The Food Environment Surrounding Vancouver Schools

Associations of Access to Food Outlets and Children's Intake of Minimally Nutritious Foods At or En-Route to School

by

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Abstract

Background: Canada has seen a dramatic increase in the prevalence of childhood obesity in recent decades. Researchers have argued that this problem could be addressed through improvements to the "food environment"—the food vendors comprised in the built environment. Children's diets are poorer in nutritional quality during school hours, suggesting that the food environments surrounding schools may be an important area of inquiry.

Objectives: This thesis sought (1) to identify the best available data set for assessing the distributions of food outlets in Vancouver, (2) to characterize the food environments surrounding Vancouver public schools, testing for demographic or socioeconomic disparities in access and (3) to examine the associations between school food environments and the dietary intakes of children and adolescents at- or en-route to school.

Methods: Food outlet data were obtained from two municipal and two commercial sources and validated against primary data on the food outlets located within 800m of 26 schools. Outlet density and proximity to Vancouver schools (n=113) were evaluated with the best performing data set; negative binomial regression models examined whether disparities existed in environments according to % aboriginal students, % English Language Learners, and school poverty, controlling for neighbourhood-level factors. Multilevel logistic regression analyses evaluated the associations of school food environment measures and 950 children's odds of daily consumption, at or en-route to schools (n=26), of minimally nutritious foods.

Results & Conclusions: The City of Vancouver Business Licenses data had the highest sensitivity (0.69) and positive predictive value (0.55). High-poverty schools had more convenience stores within 400m than low-poverty schools, even after controlling for commercial density and neighbourhood socioeconomic deprivation (IRR=1.74, 95% CI 1.003 - 3.032); no robust statistically significant relationships were identified between school food environments and school-level demographic factors. No consistent associations were identified between school food environment measures and students' intakes of minimally nutritious foods. The findings do not support policies to reduce student access to food outlets near schools.

Preface

This thesis is my original work, completed under the supervision of Dr. Jennifer Black with the guidance of committee members Carol McAusland and Nadine Schuurman. I designed and implemented the ground-truthing protocol used in this study in collaboration with Dr. Cayley Velazquez, and both Dr. Velazquez and Koharu Loulou Chayama assisted in the collection of primary food outlet location data. I analyzed the data and wrote the thesis independently with guidance from Dr. Jennifer Black and the members of my supervisory committee.

The project was a component of the Food Practices on School Days Study, which was overseen by Dr. Jennifer Black and Dr. Gwen Chapman. The third component of this thesis, the study of students' dietary intakes, relied on data from classroom surveys designed and conducted by Naseam Ahmadi, Teya Stephens, and Dr. Cayley Velazquez with the supervision of Dr. Jennifer Black and Dr. Gwen Chapman.

The procedures for the Food Practices on School Days Study were approved by the Behavioural Research Ethics Board of the University of British Columbia (certificate number H11-01369); in addition, sampling and data collection within Vancouver public schools received permission from the Vancouver School Board.

Table of Contents

Appendices

List of Tables

List of Figures

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To Pam and Ueli

Chapter 1

Introduction

Canadian children are failing to meet the dietary intake guidelines of the 2007 Canada's Food Guide. In 2004, the most recent iteration of the nationwide Canadian Community Health Survey, a majority of Canadian teenagers failed to meet the Guide's minimum recommended daily number of fruit and vegetable servings (Black and Billette, 2013). Among adolescents ages 14-18, 53% of boys and 35% of girls consumed a soft drink during the day prior to the survey (Garriguet, 2008), and over 80% of girls and 90% of boys were estimated to have a daily sodium intake high enough to increase the risks of hypertension and other health consequences (Garriguet, 2007). These dietary intake patterns likely contribute to Canada's high prevalence of diet-related disease: nearly a third of 5- to 17-year-old children were classified as overweight (19.8%) or obese (11.7%) in the 2009-2011 Canadian Health Measures Survey (Roberts et al., 2012).

Researchers and public health practitioners have argued that improvements to the "food environment"—the grocery stores, restaurants, and other food sources comprised in an area's built environment—could help mitigate the rise of obesity (Morland et al., 2002; Papas et al., 2007; Brownell and Horgen, 2004; Black and Macinko, 2008). While many factors likely contribute to diet-related disease, studies have reported desirable diet-related health outcomes for people living in census tracts with grocery stores or supermarkets, as compared to those with more limited access (Morland et al., 2002, 2006; Morland and Evenson, 2009) and higher obesity rates as well as lower diet quality for people with high access to convenience stores or fast food restaurants, as compared to those with less easy fast- and snack food access (Morland and Evenson, 2009; Maddock, 2004; Rummo et al., 2014).

In recent years, researchers have begun to examine the food environment surrounding schools. In the United States, 1 in 3 schools is located within walking distance (approximately 800 metres) of a convenience store or fast food outlet (Zenk and Powell, 2008), and a majority of public schools in British Columbia are located within walking distance of a fast food outlet, snack food outlet, convenience store, or deli (Black and Day, 2012). A number of studies have found that higher access to fast food restaurants or convenience stores at school is associated with creased dietary quality among students (He et al., 2012b; Laska et al., 2010; Davis and Carpenter, 2009), but several studies have produced conflicting results (An and Sturm, 2012; Gebremariam et al., 2012; Van Hulst et al., 2014; Richmond et al., 2013).

The Canadian school food environment may have a particularly strong impact on students' diets. Canada is the only G8 country without a federal school lunch program: while provincial and municipal programs and ad-hoc charity efforts offer lunches in some Canadian schools, a dearth of subsidized school cafeterias leaves many students particularly susceptible to the wares of nearby food vendors. Despite this unique policy context, research on the effects of the Canadian school food environment remains limited.

Several studies have examined the associations of Canadian students' access to food retailers and obesity (Seliske et al., 2009a; Héroux et al., 2012; Leatherdale et al., 2011) or food purchasing behaviours (Seliske et al., 2013; He et al., 2012a; Héroux et al., 2012), but few researchers have looked at the associations between food environment measures and Canadian children's school-day dietary behaviours (Laxer and Janssen, 2013; He et al., 2012b)

This study sought to fill the gap in Canadian school food environments research through an examination relating school food environments and the dietary behaviours of schoolchildren in Vancouver, BC. The study examined the associations between food outlet locations near schools and the school-day food intake of 950 5th – 8th grade students across 26 public schools. The objectives of the study were (1) to validate commonly used data sources for the school food environment, (2) to examine disparities in the food environments surrounding schools according to school-level demographic and socioeconomic characteristics, and (3) to assess the relations between measures of the school food environment and students' self-reported intake, at- or en-route to school, of minimally nutritious foods or beverages.

1.1 Literature Review

1.1.1 The Food Environment and Obesity

Duke professor Kelly Brownell and clinical psychologist Katherine Horgen were among the first researchers to address the role of the environment in the rise of adult obesity. In their book *Food Fight: The Inside Story of the Food Industry, America's Obesity Crisis, and What We Can Do About It*

(2004), Brownell and Horgen argue that the food environment has become "toxic". That is, the disappearance of neighbourhood produce outlets coupled with the proliferation of fast-food restaurants has, according to Brownell and Horgen, created a world in which it is far easier to consume fat- and calorie-laden happy meals than to maintain a healthful diet.

Race, Poverty and Food Access

Much of the empirical research relating food environments and dietary intake has focused on the relationship of poverty or race and access to food stores. Researchers Kimberly Morland, Steve Wing, and Ana Diez Roux conducted a pioneering study associating food frequency questionnaire (FFQ) responses from the Atherosclerosis Risk in Communities Study, stratified by race, with counts of supermarkets, fast-food restaurants, and convenience stores near study participants' residences (Morland et al., 2002). The study found only weak relations between diet and food outlet access for white Americans—but for black Americans, access to a supermarket predicted a significant increase in fruit and vegetable intake and access to a full-service restaurant predicted a significant increase in saturated fat intake. In addition, the researchers reported that black Americans faced significant constraints to supermarket access, suggesting that the food environment may contribute to the disparities in diet-related health commonly reported in U.S. health assessments (Braveman et al., 2010).

In the decade following Morland, Wing, and Diez-Roux's seminal work, more studies have uncovered racial and socioeconomic disparities in food access in the United States (Morland, 2015). In a systematic review of fast food access studies, Fleischhacker et al. (2011) found strong evidence of a relationship between the prevalence of fast food restaurants and neighbourhood socioeconomic status, with most studies finding more outlets in low-income areas. The researchers also found systematic evidence of a higher prevalence of fast food restaurants in association with higher concentrations of non-white racial and ethnic groups in the United States. However, only limited research has been conducted relating race or ethnicity and food access outside of the United States (Fleischhacker et al., 2011), and existing studies offer equivocal results: In Edmonton, Canada, for example, a higher aboriginal population was associated with a higher odds of fast food exposure at the neighbourhood level—but no significant associations were identified between visible minority or immigrant populations and fast food exposure (Smoyer-Tomic et al., 2008).

The associations of socioeconomic status and food outlet access are similarly inconsistent outside of the United States. In particular, researchers searching for socioeconomically disadvantaged neighbourhoods lacking supermarkets and grocery stores ("food deserts") were largely able to identify such areas in the United States, but studies conducted in other countries have produced mixed results (Beaulac et al., 2009). In Canada, one study found fewer well-stocked stores in low-income versus high-income areas (Latham and Moffat, 2007), but another study found mixed results (Smoyer-Tomic et al., 2006), and a Montreal study actually identified more supermarkets in low-income areas (Apparicio et al., 2007).

Current Evidence Associating Food Environments and Obesity

Examining associations of food access and obesity, researchers have reported lower obesity rates among groups living in census tracts with supermarkets (Morland et al., 2006; Morland and Evenson, 2009) and individuals who reported shopping for groceries within their census tracts (Inagami et al., 2006), as compared with groups living in supermarket-free tracts or going elsewhere to shop. In contrast, likelihood of obesity has been found to correlate positively with access to convenience stores (Morland et al., 2006; Bodor et al., 2010) small grocery stores (Morland and Evenson, 2009; Gibson, 2011), and fast food restaurants (Morland and Evenson, 2009; Maddock, 2004; Dunn, 2010; Bodor et al., 2010; Dubowitz et al., 2012). A number of studies, however, have reported inconsistent or no significant relationships between food environment measures and obesity rates (Burdette and Whitaker, 2004; Simmons et al., 2005; Sturm and Datar, 2005; Jeffery et al., 2006; Block et al., 2011; Li et al., 2008; Ford and Dzewaltowski, 2011; Hickson et al., 2011), and a recent systematic review found a large proportion of null results in studies associating food environment measures and obesity, even after accounting for study quality (Cobb et al., 2015).

Reviewing studies focused on diet, rather than obesity, Caspi et al. (2012) find "moderate" evidence that neighbourhood food environments influence dietary health. The researchers note, however, that more consistent associations were found with perceived measures of food retailer access and food availability in comparison with measures from Geographic Information Systems (GIS) of distance to retailers. At present, researchers have not attained a consensus regarding the effect of the food environment on the diet-related health of adults (Caspi et al., 2012; Cobb et al., 2015).

Results are similarly equivocal for studies focused on children and adolescents. Cobb et al. (2015), reviewing 21 studies of obesity in children and food retailer access, find some evidence that increased convenience store access is associated with increased obesity, but mixed results for associations between fast food outlet access and obesity in children as well as mostly null results for associations between supermarket access and obesity in children. It is possible that the association of obesity and the food environment is hidden by confounding factors at the neighbourhood level: examining the associations of the food environment and diet, rather than obesity, Engler-Stringer et al. (2014a) found “moderately strong evidence” that food environments played a role in children’s dietary behaviours.

1.1.2 School Food Environments

The school food environment is of particular interest because the area surrounding schools demarcates a region where children may have more autonomy to make their own dietary decisions. There is fairly consistent evidence, from studies in the U.S. and Canada, that a large proportion of schoolchildren have access to a food outlet near their schools: Zenk and Powell (2008) found that at least one in three U.S. schools was located within walking distance of a fast food restaurant or convenience store. In British Columbia, over half of schools are estimated to be located within walking distance of at least one fast food restaurant, convenience store, or similar limited-service food outlet (Black and Day, 2012).

Spatial clustering analyses conducted with data from Chicago and New Zealand have yielded evidence that the prevalence of restaurants near schools is unlikely to be the product of random chance (Austin et al., 2005; Day and Pearce, 2011). However, researchers in Germany found that relaxing the assumption of a constant probability surface across the study area—that is, recognizing that food outlets are more likely to be located in some areas of a city rather than others—led to no significant evidence of clustering around schools (Buck et al., 2013).

Some researchers have also suggested that attributes of schools may correlate with student exposure to food outlets. Most research comes from the United States, where studies suggest that there are more "unhealthy" outlets—fast food restaurants, convenience stores, or other outlets selling energy-dense foods—within walking distance of high schools versus elementary schools (Simon et al., 2008; Neckerman et al., 2010), larger versus smaller schools (Zenk and Powell, 2008), schools with higher versus lower proportions of low-income students (Sturm, 2008; Neckerman et al., 2010), and schools with higher proportions of black or hispanic students in comparison with schools with more white students (Sturm, 2008; Kwate and Loh, 2010; Neckerman et al., 2010). The handful of Canadian studies that have examined school food environments have mostly focused on associations with school- or neighbourhood-level poverty, finding more fast food outlets or convenience stores near low-income schools or schools in low-income neighbourhoods (Black and Day, 2012; Robitaille et al., 2010; Engler-Stringer et al., 2014b; Kestens and Daniel, 2010); the lone study examining ethnicity did not find significant associations between the school food environment and neighbourhood demographic characteristics (Engler-Stringer et al., 2014b).

However, area-level factors may confound differences in access between areas with and without schools: Neckerman et al. (2010), examining school food environments in New York City, found that many of the significant associations between school-level demographic or socioeconomic factors disappeared when built environment factors were included in the analyses. Similarly, Kestens and Daniel (2010), studying the distribution of food outlets surrounding schools in Montreal, found higher food outlet density in low- and middle income areas as compared with high income areas—but controlling for commercial density accounted for much of the difference. In British Columbia, Black et al. (2011) found that a majority of the variation in food outlet density could be accounted for by urban planning factors.

School Food Environments and Children's Diets

Researchers have begun to examine the potential of school food environments to contribute to rates of obesity, food purchasing behaviours, and dietary behaviours among schoolchildren. A California study found that middle and high school students whose schools were located near a fast food restaurant consumed fewer fruits and vegetables, drank more sugar-sweetened beverages, and had a higher likelihood of obesity than students without easy store access (Davis and Carpenter, 2009); another California study found significant and positive associations between obesity and 9th grade students' access to fast food outlets (Currie et al., 2010); however, a third study in the state found no significant relationship (An and Sturm, 2012).

Two studies of open-campus policies, which allow students to leave grounds during the school day, produced similarly conflicting results: Forsyth et al. (2012) found no significant association of open campus policies and student fast food consumption, but Neumark-Sztainer et al. (2005) found that open campus policies were associated with students eating more lunches at fast food restaurants. Outside of the U.S., a study conducted in Australia found no significant associations of food availability and children's diets (Timperio et al., 2009), while a study from the United Kingdom found that proximity to outlets with takeaway food was predictive of less healthy diets (Smith et al., 2013). In a recent systematic review, Williams et al. (2014) found limited evidence for an association between the food environment surrounding schools and students' dietary intakes, although evidence was stronger for an association between the school food environment and body weight.

In Canada, several published studies have examined the associations of food outlet locations near schools and childhood obesity or children's dietary behaviours (Seliske et al., 2009a, 2013; Laxer and Janssen, 2013; He et al., 2012b,a; Héroux et al., 2012; Leatherdale et al., 2011). In 2009, Seliske et al. found that food outlet density within 1 and 5 km of Canadian schools was not associated with increased levels of overweight or obesity in students. Revisiting the topic in 2013, the researchers found that food outlet density within 1km of Canadian schools was positively correlated with student likelihood of eating lunch at a food store or restaurant (Seliske et al., 2013). Laxer and Janssen (2013), in a national-level study looking just at students who lived within 1km of their school, similarly found a modest positive relationship of outlet density and the proportion of youth eating fast food two or more times per week. Finally, Héroux et al. (2012) observed that the density of chain food outlets surrounding schools was positively associated with Canadian children's odds of eating lunch at a food retailer.

Studies at the municipal or provincial level have also identified associations between the food environment and obesity, diet, and food purchasing behaviours in Canadian children. Although Gilliland et al. (2012) found inconsistent associations between children's BMIs and the number of fast food outlets or convenience stores within 500 or 1000 metre buffers of schools in London, Ontario, Leatherdale et al. (2011) found that Ontario students with more fast food retailers or more grocery stores surrounding their schools were more likely to be overweight than comparable students with more limited access to food outlets. Additionally, in two studies conducted with 7th and 8th grade students in London, Ontario, researchers found statistically significant associations of both the home and school food environment and Healthy Eating Index (HEI) scores (He et al., 2012b) or fast food purchasing (He et al., 2012a). In the former study, students living more than 1 km from a fast food restaurant had a 1.1 point increase in HEI scores, while students attending school more than 1 km from a fast food restaurant had a 2.6 point increase in HEI scores (both models controlled for gender, grade, and neighbourhood distress); in the latter, having 1-2 fast food restaurants, rather than zero, within 1km of a student's residence was associated with 1.6 times the purchasing of fast food at least once weekly, while having fast food restaurants within 1km of a student's school was associated with an odds ratio of 1.4 for the same outcome. It follows that the effect of the school food environment on children's diets could be greater than that of the home food environment—but the increased ease of fast food purchasing may not be the mechanism that amplifies this effect.

1.1.3 Gaps in the Existing Literature

City-Level Studies in Canada

Despite the proliferation of food environments studies, there are many gaps in the existing literature. Most notably, no study has been conducted relating school food environments and dietary outcomes in a major Canadian city, even though 35% of Canada's residents live in Toronto, Montreal, or Vancouver (Statistics Canada, 2011). This lack of empirical attention is particularly surprising given Canada's lack of a federal school lunch program, which may leave students more susceptible to the effect of the food environment.

Concerns Regarding Data Quality

Poor data quality may contribute to the conflicting results obtained in food environments research. Researchers commonly rely on data sources designed for commercial rather than academic purposes (Moore and Diez-Roux, 2015; Cobb et al., 2015), and recent evidence suggests that poor specificity and moderate positive predictive value for such datasets (Clary and Kestens, 2013; Fleischhacker et al., 2012; Han et al., 2012; Liese et al., 2013; Lucan et al., 2013). Other food environment studies have used governmental data sources, but these often classify outlets incorrectly (Fleischhacker et al., 2012; Hosler and Dharssi, 2010; Toft et al., 2011). Misclassification could affect results for researchers who filter the data to exclude non-food stores. "Ground-Truthing"—the systematic exploration of a region to collect field observations of store and restaurant locations—is considered the gold standard in store location assessment (Hosler and Dharssi, 2010; Paquet et al., 2008; Powell et al., 2011), but the method requires a potentially prohibitive time and monetary commitment.

Outlet Distribution and School-Level Demographic or Socioeconomic Factors

There has been limited research into the role that systematic differences in school food environments may play in explaining disparities in children's diet-related health. In Canada, several researchers have reported associations between the density of or proximity to fast food outlets in relation to schools according to neighbourhood socioeconomic status (Engler-Stringer et al., 2014b; Kestens and Daniel, 2010) or school-weighted measures of low-income populations (Black and Day, 2012; Robitaille et al., 2010), but only one study examined associations between measures of the school food environment and neighbourhood demographic characteristics (Engler-Stringer et al., 2014b). No known study has used school-level measures of student demographic characteristics in such research in Canada, and research on socioeconomic factors and school food environments would benefit from school-level measures of poverty rather than the proxies of neighbourhood or school-weighted census measures currently used in Canadian literature.

Dietary Behaviour or Body Mass Index?

Although there has been substantial research focused on food environments and obesity, fewer researchers have looked at the "food environment-diet relationship"—that is, the role food retailers play in facilitating unhealthy or healthy dietary behaviours (Caspi et al., 2012). The gap is curious considering that the food environment-diet relationship is likely the main mechanism at play in determining whether an environment fosters unhealthy eating: the easier it is for a child to access to fast food, sugar sweetened beverages (SSBs), or packaged snacks, the more likely it may be for that child to consume such minimally nutritious foods. In contrast, the more commonly used dependent variable of obesity status is a distal outcome that may be confounded by built environment factors (Cobb et al., 2015). Neighbourhoods with more convenience stores, for example, may also tend to be more walkable (Saelens et al., 2003), allowing increased physical activity that may counter the obesogenic effects of convenience store access on diet (Saelens et al., 2012). In the context of Canadian school food environments research, just two studies have examined associations of food retailer density surrounding or proximity to schools with children's dietary intakes (Laxer and Janssen, 2013; He et al., 2012b). There is thus a need for studies focused on children's dietary behaviours in association with their school food environments.

1.2 Study Objectives

This thesis sought to help fill several of the gaps in the existing body of literature. The study was comprised of three components: (1) a field validation of food outlet locations around Vancouver schools; (2) an ecologic analysis examining store distributions across the city and their associations with school attributes and (3) a multilevel analysis assessing the relations of food outlet proximity and density with students' self-reported school-day food intake. The data validation component aimed to fill researchers' need for an assessment of existing store location data sets; in addition, it ensured that the subsequent analyses were conducted with accurate information on store types and locations. Both the ecologic analysis and the dietary intake assessment help to fill the gap in Canadian research by offering a study of the food environment in Vancouver, British Columbia; the ecologic analysis also offered the first examination of school-level demographic disparities in food access conducted in Canada. Finally, the third component of this thesis adds to researchers' understandings of how the food environment may affect children's dietary intakes.

Chapter 2

The Validation of Food Environments Data

2.1 Introduction

Data quality poses a serious challenge for food environments research. Researchers commonly obtain store location data from one of three sources: (1) "ground truthing" or primary data collection, (2) commercial database providers or (3) government sources (Morland, 2015). Each of these data sources is subject to varying levels of over- or undercounting due to classification errors, incorrect geocoding or inaccurate listings (Moore and Diez-Roux, 2015). Some researchers believe that compromised data may help explain inconsistent findings regarding the contributions of food environments to diet-related health (Lucan, 2015).

The current gold standard method for obtaining food environments data is ground-truthing, the systematic surveying of a region to identify and classify food retailers (Lucan, 2015; Fleischhacker et al., 2013). Ground-truthing with validated protocols can ensure high validity and reliability of the listings identified, but conducting surveys can require a prohibitive time investment.

Furthermore, ground-truthing is not possible for past years' food retailers, and the depreciation in validity of ground-truthed data over time—as outlets close and new outlets are opened—remains poorly understood.

Commercial data sets require far less time to obtain, and many are available for historical periods (e.g. DMTI Spatial, Inc. 2003, 2006, 2009). Such data sets can be expensive, however, and researchers have argued that major commercial providers' business lists may not achieve the level of accuracy necessary to obtain valid results in the context of academic research (Moore and Diez-Roux, 2015). Though some researchers have also relied on freely available directories like Yellow Pages (Burdette and Whitaker, 2004; Jeffery et al., 2006; Maddock, 2004), a recent review found that these public sources generally perform less well in measures of validity than private data providers like InfoUSA (Fleischhacker et al., 2013).

Municipal data sets offer an attractive alternative to commercial or primary data. Business registries and inspections listings are generally inexpensive or free to obtain. They are also expected to have fewer missing listings due to the legal requirements associated with the data collection (Hosler and Dharssi, 2010; Toft et al., 2011). However, government agencies also vary in their efforts to maintain and update registries, leading Fleischhacker et al. (2013) to recommend that government registries be validated on a case-by-case basis before being used for research purposes.

For food environments research to be conducted on a multi-city or national scale, rather than at the smaller scale of municipalities, it will be necessary for researchers to identify the highest quality data sets. This study sought to address the methodological problem of data source selection through a comparative evaluation of government, commercial, and ground-truthed food outlet data for the city of Vancouver B.C. The study's objectives were threefold: (1) to assess the validity of two commercial and two municipal data sources in comparison with ground-truthed data; (2) to test each data set for evidence of systematic bias in association with neighbourhood socioeconomic deprivation or commercial density; and (3) to compare food environment measures constructed from each data source to estimate the effect of over- or undercounting in outlet listings on research outcomes.

2.2 Background

A data source is considered to have a high degree of "validity" if it measures the concept it is intended to represent (Carmines and Zeller, 1979). In the case of food outlet listings, commercial and municipal data sources would be considered valid if they offer accurate information on the locations and classes of food retailers under examination (Fleischhacker et al., 2013). Data source accuracy may be compromised, however, if the data sets undercount listings, failing to include outlets that exist in the field, or if they over-count listings, for example by including outlets that have closed. Misclassification can further compromise accuracy: if a data source tends to misclassify convenience stores, for example, as grocery stores, it will both over-count grocery stores and undercount convenience stores. Such errors could lead researchers to estimate research subjects' exposure to the food environment incorrectly. It is thus important that researchers interested in the food environments ensure that they use the data that best characterizes true outlet counts.

Over nineteen studies have characterized the validity of commonly-used food environment data sources (Fleischhacker et al., 2013). These studies generally compare the data source of interest with data collected via ground-truthing; researchers then rely on validity measures including sensitivity, positive predictive value (PPV), and concordance (Table 2.1) to characterize levels of over- and undercounting. In a review of food environment data validation studies, Fleischhacker et al. (2013) found that government registers of food outlets had higher levels of agreement with gold-standard data than did other secondary data sources, while the commercial database provider InfoUSA was among the highest performing data sources overall. Results vary widely, however, with researchers reporting aggregate sensitivity estimates from 17% (Fleischhacker et al., 2012) to 85% (Rossen et al., 2012) and positive predictive values from 13% (Fleischhacker et al., 2012) to 98% (Svastisalee et al., 2012).

