The relationship between the Index of Concentration at the Extremes (ICE) and self-rated health (SRH) in the North West region of England.

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I declare that this thesis is my own work and has not been submitted for the award of a higher degree elsewhere

Declaration of Authorship

I, Philip Stanley, hereby declare that the work contained in this thesis and the work presented in it is entirely my own and I have clearly documented all sources and materials used. This work has not been submitted in any form for the award of a degree at this university or any other institution, nor has this work been published.

ABSTRACT

Background

The associations between occupational status, spatial concentration and health have been extensively researched. However, changes in patterns of employment suggest that established measures might not be wholly representative of modern socioeconomic conditions. The study examined if the Index of Concentration at the Extremes (ICE) derived from the neighbourhood concentration of occupational classifications in the UK census described geographical changes in self rated health (SRH). A comparison was made with the commonly used Index of Multiple Deprivation (IMD) to determine the relative utility of the ICE and its contribution to modelling health inequalities in comparison to the IMD.

Research questions

A systematic review examined the association between SRH, occupational status and use of the ICE in public health research. Quantitative analysis assessed associations between the concentration of advantage, disadvantage and SRH in the North West England region of the UK, including geographic correlations between SRH, IMD and ICE in 2001 and 2011 census data.

The research questions were: what is the utility of using ICE metrics derived from employment relations compared to more traditional measures of deprivation represented by the IMD, for explaining relative spatial inequalities in SRH? Are employment relations as operationalised by occupational status better at explaining variations in SRH than more traditional measures of social deprivation?

Methods

Data on SRH, IMD, occupational status (NS-SeC) age and ethnicity in the North West England region of the UK was extracted at the Lower Super Output Level (LSOA) level

from the UK national census datasets for 2001 and 2011. The association with SRH was examined for IMD and a novel ICE derived from census returns enumerating the occupational categories of the National Statistics Socioeconomic Classifications (NS-SeC).

Bivariate analysis determined the relationship between ICE, IMD and SRH and to test for any significant relationship that varied geographically. Hot spot analysis identified statistically significant spatial clusters of high and low values. Geographically Weighted Regression (GWR) provided a local model by fitting a regression equation between dependent and independent variables in each neighbourhood of the region.

Results

Analysis of 2001 and 2011 census data found better SRH in more rural areas of the North West region such as Cumbria and Cheshire. Poorer SRH was found mainly in East Lancashire, between Liverpool and Greater Manchester, and in coastal communities in Cumbria and the Fylde coast.

Concentrations of working-class occupations were associated with poorer SRH and concentrations of higher-status occupations were associated with better SRH. The ICE derived from the NS-SeC made a greater contribution to the variance explained by a geographically weighted regression (GWR) model than the IMD.

Average age and age groups best predicted SRH for the 2001 census, while the ICE combined with age and ethnicity was the best predictors for SRH in 2011.

Discussion

ICE measures derived from NS-SeC data demonstrated that the ICE is a useful adjunct to conventional measures of material deprivation, as it may capture neighbourhood conditions not represented by the IMD. Incorporating extremes of socioeconomic status

allowed the examination of neighbourhood inequalities that do not rely on a single disadvantaged group. The ICE improves on the IMD in that occupational classifications represent qualities of employment not captured by absolute measures of deprivation. There is potential for the ICE to be used with other measure and geographies.

Keywords

Index of Concentration at the Extremes

Index of Multiple Deprivation

Employment relations

Socioeconomic status

Self-rated health

Spatial concentration

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Finally, I dedicate this thesis to the memory of my late wife. Without her belief, kindness, patience, encouragement, and occasional eye-rolling, this would never have happened. With all my love, this is

For Nan.

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List of abbreviations

AICc	Akaike Information Criterion
DHSC	Department of Health and Social Care
EPHPP	Canadian Effective Public Health Practice Project
GWR	Geographically Weighted Regression
HRP	Household reference person
ICE	Index of Concentration at the Extremes
IDACI	Income Deprivation Affecting Children Index
IDAOPI	Income Deprivation Affecting Older People Index
IMD	Index of Multiple Deprivation
NHANES III	Third National Health and Nutrition Examination Survey
NIHP	National Institute for Health Protection
NOMIS	National Online Manpower Information System
NPHS	National Population Health Survey (Canada)
NS-SeC	National Statistics Socioeconomic Classifications
OHP	Office for Health Protection
OLS	Ordinary Least Squares
ONS	Office for National Statistics
PHE	Public Health England
SES	Socioeconomic status
SRH	Self-rated health
UKHSA	UK Health Security Agency
WHO	World Health Organisation

CHAPTER 1: Introduction

The introduction sets out the context of the study. Health equity in England is considered in terms of the original Marmot review and subsequent follow-up study (Marmot, 2010; Marmot et al., 2020), which reviewed progress against the key areas of concern of the past decade. This work has been influential in faming public policy and as such is used to frame this study. World Health Organisation (WHO) definitions of health inequity and inequalities are set out (c.f. WHO, 2006), before moving on to an overview of the societal dimensions of health inequalities. Foundational constructs of modern health geography are introduced with a consideration of compositional, collective and contextual effects relating health to people and places, before proceeding to a more detailed consideration of population distribution and segregation. The social and economic circumstances which combine to influence the quality of population health are introduced as the wider determinants of health status, using Dahlgren and Whitehead's 'Rainbow' model (Dahlgren & Whitehead, 2021; Whitehead & Dahlgren, 1991). The Goldthorpe schema of employment relations is then discussed as the measure of socioeconomic status to be used in the study (Goldthorpe, 2000; Goldthorpe, 2007; Goldthorpe, 2013; Goldthorpe et al., 1987; Goldthorpe et al., 2004). Finally, the introduction will set out the study's aims and objectives.

1.1 Public health in England

In the ten-year follow-up to his original review of health in equity in England, Sir Michael Marmot concluded that public-health in England is faltering (Marmot et al., 2020) Since the beginning of the 20th century, England had experienced continuous improvements in life expectancy, but since 2011 these improvements have slowed almost to a halt. During the decade from 2010–2020 life expectancy for women actually declined in the most deprived communities outside of London, as it also did in some

regions for men. The time spent living with poor health for both women and men has also increased.

There is a vast literature on the close association between socio-economic status, life expectancy, health and disability. Having sufficient financial resources to live a healthy life is clearly important to improving health. However, one of the key findings of the Marmot review (2010) was that social disadvantage should not be understood in narrow terms as a lack of money. Having sufficient resources to allow for control over one's life is critical to health and well-being, and it is the ability to lead a dignified life that actually allows individuals to flourish.

The 2010 Marmot review concluded that good quality employment is generally protective of health while unemployment contributes significantly to poor health. However, being in employment does not guarantee better health. Characteristics of employment may be detrimental to health and well-being and poor quality or stressful work may in fact be more harmful to health than unemployment. Poor quality work is therefore one of the major drivers of inequalities and physical and mental health (Marmot, 2010, p. p136).

Since 2010 there have been significant changes in many aspects of the labour market and employment practices in England that are implicated in the availability of good quality employment. Although employment rates have increased nationally, during this time there has also been an increase in the prevalence of poor-quality work, including a rise in part-time and insecure employment (ONS, 2022). The number of people on zero hours contracts has also increased significantly (Datta et al., 2020). Increasing automation has led to job losses, particularly among low paid part-time workers with the north of England particularly badly affected (ONS, 2019b). Real pay remains below 2010 levels and there has been an increase in the proportion of people in

poverty living in a working household (Marmot et al., 2020). It is notable that there continues to be more people living in poverty are in work than unemployed (Bourquin et al., 2019). Associated with this has been an increase in the incidence of work-related stress (HSE, 2021). Taken together, these observations suggest that the measures of financial deprivation commonly used in modelling health inequalities risk misrepresenting the reality of the stresses of modern working life (see Marmot et al. (2020) for discussion of recent developments). Widely used measures of socioeconomic disadvantage, such as the Index of Multiple Deprivation, were not developed with these issues in mind. Although, the IMD represents some aspects of material disadvantage, it does not include a measure of occupational type, which would address the issues identified by Marmot and colleagues.

This study proposes an original approach to researching these issues that uses for the first time in the UK a methodology for measuring population health based on the analysis of geographical concentrations of socioeconomic status as represented by employment relations, rather than by commonly used measures of deprivation. This approach was tested using census data from the socioeconomically and geographically diverse region of North-West England, which encompasses urban, industrial, post-industrial and rural communities and also communities that face particular challenges because of their coastal location (ONS, 2020b).

This provides the context for the study, which is set out in this chapter. The principal dimensions of health inequalities are outlined in the context of current UK public health strategy. Employment relations are identified as one of the wider determinants of health and the Goldthorpe schema is discussed as means of using employment relations to derive membership of the socioeconomic class structure in the

UK census data. Evidence of the association between employment relations and SRH is presented.

1.2 Definitions of health & health inequality

In 1948 the World Health Organisation's (WHO) original definition of health was as '… a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO, 2006). In 1986, the WHO-sponsored Ottawa Charter expanded on this definition to include the health of groups of people and their context:

> *'Health promotion is the process of enabling people to increase control over, and to improve, their health. To reach a state of complete physical, mental and social well-being, an individual or group must be able to identify and to realise aspirations, to satisfy needs and to change or cope with the environment. Health is, therefore, seen as a resource for everyday life, not the objective of living. Health is a positive concept emphasising social and personal resources, as well as physical capacities. Therefore, health promotion is not just the responsibility of the health sector, but goes beyond healthy life-styles to well-being'* (WHO, 2006).

Both the WHO and Ottawa Charter definitions emphasise the positive nature of health and the multiple dimensions implicated in healthy living, but have variously been criticised for conflating happiness with health (Huber et al., 2011); for failure to recognise that some dimensions of health may conflict with each another (Saracci, 1997); and also by defining health in such aspirational terms that attainment is near impossible even where fulfilling lives are being lived (McGrail et al., 2016). Other researchers supported the high aspiration approach (using the term 'euxia' to describe an 'optimal' health-fitness standard characterised by physical vigour, long lifespan and freedom from chronic disease (see (Elrick, 1980) for a discussion). Alternative concepts of health sought to avoid some of the aspirational and absolutist problems with the WHO definitions by introducing the idea that health represents the extent to which personal or group aspirations may be realised, their needs are satisfied, and they can cope with a range of environments:

> *'[health is] the extent to which an individual or group is able, on the one hand, to realise aspirations and satisfy needs and, on the other hand, to cope with the interpersonal, social, biological and physical environments. Health is therefore a resource for everyday life, not the objective of living; it is a positive concept embracing social and personal resources as well as physical and psychological capacities'* (Starfield, 2001).
>
> *'[health is] the capability to cope with and to manage one's own malaise and well-being conditions'* (Leonardi, 2018).
>
> *'Health is the experience of physical and psychological well-being. Good health and poor health do not occur as a dichotomy, but as a continuum.*

> *The absence of disease or disability is neither sufficient nor necessary to produce a state of good health'* (Card, 2017).

These definitions are valuable because they acknowledge that health is defined by societal context and necessarily evolves over time. Because the examination of health status always involves comparison between populations or between points in time, it is important to recognise the intrinsically relative nature of health measurement and the importance of the choice of comparator populations. These considerations helped to extended public health practice to consider the health of populations, rather than just the health of individuals (Rose, 2001). Defining health in germs of populations means we may construe health as a collective condition with the property of a public good, such that the enjoyment of it by one person does not diminish its use by others:

> *'Health is a condition in which people achieve control over their lives because of the equitable distribution of power and resources. Health is thus a collective value; my health cannot be at the expense of others nor through the excessive use of natural resources'* (Huber et al., 2011).

Taken together, these definitions suggest that a definition which allows for consideration of the health, and determinants of health, for both populations and individuals may offer the greatest utility (Rose, 2001). For example, it would be possible to have a high degree of control over one's life yet die prematurely because control may be a cause of cases but not of incidence within a population. It also limits the definition of health to that which is obtained through the equitable distribution of

power and resources, which are not necessarily the only routes through which health can be achieved.

1.3 Definitions of health inequalities

The World Health Organisation offers this definition of health inequalities:

> *'Social inequities in health are systematic differences in health status between different socio-economic groups. These inequities are socially produced (and therefore modifiable) and unfair'* (Whitehead, 1991).

The key elements of the WHO definition are that inequalities comprise differences in health outcomes and that the differences occurring between social groups are systematic rather than random and should be understood at a population rather than individual level. Importantly, such differences are held to be avoidable. In a more extensive definition, Krieger defined social inequalities in health as:

> *'... health disparities, within and between countries, that are judged to be unfair, unjust, avoidable, and unnecessary (meaning: are neither inevitable nor unremediable) and that systematically burden populations rendered vulnerable by underlying social structures and political, economic, and legal institutions'* (Krieger, 2001).

It should be noted that the extent to which a health outcome is understood as avoidable or remediable changes over time. Disease processes that in the past were either misunderstood, not appreciated and for which no effective preventative or treatment measures were available, have often subsequently become avoidable, preventable or treatable. It follows from this that what is defined as an inequality can also change.

Related to the definition of health inequalities, Braveman and colleagues. provided a range of definitions of 'health equity' with varying brevity and differently for general and technical audiences. The most detailed definition for a general audience they offer is:

> *'Health equity means that everyone has a fair and just opportunity to be as healthy as possible. This requires removing obstacles to health such as poverty, discrimination and their consequences, including powerlessness and lack of access to good jobs with fair pay, quality education and housing, safe environments and health care'* (Braveman et al., 2017).

Two versions for a general audience are also offered, depending on whether health equity is defined as an outcome or process:

> *'Health equity means that everyone has a fair and just opportunity to be as healthy as possible'* (Braveman et al., 2017).
>
> *'Health equity means removing economic and social obstacles to health such as poverty and discrimination'*(Braveman et al., 2017)
>
> And the definition for a technical audience:
>
> *'For the purposes of measurement, health equity means reducing and ultimately eliminating disparities in health and its determinants that adversely affect excluded or marginalised groups'* (Braveman et al., 2017).

Braveman and colleagues propose that any definition of health inequalities should:

> *'Reflect a commitment to fair and just practices across all sectors of society; be sufficiently unambiguous that it can guide policy priorities; be actionable; be conceptually and technically sound, and consistent with current scientific knowledge; be possible to operationalise for the purpose of measurement, which is essential for accountability; be respectful of the groups of particular concern, not only defining the challenges they face but also affirming their strengths; resonate with widely held values, in order to garner and sustain broad support; and, be clear, intuitive, and compelling*

without sacrificing the other criteria, in order to create and sustain political will' (p.3).(Braveman et al., 2017, p. 3).

Absent from all the definitions is an explicit recognition that for ranked socioeconomic groups such as social class or income, the inequalities in health can be seen to occur stepwise as a gradient across the entire population. This gradient cannot be described where the social groupings cannot be ranked (e.g. gender or ethnicity), but it is an important feature of health inequalities to define because all social groups, with the exception of the most advantaged within a society, are negatively affected (Wilkinson & Pickett, 2010). Further, if the most advantaged within any particular society were to compare themselves within similarly advantaged groups in other societies, they may also find that they do less well. Wilkinson and Pickett have suggested that this is the case within the most unequal societies.

Finally, Norheim and Asada assert that definitions of health inequality should recognise that equality should not necessarily be prioritised over the overall level of health in the population or other social goods such as education. Although this may be the case, it is a question of societal priorities and values rather than definition (Norheim & Asada, 2009).

1.4 Health inequalities: an overview

Health inequalities essentially describe differences in individual health status, but can also refer to differences in treatment, access to care and the opportunity to lead a healthy life. Health status is therefore determined by a combination of some, or all, of these factors. Health inequalities can therefore involve differences in:

- Health status, measured by variations in life expectancy or the prevalence of health conditions.

- Access to care, for example, availability of treatments; the geographic heterogeneity in health care quality.
- Quality and experience of care, including variations in outcome and levels of patient satisfaction.
- Behavioural risks to health, such as diet, exercise, alcohol consumption and smoking rates.
- Wider determinants of health, including environmental factors such as access to green space or quality of housing.

1.5 People and place: compositional, collective and contextual ideas

It can be seen that health inequalities may be due to a wide range both personal and environmental characteristics. Historically, this led to a vigorous debate as to the relative importance of people or place and it is instructive to consider these questions in the context of studies of spatial effects and some of the issues associated with their measurement. An early paper by Macintyre and colleagues (Macintyre et al., 1993) made a case for the importance of place in understanding health: 'It may not be possible to make everyone middle class, but it might be possible to try to upgrade the social and physical environments of poorer people in ways which might be health promoting. Regional and District Councils should be encouraged to conduct health impact assessments on a wide range of policy options in different areas (for example in relation to housing, land use, transport, industrial development, policing, recreation, retail food provision). Health Authorities or Health Boards should be encouraged, as part of their health needs assessments, to focus on features of the local social environment as well as on characteristics of the local population.' (Macintyre et al., 1993, p. 233). An alternative view was offered by Sloggett and Joshi (Sloggett & Joshi, 1994), who asserted the primacy of person: 'The evidence does not confirm any social miasma

whereby the shorter life expectancy of disadvantaged people is further reduced if they live in close proximity to other disadvantaged people. Deprivation appears to be adequately assessed by personal and household circumstances, which are themselves associated with income. Area based measures are not efficient substitutes. For maximum effectiveness, health policy needs to target people as well as places' (Sloggett & Joshi, 1994, p. 1473&1474).

Macintyre later suggested that this apparent conflict arose from the conceptualisation of spatial effects and proposed a resolution by considering ideas of compositional, collective and contextual effects (Macintyre, 1997). Initially, it might be considered that spatial effects are purely compositional in nature. For example, deprivation is known to be associated with premature mortality, so areas with a large number of deprived residents will have low average life expectancy. Since deprived people will tend die early wherever they live and affluent people will tend to live longer regardless of where they live, the spatial effect is explained by the spatial concentration of deprived or affluent people in different neighbourhoods and life expectancy is therefore a property of the individual and not of the locality. Alternatively, health status might be mediated by collective effects, which are concerned with the idea of a 'social miasma' suggested by Sloggett and Joshi (1994). Relations between individuals, or the collective properties of groups, exert an effect over and above the properties of the individual. This model might predict that living with large numbers of deprived people might decrease an individual's life expectancy, whereas living near more socially advantaged people might result in increased life expectancy. Finally, there is the broader social or physical context, construed as an environment over and above either individuals or social groups. This might predate an individual or group and have some characteristics over which they have no direct control. For example, people of whatever

levels of personal social advantage or disadvantage might live longer if they lived in non-polluted areas with a pleasant climate and access to a good range of services and amenities.

Macintyre advocated moving beyond the established tendency to view health in terms of individual behaviours, and instead to consider the effects of wider societal structures and systems. Latterly, this has been reflected in four principal domains of UK public policy:

- Compositional socioeconomic factors, such as income or various forms of deprivation.
- Contextual geographical factors, for example, the type of administrative region or whether an area is urban or rural.
- Compositional characteristics of individuals or populations, including sex, ethnicity or disability.
- Collective factors; for example the relations with socially excluded groups such as homeless people.

People may experience different combinations of these domains, which has implications for the type and magnitude of the health inequalities that result. There are also interactions between the factors that may act to amplify inequalities. For example, minority groups might experience health inequalities over and above the general relationship between socioeconomic status and health that is experienced by the majority community (Marmot, 2010).

With regard to the inclusion of ethnicity in this study, it is understood that race and ethnicity are dynamic constructs, shaped by geographic, cultural and political forces and that there is an ongoing debate about the use and interpretation of such data. However, there is a substantial body of evidence that has shown that ethnicity can

influence people's socioeconomic position and leads to disproportionately high morbidity and mortality for racial and ethnic minorities by sustaining inequitable access to resources, including health care. Ethnicity captures important epidemiologic information, including social determinants of health such as racism and discrimination, socioeconomic position, and environmental exposures. It is for this reason that ethnicity has been included with the other study variables (see Borrell et al. (2021) for a discussion).

1.6 Multilevel modelling

In examining the relative effects of people and places on health, it is instructive to consider the contribution of multilevel modelling to health research. Multilevel modelling is not geographical but can be applied to many kinds of hierarchical data. Researchers adopted multilevel techniques for geographical research because spatial data can be ordered hierarchically with individuals located, or 'nested', within the spatial areas in which they live (Jones, 1991) Multilevel modelling was adopted in health research in the 1990s (e.g. Duncan et al., 1998), with the advantage that it incorporates geography without ignoring individual determinants on health (Pickett & Pearl, 2001). It was hoped that multilevel modelling would help to resolve a debate in health research, about whether geographical differences in health outcomes are solely due to the composition of the population, or whether they are influenced by context. In other words, is the health of an area reducible to the health of the people who live there, or does the place itself make a difference (Macintyre & Ellaway, 2003; Macintyre et al., 2002; Sloggett & Joshi, 1994)? Studies have found that contextual geographical determinants of health, although minor relative to individual effects, were usually statistically significant. In a review of twenty-five studies Pickett and Pearl (2001) found that twenty-three had at least one significant effect on health at the neighbourhood

or contextual level after controlling for the composition of the population. A similar review by Riva et al. (2007) found that eighty-two of eighty-eight studies reported differences between places after individual characteristics were taken into account.

Multilevel models allow relationships to vary between places. Instead of fitting a general model that assumes the relationship between the predictor and dependent variables holds constant everywhere, multilevel models allow the relationship to vary within the study area. In doing so, multilevel models allow two individuals living in the same neighbourhood or context to be more alike in their health outcomes than would be expected given their individual characteristics alone. Essentially, as well as modelling spatial heterogeneity (differences) between places, they also allow and account for spatial dependencies (similarities) within places (Jones, 1991).

Despite the obvious advantages for studying geographies of health, multilevel modelling has been criticised on conceptual and practical grounds. The first issue is spatial design, where the geographical context for which effects are measured is not easily defined and is often employed without any explicit consideration of how it affects health (O'Campo, 2003). Second, multilevel models are strictly hierarchical, with individuals nested into distinct neighbourhood contexts. The idea of a single, static and neatly bounded geographical context impacting upon a person's health in a clearly deterministic way seems overly simplistic where in reality such contexts are likely to be multiple, overlapping, operating at a variety of scales and time periods, with indeterminate boundaries (Morenoff, 2003). Third, and related to this, multilevel models usually adopt a discrete, 'container-driven' view of geographical space where everything stops at the boundaries of neighbourhoods and where those neighbourhoods are treated as independent of each other, even if they share a common border (Arcaya

et al., 2016). This discrete view contrasts with the more continuous view of space employed in geographically weighted regression (Fotheringham et al., 2003).

1.7 Population distribution

Population distribution deals with datasets of statistical information describing how some phenomenon regarding human population is spread across space. For the purposes of this study, population distribution has no direct spatial features and only contains attributes allowing to describe population phenomenon related to statistical units. Population data is linked to spatial object (statistical units) through their common identifier, in this case using LSOA codes.

1.8 Spatial segregation

Most analysis of segregation is based on measures that represent one or more dimension of segregation (c.f. Massey & Denton, 1988) and provides one-number indexes for a study area (for example, a region or city). Most of these measures are aspatial. For example, the standard form of the index of dissimilarity (*D*) uses counts of two population groups (e.g. White and Black African) within each zone (e.g. a ward or local authority boundary), and measures unevenness in the two groups across the area. However, no account is taken of neighbouring zones; such a purportedly global measure therefore ignores the possibility of connections between adjacent zones. Artificially imposed boundaries are consequently treated as hard physical or social barriers between two areas (Wong, 2016).

Spatial measures of segregation address this by incorporating information on the populations of neighbouring zones (defined in multiple ways, including adjacent zones or those within some predefined distance) and thereby generate different results for different spatial arrangements of the same population values (Wong, 2016). Both global aspatial and spatial measures provide only one index across a whole study area. Local

indices go further and provide a value for each individual neighbourhood area (e.g. per LSOA), rather than their collective (e.g. LSOAs in a city) (Feitosa et al., 2007). Local measures can therefore be mapped and used to explore the geographic patterning and scale of residential segregation across a wider study area.

The spatiality of segregation has been found to be scale dependent, such that the spatial level of analysis at which segregation is measured has a substantial effect on how it is understood (Reardon et al., 2008). Johnston and colleagues demonstrated the variation in spatial changes in segregation at the micro-, macro- and meso-scale in London between 2001 and 2011, using a multi-level framework which accounts for segregation across three geographical levels (Johnston et al., 2016). This study found a reduction in ethnic minority segregation in small areas by analysing a neighbourhood (micro-) level (i.e. output area geographical units), reduction in segregation, set within more stable patterns at the 'meso-scale' (middle layer super output areas), and with no change at the 'macro-scale' (local authority districts). This type of adaptable approach to defining neighbourhoods offered by local measurement overcomes the assumptions made by boundary definitions reflected in the Modifiable Areal Unit Problem and allows for a more flexible exploration of multiscale segregation.

The use of local measures allows the testing of relationships between different dimensions of neighbourhood segregation, as well as the relationships between segregation and other population characteristics (e.g. area deprivation). Local measurement allows researchers to determine what information is added for each dimension at each location. It also allows for an examination of how differing forms of segregation and the spatial and scalar characteristics of segregation are related. These interrelations are potentially important given that the experiences of segregation are not equal for every group (Johnston et al., 2007).

1.9 Distribution of inequalities

Public Health England's 2020–25 strategy identifies smoking, poor diet, physical inactivity and high alcohol consumption as the four principal behavioural risks to people's health in England (PHE, 2019a). These risks to health are more common in some groups of the population than in others. The exposure to risk is patterned by measures of deprivation, income, gender and ethnicity, with risks being concentrated in the most disadvantaged groups. For example, smoking prevalence in the most deprived fifth of the population is 28%, compared to 10% in the least deprived fifth (ONS, 2020a).

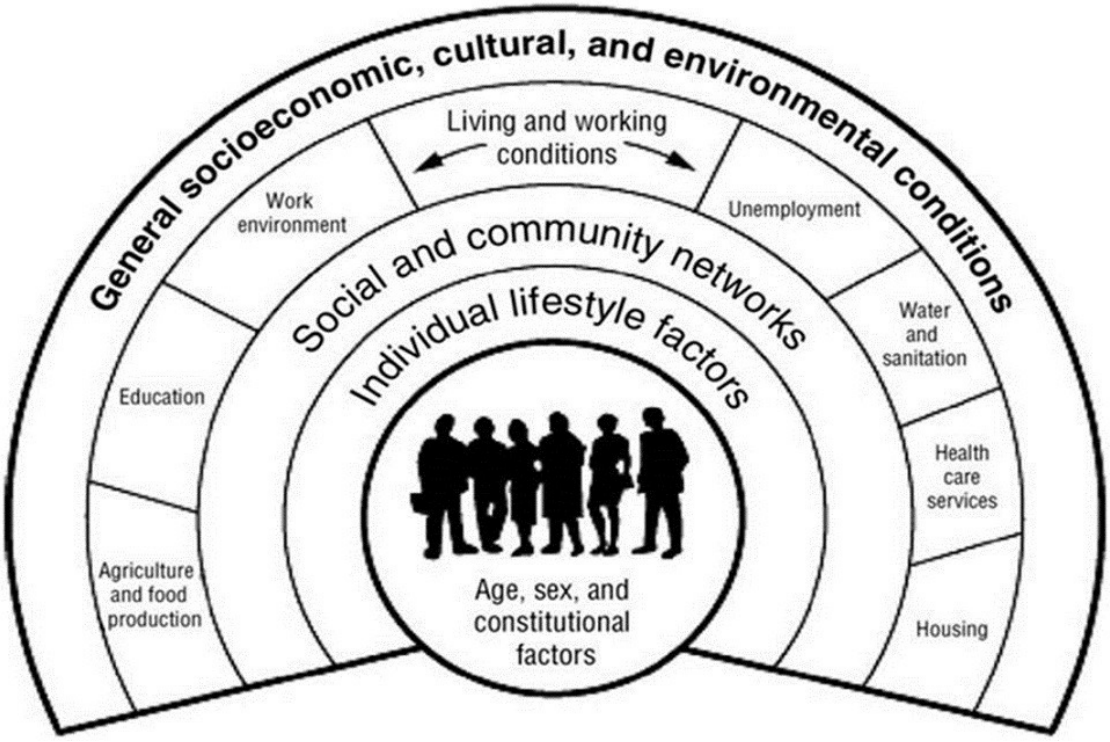
Health risks also tend to be clustered among specific population groups, with individuals in disadvantaged groups more likely to engage in multiple risky behaviours (Birch et al., 2019). In 2017, the proportion of adults in the UK with three or more behavioural risk factors was 27% in the most deprived fifth, compared with 14% in the least deprived fifth (NHS, 2018). Health risks are also influenced by cultural, social and material circumstances. Recent estimates suggest that households in the bottom fifth of income distribution may need to spend 42% of their income, after housing costs, on food if they are to eat Public Health England's recommended diet (PHE, 2019a). Disadvantage may also make it harder for people to adopt healthy behaviours, particularly for those who are disadvantaged on range of socioeconomic factors such as income deprivation or housing.

