



Food swamps by area socioeconomic deprivation in New Zealand: a national study

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Abstract

Objectives A nationwide spatial analysis of community retail food environments in relation to area socioeconomic deprivation was conducted in New Zealand.

Methods Addresses from about 20,000 registered food outlets were retrieved from all 66 Councils. Outlets were classified, geocoded and (spatially) validated. The analysis included 4087 convenience, 4316 fast food/takeaway and 1271 supermarket and fruit/vegetable outlets and excluded outlets not considered ‘healthy’ or ‘unhealthy’. The population-weighted density of different outlet types in Census areas and the proximity to different outlet types from Meshblock centres were calculated and associations with area socioeconomic deprivation assessed. Spatial scan statistics was used to identify food swamp areas with a significantly higher relative density of unhealthy outlets than other areas.

Results A significantly positive association was observed between area deprivation and density of all retailers. A

significantly negative association was observed between area deprivation and proximity to all retailers. Nationwide, 722 Census areas were identified as *food swamps*.

Conclusions Access to food retailers is significantly higher in more deprived areas than in less deprived areas. Restricting unhealthy outlets in areas with a high relative density of those outlets is recommended.

Keywords Community retail food environments · Area socioeconomic deprivation · Food swamps

Introduction

Worldwide, the proportion of adults with a body-mass index (BMI) of 25 kg/m² and above increased between 1980 and 2013 from 29 to 37% in men, and from 30 to 38% in women (Ng et al. 2014). The increase in cheap, energy-dense, processed food products has contributed to increasing obesity rates over the past four decades (Vandevijvere et al. 2015). Obesity has increased rapidly over the last 20 years in New Zealand in conjunction with profound changes in the food environment (Ministry of Health 2015). The food environment is defined as the collective economic, policy and social surroundings, opportunities and conditions that influence people’s food and beverage choices and nutritional status (Swinburn et al. 2013). The current food environment promotes obesity and over-consumption of energy-dense nutrient-poor foods (Swinburn et al. 1999, 2011).

Community retail food environments, including the number, density, type, and location of different types of food outlets, may be one factor contributing to high obesity rates in New Zealand. Current evidence is suggestive of an association between community retail food environments

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and dietary outcomes; however, substantial heterogeneity in study designs, methods and measurement tools makes it difficult to draw firm conclusions (Ni Mhurchu et al. 2013). A wide range of studies investigated the relationships between community retail food environments and area socioeconomic deprivation (Apparicio et al. 2007; Gordon et al. 2011; Pearce et al. 2007a, b, 2008a; Short et al. 2007; Walker et al. 2010). Geographic areas with disproportionate access to outlets with an overabundance of high-energy nutrient-poor foods are described as ‘Food Swamps’ (Luan et al. 2015; Osorio et al. 2013; Rose et al. 2009).

These geographic clusters have usually been assessed through mapping areas according to income or ethnicity and overlaying spatial data on distribution of different types of food retailers (Beaulac et al. 2009). Internationally, studies (Burns and Inglis 2007; Pearce et al. 2007a; Reitzel et al. 2014) have found higher clustering of unhealthy food outlets in more deprived areas than in less deprived areas, yet few studies have characterised these areas as food swamps.

North American studies provide the most support for the existence of food swamps (Hager et al. 2016). Less support for the existence of food swamps has been found in the United Kingdom (Cetateanu and Jones 2014; Fraser et al. 2012). A study conducted in a small deprived urban area in Scotland found that the residents were required to travel more than 4-miles outside the town to purchase healthy food choices from large 24-h supermarkets, while a cluster of takeaway outlets were more readily accessible in the town (Sauveplane-Stirling et al. 2014).

Previously Pearce (Pearce et al. 2007a) found a significant negative association between proximity to the closest fast food outlet and neighbourhood socioeconomic deprivation in New Zealand. The travel distances to unhealthy outlets were at least twice as far in the least deprived neighbourhoods compared to the most deprived neighbourhoods. Higher accessibility was also observed for both convenience stores and supermarkets in the most deprived communities compared to the least deprived communities (Pearce et al. 2008b). A recent national study explored proximity of unhealthy food retailers to schools and found approximately 68% urban schools had a convenience store within 800 m. Access to unhealthy foods through Fast Food/Takeaway or Convenience (FFTC) outlets was greater for the most deprived schools versus the least deprived schools (Vandevijvere et al. 2016). Pearce et al. (Day et al. 2013) found that between 1966 and 2006, the median number of supermarkets/grocery stores within 800 m of schools decreased from 5 to 1, convenience stores decreased from 2 to 1, and fast food outlets increased from 1 to 4.

The objective of this study was to comprehensively assess community retail food environments at a national level in New Zealand, particularly the density of and proximity to different types of food outlets in and from more and less socioeconomically deprived areas.

