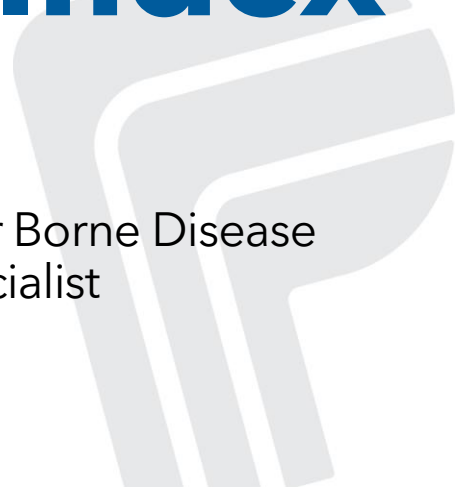


Peel Public Health's Heat Vulnerability Index

Franca Ursitti, Manager, Health Hazard Investigations & Vector Borne Disease
David Guillette, Data & Geographic Information Systems Specialist
Lydia Cheng, Epidemiologist
Peel Public Health



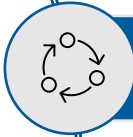
Learning Objectives

- Explain the relevance of the components of heat vulnerability (i.e., adaptive capacity, sensitivity, and exposure), in assessing heat-related health risks.
- Describe the methodology used to develop and map the Heat Vulnerability Index (HVI), including application of Principle Component Analysis (PCA).
- Identify the practical applications of the HVI in guiding targeted interventions and resource allocation to reduce inequitable health outcomes.

Agenda



Context & Objectives



Principle Component Analysis Methodology

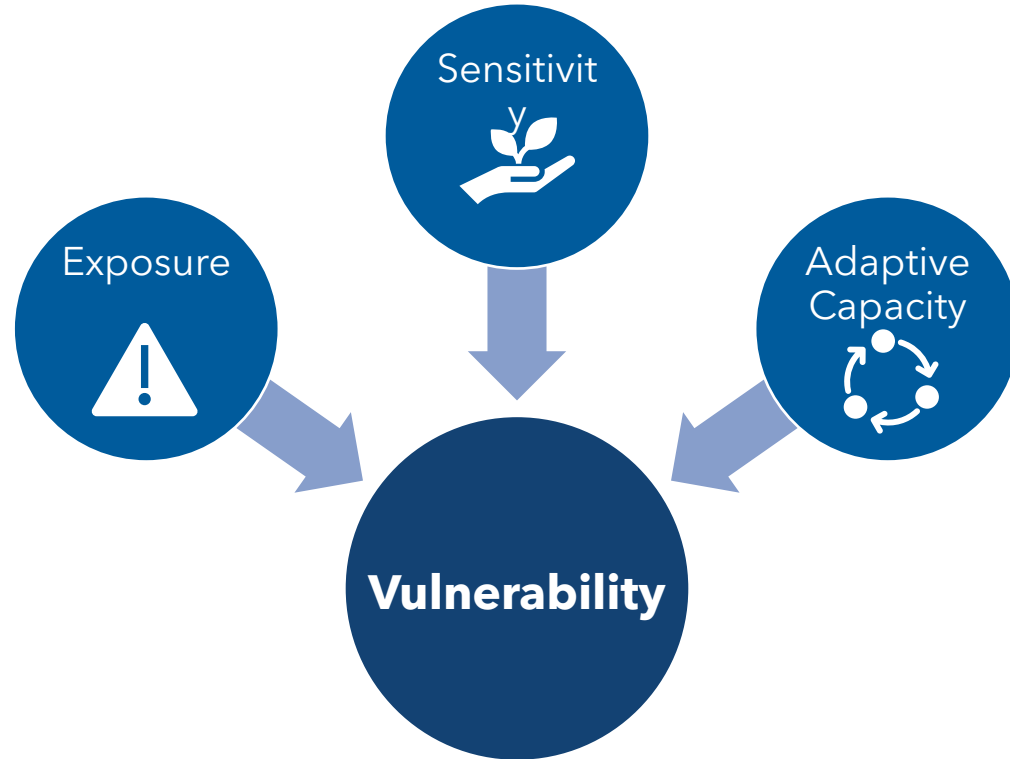


Spatial Analysis & Mapping

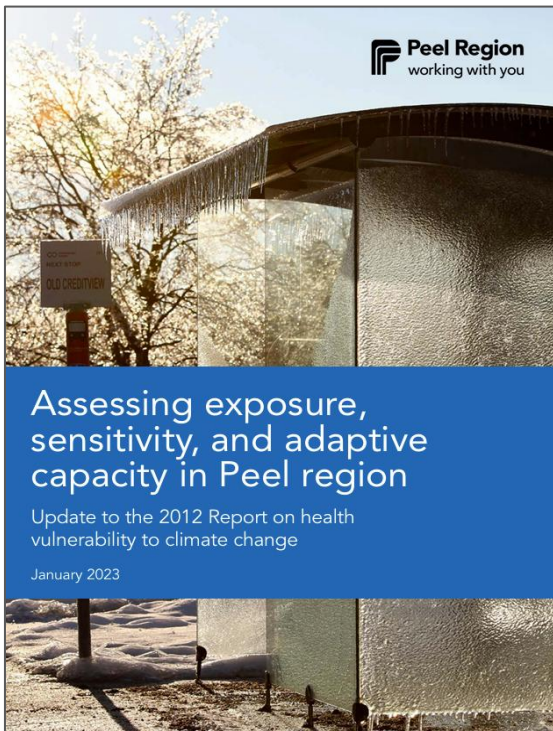


Public Health Applicability

Climate Change & Health Vulnerability Assessment



Context



- Heat is one of the top five climate-related health hazards.
- Recommendations included mapping at-risk communities.
- Temperatures projected to continue rising, increasing heat-related illness risk.

Integration of VA results into PPH's Strategic Priorities.



Health Impacts of Heat in Peel



Temperatures in Peel have been increasing, with annual mean temperatures rising from 8.1°C in 1938 to 9.3°C in 2017.



Projections show an increase in expected days above 35°C, increasing the risk of heat-related illness and death.



For every 5°C increase in daily mean temperature, there is a 2.5% increase in non-accidental deaths.



Heat-related illnesses include heat stroke, heat exhaustion, fainting, edema, heat rash and cramps.

Project Objectives

1

Identify, assess, and map communities in Peel at-risk of heat-related illness.

2

Begin discussions and strengthen understanding of how these communities are impacted by heat.

3

Ensure effective and equitable programs and policies are explored to mitigate the risk of heat on health.

Principle Component Analysis (PCA) Methodology



Methodology overview

Part 1: Principal component analysis (PCA)

Research questions

- Which indicators associated with vulnerability to heat-related harms **best explain the variance in the whole dataset?**
- Can **an index summarizing these data** be created to describe each Census Tract in Peel?

Methods

1. Select indicators based on vulnerability assessment
2. Reduce variables and test assumptions for PCA
3. Select components
4. Compute component scores and Heat Vulnerability Index score per Census Tract

Part 2: Geospatial analyses

- **Which areas have the most risk** for heat events within Peel?
- Do these areas exhibit **spatial clustering?**
- What can we learn about these communities regarding the social determinants of health, the built environment, and health outcomes?

