

Spatial Analysis of Dwelling Crowding and Disease in Sydney, Australia

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ABSTRACT

The environment in which we live greatly influences our health. One particular factor that has been related to morbidity and mortality is dwelling crowding. This factor has been associated with a wide range of diseases and disorders, including respiratory diseases such as asthma. A range of mechanisms has been proposed as the link between dwelling crowding and disease, including increased exposures to allergens, respiratory irritants, and infectious agents in crowded dwellings. Some studies have used dwelling crowding as an indicator of socioeconomic status. While studies of dwelling crowding and health have been conducted in many locations around the world, this factor has received little attention in Australian health studies. Further, few studies in this area have used geographic information systems to visualise the spatial heterogeneity of dwelling crowding within a region. This project aims to examine the relationships between dwelling crowding and health in Sydney – using three case studies. The specific aims are i) to examine the geographic variability of the three diseases and dwelling crowding, and ii) to examine the association between the distribution of these diseases and dwelling crowding. The project examines disease and dwelling crowding at the Local Government Area (LGA) level within the Sydney Statistical Division. Dwelling and demographic data from the most recent Australian census (1996 Australian Bureau of Statistics) is examined, including dwelling type, number of bedrooms per dwelling, number of persons per dwelling, income, qualifications, occupation, and language spoken at home. Four socioeconomic indexes produced by the Australian Bureau of Statistics were also examined. Hospital inpatient data for the period 1 July 1994 to 30 June 1997 (Inpatient Statistics Collection, NSW Health Department) is used as the health indicator. A combination of both spatial and statistical analysis techniques are used (the spatial analysis is performed using MapInfo Professional v4.5). Dwelling crowding varies spatially, with Sydney's central and inner western LGAs having the highest levels of crowding. Asthma hospital separations were not related to dwelling crowding, where as those for bronchitis and emphysema and all causes combined, were positively correlated with dwelling crowding. Dwelling crowding was strongly negatively correlated with all but one of the socioeconomic indicators. The preliminary results from this study suggest that dwelling crowding is a significant factor in certain diseases in Sydney.

Keywords and phrases: dwelling crowding, disease, asthma, bronchitis, emphysema, hospital separations, socio-economic, Sydney

1.0 INTRODUCTION

The environment in which we live greatly influences our health. One particular factor that has been related to morbidity and mortality is dwelling crowding. This factor has been associated with a wide range of diseases and disorders including respiratory diseases such as asthma; psychiatric disorders such as schizophrenia; tuberculosis; invasive Hib disease; coronary heart disease; diabetes mellitus, as well as infant development, burns, and hearing loss.

The study by Morris and Munasinghe (1994) serves as a good example of a study on the health impacts of dwelling crowding. This study examined geographic variability in hospital admission rates for respiratory diseases, including asthma, pneumonia, acute respiratory infections, and chronic obstructive pulmonary disease, among the elderly in the United States. By mapping annual hospital admission rates at the county level, this study clearly demonstrated the geographic variability of these diseases. For example, the asthma admission rate was shown to vary from 0 – 183 per 100000 population, to greater than 350 per 100000. In addition to this, the study showed that household crowding was a highly statistically significant predictor in univariate regression analyses of not only all respiratory diseases combined but also on an individual basis. This result was mirrored in multiple regression analyses, with the exception of acute respiratory infections.

What's more, dwelling crowding in childhood has been associated with poor health and disease later in life. For example, Power (1991) found that self-rated health, 'malaise', psychological morbidity, and height, at age 23, were associated with a number of factors, including crowding, during childhood. Similarly, Mendall *et al.* (1992) found domestic crowding at age 8 was a powerful risk factor for evidence of *Helicobacter pylori* infection (a risk factor for peptic ulceration and gastric cancer) in adult life. Therefore, the affects of dwelling crowding are both acute and chronic.

A range of mechanisms has been proposed as the link between dwelling crowding and disease. Generally, dwelling crowding may increase exposures to allergens, respiratory irritants, and infectious agents. For example, levels of passive smoking in children with asthma have been shown to be associated with crowding within the home (Irvine *et al.*, 1997). The association between *H. pylori* infection and dwelling crowding in childhood has been attributed to close person to person contact (and therefore a greater chance of disease transmission) in such settings (Fall *et al.*, 1997). Other studies (*e.g.* Morris and Munasinghe, 1994) have used dwelling crowding as an indicator of socioeconomic status.

Studies have been conducted in many locations around the world including the United States of America, Canada, Brazil, England, Scotland, Ireland, Sweden, Israel, India, and Thailand. However, this factor has received little attention in Australian health studies. In one recent study, Clements *et al.* (1995) found household crowding to be a risk factor for Hib meningitis in children in Victoria. Further, few studies in this area have used geographic information systems to visualise the spatial heterogeneity of dwelling crowding within a region.

