Applied Geography 31 (2011) 1262–1267

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Mapping spatial variation in food consumption

Kathryn T. Morrison [a,*], Trisalyn A. Nelson [a], Aleck S. Ostry [b]

[a] Spatial Pattern Analysis and Research Laboratory, University of Victoria, Department of Geography, PO Box 3060, Victoria, BC, Canada V8W 3R4
[b] Population Health Research Laboratory, University of Victoria, Department of Geography, PO Box 3060, Victoria, BC, Canada V8W 3R4

Keywords:
Regional consumption mapping
Local foods
Nutrition survey data
Spatial analysis

A B S T R A C T

Data on food consumption trends are often provided nationally and spatial variation in eating habits is difficult to estimate in Canada. Here, we present methods for mapping provincial aspatial food consumption data by accounting for spatial variability in population structure (age and gender). This type of data and analysis could be useful for researchers and policy makers interested in promoting the consumption of locally produced food, as assessing nutritional demand will be a critical first step. We present a method for constructing food consumption estimates for Local Health Areas in British Columbia; however, methods outlined could be applied to other jurisdictions and other units when demographic characteristics are known. Because age and gender impact food consumption, the demographic profile of a given local area will drive food consumption patterns. For instance, among 18–44 year olds, men consume 50% more food than women, but eat 30% fewer fruits and vegetables. Given regional differences in demographic composition, consumption patterns for men and women at different ages have notable spatial variability. Linking aspatial consumption data with demographic data enables mapping spatial variation in food consumption.

Introduction

There is a growing body of research on the benefits and limitations of local food systems. The consumption of locally produced foods has been actively promoted by non-governmental organizations as well as health officials and policy makers in some levels of government (Cowell, 2003; Dietitians of Canada, 2007; Public Health Agency of Canada, 2005; Smith & MacKinnon, 2007; United States Congress, 2008). Promotions for the consumption of local food arises due to concerns about agricultural sustainability, the need to decrease food miles travelled, supporting local economies, and strengthening community food access (Anderson & Cook, 2000; Feenstra, 1997; Hinrichs, 2003).

In order to understand the level of demand on local food systems, researchers must first know how much food is currently consumed in a region, regardless of where it was produced. Food consumption varies spatially and is driven not only by population size, but also by various demographic characteristics (Deshmukh-Taskar, 2007; Gittelsohn et al., 1998). Estimating food consumption at a local scale will allow us to assess the capacity for local food systems to meet their own populations food needs, assessed with either current agricultural productivity or agricultural potential (based on characteristics such as spatial variability in soils and climates).

The standard data used for studying population-level food consumption are aspatial and mask variation in consumption habits that may be related to demographic characteristics, discounting spatial variability in eating trends. Various methods have been employed for estimating the quantity of food consumed at a population level. Commonly used are national-level statistics that estimate what an average individual within a country would consume in a year, without adjustments for age, sex, or other characteristics. For example, Cowell and Parkinson based food consumption on National Food Disappearance (NFD) data in the U.K., where domestic food production (plus imports, minus exports and waste) is divided by the annual population (Cowell, 2003). In his U.S. study, Christian Peters et al. used a novel method of Human Nutrition Equivalents (HNE) to determine how an average American meets their nutritional needs, and performed an optimization model to calculate the amount of agricultural land required to produce that food. Although their analysis did account for spatial variation in food consumption based on population density, variability in the composition of populations was not considered (Kantor & Young, 1999; Peters, 2009). In Canada, regional estimates of the quantities of food consumed have used NFD data to measure per-capita consumption (BC Ministry of Agriculture and Lands, 2006; Markham, 1982; Riemann, 1987; Vancouver Food Policy

* Corresponding author. Tel.: +1 250 419 2712; fax: +1 250 721 6216.
E-mail addresses: ktm@uvic.ca (K.T. Morrison), trisalyn@uvic.ca (T.A. Nelson), ostry@uvic.ca (A.S. Ostry).

0143-6228/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apgeog.2010.11.020

Council, 2009, pp. 1–81). The national data are typically applied to the populations in the region of interest to generate regional food consumption values for major food categories such as fruit, meat, dairy, and vegetables. In some research, idealized consumption has been used to determine the impact of widespread adoption of recommended policies, such as the Canada Food Guide or U.S. Food Pyramid (Kantor, 1996, 1998; Peters, Fick, & Wilkins, 2003).