1.10 Wider determinants of health

The social and economic circumstances which combine to influence the quality of population health are known collectively as the social determinants of health. The interactions between the various social determinants of health or complex and may influence health throughout the life course. The various dimensions of the social

determinants of health can be understood by reference to the foundational 'Rainbow' model of Dahlgren and Whitehead (Whitehead & Dahlgren, 1991). Personal characteristics constitute the core of the model and include gender, age, ethnicity, and hereditary factors. Individual lifestyle factors include behaviours such as smoking, alcohol consumption and physical activity. Social and community networks include family and wider social contacts and resources. Living and working conditions include access to work and opportunities in relation to employment, housing, education and access to welfare services. General socioeconomic, cultural and environmental conditions include factors such as disposable income, taxation and the availability of work (Figure 1). It can be seen that several of these factors may be interrelated as they apply to Goldthorpe's employment relations construct examined by this study (Goldthorpe, 2007). It should be noted that the Rainbow model does not make causal inferences between the various elements (Dahlgren & Whitehead, 2021). However, the model has been influential in widening the scope of research into health inequalities from the former emphasis on health services and clinical care in the treatment of disease to a more holistic approach. The social determinants of health identified in the rainbow model reflect the priority areas of action set out in the Marmot review (Marmot, 2010).

Figure 1: The Dahlgren and Whitehead 'Rainbow' model of the social determinants of health



Source: (Whitehead & Dahlgren, 1991)

The Rainbow model Informed a systematic review by Bambra and colleagues, which identified the range of social determinants upon which public health interventions could be based (Bambra et al., 2010). This review considered evidence for the macro-economic, cultural and environmental conditions in the outermost layer: and also living and working conditions, access to essential goods and services in the next layer this included studies of water and sanitation, agriculture, food, access to health and social care, unemployment, welfare, work conditions, living environment, education and transport. Findings relevant to the Goldthorpe schema of employment relations included reviews of interventions in the work environment, such as changes to the organisation of work and the effects of privatisation found evidence that the effects of change may be experience differently by different levels of employee and that health outcomes differed accordingly. This is consistent with Marmot's original and

subsequent observations that the workplace is an important setting in which inequalities may be addressed (Marmot, 2010; Marmot et al., 2020).

The following provides some examples of the impacts of a range of wider determinants of health that are relevant to this study. These determinants are often experienced together and cumulatively over the life course. Some groups can be disadvantaged across a number of factors, and these disadvantages can be mutually reinforcing. For example, deprived areas in the UK have on average nine times less access to green space, higher concentrations of fast-food outlets and more limited availability of affordable healthy food (PHE, 2019a).

1.10.1 Income

Having sufficient income to lead a healthy life is essential to health and there is substantial evidence that poverty and low living standards are powerful determinants of ill health and health inequalities. Insufficient income is associated with poor long-term physical and mental health and low life expectancy (Marmot et al., 2020).

Inadequate incomes cause poor health because it is more difficult to avoid stress and feel in control, access material resources, adopt and maintain healthy behaviours and feel financially secure (Lawson, 2018).

Overall, wealth inequalities in the UK have increased in recent years. Wage growth has been low since 2010 and wage inequality persists (Costa & Machin, 2019). Rates of in-work poverty and the number of families with children that do not reach the minimum income standard has increased (Hirsch, 2019) along with a significant increase in food insecurity (Sosenko et al., 2019).

1.10.2 Housing

Poor-quality housing is damaging to health and there is evidence that demonstrates exposure to poor housing conditions (including damp, cold, mould and noise) is

strongly associated with poor health, both physical and mental (Thomson et al., 2013). The longer the exposure to poor conditions, including cold, the greater the impact on mental and physical health (Daly & Allen, 2017).

Poor-quality and overcrowded housing is associated with an increased risk of ill health, including cardiovascular and respiratory disease, depression and anxiety (Weich et al., 2002). In winter, death rates are highest for those in the coldest homes (ONS, 2020c). Minority ethnic households are more likely to live in overcrowded homes and to experience fuel poverty.

1.10.3 Environment

The built and natural environment is a key determinant of inequalities in health and wellbeing and the environment in which people live is inextricably linked to health throughout the life course (Marmot, 2010).

Access to green space is a key aspect associated with better physical and mental health, and lower levels of obesity (WHO, 2016), but this often inequitable. Access is likely to be worse for people in deprived areas, and for areas with higher proportions of minority ethnic groups (PHE, 2020).

Exposure to air pollutants is estimated to cause 28–36,000 premature deaths per year in the UK (PHE, 2019b). Disadvantaged and minority ethnic communities have been found to be at disproportionate risk of exposure to atmospheric pollution. Within the most deprived areas of London, people from minority ethnic groups have been found to be more exposed to high concentrations of nitrogen dioxide, one of the main pollutants associated with traffic fumes (PHE, 2019b).

1.10.4 Education

Higher levels of educational attainment assessed by qualifications, skills or training, are associated with better health. Among 26 OECD countries, people with a university

degree or an equivalent level of education at age 30 were found to live more than five years longer on average than people with lower levels of education (Dyson et al., 2009).

1.10.5 Employment

Unemployment is associated with lower life expectancy and also poorer physical and mental health, both for the unemployed person themselves and their households (Giatti et al., 2010). For those in employment, the quality of work in terms of aspects such as pay, job security and task control also has an impact on health. Characteristics of work, such as exposure to hazards, job security and whether work promotes a sense of belonging, all affect both physical and mental health (Atherton & Power, 2007).

1.11 Measuring inequalities: the Goldthorpe schema

1.11.1 The Goldthorpe schema

Historically, official approaches to the grading of social class in the UK were founded on the assumption that society comprises a graded hierarchy of occupations ranked by level of skill (Savage et al., 2013). Latterly, this has evolved into a theoretical construct of social class based on social relations in economic life, with a specific focus on employment relations (Rose & Pevalin, 2003).

Since historical concepts of social class have been derived from occupation, the relative social positions of employers, employees and the self-employed represent a first level of differentiation (Rose & Harrison, 2010). Further differentiation between occupational groups has been achieved by grouping them by employment contracts. This arises from the observation that in regulating employment, employers face the twin challenges of work monitoring, which comprises elements such as attendance, work rate and quality; and managing human asset specificity, which is concerned with the effective deployment of specialist skills attained through education and training. Employers will typically offer differing contracts based on monitoring and skills which

also form the basis of one of the most widely used conceptual models of social class: the Goldthorpe schema (see Goldthorpe (2000) for a complete account). The Goldthorpe schema is the conceptual basis of the UK National Statistics Socio-Economic Classification (NS-SeC) introduced in 2001.

The Goldthorpe model uses construct of social class to delineate different solutions to the contractual hazards inherent in the employment relationship (Goldthorpe, 2007). Goldthorpe proposes a continuum ranging from a service relationship, which is typically found in professional and managerial occupations, to a labour contract found in semi-skilled and lower skilled occupations.

Service relationships are characterised by a relative disconnect between earnings and productivity, better job security, longer tenure and an internal market for skills that offers more opportunities for promotion. The disconnect between earnings and productivity in the service relationship arises from difficulties in defining and monitoring such roles. Service relationships are typically more secure because they require higher asset specificity (specialist knowledge), which gives employers an incentive to retain skilled workers.

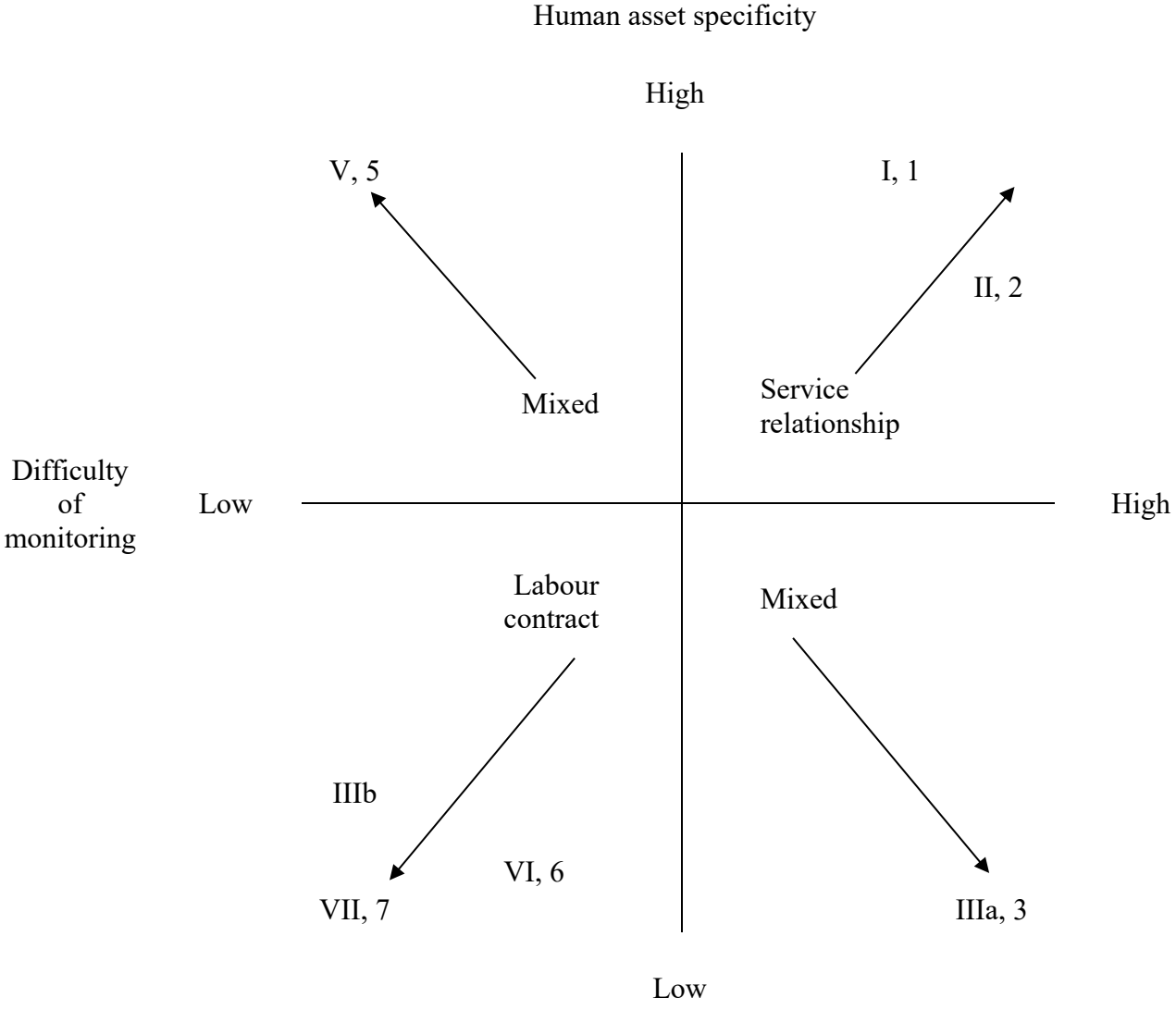
Conversely, labour contracts tie earnings to specific inputs and outputs, are of shorter duration and offer fewer opportunities for advancement. This distinction arises because easier task definition and monitoring allows employers to align workflows more closely with work demands. Since lower skilled occupations generally require less specialist skills, employers have little incentive to retain employees, who are therefore relatively expendable. Such occupations are therefore less secure and more vulnerable to downturn is in market conditions (Goldthorpe, 2007).

The Goldthorpe schema uses differences in the twin characteristics of work monitoring and human asset specificity to explain the differentiation of work by

employment relations, which is construed in terms of the difference in service relationships and labour contracts that arise between different types of roles. These differences give rise to social classes and the associated social stratification. Data on work characteristics are not routinely gathered by the UK census, so the social classes that comprise the Goldthorpe schema are derived by aggregating existing detailed occupational categories into broader occupational groups that represent the principal dimensions of employment relations. This approach has been widely used in studies of the sociology of work and also in studies of social mobility (see, for example, (Chatzitheochari & Arber, 2009; Warren, 2015).

Figure 2 presents the dimensions of the NS-SeC class structure following the Goldthorpe schema. Table 1 presents the classes of the Goldthorpe schema as they map onto the seven associated classes of the analytical version of the NS-SeC and common descriptive terms.

Figure 2: Dimensions of the NS-SeC classifications following the Goldthorpe schema



(Adapted from Goldthorpe, 2000)

Table 1: Goldthorpe schema, NS-SeC & common descriptive terms

Goldthorpe schema		**NS-SeC classifications**		**Common descriptive term**
I	Professional, administrative and managerial employees, higher grade	1	Higher managerial and professional occupations	Salariat (or service class)
II	Professional, administrative and managerial employees, lower grade; technicians, higher grade	2	Lower managerial and professional occupations	
IIIa	Routine non-manual employees, higher grade	3	Intermediate occupations	Intermediate white-collar
IV	Small employers and self-employed workers	4	Employers in small organisations, own account workers	Independents (or petty bourgeoisie)
V	Supervisors of manual workers; technicians, lower grade	5	Lower supervisory and lower technical occupations	Intermediate blue-Collar
VI	Skilled manual workers	6	Semi-routine occupations	Working class
IIIb	Routine non-manual workers, lower grade	7	Routine occupations	
VII	Semi- and unskilled manual Workers			

(Adapted from Goldthorpe, 2000)

In developing the employment relations schema, Goldthorpe divided theories of social stratification into models that focused on either class structure or social hierarchy. In this context, class structure refers to the social positions of workers as defined by their relations within the labour market. Alternatively, social hierarchy models refer to theories concerned with a single hierarchical dimension, such as prestige, social status or economic resources. Goldthorpe considered that the vertical dimension of upper and lower classes implicit in social hierarchical models did not properly represent the complexities of social structures. For example, the proprietors of small businesses, lower tier administrators and skilled industrial workers might have comparable positions in a social hierarchy but experience markedly different economic and technological challenges. Stratification by social class was preferred because classes were relatively homogenous groupings with similar resources and experiences.

The occupational groupings of the Goldthorpe schema and the associated NS-SeC classifications can be distinguished by their inherent vulnerability to socioeconomic stress in three principal domains, comprising economic security, defined as the risk of unemployment; economic stability, which is the variability in earnings; and economic prospects, or the profile of lifetime earnings. Class disparities in economic security are most obvious in rates of unemployment, with unskilled manual workers (Goldthorpe class VII) being around three times more likely to become unemployed than skilled manual workers (Goldthorpe class VI), who are in turn around two and a half times more likely to become unemployed than professional or managerial workers (Goldthorpe classes I&II) (Goldthorpe et al., 2004). Although modern employment law and welfare provision have led to a general improvement in economic stability, working class people are still more vulnerable to short-term fluctuations in their earnings than other groups. Even if they avoid unemployment and

impoverishment, working class families can still experience serious difficulties in budgeting and providing the essentials of daily living. The risks of unemployment and short-term loss of earnings have particularly damaging effects on working class people from which higher classes are generally protected, but variation in economic prospects is a long-term driver of inequalities that increases with age. The relationship between earnings and age generally follows a parabolic curve, with earnings rising as young people progress in the labour market, before levelling off in middle age and then declining. Up to their mid-twenties, class differences in earnings between young people are relatively small. As they enter their thirties however, the earning curves increasingly diverge. Earnings for workers in NS-SeC classes 6&7 tend to plateau in their early thirties, whereas NS-SeC classes 2, 3&5 continue to rise into until the late thirties before levelling out. NS-SeC class 1 rises sharply until the late thirties and then continues to rise more slowly into middle age, before declining after the mid-fifties (Goldthorpe, 2007).

1.11.2 The Goldthorpe schema and SRH.

The theoretical basis of the Goldthorpe schema and the related NS-SeC classifications have been used to examine the association between socioeconomic status and health. Studies of Swiss workers by Hämmig and colleagues (2013, 2014) offer an insight into the association between the conceptual foundations of the Goldthorpe schema and several conditions, including measures of SRH. Workers in lower-class occupations, graded by educational attainment and occupational position, reported poorer SRH and physical functioning, but less stress, than workers in so-called 'white collar' occupations. Consistent with this, workers higher in the Goldthorpe schema did not contribute to the class gradient in physical health, but explained disparities seen in mental health (Hämmig & Bauer, 2013). A further study found a strong association

between occupational class and SRH, which was primarily determined by risk factors associated with people in lower class occupations, including smoking, physical inactivity, obesity, poor posture, monotonous work and job insecurity (Hämmig et al., 2014). Poor working conditions among people lower in the schema have been found to explain inequalities in SRH. Occupational risk factors associated with poorer SRH among manual and clerical/service workers were primarily accounted for by biomechanical exposures and decision latitude (Murcia et al., 2012).

Research into UK health inequalities using the NS-SeC has found evidence for a non-linear association between socioeconomic status and health. Routine workers were found to have worse outcomes for most cardiorespiratory disease risk factors, but patterns varied by the type of factor and also by gender (Atherton & Power, 2007). In a study of the relationship between the job characteristics underlying the Goldthorpe schema (work monitoring difficulty and human asset specificity) and those underlying technological change (analytical and routine tasks) Williams (2017) found that although the Goldthorpe schema generally predicted membership of the NS-SeC categories, the dimension of asset specificity was partially confounded by analytical tasks, suggesting that the more advanced technical aspects of work that have traditionally characterised higher asset-specific occupations are increasingly being encroached upon by computerisation. Despite this reservation, the study found Goldthorpe schema provided a valid account of employment relations as they relate to inequality-producing processes.

To date, there have been no studies using the ICE to model NS-SeC data or concentrations of the Goldthorpe schema classifications in the UK and there have been no studies into the spatial concentrations of occupational classes in the North West of England (last search September 2021). This presents an opportunity to expand current

knowledge in the field by examining the utility of the ICE and gaining insight into the health of the region's population.

1.11.3 Rationale for use of ICE to examine the Goldthorpe schema

Studies of public health in the US have suggested that the ICE offer important methodological advantages over other commonly used measures of neighbourhood socioeconomic conditions (Krieger et al., 2018). This arises from ICE's ability to quantify the extent to which a neighbourhood's population are concentrated at the extremes of distributions, typically conceptualised as poverty and affluence (De Maio & Sengupta, 2016). The ICE can take a value of -1 to + 1; a value of -1 indicates that all of that community's population is concentrated in the 'most deprived' group, while a value of +1 indicates that all of that community's population is concentrated in the most privileged group. Further, the ICE can be modified to model novel indices for distributions of population characteristics other than poverty and affluence, such as educational attainment and racial/ethnic composition.

An important methodological strength of the ICE is that it can be used at the small-area level (e.g., LSOA or neighbourhood). Unlike commonly used metrics such as the Gini coefficient or the Index of Dissimilarity, it is not biased because of spatial social polarisation at the small-area level (Krieger et al., 2017; Krieger, Waterman, et al., 2016). Researchers have observed that when making observations across communities, there is a very high correlation between proportions of affluent and marginalized residents, raising problems of multicollinearity in statistical models that attempt to incorporate the percentages of both affluent and disadvantaged residents in the same equation. The ICE overcomes this problem by defining a spectrum of concentrated disadvantage and affluence, 'ranging from a negative extreme (where all families are disadvantaged) to a neutral point (where affluent and disadvantaged

families are equally balanced) to a positive extreme (where all families are affluent)' (Carpiano et al., 2009, p. 423). This makes the ICE a potentially effective measure for monitoring inequalities at the neighbourhood level.

In recent years an increasing number of studies have employed the ICE to quantify neighbourhood conditions and have demonstrated its association with health outcomes. Carpiano and colleagues examined the relationship between the ICE and child well-being in British Columbia. They proposed that the ICE 'not only allows for more precise estimation of the competing influences of concentrated affluence and disadvantage, but also facilitates examination of the potential impact of neighbourhood-level income inequality' (Carpiano et al., 2009, p. 420). Finch et al (2010) modelled the effects of the ICE on allostatic load score using the Third National Health and Nutrition Examination Survey (NHANES III) (Finch et al., 2010). The study operationalised deprivation based on the inequity in high school completion rates. It was held that 'the complex interaction and additional benefit that the well-educated receive from living in socioeconomically advantaged (i.e., educationally segregated) neighbourhoods would not be uncovered using traditional measures of poverty (Finch et al., 2010, p. 3). More recently, Krieger and colleagues (Krieger, Waterman, et al., 2016) examined the use of the ICE by deriving a novel ICE that jointly measured concentration of income as well as race/ethnicity as a public health monitoring tool in New York City and reported that the ICE is 'a metric that reveals, in a single measure, the extremes of selected social and economic relationships implicated in producing health inequities', (Krieger, Waterman, et al., 2016, p. 260).

The Goldthorpe schema forms the conceptual basis of the occupational categories used in the NS-SeC. The NS-SeC categories recorded in the national census data are enumerated by the Office for National Statistics and published at various levels

of geographical aggregation; in this case the data is aggregated at the LSOA level. It is this LSOA-level that was used to derive the ICE (ICE) used in this study. The ICE quantifies how people in a specified area are concentrated into the upper and lower groups of a specified societal distribution (Krieger et al., 2018). This study uses the NS-SeC data from the UK national census to derive two groups; salaried, higher status occupations and working class occupations. The spatial concentrations of the two groups on the ICE are then used to examine the association between occupation and SRH.

1.12 Research questions

The two overarching research questions for the study are as follows:

- What is the utility of using ICE metrics derived from employment relations compared to more traditional measures of deprivation represented by the IMD, for explaining relative spatial inequalities in SRH?
- Are employment relations as operationalised by occupational status better at explaining variations in SRH than more traditional measures of social deprivation?

1.13 Aims and Objectives

Historical research into health inequalities has generated a substantial body of evidence that demonstrates an association between socioeconomic status and health using a variety of variables, such as income or educational attainment. Much work in the field has also been concerned with those health inequalities associated with ethnicity and there is, for example, a significant literature on racial disadvantage in the US that has informed this study. However, relatively few studies have examined the association between spatial concentrations of different socioeconomic groups operationalised by

employment conditions and health status, and few of these were in the UK; a gap in the literature this study proposes to address.

The research questions were: what is the utility of using ICE metrics derived from employment relations compared to more traditional measures of deprivation represented by the IMD, for explaining relative spatial inequalities in SRH? Are employment relations as operationalised by occupational status better at explaining variations in SRH than more traditional measures of social deprivation?

This study proposes to expand the use of the Goldthorpe schema to the concepts of spatial concentration and spatial relationships by examining the question of spatial concentration of socioeconomic groups and health. Specifically, the study will examine the association between spatial concentrations of socioeconomic groups as defined by employment relations and health, both within the immediate neighbourhood and in the context of the surrounding area. There is evidence that the socioeconomic composition of the surrounding community can affect health. This study will seek to add to this evidence by examining the spatial concentration of the most advantaged and most disadvantaged residents in each LSOA, using NS-SeC census data to reflect employment relations as described by the Goldthorpe schema. Concentrations of residents with advantaged and disadvantaged occupational status at the LSOA level will be calculated by using the ICE. It is also of value to determine if spatial concentration of affluence or deprivation can explain health inequalities beyond the existing measures of deprivation that are routinely used in planning for health and social care provision. In fact, the study will examine if ICE allows a better representation of SRH than the UK government IMD.

The study focuses on the SRH in the North West region of England and its changes between 2001 and 2011 (corresponding to the census published by the UK Office for National Statistics). The initial objective is the systematic review. Once the context and extent of current knowledge is established, the study will then examine the association between concentrations of socioeconomic groupings as operationalised by the Goldthorpe schema-derived NS-SeC categories and SRH at the Lower Super Output Area (LSOA) level in NW of England. The ICE will be used to calculate the concentration of the National Statistics Socioeconomic Classifications (NS-SeC) occupational groups at the LSOA level. The study will then model the effect of concentration of socioeconomic groups in surrounding areas to determine if there is a protective effect on SRH of living in an area surrounded by like concentrations of socioeconomic peers or, conversely, if living in an enclave of concentrated higher or lower socioeconomic status surrounded by groups of differing status has a deleterious effect on SRH.

The study had the following objectives:

(i) To explore the spatial distributions of occupational status (using ICE), social deprivation (using IMD) and SRH.

(ii) To compare the spatial relationships between ICE and SRH with those of IMD and self-reported health.

(iii) To explore changes in the relationships between ICE and SRH and IMD and SRH between 2001 and 2011.

(iv) To investigate the effect of spatial concentration of occupational status on SRH.

CHAPTER 2: Literature review

This chapter reviews the literature on socioeconomic status and SRH. The introductory section gives an overview of current studies of health and place. This is followed by a systematic review, which opens with a description of the search methodology including inclusion criteria and quality assessment, before proceeding to a narrative synthesis of the selected studies. Evidence from studies using the ICE is presented. Conclusions of the systematic review are summarised at the end of the chapter.

2.1 Introduction: Geographies of health and place

There is a substantial literature investigating the relationships between health and place (Gatrell & Elliott, 2015) and a variety of place-based exposures have been linked with a range of physical and mental health outcomes (Diez Roux, 2001; Duncan et al., 1999; Richardson et al., 2015). Research has tended to focus on specific temporal or spatial risk factors, toxins or social features, with an emphasis on specific regions, neighbourhoods, networks or services (Prior et al., 2019).

Studies of health and place have examined the role of local context in influencing health and wellbeing, focusing on perspectives founded in a multi-scalar and social construction of life (Jones & Moon, 1993). This research was driven by a perceived need for a geography of health that would offer more socially informed discussions of health (Kearns, 1993). This new concern with health geography was seen as a progression from the previous field medical geography, that emphasised biomedical models focused on curative medicine and proximate causal explanations for illness (Philo, 2016). Medical geography had been criticised for its detached perspective, where context tended to be reduced to a spatial measure of location and uncritically operationalised as a 'container' for communities (Jones & Moon, 1993; Kearns, 1993). Much health geography research was concerned with the social

production of health inequalities (Kearns & Moon, 2002). The resulting awareness of the importance of place, and the structural systems that influence the lived experience of place, reflected an increased concern with mechanisms of social difference (Kearns & Moon, 2002). A concern with place therefore became a unifying theme in a model of health geography that reflected socio-ecological models, the active role of local context and the importance of lived experience (Kearns & Moon, 2002).

The development of health geography promoted a notable increase in studies of health and place. The context versus composition debate was a recurring theme, the question being whether any observed associations were the result of true contextual effects, or whether they were an expression of the characteristics of the individuals residing in that place. The increasing use of multilevel analytical techniques helped to inform this discussion by providing a means to simultaneously model data at multiple scales of analysis. Multilevel studies identified significant associations of areal or neighbourhood socioeconomic disadvantage with worse health outcomes. Contextual relationships were found for a broad range of health measures and behaviours, including: mortality (Bosma et al., 2001), SRH (Cummins et al., 2005), physical health (Voigtländer et al., 2010), limiting long-term illness (Malmström et al., 2001), cardiovascular risk factors and disease (Sundquist et al., 2004), mental health (Mair et al., 2008) and alcohol use (Matheson et al., 2012). Review studies have shown the consistency in associations of disadvantage with poor health over time and across study designs and contexts (Arcaya et al., 2016; Diez Roux & Mair, 2010; Pickett & Pearl, 2001; Riva et al., 2007; Schüle & Bolte, 2015). Although many of these studies use neighbourhood to refer to their local context, the relationships identified were active across a range of scales and are not restricted to the urban setting the description of neighbourhood traditionally connotes.

Despite the association between area disadvantage and poorer health is being widely acknowledged, inconsistencies still exist, with some studies not identifying statistically significant contextual variations and the size and nature of effects can vary considerably by the health outcome measured and the contextual measures utilised (Riva et al., 2007; Schüle & Bolte, 2015).

The context versus composition debate has been an important means by which researchers have tried to explain observed contextual associations. However, there is still a continuing debate in the search for a definitive understanding of the importance of place. The divide imposed by the context versus composition dichotomy has been criticised for failing to adequately the dynamic interaction of people and places (Cummins et al., 2007). Further, the debate has been found to encourage a tendency to concentrate on direct and independent area associations (Riva et al., 2007). In response to these concerns, researchers have been urged to explore the heterogeneous and multiscalar nature of health relations (Small & Feldman, 2012). Rather than continually searching for elusive overall effects, research addressing how different social and physical environments across the life course may variously impact the health of populations was called for (Macintyre & Ellaway, 2003).