Evaluating the geographic distribution and environmental determinants of disease can result in many valuable outcomes. Evaluating geographic variability of disease can provide valuable information for public health authorities, for example, in the planning and funding of public health facilities. The identification of environmental determinants can result in recommendations in the management or prevention of disease.

1.1 Aims

This project aims to examine the relationships between dwelling crowding and health in Sydney. The specific aims are:

- i) to examine the geographic variability of hospital admissions for selected causes (asthma, bronchitis and emphysema, and all causes) in Sydney,
- ii) to examine the geographic variability of dwelling crowding in Sydney,
- iii) to examine the association between the distribution of hospital admissions and dwelling crowding.

The results of the study will be of particular interest to those working in public health, particularly in the Sydney region.

2.0 METHODS AND TECHNIQUES

2.1 Study Area and Spatial Unit

Disease and dwelling crowding were examined at the Local Government Area (LGA) level within the Sydney Statistical Division (population 3.7 million). There are 45 LGAs within this Division (Figure 1). Analysis was conducted at the LGA level for a number of reasons. First, both the data suppliers for this project make data available at this level. This facilitated coupling of demographic and dwelling data with health data. Second, the LGA level is small enough to facilitate examination of geographic variability within the Sydney area, but is also large enough to provide disease rates large enough to be valid in statistical analysis.

2.2 Data

The project used 1996 Australian census data from the Australian Bureau of Statistics. For each LGA, selected dwelling and demographic characteristics were examined including number of bedrooms per dwelling and number of persons per dwelling (used to determine dwelling crowding – see below), dwelling type, income, education, occupation, and ethnicity (language spoken at home). In addition to these latter socioeconomic characteristics, four socioeconomic indexes produced by the Australian Bureau of Statistics were examined. These were the Urban Index of Relative Socio-Economic Advantage (UIRSEA), Index of Relative Socio-Economic Disadvantage (IRSED), Index of Economic Resources (IER), and Index of Education and Occupation (IEO). The variables underlying these indexes are as follows:

UIRSEA – indicators of relative socioeconomic well-being (e.g. high income, tertiary education, skilled occupations),

IRSED – low income, low educational attainment, high unemployment and jobs in relatively unskilled occupations,

IER – family income, rent, home ownership, dwelling size, number of cars,

IEO – level of qualification achieved, workforce classified according to the Australian Standard Classification of Occupations.

A high score on an index indicates an area of higher socioeconomic status. Further details on these indexes can be found in Australian Bureau of Statistics (1998).

Hospital inpatient data for the period 1 July 1994 to 30 June 1997 was obtained from the Inpatient Statistics Collection from the NSW Department of Health. Separations for asthma (International Classification of Diseases (ICD) 493), bronchitis and emphysema (ICD 490-492), and all causes (ICD 001-999) were examined. Separations for males, females, and all persons, and age groupings of < 1, 1-14, 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, and 85+ were obtained. The coupling of such data sets is a well-established technique in studies such as this (e.g. Barker *et al.*, 1990; Morris and Munasighe, 1994; Roberts, 1997).

2.3 Analysis

Average dwelling crowding for each LGA was calculated using a Crowding Index (CI), expressed in the following formula:

$$CI = \sum \left(\frac{\text{frequency of combination}}{\text{total number of combinations}} \times \frac{\text{number in dwelling}}{\text{number of bedrooms}} \right)$$

This index uses the ratio of number of persons in a dwelling to number of bedrooms in a dwelling, and weights this by that proportion of dwellings in the LGA with this level of crowding. The 1996 Australian census included a zero bedrooms category which is assigned a value of 0.5 in the calculation of the Crowding Index. The larger the CI the more crowded the LGA in terms of within-dwelling crowding. Table 1 shows the number of persons usually resident in a dwelling, by the number of bedrooms in that dwelling, for just one of the 45 LGAs in Sydney. As an example, calculation of the CI for this LGA is as follows:

$$CI = \left(\frac{107}{14786} \times \frac{1}{0.5} \right) + \left(\frac{12}{14786} \times \frac{2}{0.5} \right) + \left(\frac{8}{14786} \times \frac{3}{0.5} \right) + \dots$$

$$+ \left(\frac{54}{14786} \times \frac{4}{5} \right) + \left(\frac{68}{14786} \times \frac{5}{5} \right) + \left(\frac{85}{14786} \times \frac{6}{5} \right) = 1.085$$

Number of bedrooms	Number of persons usually resident						Total
	1	2	3	4	5	6 or more	
0 (0.5)	107	12	8	3	0	0	130
1	1187	443	89	13	0	0	1732
2	2100	2521	1261	661	173	46	6762
3	570	1191	932	907	361	157	4118
4	86	242	248	322	282	151	1331
5 or more	26	34	45	54	68	85	312
Not stated	182	100	56	35	17	11	401
Total	4258	4543	2639	1995	901	450	14786

Table 1: Number of bedrooms by number of persons for dwellings in Ashfield, Sydney, from the 1996 Australian census (Source: Australian Bureau of Statistics).