Methods

In this cross-sectional survey, covering the entire New Zealand territory, we excluded the off shore islands for which the population and the number of food outlets is extremely low.

Data sources

The NZ Meshblocks (MBs) are the smallest spatial unit, holding census information about, on average, 100 individuals. There are a total of 46,637 MBs in the 2013 dataset from Statistics NZ (Statistics New Zealand 2017b). For the purposes of this study, proximity measures were calculated from MB centres. All MBs aggregate to Census Area Units (CAUs). There are a total of 2020 CAUs in NZ, containing a population of about 1700–3000 individuals each. For the purposes of this study (relative) density measures were calculated within CAUs. Rural CAUs were defined as areas with a population of ≤ 999 people, and urban CAUs as areas with a population of ≥ 1000 people, consistent with definitions from Statistics NZ (Statistics New Zealand 2017a). CAUs aggregate to define regional Councils.

Information on area socioeconomic deprivation for MBs and CAUs was retrieved from Statistics New Zealand in June 2014.

We used The 2013 New Zealand Index of Deprivation (NZDep2013) which combines eight dimensions of deprivation: communication, income, employment, qualifications, owned home, support, living space, and transport. NZDep2013 apportions each MB and CAU into a decile of deprivation, with Decile 1 representing the 10% of areas with the lowest levels of deprivation, while Decile 10 depicts the most deprived 10% of areas across NZ. In this study we aggregated the Deciles into Quintiles, in which, quintile 1 (Decile 1 and 2) represents the 20% least deprived areas and the fifth quintile (Decile 9 and 10) represents the 20% most deprived areas in New Zealand.

Information on population density was sourced from Statistics New Zealand on 1st September 2014. The dataset includes all people who usually live in and were present in NZ on census night, while visitors from overseas, visitors from elsewhere in NZ, and residents temporarily overseas on census night are excluded. The population data by MB were randomly rounded to the nearest 3 by Statistics New

Zealand to protect citizen confidentiality in accordance with the Statistics Act (1975).

The NZ road network, a line shape file containing a total of 73,070 line features, was retrieved from Land Information New Zealand (LINZ) and last updated in August 2014. The compilation of the New Zealand list of food outlet addresses was performed using two main data sources: The 2014 food outlet lists from the 66 City and District Councils—the primary data source—and Zenbu.com, which is a supplementary online source with location data on food premises in New Zealand.

Food outlet categorization

A food outlet classification tool (Supplementary material 1) was developed to automatically categorise the 23,939 food outlets based on their retail name in the compiled list into 14 food retail classes: ‘bakery’, ‘café’, ‘confectionary’, ‘dairy’, ‘farmer’s market’, ‘fast food’, ‘fish and meat’, ‘fruit and vegetables’, ‘takeaway’, ‘juice bars’, ‘restaurant’, ‘supermarket’, ‘service station’, and ‘specialist store’.

To correct for misclassification any ‘excluded’ (e.g., places with licence but food service not being their primary form of business, such as hotels or sport clubs) and ‘not found’ outlets (those that did not automatically match to one of the categories through using the tool) were manually reviewed (38.5%). After classification by type and exclusion of irrelevant food outlets such as hotels and sport clubs, 18,140 outlets were included in the final list (Fig. 1).

Geocoding and spatial validation

The Google Geocoding application programming interface was used to retrieve the coordinates of each food outlet. A 95% matching confidence was aimed to ensure that the coordinates generated were as accurate as possible. Spatial validation—the process of confirming the accuracy of geocodes—was undertaken to ensure if the coordinates of the food outlets mapped were reasonably accurate (i.e., the food outlet locations fall within their Council area). Any outlets that were identified as located outside of the Council boundaries were removed from the analysis (<2%).

Validation of the compiled food outlet list

The validation process involved randomly selecting 1% of all classified and geocoded food outlets, stratified by Council and outlet type. Retailers were called by phone to check whether their address and type of food outlet were correct.

Exclusion of food outlets

For the purposes of the study, ‘café’, ‘fish and meat’, ‘juice bar’, ‘restaurant’ and ‘specialist store’ outlets were excluded since they were not considered as either ‘healthy’ or ‘unhealthy’ outlets. Farmer’s markets were also excluded since they are usually only available once a week and completeness and accuracy of the farmer’s markets list could not be verified. The retail classes ‘bakery’, ‘confectionary’, ‘dairy shops’ and ‘service stations’ were aggregated into one outlet category ‘convenience stores’, for the purposes of this study. The total number of food outlets included in this study (comprising supermarkets, fruit and vegetable stores, convenience stores and fast food/take-away outlets) was 9674 (Fig. 1).