Table 2.1: Measures of dataset validity

Classification	**Definition**
Sensitivity	Proportion of outlets observed during ground-truthing that were listed in the data set
Positive Predictive Value (PPV)	Proportion of outlets listed in the data set that were observed during ground-truthing
Concordance	Proportion of outlets both listed in the data set and observed on the ground in comparison to the total number of observed or listed outlets

In addition to examining validity, a number of studies have examined different data sets for evidence of systematic error, which could lead to confounding of the associations between neighbourhood-level factors (e.g. area income or racial makeup) and food environment measures (Powell et al., 2011; Burgoine and Harrison, 2013; Gustafson et al., 2012). Most evidence, however, suggests that the error is not systematic: Paquet et al. (2008), Cummins and Macintyre (2009), Bader et al. (2010), Lake et al. (2012), Rossen et al. (2012), Svastisalee et al. (2012), and Burgoine and Harrison (2013) reported no evidence of systematic bias according to neighbourhood socioeconomic status (SES) and Bader et al. (2010), Rossen et al. (2012), and Rummo et al. (2014) found no statistically significant differences in measures of validity according neighbourhood racial demographics—although two studies in the United States did find statistically significant differences in data set sensitivity or PPV across neighbourhoods according to levels of socioeconomic status or racial makeup (Powell et al., 2011; Liese et al., 2013). The strongest evidence for systematic bias is in relation to commercial or population density: at least four studies in the United States identified statistically significant differences in validity levels[1] according to neighbourhood commercial density (Bader et al., 2010; Longacre et al., 2011; Liese et al., 2010; Powell et al., 2011), while no significant associations were identified in two UK studies (Lake et al., 2012; Burgoine and Harrison, 2013) .

Although data set validity has been the subject of extensive research, Fleischhacker et al. (2013) note that the validation literature has not yet

[1] It should be noted, however, that the associations identified were inconsistent: Bader et al. (2010) found a positive association between levels of error and commercial density, while Longacre et al. (2011), Liese et al. (2010), and Powell et al. (2011) obtained higher validity scores in urban versus in rural areas.

resolved the question of which data sources should be used in academic research. Existing studies comparing validity levels across data sources have generally been small in scale and localized in geographic scope (Fleischhacker et al., 2013), and thus limited in the generalizability of their results. Furthermore, researchers have focused on calculating validity statistics, while only Ma et al. (2013) looked at the effect of data source choice on measures of the food environment—the reason that data quality is of interest—and at present, no known study has assessed whether results regarding associations of the food environment with BMI, dietary intake or other outcomes changes with data source choice. Finally, most research has focused on locales in the United States; no study has been conducted assessing data quality in Vancouver, BC and only three known studies have been conducted in Canada (Paquet et al., 2008; Clary and Kestens, 2013; Seliske et al., 2012).

In Montreal, Canada, Paquet et al. (2008) conducted a study examining twelve census tracts, in which the researchers validated both a commercial list (Tamec Inc) for 2005 and a listing compiled from publicly available data (e.g. www.Canada411.ca and http://www.pagesjaunes.ca). Stores in the former database were classified according to Standard Industrial Classification (SIC) codes—a classification system used by government agencies to categorize businesses for legal and statistical purposes (Economic Classification Policy Committee, 1994)—as well as with a name-based classification system; stores from the internet listings were classified according to product and business names. The commercial list had high sensitivity (81%) and high PPV (88%); the publicly available listings offered lower sensitivity (63%), but PPV remained high (93%). There was no evidence of systematic differences in PPV by tract socioeconomic status.

Revisiting the same twelve census tracts five years later, Clary and Kestens (2013) computed sensitivity and positive predictive values for the 2010 Enhanced Points of Interest from DMTI Spatial, Inc. The researchers found that just over half of outlets in the field were included in the database, while 64.4% of outlets in the database were found in the field. A fairly high proportion of the error, however, was due to small discrepancies in name or geocoded location: when researchers assessed differences in the commercial database and field validation results due, exclusively, to differences in a store's operational status, existence, or classification (ignoring name or geocoding errors), sensitivity jumped to 65.5% while PPV increased to 77.3%. The researchers did not find evidence of systematic bias in validity scores by tract-level socioeconomic status.

The final study conducted in Canada validated both the InfoCanada and Yellow Pages listings for food outlets located within 1km of 34 schools in Ontario, Canada (Seliske et al., 2012). The researchers did not, however, ground-truth each school buffer zone; instead they assessed only the existence of the stores in their list, and thus could only report a data set's PPV (77.1% for InfoCanada versus 88.1% for Yellow Pages). The study is noteworthy, though, for its geographic scope as well as for its assessment of "positional accuracy": the researchers evaluated the Euclidean distance between primary data on store coordinates and the coordinates of stores in the commercial database. Finally, the Ontario study is one of just 3 studies to focus specifically on the food environments surrounding schools (Seliske et al., 2012; Svastisalee et al., 2012; Rossen et al., 2012).

All three Canadian studies observed noteworthy discrepancies between commercially available databases and ground-truthed data. It is not possible, however, to compare the different commercial database providers examined—Tamec Inc, DMTI Spatial Inc, and InfoCanada—across studies due to differences both in approaches to store classification and in the geographic areas assessed. There is also still a need for a comparison of commercial and municipal data sources, as none of the Canadian studies examined the validity of municipal outlet registries as a data source for food environments research. Finally, the literature remains limited in geographic scope: localized research has been conducted in just two regions of Canada—the city of Montreal and the province of Ontario—and results may not be generalizable for researchers seeking to study the food environment in Vancouver, BC.

This study sought to fill gaps in the literature by offering a systematic validation of four data sources in Vancouver, BC. The research offered examinations of two commercial database providers—DMTI Spatial Inc and Pitney Bowes Software—which had not previously been compared directly. In addition, the study assessed the validity of two municipal data registries—Vancouver Coastal Health Inspection Records and City of Vancouver Business Licenses—and compared validity across time, looking at the change in the quality of Business License data in 2015 versus in 2012. This study was the first in Canada to assess whether data set error was associated with commercial density, a critical gap considering the evidence of systematic bias according to commercial density in the United States (Bader et al., 2010; Longacre et al., 2011; Liese et al., 2010; Powell et al., 2011). In addition, this chapter offers the first validation study for food environments data sources specific to Vancouver, BC.

2.3 Methodology

2.3.1 Data

Data were obtained from five sources: (1) the systematic ground-truthing of all streets within 800 metres of 26 Vancouver schools[2], (2) Business Licenses (City of Vancouver, 2016), (3) Vancouver Coastal Health inspections lists (Vancouver Coastal Health, 2015), (4) the Canada Business Points (Pitney Bowes Software, 2012), and (5) the Enhanced Points of Interest (DMTI Spatial, Inc., 2013b). An overview of these data sets can be found in Table 2.2.

The ground-truthed data were obtained through systematic surveying between June 29th and September 30th, 2015. Two researchers visited each major commercial street located within an 800m line-based buffer surrounding each school to identify, photograph, and classify all food outlets; a single researcher also examined each residential street included in the sample. The surveyors followed a surveying protocol developed for this study (see Appendix A) according to the approach in Fleischhacker et al. (2012), using a Garmin eTrex 20x Worldwide Handheld GPS Navigator to collect GPS coordinates for each outlet. One school buffer zone was visited twice by two separate surveying teams, and the results were compared with Cohen's Kappa to assess inter-rater reliability in surveyors' store classifications.

[2]The 26 schools sampled with the I-EAT survey, discussed in Chapter 4

Table 2.2: Sources of data for food outlet locations in Vancouver, BC

Data Source	Classifiers	Year
Gold Standard		
(1) Ground-Truthed Primary Data	Classification Scheme (see Appendix A)	2015
Municipal		
(2) City of Vancouver Business Licences	Business Type Business Sub-Type	2015 2012
(3) Vancouver Coastal Health Inspections Lists	Service Type	2015
Commercial		
(4) Pitney Bowes Software Canada Business Points	NAICS† codes SIC‡ codes	2012
(5) DMTI Spatial, Inc. Enhanced Points of Interest	NAICS† codes SIC‡ codes	2013

†North American Industry Classification System
‡Standard Industrial Classifcation

The two government data sources—Business Licenses and Vancouver Coastal Health inspections lists—were obtained from Vancouver Open Data Catalogue and from the Vancouver Coastal Health Inspections website, respectively, in October 2015. Historical records were available from the Vancouver Open Data Catalogue, allowing this study to examine Business Licenses from both 2015 and 2012. The Vancouver Coastal Health inspections lists comprised food service establishments, food stores, and food processors in the city of Vancouver, classified by "service type." The Business Licenses data were similar, though they offered a more fine-grained "business subtype" classification system for identifying convenience stores, grocery stores, and produce outlets.

Up-to-date data for the commercial data sources were not available at the time of this project. As a result, this study examined Canada Business Points data from 2012 and Enhanced Points of Interest data for 2013. The Canada Business Points included geographic locations, Standard Industrial Classification (SIC) codes, and North American Industry Classification System (NAICS) codes—a business establishment classification system that has replaced SIC codes for many government agencies in Canada, the United States, and Mexico (United States Census Bureau, 2016). The Enhanced Points of Interests similarly included NAICS and SIC codes for classification purposes.

All food outlet data sets were examined and outdated listings, duplicate listings, or listings without geographic information were deleted. For the Vancouver Coastal Health inspections lists, which did not include geographic coordinates, an address locator from DMTI Spatial, Inc. (2013a) was used to geolocate outlets; unmatched listings were manually assigned to the closest match. After data cleaning, geographic coordinates were projected to the NAD83 / UTM zone 10N coordinate system and mapped with ArcGIS (ESRI, 2015). Studies of the food environment surrounding schools most commonly look at the regions within 800m of schools (Williams et al., 2014), so 800 metre line-based buffers were created surrounding each of the 26 schools of interest (Oliver et al., 2007), and food outlet data sets were limited to the outlets located within at least one of the 26 buffers.

Other geographic data used for this study included a cartographic boundary shapefile for the city (Statistics Canada, 2006a), a shapefile of school locations from the Vancouver Open Data Catalogue (BC Ministry of Education, 2016) and a shapefile of Vancouver City streets (DMTI Spatial, Inc., 2013a). All geographic data were projected to the NAD83 / UTM zone 10N coordinate system. The Business License Data (City of Vancouver, 2016) were used to measure commercial density, defined as the total number of businesses of any type located within the 800m buffer surrounding schools.

Finally, the Vancouver Area Neighbourhood Deprivation Index (VANDIX) offered a dissemination area-level measure of relative socioeconomic deprivation (Bell et al., 2007; Bell and Hayes, 2012). The VANDIX is an area-based index of deprivation constructed from seven census variables—proportion of the population with less than a high school education, proportion with a university degree, the unemployment rate, proportion lone-parent families, average income[3], proportion of home owners, and the labour force participation rate—which were selected and weighted according to a survey of British Columbia medical health officers. The VANDIX has been used to identify social gradients in the frequency of assault injuries (Bell et al., 2009a), the effects of severe burns (Bell et al., 2009b), and the relative risk of motor vehicle collision mortality in rural British Columbia (Bell et al., 2012); furthermore, the VANDIX has been shown to perform comparably to other Canadian deprivation indices in identifying social gradients in the prevalence of fair or poor self-rated health in Vancouver (Bell et al., 2007). For this study, the VANDIX was constructed at the dissemination-area level with variables from the 2006 Census of Canada[4].

[3]Average income was defined as average 2006 total income, in Canadian dollars, "among population 15 years and over by sex and presence of income" (Bell and Hayes, 2012)

[4]While the mandatory long-form census in 2006 attained a response rate of 93.5%,

Outlet Classification

This study focuses on the comparison of three classes of outlets: (1) limited-service food outlets; (2) convenience stores; and (3) grocery stores or supermarkets (see Table 2.3). The ground-truthed outlets were classified following a modification of the flowchart used by Clary and Kestens (2013) with definitions from Fleischhacker et al. (2012); Han et al. (2012); Lucan et al. (2013); full details and a classification scheme can be found in Appendix A.

For the 2015 and 2012 Business Licenses, "Business Type" and "Business Subtype" columns were used to classify listings. However, the "Facility Type" classification included in the Vancouver Coastal Health inspections lists was too coarse-grained to identify each of the three outlet classes. Similarly, although the NAICS codes provided in the two commercial data sources (the Canada Business Points and the Enhanced Points of Interest) are the standard used by U.S. statistical agencies to identify business type DMTI Spatial, Inc. (2013b), these codes were only available for a subset of businesses. SIC codes were available for all listed outlets, but were inadequate for classification; many well-known fast food outlets (e.g. Mcdonald's) were listed as full-service restaurants, and the codes often failed to discriminate between convenience stores and small grocery outlets. To address these concerns, following Clary and Kestens (2013) and Burgoine and Harrison (2013), the "Facility Type" and SIC/NAICS codes were supplemented with the applica-

the long-form census in 2011—which was made optional—had a much lower response rate of 68.6% (Statistics Canada, 2015a,b). Although Smith (2015) argues that sampling adjustments mitigated the effect of non-response bias among off-reserve aboriginal people, Statistics Canada (2015b) recommended that researchers use caution when relying on variables related to low-income. As a result, this thesis relies on data from the 2006 Census.

tion of a name-based classification scheme.

First, overall facility type codes (in the Vancouver Coastal Health inspections lists) and SIC codes (in the Canada Business Points and the Enhanced Points of Interest) were used to eliminate non-food outlets from the data sets. Next, name frequencies were examined to identify national and regional chain outlets; names including words like “pub”, “bistro” or “wine”—indicative of specialty stores or full-service restaurants and pubs—were used to identify outlets to be omitted. For all outlets retained, name frequencies were tabulated to identify major chains (e.g. “Subway” for limited-service food outlets) and words indicative of each class (e.g. “Mart” for convenience stores or “pizza” and “express” for limited-service food outlets). The lists of such indicator names and words were applied and iteratively refined until all remaining outlets were classified or deleted in each of the VCH, EPOI and PBS data sets. The final classifications were determined in the Canada Business Points and Enhanced Points of Interest data by combining NAICS code classifications with name-based searches, and in the Vancouver Coastal Health data by combining the name-based approach with the Facility Type listing. Definitions and codings for each of the three final classification categories can be found in Table 2.3; the detailed name-based classification is included in Table B.1.

Table 2.3: Methods used to classify listings as limited-service outlets, convenience stores, and grocery stores

Data Source	**Ground-Truthed**	**Business Licenses**	**Vancouver Coastal Health**	**Canada Business Points**	**Enhanced Points of Interest**
	Definition†	Business Type	Facility Type§	NAICS‡ Code§	NAICS‡ Code§
Limited Service Outlets	Outlets where customers pay before eating and order at a counter; includes cafés	- “Limited Service Food Establishment” - “Restaurant Class 1” (subtype “w/o liquor”)	- “Food Service Establishment 1”	- 72251302 - 72251512 - 72251115 - 72251402 - 72251505 - 72251510 - 72251518 - 44529905	- 722211 - 722213 - 445299
Convenience Stores	Stores selling a variety of products in addition to food; includes marts at gas stations and drugstores	- “Gasoline Station” - “Retail dealer - food” (subtype “Small Pharmacy”, “Pharmacy” or “Convenience Store”)	- “Retail Food Store”	- 4512001 - 44611009 - 44719005	- 44512 - 44611 - 44719

Data Source (Continued)	**Ground-Truthed**	**Business Licenses**	**Vancouver Coastal Health**	**Canada Business Points**	**Enhanced Points of Interest**
	Definition†	Business Type	Facility Type§	NAICS‡ Code§	NAICS‡ Code§
Grocery Stores	Stores that include all sectors of a traditional grocer (produce, deli butcher, dairy, and bakery)	- "Retail dealer - Grocery" - "Retail dealer - food" (subtype "Retail Food Store", or "Produce")	- "Retail Food Store"	- 44511001 - 44529912 - 44529918	- 44511 - 44523

†Definitions were constructed following Clary and Kestens (2013), Fleischhacker et al. (2012), Han et al. (2012), and Lucan et al. (2013); see Appendix A for details.
§Additional name-based classifications were applied to ensure all outlets were classified (Appendix B).
‡North American Industrial Classification System

Outlet Matching Approach

Two approaches were applied to match outlets in the secondary data set with outlets in the primary data set. First, addresses in each data set were standardized and two outlets were matched if the listings included identical street names and house numbers. However, this approach left some stores unmatched due to small inconsistencies in addresses, so an algorithm was encoded in R 3.2.4 (R Core Team, 2016) to match each store according to name and geographic location, following the approach of Auchincloss et al. (2012) and Hoehner and Schootman (2010). For each store in the gold standard data set, geographic coordinates were used to identify all stores in the secondary data set located within 100 metres of the ground-truthed store. The Levenshtein similarity, a similarity function based on the Levenshtein distance, or the minimum number of edits necessary for one store name to become identical to the other (Winkler, 1990), was calculated for all potential matches within 100m with the RecordLinkage Package (Sariyar and Borg, 2010); the ground-truthed store was then matched with the outlet with the highest Levenshtein similarity score. The results from the two approaches were then compared and, for ground-truthed outlets with different results across the two approaches, the best match was determined manually. For the Canada Business Points, which did not include addresses, the algorithm was applied twice and each entry was reviewed and, if necessary, matched manually.

2.3.2 Analysis

Validity measures (Table 2.1) were calculated both for all stores and for each of the three classes of stores. A matched store was considered a true positive (TP) if it was listed in both the secondary source and the ground-truthed data with the same classification, a false positive (FP) if the store was listed in the secondary source but not in the ground-truthed data, and a false negative (FN) if the store was listed in the ground-truthed data but not in the secondary source. If a store was listed in both data sets but the classifications differed, the listing was considered both an FP and an FN. The resulting values were summed to evaluate the sensitivity (TP/(TP + FN)), positive predictive value (TP/(TP + FP)) and concordance (TP/(TP + FP + FN)) of each secondary data source. The approach allowed a listing to be considered a TP even if it had a different name in the secondary source from that in the gold standard data, so long as the two listings included identical addresses and classifications; as a sensitivity analysis, "strict" TP's were calculated omitting stores with highly dissimilar names.

To assess the secondary data sources for systematic bias, logistic regression was applied to examine associations between each data set's sensitivity or PPV and measures of socioeconomic deprivation and commercial density[5]. Two sets of logistic regressions were applied for each secondary data

[5]Most studies validating on food environments data have relied on Fisher's Exact Test, applied to contingency tables, to assess systematic bias in levels of sensitivity or PPV (Burgoine and Harrison, 2013; Liese et al., 2013; Cummins and Macintyre, 2009; Paquet et al., 2008; Powell et al., 2011). As Clary and Kestens (2013) point out, this approach is not ideal due to a lack of prior knowledge of the row and columns sums. Furthermore, Fisher's Exact Test generally has lower power than exact unconditional tests (Lydersen et al., 2009). This study instead uses logistic regression models to test for associations between sensitivity or PPV and neighbourhood characteristics (Bader et al., 2010).

set. For the analysis of sensitivity, regressions were run for all stores in the ground-truthed data set with the outcome equal to 1 if the store was a false negative and 0 if the outlet was an true positive; the PPV analyses were run for all stores in the secondary data set with the outcome equal to 1 if the store was a false positive and 0 if the store was an true positive.

Each model was fitted with either VANDIX score tertile or commercial density, in units of 100 outlets, as independent variables. These independent variables were assigned to each store according to its school buffer; schools were assigned a “high”, “medium” or “low” VANDIX tertile based on the VANDIX scores of the dissemination area directly surrounding the school, while commercial density was calculated as the total number of stores of any type, as listed in the 2015 Business Licenses, located within the 800 metre buffer zone of the school. A cutoff of $p < 0.05$ was used for determining statistical significance.

Finally, ArcGIS (ESRI, 2015) was used to create measures of the food environment for each school with each of the classified data sets. **Density** was calculated as the total number of outlets located within each 800m line-based school buffer and **proximity** was measured as the shortest street-based distance from each school to a food outlet. food environment measures were constructed for outlets in each of the three categories (Table 2.3) as well as for the aggregate food outlet data, and evaluated with summary statistics. In addition, similarity in the density and proximity measures calculated from the ground-truthed data and those obtained from each of the secondary data sources, ranked across schools, were evaluated through the calculation of Kendall’s Tau, a non-parametric measure of correlation (Newson, 2002).

2.4 Results

The ground-truthing protocol identified 267 limited-service food outlets, 124 convenience stores, and 64 grocery stores or supermarkets. For the subset classified by two surveyors, percent agreement was 93% and Cohen's Kappa was 0.883, indicating strong inter-rater reliability (McHugh, 2012). The Vancouver Coastal Health inspections lists, which included 225 limited-service outlets, 138 convenience stores, and 42 grocery/supermarket stores, was geocoded with 98% accuracy, and manual matches were identified for the remaining 2% of outlets. After store classification, the 2015 Business License data included 375 limited-service outlets, 156 convenience stores, and 36 grocery/supermarket stores. The 2012 Business License data were similar, comprising 361 limited-service outlets, 153 convenience stores and 38 grocery/supermarket stores. In contrast, the two commercial data sets listed fewer food outlets: the Canada Business Points included 197 limited-service outlets, 148 convenience stores, and 81 grocery or supermarket stores, and the Enhanced Points of Interest included 264 limited-service outlets, 174 convenience stores, and 35 grocery or supermarket stores.

2.4.1 Evaluation of Sensitivity, PPV, and Concordance

The 2015 Business Licenses had the highest overall scores for sensitivity, identifying 69% of the ground-truthed stores. The data set's sensitivity was highest for convenience stores (0.75) and limited-service outlets (0.72); its sensitivity for grocery stores was lower (0.42) but remained the highest validity reported for that class of stores in any of the secondary data sources examined. The Vancouver Coastal Health inspections lists, in contrast, had the highest PPV: of the outlets listed in the Vancouver Coastal Health data set, 60% were also listed in the ground-truthing results. Across all measures, the 2012 Business License data had lower validity than the 2015 Business License data; it also performed more poorly than the Vancouver Coastal Health inspections lists in terms of overall PPV and concordance. The overall PPV, sensitivity and concordance estimates obtained for each of the municipal data sets—both for 2015 and for 2012—were higher than those obtained for either of the two commercial data sets. Detailed results for the validity measures can be found in Table 2.4.

With strict name matching, the 2015 Business License data lost 28 outlet matches, leading its sensitivity to drops to 0.58 while PPV decreased to 0.49. The 2012 Business License data lost 34 matches (sensitivity=0.48, PPV= 0.41), the Vancouver Coastal Health data lost 15 matches (sensitivity=0.48, PPV=0.55), and the Enhanced Points of Interest lost 27 matches (sensitivity=0.33, PPV=0.31). The Canada Business Points had the fewest matched outlets with different names, with just 7 outlets failing the stricter name-based standard; with strict matching, its sensitivity was equal to 0.37 while PPV was 0.36. Although sensitivity, PPV and concordance decrease across all data sets when the stricter matching standards are applied, the municipal data sets remained the highest performers in terms of overall sensitivity and PPV.

Table 2.4: Sensitivity, positive predictive value (PPV), and concordance of two municipal and two commercial data sources in comparison with ground-truthed data for the locations of food outlets in Vancouver, BC

	Business Licenses 2015	**Business Licenses 2012**	**Vancouver Coastal Health**	**Canada Business Points**	**Enhanced Points of Interest**
Sensitivity	**0.69**	**0.59**	**0.54**	**0.39**	**0.41**
Ltd. Service	0.72	0.62	0.55	0.38	0.40
Convenience	0.75	0.65	0.60	0.48	0.46
Grocery	0.42	0.31	0.34	0.25	0.36
PPV	**0.55**	**0.48**	**0.60**	**0.37**	**0.44**
Ltd. Service	0.51	0.46	0.66	0.38	0.54
Convenience	0.60	0.53	0.54	0.35	0.39
Grocery	0.75	0.53	0.52	0.46	0.28
Concordance	**0.44**	**0.36**	**0.40**	**0.23**	**0.27**
Ltd. Service	0.43	0.36	0.43	0.23	0.30
Convenience	0.50	0.41	0.39	0.25	0.27
Grocery	0.37	0.24	0.26	0.19	0.19

2.4.2 Assessment of Systematic Bias

Systematic associations were observed between commercial density and the proportion of false negative versus true positive listings identified in the Vancouver Coastal Health inspections lists, the Enhanced Points of Interest, and the Canada Business Points: every 100 additional stores in a school's buffer zone were associated with an increase, in the odds that a store in the ground-truthed data would be missing from the secondary data set, of 1.07 in the Vancouver Coastal Health inspections lists (95% CI 1.01 - 1.14), 1.11 in the Canada Business Points (95% CI: 1.04 - 1.18), and 1.08 in the Enhanced Points of Interest (95% CI 1.02 - 1.15). No statistically significant associations were identified between the odds of false positive listings and commercial density. Finally, no consistent significant associations were identified between the odds of listings being false positives or false negatives and neighbourhood socioeconomic deprivation in the data sources examined. Full results can be found in Tables B.2 and B.3.

2.4.3 Comparison of Food Environment Measures

All associations of the measure of density constructed from the gold standard data set and density constructed from secondary data (Table 2.5) were significantly different from zero ($p<0.01$). In terms of similarity to the gold standard measure, commercial data sets performed slightly better for the construction of both density and proximity than did the municipal data sets: the mean, median and standard deviation for the gold standard measure of density were most similar to those obtained for measures constructed from the Enhanced Points of Interest and the Canada Business Points; similarly, the range and mean of the gold standard proximity measure—calculated across all stores—were most similar to those of the proximity measure constructed from the Canada Business Points. For density calculations across all stores, the Canada Business Points measure was 94% more likely to agree than to disagree with the gold standard measure on its rankings of schools by store densities (95% CI 86.3% - 100%) while the 2012 Business License data and the Vancouver Coastal Health inspections lists measures of density were 87% more likely to agree than to disagree with the gold standard density measure on school rankings (95% CIs 78.5% - 95.9% and 75.6ˆ 98.9%, respectively). The remaining secondary data sets both had 90% likelihoods for agreement versus disagreement, with a 95% CI of 81.2% - 98.1% for the 2015 Business Licenses measure and 82.8% - 98.1% for the measure constructed from the Enhanced Points of Interest.

Table 2.5: Density of food outlets within 800 metres of Vancouver public schools (n=26), evaluated across data sources: Summary statistics and correlations with measures constructed from gold standard data

Density†	**Ground-Truthed**	**Business Licenses**		**Vancouver Coastal Health**	**Canada Business Points**	**Enhanced Points of Interest**
		2015	**2012**			
Summary Statistics						
Minimum	0.0	0.0	0.0	0.0	0.0	0.0
Median	20.0	23.0	24.0	16.0	20.0	19.0
Mean	24.6	30.4	30.0	16.2	23.7	25.9
Std Dev	19.4	23.1	22.5	16.2	17.9	19.7
Maximum	73.0	84	80.0	65.0	62.0	66.0
Kendall's Tau						
Overall	1.00	0.90	0.87	0.87	0.94	0.90
Ltd. Service	1.00	0.87	0.84	0.83	0.86	0.91
Convenience	1.00	0.72	0.70	0.57	0.64	0.76
Grocery	1.00	0.80	0.78	0.74	0.56	0.51

†Count of outlets located within 800m line-based buffers around schools

There were more noteworthy differences in Kendall's Tau statistics by store type: although the Enhanced Points of Interest performed comparably to other data sets in evaluating density for limited-service outlets and convenience stores, it was just 51% more likely to agree than disagree with gold standard data on the rankings of grocery store densities across schools (95% CI 31.6% - 69.8%); the Canada Business Points performed similarly poorly in estimating grocery store densities. Measures of density constructed from the 2015 and 2012 Business License data sets, in contrast, had more consistent results across store types, with Kendall's Tau $\geq$ 0.70 for all three store types.