The asthma admission rates for each LGA were averaged over the three years. Why? The direct method of standardisation, using the 1996 estimated resident population for New South Wales as the standard population, was used to produce standardised morbidity rates (SMRs) per 1000 persons.

For each LGA four socioeconomic indicators were calculated as follows:

- i) % of persons aged 15 years and over with gross weekly income greater than or equal to \$500,
- ii) % of population with tertiary qualifications (bachelor degree, postgraduate diploma, higher degree),
- iii) % of employed persons employed as managers, administrators, professionals, and associate professionals,
- iv) % of population speaking English at home.

The spatial analysis was performed using MapInfo Professional v4.5. Maps for crowding index and standardised morbidity rate for each disease were produced using 4 equal ranges, where the difference between the minimum and maximum end points in each range is the same. Statistical analysis involved calculation of correlation coefficients between the CI and SMR for each cause of separations, CI and the eight socioeconomic indicators, and SMR for each cause of separations and the socioeconomic indicators.

3.0 RESULTS

3.1 Dwelling Crowding

The CI ranged from a minimum of 0.869 for Ku-ring-gai LGA, to a maximum of 1.195 for Sydney LGA. The average CI for the Sydney Statistical Division was 1.011 (standard deviation 0.080). The geographic variability of the CI in the Sydney Statistical Division is shown in Figure 2. LGAs with a CI in one of the two higher ranges are clustered in a band extending from Fairfield LGA in Sydney's west, through a number of the inner western and central Sydney LGAs, to the eastern Sydney LGA of Waverley. The LGAs within the lowest range of CIs lie mainly to the north of Sydney although the Blue Mountains LGA to the west of Sydney, and Woollahra LGA in Sydney's eastern LGAs also stand out as areas of lower dwelling crowding. About half of the LGAs in the Sydney Statistical Division have a CI in the second lowest range. These LGAs lie largely to the northwest, along the north shore and northern beaches, and throughout the southern regions of the Division.

The number of dwellings and dwelling type varied considerably (Figure 3). The minimum number of dwellings was found in Hunter's Hill LGA in Sydney's north shore and the maximum was found in Blacktown LGA in Sydney's

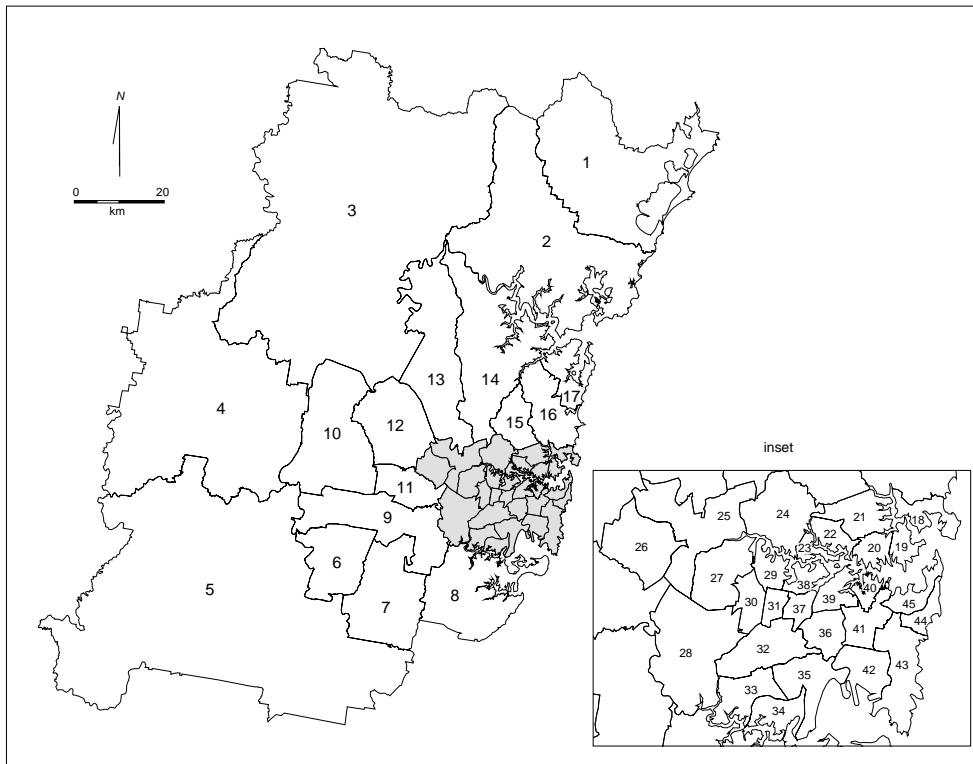


Figure 1: Local government areas in the Sydney Statistical Division. Names are given in Table 2.