1. Assess large-scale variation: spatial autocorrelation
2. Assess small-scale variation: cluster and outlier analysis
3. Explore health equity stratifiers by index quintiles

Indicator selection

Characteristics of indicators selected for inclusion in PCA:

- ✓ **Data represents the concept accurately**
- ✓ **Data are accessible** by Peel Public Health and are releasable as per data sharing agreements
- ✓ **Data are available and reliable at the census tract (CT) level**

Examples of included and excluded data sources/indicators:

- ✓ Census data
- ✓ Environmental exposure data from Canadian Urban Environmental Health Research Consortium (CANUE)
- ✓ IC/ES data request for chronic disease prevalence by CT
- ✗ Canadian Community Health Survey (CCHS) data were not validated for small-area analysis
- ✗ Healthcare utilization data → high proportion of CTs with 0-4 events
- ✗ Availability of air conditioning in homes → Census variable % dwellings built before 1960 not a good proxy
- ✗ Availability of heat response plans by municipality → no variation

Principal component analysis (PCA)

Factors associated with heat vulnerability



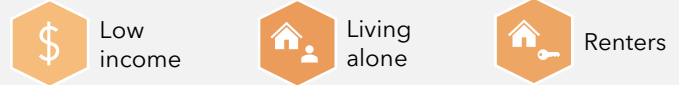
Variable reduction & test assumptions

Variables dropped during iterative process

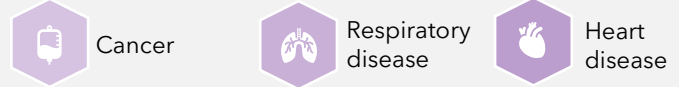
Run PCA

Final components

1. Adaptive capacity



2. Sensitivity



3. Exposure



Compute scores for each Census Tract

- For each of the 3 components (Adaptive Capacity, Sensitivity, Exposure)
- Combined: Heat Vulnerability Index (HVI)

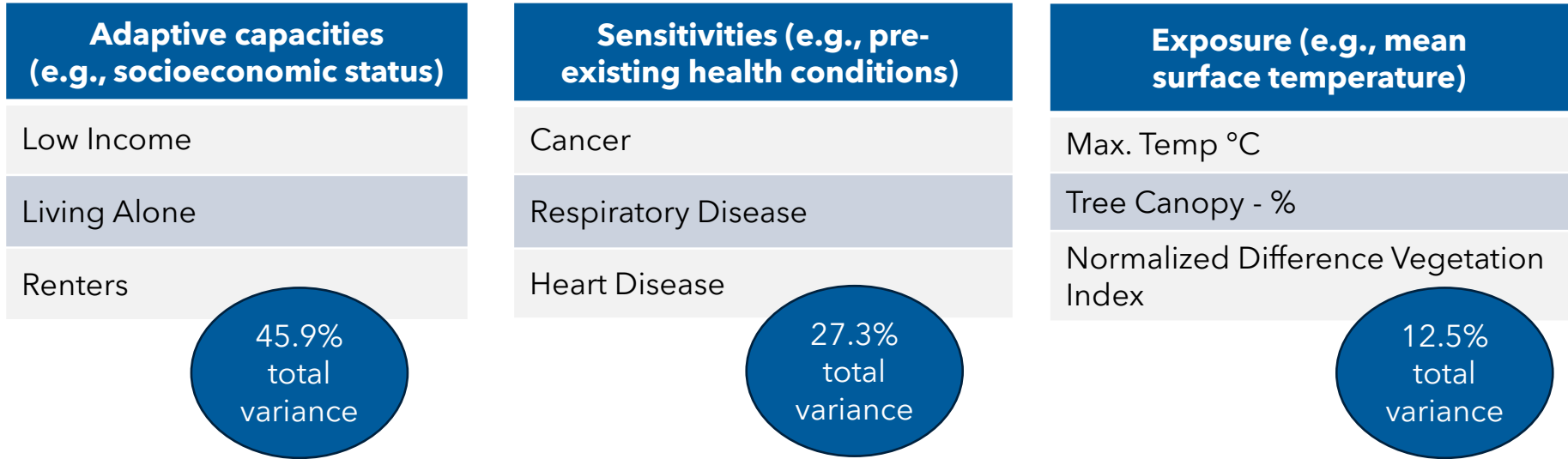
Final components & indicators

Component	Area-level indicator (at Census Tract geography)	Data source
1 - Adaptive Capacity	Percent of private households by household size: one person	Census (2021) [1]
	Percent of private households by tenure: renter	Census (2021) [1]
	Percent of population in the low income measure, after tax	Census (2021) [1]
2 - Sensitivity	Prevalence of heart disease (congestive heart failure, ischemic heart disease, or atrial fibrillation)	IC/ES data request (2023) [2]
	Prevalence of cancer	IC/ES data request (2023) [2]
	Prevalence of respiratory diseases (asthma or chronic obstructive pulmonary disease)	IC/ES data request (2023) [2]
3 - Exposure	Annual maximum mean warm-season land surface temperature	CANUE (2021) [3]
	Percent tree canopy cover	Peel Data Centre (2021) [4]
	Normalized Difference Vegetation Index : mean greenest pixel	USGS (2021) [5]

CANUE: Canadian Urban Environmental Health Research Consortium; **CT**: census tract; **IC/ES**: Institute for Clinical Evaluative Sciences; **USGS**: United States Geological Survey.
Please see reference slide for data references.

Results

Three components were selected during PCA:

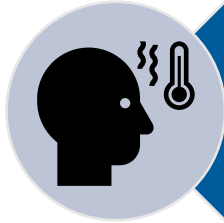


These three components together explain 85.7% of the total variance

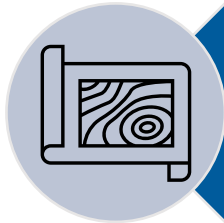
Spatial Analysis & Mapping



Spatial Mapping Objectives



Which areas have the most risk for heat events within Peel?

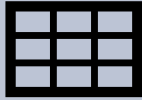


Do these areas exhibit spatial clustering within Peel?



What can we learn about these communities regarding the social determinants of health, the built environment, and health outcomes?

Mapping the results



Join the tabular data to the cartographic boundary file for Peel.

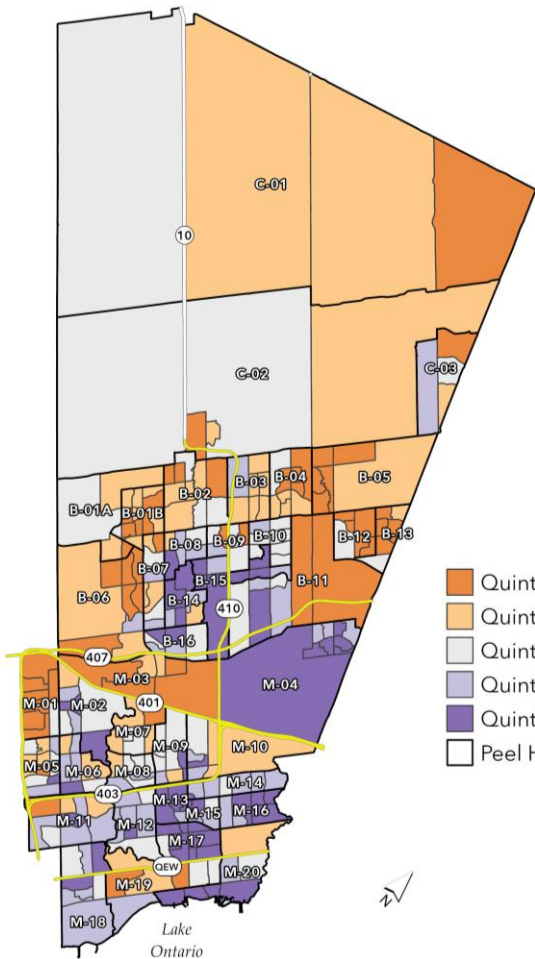


Map the results for each component and the HVI using a choropleth map and quintile classification.



Test for spatial association (similarity) and map significant results.

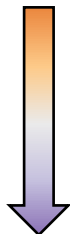
Adaptive Capacity



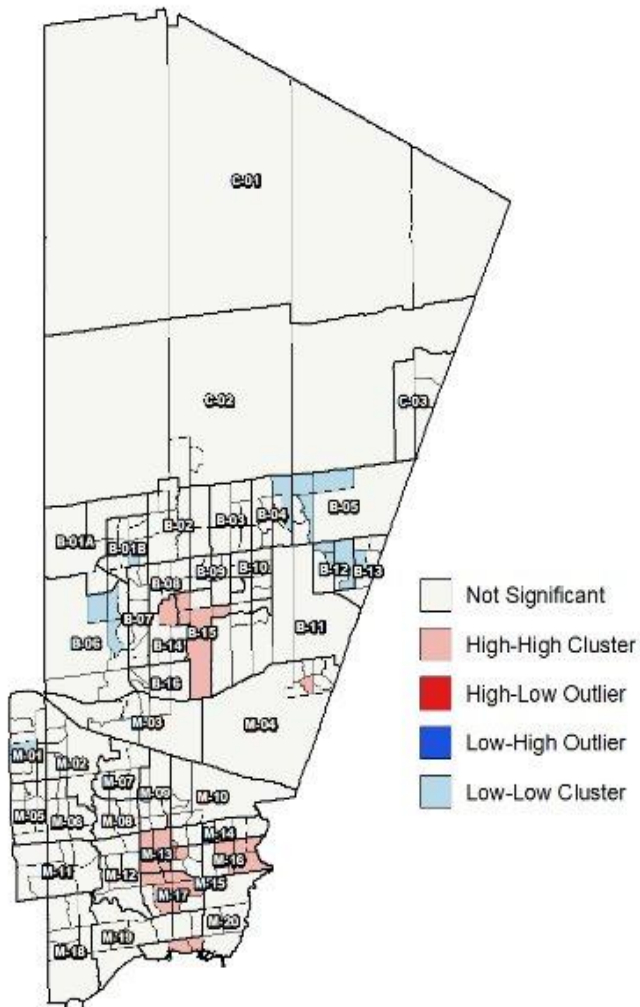
- Quintile 1 - Least Vulnerable
- Quintile 2
- Quintile 3
- Quintile 4
- Quintile 5 - Most Vulnerable
- Peel Health Data Zones



