Geographic Analysis of Areas and Schools of Highest Risk for Measles Outbreak in Vancouver

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Abstract

This geographic analysis project investigates measles immunization rates and demographic data to identify areas of highest risk for an outbreak in the city of Vancouver. Demographic factors known to affect infectious disease spread were investigated, such as population density, public transit use and, in the case of measles, proportion of youth population. Census tracts that contained a school below the defined immunization threshold (80%) and above the risk threshold for one of the demographic attributes (density: 10000/sqkm; public transit: 25%; youth population: 15%) were identified as highest risk areas. The geographic analysis identified 6 high risk areas when considering population density, 7 for youth population, and 11 for public transit. The analysis also identified that 6 schools located in high risk areas based on population density, 9 schools based on youth population, and 22 schools based on public transit usage. Of the 22 neighbourhoods designated by the City of Vancouver, only 9 did not contain a school that was identified as high risk in at least one map, while 9 other neighbourhoods contained 2 or more such schools.

Project Description

This goal of this project was to conduct a geographic analysis to identify regions within Vancouver that have the greatest risk for a measles outbreak, based on school immunization rates as well as multiple demographic attributes. Immunization rates for each school in Vancouver were combined with data on factors known to impact communicable disease outbreaks. These factors include population density, proportion of public transit use, and proportion of the population between the ages of 0 and 14 years. As measles is a highly contagious disease that most severely affects children, these factors are almost certainly of consequence to anyone tasked with monitoring or predicting measles' potential impact in Vancouver. Given that BC is currently experiencing a rise in reported measles cases, this information is applicable to the current needs of the city. However, any analysis with a similar focus would be conducted by public health organizations and professionals in order to predict future outbreaks and utilize resources more efficiently for prevention, intervention, and response in the event of an outbreak. The data used for this project is all publicly available and was obtained from the 2016 Canadian Census (tabular demographic data), Vancouver Coastal Health (tabular immunization coverage data), and the City of Vancouver (geospatial data). Areas meeting the defined risk thresholds for immunization rates and at least one demographic factor were identified as highest risk and shown using maps.

Methodology

Acquire

The data was acquired from a variety of sources including: Vancouver Coastal Health Immunization Coverage Dashboard, University of Toronto CHASS/Stats Canada Canadian

Census 2016, and the City of Vancouver open data catalogue. All data was obtained freely from the internet.

Parse Filter

The census tabular data (population density, public transit commuters, age groups) was joined to the census tract shapefiles. The school shapefile was filtered to delete all non-elementary schools. As the VCH immunization data only includes elementary school immunization rates, secondary schools were beyond the scope of this project. The immunization coverage data was converted into an excel file before being imported into ArcMap and joined to the school shapefile.

Mine

Once all tabular data had been joined to the shapefiles, I performed a select by attribute on the census data. For the population density map, I selected all census tracts above 10000 people/sqkm which represented all tracts that were one or more standard deviations above the mean density. For the public transit data, I first had to calculate the proportion of total commuters using public transit. The total number of public transit users was divided by the total number of commuters for each census tract, which was then imported into ArcMap and added to the census tract file. I then selected for all census tracts with greater than 25% of commuters using public transit. For the age group map, I selected for all census tracts that had greater than 15% of their population of those aged 0-14. I then conducted a select by attribute for the school layer, based on the immunization coverage data. I selected for all schools with less than 80% coverage, which was the average for all the Vancouver Coastal Health data. Finally, a select by location process was done for each of the demographic census attributes to isolate all schools that had a low coverage rate and were located in an area of high risk for that attribute.

Represent

When preparing the maps, I considered how best to represent the census data. The symbology was chosen because each map represents only one attribute of census data, so one colour was chosen to reflect the varying levels of this attribute across the different census tracts. For the school layer, I chose an equal interval classification system to represent the immunization coverage in all maps because, since this data is in units of percentage, equal intervals of 10 was deemed the most intuitive way to interpret percentage data. Common colour associations were also used for the schools such as green for a high (i.e. good) immunization coverage and red used for low coverage. Furthermore, a different colour (purple) was used for the schools identified as highest risk in order for the results of the analysis to stand out when looking at the map. A fourth map was also created using Vancouver neighbourhoods instead of census tracts and this was deemed an easier way to relate the results to a common reference, as well acting as a companion for the graph theory analysis.

