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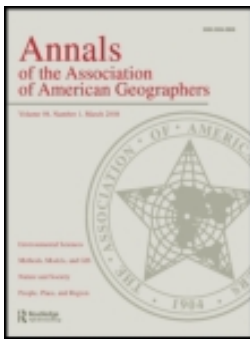
# Macro-, Meso- and Microscale Segregation: Modeling Changing Ethnic Residential Patterns in Auckland, New Zealand, 2001–2013

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# Macro-, Meso- and Microscale Segregation: Modeling Changing Ethnic Residential Patterns in Auckland, New Zealand, 2001–2013

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Most world cities can now be characterized as multiethnic and multicultural in their population composition, and the residential patterning of their major component ethnic groups remains a topic of substantial research interest. Many studies of the degree of residential segregation of ethnic groups recognize that this is multiscalar in its composition, but few have incorporated this major feature into their analyses: Those that do mostly conclude that segregation is greater at the microscale than at the macroscale. This article uses a recently developed alternative procedure for assessing the degree of segregation that differs from all others in that it analyzes the geography of all groups simultaneously, providing a single, synoptic view of their relative segregation; can incorporate data for more than one date and therefore evaluate the statistical significance of the extent of any change over time; operates at several geographical scales, allowing appreciation of the extent of clustering and congregation for the various ethnic groups at different levels of spatial resolution; and—most important—is based on a firm statistical foundation that allows for robust assessments of differences in the levels of segregation for different groups between each other at different scales over time. This modeling procedure is illustrated by a three-scale analysis of ethnic residential segregation in Auckland, New Zealand, as depicted by the country's 2001, 2006, and 2013 censuses. *Key Words: Auckland, ethnicity, segregation, spatial scale.*

今日，大多数的世界城市，皆以多元族裔和多元文化的人口组成为特徵，而其主要组成族裔群体的居住模式，仍然是诸多研究兴趣的关注主题。许多有关族裔群体居住隔离程度的研究，承认人口组成是多重尺度的，但却鲜少将此般主要面向整合进分析之中：该分析多半的结论是，隔离在微观尺度较巨观尺度更为剧烈。本文运用晚近建立的另类程序来评估隔离程度，该程序有异于其他所有的方法，因其同时分析所有群体的地理，对它们的相对隔离提供单一、全观的视角；能够整合一个以上的日期，因此能够评估任何随着时间改变的幅度的统计显着性；在数个地理尺度上操作，容纳各种族裔群体在不同的空间分辨率层级上的集群和集合程度之评价；以及最重要的是根据坚实的统计基础，该基础考量不同群体之间，随着时间在不同尺度的隔离层级的差异之稳健评估。此一模式化程序，透过对纽西兰 2001 年、2006 年与 2013 年的全国人口普查所呈现的奥克兰市族裔居住隔离所进行的三种尺度之分析进行描绘。关键词：奥克兰，族裔，隔离，空间尺度。

La composición poblacional de la mayoría de las ciudades mundiales ahora puede caracterizarse como multiétnica y multicultural, y el diseño residencial del principal componente de sus grupos étnicos sigue siendo un tópico de sustancial interés para investigación. Muchos estudios sobre el grado de segregación residencial de grupos étnicos reconocen que esa segregación es multiescalar en su composición, pero pocos han incorporado tan importante rasgo en sus análisis: Los que lo hacen, mayoritariamente concluyen que la segregación es mayor a la escala más pequeña que a escala macro. Este artículo usa un procedimiento alternativo recientemente desarrollado para evaluar el grado de segregación, que difiere de todos los demás en cuanto este analiza la geografía de todos los grupos simultáneamente, dando lugar a una visión sencilla y sinóptica de sus segregaciones relativas; puede incorporar datos para más de una fecha y en consecuencia evaluar la significancia estadística del alcance de cualquier cambio a través del tiempo; opera a varias escalas geográficas, permitiendo apreciar el alcance del agrupamiento y congregación para los varios grupos étnicos, a diferentes niveles de resolución espacial; y—lo más importante—se basa en una firme fundamentación estadística que facilita hacer robustas evaluaciones de las diferencias en los niveles de segregación para diferentes grupos a diferentes escalas en el tiempo. Se

ilustra este procedimiento de modelado por medio de un análisis a tres escalas de segregación étnica residencial en Auckland, Nueva Zelanda, como se muestra en los censos de este país de 2001, 2006 y 2013. *Palabras clave: Auckland, etnicidad, segregación, escala espacial.*

The growing volume and variety of migration to major cities across the world has resulted in many of their populations having a very diverse ethnic composition and complex residential pattern (Nightingale 2012). It is common for members of different ethnic groups to concentrate together—to a greater or lesser extent—in different parts of those cities, reflecting a combination of factors including the operation of the local labor and housing markets, the degrees of disadvantage and (in some cases) discrimination experienced by minority group members, and their cultural cum economic desires to live near their coethnics.

Unravelling those geographies—mapping and measuring the degree of residential separation, or segregation, of those groups—and how they are changing has been a substantial research concern across the several disciplines associated with urban studies for almost a century since the pioneering work of the first Chicago School scholars. Because segregation matters in so many aspects of urban life, its measurement matters (Johnston et al. 2014), so much effort has been expended devising and applying different segregation measures, with the continuation of that effort indicating that none has proved entirely satisfactory. (Reardon [2006] provided a valuable summary of much of that work.)

This article adds to that literature, applying a novel multigroup, multiscale, multiyear modeling procedure to an analysis of the changing geography of ethnic residential patterns in Auckland, New Zealand, one of the large number of cities whose multiethnic nature has changed very considerably in recent decades. Application of this novel methodology not only provides important new insights into that city's social geography but supports other arguments for a reconsideration of the theoretical appreciation of segregation processes incorporating spatial scale. The goal is to examine, for the first time in a rigorous multiscale analytical framework, whether the degree of segregation for Auckland's main ethnic groups varies according to the scale of analysis and, should that be the case, to offer an account for the observed variations. It is not anticipated that the results will differ from other studies using alternative measures of segregation at single scales, only in identifying which groups are most segregated within Auckland's residential fabric; the article's original contribution lies in assessing the extent of that segregation at different spatial scales.

## Auckland

Auckland, according to the latest New Zealand census (2013), is a metropolitan area with some 1.4 million residents—31 percent of the country's total population. For many decades after its foundation in 1840, it was an overwhelmingly white city, its population dominated by settlers from the British Isles and their descendants, with very few representatives of other ethnic groups. From the early decades of the twentieth century on, these settlers were joined by a growing number of members of the country's indigenous Maori population, which until then had been concentrated in relatively remote rural areas of the North Island. Most of the Maori who moved to the city, plus their descendants, were of relatively low economic status and were concentrated into areas of lower quality and lower priced housing, both in the inner city and, for several decades after the 1930s during the heyday of New Zealand's welfare state, on social housing estates—many of which were built on what was then the urban periphery.

In the late twentieth century, these intra–New Zealand migrants were joined by a growing stream of international immigrants from various Pacific Island countries and territories, some of which have had formal sovereignty ties with New Zealand. They, too, have been concentrated in lower status, lower paid occupations and have consequently clustered into certain segments of the housing market. More recently, this intra-Pacific basin flow has been joined by another from Asian countries—mainly China, India, and, more recently, Korea and the Philippines. A considerable number of these later new residents work in higher status occupations, allowing them wider choice within the urban housing market: Nevertheless, as previous studies of Auckland have illustrated (Johnston, Poulsen, and Forrest 2008; Grbic, Ishizawa, and Crothers 2010), they, too, have tended to concentrate in particular areas of the city (on migration to New Zealand see Trlin, Spoonley, and Watts 2005).