Protective

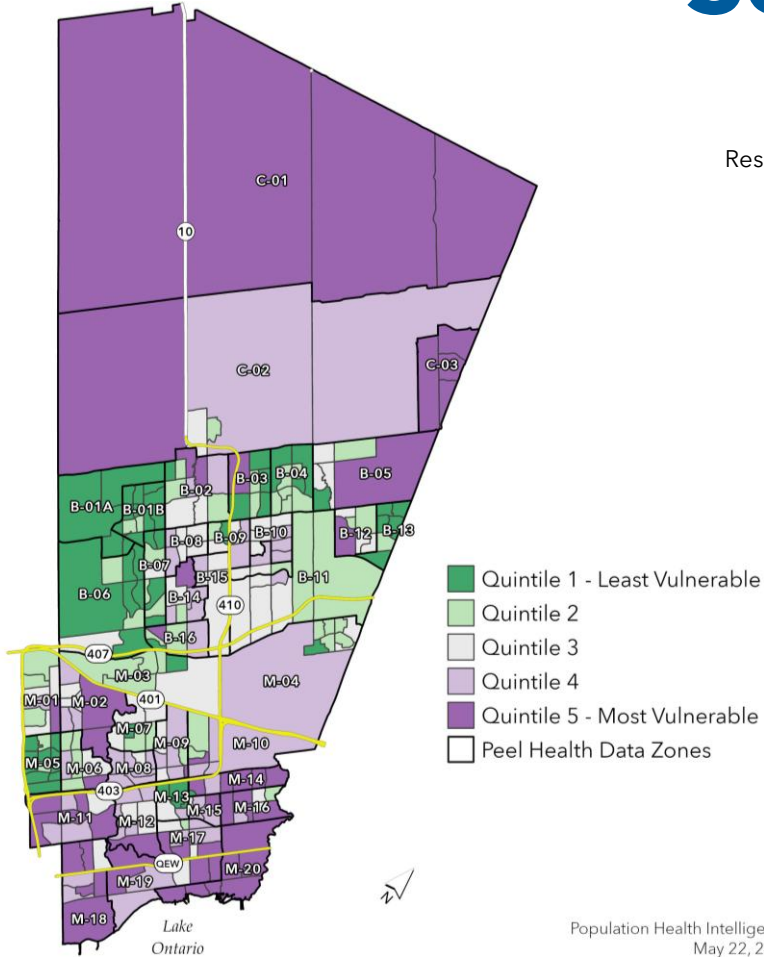


Risk



- Not Significant
- High-High Cluster
- High-Low Outlier
- Low-High Outlier
- Low-Low Cluster

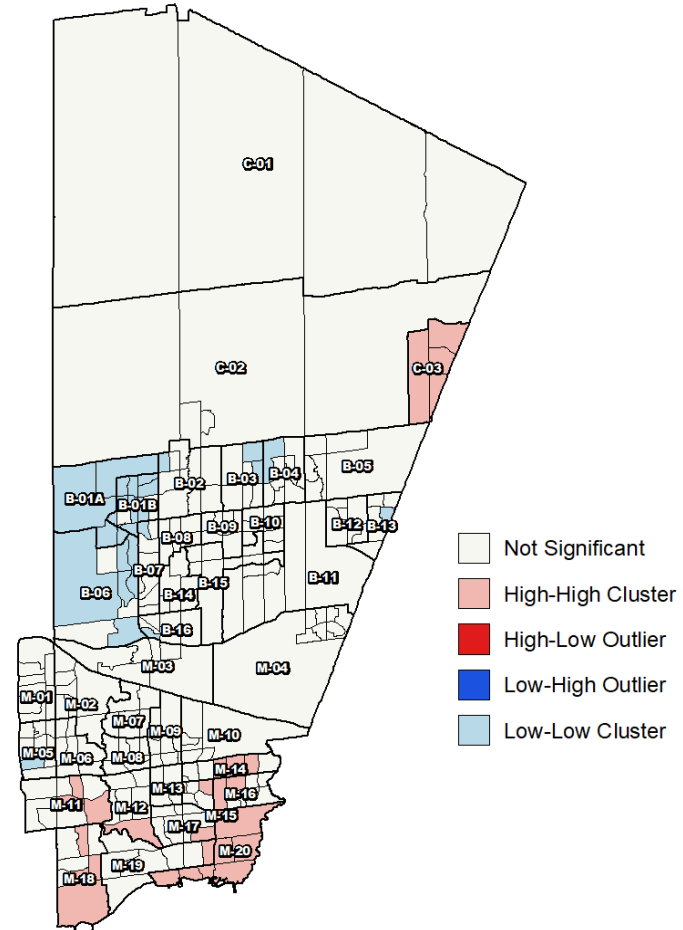
Sensitivity



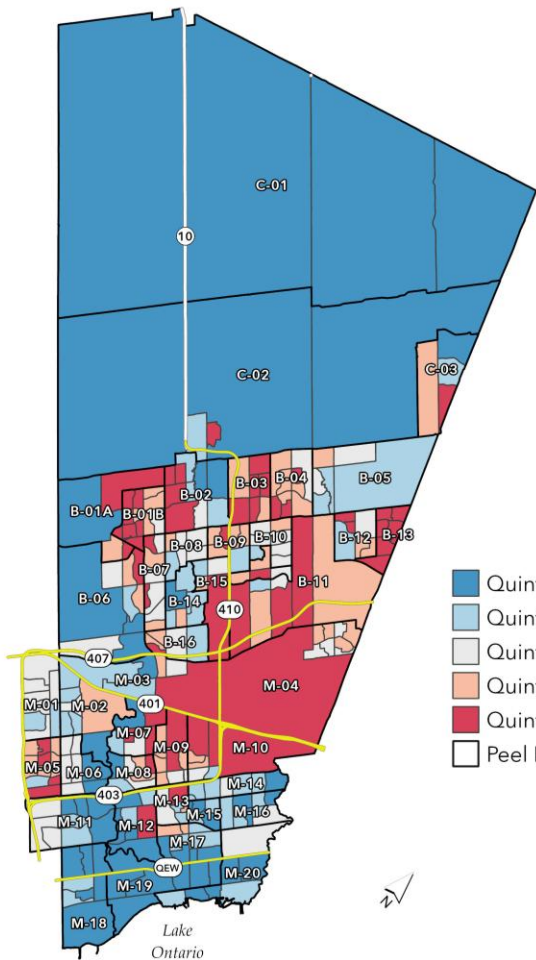
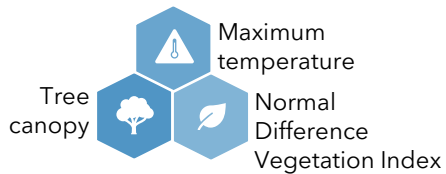
Protective