Table of dataset

Layer / datafile name	Source	Uses	Entity/data model	Attributes	Modifications
Census Tract Boundaries	*Stats Canada/UBC library*	*Determine census tracts to link to tabular data*	*polygon*	*Census boundaries, area, length*	
Schools	*City of Vancouver*	*Plot location of schools and select based on immunization coverage*	*Point layer of school locations*	*School name, address,*	*Deleted all schools that were not classified as elementary schools*
Population Density	*University of Toronto CHASS/Stats Canada Census 2016*	*Determine population density of census tracts in Vancouver*	*Tabular data*	*Census tract, area, density (/sqkm)*	*Join tabular data to census tract shapefile*
Public Transit Usage	*University of Toronto CHASS/Stats Canada Census 2016*	*Determine % of commuters in census tract using public transit*	*Tabular data*	*Census tract, area, total commuters, total public transit commuters*	*Calculate percentage of public transit users, join to census tract shapefile*
Population by Age group/Proportion of population age 0-14 years	*University of Toronto CHASS/Stats Canada Census 2016*	*Determine percentage of population in census tract under 14 years old*	*Tabular data*	*Census tract, area, population percentage by age group*	
Measles Immunization Coverage	*Vancouver Coastal Health*	*Determine percentage of students at each school who have measles vaccine*	*PDF/Tabular data*	*School name, measles immunization percentage*	*Convert tabular data to excel, join to schools shapefile*

Discussion and Results

This analysis defined a high risk area to be a census tract that was above the risk threshold for one of three demographic factors and contained at least one school with below average measles immunization coverage (<80%). The demographic factors analyzed were population density (risk threshold: >10000 people/sqkm), proportion of public transit users (risk threshold: >25%), and proportion of population aged 0-14 years (risk threshold: >15%). Generally, the risk thresholds were set at approximately one standard deviation above the mean value for that attribute. Following from the high risk area definition, a high risk school

was defined to be a school with <80% measles immunization coverage that was located within a census tract that was above the risk threshold for at least one of the demographic attributes. Three maps were created to display each of the three demographic attributes compared with the schools. The geographic analysis identified 6 high risk areas when considering population density, 7 for youth population, and 11 for public transit. Based on the above definition, 31/112 (27.7%) of schools were identified as high risk in at least one category. The analysis identified 6 schools that were located in high risk areas based on population density, 9 schools based on youth population, and 22 schools based on public transit usage.

The following 6 schools were found to have the highest risk based on immunization coverage (<80%) and density (>10000 ppl/sqkm):

> Anchor Point Montessori, Elsie Roy Elementary, L'Ecole Bilingue Elementary, Lord Roberts Annex, Lord Roberts Elementary, St Augustine's

The following 9 schools were found to have the highest risk based on immunization coverage (<80%) and a high proportion of population aged 0-14 years (>15%):

> Captain James Cook Elementary, Champlain Heights Annex, General Brock Elementary, Kerrisdale Annex, Our Lady of Perpetual Help, Queen Elizabeth Annex, Quilchena Elementary, Shaughnessy Elementary, Southlands Elementary

The following 22 schools were found to have the highest risk based on immunization coverage (<80%) and public transit usage (>25%):

> Captain James Cook Elementary, Champlain Heights Annex, Champlain Heights Community Elementary, Children's Hearing and Speech Centre BC, Dr A R Lord Elementary, Graham Bruce Community Elementary, Henry Hudson Elementary, Kerrisdale Annex, L'Ecole Bilingue Elementary, Lord Beaconsfield Elementary, Lord Roberts Annex, Lord Roberts Elementary, Our Lady of Perpetual Help, Queen Mary Elementary, Quilchena Elementary, Shaughnessy Elementary, Sir John Franklin Community Elementary, Southlands Elementary, St Augustine's, Vancouver Talmud Torah Elementary, West Coast Christian School, Westside Montessori Academy

From this result we can see that the following 10 schools are identified as high risk in more than one of the above categories:

> L'Ecole Bilingue Elementary, Lord Roberts Annex, Lord Roberts Elementary, St Augustine's, Captain James Cook Elementary, Champlain Heights Annex, Kerrisdale Annex, Our Lady of Perpetual Help, Quilchena Elementary, Shaughnessy Elementary.