In this paper, we propose a unique methodology for mapping regional variation in food consumption. Our approach is based on linking aspatial consumption aggregates to map-based demographic data. To meet our objectives, we:

1. Link aspatial individual-level consumption data for men and women in different age groups to demographic data in each region
2. Correct for missing data (youth consumption) and temporally adjust datasets
3. Compare mapped demographic-based consumption estimates with aggregate consumption estimates to assess spatial deviation from average

Mapping spatial variation in food consumption has not been incorporated into previous agriculture and food security research; the methods presented in this paper will be useful for future research on regional food consumption as well as understanding the consumption of locally produced foods.

Data & study area

The province of British Columbia is a suitable study area for this research, given that it is home to strong community, activist, and political interest in food security and nutrition. The spatial unit used in this paper is the Local Health Area, of which there are approximately 90 in BC in 2006. The LHA is a spatial unit at which health and nutrition policy is implemented in the province, and much nutrition research is performed, so it is a useful unit for this research. The methods presented in this paper can be applied to any spatial unit for which demographic data are available.

The most widely available data for studying food consumption patterns in Canada is the National Food Disappearance data (NFD) which is gathered annually and disseminated by Statistics Canada through their annual publication "Canada Food Stats" (Statistics Canada, 2009). The NFD estimates the quantity of food available for Canadian consumption each year by summing gross Canadian food production, imports, and estimates of the quantity of food in storage on January 1st. Canadian food exports, the quantity of food in storage on December 31st of the same year, and estimated waste incurred during distribution and processing are subtracted. This value can then be divided by the average annual population of that year to estimate the per-capita quantity of food available for consumption. Statistics Canada also applies adjustment factors to estimate the waste lost during retail sale and food preparation, including cooking losses and the removal of inedible portions (Statistics Canada, 2009). The final data estimate the quantity of food actually consumed by an average Canadian each year.

An alternative method to estimate population-level consumption habits is through the use of dietary surveys. Dietary survey methods were first developed in the early 1930s as policy makers in many jurisdictions became increasingly concerned about the impacts of poverty and malnutrition on health (Ostry, 2006). The world's first major national nutrition survey, involving tens of thousands of respondents, was conducted in Canada in 1972 (Sabry, 1974). Since then, nutrition surveys have been conducted only occasionally in Canada, largely because they are time consuming and costly. Instruments vary between surveys, and therefore the data collected are often not comparable as survey products measure different variables (CCHS 2.2, 2004; Forster-Coull, Milne, & Barr, 1999). The usual methods used are face-to-face interviews using detailed interview questions on the exact composition of meals consumed within the 24 h prior to interview. A strength of nutrition surveys is that they provide a direct measure of individual dietary intake. As well, they measure demographic characteristics of the participants so that comparison of consumption habits between different ethnic groups, genders, and age groups, or differences in consumption patterns of geographic regions can be undertaken. However, because they are costly they are conducted sporadically, limiting the ability to measure change in dietary intake over time.

The last detailed dietary survey conducted by the province of BC was in 1999. The Chief Nutritionist of the Province of BC provided us with a custom analysis of this BCNS dataset, reporting the annual quantities of food (by major food category) consumed by men and women aged 18 to 44, 45 to 64, and over 65. The 1999 study included only adults aged 18 and over.

To determine consumption for the youth in each region, we use data from the Canadian Community Health Survey Cycle 2.2 (conducted in 2004) (CCHS 2.2, 2004). The CCHS 2004 data are not available in units of mass, and therefore cannot be used to construct actual consumption estimates. However, they do report daily consumption habits of both youth and adults in BC, in units of food servings.

Methods

We calculate population level food consumption separately with two datasets (NFD and BCNS) for the sake of comparative analysis. The NFD method requires only the individual-level food consumption estimate, multiplied by the regional population. Methods for using the BCNS survey data to construct population-level food consumption estimates are outlined below.

Linking aspatial individual consumption data to mapped demographics

Data from the BC Nutrition Survey (BCNS) provides us with food consumption averages for men and women in different age categories. In order to calculate and map population-level food consumption variation over space, we integrate the individual-level consumption estimates for each age and sex group with demographic population data in each LHA in BC:

$$C_i = \sum_{j=1} C_j P_{ij}$$

where the average consumption *(C)* of a food group in the *i*th region is equal to the consumption of the *j*th age/sex category multiplied by the population of the *j*th age/sex category in the *i*th region, and summed for *j* age/sex categories. This allows for calculation of the total food consumption for each food, and can be summed into convenient food groups (e.g., fruits, vegetables, dairy, meat).