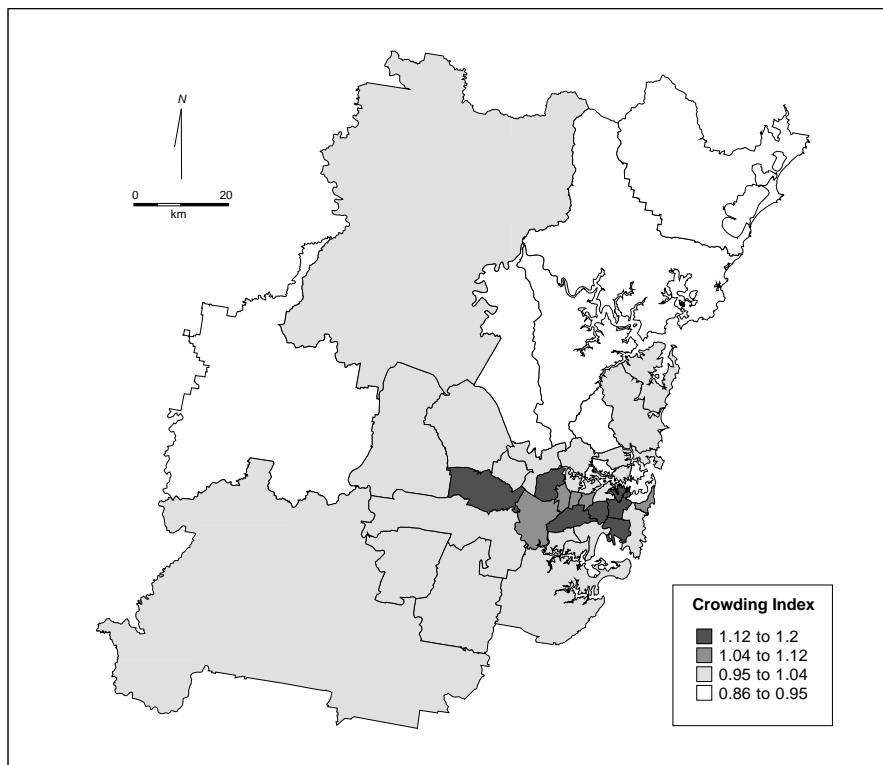


Figure 2: Crowding Index for each local government area in the Sydney Statistical Division.

1. Wyong	13. Baulkham Hills	24. Ryde	35. Rockdale
2. Gosford	14. Hornsby	25. Parramatta	36. Marrickville
3. Hawkesbury	15. Ku-ring-gai	26. Holroyd	37. Ashfield
4. Blue Mountains	16. Warringah	27. Auburn	38. Drummoyne
5. Wollondilly	17. Pittwater	28. Bankstown	39. Leichhardt
6. Camden	18. Manly	29. Concord	40. Sydney
7. Campbelltown	19. Mosman	30. Strathfield	41. South Sydney
8. Sutherland	20. North Sydney	31. Burwood	42. Botany
9. Liverpool	21. Willoughby	32. Canterbury	43. Randwick
10. Penrith	22. Lane Cove	33. Hurstville	44. Waverley
11. Fairfield	23. Hunter's Hill	34. Kogarah	45. Woollahra
12. Blacktown			

Table 2: Local government areas in the Sydney Statistical Division. Numbers correspond with those shown in Figure 1.

west. The total area of each LGA also varies considerably although the proportion of each LGA zoned for residential purposes also varies. Since within-dwelling crowding was the focus of this project (rather than dwelling-to-dwelling crowding), no analysis of dwellings per unit area was performed. Separate houses were by far the most common type of dwelling, with 65% of total dwellings in the Division of this type. LGAs around the inner and eastern areas of Sydney, particularly Sydney, North Sydney, and Waverley, tended to comprise significant proportions of flats, units, and apartments. A few LGAs, such as Leichhardt, South Sydney, and Marrickville, also included large proportions of semi-detached, row or terrace houses, and townhouses.

3.2 Hospital Separations

3.2.1 Asthma

The average number of annual asthma hospital separations for the Sydney Statistical Division as a whole, for the three years 1994-95 to 1996-97, was 12424. The standardised morbidity rate for asthma ranged from a minimum of 1.85 per 1000 for Woollahra LGA to a maximum rate of 5.51 per 1000 for Wyong LGA, the Division's northeastern most LGA (Figure 4). There was no apparent clustering of LGAs falling into the higher two morbidity ranges, although many of these were in the outer areas of the Division. The majority of LGAs (37, or 82%) had rates in the two lower ranges. These too did not appear to show any clear pattern, with LGAs with lower rates existing in all regions of the Division.