**Table 1.** Auckland's changing ethnic population, 2001–2013

|  | 2001 | 2005 | 2013 |
|---|---|---|---|
| European | 755,961 | 700,167 | 789,306 |
| Maori | 127,704 | 137,310 | 142,767 |
| Pacific People | 154,692 | 177,942 | 194,967 |
| Asian | 151,641 | 234,273 | 307,227 |
| Other | 13,611 | 118,659 | 40,584 |
| Total ethnic | 1,203,609 | 1,368,351 | 1,474,851 |
| Not elsewhere | 57,459 | 65,901 | 84,126 |
| Total residents | 1,160,277 | 1,304,964 | 1,415,550 |

Table 1 gives the ethnic composition of Auckland's population at each of the last three national censuses in 2001, 2006, and 2013.[1] Individuals' ethnicity is obtained through a self-identification question,[2] and tabulation of this information into four main categories—New Zealand European, Maori, Pacific People, and Asian[3]—presents a few small difficulties for analysts. Respondents can identify with up to five ethnic categories, and all those stated are tabulated—thus the number of individuals in the ethnic identity tabulation is larger than the total population. Only a small number declared multiple identities at any of the three censuses, however, and Table 1 shows that the total number tabulated with this double-counting procedure does not greatly exceed that of the total enumerated resident population (e.g., by some 60,000 only in 2013). In addition, a small number of respondents gave identities that could not be fitted within the major categories and they are tabulated as "Not elsewhere": In 2006 and 2013, but not 2001, this included those who identified simply as New Zealander.[4]

These difficulties are not substantial, however, and the main block of data in Table 1 gives a clear picture of an increasingly multiethnic population for the city. The New Zealand European population was relatively stable in absolute terms (with the drop in 2006 reflected in the growth of the "other" component between 2001 and then); in relative terms, however, its share of the total (i.e., the ethnic identity total) fell by some 10 percentage points from 2001, to almost exactly half of the city's total twelve years later. Both the Maori and Pacific People populations grew substantially over the period— by 12 and 26 percent, respectively; their shares of the total remained constant, however, because of the very significant growth of the Asian

population—an increase of 103 percent (some 155,000 individuals) in a little over a decade.

To analyze the residential patterning of Auckland's increasingly multiethnic population over that period, we use small area data for the Auckland region published by Statistics New Zealand, at three separate scales for which the spatial units are consistent across the three censuses. At the smallest scale are the meshblocks, of which there were 11,767—although a small number (mainly marine areas) had no residents at any of the three counts and some others had none at either or both of the first and the second; the mean meshblock (ethnic count) populations were 107, 122, and 132 at the three censuses, respectively, so they provide a very fine spatial division of the city. The meshblocks are nested within 436 area units (mean populations of 2,892, 3,290, and 3,576), and these in turn are nested within twenty-one local board areas (termed localities here; mean populations of 63,503, 71,712, and 77,949). Figure 1 shows the boundaries of the two
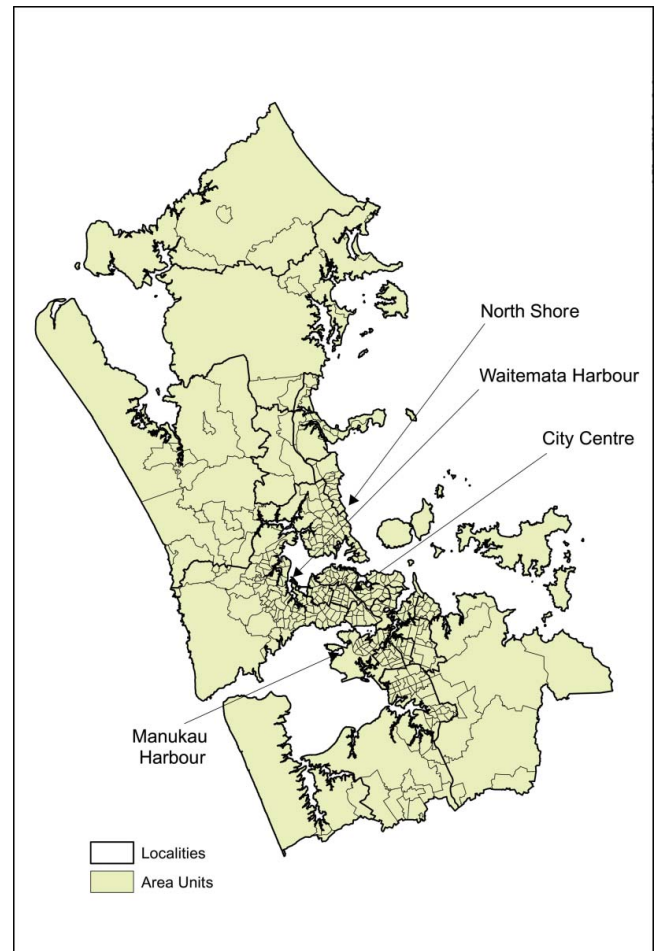


**Figure 1.** The Auckland region, showing the place names mentioned in the text. (Color figure available online.)

higher level sets of units within the Auckland region, as defined in the censuses and indicates the location of the city center and other areas mentioned in the text. In the subsequent discussion, we regularly refer to the three spatial levels as the macro-, meso-, and micro-scales, respectively, for the localities, area units, and meshblocks.

## Auckland's Ethnic Geography

Ethnic residential segregation is a well-established feature of Auckland's urban fabric, as a number of studies of pre-2013 censuses have indicated, all analyzing residential patterning at a single spatial scale only (e.g., Grbic, Ishizawa, and Crothers 2010; Maré et al. 2012; Ishizawa and Arunachalam 2014). Figures 2 through 5 show the residential distributions of the four main ethnic groups at each of the three latest censuses as percentages of each meshblock's population. Those percentage distributions are divided into quintiles for the 2001 maps, and the same divisions are then used in the following two maps to enable comparisons. (There is a residual "other" category for each mesh-block and larger scale unit. This group—which is very small in almost all cases—is included in the modeling

but its very heterogeneous character means that mapping its distribution is not meaningful.)

The first set of maps shows the distribution of the Maori population at each date (Figure 2). They formed a substantial percentage of the total population along much of the urban fringe at all three censuses, notably in the north, but this is somewhat misleading because of the low population densities and relatively large (in area) meshblocks there. The main concentration of Maori is to the southeast of the city center, on the eastern shore of the Manukau Harbor; substantial sections of that area are large estates constructed by the State Housing Authority. There is little evidence of any significant change over the twelve-year period in the distribution of Maori across Auckland's residential fabric.

The maps for the Pacific Peoples (Figure 3) also suggest little change, but their relative absence from many parts of the metropolitan area (where they form less than 4 percent of the local population), including the urban fringe, makes for a much clearer pattern of concentration than for the Maori. As with the latter group, there are major concentrations of Pacific People in the low-status housing areas fringing on the Manukau Harbor, but these are complemented by another cluster to the west of the city center on the southern shores of the inner Waitemata Harbor.
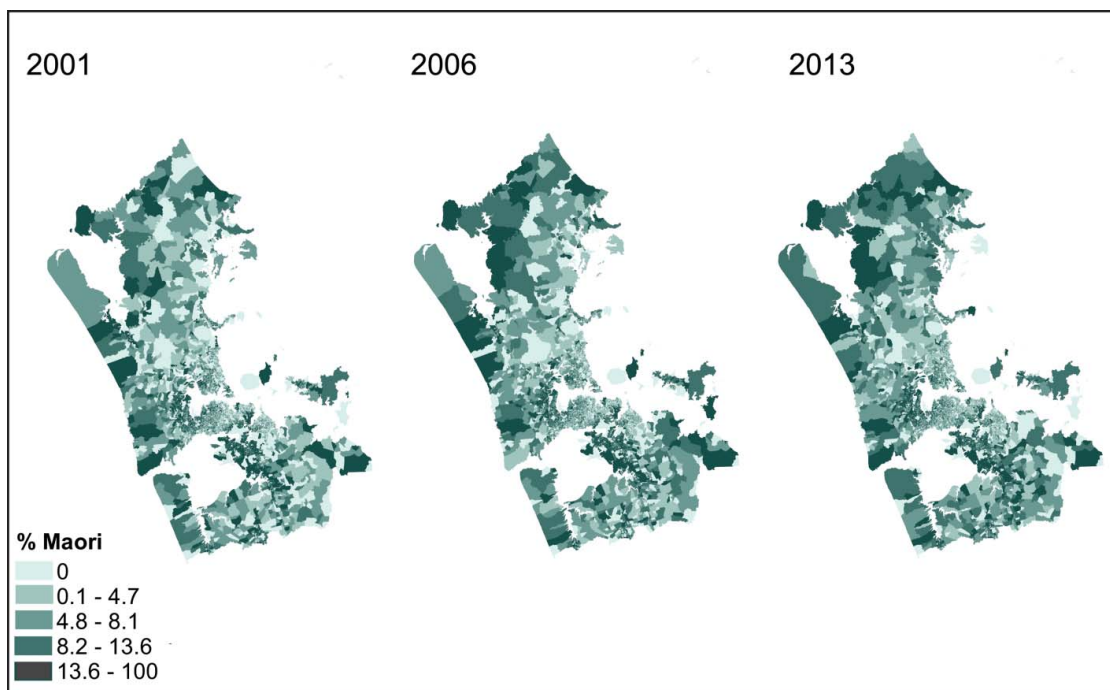