Spatial and statistical analysis

ArcMap version 10.2 and SAS 9.3 software were used to perform the spatial and statistical analysis, respectively. However, NZ MB units are too small in scale to examine food retail density, so this study used two different spatial units (MBs and CAUS) to examine proximity (from meshblock centres) and density (within CAUs).

To measure proximity, the Network Analysis closest facility tool was used on ArcMap 10.2 and road proximity was calculated from each MB centroid to the closest retail facility, separately for each food retail outlet type. To measure density, a spatial join was used to count the availability of the different types of food outlets within each CAU. The results were adjusted for population density and expressed as the number of outlets per 1000 population. Kruskal–Wallis tests were conducted to compare density and proximity measures between quintiles of area socioeconomic deprivation.

A Retail Food Environment Index (RFEI) was calculated for each CAU by dividing the number of unhealthy outlets (convenience stores, fast food/takeaway outlets) by the number of healthy outlets (supermarkets, fruit and vegetable stores) for each CAU. A higher RFEI suggests a greater relative density of unhealthy food outlets.

The GeoDa platform was used to assess spatial autocorrelation, or the extent to which spatial data from nearby locations are more likely to be similar than the data from distant locations. It is based on the Local Moran’s I statistic (Anselin et al. 2006). The relative density of unhealthy food outlets (as per the RFEI) and area socioeconomic deprivation level of each census area unit were compared to those from neighbouring CAUs. Neighbours were defined as CAUs sharing a common boundary. If the majority of CAUs are similar to one another than this is considered positive autocorrelation (Moran I value of 0.3 infers strong correlation). The spatial scan statistic