Health inequalities have become a major driver of health research. Health (the ability to achieve a state of physical, mental and social wellbeing) is recognised as a fundamental human right (Marmot, 2010). Health inequalities which reflect social hierarchies and societal structures, are viewed as avoidable and unjust (WHO, 2006). The Dahlgren and Whitehead model of the social determinants of health is an influential framework for those aiming to assess health inequalities across academic and policy spheres (Bambra et al., 2010; Dahlgren & Whitehead, 2021; Whitehead & Popay, 2010). The model the factors important to health as concentric layers,

expanding from constitutional factors such as age and sex, to individual lifestyle factors, social and community networks, living and working conditions and the prevailing socioeconomic, cultural and environmental climate. This multiscale model emphasises the interdependence between the social determinants as they act in concert, with the separate layers viewed as discrete levels for public health policy interventions (Dahlgren & Whitehead, 2021).

2.2 Analysis of current knowledge of SRH and occupational classifications: a systematic review

There is a substantial body of evidence that neighbourhood conditions influence health (see for example (Krieger et al., 2016a). Further, there is evidence that the effects of spatial polarisation, operationalised as the concentration of deprived or affluent residents in a given area, are not confined to the immediate neighbourhood and that the socioeconomic composition of the surrounding area will also have an effect on local health (Humphris & Pemberton, 2016).

In recent years the labour market insecurity characteristic of working-class life has also come to affect more affluent households. Fast-changing labour markets means job insecurity has become a fact of life for workers in middle income occupations who now face a high risk of job transformation or automation. Further to this, there is evidence from studies across the industrialised nations of increasing competition for employment between socioeconomic groups, with professionals encroaching on traditionally middle class occupations, with such competition representing a potential source of societal pressures inimical to health (Nedelkoska & Quintini, 2018).

A search of the literature found that the spatial concentration of socioeconomic advantage and disadvantage has latterly become the subject of research interest primarily in the USA, where there several studies have focused on concentrations of

racial/ethnic and income disadvantage (Badland et al., 2017; Badland et al., 2013). Much of this work was concerned with child health, with some studies covering other physical and mental health conditions. This work has used a variety of metrics to assess socioeconomic status and health, but to date, no studies have used an employment relations model of socioeconomic status to examine the spatial concentrations of occupational groups and SRH in the UK.

2.3 Objectives of the systematic literature review

The research question being addressed in this systematic review is: what is the association between the spatial concentration of socioeconomic status and SRH? The literature review will examine the effects of concentrated affluence or deprivation defined by employment relations on SRH, both at

1. a neighbourhood level and
2. also where concentrations of affluence or deprivation in the surrounding area differ from the immediate locality.

The review will provide a narrative synthesis of evidence from studies on the association between social segregation, socioeconomic status, spatial concentration and also to review methodological issues relevant to the study.

2.4 Methodology for searching the literature

2.4.1 Development of key terms

The review uses the SPICE conceptual framework for defining research questions (Booth, 2006). SPICE is an acronym for Setting, Perspective, Intervention, Comparison and Evaluation. The SPICE framework was developed to improve question formulation by librarians engaged in evidence-based practice research and builds on the PICO framework: Population, Intervention, Comparison and Outcomes (Richardson et al., 1995). The use of SPICE is preferred over PICO in this study for

two principal reasons. First, the 'population' component of PICO is split into two parts: 'setting' and 'perspective', which allows for independent consideration of both the geographical context and the characteristics of the study population. Second, the 'outcomes' component is replaced with 'evaluation' in order to encourage a broader evaluation framework and incorporate concepts such as outputs and impact together.

In the context of this review, the SPICE framework has five features and these are operationalised in this review as:

- Setting: Industrialised societies.
- Population or perspective: Adults; employed and not employed.
- Intervention: Concentration of higher socioeconomic status.
- Comparison: Concentration of lower socioeconomic status.
- Evaluation: Relative difference in health status between higher and lower socioeconomic groups.

2.4.2 Inclusion and exclusion criteria

Table 2: Inclusion and exclusion criteria using the SPICE framework

SPICE features	Inclusion criteria	Exclusion criteria
Setting	Industrialised societies	Non-industrialised societies
Population or Perspective	Working age adults.	Children, adolescents, full-time students, unemployed or retired people.
Intervention (focus of the study)	Explicit measure of socioeconomic status.	
Comparison	Comparison of higher-status socioeconomic groups vs lower status groups.	
Evaluation	Inequalities in validated measures of health status.	No use of validated measures of health status.

(With acknowledgement to (Booth, 2006)).

Since the quantitative study will analyse census data from the 2001 and 2011 cohorts the systematic review will focus on studies published after 1990.

2.4.3 Search strategy

The following electronic databases have been searched: CINAHL, Medline, PsycInfo and Scopus. The choice of these databases was informed both by similar reviews in the field (see, for example Stuckler et al. (2017)) and also by the research questions. Papers identified by the online searches were manually searched for any relevant associated material and references of additional studies identified were checked.

Medical Subject Headings (MeSH) terms and free text combined using Boolean operators are used for the database searches. The search terms are grouped as per the following exemplar search strategy:

Material type = Articles; Language = English; Publication date = 01/01/1990 to present

Concept 1: Socioeconomic status

AND

Concept 2: Spatial polarisation

AND

Concept 3: SRH

AND

Concept 4: Methodology (ICE)

Concept 1

MESH: ("Socioeconomic factors") OR ("Social class")

Free text words in Title/Abstract: ("Socioeconomic status")

Concept 2

MESH: ("Social segregation") OR ("Urban population")

OR ("Urban spatial inequality")

Free text words in Title/Abstract: ("Spatial segregation")

Concept 3

MESH: ("Patient generated health data") OR ("Self-recorded health data")

OR ("Health status")

Free text words in Title/Abstract: ("self rated health")

Concept 4

MESH: (Methodology) OR ("Research methodology")

Free text words in Title/Abstract: ("Index of Concentration at the Extremes")

2.4.4 Critical appraisal

Included studies were assessed using the Canadian Effective Public Health Practice Project (EPHPP) evaluation scheme. The scheme provides a method that can test evidence in support public health inventions and research in a wide range of health-related topics, from family and sexual health to the treatment of chronic disease, injuries, and substance abuse. Ratings for each section are given as either 1 strong, 2 moderate or 3 weak according to the criterial in the accompanying data dictionary (Appendix A). The EPHPP tool was selected for this study because the categories in which studies are rated have been shown to be relevant to a variety of topics in health research and the tool has been shown to be valid in several areas of public health research, including chronic disease prevention, early detection of cancer, injury and

substance abuse prevention, sexual health, reproductive health, child and youth health and infectious disease (Festin et al., 2017; Thomas et al., 2004).

2.4.5 Data extraction

The included studies will be grouped by study design, population (census or survey), methodology and the textual summary compiled as part of the assessment process. The heterogeneity of the data and the variety of methodological approaches in the literature indicates that a narrative synthesis approach is appropriate (Rodgers et al., 2009). Narrative synthesis brings together multiple ideas and theoretical orientations and is useful in examining the similarities and differences between studies, as well as exploring themes that may emerge from the data. The findings of individual studies are described and evidence relevant to the review question are compared and contrasted. The final results of the systematic review are presented as follows:

- A summary table of studies included in the review (Appendix B). Data extracted was summarised under the following headings:

  Author & date of publication

  Geographical area of study

  Population studied

  Methodology

  Socioeconomic status measures used

  Health status measures used

  Outcomes

- A data quality appraisal of the selected studies using the Canadian Effective Public Health Practice Project assessment scheme (see below and Appendix C for summary of results and details of scoring).
- Discussion of the quality of the included studies.

- A narrative synthesis of the included studies.

The narrative synthesis section will use a descriptive analysis approach to combine findings across a range of studies, with the aim of:

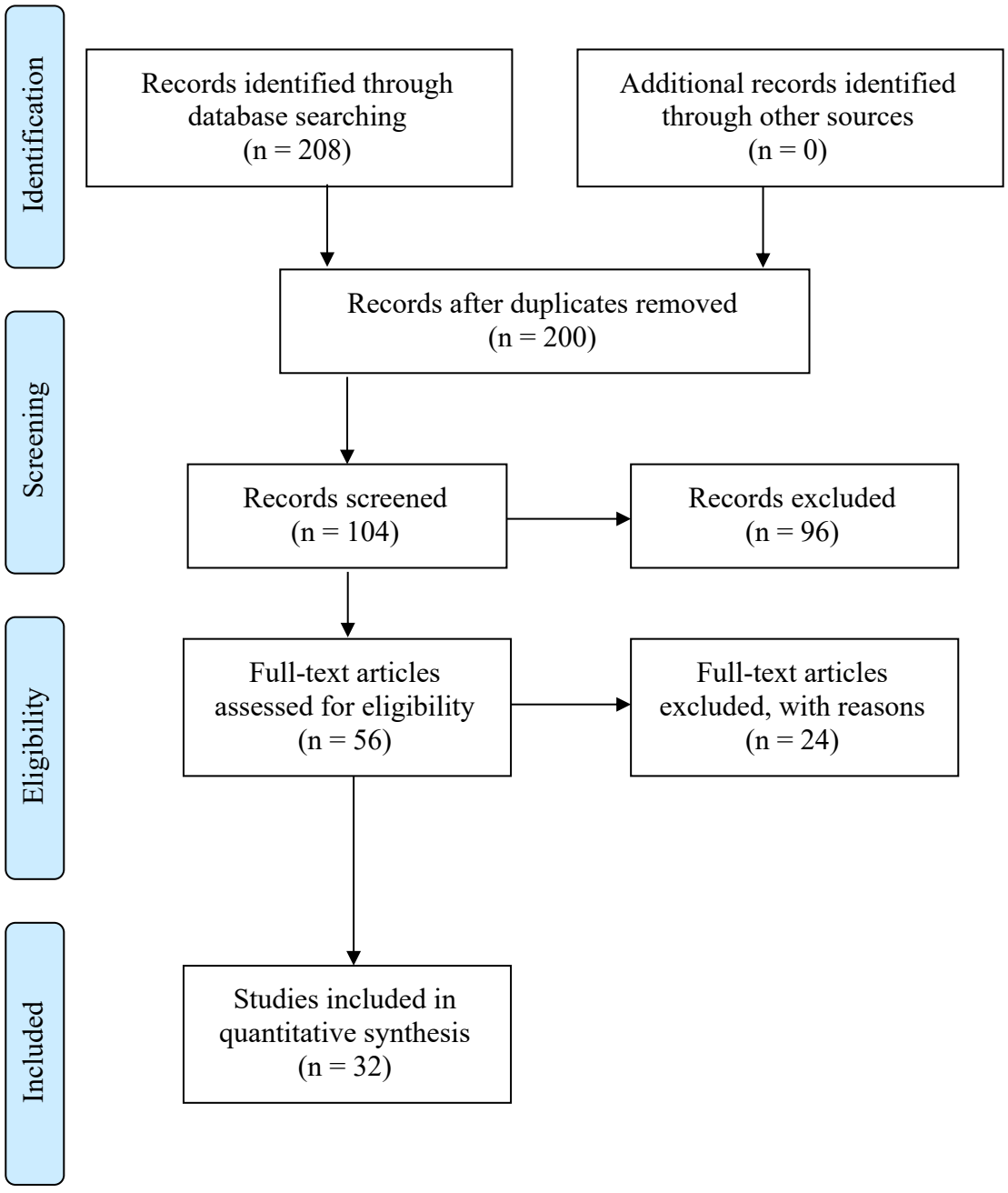
- (1) Review the findings of studies into the association of SRH and socioeconomic status as defined by employment relations, characterised by factors such as supervision and freedom to act;
- (2) Review studies on the association of spatial concentration of socioeconomic groups to understand how this affects SRH;
- (3) Identify and review examples of the use of the Index of Concentration at the Extremes (ICE);
- (4) Identify any studies using the ICE to examine SRH, either as the prime focus of research or in conjunction with other measures;
- (5) Review methodological issues in the study of spatial concentration to examine the contribution of the ICE beyond conventional measures.

Results of the search are summarised using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) format (Figure 3) PRISMA was developed to facilitate transparent and complete reporting of systematic reviews and has been updated (to PRISMA 2020) to reflect recent advances in systematic review methodology and terminology (Page et al., 2021).

2.4.6 Results of selection process

The selection process is summarised in a PRISMA flow diagram, below.

Figure 3: PRISMA 2009 Flow Diagram



2.4.7 Quality assessment using the Canadian Effective Public Health Practice Project (EPHPP) evaluation scheme

All the thirty-one selected studies were evaluated against quality standards of the EPHPP scheme (Table 3). The following summarises the collective ratings of the various scheme components (see Appendix A for a full breakdown of the EPHPP scheme standards and ratings). It should be noted that the EPHPP is used for studies into a diverse range of research questions and that not every item was significant to this study.

Table 3: Summary of study quality assessment using EPHPP evaluation scheme

EPHPP component	Summary of studies
Selection bias	All studies were rated very likely to be representative of the target population. Agreement to participate was high, with twenty-five studies (80.6%) reporting participation rates of 80-100% and five studies (16.1%) with rates of 60-79%. The assessment was found to be not applicable to one study (3.3%). Overall, this component was rated strong.
Study design	All but one of the studies (96.8%) were of cohort (pre & post) design. The remaining study used a time series design. One study was described as randomised, with an appropriate method of randomisation described. This section was rated moderate overall. Specifics of design were not reported in all studies, so although satisfying the general EPHPP requirement, this component was rated moderate overall.
Confounders	All studies identified important differences between groups, with most (80% - 100%) of confounders controlled in either design or subsequent analysis. This component was rated strong overall.
Blinding	The study designs, primarily using secondary source data, meant that researchers were aware of the intervention or exposure status of participants in all cases. However, study participants were aware of the research question in only one case. The lack of specific details of the blinding protocol in every case resulted in an overall rating for this component of moderate.
Data collection methods	Data collection tools were shown to be valid and reliable in all cases. This component was rated strong.

Withdrawals & dropouts	The extensive use of secondary source and survey data meant this was not applicable in twenty-four studies (77.4%). All seven studies where this assessment was applicable reported withdrawal and dropout rates. Completion rates were high, with twenty-seven studies (87.1%) reporting 80-100% completion and three studies (9.7%) reporting 60-79% completion. This component was rated strong overall.
Intervention integrity	Participants received the allocated intervention or exposure of interest in all studies. The consistency of the intervention was clear in all but two studies. No studies showed the likelihood that subjects received an unintended intervention (contamination or co-intervention) that may have influenced the results. The overall rating for this section was strong.
Analysis	In call cases the statistical methods were appropriate for the study design and the analysis was performed by intervention status. The overall rating for this section was strong.

(With acknowledgement to EPHPP).

2.5 Narrative synthesis

2.5.1 Introduction

This literature review will examine evidence for the association between socioeconomic status, work characteristics and SRH. Public health research into spatial concentration using the Index of Concentration at the Extremes (ICE) will also be reviewed.

This study follows the World Health Organisation definition of Public Health as 'the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society' (Acheson, 1988). Activities to strengthen public health capacities and service aim to provide conditions under which people can maintain to be healthy, improve their health and wellbeing, or prevent the deterioration of their health. Public health focuses on the entire spectrum of health and wellbeing, not only the eradication of particular diseases. Many public health activities are targeted at populations such as health campaigns. Public health services may also

include the provision of personal services to individual persons, such as vaccinations, behavioural counselling, or health advice. (WHO, 2021).

Typically, the monitoring function of public health practice is concerned with characteristics at the individual or household level such as income or education, with race or ethnicity also prominent in many US studies. Health status is typically compared between groups on the basis of such characteristics. However, the geographical concentration of affluence and deprivation has received relatively little attention from public health monitoring systems.

A study by Hertzman, Power and colleagues (2001) proposed that the social determinants of health can be aggregated at three levels. At the national level, the principal determinant of health is per capita income and the equity of its distribution. Below, at the intermediate level of civil society, determinants of health include social affiliation, trust and social cohesion. Psychosocial work characteristics are also construed as a component of this level. Finally, there is the individual level, which comprises personal factors such as social support and the quality of interpersonal relationships. The authors examined the influence of national, civil society and personal level determinants on SRH. The civil society level was the most predictive, with psychosocial job strain and social trust most strongly protective of SRH, even after adjustment for educational attainment and current material circumstances. Job insecurity also predicted SRH after controlling for educational attainment. Personal-level factors such as social support were only weakly predictive of SRH.

Although health inequalities can usefully be identified and measured by comparing groups on the basis of socioeconomic factors, this approach carries an inherent risk that the prevalence of health problems among deprived groups becomes the focus of monitoring, with more affluent groups serving merely as reference

populations. The contribution to inequalities made by problematic societal relations between groups is therefore not measured and may go unnoticed. Further, not all questions of interest can be framed at the individual or household level. An issue of particular concern to modern public health practice is the increasing degree of spatial social polarisation, with high income societies increasingly developing concentrations of affluence (Chambers et al., 2019).

2.5.2 Socioeconomic status and SRH

Socioeconomic position has been found to be a major determinant of ethnic health inequalities in SRH (Badland et al., 2017). Using data from the Health Survey for England (HSE) between 2003–2006 Mindell et al. (2014) found that a composite socio-economic measure of educational attainment, income and economic activity predicted inequalities in SRH between minority ethnic groups and the white British population. The study disclosed the complex relationships between socio-economic factors. Many minority ethnic groups receive lower incomes than their White British peers within the same occupational class or education level and employment rates tend to be lower. This suggests the importance of using multi-dimensional measures of socio-economic status as single domain measures risk underestimating the fact of socio-economic disadvantage.

Socio-economic status predicts SRH throughout the life course. In a study of working age populations in the USA, UK, Germany and Denmark, Sacker et al. (2011) found that individuals of higher socio-economic status, using a composite measure of educational attainment employment status and income, were more likely to report better SRH throughout their working lives. However, socioeconomic status better predicted an individual‘s initial baseline measure of SRH than it predicted changes in SRH over time.

Although SRH has been shown to be a valid predictor of mortality and morbidity in a variety of populations, there has been only limited research that has examined if the concept of SRH is interpreted consistently across socio-economic groups. SRH encompasses multiple dimensions of physical and mental health, and it is possible that perceptions of what constitutes good health will vary between groups. For example, expectations of health and the relative importance of physical and psychological well-being might vary between groups. The presence of systematic differences in the interpretation of SRH would obviously undermine its utility in comparing socioeconomic groups.

A study of participants in the Canadian community health survey examined relative differences in factors associated with SRH across socioeconomic groups as defined by education and household income (Smith et al., 2010). The association between SRH and a broad range of physical and mental health variables including physical health status, mental health status, health services utilisation, and health behaviours, was found to be consistent across socioeconomic groups, where these were defined by either educational attainment or income.

As described above, the relationship between social inequalities in health is mediated through both compositional (individual-level) and contextual (area-level) factors. In seeking to explain the interaction between these factors, Macintyre et al. (2008) proposed the deprivation amplification argument, in which compositional and contextual effects compound. Essentially, individuals of low socioeconomic status who live in deprived areas are exposed to a double disadvantage, conversely there is evidence of a 'raising up' effect for those with low socioeconomic status living in more advantaged areas. When matched by socio-economic status those living in less deprived areas have better health than those living in more deprived areas. Historically,

compositional factors were considered to be more important than contextual factors in explaining health outcomes. However, more recent work has suggested that the association between contextual factors and health is stronger than was previously understood, but varies by the geographical level of analysis, types of health outcomes and area-level exposures (Badland et al., 2017).

In a study of 10,932 adults living in Brisbane, Australia, Badland et al. (2013) found evidence of an effect of deprivation amplification on SRH. Residents of lower income households were doubly disadvantaged if they lived in less affluent neighbourhoods. This inequality in SRH attenuated for lower income residents in more affluent areas. Neighbourhood-level disadvantage was associated with SRH after controlling for compositional variables, including age, gender and educational attainment. There was evidence of a neighbourhood-level protective effect, in which those with the lowest household incomes living in more affluent neighbourhoods had a similar probability of excellent SRH as those with the highest household incomes living in the most deprived areas.

2.5.3 Occupational class, work characteristics and SRH

Numerous studies have demonstrated that SRH is influenced by socioeconomic and psychosocial factors such as socioeconomic status deprivation, and social support, but employment characteristics have received relatively little attention.

Income inequality is highly correlated with socioeconomic segregation. In regions with greater socio-economic segregation, we would expect to find a wider range of deprivation and affluence and larger neighbourhood effects on health than in less segregated regions. Using employment grade as a measure of socio-economic position, Stafford et al. (2004) compared neighbourhood variations in self rated health between cohorts of public sector workers in London and Helsinki. Income inequality and the

spatial separation of residents of higher and lower socioeconomic positions were both greater in London than in Helsinki. Between neighbourhood differences in SRH were also greater in London, which was characterised by large variations in health over small distances. The study attributed these findings to spatial isolation, which served to deny residents access to employment and amenities. It was also suggested that the spatial separation of residents may have emergent effects; at a certain level the concentration of disadvantaged residents may begin to affect their neighbours regardless of their own characteristics.

The social gradient in employment status has been found to make a significant contribution to the social gradient in SRH. Using data on 698,880 people of working age from the 2001 UK census for England, Popham and Bambra (2010) found prevalence differences in SRH were reduced by 50% or more after adjusting for employment status. Worse ratings of self rated health were found amongst people who were unemployed or economically inactive regardless of their socioeconomic status. Taken together, unemployment and economic inactivity contributed up to 81% of the excess in self-rated poor health amongst lower social economic groups.

Educational attainment, occupational class and income are probably the most commonly used indicators of socioeconomic status in studies of health inequalities (Pensiero & Schoon, 2019). Each of these indicators are likely to represent common effects of social hierarchy on health. Educational attainment provides formal qualifications that determine socioeconomic status through occupation and income. Occupational class indicates social status and reflects the material conditions related to employment. Income is derived primarily from employment and provides the resources necessary to maintain good health (Lahelma et al., 2004).

Lahelma et al. (2004) proposed that education, occupation and income constitute a pathway in which education determines occupational class, which in turn determines income, which ultimately affects health. In a study of 6,243 employees of the city of Helsinki, Finland, education, occupation and income all showed a clear gradient with SRH. However, the indicators were not found to be completely independent. Educational attainment made the biggest contribution to inequalities in SRH after adjustment for occupational status and household income. More than a third of the variance in these inequalities was mediated through occupational class and only a small part through income. Just over half the inequalities and SRH by occupational class were explained by education and the small part mediated by income.

Research into the effects of job demands and job control has shown a consistent association with health and well-being. Job demands describe the amount and rate of work. Job control is operationalised as the extent to which an employee can make decisions about when and how they perform their work and also the extent to which their work requires them to use and develop their skills. Poor job control is a common characteristic of low status occupations. The combination of high job demand and low job control is termed job strain and this has been linked to a range of mental and physical health problems (Smith et al., 2008).

Although the association between job control and health is biologically plausible and has been observed in various socio-economic groups, there has been a debate as to whether job control is directly associated with poor health status, or if it is moderated by other factors (confounders). Studies have found that the association between psychosocial working conditions and the risk of coronary heart disease, cardiovascular mortality and psychological distress persists after controlling for measures of material deprivation (Rahkonen et al., 2006). Rahkonen et al. (2006)

studied 8,970 employees in Helsinki, Finland, examining the effect of working conditions on the association between occupational social class and SRH. Data from the Helsinki health study (2000-2002) was grouped into four categories: managers and professionals, semi-professionals, routine non-manual workers and manual workers. Consistent with the Goldthorpe schema, the categories were principally based on education and income, but also included an element of social prestige. Categorisation of non-manual workers was based on competence requirements and supervisory status as well as on education. Psychosocial working conditions followed the conventional framework of job control and job demands. The study also found evidence that the effects of working conditions and social class on SRH are to a large degree independent and have distinct effects. Lower social class occupations were associated with poorer SRH. Further analysis for job control and job demands found both lower control and higher demands to be strongly associated with poorer SRH. However, controlling for job control attenuated the relationship between social class and self rated health, but controlling for job demands reinforced the relationship, possibly because high job demands were more common in higher status non-manual occupations.

A study of the self-rated physical health of 22,012 employees of a manufacturing company in Michigan, US, found evidence of an association between employment relations and SRH (Sathyanarayanan et al., 2012). Compared to salaried employees, hourly paid employees had 26% lower odds of reporting better physical health. The study also considered the effects of neighbourhood deprivation and found poorer levels of physical SRH for hourly paid employees compared to their salaried peers at low moderate and high levels of deprivation.

Pikhart et al. (2001) examined the association between the psychosocial work environment and SRH in economically active population samples in four countries in

central and Eastern Europe. The psychosocial work environment was conceptualised using two models; the model comprising job demand, job control and support at work proposed by Theorell and Karasek (1996) and the model of effort reward imbalance proposed by Siegrist et al. (2004). This model is concerned with the imbalance between higher effort and lower reward at work where rewards involve money, status and career opportunities, including job security. Higher levels of effort reward imbalance were strongly associated with poor SRH and this model was found to be a much stronger predictor of SRH than the demand/control/support model. A path analysis of data from the Canadian national population health survey (NPHS) found that other factors associated with low socio-economic status did not attenuate direct and indirect effects of job control on health (Smith et al., 2008). Other factors associated with lower socio-economic status such as environmental stress and income only attenuated the effects of job control to a small degree. This effect was consistent across different educational groups.

Employment frustration, operationalised as the inability to find the type of work one wants, has been found to be associated with lower levels of both self-rated physical and mental health. Employment frustration typically occurs when an individual's level of training knowledge or qualifications is undervalued. this has been shown to be particular problem for a migrant communities, especially where language difficulties prevent individuals from finding their preferred employment (de Castro et al., 2010).

The growth of casual or insecure employment has resulted in increasing job insecurity for many sections of society. Job insecurity involves both the threat of job loss and uncertainty regarding prospects of future employment. A study by D'Souza et al. (2003) found that the threat of unemployment has been associated with adverse health outcomes including poor SRH, depression, anxiety and serum cholesterol levels.

Job insecurity has been found to be strongly associated with SRH, anxiety, depression and physical health, including physical functioning and pain. These associations remained after adjusting for gender, marital status, education, employment status, major life events and negative affectivity. The association was most pronounced for SRH and depression. High strain jobs were also associated with adverse outcomes for SRH, anxiety and depression. Controlling for gender, marital status, education, employment status, major life events and negativity reduced these associations slightly particularly for physical health and SRH but strong associations remained for high job strain and mental health problems.

Employment insecurity may also have an indirect effect on the life and health of individuals. Living in a household where at least one other person was either unemployed or engaged in informal work was associated with poor SRH after controlling for individual factors and the socio-economic characteristics of the household (Giatti et al., 2008). In a further study Giatti et al. (2010) examined the moderating effect of neighbourhood influences on the SRH of unemployed people. No association was found between SRH and neighbourhood conditions. However, there was no evidence that neighbourhood conditions affected the association between unemployment and poor SRH. This is possibly due to the centrality of work in adult life, in which the impact of unemployment outweighs neighbourhood context (Stafford et al., 2004). But it is also possible that the financial or psychosocial consequences of unemployment have a different impact on the health of unemployed individuals regardless of neighbourhood conditions.

2.5.4 The ICE and health

The spatial concentration of disadvantage not only exacerbates poor health but might serve to perpetuate it for generations. For any given number of poor families in a

society, a more concentrated residential distribution will result in more people living in poor neighbourhoods. In such circumstances physical and mental health may both be undermined. While the precise extent of these effects is subject to debate, it is clear that living in economically deprived neighbourhoods, rather than in middle-class or better neighbourhoods with good schools, access to good quality employment and to other public amenities is harmful to health. For this reason, the spatial distribution of poverty has been an ongoing concern of economists, sociologists, political scientists, and urban planners (Jargowsky, 2013). The ICE offers an effective tool to examine these issues by combining measures of the spatial concentration of both poverty and affluence in a single metric.

Massey's (1996; 2001) Index of Concentration at the Extremes has been found to be an effective tool in assessing the association between socioeconomic conditions and health, with several studies using ICE measures of established risk factors, such as race/ethnicity and income deprivation. Much of work has demonstrated a stronger association between novel composite ICE measures that combined dimensions such as education, poverty or ethnicity and health than for individual measures, such as poverty, alone.