**Figure 2.** The distribution of Maori in the Auckland region 2001–2006–2013 as a percentage of the meshblock population (using 2001 quintiles). (Color figure available online.)

**Figure 3.** The distribution of Pacific People in the Auckland region 2001–2006–2013 as a percentage of the meshblock population (using 2001 quintiles). (Color figure available online.)

The geography of the Asian population is very different from the first two (Figure 4), in both the areas of concentration and their expansion. The main concentrations in 2001 were on the central isthmus; these intensified in 2006 and again in 2013; in addition they were extended both eastward and westward, as well as onto the North Shore.[5]

Finally, comparison of the maps for the majority Europeans (Figure 5; we use the shorthand term Europeans for the fuller New Zealand Europeans



**Figure 4.** The distribution of Asians in the Auckland region 2001–2006–2013 as a percentage of the meshblock population (using 2001 quintiles). (Color figure available online.)

**Figure 5.** The distribution of New Zealand Europeans in the Auckland region 2001–2006–2013 as a percentage of the meshblock population (using 2001 quintiles). (Color figure available online.)

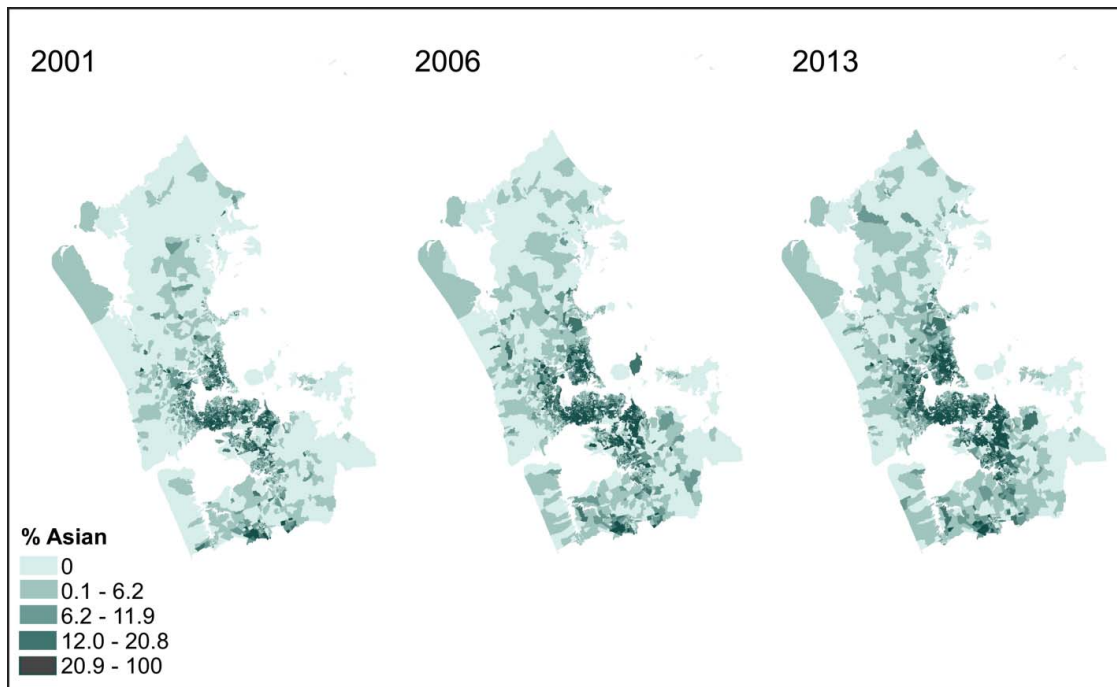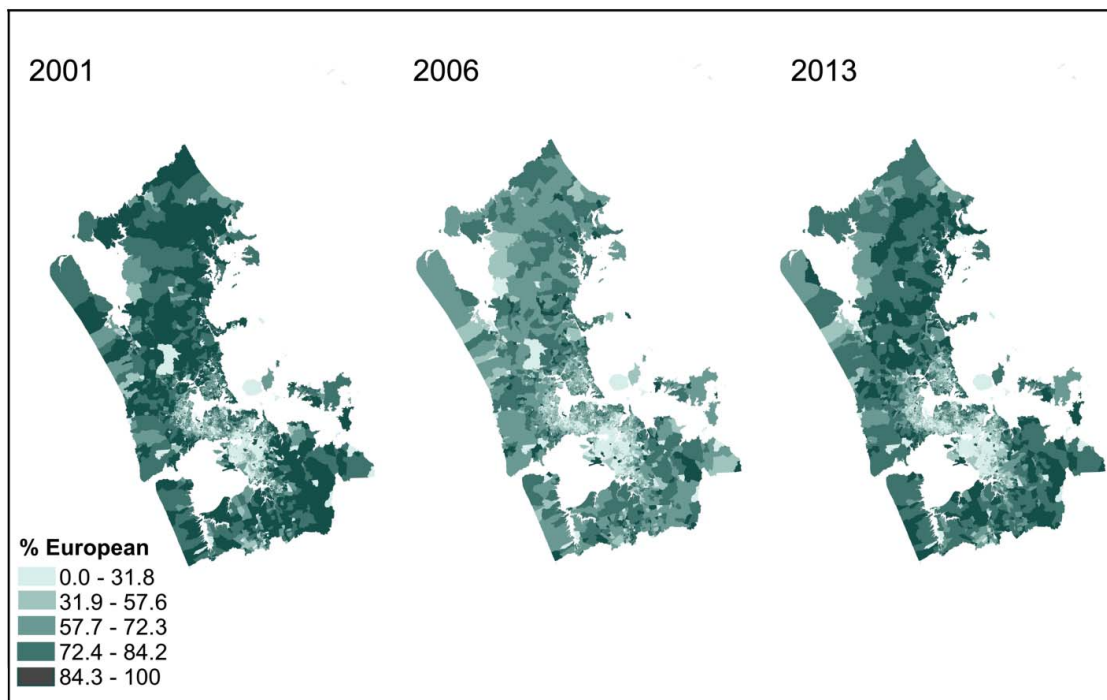throughout this article) is less straightforward because of the decline in that group's total between 2001 and 2006, in part as a consequence of the number who identified as New Zealanders and so were placed in the Not elsewhere category (Table 1). Nevertheless, the main features of their distribution are clearly discernible, especially if the focus is on the 2001 and 2013 maps. Europeans are relatively absent—forming less than one third of the population—from much of the central isthmus and the areas to the south and east of that core area where there are Maori, Pacific People, and Asian concentrations; they are relatively numerous—consistent with the classic models of urban residential structure—in the outer suburban areas.