Table 2.6: Proximity in metres of food outlets to Vancouver public schools (n=26), evaluated across data sources: Summary statistics and correlations with measures constructed from gold standard data

Proximity[†]	**Ground-Truthed**	**Business Licenses 2015**	**Business Licenses 2012**	**Vancouver Coastal Health**	**Canada Business Points**	**Enhanced Points of Interest**
Summary Statistics						
Minimum	131.5	98.8	98.8	107.6	133.7	155.6
Median	333.3	322.0	332.0	307.4	347.7	348.1
Mean	364.2	331.3	346.0	338.3	363.1	363.9
Std Dev	174.7	159.6	176.5	177.6	167.1	158.0
Maximum	793.6	744.9	750.3	798.8	798.5	750.3
Kendall's Tau						
Overall	1.00	0.72	0.61	0.70	0.74	0.73
Ltd. Service	1.00	0.58	0.57	0.71	0.72	0.63
Convenience	1.00	0.63	0.61	0.68	0.59	0.67
Grocery	1.00	0.54	0.38	0.39	0.31	0.39

[†]Shortest street-network distance (metres) from a school to an outlet

Examining similarities in proximity measures, all estimates for Kendall's Tau were statistically significant at the 5% level. For proximity calculations conducted across all stores, the 2012 Business License data were the overall poorest performer, with Kendall's Tau equal to 0.61 (95% CI 0.37 - 0.84%), while the 2015 Business Licenses offered higher results across store types (Table 2.6). The proximity measure constructed from the Canada Business Points again performed best, with Kendall's Tau=0.74 (95% CI 0.50

- 0.98) despite having the lowest Kendall's Tau for grocery store proximity (0.31, 95% CI 0.20 - 0.69). This result can be interpreted to mean that the proximity measure constructed from the Canada Business Points data were 74% more likely to agree than to disagree with the ground-truthed data on rankings of schools according to proximity of any of the three types of food outlets, but just 31% more likely to agree than to disagree on school rankings according to grocery store proximity.

2.5 Discussion

The objective of this chapter was to assess the validity of two municipal and two commercial food outlet location data sources in comparison with the gold standard of ground-truthed food outlet data in Vancouver, BC. This study assessed the sensitivity, positive predictive value, and concordance for each secondary data set, finding that all data sets were subject to high levels of error: data sets both (1) failed to include at least 20% of outlets observed in the field and (2) consisted at minimum of 25% listings not found in the field. Although no consistent evidence was observed of associations between the odds of false negative or false positive listings and school neighbourhood socioeconomic deprivation across data sets, significant associations between the odds of false negatives and commercial density were observed in the Vancouver Coastal Health inspections lists as well as in the two commercial data sets. Despite this evidence of poor validity across data sources, food environment measures constructed from the secondary data sources were similar in overall distribution to food environment measures constructed from the gold standard data.

The results for measures of validity obtained in this study were, for the municipal data sets, comparable with those obtained in previous studies. The 2015 Business License data and the Vancouver Coastal Health data had sensitivity and PPV values in the range of 0.54 - 0.69 (for all food outlets), which is similar to the results Fleischhacker et al. (2012) obtained for local health department listing sensitivity (0.66) and PPV (0.49) in North Carolina, U.S., as well as for the sensitivity estimate (0.66) obtained by Lake et al. (2010) for city council data in Newcastle, U.K. The municipal data sources' PPV scores were lower, however, than those observed by Lake et al. (2010) for Newcastle city council data PPV (0.92) and by Liese et al. (2010) for South Carolina Department of Health and Environmental Control data PPV (0.89). These differences in findings offer support for the recommendation that researchers evaluate the validity of government data on a case-by-case basis (Fleischhacker et al., 2013).

The commercial data sources had lower sensitivity, PPV and concordance measures than those observed elsewhere. Examining food outlets in the UK Points of Interest, Burgoine and Harrison (2013) obtained a sensitivity value of 0.60 and PPV of 0.75, significantly higher than the values of 0.41 and 0.44, respectively, observed in this study; Clary and Kestens (2013) similarly obtained higher PPV and sensitivity estimates (0.64 and 0.55, respectively) for their examination of the Enhanced Points of Interest data in Montreal. Both researchers, however, had a smaller temporal difference between the last update of the secondary data source and their collection of gold standard data in comparison with this study, suggesting that the difference in results may be explained by the depreciation of data quality over time (see Section 2.5.2).

Most data sets examined in this study had higher PPV, sensitivity and concordance values for limited-service outlets and convenience stores in contrast with those obtained for grocery stores. These results contrast with the findings obtained by Fleischhacker et al. (2012), who observed higher sensitivity and PPV estimates for their examination of 37 grocery stores in comparison with lower estimates for 277 convenience stores. However, Fleischhacker et al. (2012) also included a classification for "specialty markets and shops" within which, across data sets examined, validity measures were quite low. It is thus possible that the classification scheme used in Section 2.3.1 failed to eliminate specialty shops (e.g. seafood vendors or butcher shops) from the grocery store class.

A recent systematic review of food outlet data validation studies found evidence of systematic differences in validity between rural or urban areas and urban versus suburban areas, but reported "little" evidence of systematic biases according to neighbourhood socioeconomic status (Fleischhacker et al., 2013). The results obtained in this study are thus consistent with the previous literature: the statistically significant associations of commercial density and sensitivity for the Vancouver Coastal Health inspections lists, the Canada Business Points, and the Enhanced Points of Interest are aligned with findings from Bader et al. (2010) and Powell et al. (2011); the absence of consistent significant associations identified between measures of data set validity and neighbourhood socioeconomic deprivation was in keeping with Paquet et al. (2008), Cummins and Macintyre (2009), Rossen et al. (2012), Burgoine and Harrison (2013), and Clary and Kestens (2013).

When secondary data sets were used to construct food environment measures, summary statistics and nonparametric measures of correlation suggested that the measures' distributions were similar to those of measures constructed from gold standard data sets. This observation is consistent with the findings of the only other known study examining the effect of data set validity on food environment measures: Ma et al. (2013) found that food desert measures created from two commercial data sets (InfoUSA and Dun & Bradstreet) had 87.6% – 93.5% concordance with comparable measures obtained from the United States Department of Agriculture and the Centers for Disease Control and Prevention. Low validity scores do not necessarily translate into low validity for food environment measures, suggesting that a reliance on evaluations of sensitivity, positive predictive value, and concordance may be leading researchers to underestimate the usefulness of secondary data sets for food environments research.

2.5.1 Recommendations

Given the high performance of the 2015 Business Licenses data set in measures of sensitivity, PPV and concordance, its lack of systematic error in association with socioeconomic deprivation or commercial density, and the high correlations between density and proximity measures constructed from the Business Licenses and those constructed from gold standard data, this evaluation suggests that the Vancouver Business Licenses may be the best available data set for school food environments research in Vancouver, BC.

Although Vancouver Coastal Health inspections listings outperformed the Business License data in PPV, there was evidence of systematic error in association with with commercial density in the former data set; associations between the odds of including false negative listings and commercial density were also observed in the commercial data sets examined in this study. Researchers using such data sets should thus be cautious when conducting research in neighbourhoods with a range of commercial densities, because systematic error may obscure the true associations of commercial density with food outlet access.

2.5.2 Strengths and Limitations

Depreciation of data quality over time may contribute to the lower validity scores of the commercial data sets in comparison with the municipal data sets; while the former reported data for 2012 and 2013, the latter were obtained immediately after the completion of ground-truthing in 2015. However, the inclusion of both current (2015) and historical (2012) Business License data suggests that deprecation explains only part of the difference in validity: in comparison with the more temporally similar 2012 Business Licenses, the two commercial data sets performed between 5 and 10 percentage points worse in PPV and nearly 20 percentage points worse in sensitivity scores.

This study relied on a name-based classification scheme to augment the codes provided in the Vancouver Coastal Health Inspections Lists, the Canada Business Points, and the Enhanced Points of Interest. Although the name-based classifications were necessary to identify major chain fast food outlets in the Canada Business Points and Enhanced Points of Interest, as well as to distinguish store and restaurant types in the coarse-grained Vancouver Coastal Health inspections lists, it may have introduced new sources of error by, for example, failing to account for independent retailers with less recognizable names. Further research is necessary to understand the effect of classification on data set quality and to identify the optimal means of classification for these data sources.

Finally, this chapter does not predict the effect of data inaccuracy on the measure ultimately of interest, the association of the food environment and diet. However, the study does offer an examination of the correlation of food environment measures calculated from gold standard data with measures constructed from secondary data sources in an effort to bring food environments researchers a step closer to understanding the impact of over- and undercounting in common sources of food outlet location data.

2.6 Conclusion

This research examined the validity of two commercial and two government data sources for the city of Vancouver B.C. The study is one of just two studies examining the validity of data sources for Canadian food environments surrounding schools, and it is one of the most comprehensive validation studies conducted both in terms of types of secondary data sources assessed and in the evaluation of both listings and food environment measures constructed from different data sets. Furthermore, the results offer guidance for future research, suggesting that the City of Vancouver's Business Licenses offer the best source of food environments data currently available for research in Vancouver, BC. For researchers planning to use commercial data providers, this chapter suggests that researchers should be wary of systematic error in areas with varying commercial density; the high levels of over- and under-counting observed in commercial food outlet data, however, do not seem to lead to large changes in proximity or density measures constructed from such secondary data sources.

Chapter 3

Associations of School Characteristics and the Food Environments Surrounding Schools

3.1 Introduction & Background

Canadian children and youth living in socioeconomically deprived neighbourhoods are more likely to be overweight or obese than their peers from less socioeconomically deprived neighbourhoods (Oliver and Hayes, 2005). Disparities in the food environments to which children in low- versus high-income neighbourhoods and from high- versus low- SES households are exposed could help explain these differences in diet-related health. Canadian children may be particularly susceptible to the food vendors they encounter en route to school or during their lunch breaks: Tugault-Lafleur et al. (2016) find that Canadian children's diets during school hours are of poorer nutritional quality than their pre- or post- school-hour diets, and Héroux et al.

(2012) report that Canadian children are more frequent school-day patrons of food retailers than are American children.

In the United States, where Black and Mexican-American children are significantly more likely to be overweight or obese than other children (NCHS, 2012; Wang and Beydoun, 2007; Ogden et al., 2002), several studies have identified disparities in the food environments surrounding schools according to student racial or ethnic demographics (Sturm, 2008; Kwate and Loh, 2010; Neckerman et al., 2010). However, fewer studies have examined sociodemographic disparities in Canadian children's diet-related health, and the studies that have been conducted are less conclusive: researchers found no evidence of disparities in Canadian children's diets according to visible minority status (Riediger et al., 2007) or aboriginal ethnicity at the individual level (Taylor et al., 2007; Garriguet, 2009), while recent immigrants to Canada generally have fewer diet-related health conditions and maintain healthier dietary behaviours than long-term residents (Sanou et al., 2014). In Canada, then, one might expect to see socioeconomic—but not demographic—disparities in the food environments to which children are exposed at and en-route to school.

Indeed, Canadian studies have observed consistent associations between neighbourhood socioeconomic status (SES) and school food environments. Studies using school-weighted census measures of income have observed that low and medium income schools, in comparison with high income schools, had easier access—as measured by the density or proximity of stores in relation to schools—to fast food outlets or convenience stores in British Columbia (Black and Day, 2012), Saskatoon, Saskatchewan (Engler-Stringer et al., 2014b), and Quebec (Robitaille et al., 2010). In Montreal, a study found that schools in low-income neighbourhoods, versus high-income neighbourhoods, were more likely to have access to fast food outlets even after the researchers controlled for commercial density(Kestens and Daniel, 2010). One nationwide study offered contradictory results, finding that higher SES in the neighbourhood surrounding a school was associated with increased food retailer density, but the findings may be due to the researchers' failure to control for the effects of commercial density (Seliske et al., 2009b). Engler-Stringer et al. (2014b) additionally examined the associations of aboriginal or immigrant status and school food access, finding no association between the proportion of aboriginal residents or recent immigrants in the neighbourhoods surrounding schools and distance from schools to food outlets.

While Canadian school food environments research offers growing evidence of disparities in school food environments according to neighbourhood socioeconomic status, there are significant gaps in the literature. Many studies have relied on school-weighted census measures of income (Black and Day, 2012; Robitaille et al., 2010) or neighbourhood measures of income (Kestens and Daniel, 2010; Engler-Stringer et al., 2014b) and socioeconomic deprivation (Seliske et al., 2009b) as proxies for student SES, rather than using student-specific measures of poverty[6]. Because neighbourhood factors are more likely to contribute to the neighbourhood food environment (e.g. through residents' shopping behaviours) than school factors, the use of neighbourhood variables may lead researchers to overestimate associations.

[6]In the United States, researchers commonly use student eligibility for free and reduced-price lunch as a measure of poverty specific to students within a school (Sturm, 2008; Neckerman et al., 2010; Currie et al., 2010); however, such measures are not available for researchers in Canada due to the absence of a comparable federal school lunch program.

Similarly, the only study that examined disparities in access according to ethnicity relied on neighbourhood census measures rather than on school-level measures (Engler-Stringer et al., 2014b). No known studies have examined the associations of school food environments and student ethnicity or immigrant status in a Canadian city, a significant research gap given the evidence of racial and ethnic disparities in school food environments in the United States (Black, 2015).

There is also evidence, from the United States, that built environment factors confound the associations of school-level demographic or socioeconomic characteristics and food environment measures (Neckerman et al., 2010), but only one Canadian study controlled for commercial density (Kestens and Daniel, 2010)[7]. Finally, no study has examined disparities in the food environments surrounding schools in Vancouver, BC. Though 35% of Canada's residents live in one of three major cities—Toronto, Montreal, and Vancouver (Statistics Canada, 2011)—only the food environments surrounding schools in and around Montreal have been examined in association with neighbourhood socioeconomic status (Black, 2015; Kestens and Daniel, 2010). This study thus sought to offer the first city-specific study of disparities in the school food environments for Vancouver, one of Canada's three largest municipalities.

This study sought to address the current research gaps through an examination of the food environments surrounding public schools in Vancouver BC. The research had three objectives: (1) to offer a descriptive pro-

[7]Several studies did control for residential density (Black and Day, 2012; Seliske et al., 2009b) or urban versus rural status (Robitaille et al., 2010), but these measures are less likely to capture the urban planning factors at play (Black et al., 2011).

file of Vancouver school food environments, (2) to evaluate differences in access to food outlets according to school-level demographic and socioeconomic characteristics, and (3) to assess whether disparities in access could be explained by neighbourhood characteristics such as commercial density or neighbourhood-level socioeconomic deprivation. The hypothesis of this study was that schools with high levels of student poverty would have increased access to food retailers in comparison with low-poverty schools, but that differences in access would be explained by neighbourhood factors. In contrast, food environment measures were not expected to relate with the proportion of aboriginal students or recent immigrants to Canada enrolled in Vancouver schools.

3.2 Methods

3.2.1 Data

School-Level Demographic and Socioeconomic Characteristics

This study examined schools located in Vancouver, BC in operation during the 2011/2012 academic year (n=113). Data on school locations and attributes were obtained from the British Columbia Ministry of Education via the BC open data catalogue (DataBC, 2016). School demographic characteristics examined included the proportion of enrolled students who were English Language Learners (ELL) and the proportion aboriginal students. ELL status, a designation referring to students whose primary language or language spoken at home is a language other than English, served as a proxy measure of immigrant status; proportion aboriginal was included to assess whether children's exposure to food retailers would parallel evidence of shorter proximities to unhealthy food retailers from census dissemination blocks with higher aboriginal populations (Engler-Stringer et al., 2014b)

School-level poverty was assessed with a binary variable identifying schools in the Vancouver School Board's Inner City Schools Project (ICP) in 2012 (Vancouver Board of Education, 2009). The Inner City Schools Project identified schools with a high number of students living in poverty; these schools then received additional staffing and discretionary funding[8]. After a 2009 review, 14 elementary schools and 4 annexes were recommended for the program based on the numbers of vulnerable children attending as well as the schools' Ministry of Education Social Services Indices (Vancouver Board of Education, 2009). One school and one annex[9] were also identified as transitional schools[10]; analyses were conducted both including and excluding these two transitional schools as ICP schools to test the robustness of the results to the measurement of school poverty.

[8]ICP schools received additional staffing and discretionary funding as well as a breakfast program and access to a universal school meal program. The program aimed to reduce the stigma associated with food insecurity by asking parents to make confidential monthly contributions of any amount according to their self-assessed ability to pay (Vancouver Board of Education, 2009). The Inner City Schools Project was replaced by a tiered system of funding provisioning in 2014 (CBC Radio-Canada, 2014); in 2012, however, it would still have been operating in these schools.

[9]Annexes, in Vancouver, are smaller schools usually serving students in grades K - 3.

[10]These schools were transitional in the sense that they were seeing declines in the number of enrolled students living in poverty, and thus were selected to be slowly phased out of ICP program

School-Level Control Variables

In addition to the demographic and socioeconomic characteristics of a school's student body, school level and size may be associated with student access to food outlets (Simon et al., 2008; Day and Pearce, 2011; Robitaille et al., 2010; Black and Day, 2012). For this study, school size was measured as the total number of students enrolled in each school in the 2011 - 2012 academic year. School level—elementary versus secondary—was included to compare access between secondary schools, where students are often afforded more autonomy through open-campus policies, which allow students to leave the school for lunch, and elementary schools where students are more likely to stay on campus all day and to be accompanied by adults on their commutes to and from school. School level also served to compare access between older and younger students given the lower quality of adolescents' versus younger children's diets (Garriguet, 2009). Following Black and Day (2012), schools offering grades 8 to 12 were considered secondary schools; schools with lower grades were categorized as elementary schools[11].

Neighbourhood Factors

The VANDIX, discussed in Section 2.3.1, was used to assess the socioeconomic deprivation of each school neighbourhood. As in Section 2.3.2, each school was assigned the VANDIX score of its surrounding dissemination area. The final school-level VANDIX scores were split into tertiles for the analysis; "low" indicates the least deprived tertile while "high" denotes the most

[11]Ecole Secondaire Jules-Verne offered grades 7 to 12; it was included in the secondary school category.

deprived tertile.

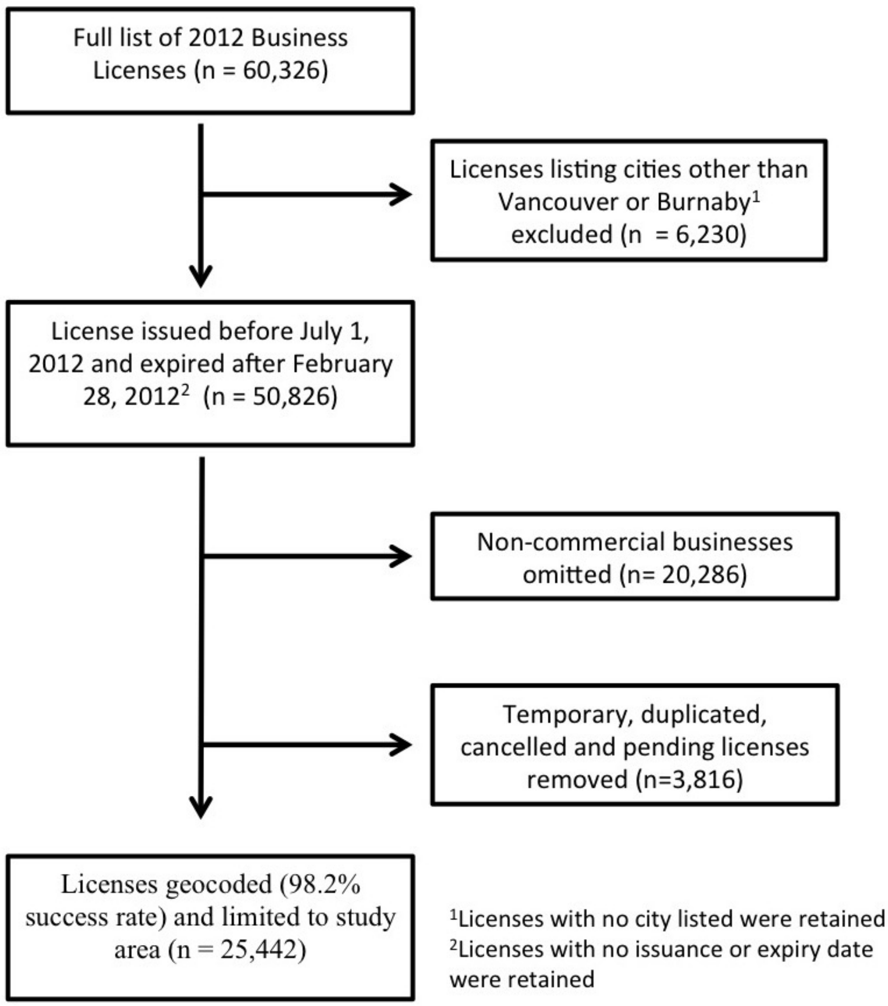

Figure 3.1: Flow chart of of 2012 Business License Data cleaning process

Commercial density was obtained from the 2012 City of Vancouver Business Licenses (City of Vancouver, 2016). As described in Figure 3.1, the business licenses were filtered to identify all businesses located in the cities of Vancouver or neighbouring Burnaby, BC. The data were then limited to stores with license expiration dates later than March 1, 2012 and issuance dates before June 30, 2012 to (1) ensure that all stores included were open and in operation at the end of the 2011/2012 academic year, when school attributes would be known to outlet owners, and (2) to limit stores to a short time period in order to prevent overcounting in neighbourhoods with high outlet turnover[12]. ArcMap 10.3.1 (ESRI, 2015) was then used to limit the data to outlets located in Vancouver or, to guard against the impact of an arbitrary geographic boundary, within 800m of the city's Eastern border. Food retailers (see Section 3.2.2) were excluded from the measure to reduce collinearity between the measures of commercial density and food retailer density. Finally, commercial density was calculated as the total number of retail or commercial outlets, excluding food retailers, located within a 160m, 400m and 800m line-based street network buffer of the school.

3.2.2 Food Environment Measures

Food outlets were identified from the final set of business licenses following the protocol outlined in Section 2.3.1. For the purposes of this study, food outlets are defined as any store meeting the classification of limited-service food outlet, convenience store, or supermarket/grocery store, defined following the flowchart given in Appendix A. In addition, business and trade names were standardized to identify the most prevalent limited-service outlets. Following Currie et al. (2010), these outlets were then used to construct a clas-

[12] The specific time period was chosen to ensure comparability with the Individual Eating Assessment Tool data (Section 4.2), which was collected between March and June 2012.

sification of major-chain fast food restaurants (Table 3.1). For each outlet type, ArcMap 10.3.1 was used to assess proximity—the shortest street-based distance from the school to a food outlet—and density, the total number of outlets included within a 800m line-based street network buffer surrounding the school. In addition to the calculation of density within 800m, used in Chapter 2, density was assessed within 400m and 160m of each school. The shorter distances were included in keeping with the possibility that students face highly nonlinear transportation costs, and thus that outlets within a 1-2 minute walk (160m) may have a stronger association with children's habits than outlets within a 5 minute walk (400m) or a 10 minute walk (800m) (Currie et al., 2010; Pikora et al., 2002).

Table 3.1: Limited-service outlets identified as "major chains"

Standardized Outlet Name	**Frequency***
1. Starbucks Coffee	89
2. Subway Sandwiches & Salads	54
3. Blenz Coffee	28
4. Tim Horton's	25
5. Freshslice Pizza	17
6. A & W Restaurant	15
7. McDonald's Restaurant	14
8. Dairy Queen	14
9. Jugo Juice	14
10. Quizno's Classic Subs	11

*Number of occurences within study area

3.2.3 Analysis

Data cleaning and measure construction were conducted with R 3.2.4 (R Core Team, 2016) and ArcMap 10.3.1 (ESRI, 2015); all statistical analyses were conducted with STATA 14 (StataCorp, 2015). First, descriptive statistics—including means and standard deviations for continuous variables and frequencies for categorical variables—were calculated across schools. Next, proximities and densities were calculated for all stores and across store types. Summary statistics, including means and standard deviations, characterized the general nature of the food environments surrounding Vancouver schools. Finally, multivariate regression analysis was applied to examine the associations between school food environments and school-level demographic or socioeconomic characteristics[13].

Negative binomial regressions were fitted with food outlet density (for limited-service food outlets, convenience stores, and supermarkets or grocery stores) at 400m as the dependent variables. Negative binomial models were preferable to Poisson models due to evidence of overdispersion in the outcome variables (Table 3.3); likelihood ratio tests confirmed that the additional parameter offered a significant improvement in fit. Models were first fitted with school-level demographic and socioeconomic characteristics as the independent variables. School controls (school level and size) and neighbourhood characteristics (VANDIX tertiles and commercial density) were then

[13]Technically, this data is from a census of Vancouver schools rather than a random sample, making statistical tests inappropriate. However, Sturm (2008) argues that there is constant turnover in both school enrolment and business. The results from this study, then, can be interpreted as a sample of school/business observations over time. Statistical tests, would distinguish effects from random variation in business and school enrolment numbers/characteristics.

included in the models, and the two nested models were compared with likelihood ratio tests. In addition, likelihood ratio tests were used to compare models with just the neighbourhood variables in comparison with models that included both neighbourhood and school characteristics as explanatory variables. Models were additionally fitted with food outlet density at 160m and 800m following Currie et al. (2010) and Sturm (2008).

A number of sensitivity analyses were run to examine the robustness of the model results. First, models were fitted with a broader definition of Inner City Program (ICP) schools that included the two transitional schools. There is no consensus on the optimal means of measuring the school food environment (Lytle, 2009; Lucan, 2015; Feng et al., 2010), so ordinary least squares regressions were additionally fitted with food outlet proximity to schools as the dependent variables. Again models were first fitted with school-level demographic and socioeconomic attributes and then with both school and neighbourhood characteristics; partial F-tests compared the two models as well as models with just neighbourhood attributes in comparison with full models. Finally, this study fitted models counting just the "major chain" outlets identified in Section 3.2.1 as limited-service food outlets given evidence of the difficulty studies face in classifying store types (Moore and Diez-Roux, 2015; Lucan, 2015).