3.2.2 Bronchitis and Emphysema

The average number of annual bronchitis and emphysema hospital separations for the Division, for the three years, was 2076. The standardised morbidity rate for bronchitis and emphysema ranged from a minimum of 0.14 per 1000 for Hawkesbury LGA, the Division's northwestern most LGA, to a maximum rate of 2.09 per 1000 for Leichhardt LGA, in Sydney's inner west (Figure 5). Only three LGAs fell into the highest morbidity range and these were clustered around Sydney's inner city and inner west. No LGAs fell into the second of the higher ranges. LGAs with rates in the second lowest range fell to the immediate west and east of the three high LGAs, as well as a couple of LGAs to Sydney's north and Blacktown in Sydney's west. The majority of LGAs fell in the lowest range and occurred in all parts of the Division except the inner city, inner west, and eastern areas.

3.2.3 All Causes

The average number of annual all causes hospital separations for the Division, for the three years, was 863143. The standardised morbidity rate for all causes ranged from a minimum of 205.3 per 1000 for Hornsby LGA, in Sydney's north, to a maximum rate of 299.9 per 1000 for Sydney LGA (Figure 6). Seven of the eight LGAs falling into the higher two morbidity ranges corresponded with the higher bronchitis and emphysema LGAs (including Sydney, South Sydney, Drummoyne, Wyong, Blacktown, and Campbelltown). Wyong, Blacktown and Campbelltown LGAs were in the higher range for all three diseases. The majority of LGAs (37, or 82%) had rates in the two lower ranges. LGAs in the lowest range were restricted to the western and northern areas, while LGAs with rates in the second lowest range were scattered throughout the Division.

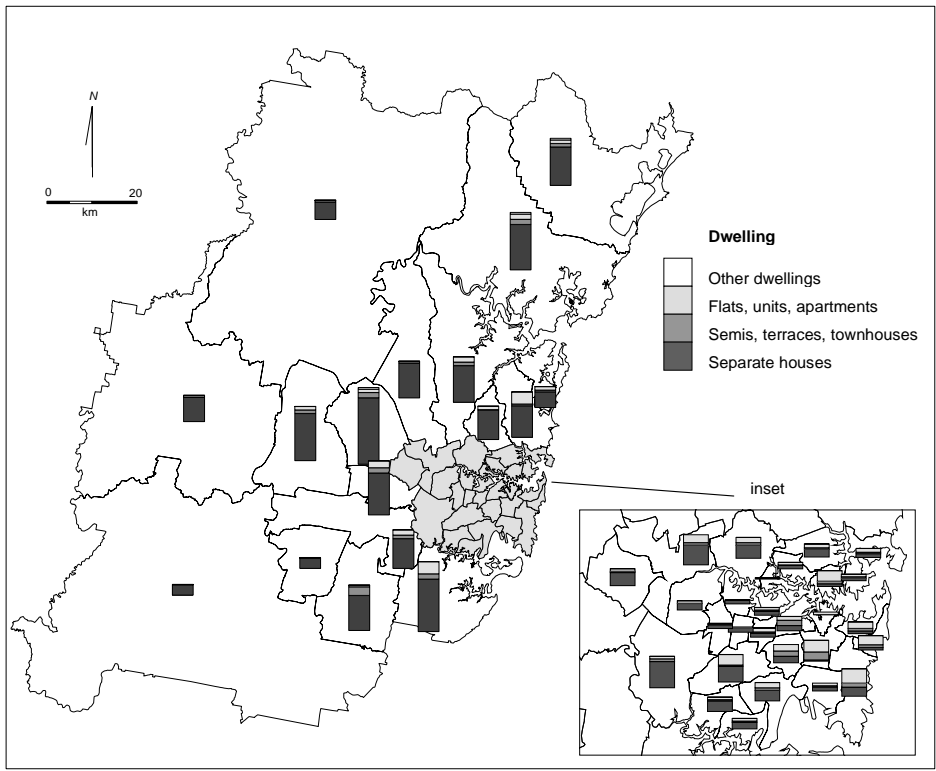


Figure 3: Number of dwellings and proportion of each dwelling type for each local government area in the Sydney Statistical Division. The height of the bar represents the total number of dwellings relative to the maximum of 72000 in Blacktown LGA. Bars in the inset are magnified by about 0.3.