## Measuring—by Modeling—Segregation

These maps provide a general overview of Auckland's geography but provide neither precise measurements of the degree to which the four ethnic groups live apart from each other nor to what extent the degree of intergroup separation has changed as their relative shares of the city's population have altered. Those questions have traditionally been answered by calculating a range of indexes—particularly those of dissimilarity, segregation, isolation, and exposure (Massey and Denton 1988)—but these have come under increasing criticism for the paucity of information they provide. A range of other measures has been proposed that are more suited to the analysis of multigroup situations (the traditional indexes all involve only pairwise comparisons), and although these offer improved appreciation of complex, multivariate geographies, they also have their drawbacks (see, e.g., Reardon and Firebaugh 2002; for more general discussion of the disadvantages of these single-number, descriptive indexes, see Johnston and Jones 2010; Johnston, Poulsen, and Forrest 2010, 2014).

In this article, therefore, we apply a novel procedure for analyzing segregation that has four main advantages. First, it analyzes the geographies of all of the ethnic groups simultaneously, thereby providing a single, synoptic view of their relative patterning. Second, it can incorporate data for more than one date, thereby facilitating the analysis of change; and, third, it operates at more than one geographical scale, allowing appreciation of the extent of clustering and concentration at different levels of spatial resolution.

The fourth, and the most important, advantage of this procedure is that it is based on a firm statistical foundation. Almost all of the very large number of segregation analyses based on the traditional indexes—plus most of the more recently proposed alternatives—
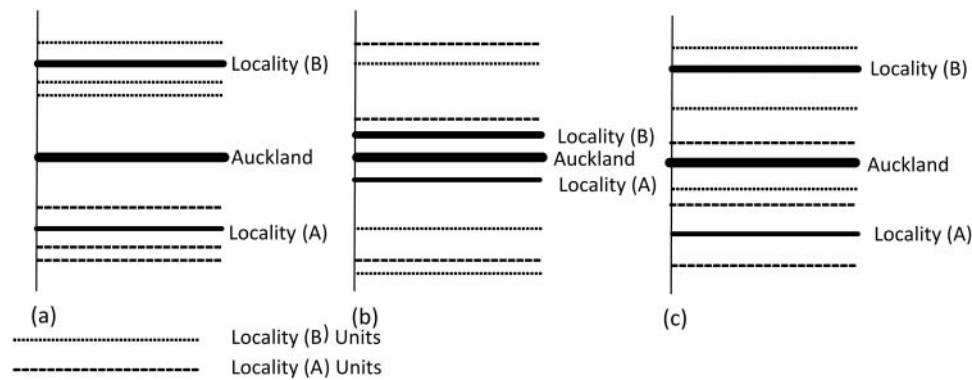
**Figure 6.** The modeling structure illustrated.

are descriptive only (see Allen et al. 2015; D. Lee, Minton, and Pryce 2015). For some researchers, this is sufficient because the measurements are based on total population enumerations; as there is no sampling involved, it is claimed, there is no need for statistical significance testing (see Gorard, Hordosy, and See's [2013] response to Leckie et al. [2012]; see also Gorard 2014; Johnston et al. 2014). Others, however, argue that all data sets contain some natural (or random) variation, the extent of which can have an impact on any measurement. This is especially the case when relatively small numbers are involved: If an area—like the vast majority of the meshblocks analyzed here—has only a small population, the percentage in any one ethnic group there can be changed substantially by a small variation in its number, and the ratio between the number in two of the groups might be far from reliable (a small change in either the numerator or the denominator when one or both is a small number can generate a substantial change in the ratio between the two).

For this reason, we have adopted the modeling approach set out in full in Jones et al. (forthcoming; see also Manley et al. 2015), developing on earlier work by Leckie et al. (2012; Leckie and Goldstein 2015) and pioneering articles by Kish (1954) and Moellering and Tobler (1972). We deploy a Poisson model, which is particularly suited for data with small absolute counts, as in the situation with the meshblock data analyzed here. The formulation allows comparison of all pairs of distributions, so no ethnic category is depicted as the baseline against which other distributions are compared.

In the model, the observed counts for each ethnic group in the smallest units (the meshblocks) are compared with the expected counts if each group were distributed evenly across all of those areas in line with the total population there. The natural log of this observed : expected ratio is modeled in a multiscale modeling framework. Because the modeling is set in a multilevel spatial framework (meshblocks nested within area units, nested within localities), one of the major criticisms of most index measures of segregation is overcome—that they are aspatial because they take no account of whether the areal units within which a group is concentrated are spatially clustered. By analyzing variations in the ratios for localities around the city-wide figure, ratios for area units around their respective locality figures, and ratios for meshblocks around their respective area unit figures, the modeling procedure adopted here explicitly incorporates the spatial element of segregation processes.

The model's structure is illustrated by Figure 6, which presents a simplified version using two scales only (macro and meso) to outline the modeling features. Figure 6A shows the situation where the ratios in two localities—the macroscale units—differ substantially from that for Auckland as a whole, whereas within each of those localities the ratios for the area units (the mesoscale units) differ only slightly from the relevant locality figure. In this case, segregation is much greater at the macroscale than at the mesoscale. In the second example (the central column; Figure 6B) the ratios for the two macro-units are very similar to that for Auckland—suggesting very little macroscale segregation—but there is wide variation within each at the mesoscale, as shown by the spread of values around each locality's ratio. Finally, the example in Figure 6C shows a situation with substantial variability at both scales; the two localities differ substantially from the Auckland-wide ratio and within each of them the individual area units differ substantially from their respective locality ratios.

Three components of the output from these models are of interest in the analysis of segregation. The first two measures, the variance and the median rate ratio (MRR), report the degree of segregation for each group, at each scale and at each date net of all higher level scales; that is, the amount of variation around its higher level comparator (the macroscale—locality—variation around the Auckland-wide rate; the mesoscale—area unit—variation around the respective locality rates; and the microscale—meshblock—variation around each respective area unit rate). Because we are using a modeling environment, each of the measures has associated Bayesian credible intervals (CIs). The credible intervals give the 95 percent range of values that are supported by the data and as usual a smaller number of units at that level give wider confidence intervals. Unlike standard confidence intervals, these Bayesian equivalents are not based on assumptions of asymptotic normality and can therefore be asymmetric.

The output from the modeling process is an estimate of the variance; if this value is low and close to zero there is little segregation occurring for that ethnic group at that level; the spread of that ethnic group is close to an expected even distribution. The interpretation of the variances is not intuitive, as they are on the log scale and like all variances summarize the square of the (log) values. Instead, we use the MRR as the most appealing way of expressing the variances in a more readily interpretable form that facilitates comparisons between standardized rates.[6] It is easiest to appreciate the meaning of this MRR by a thought experiment. Imagine that we pick two places at random from a distribution with the estimated variance on the log scale. Exponentiating these two rates, we can calculate a ratio of one to the other. We can repeat this thousands of times and take the median value of these ratios. If there is no segregation, the highest and lowest rates will be similar and the typical or median ratio will be close to 1. If there is a lot of segregation, though, the MRR will be higher than 1. When comparing the distribution of Maori across area units within localities, for example, a value of 2 would imply that there is twice the proportion of the population in the typical (i.e., median) high than in the typical low area. For interpretation, we can then classify these median ratios according to well-known effect sizes, as in Cohen's (1988) recommendations originally developed for odds ratios. Accordingly, values greater than 4.3 indicate very large ratios: MRRs between 2.5 and 4.3 and between 1.5 and 2.5 are considered medium and small, respectively; and MRRs less than 1.5 are considered low. The calculation of the MRR is a simple transformation of the variance and we can do the same operation to derive the 95 percent CIs around each MRR value for significance testing purposes.[7]

The third output from the model is the correlations, which can be interpreted in the same way as product–moment correlation coefficients; these illustrate the degree of similarity in the distributions of each pair of ratios at each scale. Significant positive correlations (e.g., between the rates for ethnic groups X and Y at one census) indicate that where ratios are high for one group (i.e., there are more members than expected in certain areas) they are also high for the other: Their segregation patterns are similar—they share the same spaces. Significant negative correlations indicate that where ratios are high for one group they are low for the other, and vice versa—they occupy separate areas rather than share space. Nonsignificant (small) correlations indicate no regularities in the two distributions.