When analyzing the data by Vancouver neighbourhood as defined by the City of Vancouver (map 4), we find that 9/22 (41%) of neighbourhoods do not contain any school identified as high risk by my criteria, while 9 other neighbourhoods contain 2 or more such schools. By using a technique from the branch of mathematics known as graph theory, we can

construct a graph (or network) where the nodes represent neighbourhoods and two nodes are connected by an edge if the corresponding neighbourhoods share a border (Figure 1). We then colour the nodes black if the corresponding neighbourhood does not contain a high risk school, and we colour it red if it does. From this method of analysis, we find that while 9 neighbourhoods do not contain a high risk school, all neighbourhoods have at least one bordering neighbourhood with such a school. In graph theory terms we see that all black nodes are adjacent to at least one red node. Furthermore, the black nodes are adjacent to an average of 2.1 red nodes. In our scenario, this means that neighbourhoods who do not contain a high risk school have, on average, approximately 2 bordering neighbourhood who do contain such a school.

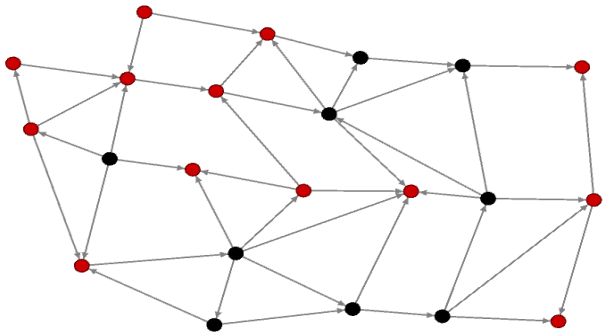


Figure 1: Red nodes are neighbourhoods containing a high risk school. Black nodes represent neighbourhoods that do not contain a high risk school. We notice that each black node is adjacent to at least one red node.

These results could be used to target the most efficient areas for public health organizations to raise awareness about the importance of getting the measles vaccine. Given that herd immunity for measles has been shown to be 93-95% (due its highly contagious properties), it is imperative that all parents and caregivers are aware of the potential dangers for their own children, as well as others, if they do not get immunized.

Error and Uncertainty

One source of uncertainty in this analysis is the risk threshold definitions for both the immunization coverage data and the demographic attributes. For the immunization coverage, the risk threshold was defined to be that those <80% were deemed high risk, as this was below the 80% average for the VCH region. However, herd immunity for measles has been shown to be 93-95%, so even schools with greater than 80% coverage may be at risk and thus this

definition carries some uncertainty. Furthermore, for the demographic data, the high risk threshold was generally defined as approximately 1 standard deviation above the mean for each attribute. If a different threshold was used, results may produce a different set of high risk regions (i.e. census tracts). Additional error could result from a few census tracts having to be excluded from the analysis as they had no data available. Given that these areas were not able to be used in the calculation, error is introduced in that a complete picture of the city cannot be captured. Fortunately, for the attributes used in this analysis, missing data occurred infrequently, and it is not expected to have a large impact on the results. As immunization data is only available from VCH for elementary schools, no secondary schools were analyzed in this study. This introduces a possibility of underestimating risk in certain areas because, even though measles is most common in young children, it can still be spread by older students and adults. Therefore, secondary school immunization rates would also be of consequence when assessing risk. Finally, this data and subsequent analysis only captures individuals enrolled in schools covered by VCH. Children outside of this group (such as those who are homeschooled) would be missed by this analysis. While this is most likely a proportionally very small number of children, given the highly contagious nature of the measles virus, even a small amount of unvaccinated people can potentially have a large impact.