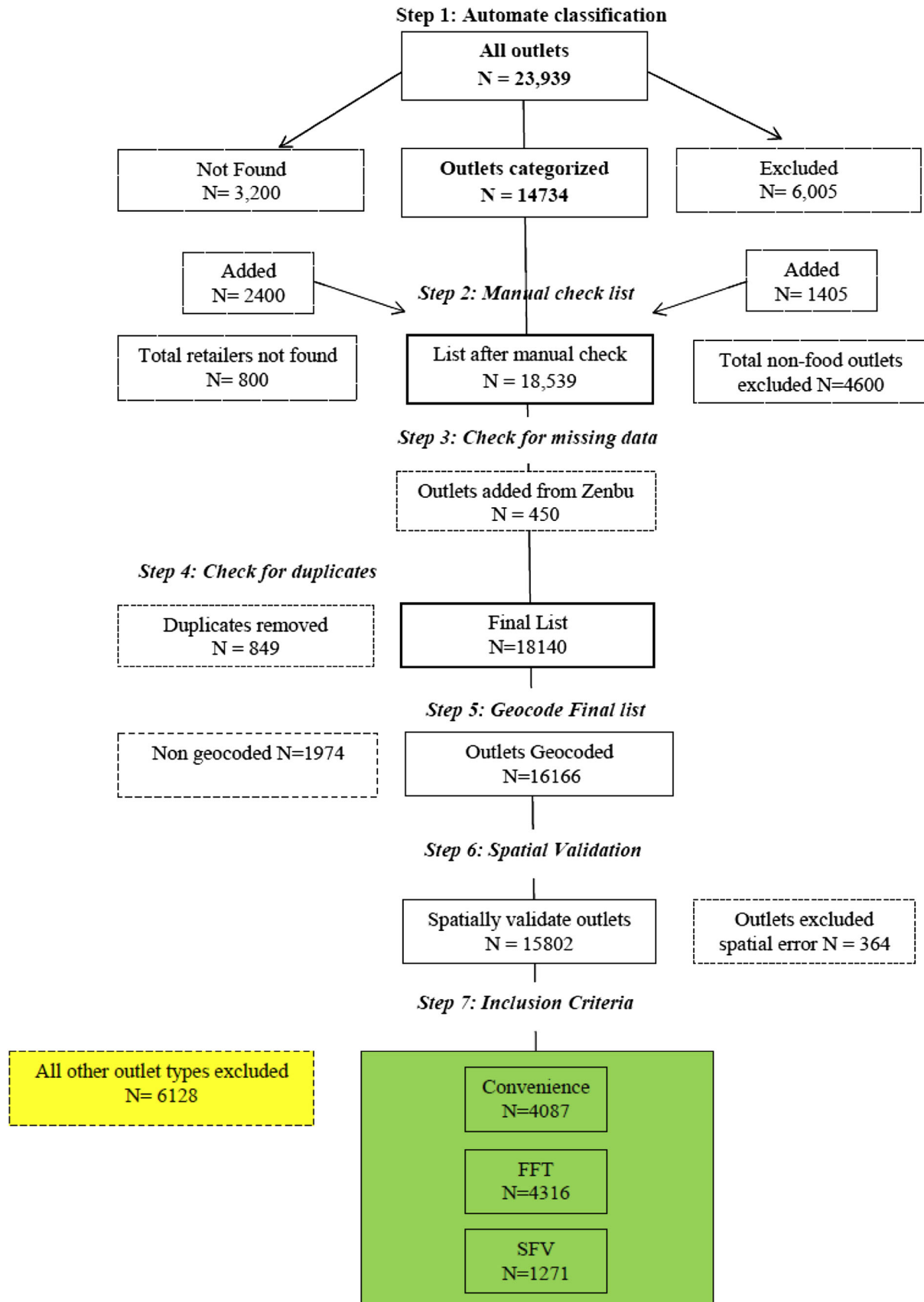


Fig. 1 Flow chart of food outlet categorisation and geocoding process (*FFT* fast food and takeaway outlets, *SFV* supermarkets and fruit and vegetable stores) in New Zealand (National study on community retail food environments, New Zealand, 2014–2015)

(Kulldorff 1997) was used to identify areas of significant geographical clustering of unhealthy food outlets (fast food outlets, takeaways and convenience stores) taking into account area deprivation level and population density. A particular strength of the scan statistic is its ability to recognise statistically the spatial dependence of adjacent areas while enabling analyses to be adjusted for different covariates, in this case area socioeconomic deprivation. The automated procedure involves moving numerous windows of different shapes and sizes over a grid reference map over New Zealand to which food outlets (incidents) and the denominator populations were attached. The window radius continuously changes from zero to a user defined maximum, based on the denominator population, which was defined in this analysis as 50% of the population at risk as recommended by Kulldorff (1997). For each window, at every location the log likelihood ratio was calculated to determine whether the relative density of unhealthy food outlets (as per the RFEI) within a circle differs significantly from the rate outside the circle. Next, a Monte Carlo simulation was performed by the software to test the statistical significance of the likely clusters of unhealthy food outlets in New Zealand. Significant clusters were defined as those with a probability p value of <0.05 .

Results

Validation of the compiled food outlet dataset

Out of the 18,140 retail addresses, 16,166 (90%) were geocoded successfully (Fig. 1). Overall, a spatial validation

Table 1 Median travel distance (metres) to the closest food outlet in urban New Zealand neighbourhoods (from meshblock centres) stratified by level of area socioeconomic deprivation as per the

NZDep2013 Quintiles	Supermarkets-F/V			Convenience stores			Fast food-takeaways		
	Q1	Median	Q3	Q1	Median	Q3	Q1	Median	Q3
Least deprived	962	1510	2423	521	879	1595	589	1009	1686
NZDep3–4	736	1249	2024	415	687	1165	465	777	1240
NZDep5–6	638	1061	1665	335	572	939	387	650	1026
NZDep7–8	551	936	1439	301	499	776	332	578	877
Most deprived	524	858	1291	297	492	756	329	565	866
<i>P</i> for trend		<0.001			<0.001			<0.001	

F/V fruit and vegetable stores, *NZDep* New Zealand Deprivation Index

confirmed that 98% of the coordinates were correctly mapped. Those 2% of incorrectly mapped outlets were examined further using Google Street View and were found to be residential buildings.

These addresses were assumed to be mailing addresses of shop owners and were, therefore, excluded from further spatial analysis, which left a total of 15,802 outlets after spatial validation. A random sample of outlets was further verified by phone calls. Of the 182 phone calls made, 157 were answered by shop attendants. About 2% had incorrect addresses and 3% had a completely different primary service. Overall, 90% of the total answered calls by retailers confirmed correct address and classification. In the final food outlet dataset ($N = 9674$), after excluding the outlets not relevant for this study, about 42.2% of food outlets were convenience stores, 44.6% fast food outlets and takeaways, and 13.1% fruit and vegetable shops and supermarkets (Fig. 1).

Proximity

The median road network distance from meshblock centres to the closest outlet for all types of food retailers was significantly greater in rural areas than in urban areas. The median travel distance from meshblock centres to the closest outlet for all types of food retailers was about twice as far in the least deprived areas compared with the most deprived areas (Tables 1, 2).

The gradient of increasing median distance from meshblock centres to all types of food outlets with decreasing level of area socioeconomic deprivation was found to be statistically significant for both urban and rural areas (Tables 1, 2).