Estimating youth consumption & temporal adjustment factor

Since youth were not surveyed in the BCNS, we needed to develop a method to estimate their food consumption for each category. There is no standardized way to do this reported in the literature, so we rely on data from the CCHS 2.2, which reports food consumption (in number of servings) for each food group in different ages, including children and youth. Because the publically available data are reported in number of servings rather than units

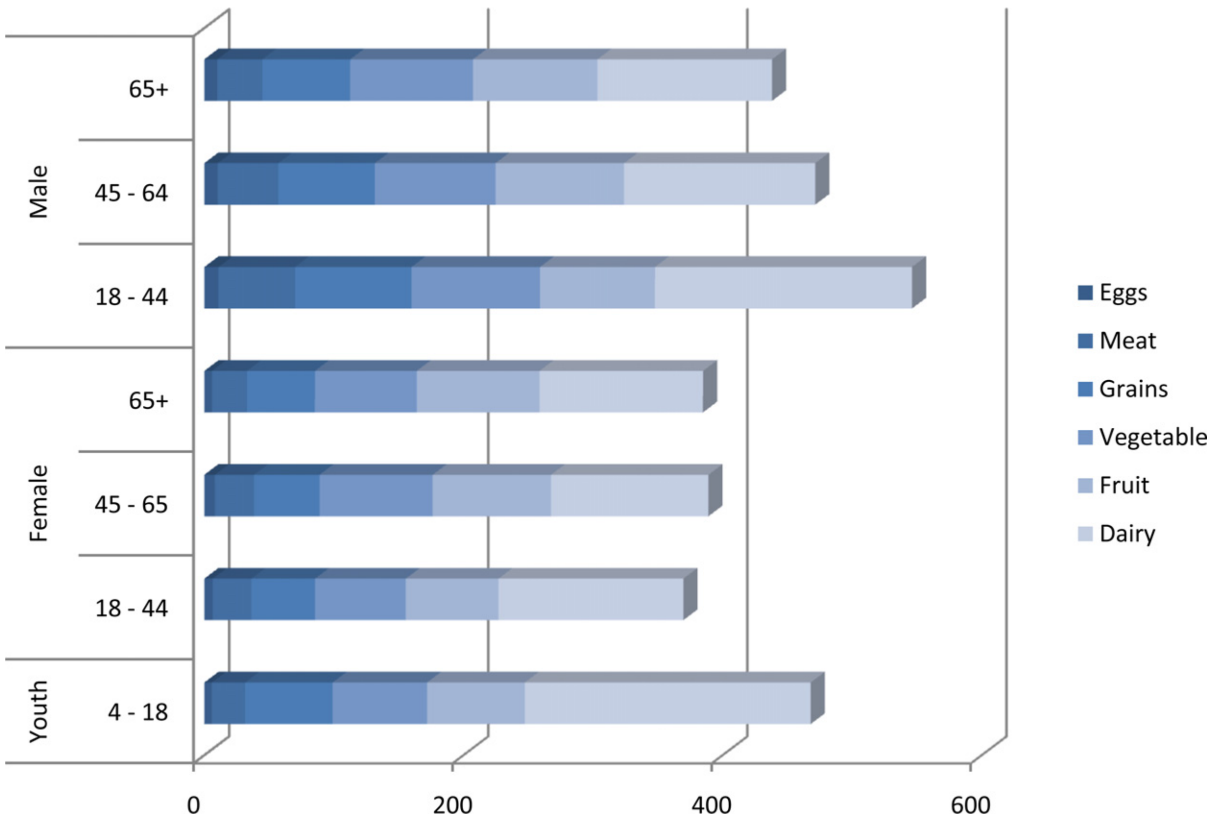

Fig. 1. Temporally adjusted food consumption estimates based on the BC Nutrition Survey, in kilograms of food, by gender and age categories.

of mass, they cannot be directly used in lieu of BCNS data. However, we developed an adjustment factor between the amounts of food consumed, on average, by a person under the age of 18 in BC, versus an adult in the province, based on these CCHS data:

$$\text{Youth Adjustment Factor} = \frac{\text{Youth Servings}}{\text{Adult Servings}}$$

This adjustment factor is calculated for each food group and applied to our BCNS data to create consumption estimates in the under 18 age group. Young children tend to eat less food than adults, with the exception of dairy, while adolescents often consume more food than adults.