Several studies in the United States have used the ICE to examine the association between neighbourhood social conditions and poor birth outcomes. Measures of income have commonly been combined with measures of racial segregation to assess the effect of combined racial/ethnic and economic segregation across a continuum of neighbourhood affluence and deprivation. For example, Carpiano et al. (2009) used the ICE to examine the effects of concentrated neighbourhood affluence on Canadian pre-school children using the Early Development Instrument (EDI), which is a holistic measure of readiness for school.

Concentrations of affluence were generally associated with better preparedness for school. For four EDI subscales (physical, social, emotional and communication) but not language, and also the total score, there was evidence of a significant curvilinear association in which the highest ratings were not found in neighbourhoods with the highest concentration of affluence, but were instead found in neighbourhoods where concentrations of affluence and deprivation were relatively even. This suggests that concentrated affluence might have a diminishing rate of return for child development and that living in mixed-income neighbourhoods might be more beneficial. Possible explanations for this effect might involve the presence of services and organisations intended to support low-income families benefitting all residents of mixed-income neighbourhoods. It is also possible that presence of wealthy residents represents a willingness to invest in public institutions, increasing the stock of social capital to the benefit of all residents. In any event, it is important to take the possibility of a non-linear association into account in research using the ICE.

In a study of New York city census data, Krieger, Waterman, et al. (2016) developed an ICE derived from a combination of race/ethnicity and income data consistently predicted the greatest Risk Ratio for infant mortality, premature mortality (deaths before the age of 65) and diabetes mortality. The combined race/ethnicity and income ICE demonstrated better predictive value than for measures of poverty alone.

Krieger et al. (2017) used the ICE to evaluate the contribution of local racial/ethnic and economic residential segregation to public health monitoring in a study of inequalities in premature mortality and preterm birth in Boston, USA. The study demonstrated the scalability of the ICE by examining health inequalities at two geographic levels; the fifteen city neighbourhoods defined by the Boston Public Health Commission and the smaller census tract level, comprising one hundred and seventy

localities with populations above one hundred residents. One of the assumptions examined by the study was that the smaller-area census tract data might be more sensitive to health inequalities than the neighbourhood level data, and there was evidence to support the value of smaller geographies in a number of findings. The ICE disclosed health inequalities for premature mortality and preterm birth at both geographical levels. However, steeper gradients were observed at the census tract level than at the neighbourhood level. Regression model-predicted rates for both preterm birth and premature mortality using the ICE for measures of income and the US census-defined threshold measure of poverty, adjusted for family size, were closer to observed rates at the census tract level than at the neighbourhood level.

The ICE was used to examine structural racism in preterm birth and infant mortality for African-American women in California, USA (Chambers et al., 2019). The study treated local measures of racial and economic segregation as proxies for structural racism, using ICE measures for race, income and race/income combined at the zip code level. African American women were found to be most likely to live in zip codes characterised by greater extreme income concentrations and moderate concentrations of race and race/income using the ICE. Women living in the most deprived quintile of the combined ICE for race/income were significantly more likely to experience preterm birth and infant mortality than those living in the most affluent quintile. After adjusting for maternal characteristics, the ICE for income, race and race/income remained significantly associated with preterm birth. However, only the race and race/income ICE retained a significant association with infant mortality.

The ICE was also used to examine similar issues of birth equity for African American women, using census tract-level data for a single county in Michigan, USA (Wallace et al., 2017). After controlling for maternal poverty, and maternal

characteristics including race, education, age, marital status, smoking and health insurance, the study found a strong correlation between the ICE and infant mortality. The odds of death among infants in the most extremely deprived ICE quartile were 70% higher than for those in the most affluent ICE quartile. It was also found that for the most deprived quartile, African American infants had approximately double the risk of mortality compared to white infants. In a related study, Wallace and colleagues examined the association between a combined racial and economic ICE measure and the major categories of infant mortality (Wallace et al., 2019). Although this study supported the previous findings of an adverse effect of concentrated economic disadvantage on infant mortality in the African American community in comparison to white residents, the pattern of associations varied by cause of death. It was found that the combined ICE was significantly associated with deaths due to preterm delivery and associated causes, but not with deaths due to congenital abnormalities. This disparity was attributed to the adverse physiological effects of social inequality experienced by women living in neighbourhoods of concentrated disadvantage.

A study of preterm birth and infant mortality in New York City, USA, assessed the ICE both as a measure of child health and also evaluated its utility compared to conventional measures of neighbourhood poverty (Huynh et al., 2018). Consistent with other studies in this field, ICE measures were calculated at the census tract level for income, race/ethnicity and a combined income/race/ethnicity index. Women in the most deprived areas were more likely to experience a preterm birth or infant mortality than women in the most affluent areas. This association remained for all measures of the ICE after adjusting for covariates. In comparison, a conventional measure of high neighbourhood poverty was associated with preterm birth only.

In addition to conventional cross-sectional analysis, the ICE has also been used to provide a life-course perspective on birth outcomes. In a study of the intergenerationally linked records of 379,794 California-born primiparous mothers and their infants Shrimali et al. (2020) used ICE measures of income, race/ethnicity and a combined income/race/ethnicity measure to examine the association between early childhood and adulthood experiences of concentrated neighbourhood privilege and subsequent preterm delivery. The combined ICE measure for income/race/ethnicity was significantly associated with preterm delivery in both early childhood and adulthood. African American and Hispanic women had a higher risk of preterm delivery than white women after adjusting for individual level confounders. Adjustment for the ICE income/race/ethnicity measure for the early childhood and adult periods resulted in the greatest decline in disparities for these groups.

Several studies have offered evidence for the value of the ICE in examining associations beyond child health. The ICE was used to examine the association between spatial concentration and hypertension in two cohorts taken from population-based observational cross-sectional studies conducted in Boston, Massachusetts (Feldman et al., 2015). Use of the ICE found lower rates of hypertension for spatial concentrations of white residents compared to black residents after controlling for age, gender, body mass index, household income, education, and self-reported experience of racial discrimination. Strong associations with hypertension were found for ICE measures that compared concentrations of affluent white residents with low-income African American residents.

Krieger, Singh, et al. (2016) demonstrated the importance of segregation for understanding how group relations contribute to inequalities in cancer outcomes in a study of oestrogen receptor status for women diagnosed with primary invasive breast

cancer using a cohort from the US Surveillance, Epidemiology and End Results (SEER) programme. ICE measures for income quintile and race/ethnicity were calculated, as well as a combined ICE for income and race/ethnicity. The study found that areas with a greater concentration of higher income white women on the ICE were associated with a more favourable oestrogen receptor status on average compared to those with a greater concentration of lower income black women.

2.5.5 The ICE and spatial patterning

The utility of the ICE at different geographical levels was assessed in a study by Krieger and colleagues that compared mortality at the census tract and city/town levels in Boston, USA. Using the ICE for income, race/ethnicity and a combined measure of income and race/ethnicity, it was found that the ICE for income had a stronger association with mortality than a conventional measure of poverty. This association was stronger for the combined income and race/ethnicity ICE. Multilevel analysis found associations between the ICE measures and mortality were typically stronger at the census tract level than those seen at the city/town level, although with mixed evidence (Krieger et al., 2018).

The ICE has also been used to examine the link between the spatial patterning of social vulnerability and environmental pollution. The association between exposure to black carbon, a traffic-related atmospheric pollutant, socioeconomic disadvantage and race/ethnicity was studied at the census tract level in Boston, USA (Krieger et al., 2015). The study found an inverse association between extreme concentrations of socioeconomic advantage and exposure to black carbon, even after controlling for individual and household characteristics. This association was stronger for the ICE measure of income than the ICE for race/ethnicity. The ICE measures for income and

race/ethnicity were both more strongly associated with black carbon exposure than were individual level socioeconomic characteristics.

2.5.6 The ICE and spatial concentration

Implicit in much of the research to date is the assumption that the adverse impact of spatial concentration on health is consistent across metropolitan areas, regardless of neighbourhood context. However, concentration is a complex multi-dimensional construct and it may in fact have a positive effect on health for some groups depending on local conditions. For example, a protective effect of ethnic concentration was found in a study of birth outcomes in neighbourhoods with a high concentration of African-American residents where these were contiguous with other neighbourhoods with a like ethnic composition (Bell et al., 2006).

Ethnic concentration has also been shown to have a protective effect for white metropolitan populations. Do et al. (2017) found a significant association between segregation and poor SRH among African American residents of impoverished neighbourhoods, but no such association was found for white residents.

2.6 Systematic review: summary of conclusions

2.6.1 What is known about the ICE and SRH:

The systematic review shows evidence of the utility of the ICE, in that it is straightforward to calculate and has shown practical applications in the study of a range of variables (Bannigan & Watson, 2009). The ICE has also shown good construct validity in that it correlates with the construct under investigation in all the studies reviewed (Polit & Beck, 2004) and has been shown to be a reliable measure of segregation that has contributed to the study of health inequalities by allowing an understanding of the association between spatial concentrations of socioeconomic disadvantage and health. Studies of communities in the US using ICE indices of

income, ethnicity, educational attainment and other measures have consistently been shown to predict conditions ranging from child health to cancer, cardiovascular disease and exposure to pollution. Several of these studies have shown that a composite ICE using combinations of risk factors, for example, ethnicity and income have shown better predictive value than single factors alone. Use of the ICE at both the city and census tract levels has shown that the ICE is scalable and has produced evidence of a link between spatial concentration and health at various levels of geographical analysis.

2.6.2 What is still not known about ICE and SRH

Studies using the ICE have all been carried out in the US. The socioeconomic factors studied, such as ethnicity, income and educational attainment are well established predictors of health, but societal conditions in the UK may not be the same and might produce different effects. It remains to be seen if neighbourhood conditions in the UK will result in findings comparable to the US.

Although the ICE has been used to examine a variety of socioeconomic risk factors that are associated with employment status, such as income, it has never been used to analyse employment relations as they are construed by Goldthorpe and operationalised in the NS-SeC categories recorded in the UK census.

There remains the question of a potential protective effect of concentration of occupational groups, such that neighbourhood concentrations of lower status residents might actually experience better SRH. The systematic review identified several studies where concentrations of disadvantaged residents were associated with diminished neighbourhood health, but the possibility of a protective effect of concentrated disadvantage was not explicitly addressed.

2.6.3 How the findings of the systematic review will support the quantitative analyses

The LSOA was designed from the outset to be used in population research and has become a common geographical aggregation unit for health inequality studies. Evidence from those studies in the systematic review that used analogous geographies, such as US census tracts, suggests that the LSOA is a good proxy for neighbourhoods and these findings will inform the analysis.

Evidence from those studies applying the ICE to small area geographies suggest that it is a useful metric for the analysis of health at the neighbourhood level. Those studies that applied the ICE to wider areas, such as city or county level, demonstrated the scalability of the ICE to other geographies. These findings will inform the analysis of local and regional associations between the NS-SeC occupational categories, the ICE, the IMD and SRH.

Evidence from the US studies included in the systematic review suggests that neighbourhoods with higher concentrations of working-class residents compared to salariat residents on the ICE will have worse SRH. Conversely, neighbourhoods with higher concentrations of salariat residents compared to working class residents should have better SRH. However, it is possible that the degree of this association may be different in the UK and this will considered at the LSOA level of analysis.

Finally, findings from the US studies suggest comparisons of a novel ICE based on occupational type vs. conventional measures of disadvantage represented by the IMD will be instructive. This evidence will inform a consideration of the predictive value of the ICE.

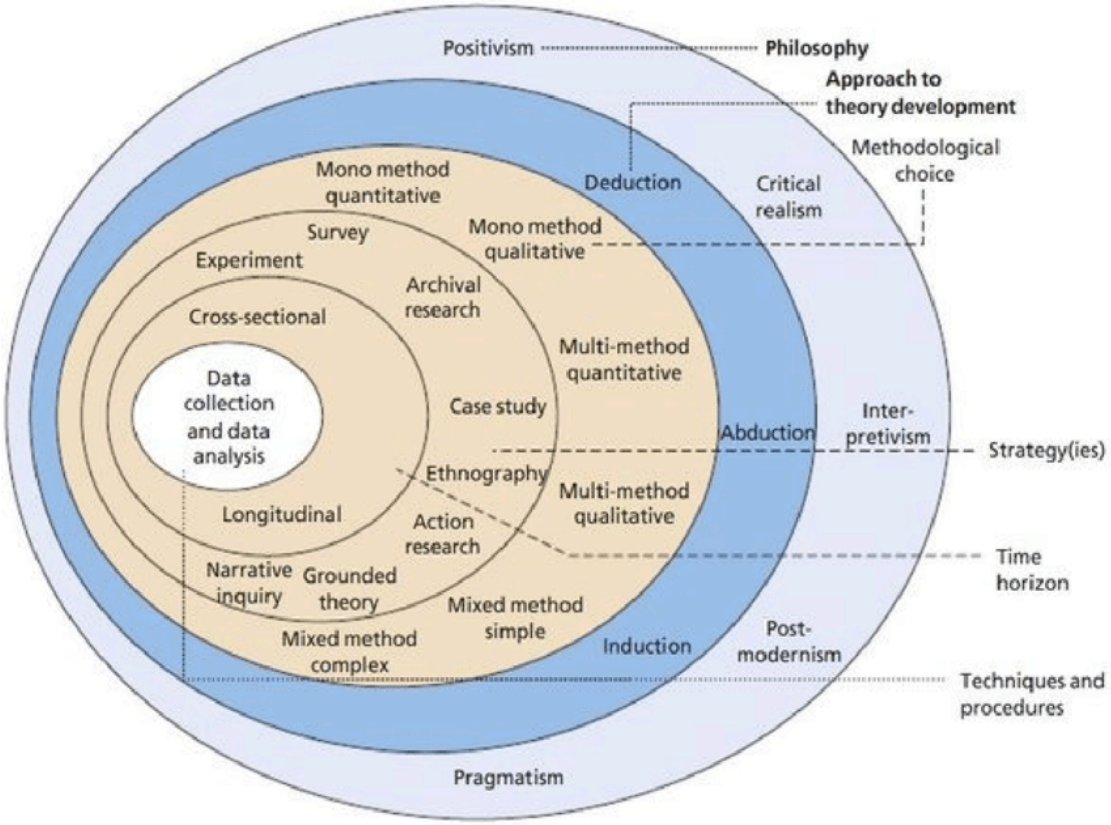
CHAPTER 3: Data & Methodology

Methodological considerations and the choice of data to address the research questions are described in this chapter. The philosophical approach is framed by the use of Saunders' research onion model (Saunders et al., 2007), before a discussion of the analytical challenges inherent in spatial segregation research. A detailed description of the 2001 and 2011 census data used in the study is provided. The chapter closes with an overview of the statistical methods used to analyse this data.

3.1 Philosophical positioning of the study

Development of the research methodology for the study was informed by the work of , which has become known as the research onion (Saunders et al., 2007). The research onion provides an effective progression through which a research methodology can be designed. Its usefulness lies in its adaptability for almost any type of research methodology and can be used in a variety of contexts (Bryman, 2016). The research onion comprises six layers: research philosophy, approach, strategy, choices, time horizon, and techniques and procedures. This section sets out the various options and decisions taken at each level of the onion.

Figure 4: Saunders' research philosophy 'onion' model



(Reproduced with acknowledgment to Saunders et al. (2007)).

3.1.1 Research philosophy

This level constitutes the foundation of the study and describes the set of beliefs underpinning the research. The onion offers five principal research philosophies: positivism, critical realism, interpretivism, post modernism and pragmatism. The positivist philosophy views knowledge as external to that which is being studied. Knowledge is gained objectively and does not include personal viewpoints or opinions. Positivism holds that there is one reality, and that meaning is consistent between all participants. From a positivist perspective, knowledge is only acquired through empirical research, which is based on observation and measurement. Critical realism is a philosophy founded in epistemological relativism, in which knowledge is held to be historically situated and transient. Facts are social constructions, to which historical causal explanations are contributory factors. Interpretivism emphasises the influence of social and cultural factors on the individual. This school of research philosophy is concerned with people's thoughts and ideas in the context of the sociocultural setting. Within the interpretivist philosophy, researchers play an active role, deriving a holistic view of research participants and their actions, thoughts and meanings. Post modernism is predicated on the concept that what is understood as 'truth' and 'knowledge' is decided by dominant ideologies. There is often a focus on absences, silences and oppressed/repressed meanings, interpretations, and voices. Consideration of power relations and the challenging of dominant views are also important to the post-modernist approach. Finally, pragmatism approaches research from a practical point of view, where knowledge is not fixed but is instead constantly questioned and interpreted. For this reason, pragmatism involves an element of researcher involvement and subjectivity, particularly when drawing conclusions based on participants responses and decisions.

Pragmatism seeks to use the best research tools available and is not committed to, or limited by, any one specific philosophy.

This study is based on positivist philosophy. The study uses empirical research methods to observe and measure changes in census data. Methods are used to derive a posteriori knowledge, which is not reliant on subjective interpretation.

3.1.2 Research approach

The next layer of the research onion is concerned with the research approach. This comprises the broader methodologies used for research; inductive or deductive. Inductive approaches generate theories from research, rather than beginning a project with a foundational theory. Deductive approaches begin with the theory and aim to test or develop it through research.

The key elements to be considered in selecting a research approach are the concepts of qualitative and quantitative research. Qualitative research commonly employs textual, visual or audio-based data while quantitative research focuses on numerical data. The inductive approach normally involves qualitative research methods, while quantitative research tends to reflect a deductive approach and is usually informed by positivist research philosophy. Quantitative research typically begins with an established theory as a foundation and makes progress through hypothesis testing. Essentially, a wider theory is applied to a particular context or observation to determine if these are consistent with established understanding.

This study uses a deductive, quantitative approach to test a hypothesis based on existing theories of socioeconomic status and health. The results will be analysed to examine the relationships between the ICE, IMD and SRH using statistical analysis that does not depend on subjective interpretation.

3.1.3 Research strategy

This layer of the research onion is concerned with the practical means by which the research is to be conducted. The positivist philosophy and deductive approach taken by this study indicated that an experimental research strategy would be most appropriate. Experimental research aims to test existing theories rather than create new ones and as such is the doctor than nature. Experimental research is aligned with the positivist research philosophy, as it is assumed that knowledge can only be gained objectively and in isolation from external factors such as context or culture. Alternative strategies such as action research, case study research, grounded theory, ethnography and archival research are associated with qualitative methodologies and focus more on participants experience and their social context. These strategies were therefore not considered appropriate for this study. This study utilises an experimental research strategy to examine the relationship between the independent variables of socio-economic status measured by the ICE and the IMD and the dependent variable of SRH.

3.1.4 Choices

This layer of the research onion is concerned with the type of data (quantitative or qualitative) to be used in the study. There are three options: mono, mixed and multi-method. Choosing a mono method means electing to use only one data type; either quantitative or qualitative. Mixed methods use both quantitative and qualitative data. Multi-method studies combine several aspects of quantitative and qualitative methodology is such as thematic analysis, content analysis and the quantitative analysis of numerical data. This study uses a quantitative mono method.

3.1.5 Time horizon

The time horizon layer is concerned with the time points at which data is collected. There are two options to be considered; the time horizon may be either cross-sectional

or longitudinal. Cross-sectional studies are concerned with the conditions at a single point in time, whereas longitudinal studies are concerned with change over time and take sample data at multiple time points. This study uses a longitudinal time horizon, sampling from the 2001 and 2011 censuses.

3.1.6 Techniques and procedures

This is the centre of the union and comprises the practicalities of the research process, including specific techniques and procedures comprising sampling, data gathering, analysis and any associated systems or materials that may be required. Techniques and procedures must align with the other layers of the research onion. For example, a deductive, quantitative research approach will require high-volume numerical data, which is better suited to a survey or secondary source approach. Alternatively, the use of interviews or focus groups are better suited to qualitative research. This informed the selection of secondary source census data and geographical analysis used in the study.

3.2 Spatial segregation

The work of Massey and Denton construes spatial segregation as the extent to which members of different groups occupy or experience different social environments (Massey & Denton, 1993). This requires that any measures used to study segregation should not only be defined in terms of the social environment of the individual, but also quantify the extent to which that environment differs between individuals.

Researchers responded to these challenges by developing a variety of indices to measure segregation, with much of the early work in the field being driven by studies in sociology and demographics (Lee et al., 2008; Reardon et al., 2008). These studies tended to treat social processes as distinct from spatial processes, with spatial processes receiving less attention in the literature. Since the 1990s, the increasing contribution of

geographers to the field has redressed this imbalance somewhat by integrating the spatial dimension into segregation measures (Wong, 2016).

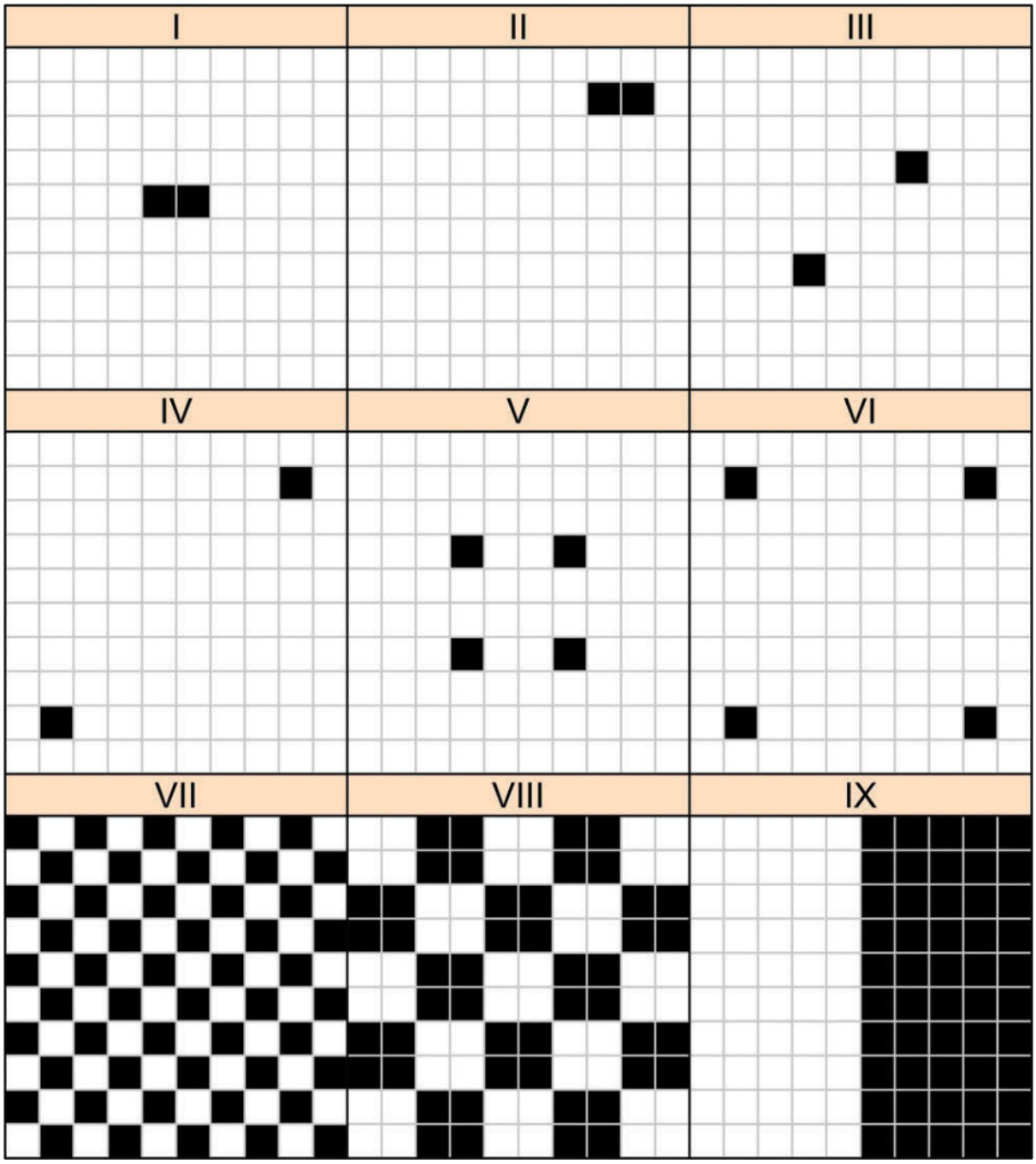
A common criticism of measures used in segregation research is that they are 'aspatial', in that they measure the socioeconomic or ethnic composition within an area and fail to capture the spatial relationships between neighbourhoods or groups of people (Oka & Wong, 2015). Also, the social environment was implicitly defined in terms of arbitrary administrative boundaries that did not necessarily reflect an individual's lived experience (Reardon & Firebaugh, 2002). Two significant methodological problems arising from the aspatial nature of commonly used measures were identified by White (White, 1983): the checkerboard problem and the modifiable areal unit problem (MAUP). The following sections focus on these two problems since they are still relevant for any spatial research.

3.2.1 The checkerboard problem

Studies of the spatial dimensions of inequalities have tended to distinguish between individual measures of inequality, construed as differences between individual or household resources, and measures of neighbourhood segregation, which are understood as variations in the distribution of neighbourhood population or per-capita resources. Several researchers have sought to develop spatial metrics derived from the ratio of these individual and neighbourhood measures, but these have not usually considered the spatial concentration of groups within neighbourhoods with specific regard to the clustering of areas with similar socioeconomic characteristics; a methodological issue that has become known as the 'checkerboard problem' (Dawkins et al., 2007). Essentially, neighbourhoods where different groups are evenly spatially distributed will return the same segregation index as those where like groups form distinct spatial clusters (Dawkins, 2004). This has the potential to mask factors that

depend on residential location, such as access to products, services and employment (see Figure 5 for a graphical representation).

Figure 5: Hypothetical patterns of two populations to give, in each case, a maximum dissimilarity index value of one



(Reproduced with acknowledgement to Harris (2017)).

In each block the distribution of populations represented by the black and white squares will return the same measure of segregation

3.2.2 The modifiable areal unit problem

Originally proposed by Openshaw (1984), the modifiable areal unit problem (MAUP) in the measurement of segregation arises as a consequence of the aggregation of population data into spatial units that do not necessarily correspond with meaningful societal structures. For analytical purposes, individuals living in proximity on either side of an arbitrary boundary will be treated as though they are more distantly associated than individuals living within the same areal unit. The modifiable areal unit problem actually comprises two interrelated effects: a scale effect and a zoning effect (Reardon & Firebaugh, 2002). The scale effect results in analytical differences that arise from the aggregation of data at different levels, with aggregate data becoming progressively less detailed with decreasing granularity. The zoning effect refers to the observation that the result of any analysis based on aggregated area data depends on the choice of the areas themselves, even if their scale is consistent (Reardon & Sullivan, 2004). Consequently, unless the areas selected for study represent spatial relationships between individuals to a reasonable degree, and also conform to meaningful neighbourhood boundaries, any understanding of the relationship of residents to their environment will be compromised.

3.2.3 Index of Concentration at the Extremes

Segregation measures based on the precise location of individuals and their spatial relationships could in principle eliminate the problems discussed above. However, as the composition of secondary source data means that such measures are not generally available to researchers, the ability of the ICE to represent concentrations of residents in conceptually related groups offers a useful compromise for the study of spatial relationships at neighbourhood level.

Unlike conventional measures of segregation, such as the dissimilarity index (which, typically, is computed at the city level by measuring how many people within the city would need to move from one census tract to another to create a uniform distribution), the ICE simultaneously measures concentrations of advantage and disadvantage, and can do so at any geographic level (Acevedo-Garcia et al., 2003). The dissimilarity index measures the percentage of one group that would have to move across neighbourhoods to be distributed the same way as another group. A dissimilarity index of 0 indicates conditions of total integration under which both groups are distributed in the same proportions across all neighbourhoods. A dissimilarity index of 100 indicates conditions of total segregation such that the members of one group are located in completely different neighbourhoods than another group. Neither extreme value is generally seen in most cities and metropolitan areas, with the index value typically between 0 and 100 (for a discussion of the dissimilarity index and the methodological issues associated with its use, see Massey et al. (2009)).

The ICE allows explicit examination of the role of spatial concentrations of groups whose pairing reflects the social relations that give rise to socioeconomic and health inequalities. Such groups may comprise any combination of characteristics of interest.