Density and relative density

Overall, the results show that higher socioeconomic area deprivation was associated with higher food retail outlet

New Zealand Deprivation Index 2013 (NZDep2013) (National study on community retail food environments, New Zealand, 2014–2015)

Table 2 Median travel distance (metres) to the closest food outlet in rural New Zealand neighbourhoods (from meshblock centres) stratified by level of area socioeconomic deprivation as per the New

Zealand Deprivation Index 2013 (NZDep2013) (National study on community retail food environments, New Zealand, 2014–2015)

NZDEP2013 Quintiles	Supermarkets-F/V			Convenience stores			Fast food-takeaways		
	Q1	Median	Q3	Q1	Median	Q3	Q1	Median	Q3
Least deprived	1469	2406	4115	955	1536	2638	1144	1802	2906
NZDep3–4	1169	1926	3619	683	1132	2076	807	1339	2522
NZDep5–6	819	1460	2879	497	860	1501	579	1014	1756
NZDep7–8	646	1142	2254	392	666	1140	447	780	1330
Most deprived	687	1224	2377	366	632	1093	431	757	1264
<i>P</i> for trend		<0.001			<0.001			<0.001	

F/V fruit and vegetable store, NZDep New Zealand Deprivation Index

Table 3 Mean Availability [standard error (SE)] of different types of food outlets (expressed per 10000 people) in New Zealand Census area Neighbourhoods Stratified by New Zealand Deprivation Index

2013 (NZDep2013) Quintile; (National study on community retail food environments, New Zealand 2014–2015)

NZDep2013 Quintile	Supermarkets-F/V (<i>n</i> = 1271)		Convenience stores (<i>n</i> = 4087)		Fast food-takeaways (<i>n</i> = 4316)	
	Mean	SE	Mean	SE	Mean	SE
Least deprived	1.3	0.04	4.5	0.09	3.7	0.09
NZDep3–4	1.9	0.05	6.6	0.12	7.1	0.15
NZDep5–6	2.6	0.05	8.4	0.14	8.4	0.18
NZDep7–8	3.5	0.08	11.8	0.18	13.0	0.29
Most deprived	3.9	0.08	12.7	0.26	13.7	0.33
<i>P</i> for trend	<0.001		<0.001		<0.001	

NZDep New Zealand Deprivation Index

availability for all outlet types ($p < 0.001$) (Table 3). Areas in the most deprived quintile had 73% higher availability of fast food and takeaway outlets, 64% higher availability for convenience stores and 66% higher availability of supermarket and fruit and vegetable stores compared to areas in the least deprived quintile. The spatial regression confirmed a statistically significant relationship between area socioeconomic deprivation and the density of unhealthy outlets per 1000 Census Area population (Table 4). There was also a statistically significant relationship between area socioeconomic deprivation and the Retail Food Environment Index (RFEI) (Table 4).

Food swamps in New Zealand

We calculated the Moran's *I* measure of spatial autocorrelation to test for food swamp areas in New Zealand. The Moran's *I* value of 0.01 indicated a statistically significant, but weak positive spatial autocorrelation between neighbouring CAUs. The spatial scan analysis found 114 potential food swamps (clusters), namely areas of differing size and shape, with significantly higher relative density of

unhealthy outlets than other areas around NZ (Supplementary Material 2). Each cluster contained a different number of CAUs. In total, 722 CAUs were found within the 144 potential food swamps.

There were about 14% more potential food swamp CAUs in the most deprived CAUs ($n = 147$) compared to the least ($n = 126$) deprived CAUs (Fig. 2).

Discussion

Summary of results

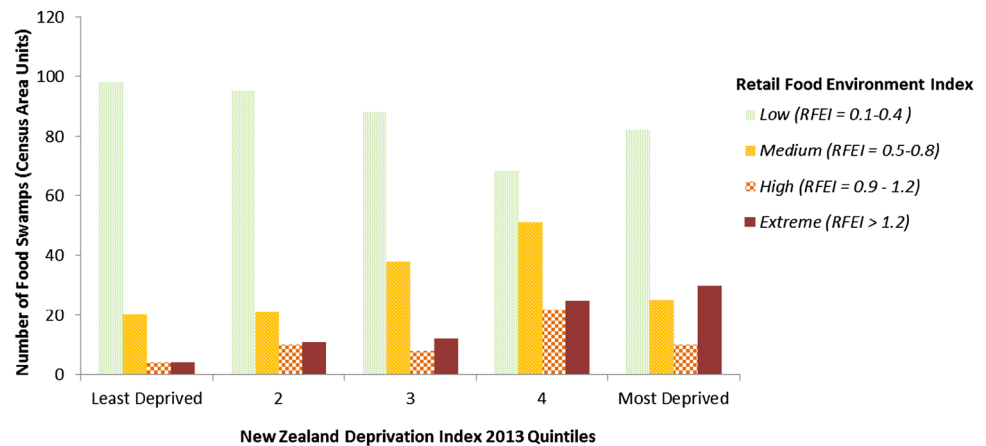
A significantly positive association was observed between the level of area socioeconomic deprivation and density of all types of food retailers in NZ, corrected for population size. A significantly negative association was observed between the level of area socioeconomic deprivation and proximity to all types of food retailers from MB centre points. Across New Zealand, 147 CAUs were identified as potential food swamps in the most deprived areas of NZ. The observed differences in distance to each outlet type