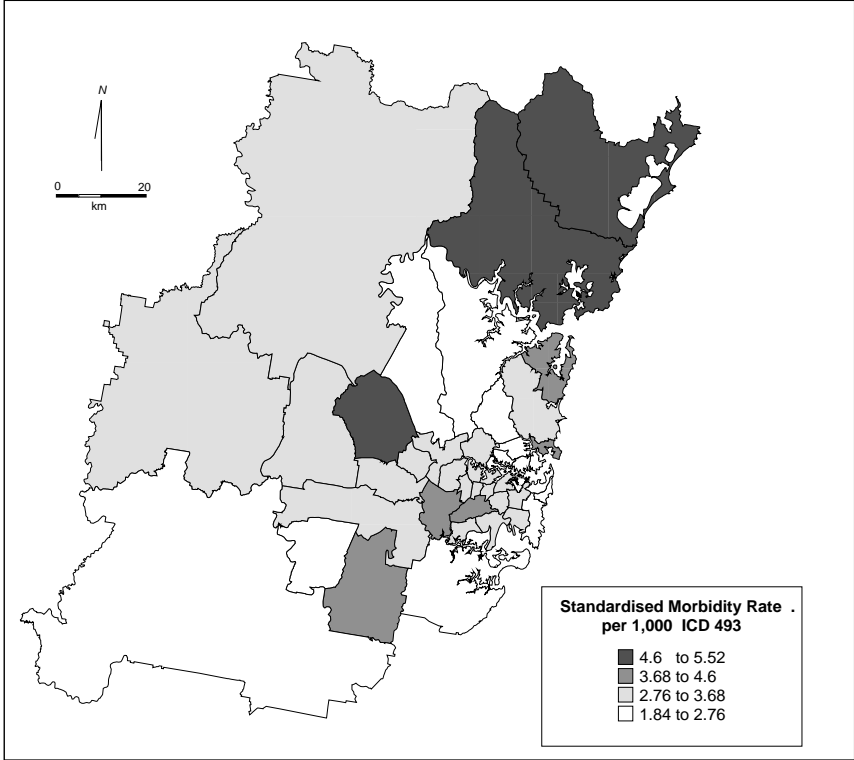


Figure 4: Standardised morbidity rate per 1000 persons for asthma in each local government area in the Sydney Statistical Division.

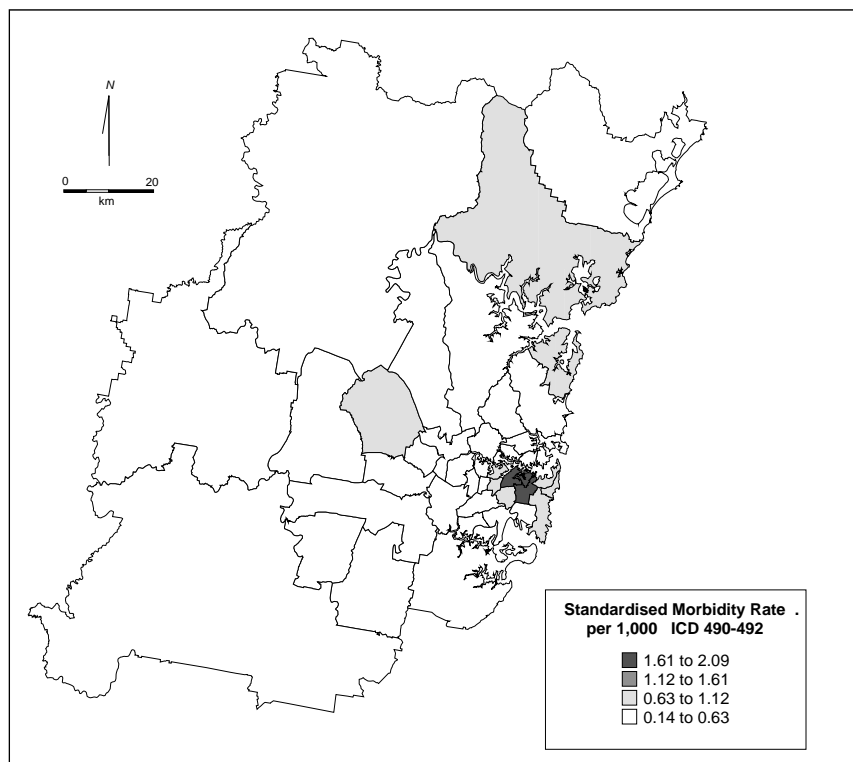


Figure 5: Standardised morbidity rate per 1000 persons for bronchitis and emphysema in each local government area in the Sydney Statistical Division.