## Modeled Segregation in Auckland, 2001–2013

Table 2 gives the MRR values for each of the four ethnic groups, at each of the three scales, at each of the three census dates; also provided are their low CI and high CI values (these encompass 95 percent of the estimated value for each MRR), which are valuable for comparing two MRR values. If their CIs overlap, it is unlikely that the two MRRs differ significantly: Where they do not overlap, it can reasonably be concluded that one segregation measure is significantly larger or smaller than the other. Thus, for example, although the MRR for Europeans at the localities scale (the twenty-one largest units in the three-level spatial hierarchy) is 1.57 in 2001 and 1.67 in 2006. Their two credible intervals (1.39–1.86 for 2001 and 1.46–1.78 for 2006) overlap, so it cannot be concluded that they differ significantly and that segregation increased for that group at that scale. On the other hand, the two CIs for Europeans in 2001 at the localities and area scales (1.39–1.86 and 1.27–1.32, respectively) do not overlap, so it can reasonably be concluded that in 2001 Europeans were more segregated at the macroscale than at the mesoscale.

In terms of the magnitude of these MRR values, given Cohen's suggested scale outlined earlier, the overall conclusion is that ethnic residential

**Table 2.** Median rate ratio values, with their associated credible intervals, by ethnic group, spatial scale, and census

|  | 2001 | | | 2006 | | | 2013 | | |
|---|---|---|---|---|---|---|---|---|---|
|  | Low CI | MRR | High CI | Low CI | MRR | High CI | Low CI | MRR | High CI |
| Europeans |  |  |  |  |  |  |  |  |  |
|   Localities | 1.39 | 1.57 | 1.86 | 1.46 | 1.67 | 1.78 | 1.52 | 1.78 | 2.20 |
|   Areas | 1.27 | 1.29 | 1.32 | 1.29 | 1.32 | 1.34 | 1.31 | 1.34 | 1.36 |
|   Blocks | 1.24 | 1.24 | 1.25 | 1.27 | 1.28 | 1.29 | 1.29 | 1.29 | 1.30 |
| Maori |  |  |  |  |  |  |  |  |  |
|   Localities | 1.64 | 1.97 | 2.52 | 1.63 | 1.95 | 2.50 | 1.57 | 1.87 | 2.34 |
|   Areas | 1.46 | 1.51 | 1.57 | 1.44 | 1.49 | 1.54 | 1.38 | 1.42 | 1.46 |
|   Blocks | 1.72 | 1.74 | 1.76 | 1.72 | 1.74 | 1.75 | 1.62 | 1.64 | 1.66 |
| Pacific Peoples |  |  |  |  |  |  |  |  |  |
|   Localities | 2.29 | 4.49 | 7.76 | 2.95 | 4.43 | 7.61 | 2.89 | 4.28 | 7.29 |
|   Areas | 1.93 | 2.03 | 2.14 | 1.97 | 2.08 | 2.21 | 1.81 | 1.89 | 1.99 |
|   Blocks | 2.21 | 2.25 | 2.29 | 2.16 | 2.20 | 2.24 | 2.00 | 2.03 | 2.06 |
| Asian |  |  |  |  |  |  |  |  |  |
|   Localities | 2.06 | 2.77 | 4.10 | 2.09 | 2.82 | 4.19 | 2.00 | 2.64 | 3.83 |
|   Areas | 1.80 | 1.89 | 1.98 | 1.83 | 1.91 | 2.01 | 1.81 | 1.89 | 1.98 |
|   Blocks | 2.00 | 2.03 | 2.06 | 1.92 | 1.94 | 1.97 | 1.76 | 1.78 | 1.80 |

*Note:* CI = credible interval; MRR = median rate ratio.

segregation was not substantial in Auckland at any of the three dates. Only two of the MRR values—for Pacific People at the localities (macro-) scale in 2001 and 2006 but not also 2013—qualify as large, with one other (for Asians at the same scale and dates) graded as medium. The great majority of MRR values at the meso- and microscales are small, with several—notably at the mesoscale—categorized as low.

A number of other conclusions can be drawn from the MRR measures. The first—and by far the most consistent—is that in general segregation for the three non-European groups was greatest at the localities (i.e., the macro-) scale and least at the area unit (meso-) scale, with the value for the meshblock (micro-) scale lying between the two; the intermediate value (for the meshblocks) was closer to that for the area units than for the localities. In terms of statistical significance, for Pacific People and Asians in 2001, the absence of overlap between each pair of CIs indicates a clear continuum of degrees of segregation: greatest at the macroscale, least at the mesoscale, and intermediate at the microscale. The same sequence applies to the Maori, but the overlap of CIs indicates no significant difference between segregation at the block and locality scales. At the start of the period, each of those minority groups was significantly concentrated (although not at high levels other than for the Pacific People) into certain segments of Auckland at the macroscale; within each of those segments they were relatively evenly distributed across the constituent

mesoscale area units, but within each of those units they were significantly (although not substantially) concentrated in some of the meshblocks. For the Europeans, however, the segregation sequence went down the scales from macro- through meso- to micro-, with each significantly different from that above it; New Zealand Europeans were concentrated into particular macrosegments of Auckland (although with an MRR categorized as small), into particular mesosegments within those localities, and into microsegments (blocks) therein—but the latter two MRRs are categorized as low, showing that the degree of segregation is limited, a pattern repeated at the next two censuses.

Did the levels of segregation change significantly over time? At the localities scale, the MRR values for the three minority groups all declined slightly across the three censuses but not significantly so. At the micro- (meshblock) scale, on the other hand, the declines in segregation for the three minority groups—albeit relatively slight—were statistically significant, but there was no similar trend at the area unit scale. Between 2001 and 2013, therefore, there was no change in the degree to which each of those three groups was concentrated into both particular macroscale segments of Auckland and, to a lesser extent, mesoscale parts of those localities. But at the microscale each was less segregated across the meshblocks within each area unit at the later date.

For Europeans there are slight, but statistically insignificant, increases in segregation at the larger two

**Table 3.** Median rate ratio values, with their associated credible intervals, by census, ethnic group, and spatial scale

| | Localities | | | | Area units | | | | Meshblocks | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low CI | MRR | High CI | | Low CI | MRR | High CI | | Low CI | MRR | High CI |
| **2001** | | | | | | | | | | | |
| Pacific | 2.29 | 4.49 | 7.76 | Pacific | 1.93 | 2.03 | 2.14 | Pacific | 2.21 | 2.25 | 2.29 |
| Asian | 2.0 | 2.7 | 4.10 | **Asian** | **1.80** | **1.89** | **1.98** | **Asian** | **2.00** | **2.03** | **2.06** |
| Maori | 1.64 | 1.97 | 2.52 | **Maori** | **1.46** | **1.51** | **1.57** | **Maori** | **1.72** | **1.74** | **1.76** |
| European | 1.39 | 1.57 | 1.86 | **European** | **1.27** | **1.29** | **1.32** | **European** | **1.24** | **1.24** | **1.25** |
| **2006** | | | | | | | | | | | |
| Pacific | 2.95 | 4.43 | 7.61 | Pacific | 1.97 | 2.08 | 2.21 | Pacific | 2.16 | 2.20 | 2.24 |
| Asian | 2.09 | 2.82 | 4.19 | Asian | 1.83 | 1.91 | 2.01 | **Asian** | **1.92** | **1.94** | **1.97** |
| Maori | 1.63 | 1.95 | 2.50 | **Maori** | **1.44** | **1.49** | **1.54** | **Maori** | **1.72** | **1.74** | **1.75** |
| European | 1.46 | 1.67 | 1.78 | **European** | **1.29** | **1.32** | **1.34** | **European** | **1.27** | **1.28** | **1.29** |
| **2013** | | | | | | | | | | | |
| Pacific | 2.89 | 4.28 | 7.29 | Pacific | 1.81 | 1.89 | 1.99 | Pacific | 2.00 | 2.03 | 2.06 |
| Asian | 2.00 | 2.64 | 3.83 | Asian | 1.81 | 1.89 | 1.98 | **Asian** | **1.76** | **1.78** | **1.80** |
| Maori | 1.57 | 1.87 | 2.34 | **Maori** | **1.38** | **1.42** | **1.46** | **Maori** | **1.62** | **1.64** | **1.66** |
| European | 1.52 | 1.78 | 2.20 | **European** | **1.31** | **1.34** | **1.36** | **European** | **1.29** | **1.29** | **1.30** |

*Note:* Groups with MRR values that are significantly smaller than that for the group immediately above them in each segment of the table are shown in bold. CI = credible interval; MRR = median rate ratio.

scales but significant increases at the microscale. Within those sections of Auckland where they are concentrated, therefore, Europeans became slightly more concentrated in particular meshblocks, whereas the opposite trend characterized the geography of the minority groups.