3.3 Results

3.3.1 Descriptive Statistics

There were 113 schools and 2,223 food outlets located within the study region. The food outlets included 1,615 limited-service food outlets, 462 convenience stores, and 146 grocery stores or supermarkets. Of the limited-service food outlets, 281 were outlets included in the major chain list. In total, the food retailers represented 8.7% of the 25,442 commercial outlets of any type identified within the study region.

Descriptive statistics for school characteristics can be found in Table 3.2. On average, 31.2% of students enrolled in Vancuver schools were English Language Learners, while an average of 5.7% of students were aboriginal. The eighteen ICP schools represented 15.9% of schools overall. There were 94 elementary schools and 19 secondary schools in operation in Vancouver during the 2011 - 2012 academic year; each school had an average of 474 students (SD=427.0) enrolled. Schools were located in neighbourhoods with a range of socioeconomic deprivation scores, as measured by the VANDIX, though there was a geographic divide in socioeconomic deprivation: the eastern side of the city had many highly deprived dissemination areas, while most dissemination areas in the West were in the least deprived categories (Figure 3.2). Commercial density also varied around schools: the number of non-food outlets located within 800m of a schools ranged from 1 to 1,636 outlets. Although all schools had at least one non-food business outlet within 400m, twelve schools (10.6%) had no non-food outlets within 160m.

Table 3.2: Descriptive statistics for school and school neighbourhood characteristics for all public schools (n=113) in operation during the 2011/2012 academic year in Vancouver, BC

School-Level Demographic & Socioeconomic Characteristics	**Mean±SD**	**Min**	**Max**
Students			
% Aboriginal	5.7±11.0	0	65.3
% English Language Learners	31.2±19.6	0	83.8
	N Schools	**Percent**	
Schools			
Inner City Project (ICP)	18	15.9%	N/A
School Controls	**Mean±SD**	**Min**	**Max**
School Size			
Total Enrolment	473.5±427.0	57	2110
	N Schools	**Percent**	
School Level			
Elementary	94	83.2%	N/A
Secondary	19	16.8%	N/A
Neighbourhood Factors	**N Schools**	**Percent**	
VANDIX tertile‡			
low	38	33.6%	N/A
medium	38	33.6%	N/A
high	37	32.7%	N/A
	Mean±SD	**Min**	**Max**
Commercial density‡			
160m	8.6±11.2	0	52
400m	58.0±57.5	1	303
800m	250.7±227.8	1	1,636

†School neighbourhood VANDIX scores were ranked and split into tertiles where "low" denotes the least deprived neighbourhoods and "high" refers to the most deprived neighbourhoods. ‡Commercial density is reported as the total number of stores located within 160, 400 or 800 metres of each school; food outlets were excluded from the measure to avoid collinearity.

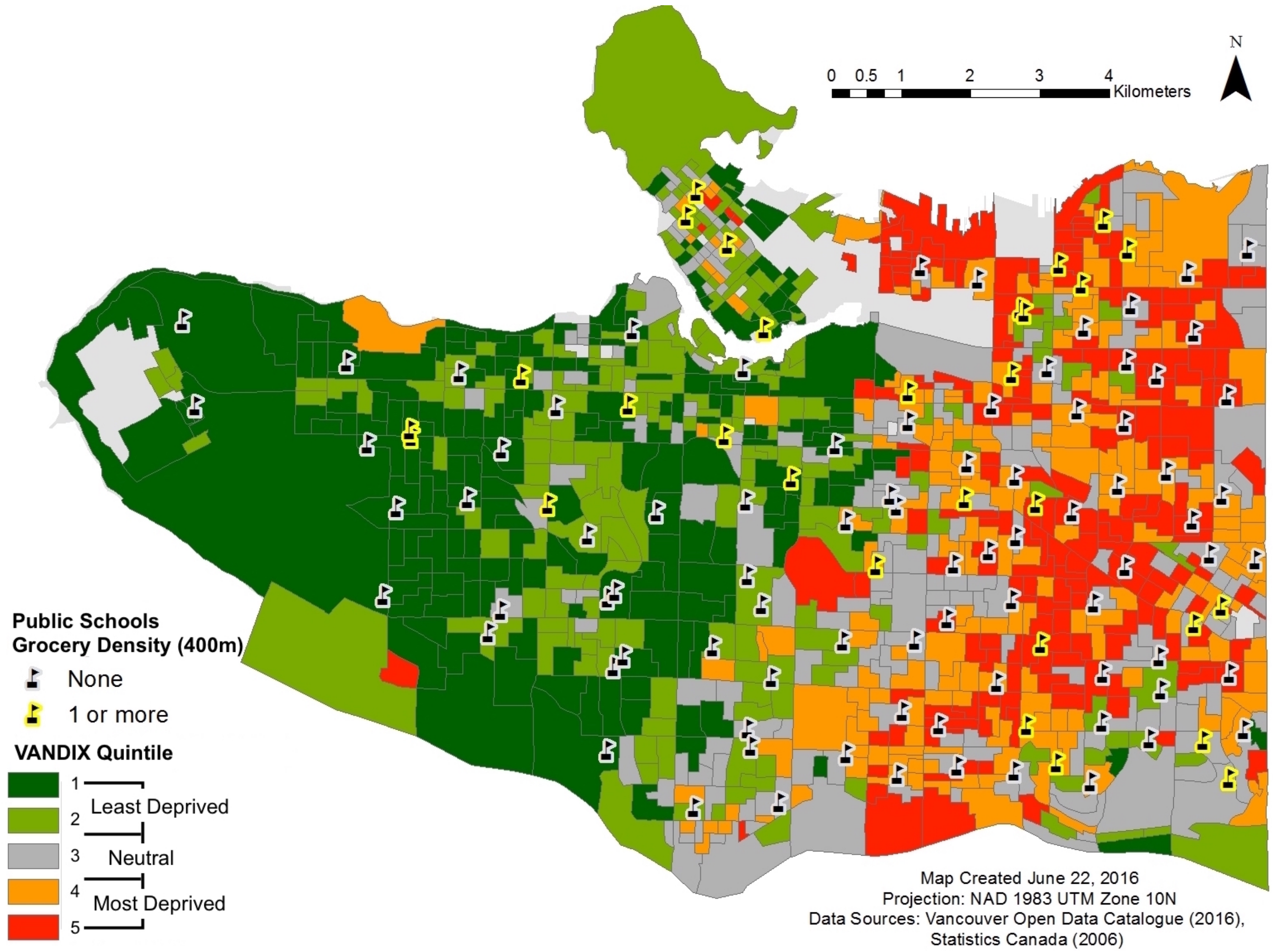

Figure 3.2: **Socioeconomic Deprivation and Access to Grocery Stores or Supermarkets within 400m of Vancouver Public Schools.** The map depicts all public schools in Vancouver, BC in the 2011/2012 academic year (n=113); Schools with 1 or more supermarkets or grocery stores within 400m are highlighted in yellow. Dissemination areas are categorized by socioeconomic deprivation—as measured by the VANDIX—with the most deprived areas indicated in red. Light grey indicates dissemination areas in which data were suppressed.

Most schools (95.6%) had at least one food outlet located within the 800m line-based buffer surrounding the school. Of the 113 schools examined, 90.2% were located within 800m of a limited-service food outlet—though just 67.2% were within 800m of a major chain—90.2% were located within 800m of a convenience store, and 68.1% were located within 800m of a supermarket or grocery store. At 400m, 69% of schools had access to any food outlet. A majority (58.4%) of schools had at least one limited-service food outlet, 54.9% had at least one convenience store, 25.7% had a major chain limited-service outlet, and 25.7% had at least one supermarket or grocery store. Access tapers off significantly with smaller boundaries: though 29.2% of schools had some type of food outlet within 160m, 22.1% had a limited-service food outlet, 16.8% had a convenience store, 5.3% had a supermarket or grocery store, and just 3.5% had a major chain limited-service outlet. Schools were, on average, closest to limited-service food outlets (median proximity=396m) and farthest from supermarkets or grocery stores (median proximity=653m). Full summary statistics for the proximity and density of the food environments surrounding Vancouver schools can be found in Table 3.3.

Table 3.3: Descriptive profile of food environments around Vancouver schools (n=113) between March and June 2012

	All Outlets	**Limited Service**	**Convenience Store**	**Grocery/ Supermarket**	**Major Chain**
N Stores	2,060	1,498	428	134	281
160m Density†					
Mean±SD	0.9±2.0	0.6±1.6	0.3±0.7	0.1±0.2	0.1±0.5
Median	0	0	0	0	0
Range	(0 - 12)	(0 - 10)	(0 - 3)	(0 - 1)	(0 - 5)
400m Density†					
Mean±SD	6.6±9.4	4.5±7.0	1.7±2.5	0.4±0.9	0.5±1.3
Median	2	1	1	0	0
Range	(0 - 50)	(0 - 38)	(0 - 16)	(0 - 5)	(0 - 7)
800m Density†					
Mean±SD	26.1±26.9	17.7±20.2	6.2±6.0	2.1±2.3	2.7±4.6
Median	18	11	5	1	2
Range	(0 - 184)	(0 - 149)	(0 - 37)	(0 - 12)	(0 - 40)
Proximity‡					
Mean±SD	411.1±349.8	450.5±366.9	534.3±389.7	774.1±470.6	759.3±437.5
Median	340.0	395.7	448.3	652.8	679.8
Range	(1.1 - 2,569.4)	(1.1 - 2,589.2)	(86.0 - 2,704.6)	(104.5 - 2,664.9)	(115.1 - 2,589.2)

†Density was measured as the count of outlets within a line-based buffer of schools.
‡Proximity was the shortest street-network based distance from a school to an outlet.

3.3.2 Results from Negative Binomial Regression Models

Results for negative binomial regressions with food outlet density at 400m as the dependent variables and school-level demographic and socioeconomic factors as the independent variables can be found in Table 3.4. Neither the percent of aboriginal students nor the percent of ELL students in a school was significantly associated with limited-service food outlet density, convenience store density, or supermarket/grocery store density within 400m of schools. Furthermore, no significant associations of the demographic variables were observed with food outlet densities within 800m (Table C.1) or 160m (Table C.2) of schools.

Table 3.4: Results from multivariate negative binomial regressions with food outlet densities within 400m of Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables

400m Density	**(1) Limited Service**	**(2) Convenience Store**	**(3) Grocery/ Supermarket**
% Aboriginal	1.03 (0.99 - 1.07)	1.02 (0.99 - 1.05)	1.01 (0.97 - 1.04)
% English Language Learners (ELL)	0.99 (0.97 - 1.00)	0.99 (0.98 - 1.01)	0.99 (0.97 - 1.01)
Inner City Project (ICP)	1.12 (0.40 - 3.08)	2.74* (1.27 - 5.89)	2.06 (0.65 - 6.51)
McFadden's Pseudo R^2	0.01	0.04	0.02

Incidence rate ratios with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001

School-level poverty was associated with convenience store density. Holding school demographic characteristics constant, ICP schools had approximately 2.74 times the number of convenience stores located within the 400m line-based buffer surrounding the schools in comparison with non-ICP schools (95% CI 1.27 - 5.89). The association of convenience store density and school ICP status remained statistically significant and positive, after adjusting for demographic factors, when 800m line-based buffers were used (IRR=1.88, 95% CI 1.13 - 3.14); ICP schools also had a significantly higher prevalence of supermarkets or grocery stores within the larger buffer (IRR=2.08, 95% CI 1.09 - 3.95) in adjusted models. No associations were statistically significant at 160m.

After controlling for school size, school level, neighbourhood commercial density, and socioeconomic deprivation, no significant associations were observed between school demographic factors and the densities of limited-service food outlets or supermarkets/grocery stores within 400m of Vancouver schools (Table 3.5). School-level poverty, as measured by ICP status, remained a statistically significant predictor of convenience store density at 400m (IRR=1.74, 95% CI 1.00 - 3.03) and of supermarket/grocery store density at 800m (IRR=1.82, 95% CI 1.05 - 3.14). Neither school level nor school size were significantly associated with food retailer density surrounding schools in any of the models.

Table 3.5: Results from multivariate negative binomial regressions with food outlet densities within 400m of Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables, adjusted for school controls and neighbourhood factors

400m Density	**(1) Limited Service**	**(2) Convenience Store**	**(3) Grocery/ Supermarket**
Students			
% Aboriginal	1.02	1.01	1.00
	(0.99 - 1.04)	(0.99 - 1.02)	(0.97 - 1.02)
% English Language Learners (ELL)	0.99 (0.98 - 1.01)	1.00 (0.99 - 1.02)	1.00 (0.98 - 1.02)
Inner City Project (ICP)	0.85 (0.41 - 1.75)	1.74* (1.00 - 3.03)	1.24 (0.52 - 3.00)
Schools			
Total Enrolment †	1.04	1.02	1.05
	(0.93 - 1.16)	(0.94 - 1.11)	(0.93 - 1.18)
School Level			
Elementary	–	–	–
Secondary	1.09	1.27	1.16
	(0.33 - 3.62)	(0.52 - 3.09)	(0.37 - 3.63)
Neighbourhoods			
Commercial density (400m)‡	1.24*** (1.18 - 1.31)	1.13*** (1.10 - 1.17)	1.15*** (1.10 - 1.20)
VANDIX tertile§			
low	–	–	–
medium	1.51	1.46	2.63*
	(0.85 - 2.70)	(0.83 - 2.58)	(1.05 - 6.60)
high	1.12	1.64	2.68*
	(0.59 - 2.15)	(0.91 - 2.98)	(1.01 - 7.12)
McFadden's Pseudo R^2	0.15	0.19	0.21

Incidence rate ratios with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001
†per 100 students; ‡per 10 non-food outlets within 400m
§"high" refers to the most deprived neighbourhoods.

As expected, neighbourhood commercial density was significantly associated with the density of food retailers surrounding schools. For every 10 additional non-food outlets located within 400m, schools had an average of 1.24 times more limited-service food outlets (95% CI 1.18 - 1.31), 1.13 times more convenience stores (95% CI 1.10 - 1.17) and 1.15 times more supermarkets or grocery stores (95% CI 1.10 - 1.20). The associations of commercial density and food retailer density were robust to the size of the buffer zone surveyed, remaining statistically significant at 800m (Table C.3) and 160m (Table C.4).

Schools with "high" VANDIX scores—indicating higher levels of deprivation and thus lower neighbourhood SES—had 2.68 times the number of supermarkets or grocery stores within 400m observed, on average, around comparable schools in the least deprived neighbourhoods (95% CI 1.01 - 7.12), after adjusting for school-level factors and neighbourhood commercial density (see Figure 3.2). At 800m, the most socioeconomically deprived neighbourhoods had more convenience stores (IRR=1.74, 95% CI 1.28 - 2.35) than did schools in the least deprived neighbourhoods, though no significant associations were observed for supermarkets/grocery stores in the adjusted models. No significant associations between retailer density and neighbourhood socioeconomic deprivation were observed within 160m of schools.

Likelihood ratio tests comparing adjusted and unadjusted models confirmed that including school controls and neighbourhood factors significantly improved model fit ($p < 0.001$ for all models). Additional likelihood ratio tests comparing models with just school controls and neighbourhood factors nested within the full models were used to assess whether the simultaneous inclusion of percent aboriginal, percent ELL, and ICP status significantly improved model fit. The likelihood ratio tests examining models with convenience store density as the dependent variables approached statistical significance (p=0.09 for 800m density, p=0.07 for 400m density), but across models, tests failed to reject the null hypothesis of no significant improvement in fit at the 5% significance level. Furthermore, likelihood ratio tests failed to reject the hypothesis that full models offered a significantly better fit than models including just commercial density and VANDIX tertiles as explanatory variables.

3.3.3 Sensitivity Analyses

The associations of school-level poverty and food outlet density were reasonably robust to the inclusion of the transitional schools as ICP schools. When the two transitional schools were included, ICP status was significantly associated with convenience store density at 800m (IRR=2.53, 95% CI 1.61 - 3.96), 400m (IRR=2.75, 95% CI 1.34 - 5.65) and 160m (IRR=4.65, 95% CI 1.50 - 14.43) and with supermarket/grocery store density at 400m (IRR=3.79, 95% CI 1.39 - 10.33) and 800m (IRR=3.13, 95% CI 1.81 - 5.42). However, the significant associations were likely the product of high commercial density surrounding the transitional ICP schools—after controlling for neighbourhood characteristics, only the association of ICP status with supermarket/retailer density at 800m remained statistically significant (IRR=1.85, 95% CI 1.08 - 3.17).

Table 3.6: Results from multivariate ordinary least squares regressions with food outlet proximities Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables

Proximity	**(1) Limited Service**	**(2) Convenience Store**	**(3) Grocery/ Supermarket**
% Aboriginal	-2.7 (-10.1 - 4.8)	-4.6 (-12.5 - 3.3)	0.2 (-9.2 - 9.5)
% English Language Learners (ELL)	3.7* (0.1 - 7.3)	1.1 (-2.8 - 4.9)	5.4* (0.8 - 9.9)
Inner City Project (ICP)	-132.5 (-361.7 - 96.7)	-149.3 (-392.9 - 94.3)	-360.5* (-648.5 - -72.4)
R^2	0.05	0.05	0.09
Adjusted R^2	0.03	0.03	0.07
Root MSE	361.7	384.4	454.5

Coefficients with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001

Proximity to food retailers was examined with OLS regressions (Table 3.6). In regressions with just school demographic variables as explanatory variables, schools were 3.7 metres farther, on average, from a limited-service food outlet (95% CI 0.1 - 7.3) and 5.4 metres farther from a supermarket or grocery store (95% CI 0.8 - 9.9) for every additional percentage point of enrolled students considered English Language Learners. Associations of the dependent variable and ICP status with convenience store or limited-service outlet proximity were not statistically significant at the 5% level. Grocery stores or supermarkets were, on average and controlling for demographic factors, significantly closer to ICP schools than to non-ICP schools.

Table 3.7: Results from multivariate ordinary least squares regressions with food outlet proximities (metres) to Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables, adjusted for school controls and neighbourhood factors

Proximity	**(1) Limited Service**	**(2) Convenience Store**	**(3) Grocery/ Supermarket**
Students			
% Aboriginal	-0.7 (-7.8 - 6.5)	-1.9 (-9.2 - 5.5)	2.4 (-6.9 - 11.6)
% English Language Learners (ELL)	3.0 (-0.9 - 6.9)	0.3 (-3.7 - 4.3)	4.7 (-0.4 - 9.7)
Inner City Project (ICP)	3.2 (-216.1 - 222.6)	13.3 (-211.7 - 238.3)	-236.5 (-519.4 - 46.3)
Schools			
Total Enrolment†	-17.2 (-43.8 - 9.4)	-16.4 (-43.8 - 10.9)	-0.7 (-35.2 - 33.7)
School Level			
Elementary	–	–	–
Secondary	194.9 (-106.6 - 496.4)	167.7 (-141.5 - 476.9)	122.8 (-265.9 - 511.5)
Neighbourhoods			
Commercial density (800m)‡	-24.8*** (-36.8 - -12.8)	-28.3*** (-40.7 - -16.0)	-30.1*** (-45.6 - -14.6)
VANDIX tertile§			
low	–	–	–
medium	-110.2 (-270.3 - 49.9)	-182.2* (-346.5 - -18.0)	-18.9 (-225.3 - 187.6)
high	-133.9 (-304.0 - 36.1)	-207.7* (-382.1 - -33.3)	25.3 (-194.0 - 244.5)
R^2	0.23	0.28	0.22
Adjusted R^2	0.17	0.23	0.16
Root MSE	333.6	342.2	430.2

Coefficients with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001
†per 100 students; ‡per 10 non-food outlets within 400m
§"high" refers to the most deprived neighbourhoods

Coefficients of the school-level demographic and socioeconomic characteristics were no longer statistically significant after school controls and neighbourhood factors were included in the models (Table 3.7). Associations of neighbourhood commercial density and socioeconomic deprivation with food outlet proximity were comparable to those observed in models of density. Partial F-tests confirmed that the inclusion of neighbourhood characteristics significantly improved fit for all proximity models at the 1% significance level. Comparing full models with models lacking the three school-level demographic and socioeconomic variables, partial F-tests failed to reject the null hypothesis of no significant improvement in model fit.

Finally, negative binomial models were fitted with the density of major chain limited-service outlets (Table C.5). Controlling for school level demographic and socioeconomic factors, schools with higher proportions of English Language Learners did have a marginally lower density of major chains within 400m (IRR=0.97, 95% CI 0.95 - 1.00), but associations were not significant for density within 800m or 160m. After adjusting for neighbourhood commercial density and VANDIX tertile, only the association of ICP status and major chain density within 800m remained statistically significant (IRR=1.77, 95% CI 1.05 - 2.97; Table C.6). Likelihood ratio tests confirmed that neighbourhood factors significantly improved model fit ($p < 0.001$ for all models). The tests rejected the null hypothesis of no improvement in fit with the inclusion of school-level demographic or socioeconomic variables in the case of major chain density at 800m (p=0.02) but not at 400m (p=0.60) or 160m (p=0.31).

3.4 Discussion

This study offered a descriptive profile of the school food environments for public schools in Vancouver, BC, examining whether disparities in schoolchildren's access to food retailers existed according to school enrolment of aboriginal students, English Language Learners, or students living in poverty. The study additionally examined whether disparities could be explained by neighbourhood commercial density or neighbourhood socioeconomic deprivation. As hypothesized, no consistent disparities in food outlet access were observed in association with student demographic characteristics, but school-level poverty was significantly and positively associated with density, at 400m and 800m, of convenience stores, and proximity to or density, at 800m, of supermarkets or grocery stores. Associations were attenuated through adjustment for neighbourhood socioeconomic deprivation and commercial density, though the association of school-level poverty with the density of convenience stores within 400m as well as with density of supermarkets/grocery stores within 800m of schools remained statistically significant in adjusted models.

The density of food outlets observed in this study is relatively high for a Canadian city: Over ninety percent of Vancouver public schools were located within 800m of at least one food retailer, and a majority (58.4%) had at least one limited-service food outlet within a 400m line-based buffer surrounding the school. Similarly, a majority (54.9%) were located within 400m of at least one convenience store. Across outlet types, the densities observed in this study are considerably higher than those obtained by researchers studying all schools in the province of British Columbia (Black and Day, 2012), Quebec

(Morin et al., 2015), Saskatoon, Saskatchewan (Engler-Stringer et al., 2014b), and the Montreal Urban Community (Kestens and Daniel, 2010). It should be noted, however, that Vancouver is unique among Canadian municipalities in its high population density (Statistics Canada, 2016). In similarly dense Boston and more dense New York City, similarly high retailer densities were observed in the areas surrounding schools[14] (Walker et al., 2013; Neckerman et al., 2010; Kwate and Loh, 2010).

This study offered the first examination of school-level demographic characteristics in association with school food outlet access in Canada. No consistent associations were observed between the percent aboriginal students or proportion English Language Learners enrolled in Vancouver schools and the food environments surrounding schools. This result is consistent with the findings of Engler-Stringer et al. (2014b) of no associations between neighbourhood census demographics (aboriginal population or recent immigrants) and the proximities of food outlets to schools, but it diverges from studies identifying racial disparities in students' access in the United States (Sturm, 2008; Kwate and Loh, 2010; Neckerman et al., 2010). This research was conducted, however, in a Canadian city with an ethnic and socioeconomic composition very different from that encountered in research in the United States (Census Bureau, 2005; Statistics Canada, 2006b).

This study also examined the associations between school-level poverty, as measured by Vancouver's Inner City Program, and the density and proximity of food outlets surrounding schools. Associations of ICP status and

[14] Walker et al. (2013) obtain slightly lower mean and median proximity estimates, consistent with their use of straight-line rather than street-network based measures of distance.

the school food environment, in adjusted models, were inconsistent: at 400m, ICP schools had significantly more convenience stores than non-ICP schools; at 800m, positive and significant associations were observed between ICP status and and supermarket or grocery store density. Positive associations with convenience store density are similar to those observed in previous studies (Engler-Stringer et al., 2014b; Robitaille et al., 2010), but the positive association of school poverty and supermarket or grocery store access is surprising given evidence, from the United States, of gaps in grocery and supermarket access ("food deserts") in low-income areas (Beaulac et al., 2009). However, the finding is consistent with research reporting better supermarket accessibility for low-income neighbourhoods in Montreal (Apparicio et al., 2007) and British Columbia (Black et al., 2011).

This study did not find that school enrolment or secondary versus elementary status were statistically significant predictors of the density of food outlets within 160, 400 or 800 metres of Vancouver schools. This finding is in keeping with the observations of Neckerman et al. (2010) in New York City, but the result contradicts other studies associating school size or level and food outlet density (Sturm, 2008; Black and Day, 2012). The differences in results may be a product of different model specifications: while both this study and the Neckerman et al. (2010) study controlled for neighbourhood commercial density, Sturm (2008) controlled only for whether a school was located in a rural, urban or suburban location and Black and Day (2012) included population/km^2 as the measure of density[15]. The differences may

[15] When the density models from this study were fitted with only school level covariates, total enrolment was a statistically significant predictor of the density of limited-service outlets within 800m of Vancouver schools

also be geographic: this study focused on a large, dense municipality, where outlets have many sources of demand, while both the Sturm and the Black and Day studies examined larger regions with many levels of population and commercial density. It is also possible that the effect size was too small to detect given the power of the analysis in this study.

Adjustment for neighbourhood factors attenuated the few associations observed between school-level demographic or socioeconomic characteristics and the food environments surrounding schools. Proportion English Language Learners, which was significantly associated with limited-service outlet density at 160m, limited-service outlet and supermarket/grocery store proximity, and major chain density at 400m, was no longer significantly associated with any dependent variables in models adjusted for neighbourhod factors. The association of ICP status and convenience store density within 400m dropped in magnitude in adjusted models, but remained statistically significant. The weakened associations, a finding similar to that observed by Neckerman et al. (2010), suggests that neighbourhood factors explain some of the associations observed between student demographic and socioeconomic characteristics and the food environments surrounding schools.