Risk

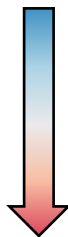


Exposure

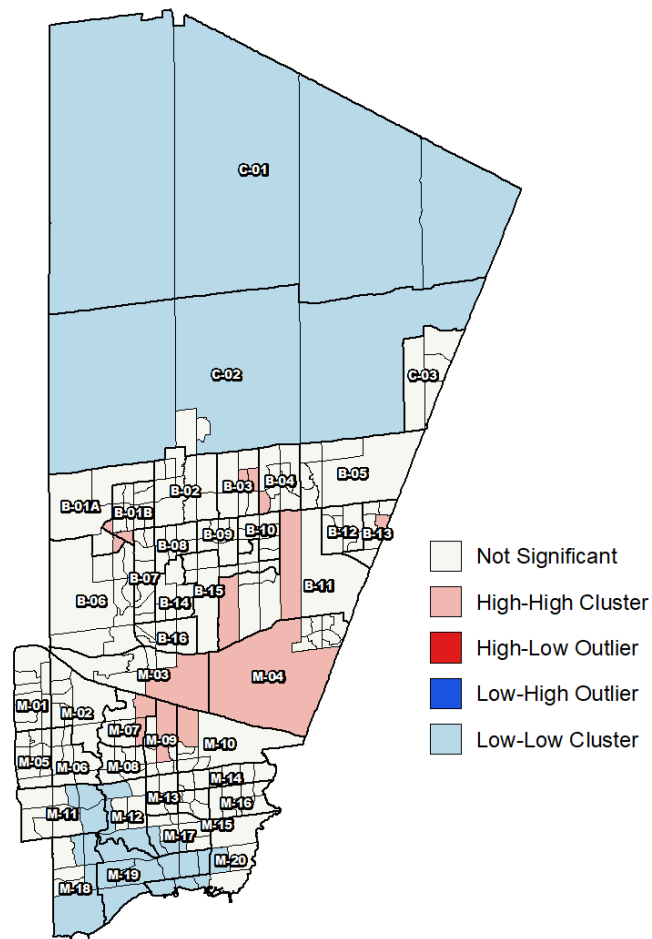


- Quintile 1 - Least Vulnerable
- Quintile 2
- Quintile 3
- Quintile 4
- Quintile 5 - Most Vulnerable
- Peel Health Data Zones

Protective

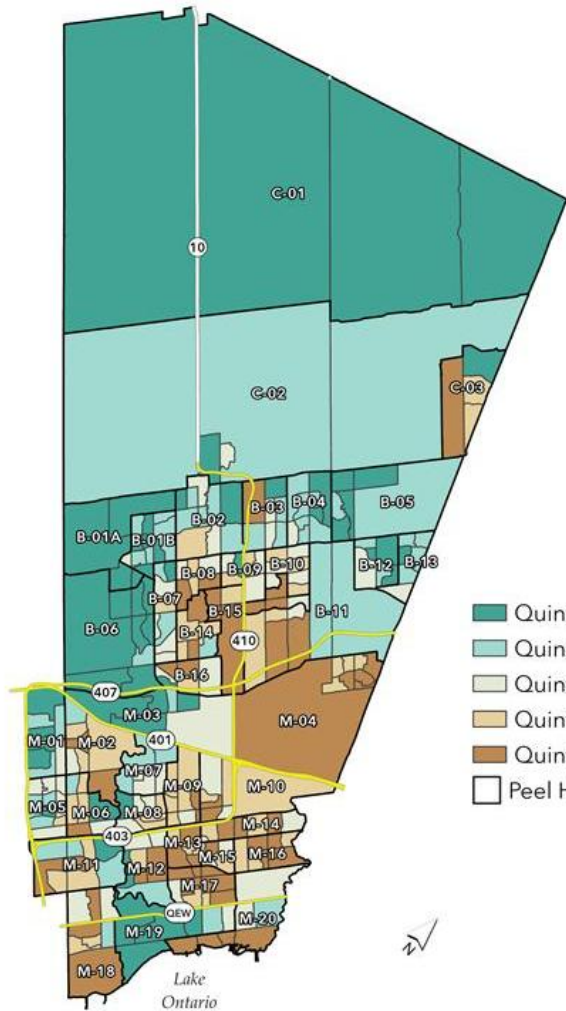


Risk



- Not Significant
- High-High Cluster
- High-Low Outlier
- Low-High Outlier
- Low-Low Cluster

Heat Vulnerability in Peel Region

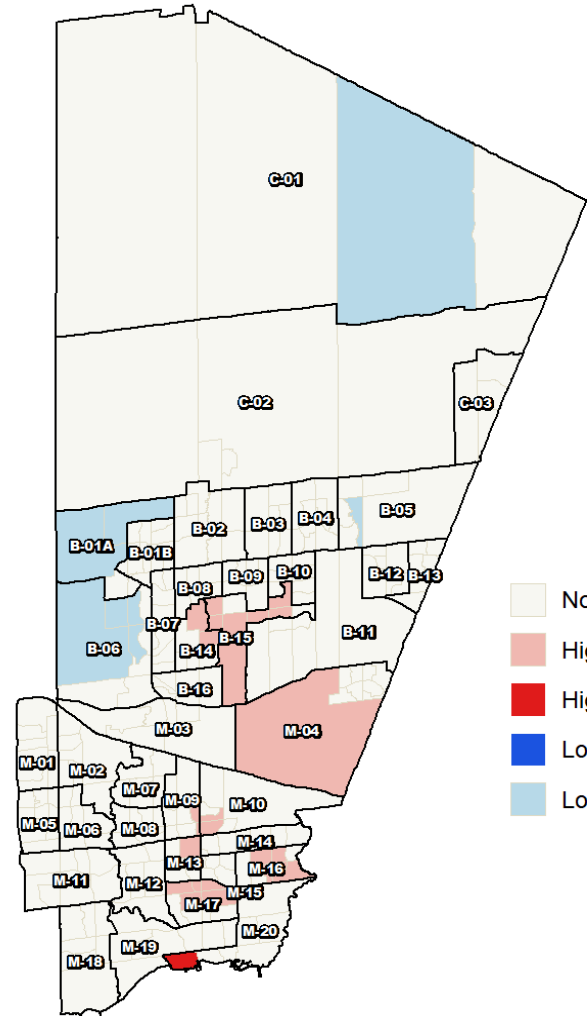


- Quintile 1 - Least Vulnerable
- Quintile 2
- Quintile 3
- Quintile 4
- Quintile 5 - Most Vulnerable
- Peel Health Data Zones

Lower
Vulnerability



Greater
Vulnerability



- Not Significant
- High-High Cluster
- High-Low Outlier
- Low-High Outlier
- Low-Low Cluster

HVI Dashboard

Heat Vulnerability Index

Municipality
Select a municipality

Peel Health Data Zones
Select a data zone(s)

Census Tracts
Select a census tract(s)

Heat Vulnerability Index (HVI)

The climate in Canada is changing. Variable weather patterns, extreme heat, and increased precipitation are all impacting Canadians. The extent of the impacts will vary depending on geographic and demographic characteristics of the population, for example the degree of exposure to climate hazards, sensitivities contributing to increased risk, and the ability to adapt to a changing climate.

The region of Peel, one of the largest municipalities in Ontario, is home to over 1.5 million people. Peel is comprised of a culturally and socio-economically diverse population, with five percent growth between 2016 and 2021. The senior's population, those over 65 years of age, are the largest and fastest growing age group in Peel, introducing unique risks associated with the health impacts of climate change.

Temperatures throughout Peel have been slowly increasing, with annual mean temperatures rising from 8.1°C in 1938 to 9.3°C by 2017. The most significant increases occurring in the summer and winter.

The purpose of the HVI is to identify and visualize areas of greater vulnerability to heat in Peel, with the goal of reducing risk, morbidity, mortality, and supporting emergency responses.

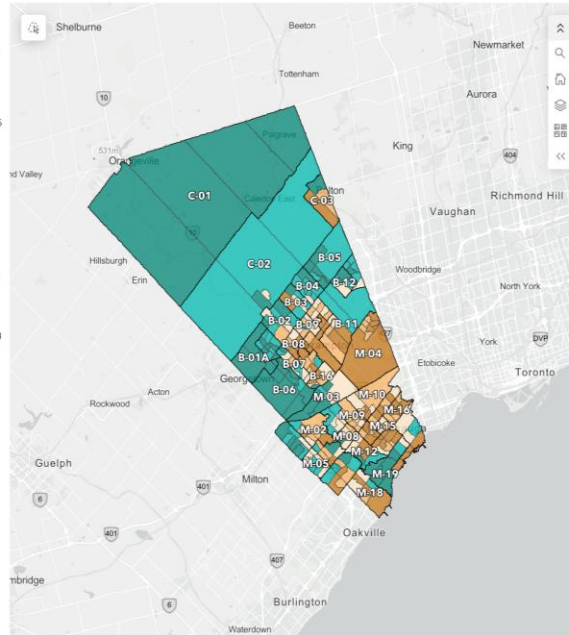
The HVI is a composite index displayed using quintiles. Quintiles reflect increasing risk to the population as values increase from one to five.