Whatever those small trends, the reworked ordering of the MRR values in Table 3 indicates that there has been no change in the differences between groups in their relative degree of segregation. At each date and at each scale, the Pacific People were the most segregated and the Europeans least, with Asians and Maori occupying the intermediate places, in that order. There is, however, a major difference in whether the levels of segregation are significantly different from each other. At the localities scale, no group is less segregated than that above it in the rank-ordering (a situation indicated in bold in the other columns). At each date, however, the MRR for the Europeans was significantly smaller than that for the Pacific People, as it was from that for Asians in 2001 and 2006 but not also 2013; the Maori MRRs were not significantly different from those for either Asians or Europeans, but they were significantly different from those for the Pacific People in 2006 and 2013.

There are clearly significant differences at the area unit and meshblock scales, however. At the former, in both 2006 and 2013 there was no significant difference between the Pacific People and Asian segregation levels, but the Maori were significantly less segregated than both of them, and the Europeans were less segregated than the Maori. Finally, at the microscale of the meshblock—at which segregation was generally higher than at the mesoscale—each group had a significantly lower level of segregation from all those above it in the rank ordering.

A further indicator of the amount of change in the distributions over the three censuses is provided by the correlations in Table 4, which indicate the degree of stability in the MRR values across all of the relevant spatial units for each group between each pair of census dates. At the localities scale there is virtually no variation in the stability levels, although the correlations are smaller for the Maori and Pacific People than for the other two groups; the geographies changed more, but by the same amount between each pair of dates, for the former than for the latter pair. At the area unit scale, again there is very considerable evidence of stability, with no correlation less than 0.88. There was much more instability at the microscale, however, indicating greater flux in the patterns of concentration, notably for the three minority groups whose numbers increased more than that for the Europeans over the period. As their populations grew, so the microscale geographies of where they were concentrated altered—although only one of the correlations was less than 0.70: The main contours of the residential geographies stayed the same.

**Table 4.** The cross-census correlations of relative rates for each spatial scale within each ethnic group

|  | 2001–2006 | 2006–2013 | 2001–2013 |
|---|---|---|---|
| **Localities** | | | |
| European | 0.74 | 0.74 | 0.73 |
| Maori | 0.54 | 0.53 | 0.53 |
| Pacific People | 0.58 | 0.57 | 0.57 |
| Asian | 0.75 | 0.76 | 0.75 |
| **Area units** | | | |
| European | 0.95 | 0.95 | 0.90 |
| Maori | 0.91 | 0.91 | 0.88 |
| Pacific People | 0.90 | 0.91 | 0.88 |
| Asian | 0.92 | 0.94 | 0.89 |
| **Meshblocks** | | | |
| European | 0.91 | 0.92 | 0.87 |
| Maori | 0.80 | 0.78 | 0.65 |
| Pacific People | 0.89 | 0.87 | 0.77 |
| Asian | 0.83 | 0.86 | 0.70 |

*Note:* All are statistically significant at the 0.05 level or better.

Turning to the geographies of each pair, the correlations in Table 5 are considerably smaller, indicative of greater relative change, especially at the microscale. All of the correlations involving the Europeans are negative, indicating that at each scale wherever they are relatively concentrated the other groups—and especially the Pacific People—are relatively absent. Only a minority of those correlations are statistically significant at the more robust 0.05 level, however, suggesting that the only strong evidence of intergroup avoidance involves Europeans and Pacific People. This is complemented by the smaller and very largely statistically insignificant correlations involving the three minority groups. The only clear finding they provide is that at the mesoscale Maori and Pacific People tended to share residential spaces—where one was relatively prevalent, so was the other. This strong finding was confined to that one scale only, however. The much smaller—and marginally significant—correlations at the macroscale indicate no substantial tendency for the two Polynesian groups to concentrate in the same localities but, to the extent that they do, they tend to congregate in the same area units—which might reflect the operation of housing (especially social housing) markets. Similarly, the small coefficients at the meshblock scale indicate that in the area units where both are relatively concentrated there is no strong evidence that they cluster together in the same small units.

As indicated at the outset, we did not expect that the analyses reported here would alter certain features of the general appreciation of residential segregation in Auckland—as portrayed in other, single-scale, single-index studies—that, for example, the Pacific People were the most spatially segregated group (as set out in Grbic, Ishizawa, and Crothers 2010; Maré et al. 2012). The prime focus here has been on the relative importance of the observed levels of segregation at different spatial scales, something not previously analyzed. The findings reported here directly contradict

**Table 5.** The cross-ethnic group correlations at each spatial scale and census

|  | 2001 | | | | 2006 | | | | 2013 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | E | M | P | A | E | M | P | A | E | M | P | A |
| **Localities** | | | | | | | | | | | | |
| European | — | −0.40 | **−0.55** | −0.27 | — | −0.33 | **−0.59** | −0.29 | — | −0.30 | **−0.59** | −0.32 |
| Maori | | — | *0.38* | −0.12 | | — | *0.35* | −0.18 | | — | *0.35* | −0.16 |
| Pacific People | | | — | *0.33* | | | — | *0.27* | | | — | *0.28* |
| Asian | | | | — | | | | — | | | | — |
| **Area units** | | | | | | | | | | | | |
| European | — | −0.39 | **−0.62** | 0.05 | — | −0.32 | **−0.57** | −0.03 | — | −0.26 | **−0.58** | −0.14 |
| Maori | | — | **0.76** | −0.18 | | — | **0.79** | −0.28 | | — | **0.73** | −0.36 |
| Pacific People | | | — | −0.09 | | | — | −0.11 | | | — | −0.12 |
| Asian | | | | — | | | | — | | | | — |
| **Meshblocks** | | | | | | | | | | | | |
| European | — | −0.31 | **−0.48** | −0.28 | — | −0.19 | −0.39 | −0.31 | — | −0.15 | −0.40 | −0.36 |
| Maori | | — | **0.39** | −0.15 | | — | *0.38* | −0.19 | | — | *0.37* | −0.23 |
| Pacific People | | | — | −0.08 | | | — | −0.10 | | | — | −0.11 |
| Asian | | | | — | | | | — | | | | — |

*Note:* Correlations statistically significant at the 0.05 level or better are shown in bold; those significant between the 0.05 and 0.10 levels are shown in italicis. E = European; M = Maori; P = Pacific People; A = Asian.

**Table 6.** Indexes of segregation for the four ethnic groups at each of the three spatial scales in 2013

| Scale | Localities | Area units | Meshblocks |
|---|---|---|---|
| Pacific People | 0.48 | 0.52 | 0.59 |
| Asian | 0.24 | 0.37 | 0.45 |
| Maori | 0.26 | 0.17 | 0.38 |
| European | 0.32 | 0.41 | 0.48 |

the conventional wisdom regarding spatial scale and segregation, as demonstrated by comparing the results in Table 3 with those in Table 6. The latter shows the conventional index of segregation (Massey and Denton 1988) for each of the three groups, at each of the three scales, in 2013. For three of the groups, that index is lowest at the macro- (localities) scale and highest at the micro- (meshblock) scale; the exception is for the Maori, for whom the lowest index is at the mesoscale but with the same difference between the micro- and macroscales as for the other three groups.