The study proposes to group the NS-SeC categories into the three major conceptual components of the Goldthorpe schema, representing the salariat (or service class), intermediate and working classes, using the ICE to examine the association of concentrations of each group with SRH. Worked examples for a range of ICE values within the North West region are shown in Table 4.

Table 4: Worked examples of ICE for Salariat compared to Working Class residents at LSOA level

		Population (LSOA)						
Local Authority	**LSOA 2011**	**All residents**	**Salariat**	**Intermediate**	**Working**	**Never worked & LT unemployed**	**Not classified**	**ICE = (Salariat - Working) / All residents**
Wigan	E01006360	1,272	94	218	680	192	88	-0.46
Wigan	E01006357	1,289	88	265	675	188	73	-0.46
Wigan	E01006386	1,389	134	299	749	167	40	-0.44
Halton	E01012389	1,526	437	531	437	32	89	0.00
Liverpool	E01006575	1,087	297	342	297	61	90	0.00
Manchester	E01005282	1,420	247	283	247	203	440	0.00
Manchester	E01033673	1,089	680	248	54	9	98	0.57
Manchester	E01033681	1,338	875	221	44	16	182	0.62
Manchester	E01033670	1,132	810	177	48	23	74	0.67

Table 4 shows worked examples for exemplar ICE values using data from the 2011 census. The ICE column represents the range from the highest concentration of working class residents, denoted by negative values of the ICE, to the highest concentration of salariat residents, denoted by positive ICE values. It can be seen that where the number of salariat and working class residents is the same the ICE equals zero. The number of residents in each employment relations group was derived from the NS-SeC categories in the census data, aggregated into the Goldthorpe schema categories. The same procedure was applied to the 2001 census data to allow for comparison between years.

3.3 Data

3.3.1 Social polarisation and the ICE

Social polarisation for public health monitoring can be analysed by using the ICE (Massey (2001). The ICE represents the extent to which an area's residents are concentrated into groups at the extremes of deprivation and affluence. The index ranges from -1 to 1, with a value of -1 indicating the entire population of an area is concentrated in the most deprived group and a value of 1 indication the entire population is concentrated in the most affluent group. The ICE was originally designed to represent the extent to which a neighbourhood's residents are concentrated into groups at the extremes of poverty and affluence (Massey, 1996), calculated as:

$$ICE_i = (A_i - P_i)/T_i$$

where Ai is the number of affluent persons, Pi the number of poor persons and T_i the total population for whom income level is known. The subscript, i is the neighbourhood. The ICE ranges from −1 (most deprived) to 1 (most privileged). A value of 0 therefore represents two possibilities: either none of the residents are in the best-off or worst-off categories or an equal number of persons are in the best-off and worst-off categories. In both cases this indicates that the neighbourhood is not dominated by extreme concentrations of either group. The ICE can be applied to other metrics than poverty and affluence, and can be computed at multiple geographic levels.

The ICE was preferred over more commonly used indices of social inequality such as the Gini coefficient for income inequality or the Index of Dissimilarity for residential segregation because they do not properly represent spatial polarisation. For example, neighbourhoods with exclusively low income or high-income residents will share the same Gini index. Similarly, neighbourhoods with 100% white or 100% black residents will share the same Index of Dissimilarity. The sign of the ICE overcomes

these limitations by returning a value that indicates the direction of concentration. Further, the ICE is also distinguished from other measures of inequality in that unlike the conventional poverty measure, it deals with both the most affluent and the most deprived groups in the same index. This avoids the methodological pitfall of focusing exclusively on disadvantaged groups. It is also more informative at lower levels of geography than measures such as the Index for Dissimilarity for racial segregation and the Gini index for income inequality, simply because people are more alike than different in smaller areas. The ICE is therefore scalable and can be used at various levels.

3.3.2 The English IMD

The English IMD is a measure of multiple deprivation comprising seven independent domains For a full description of each domain see the IMD technical manual (McLennan et al., 2019). IMD data is available through various online portals. For a collection of current and historical data, see the online resource provided by the Ministry of Housing (2020).

Income deprivation: The income deprivation domain measures the proportion of the population in an area experiencing deprivation relating to low income, set at 60% or less of median income (DWP, 2016) Measures used to compile this domain include both those people who are out of work and also those who are in work, but on low income. Additional indices for income deprivation affecting older people and income deprivation affecting children are also included in this domain.

Employment deprivation: The employment deprivation domain represents the proportion of the working age population in an area who are involuntarily excluded from the labour market. This includes all those people who are unable to work due to unemployment, sickness, disability, or caring responsibilities.

Education skills and training deprivation: The education, skills and training deprivation the domain measures the lack of attainment and skills in two subdomains: one for children and young people and the other for adults. The children and young people subdomain represents lack of attainment of educational qualifications among young people, while the adult subdomain measures the lack of qualifications and skills in the resident working-age adult population.

Health deprivation and disability: The health deprivation and disability domain represents the risk of premature death and the impairment of quality-of-life through poor physical or mental health. This domain covers morbidity, disability and premature mortality, but does not include aspects of behaviour or environment that may be predictive of future health deprivation.

Crime: The crime domain measures the risk of personal and material victimisation, including measures of violence, burglary, theft, and criminal damage.

Barriers to housing and services: This domain measures the physical and financial accessibility of housing and key local services. The indicators comprise subdomains for geographical barriers, which relate to the physical proximity of local services and wider barriers, which include problems relating to access to housing, including overcrowding, homelessness and affordability.

Living environment deprivation: The living environment deprivation domain measures the quality of the local environment in two subdomains. The 'indoors' subdomain measures the number of houses in poor condition or without central heating. The 'outdoors' subdomain measures air quality and road traffic accidents involving injury to pedestrians and cyclists.

Ranks and deciles are based on index scores, such that higher scores equate to greater deprivation in the area. In the case of the Income and Employment deprivation

domains and the supplementary children (IDACI) and older people (IDAOPI) indices, the scores are meaningful and relate to the proportion of the relevant population experiencing that type of deprivation. For example, if an LSOA has a score of 0.38 in the Income Deprivation Domain, this means that 38 per cent of the population in that area is income deprived. Scores for the overall composite IMD and the remaining five domains are less easy to interpret, as they do not relate straightforwardly to the proportion of the population experiencing deprivation. It is therefore recommended that ranks and deciles, but not scores, are used in the case of the IMD and these domains.

3.3.3 Use of the IMD

The IMD and each of its component domains can be used to rank all the LSOAs in England according to the deprivation experienced by their population. Highest scores on any of the domains or subdomains correspond to greater deprivation. Scores for the income and employment deprivation domains are rates and can be interpreted as the percentage of the population that are income deprived or employment deprived respectively.

The IMD was produced at the LSOA level using 2011 boundaries. Scores for the 32,844 LSOAs in England were ranked by their composite deprivation score, with the most deprived LSOA given a rank of 1 and the least deprived a rank of 32,844. These rankings were grouped into deciles, with decile 1 representing the most deprived 10% of areas and decile 10 the least deprived 10% of areas nationally. The rankings and deciles can be interpreted as showing whether an LSOA is broadly more or less deprived than any other area in the country. Ranks and deciles for the IMD are relative; they show that one LSOA differs from another but not by how much.

3.3.4 Interpreting and analysing the IMD

The composition of the IMD has changed over time, as components such as rates of specific benefit payments have varied. Changes in deprivation between versions of the index can therefore only be described in relative terms, for example, the extent to which an area has changed its rank or decile of deprivation. The index cannot be used to measure absolute change in deprivation between surveys. For example, an area can be said to have become more deprived relative to other areas if it was within the most deprived 20 per cent of areas nationally according to the IMD 2000 but within the most deprived 10 per cent according to the IMD 2004. However, it would not be correct to state that the level of deprivation in the area had increased on some absolute scale, as it may be that all areas had also improved, but that this area had improved more slowly and so had been 'overtaken' by other areas.

All versions of the IMD are intended to measure relative deprivation at the small area level as accurately as possible, but they are not designed to be reverse compatible with previous versions (updated in 2015, 2010, 2007, 2004 and 2000). However, because the methodology remained consistent between versions, it is possible to compare the rankings as derived at the different time points. Analysis of the index reported in the results of this study is therefore based on the IMD rankings for the LSOAs comprising the North West region at the time of the 2001 and 2011 censuses.

3.3.5 Theoretical basis for using Lower Layer Super Output Areas to represent neighbourhoods

Initiatives to improve health and wellbeing may be targeted at a range of geographical levels and in England policy has tended to shift away from the national level to focus on smaller areas, such as communities and neighbourhoods (Department of Health, 2010). There is therefore a need to identify the potential for targeting policy

interventions at the most appropriate geographical levels in order to achieve the greatest benefits. The rationale for this is that where there are greater variations in health and wellbeing indicators, there may be greater potential for policy intervention targeted at that geographical level to have an impact on the outcomes of interest, compared with a strategy of targeting policy at those geographical levels where relative variations are smaller**.** A study by Castelli and colleagues used a multi-level regression approach to identify the degree of variation that exists in a set of health indicators at different levels, taking account of the geographical hierarchical organisation of public sector organisations in England. The indicators comprised measures of quality of life, mortality, morbidity and socioeconomic conditions. Comparison of more extensive units of analysis with smaller areas, found that for each indicator, the proportion of total residual variance is greatest at smaller geographical areas that are subsumed with public service organisational boundaries, specifically LSOAs (Castelli et al., 2013).

This study uses the LSOA geography currently used by the UK national census. There is a considerable body of evidence demonstrating the association between place and numerous health conditions at various spatial scales, ranging from small localities such as local authority wards, to towns and cities and regional level. Despite this, relatively few studies have offered a consistent theoretical conception of place.

The conception of neighbourhoods in this study is informed by (Giddens, 1986) structuration theory, a social theory of the development an perpetuation of social systems based on the analysis of both structure and agency. Structure is generally understood as comprising rules and resources, and more specifically as those structuring properties that bind social systems, allowing them to persist over time and across geographical space. Agents are construed as those individuals or groups who draw upon structures to perform social actions. Giddens went on to define social structures in terms

of rules and resources. It is proposed that there are two types of resources, authoritative resources which allow command over persons or other agents and allocative resources which are concerned with the transformation of objects and material capacity. Allocative resources comprise 'material features of the environment, means of material production/reproduction and produced goods' (Giddens, 1986). Rules are understood as the learned procedures and techniques necessary to carry out social activities in relation to structural constraints and opportunities.

To determine the underlying causes of the spatial distribution of health inequalities have commonly led to a distinction between compositional and contextual explanations. Compositional explanations attribute the geographical clustering of health status to the shared characteristics of residents, who are analogous to Giddens' agents. Essentially, it is proposed that people who are similar in terms of socioeconomic status or educational attainment will tend to aggregate in proximity, either because they share a common culture, or are driven to certain locations by the lack of personal resources. Such shared characteristics have been found to partly explain the association between health and place (Macintyre & Ellaway, 2000).

Analogous to the structural aspect of Giddens' theory, the contextual explanation attributes spatial variations in health in part to the characteristics of the neighbourhood environment, elements of which may affect whole groups. These ecological attributes of neighbourhoods may influence health over and above the aggregate contribution of individual characteristics (Macintyre et al., 2002).

The influence of compositional and contextual effects cannot easily be disentangled. The distribution of residents in an area is neither entirely random nor completely intentional and reflects a complex interaction between economic resources, lifestyle preferences and neighbourhood characteristics.

Neighbourhoods are not static entities and their contextual and compositional characteristics will inevitably change over time. Galster (2001) identified four principal neighbourhood user and producer groups who influence change in neighbourhood resources: households, businesses, property owners and local government. These neighbourhood agents serve to transform context while the health of individuals is affected by the goods consumed, services used and the social relationships built up in an area.

Population data are often collated for geographical areas which may not be directly connected to the processes generating the data. Such areal units are termed 'modifiable'. Analysis undertaken on this type of data may be dependent of how these areal units are configured, and it has been shown that the results of statistical analysis may differ according to the scale and pattern of the areal units used (Openshaw, 1984). This phenomenon is called the modifiable areal unit problem (MAUP). Although its potential effect is acknowledged, it is not clear how often the MAUP occurs, how often it affects the conclusions from empirical data analysis and in what contexts it makes influences analysis.

The MAUP is often described as having two aspects – the scale effect and the zonation effect. The scale effect considers that there may be significant analytical differences depending on the size of units used. Usually, correlations will be more pronounced for larger areal units. The zonation effect, also known as the aggregation effect (Openshaw, 1984), shows that significant differences may arise from how a study area is divided up, even at the same scale. Analysis of historical data from the 1991 census found significant differences between ward level and census Enumeration Districts (Manley, 2006). The MAUP has been examined in the context of UK small

area geographies and Output Areas were found to be relatively resistant to any resulting bias (Flowerdew, 2011).

A study by Flowerdew proposed several criteria for deriving neighbourhoods from smaller areal units that informed the choice of LSOAs as the unit of analysis for this study (Flowerdew et al., 2008). The first criterion was that areas should be internally contiguous, such that each area should be accessible to every other area within a neighbourhood, and that no area should have detached portions. The second criterion was that 'doughnut' shapes should be avoided, with no area being surrounded by another. It was also considered important for area populations to be of approximately the same size. Area shape was also a notable concern. Neighbourhoods are likely to be relatively compact in shape, with some exceptions along a coastal strip or valley. Elongated areas are less likely to be a realistic representation of neighbourhoods than ones with more regular shapes. Finally, internal homogeneity could also be regarded as an important feature of area choice. If a contextual effect exists, it may well be strongest in more homogeneous neighbourhoods. The relative uniformity of size, shape and composition inherent in LSOAs satisfied these criteria and suggested their suitability to analyse neighbourhood associations. LSOAs have similar population sizes of approximately 1,600 residents. The LSOA is small enough to capture the important influence of proximity and gives this level of geography considerable utility in assessing the role of neighbourhood conditions in health. Conversely, LSOAs are also large enough to contain a representative number of individuals with different social and economic characteristics, thereby improving the stability of estimates (Cookson et al., 2016).

3.3.6 Study area: North West England

The following summarises the main characteristics of North West England in terms of its geography, population and socioeconomic conditions. A topographic map of the region is presented in Figure 6.

Figure 6: Topographic map of the North West region of England showing the study area (shadowed)

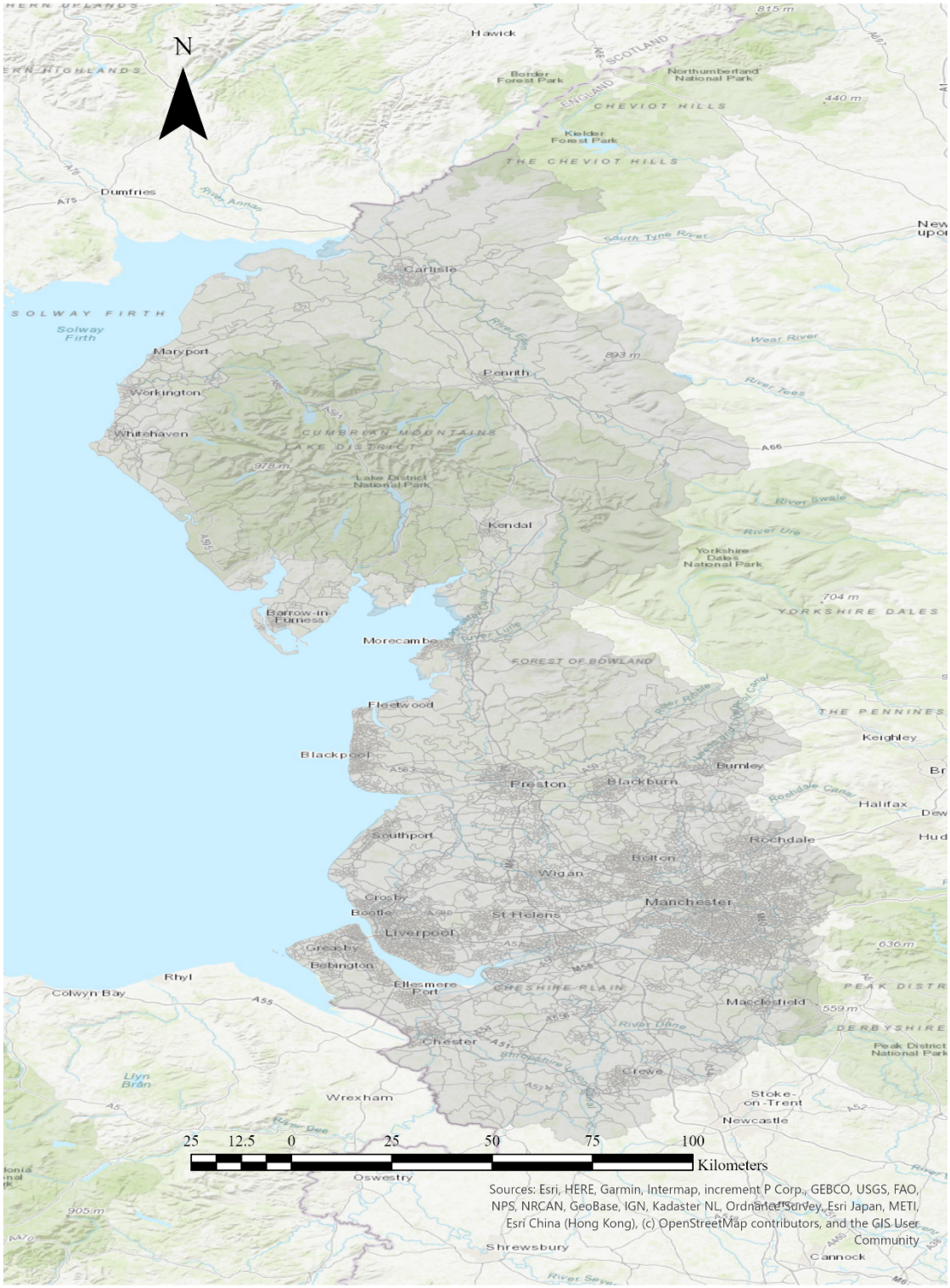


Figure 7: Local authority map of the North West region of England

3.3.7 Geography and population

North West England is bounded to the east by the Pennines and to the west by the Irish Sea. The region extends from the Scottish Borders in the north to the West Midlands region in the south and shares borders with Northeast England, Yorkshire and Humber and the East and West Midlands regions. To its southwest is North Wales.

The North West has a mix of rural and urban landscape, with two large conurbations, centred on Liverpool and Manchester, occupying much of the south of the region. The north of the region, comprising Cumbria and northern Lancashire, is largely rural and includes the Lake District national park. With an area of 2,192 square kilometres, the Lake District is the largest national park of England. The far south of the region is also predominately rural and encompasses parts of the Cheshire Plain and Peak District.

The five largest metropolitan areas by population in the North West are:

- Greater Manchester metropolitan area – 2,556,000
- Liverpool/Birkenhead metropolitan area – 2,241,000
- Blackburn/Burnley – 391,000
- Preston – 354,000
- Blackpool −304,000

Source: Office for National Statistics mid-year estimates 2012

Liverpool and Manchester are sometimes considered parts of a single large polynuclear metropolitan area, but are usually treated as separate metropolitan areas.

North West England's population accounts for just over 13% of England's overall population. 37.86% of the North West's population resides in Greater Manchester, 21.39% in Lancashire, 20.30% in Merseyside, 14.76% in Cheshire and 7.41% live in the largest county by area, Cumbria (Table 5).

Table 5: Population estimates for the North West region

Region/County	Population	Population Density	Largest town/city	Largest urban area
Greater Manchester	2,629,400	2,016/km²	Manchester (510,700) (2012 est.)	Greater Manchester Urban Area (2,240,230)
Lancashire	1,449,600	468/km²	Blackpool (142,100)	Preston/Chorley/Leyland Urban Area (335,000)
Merseyside	1,353,600	2,118/km²	Liverpool (466,415)	Liverpool Urban Area (816,000)
Cheshire	1,003,600	424/km²	Warrington (202,228)	Warrington (202,228)
Cumbria	496,200	73/km²	Carlisle (71,773)	Carlisle (71,773)

(Source: Office for National Statistics mid-year estimates 2012).

3.3.8 Social deprivation

Of the nine regions of the England, the North West has the fourth-highest Gross Value Added measure of the increase in the value to the economy of goods and services produced per capita; the highest outside southern England (ONS, 2017). Despite this, the region has above average multiple deprivation, with wealth heavily concentrated in very affluent areas like rural Cheshire, rural Lancashire, and south Cumbria. As measured by the ONS index of multiple deprivation, the region has many more LSOAs in the 20% most deprived districts than the 20% least deprived council districts. Only Northeast England has more indicators of deprivation than the North West.

The most deprived local authority areas in the region (based on specific wards within those borough areas) are, in descending order—Liverpool, Manchester, Knowsley, Blackpool, Salford, Blackburn with Darwen, Burnley, Rochdale, Barrow-in-Furness, Halton, Hyndburn, Oldham, Pendle, St Helens, Preston, Bolton, Tameside, Wirral, Wigan, Copeland, Sefton, and Rossendale.

Unemployment in the region increased between the 2001 and 2011 censuses. At the 2011 census, the overall unemployment claimant rate for the region was 4.2%. The highest rate was found in Liverpool with 6.8%, followed by Knowsley at 6.3%, Halton at 5.5% and Rochdale at 5.1%. The lowest claimant count is in Eden (Cumbria) and Ribble Valley (Lancashire) each with 1.3%, followed by South Lakeland at 1.4%. At the 2001 census the regional rate was 3.6%. The highest rates were in Knowsley at 5.87% and Liverpool at 6.04%. The lowest rates were in Ribble Valley at 1.61% and Fylde at 1.97%

3.3.9 Ethnicity

The population of the North West region increased from 6,729,764 at the 2001 census to 7,052,177 at the 2011 census. This was accompanied by increasing ethnic diversity (see Table 6 for a breakdown of ONS ethnicity data). The proportion of residents identifying as 'white' decreased between 2001 and 2011, from 94.4% (6,355,495) to 90.2% (6,361,716).

The proportion of Asian/Asian British residents increased from 3.4% (229,875) in 2001 to 6.2% (437,485) in 2011, as did residents in mixed/multiple ethnic groups, from 0.9% (62,539) in 2001 to 1.6% (110,891) in 2011 and Black/African/Caribbean/Black British groups, from 0.6% (41,637) in 2001 to 1.4% (97,869) in 2011.

Although the population is predominately 'white', North West England has areas of notable diversity, with the Manchester and Liverpool conurbations being home to some of the most diverse populations in Europe. Areas such as Moss Side in Greater Manchester are home to more than 30% of black British population. In contrast, the town of St. Helens in Merseyside, unusually for a city area, has a very low percentage of ethnic minorities with 98% identifying as white British.

Table 6: Ethnicity in the region at the 2001 and 2011 censuses

2011	Number	%	2001	Number	%
All usual residents	7,052,177	100	All categories: Ethnic group	6,729,764	100
White	6,361,716	90.2	White	6,355,495	94.4
White: English/Welsh/Scottish/Northern Irish/British	6,141,069	87.1	White: British	6,203,043	92.2
White: Irish	64,930	0.9	White: Irish	77,499	1.2
White: Gypsy or Irish Traveller	4,147	0.1			
White: Other White	151,570	2.1	White: Other	74,953	1.1
Mixed/multiple ethnic groups	110,891	1.6	Mixed	62,539	0.9
Mixed/multiple ethnic groups: White and Black Caribbean	39,204	0.6	Mixed: White and Black Caribbean	22,119	0.3
Mixed/multiple ethnic groups: White and Black African	18,392	0.3	Mixed: White and Black African	9,853	0.1
Mixed/multiple ethnic groups: White and Asian	30,529	0.4	Mixed: White and Asian	17,223	0.3
Mixed/multiple ethnic groups: Other Mixed	22,766	0.3	Mixed: Other	13,344	0.2
Asian/Asian British	437,485	6.2	Asian/Asian British	229,875	3.4
Asian/Asian British: Indian	107,353	1.5	Asian/Asian British: Indian	72,219	1.1
Asian/Asian British: Pakistani	189,436	2.7	Asian/Asian British: Pakistani	116,968	1.7
Asian/Asian British: Bangladeshi	45,897	0.7	Asian/Asian British: Bangladeshi	26,003	0.4
Asian/Asian British: Chinese	48,049	0.7	Chinese/Other: Chinese	26,887	0.4
Asian/Asian British: Other Asian	46,750	0.7	Asian/Asian British: Other	14,685	0.2
Black/African/Caribbean/Black British	97,869	1.4	Black/Black British	41,637	0.6
Black/African/Caribbean/Black British: African	59,278	0.8	Black/Black British: Black African	15,912	0.2
Black/African/Caribbean/Black British: Caribbean	23,131	0.3	Black/Black British: Black Caribbean	20,422	0.3
Black/African/Caribbean/Black British: Other Black	15,460	0.2	Black/Black British: Other	5,303	0.1
Other ethnic group	44,216	0.6	Chinese/Other	40,218	0.6
Other ethnic group: Arab	24,528	0.3			
Other ethnic group: Any other ethnic group	19,688	0.3	Chinese/Other: Other	13,331	0.2

Note: Table 6 reports the categories used in each census, which varied slightly from 2001 to 2011 (Source: NOMIS).

3.3.10 Coastal communities

A substantial number of region's population live in coastal communities, which face challenges in terms of population, age profile and employment. National studies have provided evidence of the long-term disadvantage of coastal communities compared to inland communities (ONS, 2020b). Specifically, the North West's coastal communities share several of the socioeconomic challenges of the 'Seaside Towns' identified in national studies (see, for example, Beatty and Fothergill (2003)):

- They tend to have a higher proportion of self-employment and part-time employment than non-coastal towns, as well as a lower proportion of residents with degree-level qualifications.
- Their demographic profile is older than the regional average
- Deprivation as measured by the IMD is higher in the coastal communities
- Incomes are lower and the proportion of benefits claimants higher
- There is a higher incidence of lone parent and households in multiple occupancy

In addition, many of the region's coastal communities are losing population, have high levels of social rented housing stock and overall employment is higher in public administration than the retail and tourism sectors.

The North West region has several coastal communities that face these socioeconomic and demographic challenges, with some communities such as Blackpool being among the most deprived in the UK.

Using a framework developed by the Office for National Statistics (ONS), coastal communities have been grouped according to their workplace and residential characteristics (ONS, 2019a). Each community has been allocated to one of three categories depending on their level of job density: working towns (with high job density), residential towns (with low job density) or mixed (with medium-level job

density). They have then been grouped by their level of income deprivation among residents (lower deprivation towns, mid-deprivation towns and higher deprivation towns). This results in nine potential groupings. Table 7 presents the groupings and illustrative population and growth data for the region's coastal communities.