Heat Vulnerability Index

Heat Vulnerability Index - Quintile

- Quintile 5 (Increased Risk)
- Quintile 4
- Quintile 3
- Quintile 2
- Quintile 1 (Decreased Risk)

Heat Vulnerability Index



Census Tract Insights

5350500.01 | M-20

The **Heat Vulnerability Index (HVI)** was developed to identify area-level characteristics related to adaptive capacity to mitigate heat risk, heat exposure, and sensitivity to heat, using available sociodemographic, exposure, and health status data. Higher quintile values indicate greater vulnerability due to heat, and heat related events.

Quintile - 5 (Very High)

Adaptive capacity refers to the ability of individuals, communities, or systems to adjust to, mitigate, and cope with the consequences of heat related events. It plays a crucial role in determining how vulnerable a population is to heat-related risks. Key aspects include community and individual supports, adequate housing and economic stability.

Quintile - 5 (Very High)

Exposure refers to the degree to which individuals or communities are exposed to extreme heat conditions. Key aspects include the surface temperature, the density and health of vegetation, and the presence of tree canopy cover. Trees and vegetation provide shade, which reduces the amount of solar radiation reaching the ground and buildings, lowering ambient temperatures

Quintile - 1 (Very Low)

Sensitivity refers to the degree to which individuals, communities, or systems are affected by exposure to heat related events. Key aspects include demographics (older and younger populations are more impacted) and pre-existing health conditions that can worsen during heat events. Health conditions included in this index are cancer, heart disease, and respiratory disease

Quintile - 5 (Very High)

Heat Vulnerability Index

 **3.0**
Average

Adaptive Capacity
 **3.0**
Average

Exposure
 **3.0**
Average

Sensitivity
 **3.0**
Average

Find the HVI maps here <https://peelregion.ca/health/health-status-data/peel-health-data-zone-information-tool> under the "Heat Vulnerability Index" tab.

Additional Analyses

- Compare social determinants with heat vulnerability.
- Identify disproportionate representation.
- Support targeted planning and interventions to reduce inequities.

Limitations and reflections

Limitations of area-based indices

- Ecological fallacy
- Modified area unit problem

Reflections on the maps and analysis

- What are the intended uses of these maps and analysis?

Public Health Applicability



Applicability

Support planning
and
program/policy
development.

Increase
understanding of
neighbourhood
specific needs.

Development of an
all-hazards climate
change emergency
plan.

Collaboration
across public
health, broader
organization and
community
partners

Application
support.

Heat Vulnerability Index and Peel Living Buildings

Census Tracts

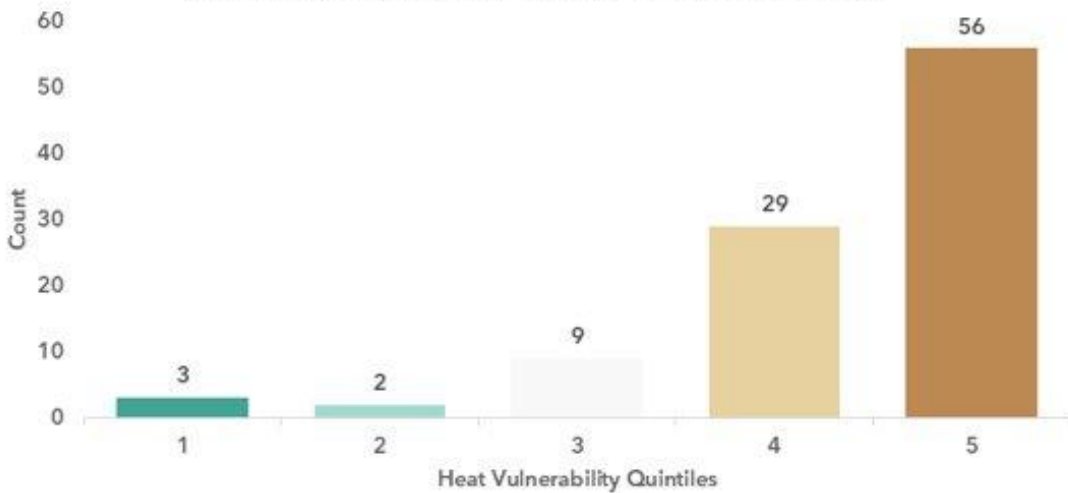


Heat Vulnerability Index - Quintiles

- Quintile 1 (Least Vulnerable)
- Quintile 2
- Quintile 3
- Quintile 4
- Quintile 5 (Most Vulnerable)
- Peel Living Buildings

Prioritization of Climate Retrofits in Peel Buildings

Peel Living Buildings by Heat Vulnerability Index Quintile



Lower risk Greater risk

Acknowledgements

- David Guillette, GIS Specialist
- Elena Galatsis, Health Analyst
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- Greg Kujbida, Program Manager
- Jessica Mammone, Analyst
- Louise Aubin, Director
- Lydia Cheng, Epidemiologist
- Maureen Horn, Program Manager
- Meagan Temporale, Advisor
- Monali Varia, Director
- Nicholas Brandon, AMOH

References

1. Statistics Canada. 2021 Census
2. Wilton D, Diong C, Paterson M. Climate Change Vulnerability Assessment through Principal Component Analysis and Data Mapping by Census Tracts in Peel Region, Applied Health Research Question (AHRQ) #2024 0950 156 000. Toronto: Institute for Clinical Evaluative Sciences; 2023.
3. Metrics of land surface temperature, indexed to DMTI Spatial Inc. postal codes were provided by CANUE (Canadian Urban Environmental Health Research Consortium). References: [1] Setton, E; Redivo A. (2022). Three-year warm-season maximum land surface temperature from LandSat 8. Developed for the Canadian Urban Environmental Health Research Consortium. [2] Osei, Edwin (2022). Google Earth Engine code for calculating LST using LandSat 8. Computer code, posted on Stack Exchange April 22, 2022. [3] CanMap Postal Code Suite [compute file] DMTI Spatial Inc,. various years.
4. Peel Data Centre
5. NDVI values for Peel were determined using the NDVI Function (ArcGIS Pro 2.9.9) and the red band (Band 4) and near-infrared (NIR) band (Band 5) from Landsat imagery (USGS, July 13, 2021). The mean NDVI value for each census tract in Peel was extracted using the Zonal Statistics function (ArcGIS Pro 2.9.9)

Data Sources

Institute for Clinical Evaluative Sciences (IC/ES)

- Wilton D, Diong C, Paterson M. Climate Change Vulnerability Assessment through Principal Component Analysis and Data Mapping by Census Tracts in Peel Region, Applied Health Research Question (AHRQ) #2024 0950 156 000. Toronto: Institute for Clinical Evaluative Sciences; 2023.

The Canadian Urban Environmental Health Research Consortium (CANUE)

- Setton, E; Redivo A. (2022). Three-year warm-season maximum land surface temperature from LandSat 8. Developed for the Canadian Urban Environmental Health Research Consortium.
- Osei, Edwin (2022). Google Earth Engine code for calculating LST using LandSat 8. Computer code, posted on Stack Exchange April 22, 2022.
- CanMap Postal Code Suite [compute file] DMTI Spatial Inc., various years

Peel Data Centre

- PDC, 2021, Tree Canopy (% of CT with tree canopy cover), accessed September 2023.

United States Geological Survey (USGS)

- U.S. Geological Survey, 2021, Landsat Normalized Difference Vegetation Index: U.S. Geological Survey database, accessed September 2023, at <https://www.usgs.gov/landsat-missions/landsat-normalized-difference-vegetation-index>.

Statistics Canada Census Data (2021)

- Statistics Canada. (2021). Family Characteristics: Living Alone
- Statistics Canada. (2021). Household Characteristics: Renter
- Statistics Canada. (2021). Low income and income inequality in 2020: Prevalence of low income based on the Low-income measure, after tax (LIM-AT) (%)

Food Environment Analyses

- The total number of food retailers included in the analysis increased 26% (4,360 in 2025 and 3,730 in 2019) but the number of records included as a percentage of the food inspector database was stable (80.1% in 2025 and 81.0% in 2019)
- Modified Retail Food Environment Index (unadjusted and adjusted) remained stable across Peel between periods (84.9% in 2025 and 85.4% in 2019). Decreases were observed in Mississauga and Brampton, with a slight increase was observed in Caledon.
- Restaurants market share grew 5.7% (687 new locations) with limited-service restaurants accounting for 560 of these locations. With hybrid, fast food, and beverage and treat retailers being the most common.