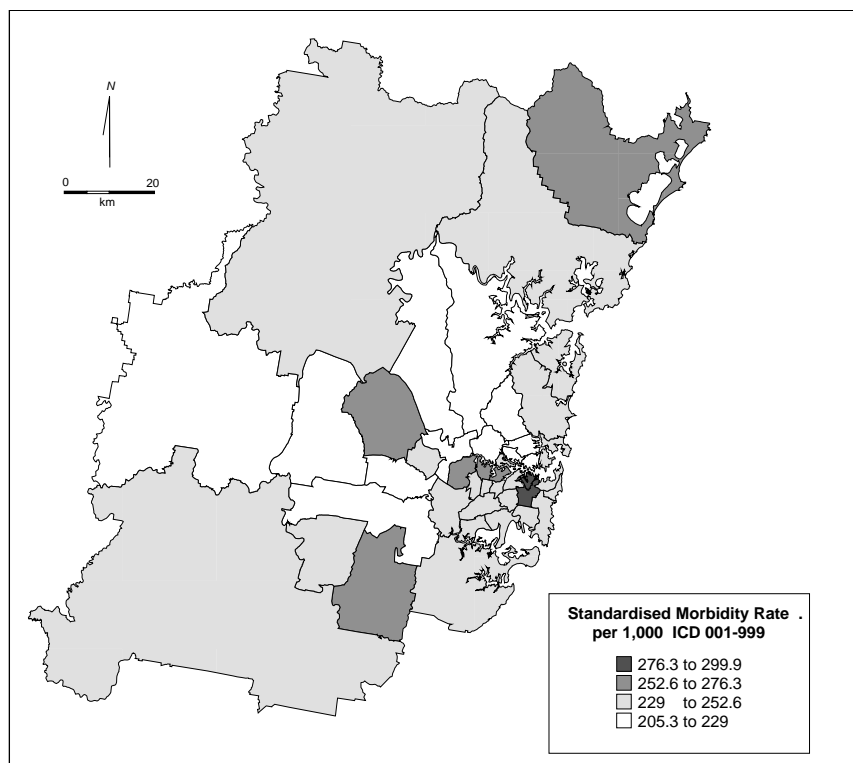


Figure 6: Standardised morbidity rate per 1000 persons for all causes in each local government area in the Sydney Statistical Division.

3.3 Relationship Between Dwelling Crowding, Disease Rates, and Socioeconomic Indicators

Table 3 presents correlation coefficients of relations between the crowding index, disease rates, and socioeconomic status. The crowding index was highly significantly negatively correlated with all but one of the socioeconomic indicators. Asthma was not significantly correlated with the crowding index although it was highly significantly negatively correlated with all the socioeconomic indicators except the proportion of the population with tertiary qualifications and the proportion of the population speaking English at home. Bronchitis and emphysema and all causes separations rates were positively correlated with the crowding index. These correlations were highly significant. These separations categories seemed unrelated to socioeconomic indicators with the exception of all causes separations, which was significantly negatively correlated with IRSED and UIRSEA, and IER which was significantly correlated with Bronchitis and Emphysema and all causes.

Socio-economic indicators	CI	Asthma	Bronchitis and Emphysema	All causes
CI	1.000	0.103	0.389	0.391
Income	-0.524	-0.564	0.104	-0.134
Quals.	0.008	-0.165	0.105	0.090
Occup.	-0.440	-0.559	0.231	-0.068
Lang.	-0.821	-0.022	-0.129	-0.108
IRSED	-0.692	-0.577	-0.119	-0.301
UIRSEA	-0.646	-0.586	-0.063	-0.295
IER	-0.797	-0.490	-0.343	-0.461
IEO	-0.407	-0.603	0.202	-0.098

Table 3: Correlation coefficients (including statistical significance) of relations between the crowding index (CI), asthma, bronchitis and emphysema, and all causes hospital separations (for total persons), and selected socio-economic indicators for Sydney Local Government Areas.

Bold italic text = 0.05 \exists P > 0.01 and **Bold text** = P # 0.01

4.0 DISCUSSION AND CONCLUSIONS

The results of this study indicate that morbidity from bronchitis and emphysema, and all causes combined, is related to dwelling crowding. Increased exposure to infective agents and respiratory irritants, such as tobacco smoke, may be factors underlying the relationship between dwelling crowding and bronchitis and emphysema. Asthma, on the other hand, was not found to be associated with dwelling crowding. This latter finding is contrary to a number of studies that have found such a relationship (e.g. Burr *et al.*, 1989; Morris and Munasinghe, 1994; Yazicioğlu *et al.*, 1998). Although this result, in particular, requires further investigation and clarification, one explanation may be related to differences between previous study locations and the area of focus in this study, Sydney. Previous studies have suggested that the association between dwelling crowding and asthma may be the result of increased exposure to allergens (such as house dust mite and mould), which could result from a more conducive environment for such allergens (e.g. increased temperature, moisture and food) in crowded dwellings. This is reasonable in cold and dry climates where a number of previous studies have been conducted. In Sydney, however, levels of house dust mite allergen (and probably mould) are consistently very high. Although the reasons for this are not certain, it is clear that Sydney's temperate and coastal climate is an important factor. As such, the ambient conditions in Sydney may be so conducive to indoor allergens, that crowding has little or no effect.