Table 7: North West coastal communities; classification, job density deprivation, and age bands at the 2011 census

				2011 population (change from 2001 census)				
	Coastal Classification	**Job Density**	**Income**	**0-15**	**16-24**	**25-64**	**65+**	**Total**
Barrow-in-Furness	Larger other coastal towns	Working	High Deprivation	8,265 (-17%)	5,198 (15%)	24,012 (-4%)	8,389 (5%)	45,864 (-3%)
Birkenhead	Larger other coastal towns	Mixed	High Deprivation	27,701 (-8%)	16,178 (12%)	74,760 (3%)	24,476 (5%)	143,115 (2%)
Blackpool	Larger seaside towns	Working	High Deprivation	26,145 (-6%)	15,980 (17%)	76,668 (-1%)	28,876 (-1%)	147,669 (-1%)
Bootle	Larger other coastal towns	Working	High Deprivation	10,226 (-25%)	6,517 (6%)	26,629 (-5%)	8,130 (-6%)	51,502 (-9%)
Cleveleys	Smaller seaside towns	Residential	High Deprivation	1,574 (-11%)	943 (28%)	4,976 (-1%)	3,234 (2%)	10,727 (%)
Crosby	Larger other coastal towns	Residential	High Deprivation	8,464 (-21%)	5,591 (6%)	26,716 (%)	9,277 (2%)	50,048 (-3%)
Fleetwood	Larger seaside towns	Mixed	High Deprivation	4,633 (-19%)	2,885 (13%)	12,391 (-5%)	5,411 (6%)	25,320 (-4%)
Formby	Larger seaside towns	Residential	Low Deprivation	3,728 (-14%)	2,018 (-2%)	11,035 (-14%)	6,516 (26%)	23,297 (-4%)
Heysham	Smaller other coastal towns	Residential	High Deprivation	3,019 (-2%)	1,512 (10%)	7,993 (8%)	3,063 (8%)	15,587 (6%)
Hoylake	Smaller seaside towns	Residential	Low Deprivation	1,832 (-14%)	1,057 (13%)	5,631 (1%)	2,377 (1%)	10,897 (-1%)
Lytham St Anne's	Larger seaside towns	Mixed	Middle Deprivation	6,479 (2%)	3,477 (21%)	21,294 (5%)	11,844 (4%)	43,094 (5%)
Maryport	Smaller other coastal towns	Residential	High Deprivation	1,712 (-13%)	1,018 (4%)	4,939 (-1%)	1,895 (14%)	9,564 (%)

				2011 population (change from 2001 census)				
	Coastal Classification	**Job Density**	**Income**	**0-15**	**16-24**	**25-64**	**65+**	**Total**
Morecambe	Larger seaside towns	Working	High Deprivation	5,886 (-14%)	3,389 (2%)	16,540 (-2%)	7,497 (1%)	33,312 (-3%)
North Walney	Smaller other coastal towns	Residential	High Deprivation	1,683 (-18%)	955 (%)	5,124 (-9%)	2,156 (8%)	9,918 (-7%)
Preesall	Smaller other coastal towns	Residential	High Deprivation	682 (-18%)	458 (43%)	2,436 (1%)	1,784 (16%)	5,360 (5%)
Seaton	Smaller other coastal towns	Residential	Low Deprivation	902 (-5%)	466 (10%)	2,704 (-1%)	960 (26%)	5,032 (3%)
Southport	Larger seaside towns	Mixed	High Deprivation	15,364 (-8%)	8,856 (14%)	46,101 (-1%)	21,389 (7%)	91,710 (%)
Wallasey	Larger other coastal towns	Residential	High Deprivation	11,595 (-10%)	7,133 (17%)	31,570 (5%)	9,988 (2%)	60,286 (2%)
West Kirby	Smaller seaside towns	Residential	Low Deprivation	2,603 (-5%)	1,237 (1%)	7,384 (2%)	3,704 (9%)	14,928 (2%)
Whitehaven	Larger other coastal towns	Mixed	High Deprivation	4,245 (-11%)	2,447 (-1%)	12,959 (1%)	4,345 (14%)	23,996 (%)
Workington	Larger other coastal towns	Mixed	High Deprivation	3,890 (-4%)	2,408 (9%)	11,697 (3%)	4,135 (11%)	22,130 (3%)

(Source: Office for National Statistics)

3.3.11 The UK census and associated geographies

The following overview of the UK census and the geographies used to collate the resulting data is presented with acknowledgement to the Office for National Statistics (ONS, 2021a).

The national UK census is undertaken every 10 years. At the time of writing the most recent census was carried out on the 27th March, 2011. The census collects population and other data essential for the planning and allocation of resources. The principal users of this data include departments of national and local government, and providers of services such as health and education.

The census is administered simultaneously in all parts of the UK. In England and Wales, the Office for National Statistics (ONS) is the responsible body. Scotland and Northern Ireland have their own census bodies.

The main geographies for reporting census data are Output Areas (OA) and Lower and Middle Layer Super Output Areas (LSOA/MSOA) which are formed from aggregates of OAs. Output Areas are the base unit for census data releases. For other geographies, census data can be produced by best-fitting from the OA level to the required output geography using boundaries current at 31st December 2011.

The average population of the Output Areas in England and Wales on the day of the 2011 census was 309, with 95% of OAs having a population of between 171 and 486. The average population of the LSOAs was 1,614 with 95% of LSOAs having a population of between 1,157 and 2,354.

3.3.12 2001 and 2011 Output Areas

Output areas (OA) were created for the reporting of census data, specifically for the output of census estimates. The OA is the lowest geographical level at which census estimates are provided. OAs were originally introduced in Scotland at the 1981 census and in all the countries of the UK at the 2001 census.

In England and Wales 2001 OAs were assembled from clusters of adjacent postcodes as at census day. They were designed to have similar population sizes and be as socially homogenous as possible, based on tenure of household and dwelling type. As far as possible, urban/rural mixes were avoided and for this reason OAs preferably consisted entirely of urban postcodes or entirely of rural postcodes. OAs had approximately regular shapes and tended to be constrained by obvious boundaries such as major roads. They followed existing ward and parish boundaries unless a postcode straddled an electoral ward/division or parish boundary, in which case it was split between two or more OAs. OAs have a specified minimum size of 40 resident households to ensure the confidentiality of data, but the recommended size was 125 households. These size limits meant that unusually small wards and parishes were incorporated into larger OAs.

A key objective of the 2011 census was to maintain as far as possible the 2001 OA geography to allow for consistent comparisons of data. However, some modification of the 2001 OAs and associated super output areas (SOA) took place. Table 8 shows the increase in OA at each level of geography. Table 9 shows the upper and lower population and household thresholds for each level of geography.

Table 8: Changes in OA/LSOA/MSOA between 2001 and 2011 censuses

			Change	
	2001	**2011**	**Number**	**%**
Output Areas	22,710	23,343	633	+2.79%
Lower Layer Super Output Areas	4,459	4,497	38	+0.85%
Middle Layer Super Output Areas	922	924	2	+0.22%

(Source: Office for National Statistics)

Table 9: Output Area & Super Output Area thresholds

Area type	**Lower threshold**		**Upper threshold**	
	People	**Households**	**People**	**Households**
Output Areas	100	40	625	250
Lower Layer Super Output Areas	1,000	400	3,000	1,200
Middle Layer Super Output Areas	5,000	2,000	15,000	6,000
Electoral wards/divisions	100	40	n/a	n/a

(Source: Office for National Statistics)

Changes in OA and SOA boundaries for the 2011 census were imposed when:

- Significant population change has occurred since the 2001 census.
- Local Authority District boundaries changed between 2003 and 2011.
- OA boundaries were realigned to the England/Scotland border.
- Areas were adjudged to have been lacking social homogeneity when they were originally created for the 2001 census.

Redesigned OAs and SOAs for the 2011 census:

- Are not aligned to ward and parish boundaries that changed since 2003.
- Do not necessarily align to real-world features.
- Contain more than 100 persons and 40 households, even if they contain one or more communal establishment.

The ONS automatically modifies those OAs and SOAs where 2011 census populations had significantly grown or declined since 2001. If OAs breached a

specified upper population threshold (their populations became too large), they were split into two or more OAs using their constituent postcodes as building blocks.

Output areas were modified where:

- An OA's population exceeded 625 people or 250 households.
- An LSOA's population exceeded 3,000 people or 1,200 households.
- An MSOA's population exceeded 15,000 people or 6,000 households.

Where splits were required, blocks of postcodes were used to create two or more new OAs constrained to the boundary of the original OAs from which they were created. The use of postcodes is consistent with the 2001 methodology, and lookup tables are available to allow the linking of data sets.

Where the population of an OA or SOA became too small and therefore potentially disclosive, they were merged with an adjacent OA or SOA.

Merges were applied where:

- An OA population fell below 100 people or 40 households.
- An LSOA population fell below 1,000 people or 400 households.
- An MSOA population fell below 5,000 people or 2,000 households.

The practice of splitting and merging existing OA and SOA geographies in response to population changes was preferred to a complete redesign for each census as allows better linkage and comparison between statistical outputs for the 2001 and 2011 data sets. The study analysed data on the thirty-nine district and borough local authorities in North West England, which comprise a total of 4,497 Lower Super Output Areas (Table 10).

Table 10: Count of Lower Layer Super Output Areas in North West England by local authority

Local Authority	LSOA	Local Authority	LSOA
Allerdale	60	Oldham	141
Barrow-in-Furness	49	Pendle	57
Blackburn with Darwen	91	Preston	86
Blackpool	94	Ribble Valley	40
Bolton	177	Rochdale	134
Burnley	60	Rossendale	43
Bury	120	Salford	150
Carlisle	68	Sefton	189
Cheshire East	234	South Lakeland	59
Cheshire West and Chester	212	South Ribble	70
Chorley	66	St. Helens	119
Copeland	49	Stockport	190
Eden	36	Tameside	141
Fylde	51	Trafford	138
Halton	79	Warrington	127
Hyndburn	52	West Lancashire	73
Knowsley	98	Wigan	200
Lancaster	89	Wirral	206
Liverpool	298	Wyre	69
Manchester	282	**Grand Total**	**4,497**

(Source: Office for National Statistics)

3.3.13 National Statistics Socioeconomic Classifications and SRH.

This study is based on secondary source data from the two most recent UK national censuses, which held on 29th April 2001 and on 27th March, 2011. Data is published online by the Office for National Statistics (ONS). This comprises National Statistics Socioeconomic Classifications (NS-SeC) and measures of SRH.

The National Statistics Socioeconomic Classification (NS-SeC) is an Office for National Statistics standard classification that assigns census participants to a socioeconomic class based on their occupation. To assign a person to an NS-SeC category their occupation title is combined with information about their employment status, whether they are employed or self-employed, and whether or not they supervise

other employees. Full-time students are recorded in the 'full-time students' category regardless of whether they are economically active or not. The 2011 census did not ask a question about the number of employees at a person's workplace, so the reduced method of deriving NS-SeC (which does not require this information) was used.

The NS-SeC follows established methodology by taking the nuclear family as its unit of analysis, rather than the individual. The family unit is seen as the basic structural element due to the interdependence and shared conditions of family members. However, this raises the question of which family member best represents a household. The NS-SeC assigns one member of the family or household as a reference person and using their status as a proxy for the whole household. This person is known as the household reference person (HRP). Since 2001, the HRP has been defined by the Office for National Statistics as '*the person responsible for owning or renting or who is otherwise responsible for the accommodation. In the case of joint householders, the person with the highest income takes precedence and becomes the HRP. Where incomes are equal, the oldest person is taken as the HRP. This procedure increases the likelihood both that a woman will be the HRP and that the HRP better characterises the household's social position.*' (ONS, 2021b).

Table 11 presents the analytic classes of the NS-SeC.

Table 11: Analytic classes of the NS-SeC

Analytic classes		Operational categories and sub-categories classes
1.1	L1	Employers in large establishments
	L2	Higher managerial and administrative occupations
1.2	L3	Higher professional occupations
		L3.1 'Traditional' employees
		L3.2 'New' employees
		L3.3 'Traditional' self-employed
		L3.4 'New' self-employed
2	L4	Lower professional and higher technical occupations
		L4.1 'Traditional' employees
		L4.2 'New' employees
		L4.3 'Traditional' self-employed
		L4.4 'New' self-employed
	L5	Lower managerial and administrative occupations
	L6	Higher supervisory occupations
3	L7	Intermediate occupations
		L7.1 Intermediate clerical and administrative occupations
		L7.2 Intermediate sales and service occupations
		L7.3 Intermediate technical and auxiliary occupations
		L7.4 Intermediate engineering occupations
4	L8	Employers in small organisations
		L8.1 Employers in small establishments in industry, commerce, services etc.
		L8.2 Employers in small establishments in agriculture
	L9	Own account workers
		L9.1 Own account workers (non-professional)
		L9.2 Own account workers (agriculture)
5	L10	Lower supervisory occupations
	L11	Lower technical occupations
		L11.1 Lower technical craft occupations
		L11.2 Lower technical process operative occupations
6	L12	Semi-routine occupations
		L12.1 Semi-routine sales occupations
		L12.2 Semi-routine service occupations
		L12.3 Semi-routine technical occupations
		L12.4 Semi-routine operative occupations
		L12.5 Semi-routine agricultural occupations
		L12.6 Semi-routine clerical occupations
		L12.7 Semi routine childcare occupations
7	L13	Routine occupations
		L13.1 Routine sales and service occupations
		L13.2 Routine production occupations

Analytic classes		Operational categories and sub-categories classes
		L13.3 Routine technical occupations
		L13.4 Routine operative occupations
		L13.5 Routine agricultural occupations
8	L14	Never worked and long-term unemployed
		L14.1 Never worked
		L14.2 Long-term unemployed
*	L15	Full-time students
*	L16	Occupations not stated or inadequately described
*	L17	Not classifiable for other reasons

(Source: NOMIS)

Data on the numbers of residents in each of the NS-SeC groups by health status was obtained from the ONS at the LSOA level.

Data was downloaded from the National Online Manpower Information Service (Nomis), which is a web-based database of labour market statistics run by the University of Durham on behalf of the UK Office for National Statistics. First launched in 1981, Nomis houses an extensive range of government statistical information on the UK labour market including Employment, Unemployment, Earnings and Annual Population Survey. Nomis is available online at: https://www.nomisweb.co.uk/

3.3.14 CS023 - Age and Self-rated general health by NS-Sec in 2001

This dataset provides 2001 Census estimates that classify usual residents in England and Wales aged 16 to 74 by age and general health by NS-Sec. Pensionable age at the time of the Census was 65 for men and 60 for women. The census question for general health differed from the 2011 census in that it grouped participants in three categories: 'good', 'fairly good', or 'not good' health over the 12 months prior to census day.

3.3.15 LC3601EW - Self-rated General Health (SRH) in 2011

In the LC3601EW Nomis dataset, residents aged 16 and over in England and Wales are classified by self-rated general health and by NS-SeC. General health is a self-assessment of a person's general state of health. People were asked to assess whether

their health was very good, good, fair, bad or very bad. This assessment is of the person's health on census day and is not based on the person's health over any other period of time.

3.3.16 QS103EW – Age in 2011

Age is derived from the census date of birth question and is a person's age at their last birthday, at 27 March 2011. Infants less than one year old are classified as 0 years of age. A combined total is reported for the number of residents aged 100 and older in each LSOA.

3.3.17 KS006 (2001) & KS201EW (2011) Ethnicity

Ethnic group classifies people according to their own perceived ethnic group and cultural background. The main changes between the 2001 and 2011 census were that the Chinese ethnic group moved from the 'Other' group in 2001 to the 'Asian' group in 2011 and there were no 'Gypsy or Irish Traveller' or 'Arab' groups listed in 2001 (Table 12). The following ethnic groups were recorded:

Table 12: KS006 & KS201EW census ethnicity groups for 2001 & 2011

KS006 - 2001 census	KS201EW - 2011 census
Asian or Asian British	**Asian or Asian British**
Indian	Indian
Pakistani	Pakistani
Bangladeshi	Bangladeshi
Any other Asian background	Chinese
	Any other Asian background
Black or Black British	**Black, African, Caribbean or Black British**
African	African
Caribbean	Caribbean
Any other Black background	Any other Black, African or Caribbean background
Mixed	**Mixed or multiple ethnic groups**
White and Black Caribbean	White and Black Caribbean
White and Black African	White and Black African
White and Asian	White and Asian
Any other Mixed background	Any other Mixed or multiple ethnic background

KS006 - 2001 census	KS201EW - 2011 census
White	**White**
British	English, Welsh, Scottish, Northern Irish or British
Irish	Irish
Any other White background	Gypsy or Irish Traveller
	Any other White background
Chinese or other ethnic group	**Other ethnic group**
Chinese	Arab
Any other	Any other ethnic group

(Source: Office for National Statistics)

3.3.18 Urban and rural classifications

The Office of National Statistics defines areas as rural if they are outside settlements with more than 10,000 resident population (ONS, 2016). Areas are further divided into six categories, all of which are present in the region:

- Town and fringe
- Town and fringe in a sparse setting
- Village
- Village in a sparse setting
- Hamlets and isolated dwellings
- Hamlets and isolated dwellings in a sparse setting

3.4 Methods

The following paragraphs describe the software and analyses of the census datasets that were compiled from Nomis for use in this study. It should be noted that the structure of the published datasets changed between the 2001 and 2011 census and this required each block of data to be compiled into matched tables to allow for comparison of the two census results.

Bivariate analysis was chosen to visualise the relationships before modelling to determine the relationship between SRH and ICE to test for any significant relationship

that varies geographically. Bivariate analysis allows a visualisation of the association between the ICE, IMD and SRH. It also provides an unadjusted measure of the geographical association between two variables. GWR was used to account for neighbourhood effects and allows for multiple variables and not only two as in bivariate analysis The choice of GWR is due to the requirement to account for dynamic regression coefficients using average SRH per LSOA and this why GWR was used and not logistic regression. Further, GWR provides an adjusted measure of the association between the response and predictors. Hotspot analysis was used to see the intra-geographical variability of SRH and ICE independently. Hotspot analysis is a clustering measure. The null hypothesis here is that there is no spatial aggregation in the outcome under study.

3.5 The null hypothesis

The study used models and not statistical tests. The null hypothesis for the models is that there is no relationship between SRH, ICE, deprivation, age & demographics. The study tested this hypothesis. All the variables are numerical and therefore suitable for the modelling approach. The dependent variable is SRH and the independents are all variants of the ICE, IMD, ethnicity and age.

3.5.1 Homogenisation of 2001 and 2011 LSOA

Changes in boundaries between census dates mean that not all LSOAs could be mapped from 2001 and 2011datasets. A total of 125 LSOAs were removed from both dataset when was not possible to aggregate or split to reflect the boundaries changes. Polygons were not removed if the change in area was <10% of the LSOA polygon area between 2001 and 2011. Existing methods to adjust LSOA boundaries are based on gridding the population or using a complex set of geographic variables which were not employed, due to the fact that a discrete analysis (at LSOA unit) was preferred to a continuous one.

Those LSOAs without a direct equivalent match from the 2001 to the 2011 census are distributed across areas of both better and worse SRH, with some in the Liverpool, Manchester, Morecambe Bay, East Lancashire and Cheshire areas. There does not appear to be any systematic pattern of distribution of these areas that will have skewed the analysis. The mean SRH for excluded LSOAs was 1.91 (range = 1.76-2.00, SD = 0.06) compared to a mean overall SRH of 1.90 (range = 1.71-2.00, SD = 0.05), suggesting the excluded areas do not differ significantly from the region.

3.5.2 Use of Geographically Weighted Regression

Historically, the conventional approach to the analyses of spatial data has been to calibrate a global model. The term 'global' implies that spatial data are used to compute a single statistic that essentially represents an average of the conditions that exist throughout a study area. The underlying assumption in a global model is that the relationships between predictive and the outcome variables are homogeneous (or stationary) across space. More specifically, the global model assumes that the same stimulus provokes the same response in all parts of the study area (Matthews & Yang, 2012). However, in practice, the relationships between variables might be nonstationary and vary geographically (Jones III & Hanham, 1995). Spatial nonstationarity exists when the same stimulus provokes a different response in different parts of the study area. If nonstationarity exists, then it is possible that different processes are at work within the study area. Global modelling techniques, such as ordinary least squares (OLS) linear regression or spatial regression methods, cannot detect nonstationarity and their use may potentially obscure areal variations in the relationships between predictors and outcome variables. This may affect public policies that are based on the results of studies using global models. For example, where

nonstationarity is present but not detected, the resulting findings have been found to be unsatisfactory in specific local or regional settings (Ali et al., 2007).

Geographically Weighted Regression (GWR) is a statistical technique that allows variations in relationships between predictors and outcome variable over space to be measured within a single modelling framework (Fotheringham et al., 2003). GWR has been applied to studies in a wide variety of demographic fields including, but not limited to, the analysis of health and disease, such as environmental equity (Mennis & Jordan, 2005), population density and housing (Mennis, 2006)and urban poverty (Longley & Tobón, 2004).

GWR extends OLS linear regression models by accounting for spatial structure and estimates a separate model and local parameter estimates for each geographic location in the data based on a 'local' subset of the data using a differential weighting scheme. The GWR model can be expressed as:

$$y_i=\beta_0(u_i,v_i)+\sum j=1k\beta_j(u_i,v_i)xij+\varepsilon i$$

where y_i is the value of the outcome variable at the coordinate location i where (u_i,v_i) denotes the coordinates of i, β_0 and β_j represents the local estimated intercept and effect of variable j for location i, respectively. To calibrate this formula, a bi-square weighting kernel function is frequently used to account for spatial structure (Brunsdon et al., 1998). Those locations near to i have a stronger influence in the estimation of $\beta_j(u_i,v_i)$ than locations farther from i. In the GWR model, localized parameter estimates can be obtained for any location i which in turn allows for the creation of a map showing a continuous surface of parameter values and an examination of the spatial variability (nonstationarity) of these parameters (Matthews & Yang, 2012).

GWR has been likened to a 'spatial microscope' for its ability to measure variations in relationships that are unobservable in aspatial, global models

(Fotheringham et al., 2003). This approach places an emphasis on differences across space, and the search for the exceptional, or local, 'hot spots.'

GWR is designed to determine if relationships vary across space. However, it is important to note that use of a GWR approach does not assume that relationships will vary across space, but is a means to identify whether or not they do. If relationships do not vary across space, the global model is an appropriate analytical tool for the data under consideration. GWR can be used as a model diagnostic or to identify interesting locations (areas of variation) for investigation. Researchers typically use the Akaike Information Criterion (AIC) (Akaike, 1974) to take model complexity into account and thus facilitate a comparison between the overall model results from a 'global' OLS linear regression model with those from the local GWR model. The AIC comparison reveals whether a spatial perspective significantly improves the model fit.

3.5.3 Geographical information system: ArcGIS Pro

The study data was processed and analysed using a geographic information system (GIS), which is a computer system for representing data related to positions on Earth's surface. GIS can bring together data on dimensions of interest and help to better understand spatial patterns and relationships. GIS can use any information that includes location. The location can be expressed in different formats, such as latitude and longitude, address, or postal code.

GIS can analyse data about people, such as population, income, or education level. It can also include information about the environment, such as the location of water courses, vegetation, soil types and information about the built environment, such as the sites of factories, farms, and schools, drains, roads and power lines. Using GIS, researchers can compile the variables of interest using their geographical locations to study their interactions.

Mapping and analysis for this study were carried out in ArcGIS Pro. ArcGIS Pro is a commercial software produced by ESRI and being used by public and private organisations to manage geographic data. The rationale for use of the various ArcGIS Pro geoprocessing tools is set out below. Full details are available online at: https://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/an-overview-of-the-spatial-statistics-toolbox.htm

3.5.4 Local Bivariate Relationships

The Local Bivariate Relationships tool in ArcGIS allows the quantification of the relationship between two variables (or layers) on the same map by determining if the values of one variable are dependent on or are influenced by the values of another variable within a pre-defined neighbourhood, and if those relationships vary over geographic space. The tool calculates an entropy statistic in each local neighbourhood that quantifies the amount of shared information between the two variables (Guo, 2010). Unlike other statistics that can often only capture linear relationships (such as Pearson correlation), entropy can capture any structural relationships between the two variables, including exponential, quadratic, sinusoidal, and even complex relationships that cannot be represented by typical mathematical functions. This tool accepts polygons or points and creates an output feature class summarizing the significance and form of the relationships of each input feature.

Each local relationship between the two variables is classified into one of the following categories:

- **Not Significant**—The relationship between the variables is not statistically significant.
- **Positive Linear**—The dependent variable increases linearly as the explanatory variable increases.

- **Negative Linear**—The dependent variable decreases linearly as the explanatory variable increases.
- **Concave**—The dependent variable changes by a concave curve as the explanatory variable changes.
- **Convex**—The dependent variable changes by a convex curve as the explanatory variable changes.
- **Undefined Complex**—The variables are significantly related, but the type of relationship cannot be reliably described by any of the other categories and may contain combinations of the relational structures described above.

It should be noted that it is possible for one variable to accurately predict a second variable, but the second variable cannot accurately predict the first.

3.5.5 Hot Spot Analysis (Getis-Ord Gi*)

Hot spot analysis identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). It is based on z-score representing the intensity of the process which significance can be evaluated from the relative p-value, and confidence interval. The z-scores and p-values indicate whether the observed spatial clustering of high or low values (z-score) is more pronounced than would be expected if those values were randomly distributed (p-value, smaller the p-value less likely is that the values are randomly distributed) (Getis & Ord, 1992).

ArcGIS uses a feature binning process to aggregate large amounts of point features into dynamic polygons called bins. A single bin represents all features within its boundaries and appears wherever at least one feature lies within it. The output provided by ArcGIS show spots in the +/-3 bins as statistically significant at 1% level; spots in the +/-2 bins as statistically significant at 5% level; and spots in the +/-1 bins as statistically significant at 10% level. Under +/- 2 bins the spots are not considered statistically significant. The sign + indicated 'hot' spot and – 'cold' spot. In fact, a high positive z-score and small p-value indicate a spatial clustering of high values (hotspot). A low negative z-score and small p-value indicate a spatial clustering of low values (cold spot). The higher (or lower) the z-score, the more intense the clustering. A z-score near zero indicates no apparent spatial clustering.

3.5.6 Geographically Weighted Regression important variable selection: predictors of SRH in 2001 and 2011

The study used variable selection within the Geographically Weighted Regression function in ArcGIS to find the best predictors for SRH in the region. Geographically

Weighted Regression (GWR) is a local form of linear regression used to model spatially varying predictor coefficients. The GWR tool provides a local model of the variable or process to be analysed by fitting a regression equation between dependent and independent variables in each neighbourhood of the dataset (similarly to any 'moving' functions) (Brunsdon et al., 1996). The shape and extent of each neighbourhood is user-defined. For this analysis, the number of neighbours option was elected in ArcGIS. The neighbourhood size is a function of a specified number of neighbours included in calculations for each feature. Where features are dense, the spatial extent of the neighbourhood is smaller; where features are sparse, the spatial extent of the neighbourhood is larger. For this analysis, the number of neighbours was set to eight.

Table 13 presents a list of the variables considered in the variable selection, derived from both 2001 and 2011 census data. The list is informed by the systematic literature review, in which ethnicity and age were included in US studies using the ICE:

Table 13: List of variables considered in variable selection

Variable
ICE Salariat vs Working
ICE Salariat vs Intermediate
ICE Intermediate vs Working
ICE Salariat & Intermediate vs Working
ICE Salariat vs Intermediate & Working
ICE Salariat vs Intermediate, Working & LT Unemployed
ICE Salariat & Intermediate vs Working & LT Unemployed
ICE Salariat & Intermediate & Working vs LT Unemployed
Mean Age
Median Age
0-15
16-64
65+
Ethnicity; non-white

Table 14 summarises the variable selection method using the Ordinary Least Squares function in ArcGIS.

Table 14: Variable selection using exploratory regression in ArcGIS

Search criteria	Data Type	Selected value
Dependent Variable	The numeric field containing the observed values to be modelled using OLS.	SRH
Candidate explanatory variables	A list of fields to try as OLS model explanatory variables.	Field
Maximum number of explanatory variables	All models with explanatory variables up to the value specified here will be assessed.	5
Minimum number of explanatory variables	This value represents the minimum number of explanatory variables for models evaluated. If, for example, the Minimum Number of Explanatory Variables is 1 and the Maximum Number of Explanatory Variables is 5, the Exploratory Regression tool will try all models with one explanatory variable, and all models with every combination of five explanatory variables.	1
Minimum acceptable Adj R Squared	This is the lowest Adjusted R-Squared value to be considered a passing model. Valid values for this parameter range from 0.0 to 1.0. The default value is 0.5, indicating that passing models will explain at least 50 percent of the variation in the dependent variable.	0.5
Maximum coefficient p value cutoff	The cutoff p-value represents the confidence level required for all coefficients in the model to consider the model passing.	0.05

Search criteria	Data Type	Selected value
Maximum VIF value cutoff	Small p-values reflect a stronger confidence level. The default value is 0.05, indicating passing models will only contain explanatory variables whose coefficients are statistically at the 95 percent confidence level. This value reflects how much redundancy (multicollinearity) among model explanatory variables is acceptable. When the VIF (Variance Inflation Factor) value is higher than about 7.5, multicollinearity can make a model unstable; consequently, 7.5 is the default value for this analysis.	7.5
Minimum Acceptable Spatial Autocorrelation p value (Optional)	For models that pass all of the other search criteria, the Exploratory Regression tool checks model residuals for spatial clustering using Global Moran's I. Passing models should have large p-values for this diagnostic test. The default minimum p-value is 0.1. Only models returning p-values larger than this minimum will be considered passing.	0.1

(Reproduced with acknowledgments to ESRI ArcGIS).