These findings are in clear contradiction to the 2013 MRR values in Table 3, which show segregation for all four groups higher at the macroscale than at the microscale (with Table 2 showing that, with the exception of the Maori, those differences between the two scales were statistically significant). This is because calculation of the level of segregation at the meshblock level alone necessarily incorporates—to an unknown extent—segregation at higher levels, revealed in our analyses at the meso- and macroscales. Identification of the relative importance of these different levels of segregation calls for a variance decomposition approach, as conceived by Haggett (1965), put in a multilevel modeling context by Browne et al. (2005) and Subramanian, Duncan, and Jones (2001) and made explicit by Tranmer and Steel (2001)[8]; see also Fischer et al. (2004), Voas and Williamson (2000), and Johnston, Voas, and Poulsen (2003) for alternative approaches to the variance decomposition issue. The modeling approach developed here builds on those insights and the next section explores a possible explanation for its clear conclusion that ethnic segregation was greater for all groups in Auckland at the macroscale than at the microscale.

## Discussion

Several main findings emerge from this pioneering study of multigroup, multiscale, multidate ethnic residential segregation in Auckland:

- A clear continuum regarding the levels of segregation of the four main ethnic groups—with the Pacific People the most and Europeans the least segregated at each of the three spatial scales and each of the three censuses.[9]
- Little evidence of intense segregation, with the measure for only one group—Pacific People—at one scale qualifying as large using a standard metric for the chosen index (MRR) and with the great majority of the measures categorized as small.
- Evidence that for the three minority groups within the population segregation declined slightly over the three censuses, notably at the microscale.
- Little evidence of strong tendencies for individual groups either to cluster together in the same areas or of mutual avoidance in residential space.
- Clear evidence that segregation is at its most intense at the macroscale, especially for the minority groups.

The first four of these findings provide stronger evidence of the extent, nature, and intensity of segregation in Auckland than is available from other studies (Johnston, Poulsen, and Forrest 2011; Maré et al. 2012; Ishikawa and Arunachalam 2014), because of the firm modeling framework within which the analyses reported here have been set. The final finding appears counterintuitive, however, and inconsistent with other studies that have explored segregation variation by scale—which tend to show (as does Table 6 here using a similar metric) that the finer-grained the spatial scale of analysis, the greater the overall level of segregation. For example, Peach (1996; see also Woods 1976) found that indexes of dissimilarity and segregation were higher for London in 1991 at the microscale (enumeration district) than at the mesoscale (ward)—although his conclusion that members of the ethnic minority groups "tend to be found in the older inner areas rather than the suburbs" (Peach 1996, 232) suggests a macroscale pattern consistent with that outlined here. (Note that in a later article, Peach [1999, 333] reported that most Indians in London "are suburban.") Krupka (2007) provided clear evidence across a number of U.S. cities of declining segregation with increasing scale, with data for up to seven separate scales (although his analyses falsify the argument that, at any scale, segregation is greater in larger cities). Using their more sophisticated—although still only descriptive—measure of segregation at multiple scales, Reardon et al.'s (2008) graphs also show that segregation is greatest at the smaller scales—"as expected"

(498)—although the extent of scalar variation differed across the forty metropolitan areas studied (see also B. A. Lee et al. 2008). They also identified variations across time with, for example, black–white segregation tending to decline at smaller but not larger scales (Reardon et al. 2009). Finally, using comparable methodologies, Östh, Clark, and Malmberg (2015) showed that various ethnic groups were more spatially isolated in Los Angeles the smaller the spatial scale.

All of these analyses either (in the majority of cases) look at levels of segregation at each scale separately or aggregate across scales; none, as in the analyses here, integrate various scales into a single model. B. A. Lee et al.'s (2008, 785) findings lead them to identify "an even greater need for scale-specific theorizing about segregation"—a task that they, however, say is beyond the scope of that and their other articles. The findings here for Auckland—plus those already reported for London (Jones et al. forthcoming)—support that claim. Our argument is that, for large cities especially, macroscale processes are the most important influence on the evolving residential mosaic, especially for ethnic minority groups in which the majority of members' labor market situations mean that they are relatively disadvantaged in the housing market, substantial segments of which are closed to them. Nevertheless, they have some choice, because all cities have more than one segment of relatively low-cost housing. The initial migrants in a particular minority group select a particular part of the city in which to live, and many later arrivals—who might move there through chain migration networks—join them in and around that core area. As the group grows in size, especially as new households are formed in the second and subsequent generations, many will seek homes in adjacent areas; their search spaces will be somewhat spatially limited and in many cases further constrained by their desire to remain in relative proximity to their coethnics, to cultural institutions, and to local employment opportunities. The relatively permanent macroscale structuring of the city is thus the framework within which the microscale residential mosaic is formed. Each minority group is focused on a particular segment of the urban fragment and is largely absent from others. Within that favored segment there are then microscale concentrations, small neighborhoods some of which have larger proportions of their population drawn from the group concentrated in that part of the city than others.

For groups other than ethnic minorities (e.g., the New Zealand Europeans in this case study), decisions on which segments of the city to move to might be made on other grounds—such as access to employment centers or social, educational, and cultural facilities, plus housing density and costs. In addition, there might be negative influences suggesting that they avoid certain segments—such as those with the presence of substantial ethnic minority populations. Again, once a mosaic is established it then influences future choices of where to live or move to, with major changes only emerging if one group occupies an area formerly dominated by another—as in the classic invasion-and-succession processes identified in many twentieth-century cities.

Our MRR measures of segregation in Auckland are very clearly consistent with this outline of a scale-specific theory of residential choice and patterns. The focus on macro- as well as microscale patterns indicates that each of Auckland's four main ethnic groups is concentrated both in particular segments of the residential fabric—identified here at the macroscale of the locality—and in particular small neighborhoods—the microscale of the meshblock. What is perhaps unexpected is the lower level of segregation at the mesoscale, but this, too, can be readily incorporated into an evolving scale-specific theory. Unless there are processes creating large tracts of an urban area in which one ethnic group predominates—as was the case with black–white segregation in U.S. cities throughout the twentieth century—it is unlikely that within their chosen macroscale segment of a city, one group will be either predominant in or largely absent from each of its mesoscale areas (the area units in Auckland's case). As Simpson (2004) argued with British examples, and Johnston, Poulsen, and Forrest's (2008) findings for several of Auckland's main groups imply, although many members of a minority ethnic group might wish to live in the same general area of a city, for sociocultural and other reasons, few want to separate themselves entirely from other groups in exclusive enclaves. Furthermore, their desire for social advancement sees some of them move into neighborhoods near those where their coethnics are by far the largest group, neighborhoods that are ethnically more mixed in their composition. Within any macroscale segment of the city, therefore, a group might be relatively evenly distributed through its mesoscale areas (i.e., the twenty or so area units within each Auckland locality) but within at least some of those areas, the group might be more concentrated in some microscale neighbourhoods (e.g., the twenty-seven meshblocks in the average Auckland area unit) than others—perhaps

the core areas where it was initially concentrated and to which subsequent arrivals to the city were initially drawn.

In part, this three-scale patterning will reflect the size and number of the districts at each spatial scale, and thus the relative importance of the macro-, meso-, and microscale components of the residential fabric might be place-specific—no analysis of spatial patterns using fixed areal units can avoid the modifiable areal unit problem. Nevertheless, the findings reported here regarding macro- and microscale patterns are strong and, we believe, would be replicated whatever the available hierarchical spatial structuring of the data set: They are consistent with our understanding of how choice operates within urban housing markets where minority ethnic groups are concerned. The relative unimportance of the mesoscale patterns calls for further exploration—with perhaps some combination of the modeling approach adopted here (which requires a nested spatial structure of areas) and the more flexible approaches adopted by Reardon et al. (2009) and Östh, Clark, and Malmberg (2015).