Table 4 Spatial regression results on the relationship between area socioeconomic deprivation and the density of food outlets in New Zealand (National study on community retail food environments, New Zealand, 2014–2015)

Dependent variables	Coefficient	SE	T-statistic	Prob
Retail Food Environment Index	0.67	0.21	2.61	0.009
Unhealthy outlets per 1 k pop	1.19	0.396	3.02	0.002
Healthy outlets per 1 k pop	0.48	0.25	1.89	0.05

Independent variable = NZDEP2013 Quintile, *NZDep* New Zealand Deprivation Index

Fig. 2 Number of food swamps by New Zealand Deprivation Index Quintiles [higher RFEI (Retail food environment index) indicates a higher relative availability of unhealthy food outlets] (National study on community retail food environments, New Zealand, 2014–2015). *NZDep* New Zealand Deprivation Index



from MB centres between more and less deprived areas were statistically significant and are consistent with findings of other NZ studies (Pearce et al. 2007a, 2008b) that found similar relationships between distance to fresh produce stores and fast food outlets and area deprivation.

Such findings also coincide with findings in the United Kingdom (Smith et al. 2010). These findings suggest that people who live and work in more deprived neighbourhoods in NZ are likely to experience a higher relative exposure to unhealthy outlets, which increases the likelihood of unhealthy food consumption.

The results of this study suggest that there are mechanisms other than population density which might be encouraging more unhealthy food outlets in poorer areas.

It is known from other studies that companies target more deprived communities through their marketing practises. (Grier and Kumanyika 2008; Isgor et al. 2016; Powell et al. 2014; Settle et al. 2014). Therefore, it is equally possible that companies strategically target the development of new unhealthy outlets in lower socioeconomic neighbourhoods.

Policy implications

In NZ, the zoning laws are designed to permit activity reflective of their anticipated land use (Swinburn et al. 2014). Commercial activities of all kind are permitted and

can take place without Council consent. Councils do not regulate commercial activity unless it is impacted by other regulations such as the Hazardous Substances Legislation that controls the number and certain type of goods which can be stored. At present, the NZ Government has no specific rules for regulating the number and location of food outlets. However, the Health Act 1956 imposes on Councils a general duty to improve, promote and protect public health.

Councils have the ability to produce bylaws under the Local Government Act 2002. A bylaw allows plan changes to development and subsequently zoning laws.

Based on the evidence from this study, the following policy recommendations are made following the results from this study:

- Introducing legislation that allows considerations like health and wellbeing (not just safety) to be taken into account in zoning and planning permissions.
- Developing guidelines for urban planners and Councils on the promotion and favourable zoning treatment for fruit and vegetable store outlets.
- Engagement of communities and health promoters with convenience store owners to increase the healthiness of the in-store food availability.
- Identification of high risk communities and restriction of future introduction of fast food outlets through zoning rules. In such cases, a proposal to develop an

outlet in a high risk area would then require notified resource consent. This would give an opportunity for community members to express their views on the potential of a fast food outlet opening in their neighbourhood.

Strengths and Limitations

This study includes a number of limitations. This study only evaluates one dimension of accessibility which relates to spatiality (e.g., proximity and density). It is well understood that accessibility is more than just a component of distance over space (Penchansky and Thomas 1981). The phone call validation recognised that the categorisation of outlets does not always reflect the true nature of the retailer and the reality of their service. Only 1% of outlets were validated in this way in this study. However, a large portion of the dataset, approximately 4000 outlets, was manually checked through Google Street View. In addition, a large number of food outlets (such as restaurants and cafes) were excluded because there is no agreement among experts about whether these should be classified as ‘healthy’ or ‘unhealthy’ in New Zealand. Another major limitation was using predefined spatial units to define neighbourhoods. This is related to the well documented Modifiable Areal Unit Problem. In New Zealand, the most readily available spatial unit for research are MBs and CAUs. However, MBs contain very few people, while CAUs might be too large to be described as a community.

While there are a number of noted limitations, there are also significant strengths of this study. This study had the largest assembled food outlet list amongst non U.S studies. It was the first New Zealand study to use spatial validation techniques to assess the accuracy of the geocoding process successfully. This is the first survey of community food environments to account information from all 66 Councils in New Zealand. The study developed an effective, automatic self-classification tool to categories outlets.