As in Kestens and Daniel (2010), neighbourhood socioeconomic deprivation was a significant predictor of outlet density even after adjusting for commercial density. The most highly deprived neighbourhoods had more than twice as many supermarkets or grocery stores within 400m and significantly more convenience stores within 800 metres than did the least deprived neighbourhoods; a socioeconomic gradient was also observed in proximity to convenience stores. The finding of high supermarket or grocery store densities in the most deprived school neighbourhoods (Figure 3.2) again aligns with studies suggesting that socioeconomic inequities in access to grocery stores (the "food desert" problem) is of less relevance in Canadian cities (Apparicio et al., 2007; Smoyer-Tomic et al., 2006; Black et al., 2011).

Commercial density was statistically significant across models, with schools in more commercially dense areas having more access (either through higher density or shorter proximity) to food outlets of all types. This is in keeping with previous findings (Kestens and Daniel, 2010; Neckerman et al., 2010; Day and Pearce, 2011). Likelihood ratio tests and partial F-tests confirmed the importance of including neighbourhood factors; significance tests further failed, across models, to reject the null hypothesis of no significant improvement in fit with the inclusion of school-level demographic or socioeconomic variables in comparison with models including only commercial density and neighbourhood socioeconomic deprivation as explanatory variables. Given increasingly strong empirical evidence for the association of commercial density and food outlet access, as well as the evidence presented in this study as well as by Neckerman et al. (2010) and (Kestens and Daniel, 2010) that commercial density may confound the associations of school-level characteristics and the food environment surrounding schools, this result suggests that researchers should control for commercial density in future food environments research.

3.4.1 Endogeneity Concerns in Food Environments Research

Studies of disparities in the food environments surrounding schools often serve as a preliminary step for researchers seeking to examine disparities in children's diet-related health or dietary behaviours in associations with the food environments surrounding their schools. Some researchers have raised concerns that endogeneity may compromise the results of such studies. Endogeneity refers to the correlation of an independent variable with the error term in a regression analysis, violating the assumption that $E[\epsilon|X] = 0$, or that the errors have conditional mean zero. Such a violation could be leading researchers to biased or inconsistent results (Verbeek, 2012). Though the concept encompasses a number of more specific problems, the cause of endogeneity most relevant to food environments researchers is simultaneity—-the idea that just as the independent variable causes the dependent variable, the dependent variable also causally affects the independent variable[16] (Verbeek, 2012). As Currie et al. (2010) and Sturm (2008) point out, the location decision of a fast food outlet is not random: stores choose to locate in areas

[16]Other problems encompassed by endogeneity include omitted variable bias, which occurs when researchers fail to account for a variable that is both related with the dependent variable and correlated with other explanatory variables, unobserved heterogeneity, or unmeasured variance across inviduals, and self-selection—the idea that students who consume higher intakes of snacks, sugar-sweetened beverages, or fast food meals would choose to go to schools with easier access to convenience stores or fast food outlets. Omitted variable bias can be mitigated through the measurement and inclusion of the relevant factors as well as through strong theoretical grounding (Clarke, 2005), unobserved heterogeneity at the school level can be accounted for at the group-level residual in multilevel models (Dieleman and Templin, 2014), and self-selection is unlikely: Ries and Somerville (2010) offer evidence that Vancouver public schools accept few applications from students outside of their catchment areas. For those students who do leave their catchment areas, factors like school quality and special program offerings are probably more important than food environments.

where they expect high demand. Certainly easy access to food outlets could lead students to purchase more fast food, but a population of students who are particularly eager purchasers of fast food may also be appealing to a fast food vendor who is choosing a new location.

Fundamentally, the detection of simultaneity requires that researchers explore the direction of the association between food outlet locations and children's dietary choices. No observational study can answer such a question of causality, but the absence of correlations between outlet density or proximity in relation to schools and school characteristics would weaken the hypothesis of simultaneity. Applying likelihood ratio tests and partial F tests to compare models with and without school characteristics, this study found no evidence of such associations for student demographic characteristics, school-level poverty, school size or school level and food outlet density or proximity in Vancouver, BC., a result in keeping with that observed by Currie et al. (2010). This study thus helps to assuage researchers' concerns, though improved study designs and statistical approaches informed by causal inference remain necessary to ensure that endogeneity does not compromise results.

3.4.2 Strengths and Limitations

This study focused on the associations of student demographic characteristics and school-level poverty with the density or proximity of food outlets surrounding schools. Disparities may still exist in association with other student characteristics such as student health; however, this study utilized the best available data to offer insight on demographic and socioeconomic disparities in Vancouver school food environments. Similarly, this study examined only the neighbourhood factors of socioeconomic deprivation and commercial density; the contribution of transit stops or other built environment factors to the school food environment would be worthy of further examination given their relevance for policy.

Measurement error could also compromise the results of this research. In diagnostic examinations of the OLS regressions, two schools (University Hill Elementary and University Hill Secondary) were high leverage observations. The two schools are located on the University of British Columbia campus, on the far Western edge of the city, outside of official municipal boundaries, and thus may be outside the bounds of the business license data; indeed, though there is evidence that University Hill Secondary School would have had access to a supermarket within approximately 450m in 2012 (Coopersmith, 2012), no outlet is found in the data set for that time. Coefficients and standard errors in models including just the three school factors were robust to the exclusion of the two schools from the analysis. In models controlling for neighbourhood factors, the association of limited service food outlet density at 800m with medium VANDIX scores was no longer statistically significant; at 400m, the association of supermarket/grocery store density and high VANDIX scores is no longer statistically significant, although grocery stores density remains significantly higher near schools with medium versus low VANDIX scores. Finally, the associations of the VANDIX and convenience store proximity are similarly attenuated, and no longer statistically significant, in OLS models. Likelihood ratio tests and partial F test results, however, are robust to the omission of the University Hill schools from the models.

The results of this study are not conclusive: both small sample size and multicollinearity could inflate standard errors and thus obscure the statistical significance of school-level predictors (Woolridge, 2009). However, variance inflation factors were low (below 10) for all explanatory variables (Woolridge, 2009); furthermore, the use of likelihood ratio tests and incremental F-tests to examine the simultaneous contribution of multiple variables to the model reduces the potential impact of multicollinearity. While the study's sample size may have been too small to detect significant effects at the school level, the number of schools examined was the maximum possible given the study region. Multiple sensitivity analyses supported the robustness of findings to errors in the assessment of school-level poverty, the classification scheme for food outlet types, and the measurement of the food environment surrounding Vancouver schools.

3.5 Conclusions

Ultimately, this study does not find consistent evidence that the characteristics of Vancouver public schools are associated with students' access to limited-service food outlets, convenience stores, or supermarkets. This study focused on demographic and socioeconomic characteristics of students within schools; further research is needed to examine whether other factors such as school food policies (e.g. open versus closed campuses) or programs (e.g. universal breakfast or school lunch offerings) are also associated with the food environment surrounding schools. Nevertheless, the results of this study suggest that while some disparities may exist in students' access to convenience stores according to school poverty, neighbourhood characteristics—particularly commercial density—play a more important role than student demographic or socioeconomic characteristics in predicting food outlet density and proximity.

Chapter 4

Associations of School Food Environment Measures and Children's School-Day Dietary Intakes

4.1 Introduction

Canadian adolescents have the poorest quality diets of any Canadian age group (Garriguet, 2009). According to the most recent iteration of the Canadian Community Health Survey: Nutrition (2004), Canadian children and youth consumed more sugar—and more sugar from soft drinks—than other Canadians (Langlois and Garriguet, 2011). Furthermore, over 80% of Canadian adolescents exceeded the Institute of Medicine's recommended upper limits for sodium consumption (Garriguet, 2007). Excessive sugar consumption, particularly consumption of added sugars from sugar-sweetened beverages, is a risk factor for dental caries, obesity, and type 2 diabetes mellitus (The Lancet Diabetes Endocrinology, 2015; Malik et al., 2010); excessive sodium consumption is associated with hypertension and cardiovascular disease (World Health Organization, 2012). Canadian children consume approximately one third of their weekday calories during school hours (Tugault-Lafleur et al., 2016), making schools a potentially critical leverage point for the amelioration of children's diets.

Policy efforts aimed at improving Canadian children's school-day diets have largely focused on nutrition education and food access within schools (Leo, 2007; Lassard, 2006). In British Columbia, for example, foods sold within schools are required to meet the Guidelines for Food & Beverage Sales in BC Schools (Ministry of Health and Ministry of Education, 2013). Vancouver schools can also participate in nutrition education programs such as Action Schools! BC, Farm to School BC, Sip Smart! BC, and the British Columbia School Fruit and Vegetable Nutritional Program (Romses and Lam, 2015). The efficacy of such within-school interventions may be limited, however, if interventions lead more students to purchase food from off-campus sources.

A number of studies have sought to elucidate the impacts of children's access to off-campus food sources on diet and ultimately on the prevalence of diet-related disease (Engler-Stringer et al., 2014a; Williams et al., 2014). Most studies of the public health impacts of the school food environment have focused on associations with obesity (Caspi et al., 2012). Results have been mixed: several researchers found positive associations between food outlet density or proximity and body mass index (BMI) (Gilliland et al., 2012; Leatherdale et al., 2011; Howard et al., 2011; Currie et al., 2010; Grier and Davis, 2013; Alviola et al., 2014), but other researchers reported null or inconsistent results (Seliske et al., 2009a; Griffiths et al., 2014; Langellier, 2012; Harris et al., 2011). Obesity is a distal outcome, however, produced by many complex factors interacting over time; small, cross-sectional studies may be inadequate to separate the effects of food access on caloric intake from other long-term contributors to BMI such as neighbourhood walkability (Saelens et al., 2003; Cobb et al., 2015).

Fewer studies have examined the more proximal outcome of dietary quality in association with school food environment measures, though the research that has been conducted has uncovered statistically and clinically significant results. In London, Ontario, He et al. (2012b) found that children's Healthy Eating Index scores were higher (better) for students with no fast food outlets within 1km of their schools in contrast with students who did have a fast food outlet within 1km. Two U.S. studies similarly found statistically significant associations of fast food outlet proximity to schools and students' sugar-sweetened beverage intake (Laska et al., 2010; Davis and Carpenter, 2009). However, the evidence remains inconsistent: several studies failed to find robust significant associations between dietary intake and the food environments surrounding schools (Gebremariam et al., 2012; Van Hulst et al., 2014; Richmond et al., 2013; An and Sturm, 2012).

In addition to the limited number of studies examining children's school-day dietary intakes, there are persistent gaps in the literature. Foremost, Canadian studies associating the food environment and children's diet-related health have either been national in scale (Seliske et al., 2009a, 2013; Héroux et al., 2012; Laxer and Janssen, 2013) or have been conducted in London, Ontario (Gilliland et al., 2012; He et al., 2012a,b)[17]. No study of the effect of the school food environment on children's diets has been conducted in one of Canada's three biggest cities—Toronto, Montreal, or Vancouver—despite evidence that Vancouver students may be exposed to far more dense food environments from students elsewhere in Canada (see Chapter 3). An additional gap is an exclusive reliance on objective measures of the food environment: all of the aforementioned studies used GIS to measure school food environments, but a recent review finds a need for further examination of measures of the perceived food environment (Williams et al., 2014). Finally, the majority of Canadian school food environments studies obtained food retailer locations from Yellow Pages (Seliske et al., 2009a; Laxer and Janssen, 2013; Héroux et al., 2012; Seliske et al., 2013), despite evidence that these data sources perform less well than government data sources (Fleischhacker et al., 2012; Lake et al., 2010) and may substantially misrepresent spatial distributions of food retailers (Longacre et al., 2011). There is thus a need for a study with high-quality data, using both perceived and objective food environment measures, to be conducted in one of Canada's more populous cities.

This study seeks to contribute to the school food environments literature through an examination of the associations between Vancouver 5th - 8th grade students' school-day consumption of sugar-sweetened beverages, fast foods, or packaged snacks and the proximity or density of food retailers surrounding their schools. The primary research objective was to examine

[17] One additional study was conducted in the province of Ontario more generally (Leatherdale et al., 2011).

whether elementary and secondary students' dietary intakes at or en-route to schools were associated with access to fast food outlets, convenience stores, or supermarket/grocery stores surrounding schools; a secondary objective was to evaluate the potential of survey-based measures of the food environment to serve as an alternative to objective measures through an assessment of the agreement between students' perceived proximity and objective proximity to each type of food outlet.

4.2 Methods

Students' dietary intakes at or en-route to school were assessed with the Individual Eating Assessment Tool (I-EAT) as part of the Food Practices on School Days Study. Questions and protocols were adapted from survey tools previously developed and validated for the study of eating behaviours in elementary and secondary school students (Birnbaum et al., 2002; Hanning et al., 2009; Pawlak and Malinauskas, 2008). The protocol was pilot-tested with 10 content experts as well as with 54 students in grades 7 - 12; a revised protocol was further field tested with an additional class of grade 6 and 7 students. Researchers visited each participating class between March and June 2012 to facilitate completion of computerized surveys[18].

The sampling approach was similar to a two-stage cluster sample. First, schools were recruited from each of the six geographic sectors of the Vancouver School Board, ensuring that schools in neighbourhoods with differing

[18] The development and design of the survey was part of the thesis work of Naseam Ahmadi and Teya Stephens; further details can thus be obtained from their publications (Ahmadi et al., 2015; Stephens et al., 2016)

levels of socioeconomic deprivation and commercial density would be represented in the study (Vancouver School Board, 2012). Next, teachers and administrators were invited to the study; all students in a sampled class participated unless a parent dissented, a student dissented, or a teacher requested that a student be excluded[19]. The final sample included 964 students (student-level participation rate: 81%) from twenty elementary schools and six secondary schools (School-level participation rate: 74%). Fourteen surveys were excluded due to inappropriate answers, allowing for a final sample size of 950 students in 26 schools. The Behavioural Research Ethics Board at the University of British Columbia and the Vancouver Board of Education approved all protocols.

4.2.1 Dependent Variables: Dietary Intake

Dietary intake measures served as the dependent variables in this study. Student dietary intake was assessed with a modified food frequency questionnaire adapted from the Student Health Action Planning & Evaluation System (SHAPES) Healthy Eating Module (University of Waterloo, 2008). Food frequency questionnaires are a practical and cost-effective means of assessing dietary intake (Willett, 2012); furthermore, several studies have documented acceptable levels of validity and reliability for similar food frequency questionnaires assessing food group intake in older children (Speck et al., 2001; Wong et al., 2012). However, all self-reported measures are subject to error. In the case of food frequency questionnaires, several studies

[19]Teachers excluded students based on behavioural or learning challenges and english language proficency, among other reasons.

offer evidence that subjects misreport total intake (Deschamps et al., 2009; Perks et al., 2000; Watson et al., 2009). As a result, Lietz et al. (2002) suggest that researchers should not rely on FFQs to evaluate children's absolute dietary intakes, but that the approach remains reliable and valid for use in comparison through the ranking of children's intakes. This study thus used daily intake measures to compare students who were frequent versus infrequent consumers of particular categories of foods.

For each food item, students were asked whether they consumed each item "never", "once a month or less", "2 - 3 times a month", "once a week", "2 - 4 times a week", "once a day", or "2 or more times a day". Responses were then summed across intake categories of fruits, vegetables, whole grains, and low-fat milks (all considered "more nutritious" foods) or sugar-sweetened beverages, fast food, and processed snacks ("minimally nutritious" foods, Table 4.1), with groupings adapted from Canada's Food Guide (2011) and the British Columbia Ministry of Education Food and Beverage Sales Guidelines (2013). Combined responses were split into a binary variable equal to 1 if reported intake was "daily"—defined as a summed response $\geq$ 20 times per month—and 0 otherwise. For this chapter, results are presented for students' daily consumption of foods in each of the three minimally nutritious intake categories given their theoretical relevance to the study of food retailers[20].

[20] Analyses were additionally tested with daily intake of "more nutritious" food categories—fruits, vegetables, whole grains, and low fat milk—but no statistically significant associations were observed with school food environment measures in adjusted models with daily versus less-than-daily intake of vegetables or whole grains. While associations were identified for low-fat milk intake and daily fruit intake, access to convenience stores and fast food outlets was more relevant in the context of the minimally nutritious food items—which are easily purchased at such stores—rather than in potentially less accessible food items like whole grains and low-fat milk (Glanz et al., 2007; Saelens et al., 2007). This thesis chapter thus focuses on minimally nutritious foods.

Table 4.1: Minimally nutritious intake categories and their component food items

Intake Category	Definition
Sugar-Sweetened Beverages	Fruit-flavoured drinks
	Regular pop or soft drinks†
	Iced tea‡
	Sports drinks
	Energy drinks
	Slurpees®, slushees, or snow cones
Fast Foods	Pizza
	Hotdogs
	Hamburgers or cheeseburgers
	Breaded or fried chicken/fish
	Fries or other fried potatoes
	Tacos or nachos
	Frozen packaged dinners
Packaged Snacks	Frozen desserts
	Baked sweets
	Candy or chocolate bars
	Salty packaged snacks

List of items included in the food frequency questionnaire in the Individual Eating Assessment Tool (I-EAT).
†Not including diet drinks; ‡sugar-sweetened

4.2.2 Independent Variables: Food Environment Measures

There is no consensus on the optimal measurement of the food environment surrounding schools (Black, 2015). This study thus used several sets of measures: objective food outlet density, objective food outlet proximity, and students' perceived proximity to food outlets. The two objective measures were constructed from the City of Vancouver (2016) Business Licenses data validated in Chapter 2, which was limited to retailers in operation when the IEAT surveys were conducted (see Figure 3.1), and classified as limited-service food outlets, convenience stores, or supermarket/grocery stores following the approach used in Section 2.3.1. Following the description in Section 2.3.2, objective proximity was evaluated as the shortest street network-based distance from a school to a food outlet. Objective density was defined as the total count of food outlets located within a line-based buffer surrounding each school. For the main analyses in this model, objective density was evaluated within 400 metre line-based buffers of each school—a distance at which 69% of all Vancouver schools had at least one food outlet during the study period (Section 3.3)—but associations were also tested for line-based buffers within 800m, the distance most commonly used in the food environments literature (Williams et al., 2014)[21].

Although most studies associating food environments and adolescent health rely on objective measures of access (Williams et al., 2014), recent research suggests that perceived measures may be more strongly associated with adolescent intake of minimally nutritious foods (Hearst et al., 2012; Svastisalee et al., 2015). A perceived measure of proximity was thus derived from a module in the I-EAT survey. Students were asked to estimate how long it would take them to obtain a variety of foods including fast food, salty packaged snacks, and fruits or vegetables; possible responses were "less than 5 minutes", "5–10 minutes", "10–15 minutes", "more than 15 minutes" and "I don't know". A five minute walk is approximately equivalent to a

[21] Currie et al. (2010) recommends evaluating density within 160m, a 1-2 minute, but just two schools in the I-EAT survey had food outlets within such a short distance.

400m distance (Pikora et al., 2002), so responses were recoded into three categories—<5 minutes, 5–10 minutes, and ≥ 10 minutes—to be comparable to the measure of objective proximity. Each student's perceived proximity to limited-service outlets was assessed as the minimum of that student's reported distance from a source of fast food or French fries; proximity to convenience stores was the minimum reported distance to candy or salty packaged snacks; and distance to a grocery store was the minimum reported distance a student would need to walk to obtain fruits or vegetables. Although these definitions are slightly different from those used in classifying stores, they were the classifications most similar to those used in Appendix A, given the limitations of the I-EAT survey.

4.2.3 Independent Variables: Controls

This study additionally included student-level measures of gender, childhood food security, acculturation, bringing lunch from home, and spending money, as well as school-level median family income and school level (elementary versus secondary) given evidence that these variables associate with children's dietary behaviours (Svastisalee et al., 2015; Velazquez et al., 2015; Kirkpatrick et al., 2015; Sanou et al., 2014; Hanson and Chen, 2007) as well as—for the student-level variables—their inclusion in the I-EAT tool.

Self-reported gender was included based on previous evidence observing stronger associations between perceived access to food retailers and children's fast food intake (Svastisalee et al., 2015). Childhood food security—defined by Coleman-Jensen et al. (2014) as access to adequate food to be healthy and active—was additionally included given evidence of poorer dietary quality in food insecure children in comparison with food secure children (Velazquez et al., 2015). The concept was measured with five questions from a tool developed by the United States Department of Agriculture (Economic Research Service, 2012), included in Table 4.2. Children were considered food insecure if they responded “sometimes” or “a lot” to two or more of the questions included in the module.

Table 4.2: Individual Eating Assessment Tool: Food insecurity module

In the past 12 months:	Never	Sometimes	A Lot
Did the food that your family bought run out, and you didn’t have money to get more?	○	○	○
Were you not able to eat a balanced meal because your family didn’t have enough money?	○	○	○
Have you skipped a meal or has the size of your meals been cut because your family didn’t have enough money for food?	○	○	○
Did you have to eat less because your family didn’t have enough money to buy food?	○	○	○
Were you hungry but didn’t eat because your family didn’t have enough food?	○	○	○

The Vancouver School Board serves a diverse student body, including many students who have recently arrived in Canada (Vancouver School Board, 2016) and thus may have dietary practices informed by their specific cultural backgrounds. Velazquez et al. (2015) thus developed a measure of “acculturation” as a proxy for factors related to immigrant status. Student acculturation was considered “high” for students who reported speaking English at home, who reported being born in Canada, and who reported that their parents or guardians were born in Canada. Acculturation was considered "low" for students who reported speaking a language other English at home, who were born outside Canada, and whose parents or guardians were born outside Canada. "Medium" acculturation comprised students with a mixed set of responses to the three acculturation questions.

Students who report bringing lunch from home (1 if students bring food on approximately a daily basis, 0 otherwise) may be less likely to make purchases at food vendors. Spending money, split into four categories ("none", \$0 - \$10, \$10 - \$20, and >\$20), was similarly expected to affect the ability of students to make purchases at nearby food retailers. School level (secondary versus elementary) was included due to increased autonomy of secondary school students, who are more likely to attend schools with open-campus policies where students are free to leave school grounds during lunchtime.

Finally, school-level median family income was included in adjusted models following Velazquez et al. (2015). Several studies have reported associations between measures of neighbourhood income or socioeconomic status and children's dietary behaviours (Minaker et al., 2006; Velazquez et al., 2015), and previous research has shown a socioeconomic gradient in food outlet proximity to or density surrounding schools (Morin et al., 2015; Day and Pearce, 2011; Zenk and Powell, 2008) as observed in Chapter 3. The measure of school-level median income used in the study, obtained from the BC Ministry of Education, was constructed from 2006 Canadian Census dissemination area-level measures and weighted according to the proportion of students enrolled in the school residing in each dissemination area.

4.2.4 Data Analysis

Descriptive Statistics

Descriptive statistics were calculated for all variables included in models. Response frequencies were tabulated for categorical variables; descriptive statistics calculated for perceived proximity included frequencies of each response. For continuous variables, summary statistics included means and standard deviations. Finally, missing observations were tabulated for each variable constructed from the I-EAT survey.

Reliability of Perceived Measures of Proximity

The reliability of students' perceptions of proximity was evaluated in comparison with objective proximity. Objective proximity for each outlet type was split into three categories (0 –400 metres, 400–800 metres, or $\geq$800 metres) comparable to the categories of perceived proximity ($<$5 minutes, 5–10 minutes, or $\geq$10 minutes), and agreement was evaluated with Cohen's Kappa.

Multilevel Models

Bivariate and multivariate regression models were then applied to examine associations between food environment measures and dietary intake outcomes; multilevel logistic models with random intercepts were fitted to account for the correlation of errors between students attending the same school (Diez Roux, 2004; Singer and Willett, 2003). The varying-intercept multilevel model comprised two levels: Eq. 4.1 predicting individual outcomes and Equation 4.2 predicting group-level intercepts. For student i in school j,

$$log(\frac{\pi_{ij}}{1-\pi_{ij}}) = \beta_{0j} + \beta_1 x_{ij} \quad (4.1)$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01} z_j + u_{0j} \quad (4.2)$$

where π_{ij} is the student's probability of daily consumption of the dietary intake of interest. The level 1 model includes a coefficient β_1 for individual-level explanatory variable x_{ij} and an intercept β_{0j} that consists of, at level 2, an overall intercept γ_{00}, a coefficient γ_{01} for the contribution of school-level variable z_j to differences between schools, and school-level residual error u_{0j} (Singer and Willett, 2003).

Several iterations of modeling were conducted with each of the dependent variables. First, null models with varying intercepts were fitted and intraclass correlation coefficients (ICCs) were calculated to compare within-group and between-group variation. The ICC measures the percent of total variance attributable to variation at the group level (Singer and Willett, 2003). Although ICCs were small across models (0.042 - 0.076), Wald tests found that variance was significantly different 0, meaning that there was unexplained variance at the school level. In addition, likelihood ratio tests comparing the multilevel model with simple logistic regression further confirmed that including random intercepts offered a significant improvement in fit.

Next, bivariate varying-intercept models were fitted with each of the objective measures of density and proximity as well as with the individual-level measures of perceived proximity. Additional explanatory variables, discussed in Section 4.2.3, were then iteratively included in multivariate models. Finally, varying-intercept, varying-slopes model were fitted. Including a random slope did not significantly improve model fit; thus only the more parsimonious varying intercept model is reported here. For all multi-level models, odds ratios and 95% confidence intervals were evaluated as measures of the direction and strength of associations.

Data were missing from 0.2% - 33.7% of responses on variables constructed from the I-EAT survey, so observations were imputed with multiple imputation by chained equations (10 data sets)[22]. Following Von Hippel (2007), this study used multiple imputation then deletion, including dependent variables in the imputation but omitting imputed dependent observations in the analysis. All statistical analyses were completed with STATA 14 (StataCorp, 2015).

4.2.5 Sensitivity Analyses

Although multiple imputation was used to impute missing observations in the final analyses, models were also fitted with listwise deletion of missing observations. In addition, final models were fitted with cutoffs of weekly ($\geq$ 4x per month) versus less-than-weekly consumption to assess the robustness of the results to the particular cutoff used to create binary outcomes. Multilevel OLS regressions with students' self-reported frequency of consumption per month as continuous outcomes served to further test the effect of dichotomizing the dependent variables.

[22] Jean-Michel Billette wrote the original multiple imputation code used by Velazquez et al. (2015); my code was adapted from his template.

4.3 Results

The final sample comprised 950 students across 20 elementary schools and 6 secondary schools. Almost all students (98.6%) in the final sample were in grades 6 - 8; due to the inclusion of split classes, the study also included 13 grade 5 students[23].

The study included slightly more male (51.4%) than female students and significantly more elementary (74.7%) than secondary school students. A substantial number of students (n=131, 15.8%) reported at least some level of household food insecurity and most students (81.9%) either were not born in Canada, had parents or guardians who were not born in Canada, or spoke a language other than English or French at home. A majority of students (57.9%) reported bringing lunch from food at home on a daily basis, and many students (85.9%) reported access to at least some spending money. Full descriptive statistics can be found in Table 4.3.