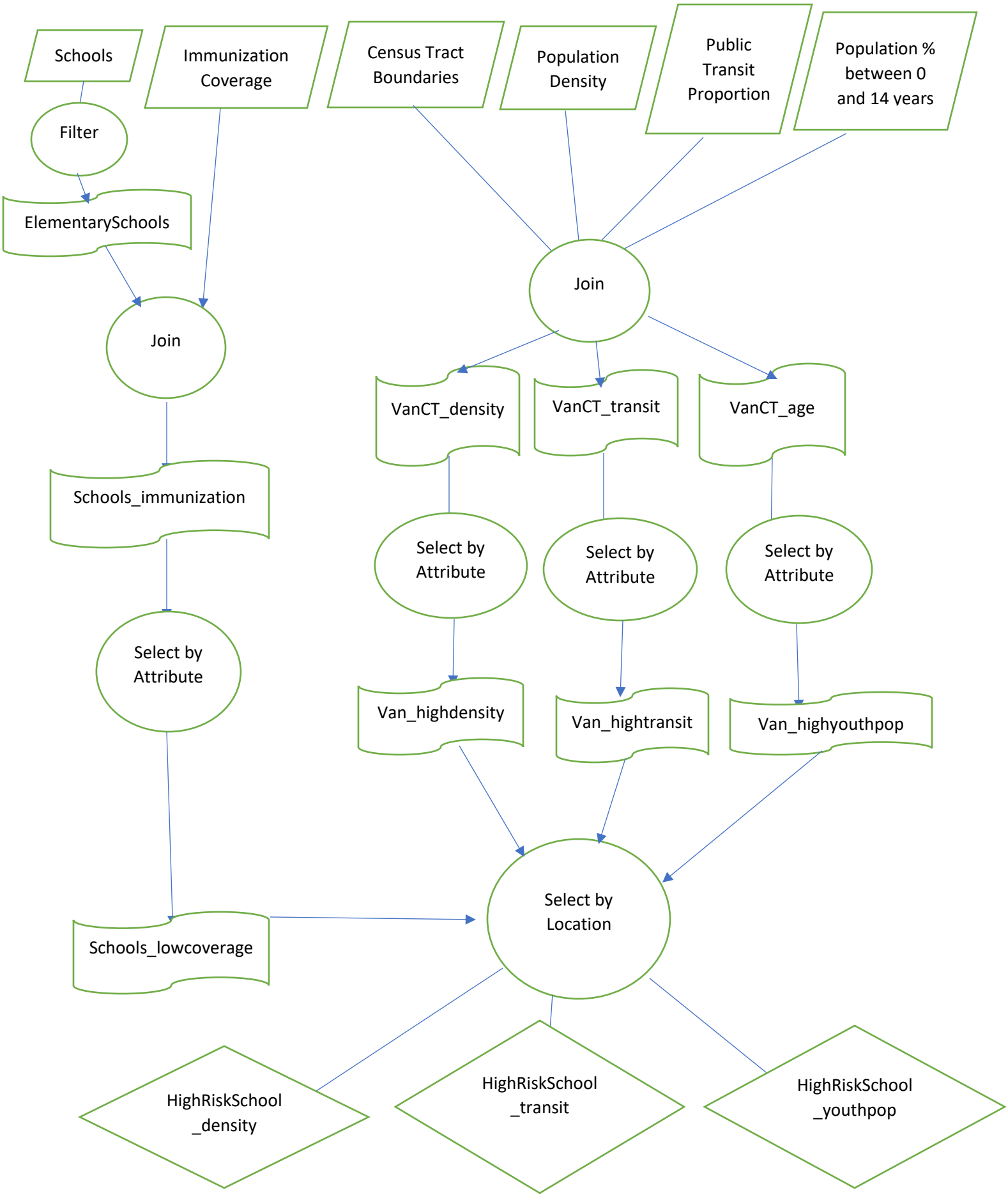
Further Research Recommendations

Further research could be conducted with additional demographic data (such as socioeconomic attributes) to gain a better understanding of the characteristics of high risk areas and schools. As mentioned above, secondary school immunization rates could also be included to strengthen the analysis, if obtaining such data was possible. This analysis could be expanded to utilize more rigorous statistical techniques to determine correlations between various demographic information and immunization coverage. Mathematical modelling and statistics could also be used to construct a model of risk that could be validated against data from past outbreaks in both Vancouver and other cities. Graph theory mathematics could be put to further use in this analysis as well. A graph could be constructed with the nodes representing all the identified high risk schools, with edges connecting schools within a certain distance of each other (eg. 5km) as the student populations of such schools are more likely to come into contact with each other which would increase the risk of spread.