In conclusion, this study has found evidence to support the potential existence of food swamps in New Zealand. Policy implications include restricting the introduction of new unhealthy food outlets in high risk areas with asignificantly higher relative density of those outlets than in other areas in New Zealand

Compliance with ethical standards

Ethical statement All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

- Anselin L, Syabri I, Kho Y (2006) GeoDa: an introduction to spatial data analysis. *Geogr Anal* 38(1):5–22. doi:[10.1111/j.0016-7363.2005.00671.x](https://doi.org/10.1111/j.0016-7363.2005.00671.x)
- Apparicio P, Cloutier MS, Shearmur R (2007) The case of Montreal’s missing food deserts: evaluation of accessibility to food supermarkets. *Int J Health Geogr* 6:4
- Beaulac J, Kristjansson E, Cummins S (2009) A systematic review of food deserts, 1966–2007. *Prev Chronic Dis* 6(3):A105
- Burns CM, Inglis AD (2007) Measuring food access in Melbourne: access to healthy and fast foods by car, bus and foot in an urban municipality in Melbourne. *Health Place* 13(4):877–885
- Cetateanu A, Jones A (2014) Understanding the relationship between food environments, deprivation and childhood overweight and obesity: evidence from a cross sectional England-wide study. *Health Place* 27:68–76. doi:[10.1016/j.healthplace.2014.01.007](https://doi.org/10.1016/j.healthplace.2014.01.007)
- Day PL, Pearce JR, Pearson AL (2013) A temporal analysis of the spatial clustering of food outlets around schools in Christchurch, New Zealand, 1966 to 2006. *Public Health Nutr*. doi:[10.1017/S1368980013002863](https://doi.org/10.1017/S1368980013002863)
- Fraser LK, Edwards KL, Tominitz M, Clarke GP, Hill AJ (2012) Food outlet availability, deprivation and obesity in a multi-ethnic sample of pregnant women in Bradford, UK. *Soc Sci Med* 75(6):1048–1056
- Gordon C, Purciel-Hill M, Ghai NR, Kaufman L, Graham R, Van WG (2011) Measuring food deserts in New York City’s low-income neighborhoods. *Health Place* 17(2):696–700
- Grier SA, Kumanyika SK (2008) The context for choice: health implications of targeted food and beverage marketing to African Americans. *Am J Public Health* 98(9):1616–1629. doi:[10.2105/AJPH.2007.115626](https://doi.org/10.2105/AJPH.2007.115626)
- Hager ER et al (2016) Food swamps and food deserts in Baltimore City, MD, USA: associations with dietary behaviours among urban adolescent girls. *Public Health Nutr*. doi:[10.1017/S1368980016002123](https://doi.org/10.1017/S1368980016002123)
- Isgor Z, Powell L, Rimkus L, Chaloupka F (2016) Associations between retail food store exterior advertisements and community demographic and socioeconomic composition. *Health Place J Transl Name Health Place* 39:43–50. doi:[10.1016/j.healthplace.2016.02.008](https://doi.org/10.1016/j.healthplace.2016.02.008)
- Kulldorff M (1997) A spatial scan statistic. *Commun Stat Theor Methods* 26(6):1481–1496. doi:[10.1080/03610929708831995](https://doi.org/10.1080/03610929708831995)
- Luan H, Law J, Quick M (2015) Identifying food deserts and swamps based on relative healthy food access: a spatio-temporal Bayesian approach. *Int J Health Geogr* 14:37. doi:[10.1186/s12942-015-0030-8](https://doi.org/10.1186/s12942-015-0030-8)
- Ministry of Health (2015) Annual update of key results 2014/15: New Zealand Health Survey. In: Ministry of Health. <http://www.health.govt.nz/publication/annual-update-key-results-2014-15-new-zealand-health-survey>. Accessed 15 Nov 2016
- Ng M et al (2014) Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 384(9945):766–781. doi:[10.1016/S0140-6736\(14\)60460-8](https://doi.org/10.1016/S0140-6736(14)60460-8)
- Ni Mhurchu C et al (2013) Monitoring the availability of healthy and unhealthy foods and non-alcoholic beverages in community and consumer retail food environments globally. *Obes Rev* 14(Suppl 1):108–119. doi:[10.1111/obr.12080](https://doi.org/10.1111/obr.12080)
- Osorio AE, Corradini MG, Williams JD (2013) Remediating food deserts, food swamps, and food brownfields: helping the poor access nutritious, safe, and affordable food. *AMS Rev* 3(4):217–231