As can be seen in Table 4.3, many students reported frequent consumption of minimally nutritious foods at or en-route to school: 294 students (31.4%) were classified as daily consumers of sugar-sweetened beverages, 162 students (17.2%) were daily consumers of fast food, and 192 students (20.3%) were daily consumers of packaged snacks.

[23]Similarly, due to the inclusion of split classes, a small number of students were quite young. Though 88.9% of students were age 12 or older, the sample also included 89 11-year-old students and 8 10-year-old students.

Table 4.3: Sample characteristics (n=950)

	Count	%	N Missing (%)
Daily Consumers of			
Sugar-Sweetened Beverages	294	31.4	14 (1.5%)
Fast Food	162	17.2	8 (0.8%)
Packaged Snacks	192	20.3	2 (0.2%)
Gender			2 (0.2%)
Female	461	48.6	
Male	487	51.4	
Food Security Status			19 (2.0%)
Food Secure	700	84.2	
Food insecure	131	15.8	
Acculturation			73 (7.7%)
high	159	18.1	
medium	619	70.6	
low	99	11.3	
Brought Lunch From Home			11 (1.2%)
Daily	544	57.9	
Less than daily	395	42.1	
Spending Money			320 (33.7%)
None	89	14.1	
$0 - $10	234	37.1	
$10 - $20	146	23.2	
>$20	161	25.6	
School Level			0 (0%)
Elementary	710	74.7	
Secondary	240	25.3	
	Mean	Std Dev	Range
Median Family Income†	$60,393	$11,744	$33,928 - $82,823

†School-level variable constructed by the BC Ministry of Education

Most schools (69.2%) were located within 400 metres of some food outlet (Table 4.4.) Fifteen schools (57.7%) were located within 400m of at least one limited-service food outlet, fourteen schools (53.9%) were located within 400m of at least one convenience store, and two schools (7.69%) were located within 400m of a supermarket or grocery store as measured by objective proximity. Sixteen schools (61.5%) were located within 800 metres of a supermarket or grocery store, while 25 schools (96.2%) were within 800 metres of a limited-service food outlet and 24 schools (92.3%) were within 800 metres of a convenience store. Just two schools had access to food outlets within 160m; in both cases, the outlets were convenience stores. On average, schools had almost 6 limited service outlets within 400 metres.

Perceived proximities displayed noteworthy differences from objective proximities. Agreement between students' perceived proximities and objective proximity ranged from 42.0% for supermarket or grocery stores (Cohen's Kappa = 0.106, $p<0.001$) to 55.2% for convenience stores (Cohen's Kappa = 0.181, $p<0.001$); agreement for limited-service food outlets was 42.8% (Cohen's Kappa = 0.114, $p<0.001$). Although student responses were significantly different from the responses that would be expected if students were answering randomly, the strength of the Kappa statistic was less than 0.2 in all cases, or "slight" according to the scale proposed by Landis and Koch (1977). In comparison with the gold standard of objective proximity, perceived measures of proximity thus do not seem to offer reliable estimates of student access to food outlets.

Table 4.4: Descriptive statistics for objective density, objective proximity and perceived proximity of food outlets in association to Vancouver Schools

	Median	Mean	Std. Deviation
Density within 800m (n=26)			
Limited-Service Outlets	18	18.8	13.5
Convenience Stores	6	8.5	8.0
Supermarket/Grocery Stores	1	2.1	2.2
Density within 400m (n=26)			
Limited-Service Outlets	4	5.8	6.6
Convenience Stores	1	2.6	3.6
Supermarket/Grocery Stores	0	0.3	0.7
Density within 160m (n=26)			
Limited-Service Outlets	0	0.2	0.7
Convenience Stores	0	0.4	0.9
Supermarket/Grocery Stores	0	0	0
Proximity in metres (n=26)			
Limited-Service Outlets	341	391	174
Convenience Stores	370	412	221
Supermarket/Grocery Stores	648	776	330
	Count	%	N Missing (%)
Perceived Proximity (n=950)			
Limited-Service Outlets			203 (21.4%)
< 5 minutes	275	36.8	
5 - 10 minutes	254	34.0	
>10 minutes	218	29.2	
Convenience Stores			177 (18.6%)
< 5 minutes	467	60.4	
5 - 10 minutes	213	27.6	
>10 minutes	93	12.0	
Supermarket/Grocery Stores			254 (26.7%)
< 5 minutes	205	29.5	
5 - 10 minutes	249	35.8	
>10 minutes	242	34.8	

The null model with log-odds of daily intake of sugar-sweetened beverages as the dependent variable had an intraclass correlation coefficient (ICC) of 0.042 ($p < 0.01$), meaning that approximately 4% of the total variance in the model was at the school level. The ICC was not noticeably decreased through the inclusion of proximity to limited-service outlets, proximity to convenience stores, or proximity to supermarkets/grocery stores in the model, suggesting that objective proximity could explain little of the between-school variance in students' odds of daily sugar-sweetened beverage intake. Including objective density at 400m of convenience stores led to a decrease in ICC to 0.038, but likelihood ratio tests failed to reject a null hypothesis of no significant improvement in model fit.

Approximately 7.5% of the total variance in the null model for log-odds of daily intake of fast foods was at the school level ($p=0.01$). Neither including objective proximity variables or objective density (at 400 or 800 metres) led to a notable decrease in ICC.

Finally, 4.6% of the total variance in the null model for log-odds of daily intake of packaged snacks was at the school level ($p < 0.01$). Including objective proximity to convenience stores led to a small decrease in ICC to 0.040; however, a likelihood ratio test again failed to identify a significant improvement in model fit with the inclusion of proximity variables, and no other food access variables led to a noticeable reduction in ICC.

Table 4.5: Bivariate associations of outlet proximity and students' daily intakes of minimally nutritious foods[a] at or en-route to school from multilevel logistic regression models

Proximity[b]	Sugar-Sweetened Beverages (n=936†)		
Ltd. Service Outlet	0.97 (0.86 - 1.09)		
Conv. Store		0.97 (0.88 - 1.07)	
Grocery Store			0.98 (0.92 - 1.05)
	Fast Foods (n=942†)		
Ltd. Service Outlet	1.00 (0.86 - 1.17)		
Conv. Store		0.95 (0.84 - 1.08)	
Grocery Store			0.96 (0.89 - 1.05)
	Packaged Snacks (n=948†)		
Ltd. Service Outlet	1.08 (0.96 - 1.23)		
Conv. Store		1.04 (0.93 - 1.15)	
Grocery Store			1.01 (0.94 - 1.08)

Results are from multilevel logistic models with school random intercepts
Odds Ratios are reported; 95% confidence intervals are in parentheses.
[a]Dependent variables = 1 if a student reported daily consumption
[b]Distance to the nearest outlet, reported in increments of 100 metres
†Cases with missing dependent variables were omitted from the analysis
No statistically significant associations were identified.

Unadjusted multilevel models examining the bivariate associations of objective food outlet proximity and students' odds of daily intake of sugar-sweetened beverages, fast foods, or packaged snacks did not show evidence of odds ratios significantly different from 1 (Table 4.5). Similarly, coefficients were not statistically significant for bivariate models examining the associations of objective density within 400m (Table D.1) or 800m (Table D.2).

In the case of perceived proximity (Table D.3), one association was statistically significant: students who reported that their school was more than a ten-minute walk from a grocery store had significantly lower odds of daily sugar-sweetened beverage intake (OR=0.63, 95% CI 0.41 - 0.96). This is a single significant association in 36 tested unadjusted associations, however, making a false positive the most likely explanation (Rothman, 1990).

After adjusting for multiple factors (Table 4.6), no statistically significant associations were observed between objective proximity of limited-service food outlets, convenience stores, and grocery stores at the 5% level. Adjusted models were also fitted with objective density within 400m and 800m and students' perceived proximity to sources of fast food, sources of packaged snacks, and sources of fruits or vegetables. Densities of convenience stores at 400m and at 800m were associated with students' odds of daily snack intake, but the directions of the associations (OR=0.93, 95% CI 0.86 - 1.00 and OR=0.96, 95% CI 0.93 - 0.99, respectively) were the inverse of the association that theory would expect. No other measures of density at 400m or 800m were significantly associated with students' odds of daily minimally nutritious dietary intakes, and no associations with perceived proximity were statistically significant in the adjusted models.

Table 4.6: Multivariate adjusted associations from multilevel logistic models of outlet proximity and students' odds of daily intake of minimally nutritious foods at or en-route to school

	Sugar-Sweetened Beverages[a]			Fast Foods[a]			Packaged Snacks[a]		
Proximity[b]									
Ltd. Service Outlet	1.01 (0.90 - 1.13)			1.07 (0.92 - 1.25)			1.14 (1.00 - 1.30)		
Convenience Store		1.00 (0.91 - 1.10)			0.99 (0.87 - 1.12)			1.05 (0.94 - 1.18)	
Grocery Store			0.99 (0.93 - 1.05)			0.97 (0.90 - 1.05)			1.01 (0.94 - 1.08)
Controls									
Gender									
Female	–	–	–	–	–	–	–	–	–
Male	1.73^{***} (1.29 - 2.33)	1.73^{***} (1.29 - 2.33)	1.73^{***} (1.29 - 2.33)	2.41^{***} (1.62 - 3.57)	2.41^{***} (1.62 - 3.57)	2.41^{***} (1.62 - 3.58)	1.43^{*} (1.02 - 2.00)	1.44^{*} (1.03 - 2.01)	1.44^{*} (1.03 - 2.02)
Food Insecure[d]	1.55^{*} (1.02 - 2.35)	1.55^{*} (1.02 - 2.34)	1.55^{*} (1.02 - 2.34)	1.87^{*} (1.12 - 3.12)	1.86^{*} (1.12 - 3.09)	1.85^{*} (1.11 - 3.08)	0.88 (0.54 - 1.43)	0.87 (0.54 - 1.41)	0.87 (0.54 - 1.41)
Acculturation[e]									
high	–	–	–	–	–	–	–	–	–
medium	1.07 (0.69 - 1.63)	1.07 (0.69 - 1.64)	1.07 (0.70 - 1.64)	2.14^{*} (1.12 - 4.07)	2.17^{*} (1.14 - 4.12)	2.17^{*} (1.14 - 4.13)	0.78 (0.49 - 1.25)	0.79 (0.50 - 1.27)	0.79 (0.50 - 1.27)
low	1.68 (0.96 - 2.96)	1.69 (0.96 - 2.97)	1.70 (0.97 - 2.98)	7.08^{***} (3.29 - 15.19)	7.29^{***} (3.38 - 15.69)	7.31^{***} (3.40 - 15.72)	1.46 (0.78 - 2.71)	1.50 (0.81 - 2.79)	1.52 (0.82 - 2.82)
Brought from home daily[c]	1.07 (0.78 - 1.47)	1.07 (0.78 - 1.47)	1.07 (0.78 - 1.47)	1.05 (0.69 - 1.59)	1.05 (0.69 - 1.60)	1.06 (0.69 - 1.60)	1.77^{**} (1.23 - 2.54)	1.74^{**} (1.21 - 2.51)	1.77^{**} (1.23 - 2.55)

(Cont.)	Sugar-Sweetened Beverages[a]			Fast Foods[a]			Packaged Snacks[a]		
Spending Money									
None	–	–	–	–	–	–	–	–	–
$0 - $10	0.91	0.91	0.91	1.85	1.85	1.86	0.99	0.99	0.99
	(0.53 - 1.56)	(0.53 - 1.56)	(0.54 - 1.56)	(0.80 - 4.27)	(0.80 - 4.28)	(0.81 - 4.30)	(0.55 - 1.79)	(0.55 - 1.79)	(0.55 - 1.79)
$10 - $20	1.15	1.15	1.15	3.07*	3.08*	3.09*	1.45	1.45	1.46
	(0.65 - 2.02)	(0.65 - 2.02)	(0.65 - 2.03)	(1.22 - 7.74)	(1.22 - 7.77)	(1.22 - 7.79)	(0.74 - 2.82)	(0.74 - 2.83)	(0.75 - 2.84)
>$20	1.91	1.91	1.91	5.29**	5.32*	5.31*	1.64	1.64	1.65
	(0.99 - 3.67)	(1.00 - 3.67)	(1.00 - 3.67)	(2.06 - 13.61)	(2.08 - 13.65)	(2.07 - 13.62)	(0.88 - 3.04)	(0.88 - 3.05)	(0.89 - 3.06)
School Level									
Elementary	–	–	–	–	–	–	–	–	–
Secondary	1.32	1.31	1.30	1.81*	1.71	1.71	1.50	1.44	1.37
	(0.85 - 2.04)	(0.85 - 2.03)	(0.85 - 2.00)	(1.04 - 3.15)	(0.97 - 3.03)	(0.98 - 2.98)	(0.90 - 2.50)	(0.84 - 2.50)	(0.81 - 2.34)
Median Family	0.83*	0.83*	0.84*	0.72**	0.75*	0.76*	0.75**	0.78*	0.80*
Income†	(0.69 - 0.98)	(0.70 - 0.99)	(0.71 - 0.98)	(0.58 - 0.91)	(0.60 - 0.95)	(0.61 - 0.95)	(0.61 - 1.66)	(0.63 - 0.97)	(0.65 - 0.99)
N	936‡	936‡	936‡	942‡	942‡	942‡	948‡	948‡	948‡
ICC	0.02**	0.02**	0.02**	0.04*	0.04*	0.04**	0.03**	0.04**	0.04**

Each column reports a model with dietary intake as the dependent variable and objective proximity as independent variables adjusted for gender, food insecurity, bringing lunch from home, acculturation, spending money and school median income. Coefficients are reported as odds ratios with 95% confidence intervals in parentheses.

[a]Dependent variables = 1 if consumed at least daily. [b]Distance to nearest outlet, reported in units of 100 metres.

[c]Brought from home = 1 if a student reported bringing lunch daily; [d]Reference level is food secure students

†School-level variable constructed by the BC Ministry of Education; reported in $10,000 units

‡Missing values on independent variables were imputed with Multiple Imputation with Chained Equations (MICE, 10 data sets) missing dependent observations were included in MICE omitted from models.

*significant at 0.05; **significant at 0.01; ***significant at 0.001

All other explanatory variables were significantly associated with at least one of the three dietary intake outcomes. For all three dependent variables, male students had significantly higher odds of being daily consumers than did female students. Food insecurity was associated with increased odds of daily sugar-sweetened beverage consumption and daily fast food consumption, though not with increased odds of packaged snack consumption among students. Similarly, the least acculturated students had more than seven times the odds of being daily fast food consumers in comparison with the most acculturated students in the sample. Though students who brought lunch from home on a daily basis did not have odds significantly different from 1 of daily versus less frequent sugar-sweetened beverage consumption or fast food consumption, bringing lunch from home was associated with increased odds of daily packaged snack consumption. Finally, students with $10 or more of spending money had increased odds of being daily consumers of fast foods. The inclusion of school level (elementary or secondary) and median family income reduced the amount of unexplained variance observed at the school level, but one-sided Wald Tests confirmed that ICC's remained significantly greater than zero at the 2.5% significance level.

4.3.1 Sensitivity Analyses

Results from models with multiple imputation on missing observations were similar to those obtained from models fitted with listwise deletion of missing observations (Table D.4). Models with listwise deletion did have lower ICC's—and in several cases ICC's that were not significantly different from zero—but the result is likely due to the smaller sample size in the models.

As in models with daily versus less-than-daily cutoffs, there were no statistically significant associations between measures of objective proximity and consumption of sugar-sweetened beverages in models comparing weekly with less-than-weekly consumption. In adjusted models, significant associations were observed between odds of weekly packaged snack consumption and limited-service outlet density at 400m (OR=0.97, 95% CI 0.94 - 1.00), but the association was the inverse of the expected relationship. No associations were observed between weekly consumption of minimally nutritious foods and perceived proximity in adjusted or bivariate models with weekly intake as the outcome variables.

In OLS regressions with continuous outcomes, no significant associations were observed monthly frequencies of intake of sugar-sweetened beverages, fast food, or packaged snacks and objective proximity. Associations between food access measures and students' self-reported frequency of consumption per month were the opposite of theoretical expectations: students reporting a $\geq$10 minute walk to convenience stores or fast food retailers reported consuming significantly more sugar-sweetened beverages, fast foods and packaged snacks than comparable students reporting a $<$5 minute walk to such retailers. Although several significant associations were identified, in adjusted models, between frequency of consumption and density of convenience stores at 400 or 800 meters, associations were again in the opposite of the expected directions and most associations examined were null, in keeping with the results observed in multilevel logistic regressions.

4.4 Discussion

This study examined the relationships between children's access to food retailers and their consumption, at or en-route to school, of minimally nutritious foods. The analyses examined three main sets of explanatory variables: (1) objective proximity, (2) objective density within 400 or 800 metres, and (3) perceived proximity of limited-service food outlets, convenience stores, and supermarkets or grocery stores in relation to Vancouver schools. The study did not observe evidence of meaningful associations between these food environment measures and children's odds of being daily consumers of sugar-sweetened beverages, fast foods, or packaged snacks.

Only one bivariate association—sugar-sweetened beverage intake and perceived proximity to a grocery store—was statistically significant, and the association was no longer significant after controlling for any one of gender, acculturation, or spending money. Given the number of associations tested, it is plausible that this result is a false positive (Rothman, 1990). In adjusted models, convenience store density at 400m and 800m was associated with a decreased odds that children would be daily packaged snack consumers–an association that is the inverse of the expected relationship. The results of this study thus suggest that ease of access is not associated with frequent consumption of minimally nutritious foods among Vancouver children and youth. This finding contrasts with the associations of Healthy Eating Index scores and fast food outlet access identified by He et al. (2012b) in London, Ontario as well as the relationships Davis and Carpenter (2009) observed for soda consumption and fast food outlet access. However, the results are in keeping with those obtained by An and Sturm (2012), who did not find associations of daily servings of soda, high-sugar foods and fast foods among California students and food retailer densities surrounding schools.

The models fitted in this study included controls for school level (secondary versus elementary) and whether students reported bringing lunch from home on a daily basis; food insecurity offered a measure for student-level socioeconomic status while school-level median family income was used as a measure of socioeconomic status at the school level. Associations of control variables and students' regular consumption of minimally nutritious foods are comparable to those obtained in a previous study with the I-EAT data (Velazquez et al., 2015).

Finally, this study also examined the agreement between students' perceptions of food outlet proximity and objective proximity, finding "slight" agreement according to the Landis scale (Landis and Koch, 1977). This result may explain inconsistencies in previous research between associations with perceived and objective food outlet measures; Svastisalee et al. (2015), for example, find that boys who reported perceived access to 2 or more outlets within 5 minutes had an increased odds of weekly fast food consumption in comparison with boys who reported a lower level of access, but failed to find statistically significant associations of fast food consumption and comparable objective measures of proximity. Some studies have relied on principals' perceptions of food access rather than on students' reports (Gebremariam et al., 2012; Morin et al., 2015); further research is necessary to examine whether administrators can offer reliable and valid estimates of food environment measures.

4.4.1 Limitations

Although the null findings obtained in this study are comparable to those obtained by other researchers, they may be due to limitations of the study design. With 26 schools, the study had limited power to detect statistically significant associations of dependent variables and food environment measures at the school level. In addition, the study included both elementary and secondary school students; there is evidence that secondary students may be more likely to frequent off-campus vendors (Velazquez et al., 2015) and thus a need remains for research focused exclusively on older students.

In addition, the study was conducted in a commercially dense city. The maximum distance from any school to at least one food outlet was 931 metres (Southlands Elementary); thus there may not be enough variance in the school food environment to detect statistically significant effects.

The findings could also be affected by measurement error: the dependent variables used in this study were constructed from self-reported data and thus may be subject to the problems of over- or underreporting commonly observed in food frequency questionnaire data (Deschamps et al., 2009; Perks et al., 2000; Watson et al., 2009). However, the food frequency questionnaire remains the most appropriate means of assessing diets in the context of this study given its scope and low burden to participants (Willett, 2012) as well as evidence of acceptable validity and reliability for the measurement of dietary intake in older children and adolescents (Maruti et al., 2006).

Finally, dietary intake outcomes for this study were dichotomized into binary measures of daily- versus less-than-daily consumption, potentially introducing bias through the choice of cutoff (Royston et al., 2006). However, results were reasonably robust to the use of alternative dichotomizations (weekly versus less-than-weekly consumption) as well as to the use of multilevel OLS regressions with continuous outcomes.

4.4.2 Strengths

Although limitations of study design may underlie the null results, the methods used in this study represented the best practices recommended by food environments researchers. The study relied on validated food environments data (Chapter 2). In addition, multiple measures of the food environment were examined, including objective density at 400 and 800m, objective proximity, and students' perceptions of proximity. Objective density was evaluated with line-based road network buffers, as recommended by Oliver et al. (2007), while the evaluation of street network distance—as used in this study—is considered the best available means of quantifying proximity (Thornton et al., 2011). Multilevel modeling allowed for the simultaneous study of both school- and student-level variables (Diez Roux, 2004), while results were robust to the use of listwise deletion or multiple imputation for missing observations. Finally, models were adjusted for gender, spending money and school-level socioeconomic status. Although controlling for race, recommended by Cobb et al. (2015), was not appropriate in the Canadian context, the measure of "acculturation" allowed this study to approximate a control immigrant status.

4.5 Conclusions

This study did not find statistically significant associations between students' intake of minimally nutritious foods and the density or proximity of fast food retailers, convenience stores or grocery/supermarket stores surrounding those students' schools. Furthermore, this study found that students' perceptions of access were not reliable alternatives to researchers' measurements of street-based proximity; however, results were robust to the use of objective or perceived measures of food outlet access. While the null results obtained in this study may be a product of low statistical power or a lack of variance in access at the school level, the methods used in this study represent best practices from current food environments research. In Vancouver, the evidence for restrictive zoning or other policy measures to restrict food vendor access near schools remains weak; further research is needed to identify effective policies for improving the nutritional quality of children's school-day diets.

Chapter 5

Conclusion

This thesis consisted of three connected studies of the food environments surrounding schools in Vancouver, BC. Chapter 2 examined the validity of two commercial and two municipal data sources for food retailers; the best-performing data set, the City of Vancouver Business License Lists, was then used in Chapter 3 to search for socioeconomic or demographic disparities in Vancouver school food environments. Finally, Chapter 4 assessed the relationships between measures of the food environments surrounding a subset of Vancouver Schools and student consumption of sugar-sweetened beverages, fast foods, or packaged snacks. Ultimately, the study did not find evidence of consistent associations between the density or proximity of food outlets in relation to Vancouver schools and students' consumption, at or en-route to school, of these minimally nutritious foods.

5.1 Contributions and Significance

This thesis joins a growing literature suggesting that the food environments surrounding schools have, at most, a weak association with students' diet-related health (Williams et al., 2014). In this study, significance tests failed to reject the null hypothesis of no association for almost all relationships examined between food environment measures and students' intake of sugar-sweetened beverages, fast food, or packaged snacks. The study additionally included a comparison of objective and perceived food environment measures, finding that perceived measures had poor reliability for the measurement of students' access to food outlets.

The comparative validation of two commercial and two municipal sources of data on food retailer locations (Chapter 2) offers methodological insight: for other researchers hoping to study food outlets in Vancouver, BC, the results from Chapter 2 suggest that the City of Vancouver's Business Licenses data have higher sensitivity, PPV, and concordance than do other available data sets; furthermore, the Business Licenses data did not show evidence of systematic over- or undercounting in association with socioeconomic deprivation or commercial density. The study offers the first comparative study of the validity of municipal and commercial data sets for food outlet locations in Canada; in addition, it joins just one other known study (Ma et al., 2013) examining the effect of over- or undercounting in food outlet data sources on measures of the food environment.

This thesis also examined the associations between school demographic and socioeconomic characteristics and the food environments surrounding schools (Chapter 3). The study did not find significant associations between the percent of aboriginal students or the percent of English Language Learners enrolled in Vancouver schools and food outlet density or proximity, but higher convenience store densities were observed within 400m and 800m regions of high-poverty schools in comparison with schools with fewer students living in poverty; including neighbourhood commercial density and neighbourhood socioeconomic deprivation weakened these associations. Although this study begins to address an important research gap—only Engler-Stringer et al. (2014b) previously examined for demographic disparities in the food environments surrounding schools in Canada, and no previous study in Canada has used school-level measures of student demographics for such research—the potential existence of ethnic disparities in food access and food retail exposure remains an important and under-examined issue in Canada (Black, 2015).

5.2 Strengths and Limitations of the Research

In a systematic review of 71 food environments studies, Cobb et al. (2015) identify common flaws in examinations of the associations between food retailer access and obesity. Among other concerns, the researchers argue that food outlet locations should be validated, that researchers should control for socioeconomic and demographic factors, and that analyses should account for multilevel data structures. This study addressed such issues by validating the data sets used (Chapter 2), including controls for demographic and socioeconomic factors (Chapters 3 and 4) and using multilevel modeling (Chapter 4).

However, Cobb et al. (2015) also suggest that studies should use objective—rather than self-reported—outcome measures and that study designs should account for neighbourhood self-selection. Dependent variables for Chapter 4 were constructed from self-report data, and the cross-sectional research design of both chapters 3 and 4 failed to account for the possibility of self-selection—though the ecological analysis of food retailer locations (Chapter 3) served to assuage some fears regarding possible simultaneity in food retailer access and students' dietary behaviours.

Some of the data sources used in this research were also subject to temporal mismatch (Fleischhacker et al., 2011); in particular, the school-level measure of socioeconomic deprivation used in Chapter 3 was constructed from the 2006 Census of Canada, but all other measures used in that chapter were from the 2011-2012 school year. Similarly, the commercial business location data validated in Chapter 3 was several years older than the municipal and gold standard data, though the validation of both 2015 and 2012 Business License data offered insight on the amount of over- or under-counting that might be attributable to temporal changes in outlet locations. Both survey data collection and food outlet location data in Chapter 4, however, were limited to data collected between March and June of 2012.