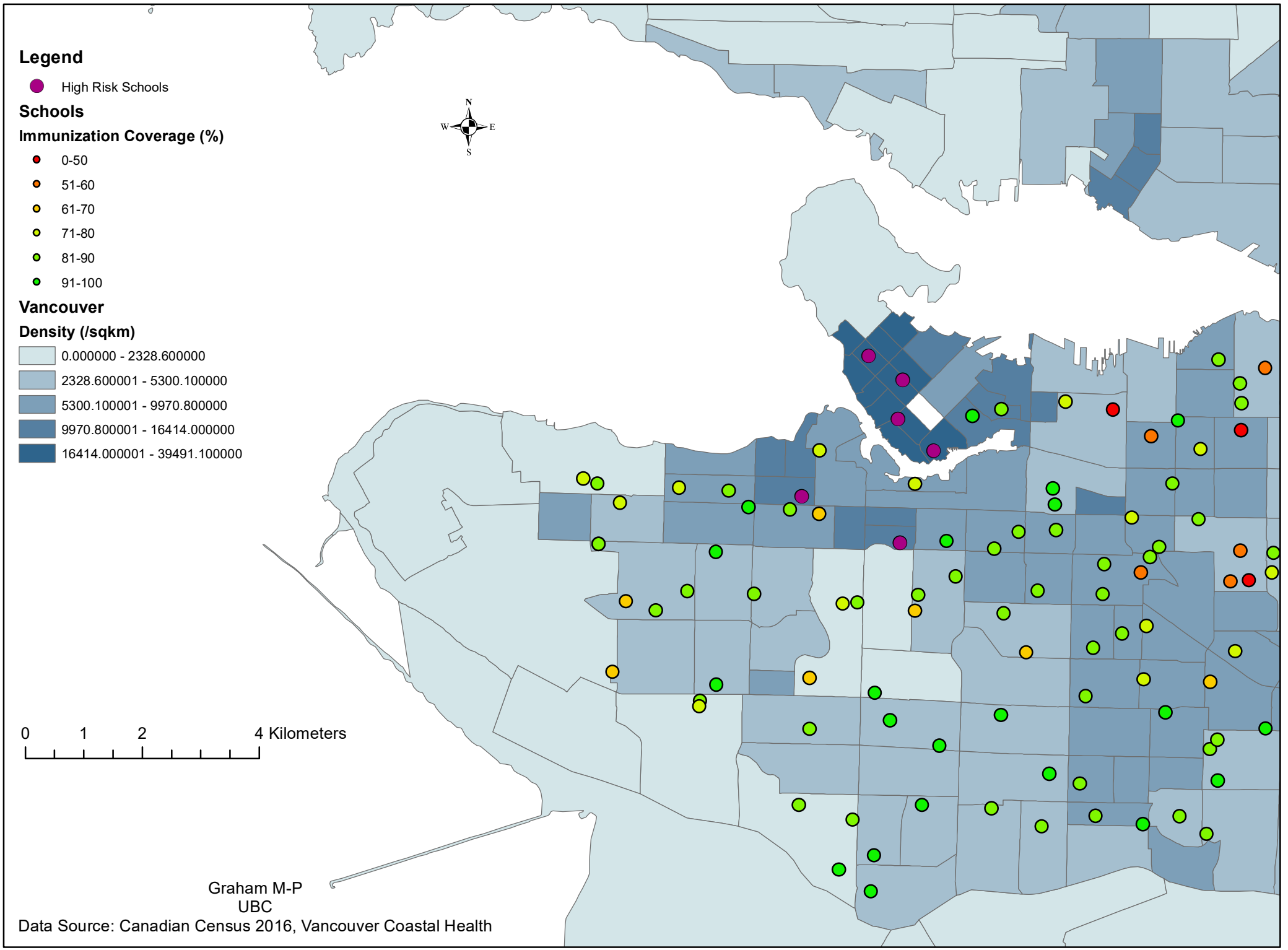
Appendix 1: Bibliography

1) https://public.tableau.com/profile/phsu.dashboard#!/vizhome/VCHSchoolImmunizationCoverageDashboard/Dashboard
2) http://www.vch.ca/for-health-professionals/health-data/immunization-coverage
3) https://data.vancouver.ca/datacatalogue/localareaboundary.htm
4) http://datacentre.chass.utoronto.ca.ezproxy.library.ubc.ca/census/
5) https://data.vancouver.ca/datacatalogue/schools.htm