- Pearce J, Blakely T, Witten K, Bartie P (2007a) Neighborhood deprivation and access to fast-food retailing: a national study. *Am J Prev Med* 32(5):375–382. doi:[10.1016/j.amepre.2007.01.009](https://doi.org/10.1016/j.amepre.2007.01.009)
- Pearce J, Witten K, Hiscock R, Blakely T (2007b) Are socially disadvantaged neighbourhoods deprived of health-related community resources? *Int J Epidemiol* 36(2):348–355. doi:[10.1093/ije/dyl267](https://doi.org/10.1093/ije/dyl267)
- Pearce J, Day P, Witten K (2008a) Neighbourhood provision of food and alcohol retailing and social deprivation in urban New Zealand. *Urban Policy Res* 26(2):213–227. doi:[10.1080/08111140701697610](https://doi.org/10.1080/08111140701697610)
- Pearce J, Hiscock R, Blakely T, Witten K (2008b) The contextual effects of neighbourhood access to supermarkets and convenience stores on individual fruit and vegetable consumption. *J Epidemiol Commun Health* 62(3):198–201
- Penchansky R, Thomas JW (1981) The concept of access: definition and relationship to consumer satisfaction. *Med Care* 19(2):127–140
- Powell LM, Wada R, Kumanyika SK (2014) Racial/ethnic and income disparities in child and adolescent exposure to food and beverage television ads across the U.S. media markets. *Health Place* 29:124–131. doi:[10.1016/j.healthplace.2014.06.006](https://doi.org/10.1016/j.healthplace.2014.06.006)
- Reitzel LR et al (2014) Density and proximity of fast food restaurants and body mass index among African Americans. *Am J Public Health* 104(1):110–116. doi:[10.2105/Ajph.2012.301140](https://doi.org/10.2105/Ajph.2012.301140)
- Rose D, Bodor JN, Swalm C, Rise JC, Farley TA, Hutchinson PL (2009) Deserts in new orleans? Illustrations of urban food access and implications for policy. In: Paper presented at the understanding the economic concepts and characteristics of food access, University of Michigan National Poverty Center/USDA Economic Research Service Research
- Sauveplane-Stirling V, Crichton D, Tessier S, Parrett A, Garcia AL (2014) The food retail environment and its use in a deprived, urban area of Scotland. *Public Health* 128(4):360–366. doi:[10.1016/j.puhe.2013.11.005](https://doi.org/10.1016/j.puhe.2013.11.005)
- Settle PJ, Cameron A, Thornton L (2014) Socioeconomic differences in outdoor food advertising at public transit stops across Melbourne suburbs. *Aust N Z J Public Health* 38(5):414–418. doi:[10.1111/1753-6405.12257](https://doi.org/10.1111/1753-6405.12257)
- Short A, Guthman J, Raskin S (2007) Food deserts, oases, or mirages? Small markets and community food security in the San Francisco bay area. *J Plan Educ Res* 26(3):352–364. doi:[10.1177/0739456x06297795](https://doi.org/10.1177/0739456x06297795)
- Smith DM et al (2010) Neighbourhood food environment and area deprivation: spatial accessibility to grocery stores selling fresh fruit and vegetables in urban and rural settings. *Int J Epidemiol* 39(1):277–284. doi:[10.1093/ije/dyp221](https://doi.org/10.1093/ije/dyp221)
- Statistics New Zealand (2017a) Geographic definitions. In: Wellington. <http://www.stats.govt.nz/Census/2013-census/info-about-2013-census-data/2013-census-definitions-forms/definitions/geographic.aspx>. Accessed 19 March 2017
- Statistics New Zealand (2017b) Statistical standard for mesh block. In. <http://www.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/meshblock/definition.aspx>. Accessed 19 March 2017
- Swinburn B, Egger G, Raza F (1999) Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med* 29(6):563–570. doi:[10.1006/pmed.1999.0585](https://doi.org/10.1006/pmed.1999.0585)
- Swinburn BA et al (2011) The global obesity pandemic: shaped by global drivers and local environments. *The Lancet* 378(9793):804–814. doi:[10.1016/S0140-6736\(11\)60813-1](https://doi.org/10.1016/S0140-6736(11)60813-1)
- Swinburn B et al (2013) International network for food and obesity/non-communicable diseases research, monitoring and action support (INFORMAS): overview and key principles. *Obes Rev* 14(Suppl 1):1–12. doi:[10.1111/obr.12087](https://doi.org/10.1111/obr.12087)
- Swinburn B, Dominick CH, Vandevijvere S (2014) Benchmarking food environments: experts' assessments of policy gaps and priorities for the New Zealand Government. In: University of Auckland. <https://cdn.auckland.ac.nz/assets/fmhs/soph/globalhealth/informas/docs/Food-EPI%20report.pdf>
- Vandevijvere S, Chow CC, Hall KD, Umali E, Swinburn BA (2015) Increased food energy supply as a major driver of the obesity epidemic: a global analysis. *Bull World Health Organ* 93(7):446–456. doi:[10.2471/BLT.14.150565](https://doi.org/10.2471/BLT.14.150565)
- Vandevijvere S, Sushil Z, Exeter DJ, Swinburn B (2016) Obesogenic retail food environments around New Zealand Schools: a National Study. *Am J Prev Med* 51(3): e57–66
- Walker RE, Keane CR, Burke JG (2010) Disparities and access to healthy food in the United States: a review of food deserts literature. *Health Place* 16(5):876–884