The use of school-day dietary intakes, rather than obesity or other measures of diet-related health, as outcomes in Chapter 4 reduced the potential of walkability or other neighbourhood factors to confound associations—as may occur in the study of the school food environment and BMI or obesity status (Cobb et al., 2015)—but its use introduced the potential for measurement error in the construction of a binary measure of "daily" versus "less-than-daily" consumption of each dietary intake category. The results were robust, however, to the use of different cut-points (Section 4.3.1). Chapter 4 may also have had low power to detect effects specific to secondary school students, due to the lower percentage of secondary schools versus elementary schools (and secondary school students versus younger students) in the sample, which could obscure associations that affect only more autonomous older students. In addition, this thesis focused exclusively on students' *access* to food retailers, though the food environment includes other dimensions such as affordability or acceptability (Caspi et al., 2012); further work remains necessary to examine whether the prices of items within food retailers or the quality of foods available to students affect dietary behaviours.

This thesis also had important strengths in the high standard of quality for methodological approaches used, given the diversity of measurement and statistical approaches used in current food environments research (Caspi et al., 2012; Williams et al., 2014; Moore and Diez-Roux, 2015). Food outlet locations were validated against ground-truthed data, the gold standard in food environments research (Lucan, 2015; Fleischhacker et al., 2013), and all analyses were conducted with the best performing data set. In contrast with studies that have considered food environments exposure within neighbourhoods based on administrative units like census tracts (e.g. Maddock (2004), Sturm and Datar (2005), or Inagami et al. (2006)), which have limited validity as a measure of student exposure (Holsten, 2009), this study assessed density and proximity for outlets within walking distance of schools; furthermore, proximity was measured with street-network distances, considered a more accurate measure of walkable areas than Euclidean (straight-line) measures (Sparks et al., 2010), and density was evaluated within line-based buffers following Oliver et al. (2007). Finally, this thesis tested robustness of the results to both the choice of distance considered "walking" distance and to the choice of food environments measure used, evaluating density within 160, 400 and 800 meters from schools and conducting all analyses with both density and proximity.

5.3 Avenues for Future Research

5.3.1 Understanding Adolescents' Dietary Behaviours

Despite the proliferation of food environments studies, the nature of children's and adolescents' interactions with food retailers remains poorly understood. Although few studies of the food environment explicitly state the mechanism by which food outlets are expected to be affecting students' diets (Caspi et al., 2012), it is likely that most researchers see food purchases as a critical component of the causal pathway—that is, that researchers think ease of access to food retailers translates into increased consumption by making it easier for students to purchase fast and snack foods. Advertising exposure, however, may offer another means by which outlet exposure affects students' diets: posters or other advertisements are often located on or near stores (Walton et al., 2009), so children who see multiple stores at or en-route to schools may be exposed to more unhealthy advertisements and may, as a result, develop less healthful dietary preferences. Other mechanisms beyond advertising may affect children's choices; qualitative studies with schoolchildren could help researchers identify other relevant mechanisms.

The associations between within-school food environments and the food environments surrounding schools would also be worthy of inquiry. Recent changes in policies regarding vending and school food availability might be leading more students to make purchases off campus (Mâsse et al., 2013); food retailers may also be more successful near schools without cafeterias, where students are in need of alternative lunch options. Finally, the associations of student ethnicity and food access remain understudied in Canada (Black, 2015); further research testing for disparities in food environments both within and surrounding schools in association with student sociodemographic characteristics is necessary fill this critical research gap.

5.3.2 Methodological Improvements

Although there have been a number of small-scale studies validating food environments data sources, there is still no data source validated for national or multi-city inquiry in Canada. Canadian studies have largely focused on individual cities; the few national food environments studies may be compromised by systematic bias according to urban density (discussed in Section 3.4). But nationwide work remains critical given evidence of serious disparities in supermarket and grocery store access in rural Northern communities (Health Canada, 2013) as well as evidence in Section 3.4 of noteworthy differences between municipalities and provinces in terms of food retailer distributions.

The field of food environments research also suffers from a lack of consensus regarding gold-standard measures of the food environment (Cobb et al., 2015; Caspi et al., 2012; Feng et al., 2010). In the case of food retailer density, for example, researchers have measured the food environment within distances as short as 160m from schools (Currie et al., 2010) and as far as 3000m from schools (Laska et al., 2010). Although different measures are necessary in the diverse of regions examined as well as in contexts of older versus younder students, some measures are probably more valid than others

(Cobb et al., 2015). Several studies have examined activity spaces—the set of locations people visit regularly throughout their daily activities—rather than focusing on buffers (Zenk et al., 2011; Christian, 2012; Stewart et al., 2015). Activity spaces should not replace buffer zones, because the former introduce endogeneity (students choose to include food outlets in their visited locations (Chaix et al., 2012)), but activity space research could be used to identify buffer sizes most representative of the distances schoolchildren travel during lunchtime breaks.

Finally, a recent review of studies associating obesity outcomes and school food environments observed that almost all studies have been cross-sectional in design (Williams et al., 2014). Smith et al. (2013) and Rossen et al. (2013) offered longitudinal examinations, which allow researchers to examine associations between the length of a students' exposure and change in outcomes over time, offering more utility than cross-sectional studies for researchers hoping to uncover cause and effect (Smith et al., 2013). But even in longitudinal studies, the possibility of endogeneity prevents researchers from making causal statements. A need remains for study designs and analytical approaches informed by causal inference, such as the identification and evaluation of natural experiments—a natural variation in the exposure of interest, for example due to a policy change (Petticrew et al., 2005)—or the use of instrumental variables as in Alviola et al. (2014).

5.4 Policy Relevance and Implications

Some local governments in the United States have restricted the ability of fast food vendors to locate near schools. Detroit, Michigan has an ordinance requiring a minimum of 500 feet between schools and fast food or drive-in restaurants, while Arden Hills, Minnesota requires that drive-in and fast food restaurants be located at least 400m from schools (Mair et al., 2005). While these policies have not been evaluated, a systematic review of studies associating obesity outcomes and school food environments (Williams et al., 2014) finds that the empirical evidence does not, at present, offer strong support for such policies from the perspective of public health advocacy. Given the present limitations of the empirical study of school food environments as well as the findings, in this thesis similarly, of no consistent evidence that the school food environment plays a significant role in Vancouver children's dietary behaviours at or en-route to school, efforts to alter the food environments surrounding Vancouver public schools would be premature.

For public health practitioners and policymakers seeking to reduce children's intakes of minimally nutritious foods, there are other intervention areas with more reliable results. Increasing within-school availability of fruits and vegetables, for example, and decreasing within-school availability of sugar-sweetened beverages has been consistently associated with desirable dietary behaviours in children (Afshin et al., 2015). Nutrition standards for food items available within schools have similarly been shown to encourage healthier dietary intakes in students (McKenna, 2010), though an evaluation of Canadian school nutrition policies found that current standards were in need of improvement (Leo, 2007).

In the face an obesity epidemic of unprecedented global scale, incremental interventions have been inadequate: Ng et al. (2014) found that despite some evidence of slowdowns in the increasing prevalences of obesity in developed countries, no country showed a significant decrease in obesity prevalence. There were, according to the researchers, "no national success stories" in the 33-year time period examined. While methodological improvements may help food environments researchers uncover a role of food retailer exposure in the rise of childhood obesity and diabetes (Cobb et al., 2015), this thesis research joins an increasing number of studies suggesting that public health practitioners will need to look elsewhere for high-impact approaches to obesity prevention.

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Appendix A

Ground-Truthing Protocol and Classification Scheme

Ground Truthing Protocol
Data Validation Project

Checklist

- ☐ Packet/binder with
  - Log Sheet
  - Store Observation Sheet
  - Advertisement Observation Sheet
  - Store Classification Guidelines
  - Advertisement Observation Guidelines
  - Overall Map
  - Individual School Map
  - Official Letter
- ☐ Digital camera or Camera Phone
- ☐ Mobile GPS Unit

Strategy:

1. Record start date and time. All surveys should be conducted on weekdays between 9 a.m. and 5 p.m.
2. For each school, first survey both sides of each major commercial road
    a. Then start at the north-most point on the individual school map.
        i. Walk each east-west road (except for the center road) first on the north side and then on the south side. Take the most central road to move from north to south.
        ii. Once both sides of each east-west road have been examined, apply the same pattern to the north-south roads, again using the center road to move between parallel roads.
    b. Now examine all remaining roads.
3. Upon identifying a potential food vendor:
    a. Assign unique id number representing the school, number representing identification order.
    b. Photograph site.
        i. The photo should be recorded with coordinates & ID number.
        ii. At least one photo should include the store name.
    c. Record store name and street address.
    d. Record GPS coordinates.
    e. Follow classification chart to determine classification.
4. Upon identifying a potential advertisement or signage:
    a. Check to make sure the object is visible from the street or sidewalk.
    b. Assign a unique id number representing the school and the identification number.
    c. Photograph the advertisement.
        i. The photo should be recorded with coordinates & ID number.
    d. Record the advertisement type, description, and location type (e.g. shop window, bus station, etc.).
    e. Record the GPS coordinates.
5. As streets are visited, record on individual map. Once both sides of each street have been examined, record end time.
6. At the end of each day, download photographs to the project computer.

Notes:

- If you encounter someone while ground-truthing, offer the attached letter to describe the research activities.
- If a potential storefront is empty, record the location and notes on what may have been there previously; similarly, if an outlet is opening, note the date.

Log Sheet

School #1:
School Name ____
Date visited ____
Start Time __________ **End Time** __________ **Break Periods** __________
Roads examined ____
____
____
No. Stores Identified ____
No. Advertisements Identified ____
Notes ____
____
____

School #2:
School Name ____
Date visited ____
Start Time __________ **End Time** __________ **Break Periods** __________
Roads examined ____
____
____
No. Stores Identified ____
No. Advertisements Identified ____
Notes ____
____
____

School #3:
School Name ____
Date visited ____
Start Time __________ **End Time** __________ **Break Periods** __________
Roads examined ____
____
____
No. Advertisements Identified ____
No. Stores Identified ____
Notes ____
____
____

Store Observation Sheet: School #2

Unique ID	Name	Address & coordinates	Classification	Notes
2001		N ___.________ W___.________		
2002		N ___.________ W___.________		
2003		N ___.________ W___.________		
2004		N ___.________ W___.________		
2005		N ___.________ W___.________		
2006		N ___.________ W___.________		
2007		N ___.________ W___.________		
2008		N ___.________ W___.________		
2009		N ___.________ W___.________		
2010		N ___.________ W___.________		
2011		N ___.________ W___.________		
2012		N ___.________ W___.________		

Unique ID	**Name**	**Address & coordinates**	**Classification**	**Notes**
2013		N ___.________ W___.________		
2014		N ___.________ W___.________		
2015		N ___.________ W___.________		
2016		N ___.________ W___.________		
2017		N ___.________ W___.________		
2018		N ___.________ W___.________		
2019		N ___.________ W___.________		
2020		N ___.________ W___.________		
2021		N ___.________ W___.________		
2022		N ___.________ W___.________		
2023		N ___.________ W___.________		
2024		N ___.________ W___.________		
2025		N ___.________ W___.________		

Advertisement Observation Sheet: School ____________________

<table>
<tr><th>Unique ID</th><th>Category</th><th>Type</th><th>Location</th><th>Setting</th><th>Coordinates</th></tr>
<tr><td rowspan="2">2001</td><td>Ad
Signage</td><td></td><td></td><td>Main Street
Residential</td><td>N ___.________
W___.________</td></tr>
<tr><td colspan="5">Content: Food Alcohol Tobacco Other _____________
Description (include size, product and brand name):

Notes:</td></tr>
<tr><td rowspan="2">2002</td><td>Ad
Signage</td><td></td><td></td><td>Main Street
Residential</td><td>N ___.________
W___.________</td></tr>
<tr><td colspan="5">Content: Food Alcohol Tobacco Other _____________
Description (include size, product and brand name):

Notes:</td></tr>
<tr><td rowspan="2">2003</td><td>Ad
Signage</td><td></td><td></td><td>Main Street
Residential</td><td>N ___.________
W___.________</td></tr>
<tr><td colspan="5">Content: Food Alcohol Tobacco Other _____________
Description (include size, product and brand name):

Notes:</td></tr>
<tr><td rowspan="2">2004</td><td>Ad
Signage</td><td></td><td></td><td>Main Street
Residential</td><td>N ___.________
W___.________</td></tr>
<tr><td colspan="5">Content: Food Alcohol Tobacco Other _____________
Description (include size, product and brand name):

Notes:</td></tr>
</table>

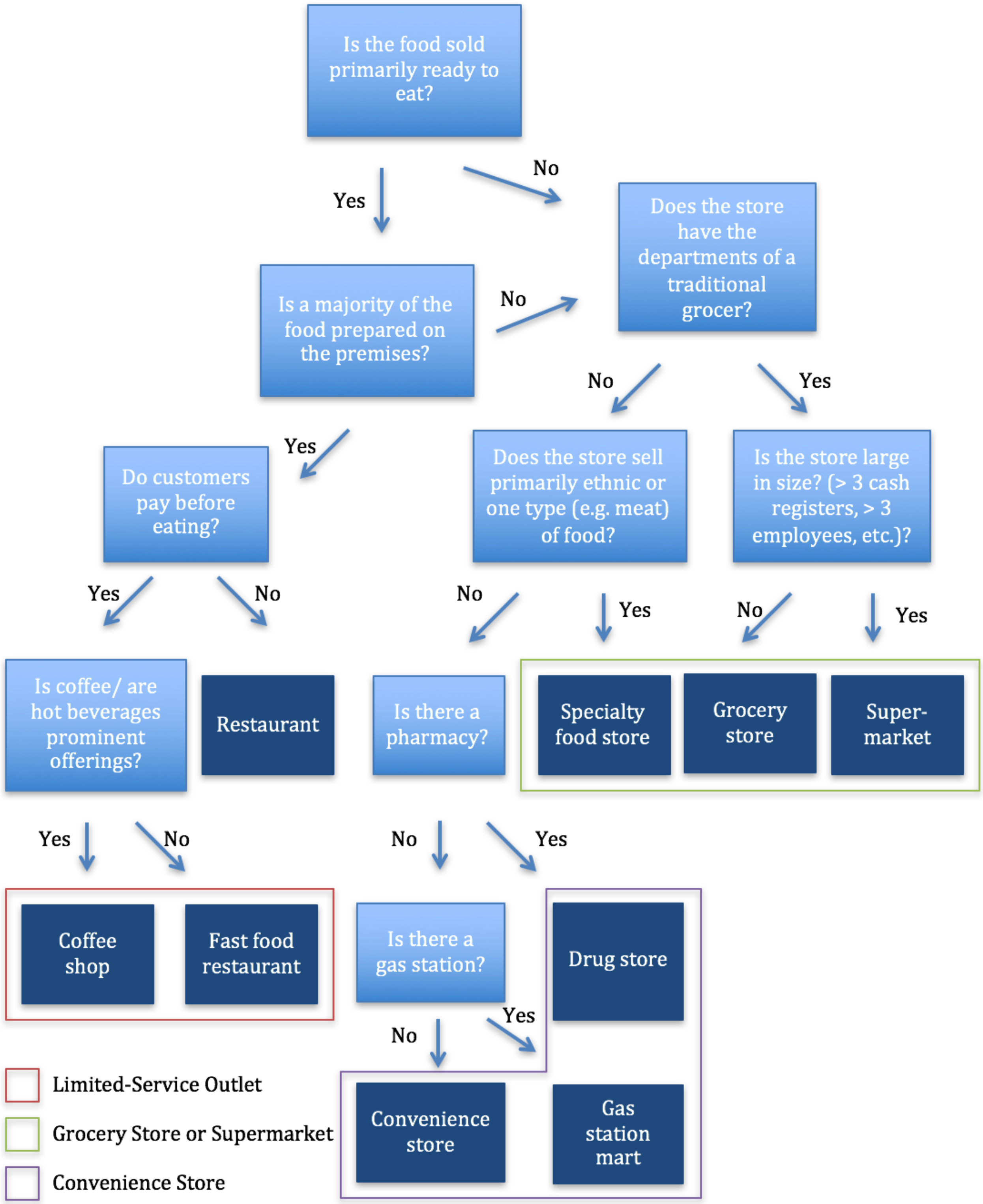
Unique ID	Category	Type	Location	Setting	Coordinates
2005	Ad Signage			Main Street Residential	N ___.________ W___.________
	Content: Food Alcohol Tobacco Other ____________ Description (include size, product and brand name): Notes:				
2006	Ad Signage			Main Street Residential	N ___.________ W___.________
	Content: Food Alcohol Tobacco Other ____________ Description (include size, product and brand name): Notes:				
2007	Ad Signage			Main Street Residential	N ___.________ W___.________
	Content: Food Alcohol Tobacco Other ____________ Description (include size, product and brand name): Notes:				
2008	Ad Signage			Main Street Residential	N ___.________ W___.________
	Content: Food Alcohol Tobacco Other ____________ Description (include size, product and brand name): Notes:				

Classification Guidelines

Store Type	Description	Key Questions	Code
Drugstore	A retail store including a pharmacy that offers snacks or beverages	1. Does the store have a pharmacy?	**CvPh**
Gas station convenience store	A retail store attached to a gas station offering primarily snacks and beverages	1. Is the store connected with a gas station? 2. Do snack food items and beverages comprise a majority of the goods sold?	**CvGa**
Regular convenience store	A retail store offering primarily snack foods – but may offer a variety of other products; open 18-24 hours	1. Do snack food items and beverages comprise a majority of the goods sold? 2. Does the store have fewer than three cash registers, or is otherwise smaller than a traditional grocery store? 3. Is the store's stock more limited than what would be available in a grocery store or supermarket?	**Cv**
Supermarket	A large retail store with all of the departments of a traditional grocery store earning over $2mil/year in revenues	1. Does the store have all of the departments of a traditional grocer (dairy, bakery, produce, butcher)? 2. Is the store open more than 18 hours per day or 7 days per week? 3. Does the store have more than two cash registers?	**Sm**
Grocery store	A retail store with all the depart-ments of a traditional grocery, but smaller than a supermarket.	1. Does the store have dairy, deli, bakery, butcher and produce departments? 2. Is the store closed during the week or in the evening? 3. Is the store smaller than a conventional supermarket? 4. Does the store have two or fewer cash registers?	**SmGr**

Store Type	Description	Key Questions	Code
Produce Outlet	A retail store primarily engaged in the sale of fruits and vegetables.	1. Is produce displayed prominently outside of or within the store? 2. Does produce comprise a majority of the store's offerings?	**SmPr**
Other specialty food store	Any retail store selling food or beverages that does not qualify in the above categories.	1. Does the store sell mostly one type of food item to be prepared/eaten at home (meat, cheese, etc.)? **2.** Are the majority of the store's food items associated with one or several ethnic groups?	**SmSp**
Fast food restaurant	A restaurant offering eat-in or takeaway options and more limited service than that of a traditional restaurant	1. Does the outlet provide both food to be eaten on the premises and takeaway options? 2. Do patrons primarily pay before consuming foods or beverages?	**ReFF**
Coffee shop	A restaurant offering eat-in or takeaway options, primarily engaged in the sale of beverages, with limited service.	1. Does the outlet offer coffee and other hot beverages? Are these items a majority of the offerings or particularly prominently advertised and offered? 2. Do patrons primarily pay before consuming food or beverages?	**ReCo**
Other Restaurant	A traditional restaurant offering table service, where eat-in is a more significant portion of sales than takeaway service	1. Does the outlet provide food to be eaten on the premises? 2. Do patrons primarily pay after eating? 3. Are orders generally taken while patrons are seated?	**Re**

Classification Choice Flow Diagram



Advertisement Recognition Guidelines

In addition to store locations, we are also recording the locations of commercial grade outdoor advertisements. We are looking for two types of marketing materials

Advertisement: a sign with branded information, pictures, or logos.
Signage: all signs unaccompanied by additional branded product information

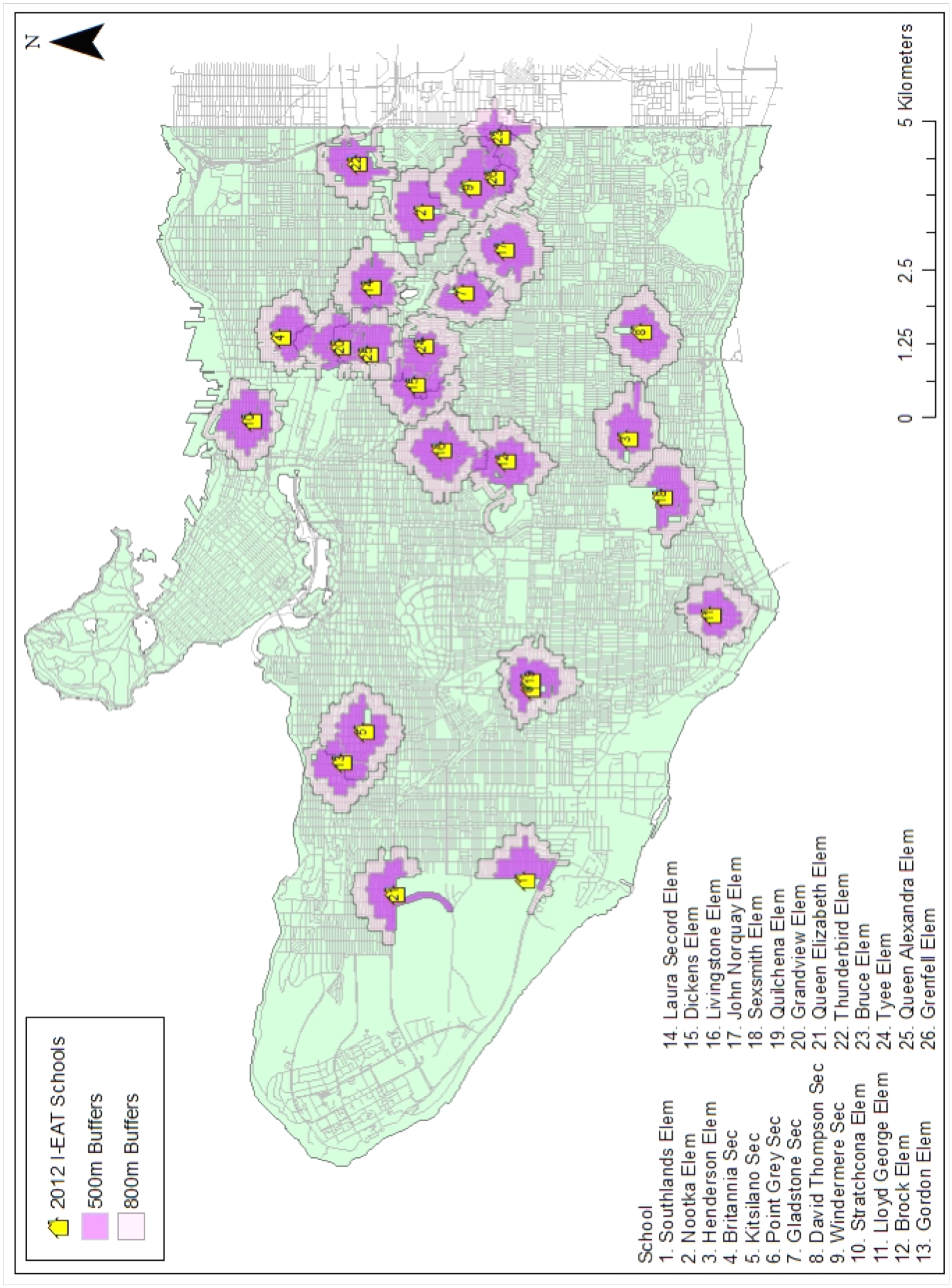
In order to be considered for this study, an advertisement must be:

1. visible from the street or sidewalk
   a. e.g. billboards, bus shelter advertisements, and store window posters
2. Stationary
   a. Hand-drawn or painted advertisements or advertisements on buses should not be included.
3. Related to food or diet

Once an advertisement is identified, the category, type, location, setting, and subject should be recorded in the advertisement observation sheet. Possible observations include:

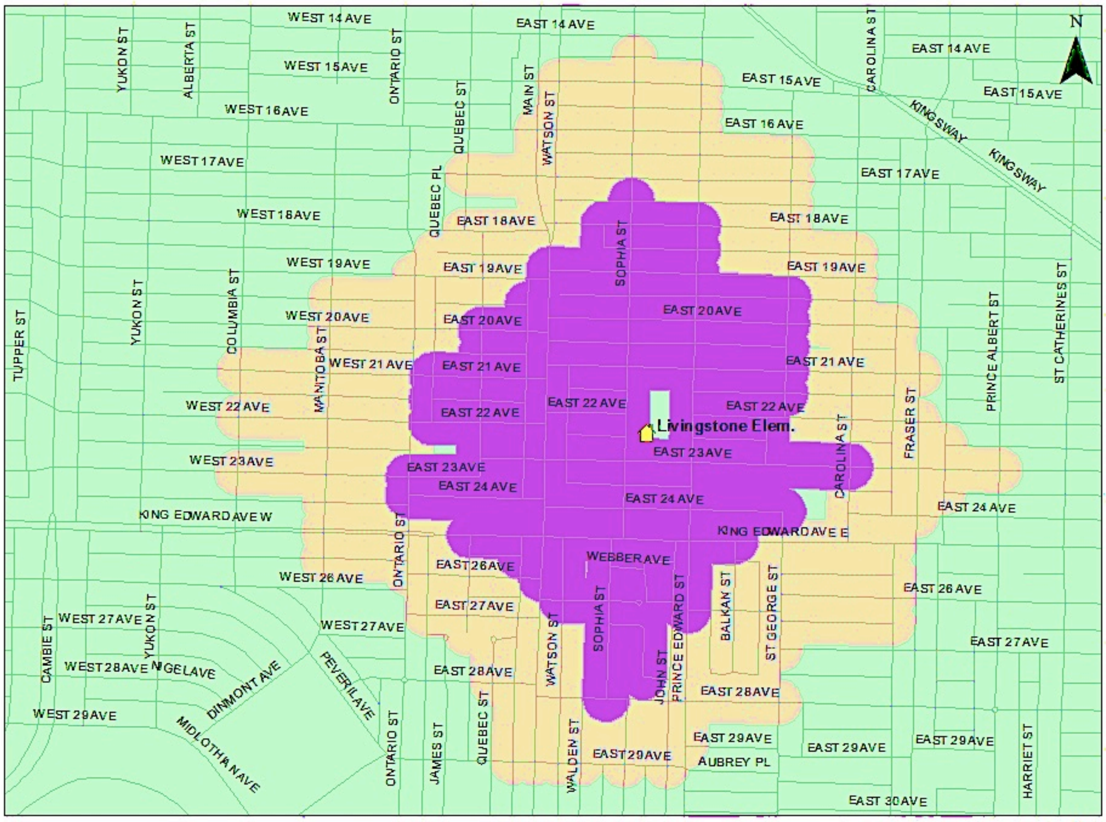
1. Category	2. Type & Size	3. Location	4. Setting	5. Subject
• **Advertisement** ○ e.g. billboards/ posters, event advertising, advertisements on outdoor furniture, building signs w/ branded product information. • **Signage** ○ signs identifying and naming sites/ buildings/ building uses; should be limited to symbols or words only.	• Billboard • Poster • Freestanding sign • Neon sign • Electronic boards • Banners • Bus shelter signs • Other ______ **Size:** • small: ≥21 cm × 20 cm but <1.2 m × 1.9 m • medium ≥1.2 m × 1.9 m but <2.0 m × 2.5 m • large: ≥2m×2.5m	• Drugstore • Gas station convenience store • Regular convenience • Supermarket • Grocery store • Produce outlet • Other specialty food store • Fast food restaurant • Coffee shop • Other restaurant • Other ________	• Main street • Residential street	• Food & Beverage • Alcohol • Tobacco • Other _______________

Maps



N
2012 I-EAT Schools
500m Buffers
800m Buffers
School
1. Southlands Elem
2. Nootka Elem
3. Henderson Elem
4. Britannia Sec
5. Kitsilano Sec
6. Point Grey Sec
7. Gladstone Sec
8. David Thompson Sec
9. Windermere Sec
10. Stratchcona Elem
11. Lloyd George Elem
12. Brock Elem
13. Gordon Elem
14. Laura Secord Elem
15. Dickens Elem
16. Livingstone Elem
17. John Norquay Elem
18. Sexsmith Elem
19. Quilchena Elem
20. Grandview Elem
21. Queen Elizabeth Elem
22. Thunderbird Elem
23. Bruce Elem
24. Tyee Elem
25. Queen Alexandra Elem
26. Grenfell Elem
0
1.25
2.5
5 Kilometers

Individual School #2: David Livingstone Elementary



a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

To Whom It May Concern:

During the summer and fall of 2015, researchers at the University of British Columbia will be conducting research on the sources of food available to secondary and elementary school students in the city of Vancouver.