Appendix 2: Flowchart



Risk of Measles Outbreak by School Immunization Coverage and Population Density in Vancouver



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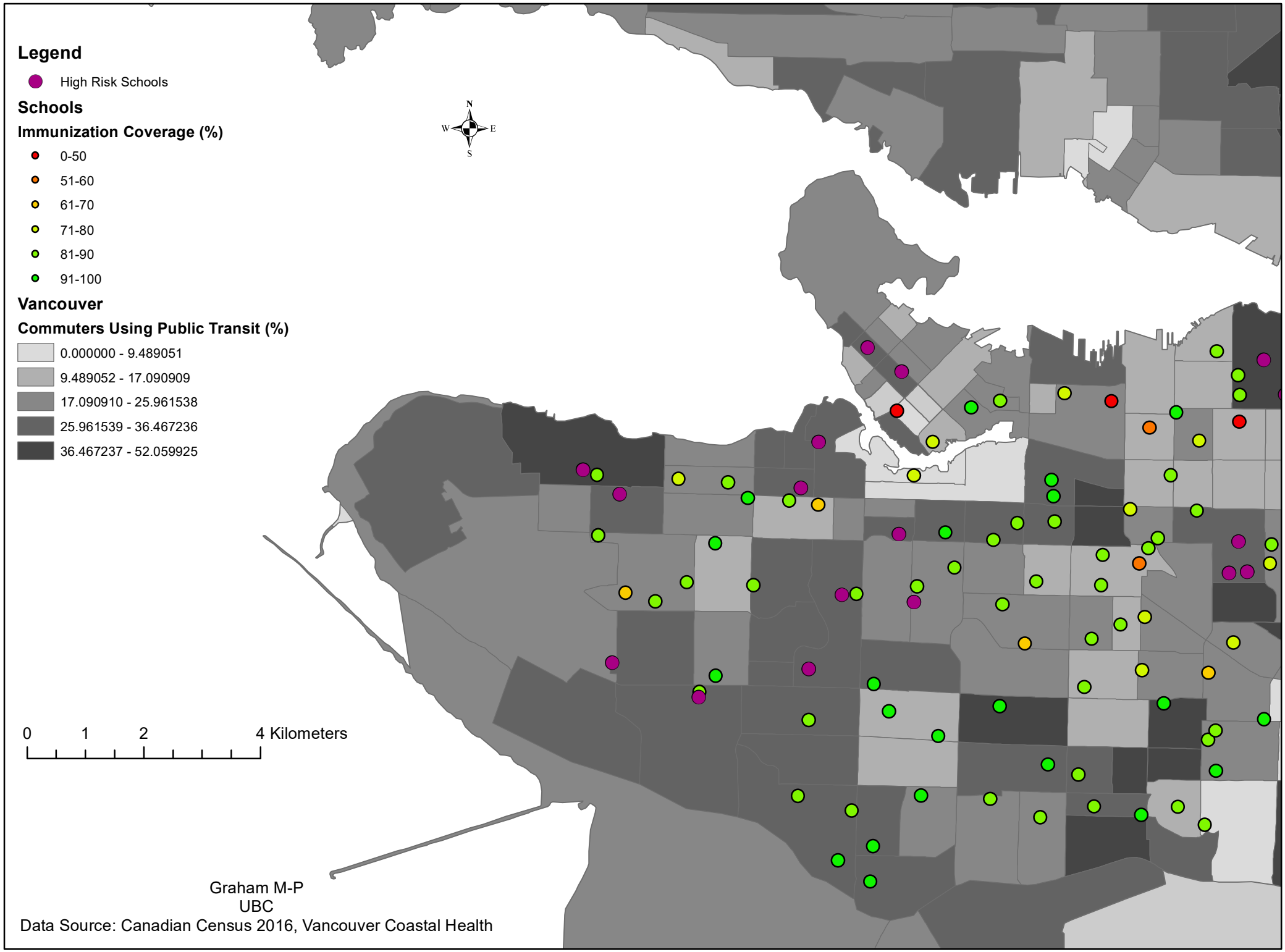
Data Source: Canadian Census 2016, Vancouver Coastal Health