Change in food retail by type

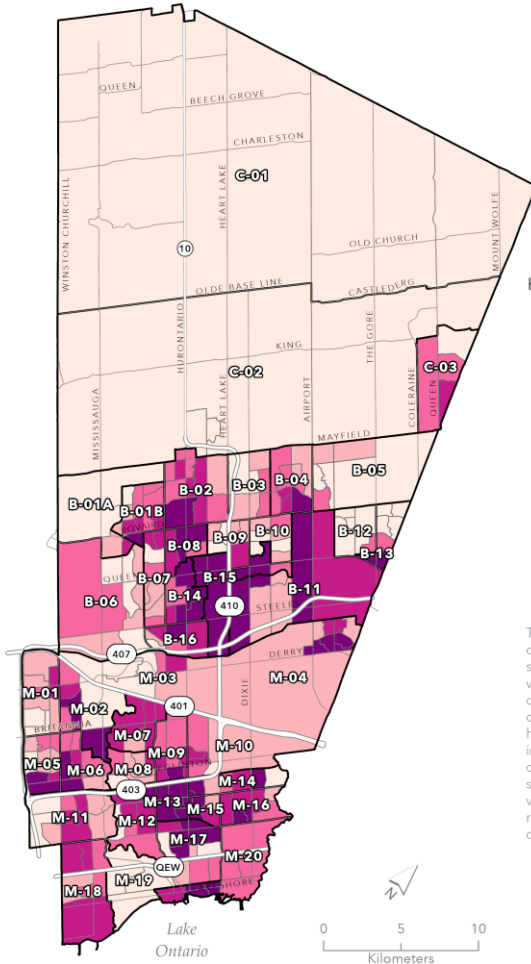
Retail Food Outlets	Peel		Mississauga		Brampton		Caledon	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
All Retailers	630	-	320	-	258	-	52	-
Restaurant	687	5.7%	373	5.6%	270	6.1%	44	5.3%
Full Service Restaurant	127	-0.2%	86	0.4%	31	-1.0%	10	-1.9%
Limited Service Restaurant	560	5.9%	287	5.2%	239	7.1%	34	7.2%
Beverage and Treat	140	2.5%	98	3.1%	37	1.7%	5	0.6%
Fast Casual	57	-0.8%	11	-1.6%	41	0.3%	5	0.2%
Fast Food	161	0.8%	78	0.7%	72	0.9%	11	1.5%
Hybrid	202	3.5%	100	2.9%	89	4.2%	13	4.9%
Store	- 57	-5.7%	- 53	-5.6%	- 12	-6.1%	8	-5.3%
Food Store	150	1.6%	67	1.0%	69	2.2%	8	0.7%
Grocery Store	88	1.3%	36	0.8%	49	2.1%	3	0.8%
Supermarket	2	-0.3%	6	0.0%	4	-0.6%	-	-0.5%
Specialty	54	0.4%	25	0.2%	24	0.8%	5	0.4%
Whole Foods	28	0.2%	13	0.1%	13	0.4%	2	-0.6%
Desserts	15	0.2%	7	0.1%	7	0.2%	1	0.3%
Other	11	0.1%	5	0.0%	4	0.1%	2	0.6%
Variety Store	1	-1.7%	19	-2.1%	12	-1.5%	8	-0.6%

Change in adjusted density by retail by type

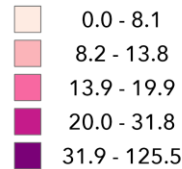
Density (Population Weighted)	Peel		Mississauga		Brampton		Caledon	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
All Retailers	19.1	-	25.1	-	14.5	-	6.0	-
Restaurant	15.3	8.4%	20.5	9.2%	11.0	6.1%	4.5	8.7%
Full Service Restaurant	3.6	0.6%	5.1	0.5%	2.2	-0.2%	1.4	-0.5%
Limited Service Restaurant	11.7	7.8%	15.3	8.4%	8.9	6.8%	3.0	8.1%
Beverage and Treat	2.1	3.0%	3.4	4.8%	1.0	0.3%	0.6	4.4%
Fast Casual	2.5	-1.0%	3.5	-1.0%	1.8	-0.2%	0.4	-2.5%
Fast Food	4.2	0.8%	5.4	1.7%	3.6	1.1%	1.1	0.7%
Hybrid	2.7	4.3%	3.1	3.2%	2.5	5.7%	0.9	5.5%
Store	3.9	-7.6%	4.6	-9.2%	3.5	-6.1%	1.5	-8.7%
Food Store	3.4	3.1%	4.1	1.7%	2.7	3.8%	1.0	1.9%
Grocery Store	1.7	1.5%	2.0	1.3%	1.5	2.2%	0.3	1.0%
Supermarket	0.3	-0.5%	0.5	0.0%	0.2	-0.3%	0.1	-1.2%
Specialty	1.3	1.3%	1.8	1.2%	0.9	1.5%	0.7	3.8%
Whole Foods	0.7	0.6%	0.8	0.0%	0.6	1.7%	0.3	0.7%
Desserts	0.4	0.6%	0.7	1.0%	0.2	0.0%	0.1	1.1%
Other	0.3	0.2%	0.4	0.3%	0.1	-0.1%	0.3	3.2%
Variety Store	1.6	-2.9%	1.6	-3.7%	1.8	-0.8%	0.8	-0.3%

Retail Food Environment - Density (Less Healthy)

Census Tracts - 2021



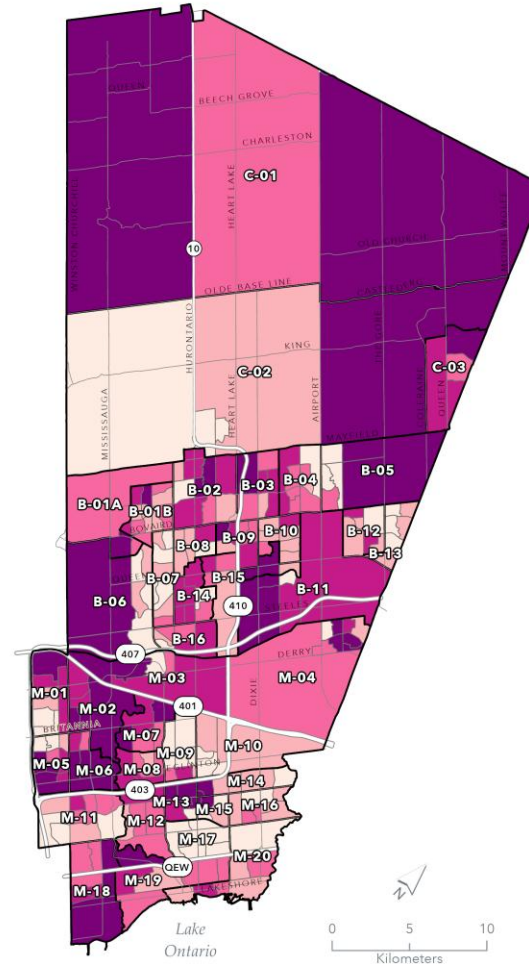
Population-weighted count of less healthy food retailers within 1,000m of dissemination blocks, aggregated to census tract level.



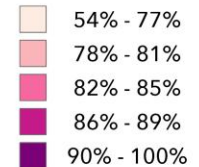
This map shows the population-weighted density of less healthy food retailers—specifically limited-service restaurants and variety stores—within a 1,000-meter radius of dissemination blocks, aggregated to the census tract level. Darker shades represent higher densities of these retailers, indicating areas with greater concentration of less healthy food options, while lighter shades indicate lower densities. This visualization highlights spatial patterns of retail food environments that may influence dietary behaviors and health outcomes.