Researchers will be examining many of the roads within 1km of Vancouver Public schools to identify store locations and to collect basic information such as store name or type. We do not work for the city or provincial governments, and our findings will be made publicly available within the next year, but will not identify stores by name.

If you have any questions about the research, please contact Madeleine Daepp at mdaepp@alumni.ubc.ca. Thank you for your interest in this study.

Sincerely,

Madeleine Daepp
M.Sc. Candidate – Integrated Studies in Land & Food Systems
University of British Columbia, Vancouver

Appendix B

Additional Tables for Chapter 2

Table B.1: Name-based classifications system applied to identify major store types

	Vancouver Coastal Health	**Canada Business Points**	**Enhanced Points of Interest**
Limited-Service Outlet	“McDonald’s”, “Wendy’s”, “Subway”, “Quizno”, “freshslice”, “Church’s Chicken”, “Vera’s”, “Kentucky Fried” “Panago”, “Al Basha”, “nando’s”, “Buddha’s Orient”, “Solly’s”, “creme”, “Freshii”, “Tim Hortons”, “Starbucks”, “Waffle Gone Wild”, “Dairy Queen”, “shawarma”, “Pizza”, “Gelat”, “Bagel”, “Falafel”, “sandwich”, “burrito” “pizzeria”, “sweet”, “burger” “donair”, “ice cream” “donut”, “Cafe”, “coffee”, “caffe”, “juice”, “bean”, “chai”, “cream”, “express”	“McDonald’s”, “Wendy’s”, “Subway”, “Quizno”, “freshslice”, “Church’s Chicken”, “Vera’s”, “Kentucky Fried” “Panago”, “A & W” “nando’s”, “Buddha’s Orient”, “Solly”, “creme”, “Freshii”, “Tim Hortons”, “Starbucks”, “Waffle Gone Wild”, “Dairy Queen”, “shawarma”, “Pizza”, “Gelat”, “Bagel”, “Falafel”, “sandwich”, “burrito” “pizzeria”, “sweet”, “donair”, “ice cream” “donut”, “blenz”, “coffee”, “juice”, “tea”, “burger”, “chai”, “cream”, “express”	“McDonald’s”, “Wendy’s”, “Subway”, “Quizno”, “freshslice”, “Church’s Chicken”, “Vera’s”, “Kentucky Fried” “Panago”, “A & W” “nando’s”, “Buddha’s Orient”, “Solly”, “creme”, “Freshii”, “Tim Hortons”, “Starbucks”, “Waffle Gone Wild”, “Dairy Queen”, “shawarma”, “Pizza”, “Gelat”, “Bagel”, “Falafel”, “sandwich”, “burrito” “pizzeria”, “sweet”, “donair”, “ice cream” “donut”, “blenz”, “coffee”, “juice”, “tea”, “burger”, “chai”, “cream”, “express”

(Continued)	**Vancouver Coastal Health**	**Canada Business Points**	**Enhanced Points of Interest**
Convenience Stores	"Convenience", "Mart" "Shell" , "Chevron", "Stop", "Drug", "Rx" "Gas", "Store", "food", "Petro", "Town Pantry", "Husky", "Pharmacy" "Rexall", "Shoppers", "7-Eleven", "Medicine" "market", "Esso",	"Convenience", "Mart" "Shell" , "Chevron", "Esso", "Food Stop", "Drug", "Rx" "Gas", "Store", "food", "Petro", "Town Pantry", "Husky", "Pharmacy" "Rexall", "Shoppers", "7-Eleven", "Medicine", "Pharmasave", "market"	"'Convenience", "Mart" "Shell" , "Chevron", "Esso", "Food Stop", "Drug", "Rx" "Gas", "Store", "food", "Petro", "Town Pantry", "Husky", "Pharmacy" "Rexall", "Shoppers", "7-Eleven", "Medicine", "Pharmasave", "market"
Supermarket or Grocery Stores	"Grocery", "Supermarket", "Super Valu", "Safeway", "Choices", "Persia", "Donald's", "Marketplace" "Famous Foods", "Nesters", "Co-op", "Save-on", "Farm Market", "Price smart"	"Grocery", "Supermarket", "Super Valu", "Safeway", "Choices", "Persia", "Donald's", "Marketplace" "Famous Foods", "Nesters", "Co-op", "Save-on", "Farm Market", "Price smart", "Grocer", "Stop & Shop", "Loblaw"	"Grocery", "Supermarket", "Super Valu", "Safeway", "Choices", "Persia", "Donald's", "Marketplace" "Famous Foods", "Nesters", "Co-op", "Save-on", "Farm Market", "Price smart", "Stop & Shop"

Relevant terms were identified with frequency tabulations and lists of terms were iteratively refined until all food outlets were classified. Name-based classifications were not case sensitive.

Table B.2: Bivariate associations of commercial density or socioeconomic status and the odds of false positive listings† in each secondary data source

	Business Licenses 2015	**Business Licenses 2012**	**Vancouver Coastal Health**	**Canada Business Points**	**Enhanced Points of Interest**
Commercial Density					
Per 100 outlets	0.95 (0.90 - 1.01)	0.96 (0.91 - 1.02)	1.02 (0.95 - 1.10)	1.05 (0.98 - 1.12)	1.06 (0.99 - 1.12)
VANDIX§					
low	–	–	–	–	–
medium	1.05 (0.76 - 1.44)	0.97 (0.70 - 1.33)	0.86 (0.59 - 1.25)	0.70* (0.50 - 0.99)	0.74 (0.53 - 1.03)
high	0.98 (0.72 - 1.35)	1.07 (0.79 - 1.47)	1.20 (0.82 - 1.75)	0.85 (0.60 - 1.21)	0.86 (0.62 - 1.21)
N	923	929	677	778	851

Odds ratios with 95% confidence intervals in parentheses. †A listing was a false positive if an outlet was listed in the secondary data but not identified or misclassified in the ground-truthed data. §"high" refers to the most deprived neighbourhoods.
*significant at 0.05; **significant at 0.01; ***significant at 0.001

Table B.3: Bivariate associations of commercial density or socioeconomic status and the odds of false negative listings† in each secondary data source

	Business Licenses 2015	**Business Licenses 2012**	**Vancouver Coastal Health**	**Canada Business Points**	**Enhanced Points of Interest**
Commercial Density					
Per 100 outlets	0.95 (0.89 - 1.01)	0.97 (0.91 - 1.03)	1.07* (1.01 - 1.14)	1.11** (1.04 - 1.18)	1.08* (1.02 - 1.15)
VANDIX§					
low	–	–	–	–	–
medium	1.11 (0.78 - 1.58)	1.26 (0.89 - 1.77)	0.95 (0.68 - 1.34)	0.67* (0.47 - 0.95)	0.84 (0.59 - 1.19)
high	0.93 (0.65 - 1.33)	1.08 (0.76 - 1.53)	1.36 (0.96 - 1.92)	0.94 (0.66 - 1.33)	1.10 (0.78 - 1.56)
N	788	788	788	788	788

Odds ratios with 95% confidence intervals in parentheses. †A listing was a false negative if an outlet was identified while ground- but not identified or misclassified in the secondary data source. §"high" refers to the most deprived neighbourhoods.
*significant at 0.05; **significant at 0.01; ***significant at 0.001

Appendix C

Additional Tables for Chapter 3

Table C.1: Results from negative binomial regressions with food outlet densities within 800m of Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables

800m Density	**(1) Limited Service**	**(2) Convenience Store**	**(3) Grocery/ Supermarket**
% Aboriginal	1.01 (0.99 - 1.04)	1.01 (1.00 - 1.03)	1.01 (0.99 - 1.03)
% English Language Learners (ELL)	1.00 (0.99 - 1.01)	1.00 (0.99 - 1.01)	1.00 (0.99 - 1.01)
Inner City Project (ICP)	1.35 (0.69 - 2.61)	1.88* (1.13 - 3.14)	2.08* (1.09 - 3.95)
McFadden's Pseudo R^2	0.01	0.03	0.02

Incidence rate ratios with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001

Table C.2: Results from negative binomial regressions with food outlet densities within 160m of Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables

160m Density	**(1) Limited Service**	**(2) Convenience Store**	**(3) Grocery/ Supermarket[§]**
% Aboriginal	1.02 (0.97 - 1.07)	1.02 (0.98 - 1.06)	
% English Language Learners (ELL)	0.97* (0.97 - 1.00)	0.99 (0.97 - 1.03)	
Inner City Project (ICP)	1.63 (0.33 - 8.01)	2.99 (0.82 - 10.88)	
McFadden's Pseudo R^2	0.01	0.06	

Incidence rate ratios with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001
[§]Model failed to converge; only six schools had any outlets within 160m.

Table C.3: Results from negative binomial regressions with food outlet densities within 800m of Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables, adjusted for school controls and neighbourhood factors

800m Density	**(1) Limited Service**	**(2) Convenience Store**	**(3) Grocery/ Supermarket**
Students			
% Aboriginal	1.00	1.00	1.00
	(0.99 - 1.01)	(0.99 - 1.01)	(0.98 - 1.01)
% English Language Learners (ELL)	1.00 (0.99 - 1.00)	1.00 (0.99 - 1.00)	1.00 (0.98 - 1.01)
Inner City Project (ICP)	1.14 (0.76 - 1.72)	1.38 (0.98 - 1.94)	1.82* (1.05 - 3.14)
Schools			
Total Enrolment†	0.98	0.98	0.95
	(0.93 - 1.04)	(0.94 - 1.03)	(0.88 - 1.04)
School Level			
Elementary	–	–	–
Secondary	1.21	1.18	1.34
	(0.65 - 2.27)	(0.70 - 1.98)	(0.58 - 3.13)
Neighbourhoods			
Commercial density (800m)‡	1.04*** (1.03 - 1.05)	1.02*** (1.02 - 1.03)	1.02*** (1.01 - 1.03)
VANDIX tertile§			
low	–	–	–
medium	1.38*	1.57**	1.42
	(1.01 - 1.91)	(1.17 - 2.10)	(0.88 - 2.30)
high	1.39	1.74***	1.37
	(0.99 - 1.94)	(1.28 - 2.35)	(0.82 - 2.27)
McFadden's Pseudo R^2	0.13	0.17	0.11

Incidence rate ratios with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001
†per 100 students; ‡per 10 non-food outlets within 800m
§"high" refers to the most deprived neighbourhoods.

Table C.4: Results from negative binomial regressions with food outlet densities within 160m of Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables, adjusted for school controls and neighbourhood factors

160m Density	**(1) Limited Service**	**(2) Convenience Store**	**(3) Grocery/ Supermarket[a]**
Students			
% Aboriginal	1.01	1.01	
	(0.97 - 1.05)	(0.99 - 1.04)	
% English Language Learners (ELL)	0.98	1.01	
	(0.95 - 1.01)	(0.99 - 1.04)	
Inner City Project (ICP)	1.06	1.19	
	(0.27 - 4.15)	(0.37 - 3.82)	
Schools			
Total Enrolment[†]	1.00	1.04	
	(0.84 - 1.19)	(0.87 - 1.25)	
School Level			
Elementary	–	–	–
Secondary	1.17	0.95	
	(0.19 - 7.04)	(0.14 - 6.41)	
Neighbourhoods			
Commercial density (160m)[‡]	2.71***	2.06***	
	(1.90 - 3.87)	(1.59 - 2.67)	
VANDIX tertile[§]			
low	–	–	–
medium	1.01	1.59	
	(0.38 - 2.70)	(0.48 - 5.28)	
high	0.43	1.18	
	(0.13 - 1.45)	(0.32 - 4.29)	
McFadden's Pseudo R^2	0.22	0.24	

Incidence rate ratios with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001
[a]Model failed to converge; only six schools had any outlets within 160m.
[†]per 100 students; [‡]per 10 non-food outlets within 160m
[§]"high" refers to the most deprived neighbourhoods.

Table C.5: Results from negative binomial regressions with major chain limited-service outlet densities surrounding Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables

Density	**(1) Major Chains (160m)**	**(2) Major Chains (400m)**	**(3) Major Chains (800m)**
% Aboriginal	0.68 (0.25 - 1.81)	1.01 (0.97 - 1.05)	1.01 (0.98 - 1.04)
% English Language Learners (ELL)	0.95 (0.86 - 1.06)	0.97* (0.95 - 1.00)	1.00 (0.98 - 1.01)
Inner City Project (ICP)	0.00 (0 - .)	2.24 (0.57 - 8.76)	1.42 (0.62 - 3.26)
McFadden's Pseudo R^2	0.07	0.03	0.01

Incidence rate ratios with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001

Table C.6: Results from negative binomial regressions with major chain limited-service outlet densities surrounding Vancouver schools (n=113) as dependent variables and student socioedemographic factors as independent variables, adjusted for school and neighbourhood factors

Density	**(1) Major Chains (160m)**	**(2) Major Chains (400m)**	**(3) Major Chains (800m)**
Students			
% Aboriginal	1.08 (0.81 - 1.45)	1.00 (0.97 - 1.03)	1.00 (0.99 - 1.02)
% English Language Learners (ELL)	1.05 (0.99 - 1.12)	1.00 (0.98 - 1.02)	0.99 (0.98 - 1.00)
Inner City Project (ICP)	0.00 (0 - .)	1.92 (0.69 - 5.37)	1.77* (1.05 - 2.97)
Schools			
Total Enrolment†	0.63 (0.15 - 2.69)	1.02 (0.88 - 1.17)	1.00 (0.93 - 1.07)
School Level			
Elementary	–	–	–
Secondary	15.32 (0.15 - 1528.4)	1.61 (0.42 - 6.20)	1.21 (0.58 - 2.53)
Neighbourhoods			
Commercial density‡	5.46**[a] (1.93 - 15.44)	1.20***[b] (1.14 - 1.26)	1.03***[c] (1.02 - 1.04)
VANDIX tertile§			
low	–	–	–
medium	0.00 (0 - .)	0.62 (0.25 - 1.51)	1.01 (0.67 - 1.52)
high	0.05 (0 - 3.65)	0.55 (0.20 - 1.48)	0.70 (0.44 - 1.11)
McFadden's Pseudo R^2	0.64	0.25	0.19

Incidence rate ratios with 95% confidence intervals in parentheses
*significant at 0.05; **significant at 0.01; ***significant at 0.001
†per 100 students; §"high" refers to the most deprived neighbourhoods.
‡per 10 non-food outlets within [a]160m, [b]400m or [c]800m

Appendix D

Additional Tables for Chapter 4

Table D.1: Bivariate associations of outlet density within 400m and students' daily intakes of minimally nutritious foods[a] at or en-route to school

Density (400m)[b]	Sugar-Sweetened Beverages (n=936[†])		
Ltd. Service Outlet	1.02 (0.98 - 1.05)		
Conv. Store		1.04 (0.98 - 1.09)	
Grocery Store			1.19 (0.86 - 1.64)
	Fast Foods (n=942[†])		
Ltd. Service Outlet	1.01 (0.97 - 1.05)		
Conv. Store		1.03 (0.95 - 1.10)	
Grocery Store			1.08 (0.70 - 1.67)
	Packaged Snacks (n=948[†])		
Ltd. Service Outlet	0.98 (0.95 - 1.02)		
Conv. Store		0.96 (0.90 - 1.02)	
Grocery Store			0.98 (0.67 - 1.42)

Results are from multilevel logistic models with school random intercepts
Odds Ratios are reported; 95% confidence intervals are in parentheses.
[a]Dependent variables = 1 if a student reported daily consumption
[b]Count of outlets within 400m line-based buffers of each school
[†]Cases with missing dependent variables were omitted from the analysis

Table D.2: Bivariate associations of outlet density within 800m and students' daily intakes of minimally nutritious foods[a] at or en-route to school

Density (800m)[b]	Sugar-Sweetened Beverages (n=936†)		
Ltd. Service Outlet	1.00 (0.99 - 1.02)		
Conv. Store		1.01 (0.99 - 1.04)	
Grocery Store			1.04 (0.95 - 1.13)
	Fast Foods (n=942†)		
Ltd. Service Outlet	1.01 (0.99 - 1.03)		
Conv. Store		1.02 (0.98 - 1.05)	
Grocery Store			1.08 (0.97 - 1.21)
	Packaged Snacks (n=948†)		
Ltd. Service Outlet	0.99 (0.98 - 1.01)		
Conv. Store		0.98 (0.95 - 1.01)	
Grocery Store			0.99 (0.90 - 1.10)

Results are from multilevel logistic models with school random intercepts
Odds Ratios are reported; 95% confidence intervals are in parentheses.
[a]Dependent variables = 1 if a student reported daily consumption
[b]Count of outlets within 800m line-based buffers of each school
†Cases with missing dependent variables were omitted from the analysis

Table D.3: Bivariate associations of perceived outlet proximity and odds of daily intake, at or en-route to school, of minimally nutritious[a] foods

Perceived Proximity	Sugar-Sweetened Beverages		
Ltd. Service Outlet (n=740†)			
< 5 minutes	1.00		
5 - 10 minutes	0.98		
	(0.66 - 1.44)		
> 10 minutes	0.90		
	(0.60 - 1.37)		
Convenience Store (n=765†)			
< 5 minutes		1.00	
5 - 10 minutes		0.81	
		(0.56 - 1.19)	
> 10 minutes		1.43	
		(0.88 - 2.34)	
Supermarket/Grocery Store (n=691†)			
< 5 minutes			1.00
5 - 10 minutes			0.75
			(0.50 - 1.12)
> 10 minutes			0.63*
			(0.41 - 0.96)
	Fast Foods		
Ltd. Service Outlet (n=743†)			
< 5 minutes	1.00		
5 - 10 minutes	1.41		
	(0.89 - 2.23)		
> 10 minutes	0.92		
	(0.54 - 1.55)		
Convenience Store (n=769†)			
< 5 minutes		1.00	
5 - 10 minutes		1.28	
		(0.82 - 2.01)	

Perceived Proximity (Continued)	Fast Foods		
> 10 minutes		1.80 (0.99 - 3.27)	
Supermarket/Grocery Store (n=694†)			
< 5 minutes			1.00
5 - 10 minutes			0.87 (0.54 - 1.39)
> 10 minutes			0.60 (0.36 - 1.00)
	Packaged Snacks		
Ltd. Service Outlet (n=746†)			
< 5 minutes	1.00		
5 - 10 minutes	1.11 (0.71 - 1.72)		
> 10 minutes	1.17 (0.73 - 1.86)		
Convenience Store (n=772†)			
< 5 minutes		1.00	
5 - 10 minutes		1.10 (0.72 - 1.67)	
> 10 minutes		1.40 (0.81 - 2.42)	
Supermarket/Grocery Store (n=936†)			
< 5 minutes			1.00
5 - 10 minutes			1.06 (0.67 - 1.66)
> 10 minutes			0.75 (0.46 - 1.21)

Results are from multilevel logistic models with school random intercepts
Odds Ratios are reported; 95% confidence intervals are in parentheses.
[a]Dependent variables = 1 if a student reported daily consumption
†Cases with missing observations were omitted from the analysis
*significant at 0.05

Table D.4: Multivariate adjusted associations from multilevel logistic models of outlet proximity and students' odds of daily intake of minimally nutritious foods at or en-route to school, complete case analysis

	Sugar-Sweetened Beverages[a]			Fast Foods[a]			Packaged Snacks[a]		
Proximity[b]									
Ltd. Service Outlet	1.00 (0.99 - 1.00)			1.00 (1.00 - 1.00)			1.00 (1.00 - 1.00)		
Convenience Store		1.00 (1.00 - 1.00)			1.00 (1.00 - 1.00)			1.00 (1.00 - 1.00)	
Grocery Store			1.00 (1.00 - 1.00)			1.00 (1.00 - 1.00)			1.00 (1.00 - 1.00)
Controls									
Gender									
Female	–	–	–	–	–	–	–	–	–
Male	1.57* (1.08 - 2.29)	1.57* (1.08 - 2.29)	1.58* (1.08 - 2.30)	2.17** (1.33 - 3.54)	2.19** (1.34 - 3.59)	2.17** (1.32 - 3.55)	1.58* (1.02 - 2.47)	1.60* (1.03 - 2.51)	1.60* (1.02 - 2.51)
Food Insecure[d]	1.61* (1.00 - 2.60)	1.59 (0.99 - 2.57)	1.60 (0.99 - 2.58)	2.20** (1.25 - 3.87)	2.15** (1.22 - 3.79)	2.19* (1.19 - 3.69)	0.93 (0.51 - 1.67)	0.90 (0.50 - 1.63)	0.89 (0.49 - 1.60)
Acculturation[e]									
high	–	–	–	–	–	–	–	–	–
medium	1.05 (0.65 - 1.69)	1.06 (0.66 - 1.71)	1.07 (0.66 - 1.72)	1.76 (0.88 - 3.53)	1.81 (0.90 - 3.62)	1.84 (0.92 - 3.69)	0.71 (0.41 - 1.21)	0.73 (0.42 - 1.25)	0.73 (0.43 - 1.26)
low	1.51 (0.73 - 3.11)	1.53 (0.74 - 3.15)	1.56 (0.76 - 3.22)	4.06** (1.63 - 10.10)	4.17** (1.67 - 10.44)	4.25** (1.69 - 10.70)	1.37 (0.61 - 3.08)	1.43 (0.63 - 3.22)	1.45 (0.64 - 3.26)
Brought from home daily[c]	1.12 (0.76 - 1.66)	1.14 (0.77 - 1.69)	1.14 (0.77 - 1.69)	1.13 (0.68 - 1.85)	1.11 (0.67 - 1.83)	1.14 (0.69 - 1.88)	2.21** (1.39 - 3.52)	2.21** (1.38 - 3.54)	2.26** (1.41 - 3.61)

(Continued)	Sugar-Sweetened Beverages[a]			Fast Foods[a]			Packaged Snacks[a]		
Spending Money									
None	–	–	–	–	–	–	–	–	–
\$0 - \$10	0.70	0.70	0.70	1.68	1.70	1.73	0.82	0.83	0.83
	(0.40 - 1.23)	(0.39 - 1.23)	(0.40 - 1.24)	(0.67 - 4.19)	(0.68 - 4.25)	(0.69 - 4.32)	(0.40 - 1.68)	(0.40 - 1.70)	(0.40 - 1.71)
\$10 - \$20	0.85	0.85	0.85	2.52	2.49	2.53	1.64	1.64	1.66
	(0.46 - 1.56)	(0.46 - 1.56)	(0.46 - 1.57)	(0.99 - 6.43)	(0.97 - 6.37)	(0.99 - 6.48)	(0.79 - 3.39)	(0.79 - 3.41)	(0.80 - 3.44)
>\$20	1.52	1.53	1.51	4.95***	4.97***	4.96***	1.58	1.58	1.59
	(0.85 - 2.73)	(0.85 - 2.74)	(0.85 - 2.71)	(2.01 - 12.16)	(2.02 - 12.25)	(2.01 - 12.21)	(0.77 - 3.26)	(0.77 - 3.27)	(0.77 - 3.28)
School Level									
Elementary	–	–	–	–	–	–	–	–	–
Secondary	1.37	1.31	1.29	2.07**	1.99**	1.86*	1.58	1.50	1.41
	(0.84 - 2.22)	(0.81 - 2.14)	(0.81 - 2.05)	(1.20 - 3.56)	(1.11 - 3.56)	(1.03 - 3.34)	(0.92 - 2.72)	(0.83 - 2.70)	(0.79 - 2.52)
Median Family Income†	0.85*	0.88	0.88	0.66**	0.67**	0.71**	0.63***	0.66**	0.68**
	(0.69 - 1.04)	(0.71 - 1.08)	(0.73 - 1.06)	(0.51 - 0.84)	(0.52 - 0.87)	(0.55 - 0.91)	(0.50 - 0.80)	(0.51 - 0.85)	(0.54 - 0.87)
N	570‡	570‡	570‡	573‡	573‡	573‡	575‡	575‡	575‡
ICC	0.02	0.02*	0.01	0.01	0.02	0.03	0.01	0.03	0.03

Each column reports a model with dietary intake as the dependent variable and objective proximity as independent variables adjusted for gender, food insecurity, bringing lunch from home, acculturation, spending money and school median income. Coefficients are reported as odds ratios with 95% confidence intervals in parentheses.

[a]Dependent variables = 1 if consumed at least daily. [b]Distance to nearest outlet, reported in units of 100 metres.

[c]Brought from home = 1 if a student reported bringing lunch daily; [d]Reference level is food secure students

†School-level variable constructed by the BC Ministry of Education; reported in \$10,000 units

‡Missing values were handled through complete case analysis as a sensitivity analysis to multiple imputation