Risk of Measles Outbreak by School Immunization Coverage and Percentage of Public Transit Commuters in Vancouver



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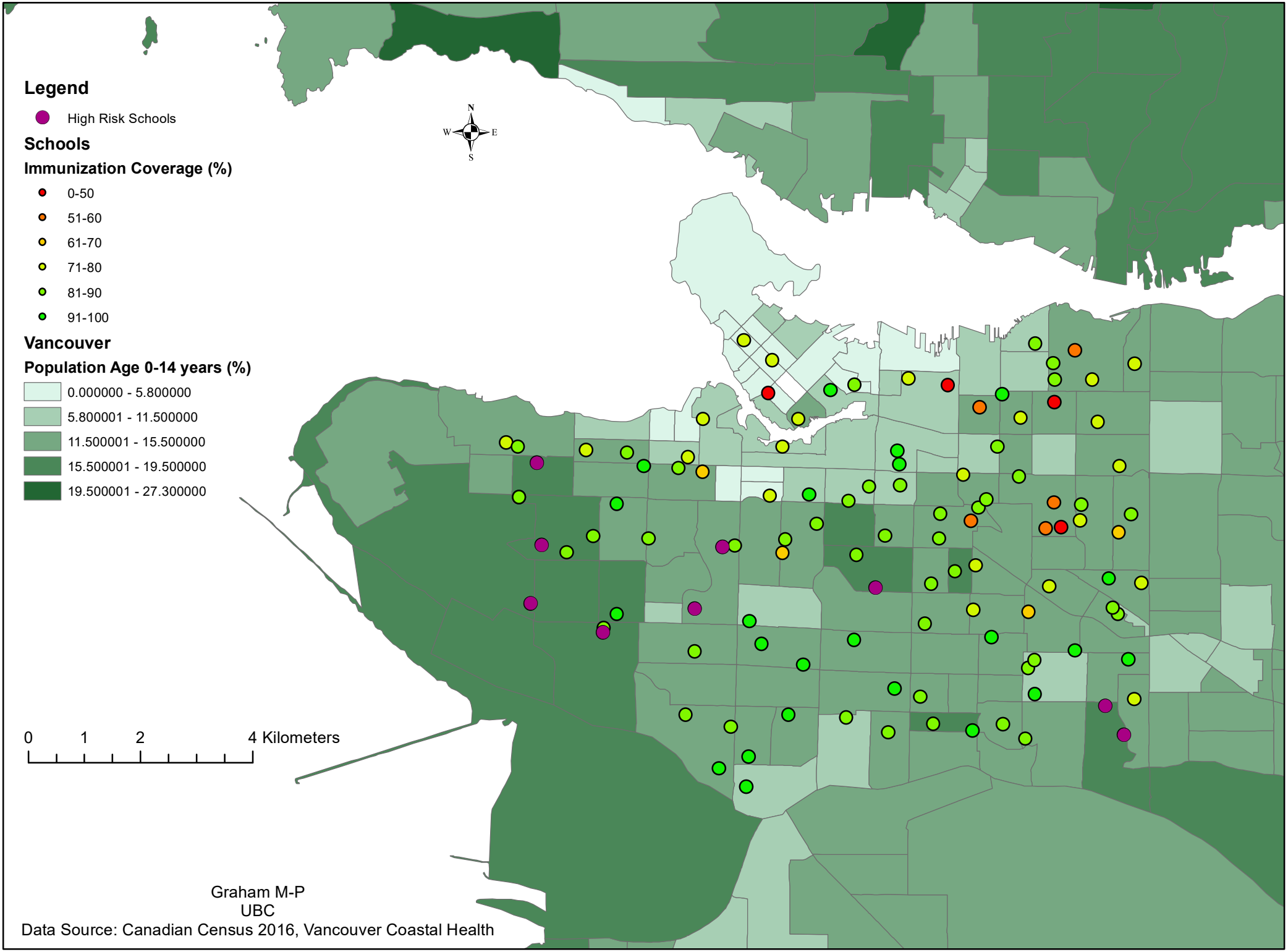
Data Source: Canadian Census 2016, Vancouver Coastal Health

Risk of Measles Outbreak by School Immunization Coverage and Proportion of Population Under 14 in Vancouver