The major benefit of the NFD data normally used in estimating population-level food consumption is the temporal availability of data; in Canada, NFD are available from 1960 to 2009 inclusive. These data show that there have been some changes in the Canadian diet between 1999 and 2006, with some foods consumed in slightly larger quantities (e.g., vegetables) and some foods consumed less. To account for this temporal mismatch between our 2006 demographic data, and our 1999 BC Nutrition Survey consumption data, we use NFD data to create a temporal adjustment factor, equal to the ratio between the 2006 and 1999 reported consumption values in the NFD data. This is applied to all consumption estimates in all gender and age groups in our BCNS dataset.

$$\text{Temporal Adjustment Factor} = \frac{\text{NFD 2006}}{\text{NFD 1999}}$$

Both the Canadian Community Health Survey Cycle 2.2 data and the Food Statistics data from Statistics Canada are widely used in the food security and population nutrition literature (Riediger, 2007; Witkos, Uttaburanont, Lang, & Arora, 2008).

Mapping variation between BCNS and NFD consumption estimates

We perform exploratory mapping on the spatial patterns in the two consumption estimates. We will refer to the NFD method as aspatial and the BCNF method as spatial. We calculate the percent difference ("error") between spatial and aspatial methods, and consider the spatial distribution of the errors. The two datasets are compared with a non-parametric two-sample paired test to determine if the difference between the distributions differs significantly from zero (Wilcoxon Rank Sum, $\alpha = 0.10$) (Pal, 1998).

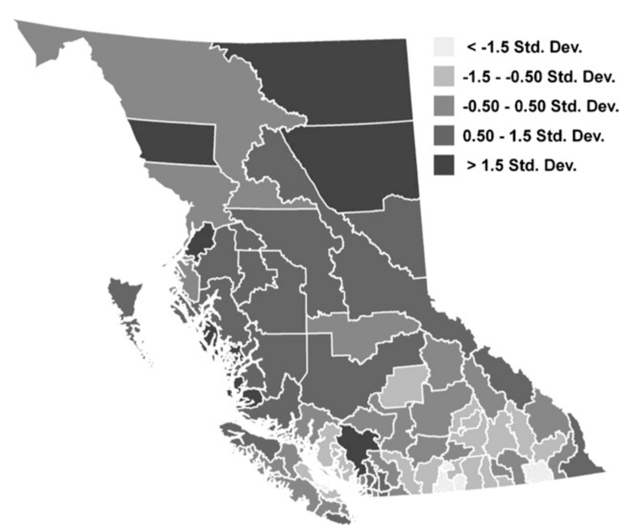

Fig. 2. Map is classified by standard deviation, revealing areas of significant deviation from the mean error between consumption estimate methods.

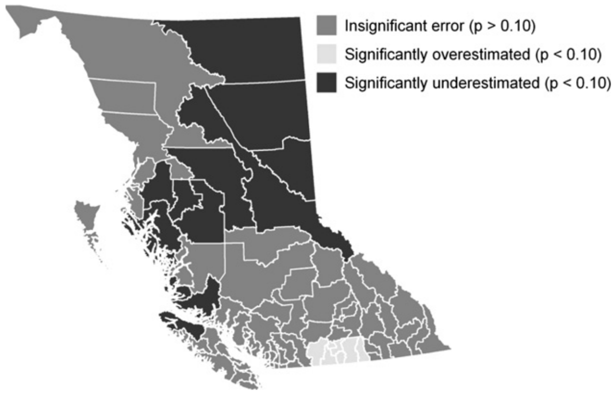

Fig. 3. Moran's I local cluster detection. Significant clusters ($p < 0.10$) of high or low mean error are shown.

Global and local Moran's I statistics are used to assess and map spatial clustering (consumption overestimate or underestimate) of errors ($\alpha = 0.10$), with neighbourhoods defined with first order polygon contiguity, as is commonly used in spatial cluster detection (Pal, 1998). Finally, we explore the demographic explanations for the spatial distribution of errors between these methods.

Results

Constructing adult consumption estimates

The BCNS individual-level consumption estimates are relatively similar the NFD averages, confirming that the BCNS dietary recall data has been used here to construct reasonable consumption estimates for these categories. Consumption estimates from the BCNS show substantial differences in consumption between age and gender groups. For example, adult men age 18-44 eat 50% more food than women, but only 30% more fruits and vegetables (Fig. 1). Nearly half of total food consumed in youth is in dairy products (47%) but only approximately one third for adults. Adult women tend to consume more fruits and vegetables and less meat and grains than men in the same age group. Women consume similar amounts of food throughout each age group, while men's food consumption drops considerably over their lifecourse.

