	IMA 11	R.
Population	17770	11	15510	8	14825	7	10705	1
Percentage Indigenous	10.40%	6	8.71%	4	14.00%	9	15.55%	11
Percentage Visible Minority	7.10%	1	22.70%	10	8.52%	3	9.00%	4
Percentage Recent Immigrant	4.07%	7	5.59%	9	1.95%	2	1.84%	1
Major Repair Needed	9.49%	6	4.34%	2	5.88%	3	12.32%	9
Median Household Income (Ranked Inverse)	$49,155.04	3	$69,828.55	9	$69,790.09	8	$58,143.92	5
Proportion of Renters	45.16%	9	23.77%	5	12.88%	1	24.58%	7

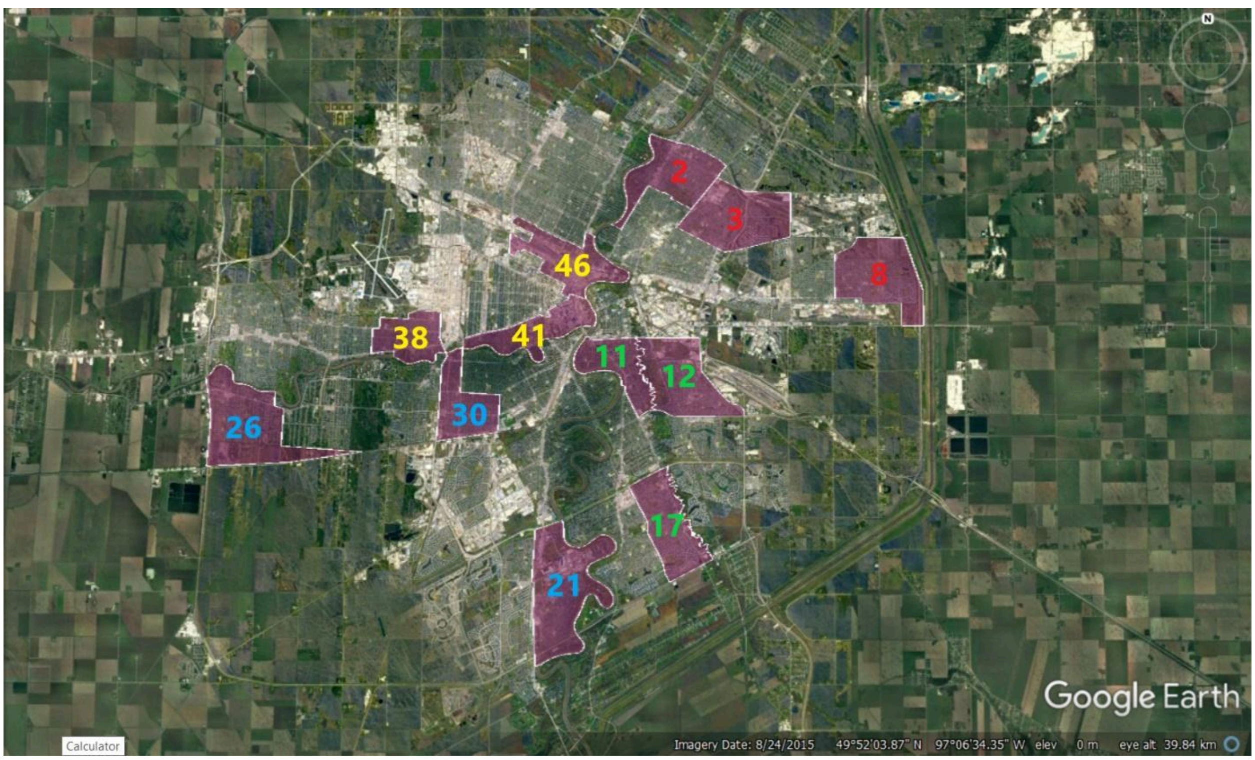
Factors	IMA 12	R.	IMA 17	R.	IMA 21	R.	IMA 26	R.
Population	13755	6	17650	10	16930	9	12875	4
Percentage Indigenous	14.78%	10	10.36%	5	6.77%	2	7.22%	3
Percentage Visible Minority	10.94%	7	17.38%	9	36.64%	#	7.86%	2
Percentage Recent Immigrant	2.96%	5	4.75%	8	13.50%	#	1.96%	3
Major Repair Needed	11.29%	8	2.83%	1	6.34%	4	8.06%	5
Median Household Income (Ranked Inverse)	$63,746.46	7	$81,479.57	12	$57,080.61	4	$72,582.16	11
Proportion of Renters	3.87%	8	18.02%	3	25.51%	#	16.68%	2

Factors	IMA 30	R.	IMA 38	R.	IMA 41	R.	IMA 46	R.
Population	12945	5	11420	3	20465	#	11170	2
Percentage Indigenous	5.48%	1	13.42%	8	13.33%	7	39.59%	12
Percentage Visible Minority	10.45%	6	9.76%	5	15.70%	8	25.20%	11
Percentage Recent Immigrant	3.58%	6	2.15%	4	6.02%	#	8.58%	11
Major Repair Needed	11.17%	7	15.32%	11	13.87%	#	16.20%	12
Median Household Income (Ranked Inverse)	$72,500.62	10	$60,006.29	6	$40,373.37	2	$28,862.03	1
Proportion of Renters	5.70%	4	23.81%	6	71.66%	#	70.50%	11

Table 5: Park/Open Space and Industrial Cover

IMAs	%PO	%I	Parks/Open Rank	Industrial Rank
2	5.88%	0.00%	4	1
3	10.30%	1.32%	11	11
8	7.04%	0.11%	5	6
11	8.33%	0.00%	7	1
12	5.51%	0.00%	3	1
17	11.43%	0.24%	12	7
21	8.98%	0.00%	9	1
26	9.24%	1.16%	10	10
30	4.43%	0.27%	2	8
38	7.73%	0.58%	6	9
41	3.53%	0.00%	1	1
46	8.40%	23.40%	8	12

Figure 13: IMAs



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