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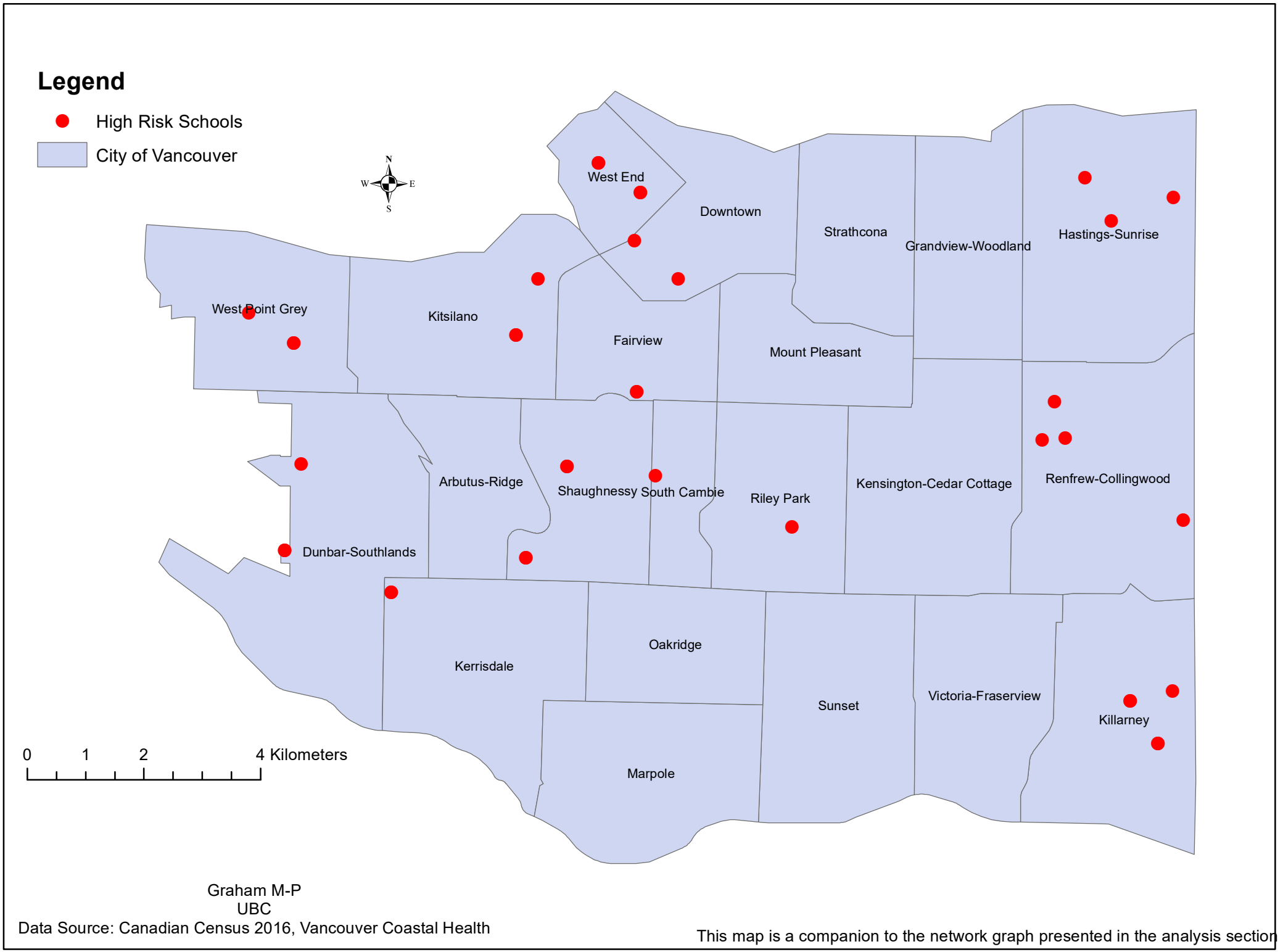
Data Source: Canadian Census 2016, Vancouver Coastal Health

Schools with Highest Measles Risk by Vancouver Neighbourhood



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Data Source: Canadian Census 2016, Vancouver Coastal Health

This map is a companion to the network graph presented in the analysis section