Analyzing geographic variation in food consumption

There are minor differences between the average consumption estimates of the BCNS and NFD datasets, which is to be expected given the different methods used to derive them. For example, the meat consumption estimates differ by approximately 2%, but range from −9% to +7% depending on location. It is this spatial variability in the difference that is of interest. In this section we will present the differences in spatial patterns of total food consumption for illustration, but the patterns are similar within each food group.

The primary driving force of food consumption in each LHA is the regional population, which is expected. However, there are variations between the two consumption datasets. Fig. 2 shows a map of the percent difference between the two total food consumption datasets, classified by standard deviations from the mean.

The Wilcoxon Sum Rank Test compared the distributions of the two datasets, and reveals a statistically significant difference ($W = 3387$, $p = 0.095$, $\alpha = 0.10$) against the null hypothesis that the distributions do not differ significantly. The global Moran's I analysis reveals highly significant clustering of error ($Z = 5.911$, $p < 0.01$). The local Moran's I cluster analysis reveals the regions which have significant clustering of relatively high or low error, indicating difference between the two methods ($p < 0.10$). Clusters of high error indicate regions in which the NFD method underestimated the total food consumption; clusters of low error indicate regions in which the NFD overestimated the total food consumption.

These overestimated and underestimated regions have demographic makeup which are markedly different from the remainder of the province; for example, the demographic breakdown of age groups as a provincial average is shown in Fig. 3, along with four of the cluster LHAs in the province. The total food consumption estimates in each of these regions deviates significantly depending on the method used to estimate it (NFD vs. BCNS). Regions with higher error have a younger than average population, and therefore consume more food in total, which the NFD method underestimates.

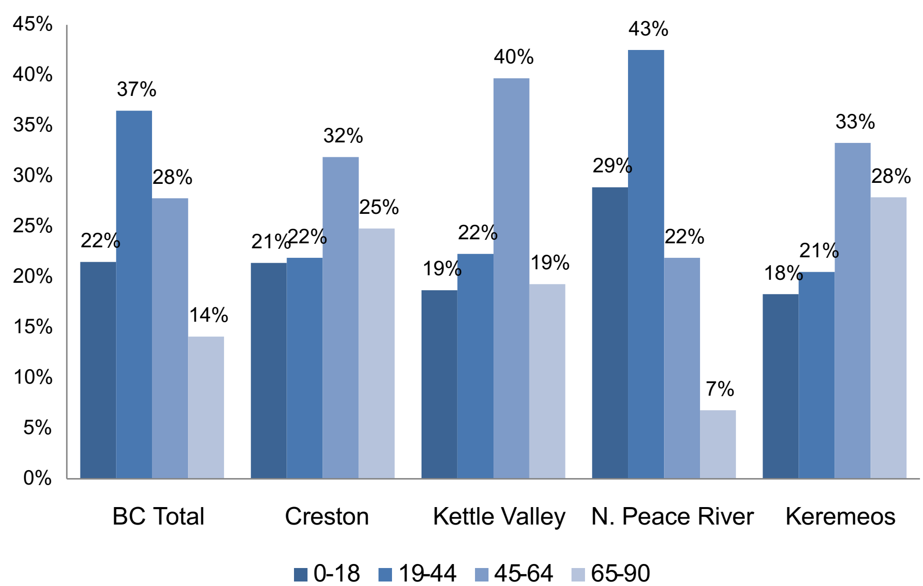

Fig. 4. Demographic breakdown of British Columbia and four selected Local Health Areas, as a percentage of the total regional population.

Conversely, the regions with lower error have older populations than average, consume less total food, and their total regional food consumption is overestimated by the NFD data (Fig. 4).

Discussion

Regional estimates of food consumption are often based on aggregate national food disappearance estimates and applied to population data at a finer spatial scale (BC Ministry of Agriculture and Lands, 2006; Riemann, 1987; Vancouver Food Policy Council, 2009). The major limitation in using NFD to develop estimates of food consumption at the LHA level is that they represent Canadian averages, and do not necessarily reflect the consumption habits of British Columbians. Food consumption differs greatly between individuals, especially between gender and age groups, with men consuming much more of most food types than women, and teens and young adults tending to consume more than the very young and seniors. If NFD data are used to construct regional consumption estimates, regional consumption will simply be a function of population size, without accounting for any other regional variation. When the objective is to compare regional differences in food consumption at a local scale, these data are largely unsuitable.