Scale is important in appreciating the geography of segregation, therefore, which most studies do not appreciate because they involve analyses at a single scale only; when they do include multiple scales, they do not report the results at each scale net of the others, as done here. In Auckland—and in London, too (Jones et al. forthcoming)—the conjoint operations of the owner-occupier and social housing markets plus individual and group preferences to live in certain areas rather than others (based on a range of factors, including proximity to coethnics and distance from other ethnics as well as myriad other socioeconomic and cultural factors) mean that the dominant sorting of households across a city operates at the macroscale. The choice or allocation is between the central city and the suburbs; for example, between the southern and northern sectors, perhaps, or between areas with many or few members of a particular ethnic group. In this analysis of Auckland, the choice of the twenty-one localities to represent this macroscale has been largely arbitrary—they are combinations of the meso-scale area units, which are administrative territories—but there is no reason to believe that alternative definitions of twenty-one (or some similar number) macro-units would not result in the same general conclusions. (In 2001, for example, the Pacific People formed less than 10 percent of the population in twelve of the twenty-one localities and more than 25 percent in only four, with a maximum of 60 percent in

one locality; Maori, too, formed less than 10 percent of the population in twelve localities and over 25 percent in only one—the maximum in any one locality was 27 percent; Asians formed less than 10 percent of the population in eight localities and more than 25 percent in only one—with a maximum of 28 percent. Almost certainly such congregation into certain parts of the urban area would be apparent in virtually any division into twenty-one alternative localities.)

Having either chosen or been allocated to a particular macrosegment of the city, our analyses of the meso- and microscale patterns have shown that there is greater clustering of members of each ethnic group at the latter than at the former scale. Within each macrosegment, each group is relatively concentrated, although with no great intensity, in some of the constituent mesoscale units rather than others. Because the three ethnic minority groups form only a small proportion of the total population in many of the macroscale localities, it is thus not surprising that they show no segregation at the mesoscale area units; the MRR values at that scale are small because the rates between pairs of area units within localities differ little. Segregation is then greater at the microscale within those mesoscale units—although not as great as at the macroscale. Members of each ethnic group—in this case the Pacific People more than the Asians, the Asians more than the Maori, and the Maori more than the Europeans—cluster much more in some meshblocks than others.

## Conclusions

This article has reported on one of the first applications of a new procedure for measuring residential segregation using a modeling rather than a descriptive approach. This has the advantage over virtually all other approaches to studying segregation in that it has a firm statistical foundation; it can be applied to multigroup situations in multiethnic cities, at multiple spatial scales simultaneously and to data for more than one date. Its measure of segregation—the MRR—has associated Bayesian CIs that allow assessments of the statistical significance of any differences identified—between ethnic groups in their degree of segregation at any pair of spatial scales; within any ethnic group in its degree of segregation across two or more spatial scales; and within any ethnic group at two more separate enumerations at any particular spatial scale. Associated statistics—correlations—allow evaluation of

the degree to which separate groups congregate in the same areas. Such output is much more informative than that produced by the vast range of other approaches to the study of segregation and provides a framework within which detailed comparative studies can be undertaken.

The approach has been applied here to the case of Auckland, New Zealand, an increasingly multiethnic city for which there is a wealth of census data at three separate spatial scales at three separate censuses held in the twenty-first century—using the same spatial units at each. The findings allow clear conclusions to be drawn about the comparative intensity of segregation for each of the four main ethnic groups separately identified in the censuses: Each is most segregated at the macroscale and least segregated at the mesoscale, and all three of the minority groups (but not the majority New Zealand Europeans) experienced significant declines in segregation at the microscale of small residential neighborhoods over the twelve-year period studied.

One of those conclusions—that segregation was greatest at the macroscale—differs from the conventional view that the smaller the spatial scale studied the greater the segregation. Because this analysis is set within a multilevel modeling framework, it can evaluate different aspects of the sorting process by which group members come to occupy different parts of the urban fabric. It has shown very clearly that members of each of the three minority groups—more so than those of the majority New Zealand European population—are relatively absent from major segments of the residential mosaic. Within each of those major segments (of which there were twenty-one) they are relatively evenly distributed across the next level of subdivisions, but within those subdivisions they are more concentrated in certain microneighborhoods than others. Members of minority ethnic groups cluster in certain parts of Auckland and, within those districts, in certain small neighborhoods rather than others—a situation also identified in London (Jones et al. forthcoming) and that further research might find is general: The decision on where to live in a city is a multiscale process.

Ethnic segregation is only one element of the multiple ways in which a city's residential fabric is structured: Kapoor (2013), for example, argued that ethnic segregation should be analyzed alongside that of socioeconomic class. This article provides a methodology by which that can be undertaken. Its specific goal has been using that method to explore

scalar variations in ethnic segregation patterns and, in so doing, challenging the conventional wisdom regarding the relative importance of macro-, meso-, and microscale location decision making in the creation and re-creation of a city's internal structuring. Future research can build on those findings, using the framework provided by the modeling strategy deployed here for analyzing the intersections among ethnic, class, and other dimensions of urban residential space (as explored at a single spatial scale only by Ishikawa and Arunachalam [2014]) as well as the context for detailed case studies of individual areas (Meares and Gilbertson 2013; Spoonley et al. 2014). The modeling strategy introduced and evaluated here can form the foundation for much more detailed evaluations of how the residential mosaic of large cities is spatially structured than feasible heretofore.

## Funding

## Notes

1. Censuses are normally taken every five years in New Zealand but that scheduled for 2011 was postponed for two years because of the devastating earthquakes in the South Island city of Christchurch in 2010 and 2011.
2. The question asks "Which ethnic group do you belong to?" with eight possibilities listed, and a further box allowing the respondent to indicate any other group.
3. A much finer grained categorization was deployed but this was collapsed to just those shown here in the tables published for the smallest areas and analyzed here. A new category of Middle East, Latin America, and Africa (MELAA) was introduced for the 2006 census but the numbers were small (18,552 in 2006 and 24,942 in 2013) and they were included with the "other" group for analysis here.
4. For the current analyses, these are included in the "other" category.
5. Data at other, coarser, spatial scales show that the concentrations immediately south of the city center are dominated by Indians, those to the east by Chinese, and those on the North Shore by Koreans.

6. The approach was originally developed by Larsen (Larsen and Merlo 2005) for multilevel logit models—the median odds ratio and extended by him (Larsen 2006) to log Poisson models—the median mean ratio. We prefer the term median rate ratio as being more descriptive of what it measures, as does Chan et al. (2011). The term *mean ratio* comes from the use of the Poisson model in the analysis of mean incidence rates, and Larsen was aiming to develop a comparable measure for the interpretation of random effects.

7. The calculation of the MRR is a simple transformation of the between-area variance for a particular group at a particular scale: $MRR = \exp[\sqrt{2} * \text{Variance} * 0.6745]$; the value 0.6745 is the 75th percentile of the cumulative distribution function of the normal distribution with mean 0 and variance 1.

8. Tranmer and Steel (2001, 947) showed both theoretically and empirically that if a model is specified without an important level "the effects of the levels above the highest level included in the analysis will be reflected in estimated components for the highest level included": Thus, in the Auckland case, calculation of indexes of dissimilarity at the microscale meshblock level only necessarily incorporates unknown components of the segregation pattern at the higher district (meso-) and locality (macro-) scales.

9. It is of interest to note that using the traditional index of segregation (calculated using the GeoSegregation Analyser© software [Apparicio et al. 2014]) at the micro- (meshblock) scale the most segregated group at each date—according to the Index of Segregation—was the Pacific People, followed by the Asians, Europeans, and Maori. Using the Index of Isolation, however, the Europeans were the most segregated at that scale at each date, followed by the Pacific People, Asians, and Maori in 2001 and 2006 but by Asians, Pacific People, and Maori in 2013. The only consistent feature of these findings was that the Maori were the least segregated group—a finding not confirmed by our modeling approach.

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