Modified Retail Food Environment - Less Healthy

Census Tracts - 2021



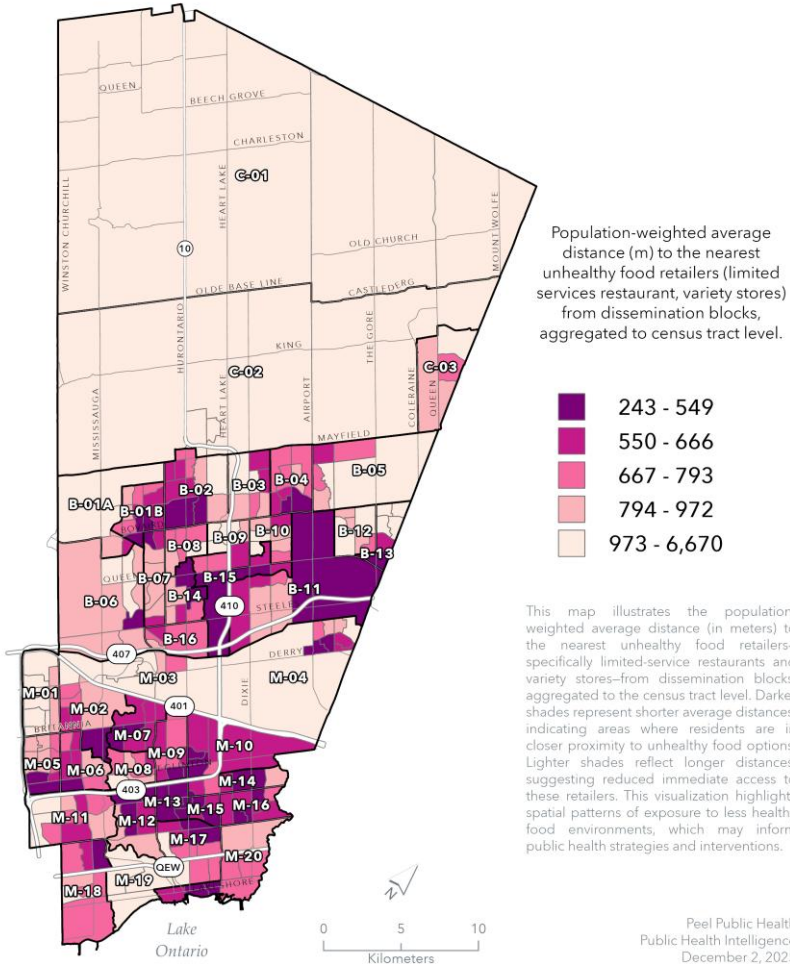
Population-weighted Modified Retail Food Environment Index (mRFEI) for less healthy food retailers within 1,000m of dissemination blocks, aggregated to census tract level.



This map illustrates the population-weighted Modified Retail Food Environment Index (mRFEI) for less healthy food retailers (limited-service restaurants and variety stores) within a 1,000-meter radius of dissemination blocks, aggregated to the census tract level. Darker shades represent areas with a higher concentration of these less healthy retailers relative to population, indicating environments with greater exposure to unhealthy food options. Lighter shades indicate lower concentrations, suggesting relatively healthier retail food environments. This visualization helps identify spatial patterns that may influence dietary behaviors and inform public health interventions.

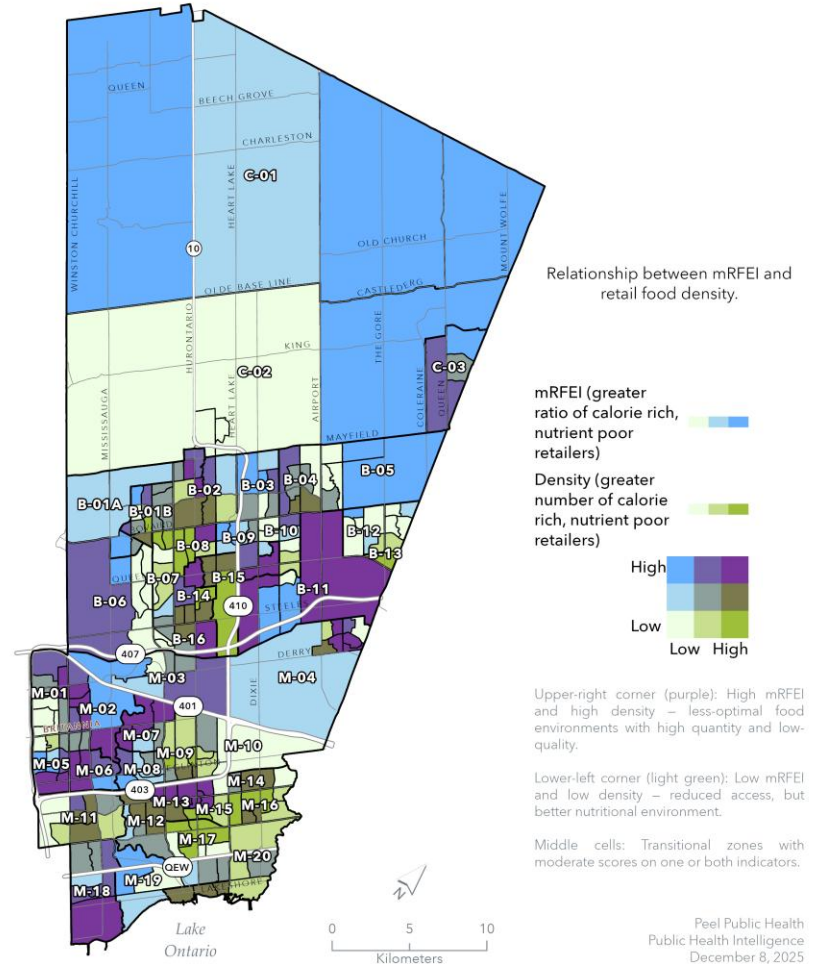
Retail Food Environment - Proximity (Less Healthy)

Census Tracts - 2021



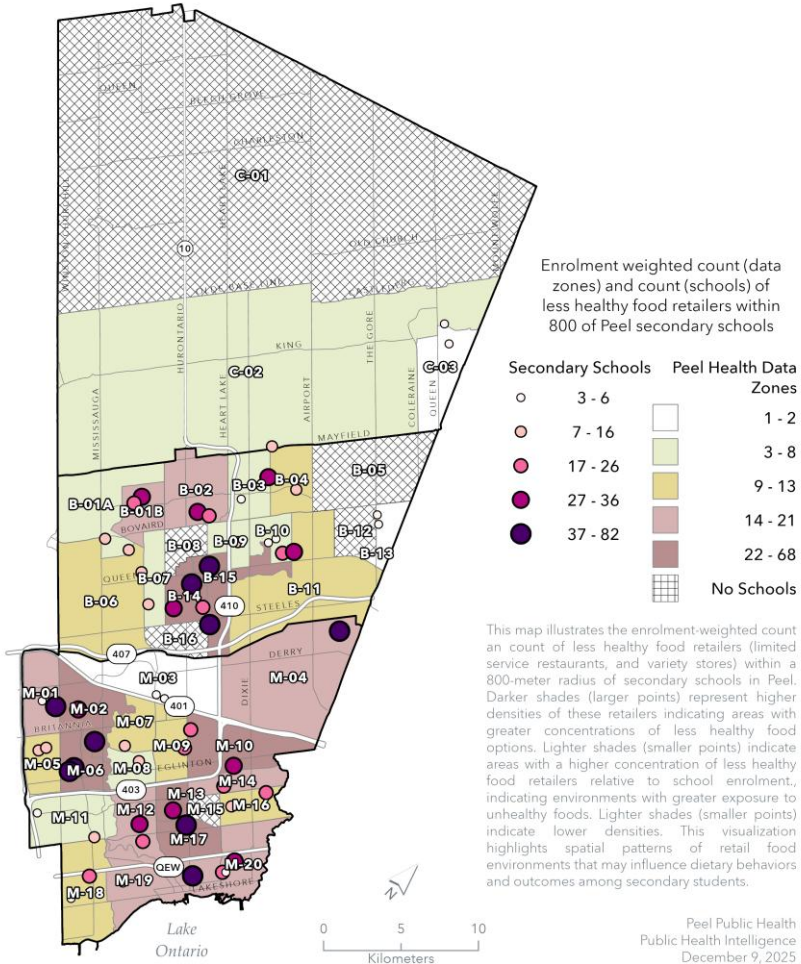
Relationship Between Modified Food Retail Environment Index (mRFEI) and Food Retail Density