A neighbourhood is the distance band or number of neighbouring LSOAs used for each local regression equation and is perhaps the controls the degree of smoothing in the model. The Neighbourhood Type parameter was be based on the Number of Neighbours, in which neighbourhood size is a function of a specified number of neighbours, which allows neighbourhoods to be smaller where features are dense and larger where features are sparse. The Neighbourhood Selection Method parameter specifies how the size of the neighbourhood is determined (the number of neighbours used). The golden section search option was selected, in which the GWR tool determines the best values for the number of neighbours parameter using the golden search method. Golden section search first finds maximum and minimum distances and tests the Akaike Information Criterion (AICc) at various distances incrementally between them. AICc is a measure of model performance and can be used to compare regression models. Taking into account model complexity, the model with the lower AICc value provides a better fit to the observed data. AICc is not an absolute measure of goodness of fit, but it is useful for comparing models with different explanatory variables if they apply to the same dependent variable. When there are more than 1,000 features in a dataset, the maximum distance is the distance at which any feature has at most 1,000 neighbours. The minimum distance is the distance at which every feature has at least 20 neighbours. Golden section search then determines the number of neighbours with the lowest AICc as the neighbourhood size.

GWR takes into account the co-located processes but also the surrounding conditions. The effect of the surrounding conditions is modulated through the geographical weighting. Features that are farther away from the regression point are given less weight and thus have less influence on the regression results for the target feature; features that are closer have more weight in the local linear regression

coefficients. The weights are determined using a kernel, which is a distance decay function that determines how quickly weights decrease as distances increase. For this analysis, the Gaussian weighting function was selected. A Gaussian weighting function does not attribute zero weights and ensures that each regression LSOA will have a sufficient number of neighbours to estimate the predictor's coefficients. This avoids the problem of extreme collinearity, which commonly encountered in geographically weighted regression. Collinearity refers to potential dependencies among local coefficients. These can be expressed either as the correlation between pairs of local regression coefficients at one location, or as the correlation between two overall sets of local coefficient estimates associated with two exogenous variables at all locations. Weak dependencies of either form may interfere with a substantive interpretation of local GWR estimates, whereas strong dependencies may induce artifacts that invalidate any meaningful interpretation and search for spatial heterogeneities because the regression coefficients are no longer uniquely defined (see Wheeler and Tiefelsdorf (2005) for a review).

3.6 Ethical approval

LSOA-aggregated secondary source data derived from the UK national census was obtained from the National Online Manpower Information System (Nomis) portal of the Office for National Statistics (ONS). Data does not include any personally identifiable information. Ethical approval for the study was obtained from the Faculty of Health and Medicine Research Ethics Committee (FHMREC) of the University of Lancaster, reference: FHMREC17042.

CHAPTER 4: Results

This chapter reports the results of the spatial analysis. Variable selection for GWR analysis is described, before presenting findings under the broad headings of the study aims.

4.1 Variable selection

The summary of variable significance from the initial exploratory regression presented in Table 15 and Table 17 provides information about variable relationships and their consistency. Each candidate explanatory variable is listed with the proportion of times it was statistically significant. The first few variables in the list have the largest values for the % Significant column. The stability of variable relationships is given by examining the % Negative and % Positive columns. Strong predictors will be consistently significant (% significant), and the relationship will be stable (primarily negative or primarily positive).

4.1.1 Variable selection for SRH in 2001

Although the model with highest explained variance does not include any of the 2001 Indices of Concentration at the Extremes, the table of the most significant predictor variables (Table 15) for SRH in 2001 indicates that seven of the eleven most significant predictor variables (i.e., selected in more than 95% of the explored models) are ICE-based measures. This indicates that there is a significant effect of socioeconomic concentration on SRH and mostly masked by age measures which seem to produce better linear relationships with SRH than the ICE-based measures alone.

A significant positive association between mean age and SRH was found in 100% of models. This association appears to be driven by the number of working age and younger residents, with the 16 to 64 population being significantly positively associated with better SRH in 99.93% of cases and the 0 to 15 population in 96.95%.

Aggregate measures of ethnicity showed a slight difference between white and non-white residents. The number of white residents was a significant predictor of SRH in 95.42% of models, with the great majority of these (82.3%) showing a significant positive association such that greater numbers of white residents were associated with better SRH.

Table 15: Selected variables with direction of effect for 2001

Variable	% Significant	% Negative	% Positive
Mean age	100.00	0.00	100.00
Age 16 to 64	99.79	0.07	99.93
ICE Salariat & Intermediate & Working vs LT Unemployed	98.79	6.91	93.09
ICE Salariat vs Intermediate, Working & LT Unemployed	97.69	95.97	4.03
ICE Salariat & Intermediate vs Working	97.23	16.85	83.15
ICE Salariat & Intermediate vs Working & LT Unemployed	96.59	56.01	43.99
Age 0 to 15	95.98	3.05	96.95
ICE Intermediate vs Working	95.76	72.97	27.03
Ethnicity: all white	95.42	17.70	82.30
ICE Salariat vs Working	95.32	42.75	57.25
ICE Salariat vs Intermediate & Working	95.18	73.25	26.75

Table 16: Highest Adjusted R-Squared GWR model's results for 2001 (best model)

$AdjR^2$	Model				
0.97	+Mean age***	-Median age ***	+Age 0 to 15***	+Age 16 to 64***	-Age 65+***

Model Variable significance (* = 0.10; ** = 0.05; *** = 0.01)

4.1.2 Variable selection for SRH in 2011

The table of the most significant predictor variables (Table 17) for the SRH 2011 data indicates that three of the six most significant predictor variables (i.e., selected in more than 95% of the models) are ICE-based measures. More importantly, the most significant predictor was the ICE for salariat & intermediate occupations compared with working class & long-term unemployed (which appeared in the best model, Table 18). The 2011 analysis indicates stronger linear relationships of ICE-based measured with SRH than in 2001 analysis.

The ICE for Salariat & Intermediate compared with working class & LT unemployed was most frequently associated with SRH, with significant associations in

99.21% of models, of which 98.22% were positive, such that a greater concentration of higher occupational status was associated with better SRH.

The direction of the association between the ICE and SRH varies with the socioeconomic groups included in the ICE. The ICE for the Salariat & Intermediate vs Working & LT Unemployed groups has a positive association, such that a higher concentration of more affluent groups is associated with better SRH. A positive association is also seen for the ICE for the Intermediate compared with Working class groups.

However, the opposite effect is seen for the ICE for the salariat compared with intermediate and salariat & intermediate compared with working class groups, such that a higher concentration of more disadvantaged groups is associated with better SRH. It is possible that this provides some evidence of a buffering effect, in that lower socioeconomic class residents might receive some degree of protection from sharing their neighbourhood with a greater concentration of people of similar status.

It is noted that the mean age value for the 2001 data was positive, while the median age in 2011 is negative. This may be due to the age distribution changes or for the relationships between age, ICE and IMD. Other than this, the 16 to 64 age group shows similar relationships and importance for both years.

Table 17: Selected variables with direction of effect for 2011

Variable	% Significant	% Negative	% Positive
ICE Salariat & Intermediate vs Working & LT Unemployed	99.21	1.78	98.22
Age 65+	98.40	98.21	1.79
Median age	97.46	88.43	11.57
Age 16 to 64	97.27	3.48	96.52
ICE Salariat vs Intermediate, Working & LT Unemployed	96.65	5.61	94.39
ICE Salariat & Intermediate vs Working	96.16	36.93	63.07

Table 18: Highest Adjusted R-Squared GWR model's results for 2011 (best model)

$AdjR^2$	Model			
0.81	-ICE Salariat & Intermediate vs Working ***	+ICE Salariat & Intermediate vs Working & LT Unemployed***	-Median age***	+Ethnicity: Non-white***

Model Variable significance (* = 0.10; ** = 0.05; *** = 0.01)

The most obvious difference between the 2001 and 2011 models is the absence of any of the ICE or ethnicity measures from the 2001 model. Mean age, median age and the principal age groups of young people, working age adults and older adults together accounted for an adjusted R^2 measure of variance explained of 97% (Table 16).

Two versions of the ICE were included in the 2011 best model (Table 18), both of which represent a comparison between advantaged and disadvantaged groups as defined by employment relations, but with different associations with SRH. The ICE for salariat and intermediate occupations compared with working class occupations was negatively associated such that higher concentrations of working-class residents were associated with better SRH. Conversely, the ICE for salariat and intermediate occupations compared with working class and long-term unemployed residents was positively associated, with higher concentrations of salariat and intermediate residents being associated with better SRH. This finding is somewhat counterintuitive, and one

possible explanation for it might be that working class and intermediate occupations are not as distinct in terms of employment relations and their association with SRH is attenuated compared to the ICE that includes long-term unemployment.

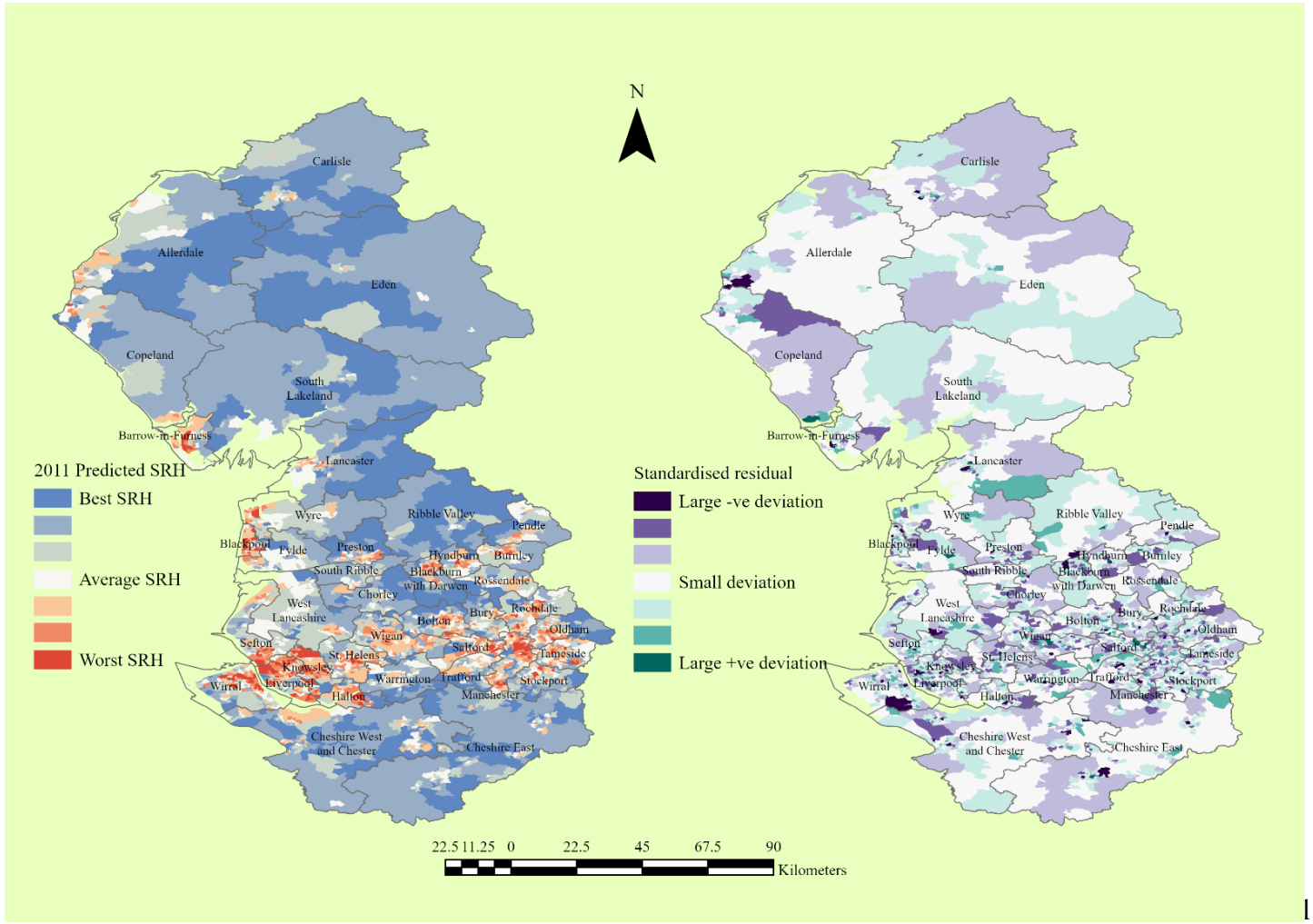
Median age was selected in the 2011 best model such that younger people were associated with better SRH. Ethnicity was also included in the 2011 model, with a higher concentration of non-white residents being associated with better SRH (Table 18).

4.1.3 Mapping SRH from GWR model

The variable selection exercise for the 2001 data did not result in the ICE being included in the GWR model. The 2011 GWR model was therefore selected for analysis, as it included the ICE. Mapping the output of the Geographically Weighted Regression for 2011 shows that the model predicts a pattern of association with SRH that is consistent with previous findings, such that worse SRH is predicted in coastal communities, in East Lancashire and between Liverpool and Greater Manchester. Better SRH is predicted in rural areas in the north of the region and in affluent areas in Cheshire to the south (Figure 8 , left panel).

Examination of the standardised residuals for the Geographically Weighted Regression (Figure 8, right panel) indicates a generally low level of deviation across the region, which suggests that a good degree of confidence in the model or just low uncertainty. Where there are localised areas of higher deviation, these are generally associated with areas of poorer SRH on the Cumbrian and Fylde coasts, in East Lancashire and between Liverpool and Manchester reflecting larger spatial heterogeneities in the distribution of SRH and its predictors

Figure 8 Predicted SRH and standard deviations of residuals for 2011 GWR model



4.2 The spatial relationships between occupational status using the ICE and SRH.

4.2.1 Mapping SRH, the ICE and the IMD

The following maps present the distribution of 2001 and 2011 data for SRH (see Figure 9 and Figure 10 respectively), distribution of the ICE for salariat compared with working-class occupations as the best exemplar of the Goldthorpe schema (see Figure 11 and Figure 12 respectively) and the IMD (see Figure 13 and Figure 14 respectively), along with hotspot analysis of the distribution of each variable (see Figure 15 and Figure 16 for SRH 2001 & 2011; see Figure 17 and Figure 18 for ICE 2001 & 2011; see Figure 19 and Figure 20 for IMD 2001 & 2011 respectively). The study considered those values beyond the 95% confidence interval.

The Gi* statistic returned for each feature in the dataset is a z-score. A quick reminder that for statistically significant positive z-scores, the larger the z-score is, the more intense the clustering of high values (hot spot) and vice-versa for negative z-scores (cold spot). From this it follows that although an individual LSOA with a high value might be of interest, it may not itself constitute a statistically significant hot spot if the neighbourhood shows a mixture of high and low values. To be reported as a statistically significant hot spot, an LSOA will have a high value and also be surrounded by other LSOAs with high values as well.

Hotpots represent clusters of better SRH (groups of higher values on the composite rating scale) and cold spots represent clusters of poorer SRH (groups of lower values on the composite rating scale). For consistency, the charts have been formatted to represent adverse health or socioeconomic factors in red and favourable factors in blue. Areas that changed due to LSOA recoding from 2001 to 2011 are marked in yellow (Figure 9).

Figure 9: Distribution of 2001 SRH

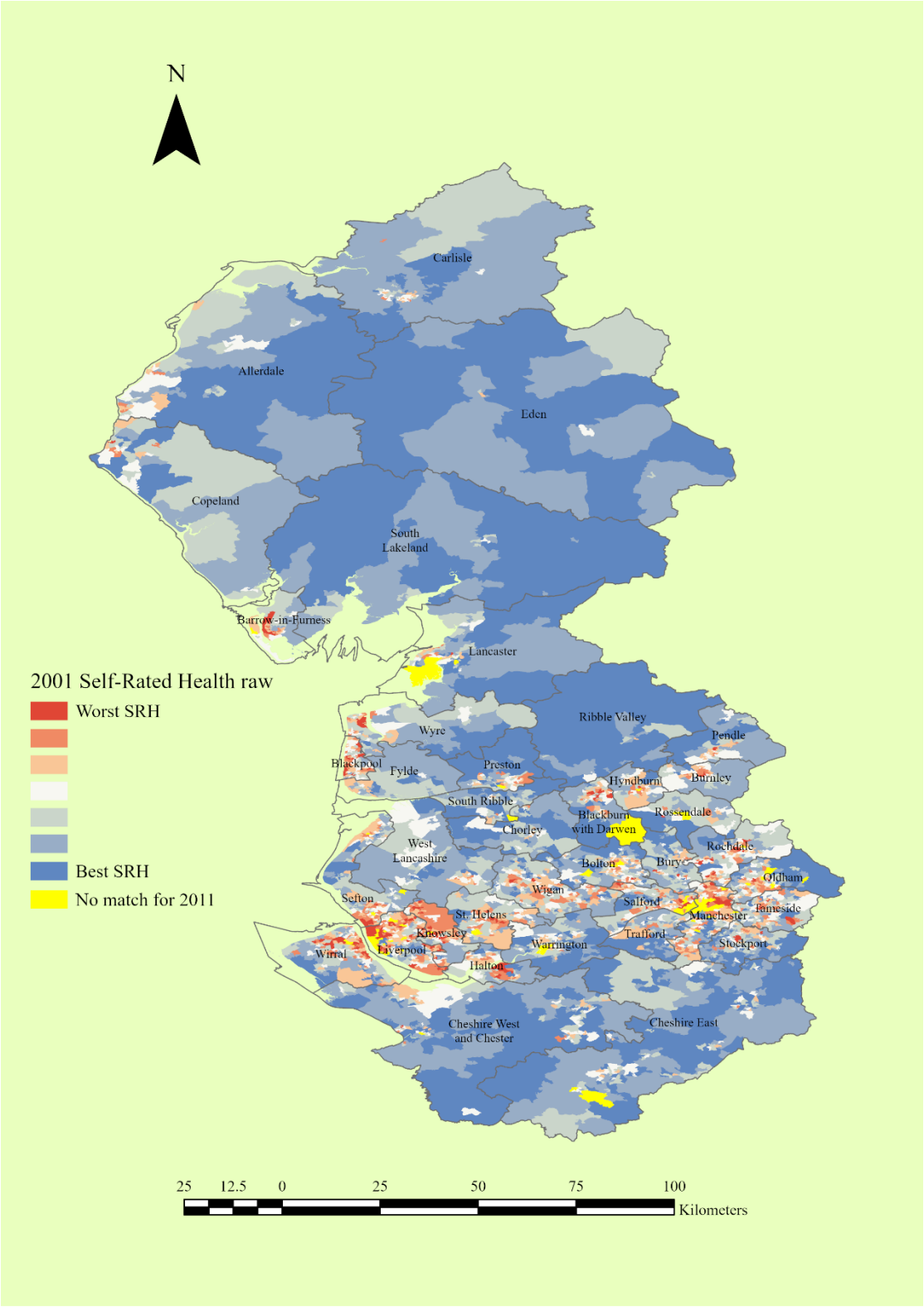


Figure 10: Distribution of 2011 SRH

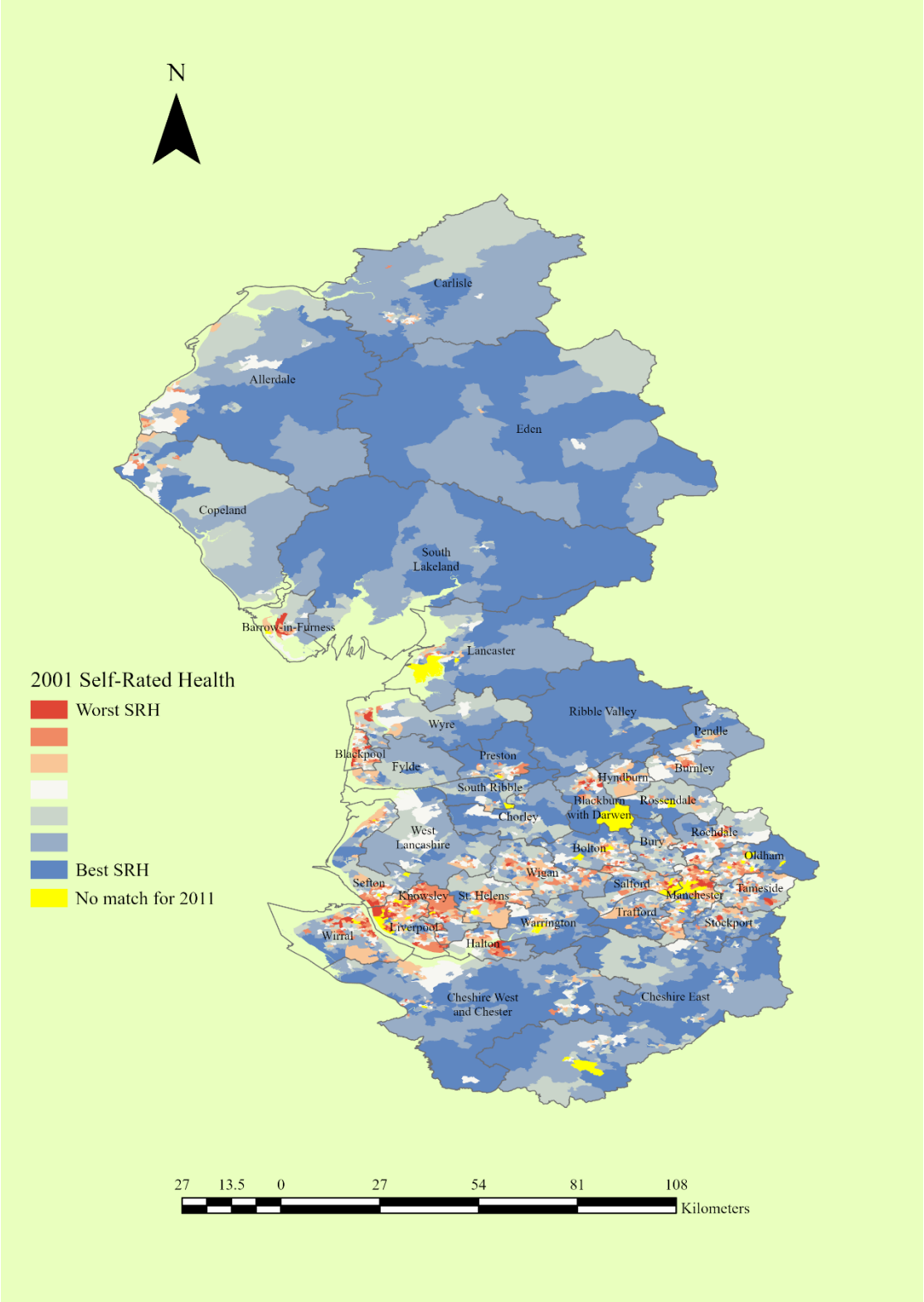


Figure 11: Distribution of the ICE for salariat class compared to working class occupations for 2001

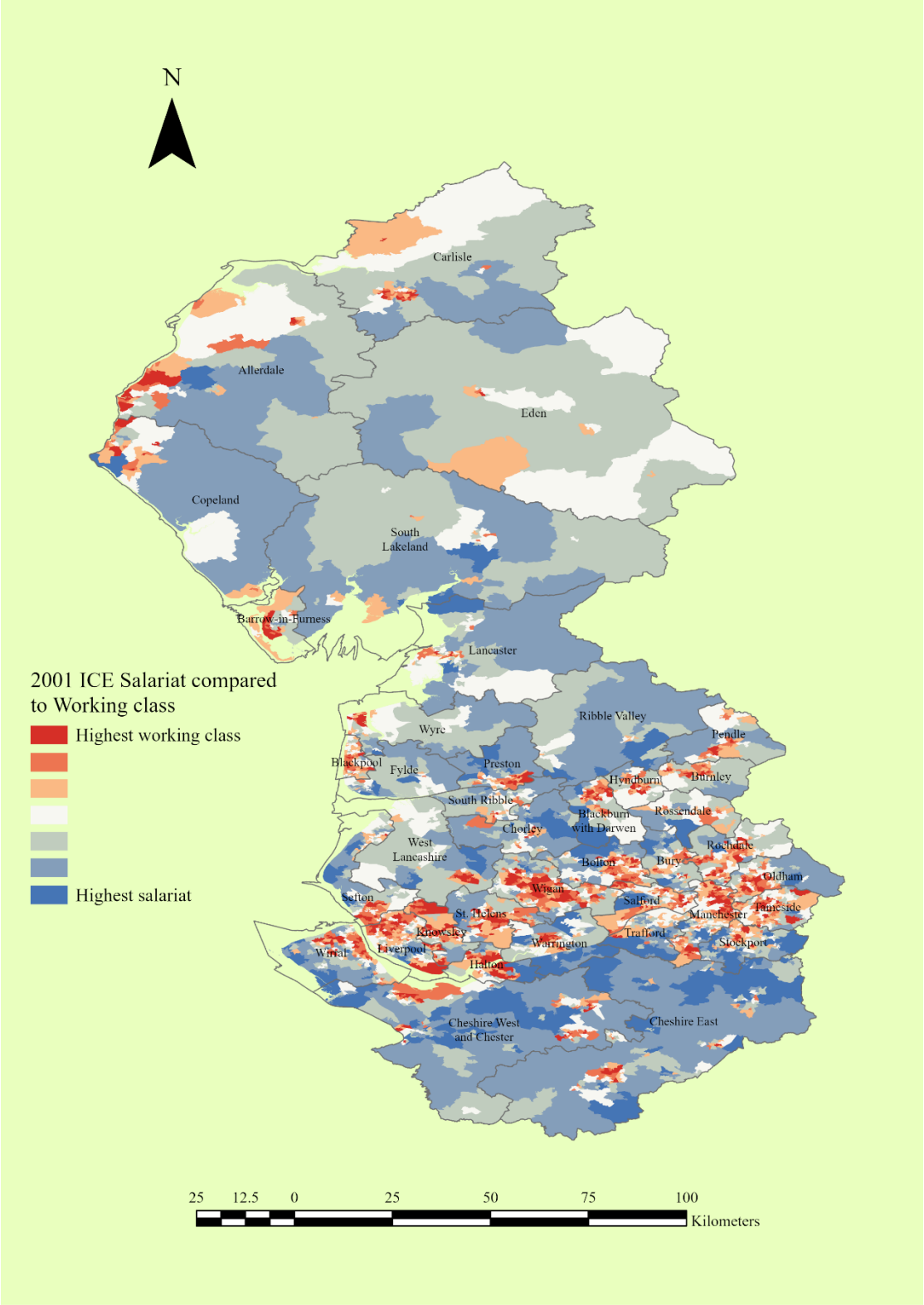


Figure 12: Distribution of the ICE for salariat class compared to working class occupations for 2011