The crowding index was consistently associated with the socioeconomic indicators. This result can be explained by the increased ability of those with higher socioeconomic status to afford more expensive (and therefore larger) dwellings. Although it has been stated that dwelling crowding is related to, and can be an indicator of, socioeconomic status, the results presented in this study suggest that although the two are clearly related, there are also significant differences in the role each plays in the aetiology of various diseases.

It is concluded that dwelling crowding is a significant environmental factor in some diseases in the Sydney region, as reflected in hospital admission rates. It is also clear that dwelling crowding is strongly related to indicators of socioeconomic status such as income and occupation. Dwelling crowding should be the focus of further research in Sydney and elsewhere. Should further research continue to reveal relationships between disease and dwelling

crowding, public health authorities would be well advised to consider this factor. Spatial analysis is a useful tool with which to examine variability in dwelling crowding.

4.1 Further Work

This paper reports on preliminary findings and it is the intention of the author that this work continues. This study used three years of hospital separation data. More reliable results may be obtained by conducting the analysis on a longer period around the last Australian census year (1996). Similarly, other (perhaps more sensitive) health indicators could be examined, including hospital attendances, general practitioner visits, and the national health survey (although the latter is currently not available at the LGA level). It is intended that further work will examine age and gender differences in disease rates. This study has focussed on asthma, bronchitis and emphysema, and all causes hospital admission. Given the contrasting results from this study, it will be interesting to extend the work to examine other diseases.

This study has only presented an analysis of dwelling crowding (the CI) at the LGA level. Further work will determine the CI at the sub-LGA level so that the range and variability in each LGA can be examined. Comparison of CI values in the Sydney Statistical Division with those in other urban areas around Australia and in other countries will enable the range of values encountered in Sydney to be put into perspective against a broader range encountered over other regions.

Many diseases, such as asthma, are multifactorial, with many environmental and socioeconomic factors playing a part. Further work will hopefully include examination of other environmental characteristics, including other dwelling characteristics and outdoor factors such as air quality or traffic volume. Further statistical examination, including multiple regression analysis, will reveal more complex relationships between disease and environmental, demographic, and socioeconomic factors.

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REFERENCES

- Australian Bureau of Statistics (1998) 1996 Census of Population and Housing: Socio-Economic Indexes for Areas. Information Paper 2039.0.
- Barker, D.J.P., D. Coggon, C. Osmond and C. Wickham (1990) Poor housing in childhood and high rates of stomach cancer in England and Wales. *British Journal of Cancer* 61(4), pp. 575-578.
- Burr, M.L., F.G. Miskelly, B.K. Butland, T.G. Merrett, E. Vaughan-Williams (1989) Environmental factors and symptoms in infants at high risk of allergy. *Journal of Epidemiology and Community Health* 43, pp. 125-132.
- Clements, D.A., K.A. Weigle and G.L. Gilbert (1995) A case-control study examining risk factors for invasive *Haemophilus influenzae* type b disease in Victoria, Australia 1988-90. *Journal of Paediatrics & Child Health* 31(6), pp. 513-518.
- Fall, C.H.D., P.M. Goggin, P. Hawtin, D. Fine and S. Duggleby (1997) Growth in infancy, infant feeding, childhood living conditions, and *Helicobacter pylori* infection at age 70. *Archives of Disease in Childhood* 77(4), pp. 310-314.
- Irvine, L., I.K. Crombie, R.A. Clark, P.W. Slane, K.E. Goodman, C. Feyerabend and J.I. Cater (1997) What determines levels of passive smoking in children with asthma? *Thorax* 52(9), pp. 766-769.
- Mendall, M.A., P.M. Goggin, N. Molineaux, J. Levy, T. Toosy, D. Strachan and T.C. Northfield (1992) Childhood living conditions and *Helicobacter pylori* seropositivity in adult life. *The Lancet* 339(8798), pp. 896-897.

Morris, R.D. and R.L. Munasinghe (1994) Geographic variability in hospital admission rates for respiratory disease among the elderly in the United States. *Chest* 106(4), pp. 1172-1181.

Power, C. (1991) Social and economic background and class inequalities in health among young adults. *Social Science & Medicine* 32(4), pp. 411-417.

Roberts, E.M. (1997) Neighborhood social environments and the distribution of low birthweight in Chicago. *American Journal of Public Health* 87(4), pp. 597-603.

Walter, S.D. (1992) The analysis of regional patterns in health data: I. the power to detect environmental effects. *American Journal of Epidemiology* 136, pp. 742-759.

Yazicioğlu, M., A. Saltık, Ü. Öneş, A. Şam, H.Ç. Ekerbiçer, O. Kirçuval (1998) Home environment and asthma in school children from the Edirne region in Turkey. *Allergologia et Immunopathologia* 26(1), pp. 5-8.