Variation exists in the distribution of age and gender groups throughout the province of BC and regional food consumption estimates should reflect these patterns. This finding is somewhat intuitive, but is of particular importance to food security research. Many of the demographically atypical regions are located in the north of the province. These regions have very young populations with high fertility rates and large numbers of First Nations people, who are affected disproportionately by nutrition-related disease (Kirkpatrick & McIntyre, 2009; Power, 2008). They are also extremely rural, remote locations, far from the agricultural and urban hubs of the lower mainland; food price are often significantly higher in remote areas (Minister of Indian Affairs and Northern Development, 2007). For these reasons, individuals in northern Canadian provinces and territories experience much higher rates of food insecurity, evidenced from both from self-reported surveys and indirect measures such as rates of food bank usage (Act Now BC, 2006; CCHS 2.2, 2004; Lawn & Harvey, 2004; Power, 2008). Northern areas are also more susceptible to the effects of climate change, including agricultural impacts (Wesche & Chan, 2010). It is therefore extremely important to estimate their food consumption accurately, not underestimating it as the NFD data would do, as these populations are of key interest and consequence in food security and population nutrition research.

The BC Nutrition Survey data are ten years old, which is the major drawback of using this data. It is difficult to know, in the absence of a more recent survey in BC, whether or not consumption has changed significantly over the past decade in the province. However, we can estimate crudely at the national level using NFD to show changes in consumption by major food category over this time, and this adjustment addresses some of this temporal change issue.

Researchers are often interested in more detailed consumption comparisons than age and gender, such as between minority groups or vulnerable subpopulations (Deshmukh-Taskar, 2007; Gittelsohn et al., 1998). Further research could utilize our methodology by expanding the age and gender sub-groups to include, for instance, ethnic groups, urban versus rural area typology, and socio-economic measures.

The methods presented here set the stage for other research which might utilize aspatial consumption estimates to perform spatially explicit analysis, particularly in nutrition and food security research. BC is a unique province with high citizen involvement in local food systems, and a motivated health ministry concerned with local scale provincial food security. Understanding consumption demand, particularly at the regional level, is a key component of studying the impact of nutrition policies made at the provincial level.

Conclusion

In this paper, we present a unique method of using the aspatial nutrition survey data to assess differences consumption between age groups and genders. We found considerable variation in consumption of each food group based on these demographic differences. In addition, we studied the demographic makeup of different regions, finding significant differences in the age and gender distribution over space. We can conclude that applying a purely population-based consumption estimate would not accurately represent regional food consumption in the province. Our method accounts for these regional demographic differences so as to better estimate the consumption habits of local residents.

Two patterns largely drive spatial variation in food consumption. Firstly, consumption habits differ between men and women, and eating habits change as people age. Secondly, our analysis shows significant demographic differences between regions. If the demographic variation is not taken into account through gender and age based consumption estimates, and instead is based exclusively on population size, then regions with atypical demographic characteristics will be poorly estimated. This is particularly problematic when these areas are already vulnerable to food insecurity, and thus are of special research interest.

Acknowledgements

This research was supported by the Social Sciences and Humanities Research Council of Canada, as well as the Michael Smith Foundation for Health Research with which Dr. Ostry is a senior scholar. We greatly appreciate the input of the four anonymous reviewers whose feedback improved this manuscript.

References

Act Now BC. (2006). *Healthy eating*. In (Vol. 2008). Province of British Columbia.

Anderson, M. D., & Cook, J. T. (2000). Does food security require local food systems? In J. Harris (Ed.), *Rethinking sustainability: Power, knowledge and institutions* (pp. 228–245) Michigan: University of Michigan Press.

BC Ministry of Agriculture and Lands. (2006). *B.C. food self reliance report*. Vancouver: Government of British Columbia.

CCHS 2.2. (2004). Income-related household food security in Canada. Nutrition *Canadian community health survey Cycle 2.2* (pp. 1–108). Ottawa, ON: Health Canada.

Cowell, S. J. (2003). Localisation of UK food production: an analysis using land area and energy as indicators. *Agriculture, Ecosystems & Environment, 94*(2), 221–236.