Census Tracts - 2021



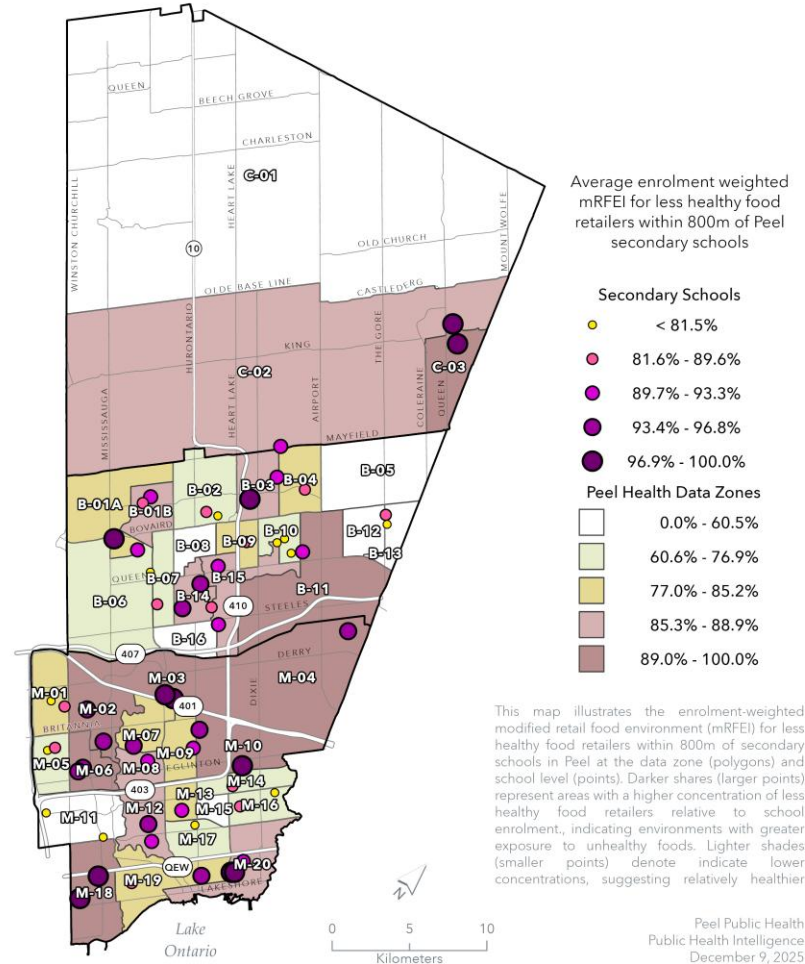
Retail Food Environment - Density (Less Healthy)

Secondary Schools, Peel Health Data Zones - 2021



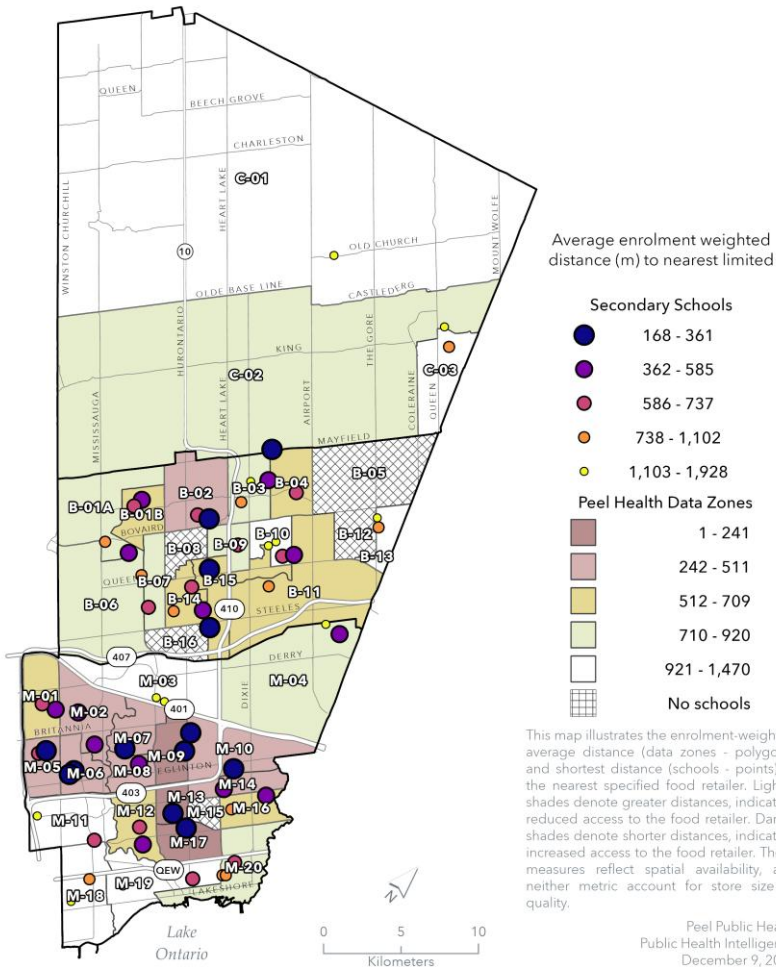
Modified Retail Food Environment Index (mRFEI) - Less Healthy

Secondary Schools, Peel Health Data Zones - 2021



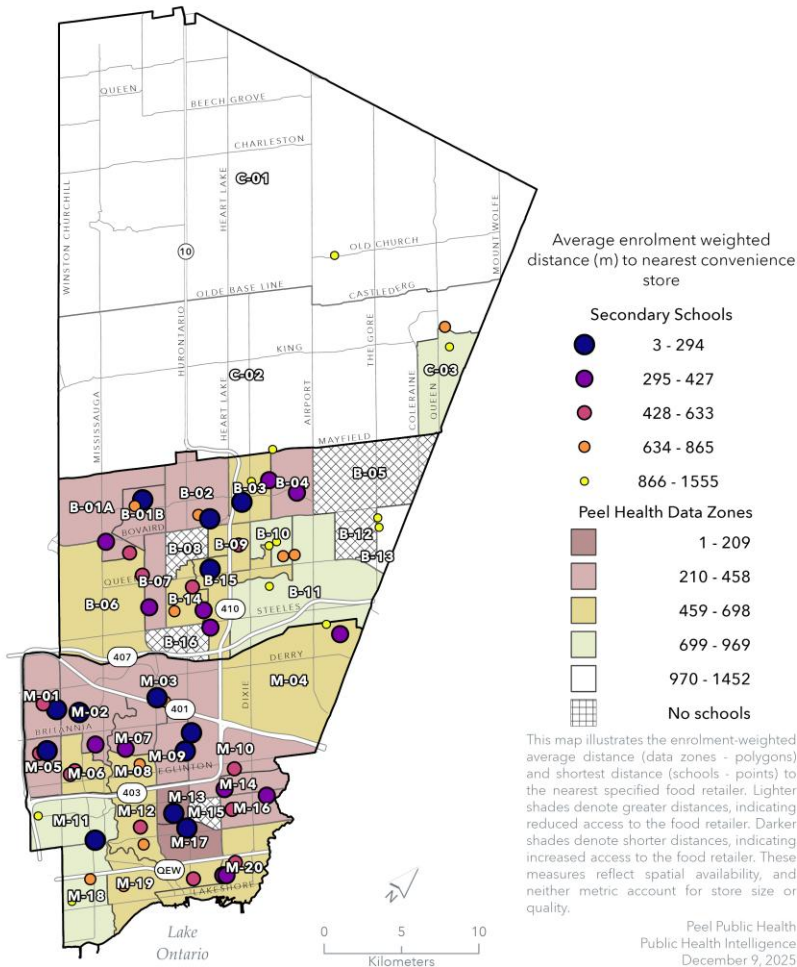
Proximity to Limited-Service Restaurants from Secondary Schools in Peel

Secondary Schools, Peel Health Data Zones - 2021



Proximity to Convenience Stores from Secondary Schools in Peel

Secondary Schools, Peel Health Data Zones - 2021



Next steps

- Co-op student from Dalla Lana School of Public Health will explore links between the food environment and diabetes incidence and prevalence rates at the census tract level to evaluate significant trends in Peel using spatial regression analysis.
- Create a story map to highlight these finds and share with internal and external partners.

Thank you.

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