Deshmukh-Taskar, P. (2007). Does food group consumption vary by differences in socioeconomic, demographic, and lifestyle factors in young adults? The Bogalusa heart study. *Journal of the American Dietetic Association, 107*(2), 223–234.

Dietitians of Canada. (2007). *Community food security: Position of dietitians of Canada*. Public policy Statements.

Feenstra, G. (1997). Local food systems and sustainable communities. *American Journal of Alernative Agriculture, 12*(1), 28–36.

Forster-Coull, L., Milne, R. L., & Barr, S. I. (1999). In *British Columbia nutrition survey*. BC Ministry of Health.

Gittelsohn, J., Wolever, T. M. S., Harris, S. B., Harris-Giraldo, R., Hanley, A. J. G., & Zinman, B. (1998). Specific patterns of food consumption and preparation are associated with diabetes and obesity in a native Canadian community. *Journal of Nutrition, 128*(3), 541–547.

Hinrichs, C. C. (2003). The practice and politics of food system localization. *Journal of Rural Studies, 19*(1), 33–45.

Kantor, L. S. (1996). Many Americans are not meeting food guide pyramid dietary recommendations. *Food Review*, 7–15.

Kantor, L. S. (1998). A dietary assessment of the U.S. food supply: comparing per capita food consumption with food guide pyramid serving recommendations. In *Economic research services* (pp. 1–4). United States: Department of Agriculture.

Kantor, L. S., & Young, C. E. (1999). Moving toward the food guide pyramid: implications for U.S. agriculture. In *Economic research services* (pp. 1–4). United States: Department of Agriculture.
Kirkpatrick, S., & McIntyre, L. (2009). The chief public health officer's report on health inequalities: what are the implications for public health practitioners and researchers? *Canadian Journal of Public Health, 100*(2), 93–95.
Lawn, J., & Harvey, D. (2004). *Nutrition and food security in fort severn*. Ontario: Minister of Indian Affairs and Northern Development.
Markham, R. (1982). *Supply and demand balance in the B.C. Food sector: A statistical analysis*. ARDSA Project No. 271304.
Minister of Indian Affairs and Northern Development. (2007). *The Revised northern food basket*. Catalogue No. R3–56/2007E-PDF.
Ostry, A. (2006). *Nutrition policy in Canada, 1870–1939*. Vancouver: University of British Columbia Press.
Pal, S. (1998). *Statistics for Geoscientists, Techniques and Applications*. New Delhi, India: Concept Publishing Company.
Peters, C., Fick, G. W., & Wilkins, J. L. (2003). Cultivating better nutrition: can the food pyramid help translate dietary recommendations into agricultural goals? *Agronomy Journal, 95*(6), 1424–1431.
Peters, C. J. (2009). Mapping potential foodsheds in New York state: a spatial model for evaluating the capacity to localize food production. *Renewable Agriculture and Food Systems, 24*(01), 72–84.
Power, E. M. (2008). Conceptualizing food security for aboriginal people in Canada. *Canadian Journal of Public Health, 99*(2), 95–97.
Public Health Agency of Canada. (2005). In B. Practices (Ed.), *Good food box program*. Government of Canada.
Riediger, N. D. (2007). The influence of sociodemographic factors on patterns of fruit and vegetable consumption in Canadian adolescents. *Journal of the American Dietetic Association, 107*(9), 1511–1518.
Riemann, W. B. C. (1987). *The B.C. food balance*. British Columbia Ministry of Agriculture and Fisheries.
Sabry, Z. I. (1974). Nutrition Canada: a national nutrition survey. *Nutrition Reviews, 32*(4), 105–111.
Smith, A., & MacKinnon, J. B. (2007). *The 100-Mile diet: A year of local eating*. Random House.
Statistics Canada. (2009). *Canada food Stats*. Catalogue no 23F0001XCB.
United States Congress. (2008)*Food, Conservation, and Energy Act, 122*. 110–234.
Vancouver Food Policy Council. (2009). *Food Secure Vancouver: Baseline report*. Vancouver.
Wesche, S., & Chan, H. (2010). Adapting to the impacts of climate change on food security among Inuit in the Western Canadian Arctic. *EcoHealth*, 1–13.
Witkos, M., Uttaburanont, M., Lang, C. D., & Arora, R. (2008). Costs of and reasons for obesity. *Journal of the CardioMetabolic Syndrome, 3*(3), 173–176.