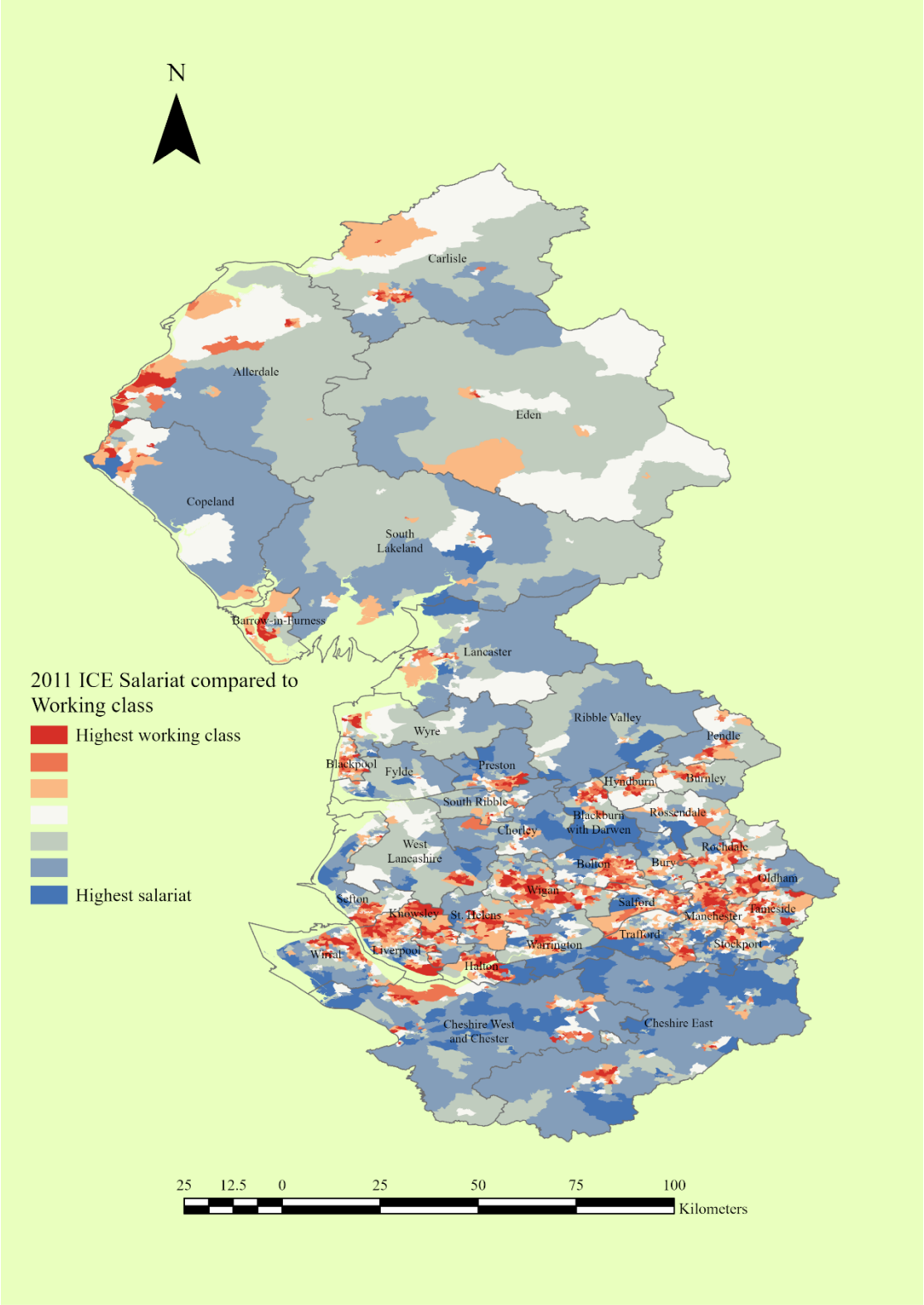


Figure 13: Distribution of 2001 Index of Multiple Deprivation

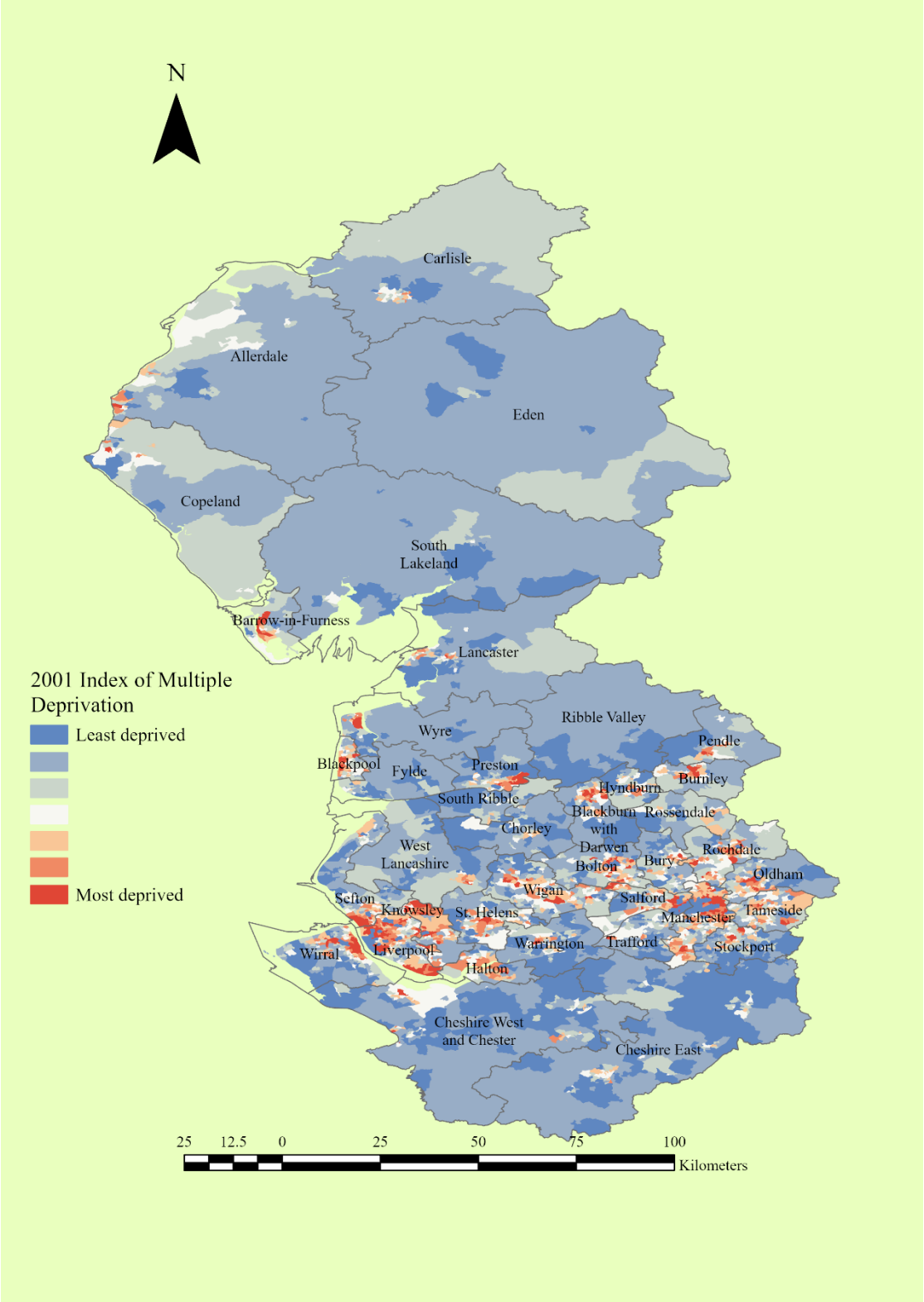


Figure 14: Distribution of 2011 IMD

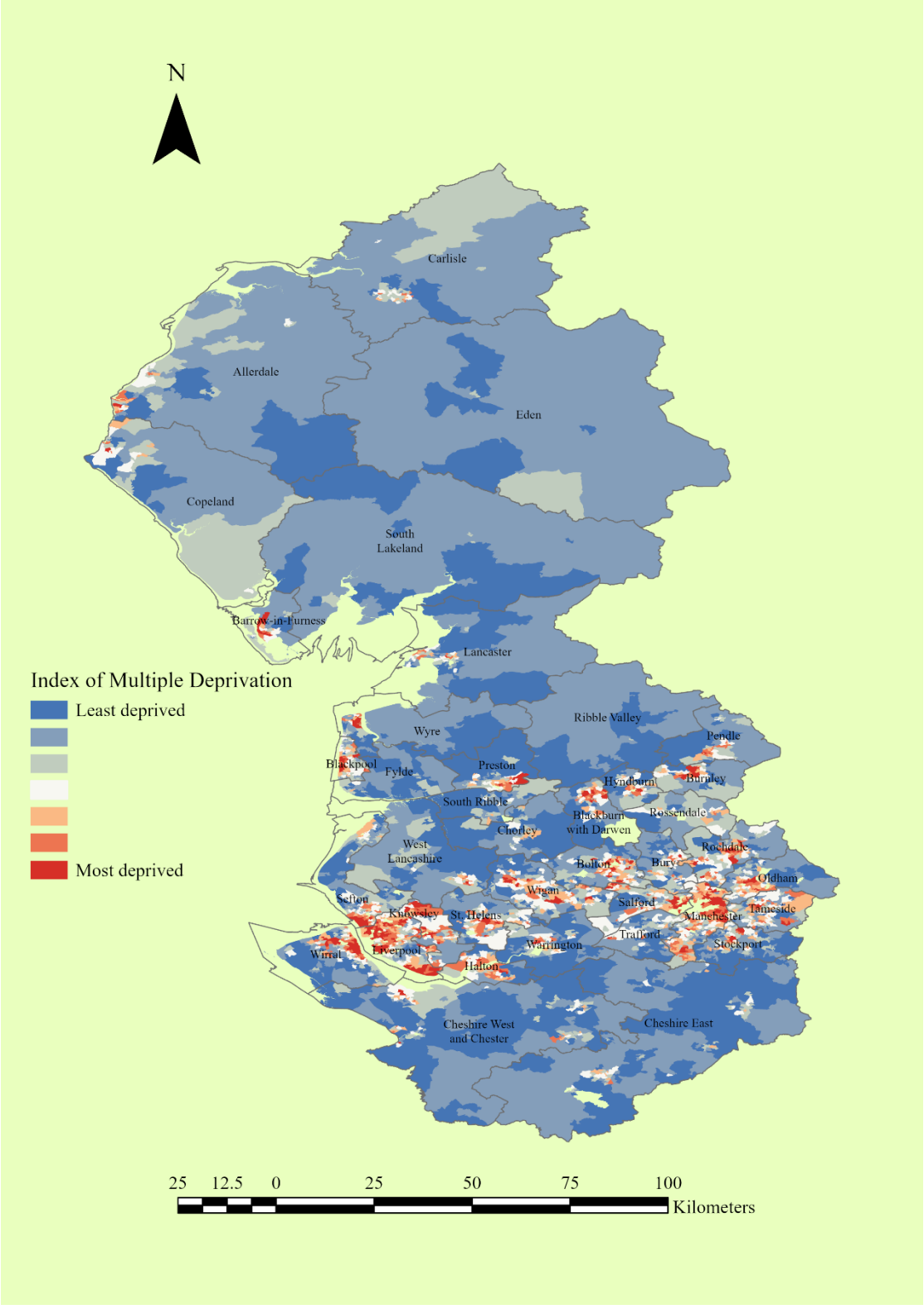


Figure 15: Hotspot analysis of 2001 SRH

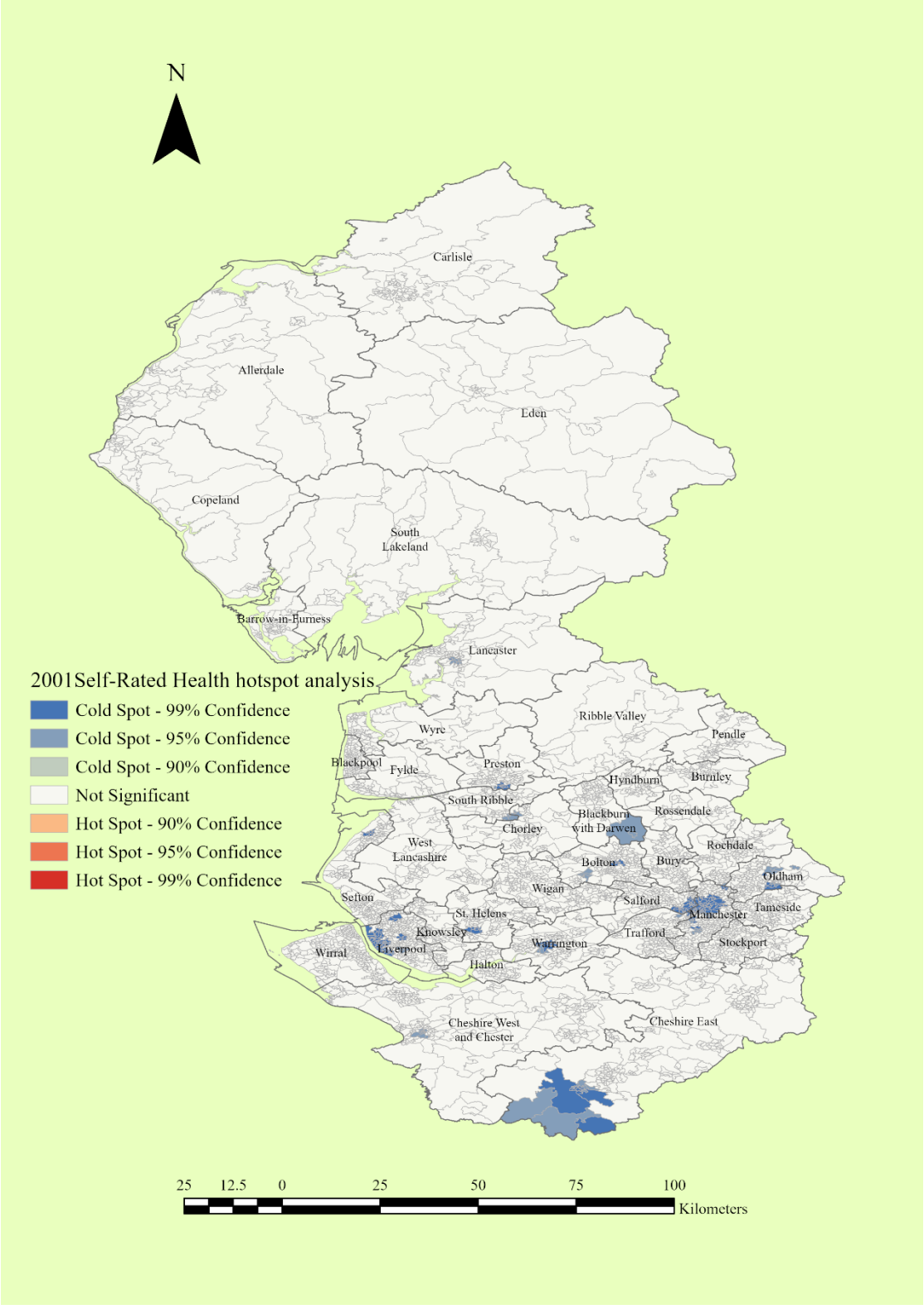


Figure 16: Hotspot analysis of 2011 SRH

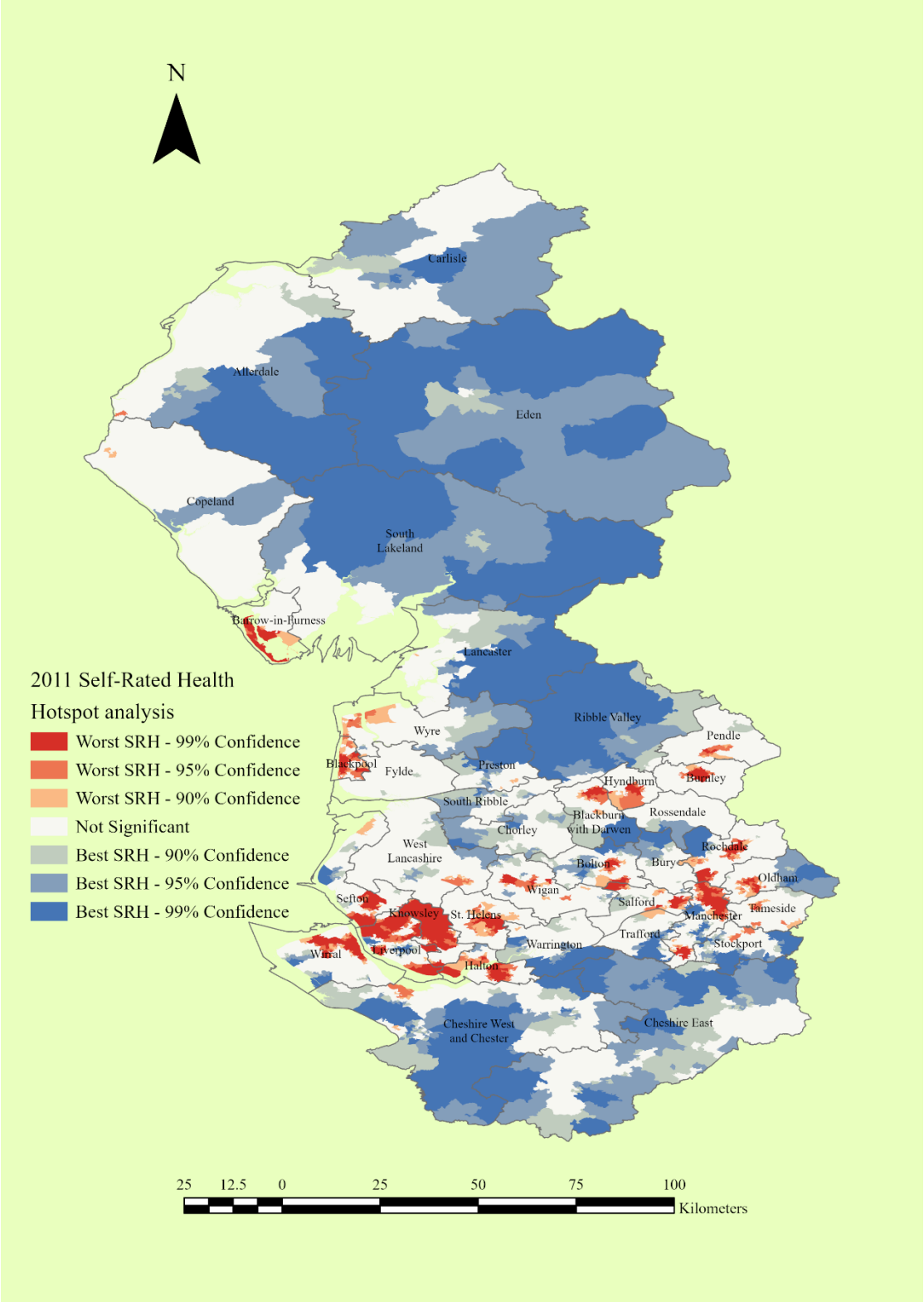
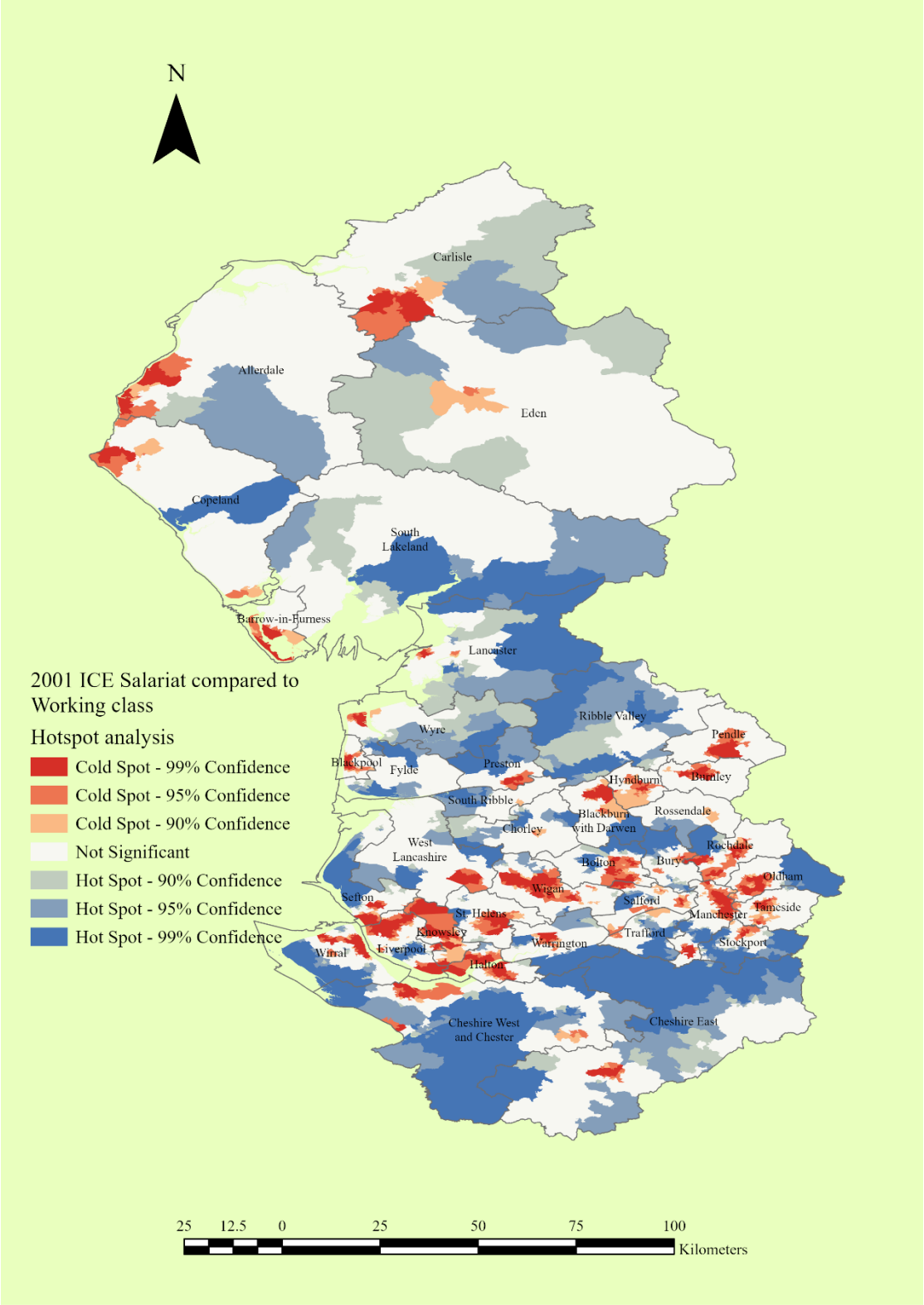
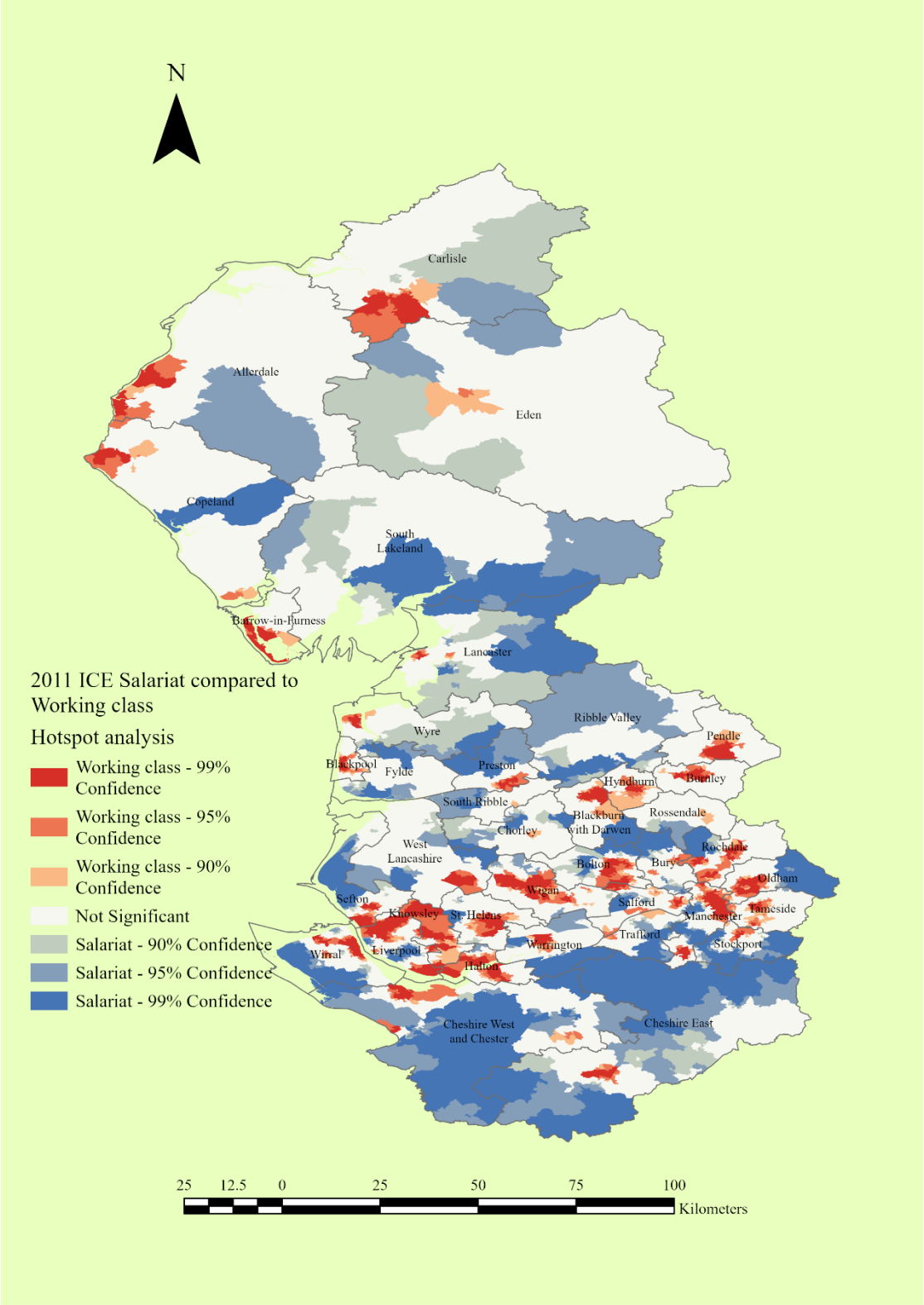


Figure 17: Hotspot analysis of the ICE for salariat class compared to working class occupations for 2001



Note on legend: Direction of ICE means cold spot = concentrations of working class residents; hotspot = concentrations of salariat.

Figure 18: Hotspot analysis of the ICE for salariat class compared to working class occupations for 2011



Note on legend: Direction of ICE means cold spot = concentrations of working class residents; hotspot = concentrations of salariat

Figure 19: Hotspot analysis of 2001 IMD

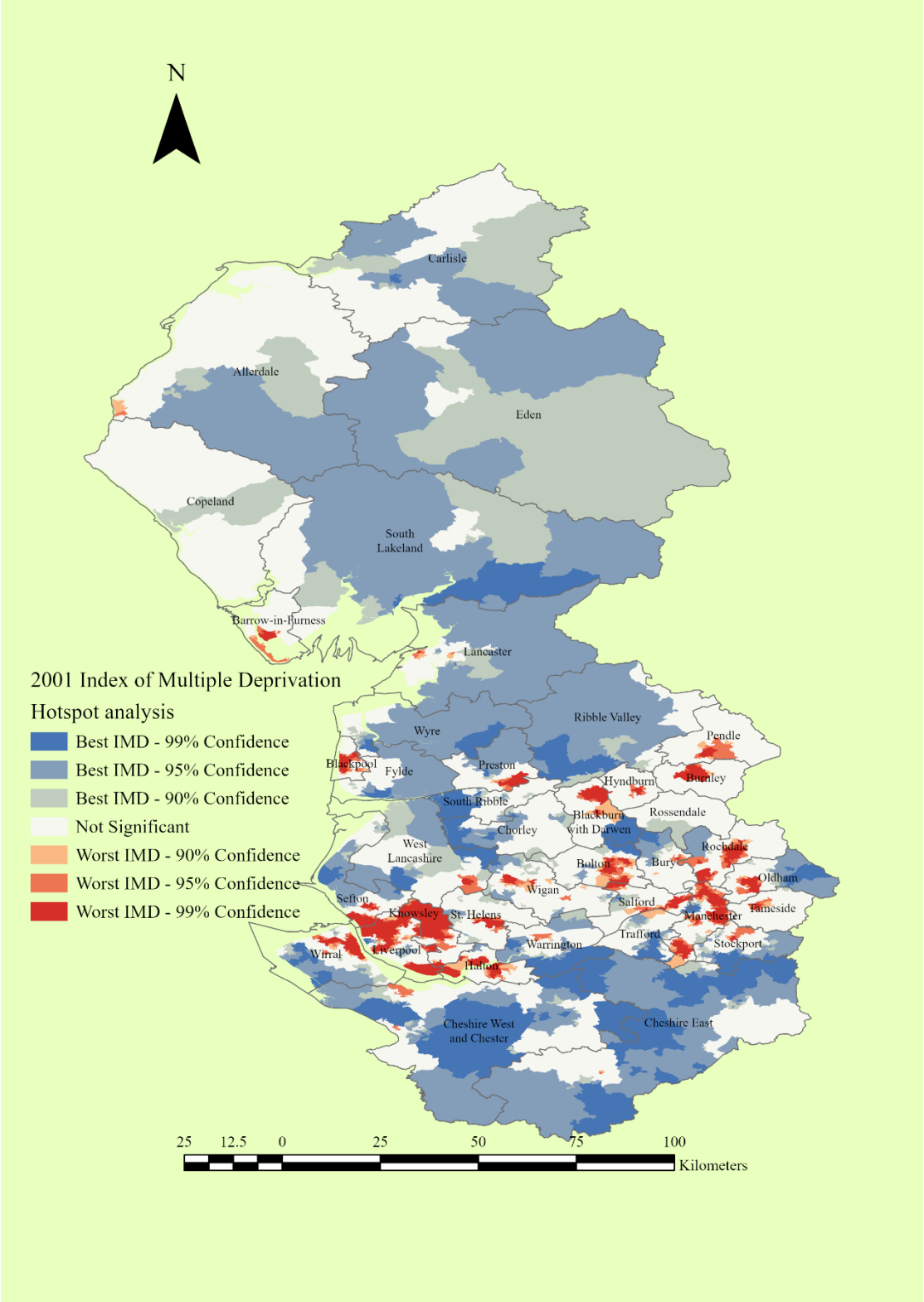
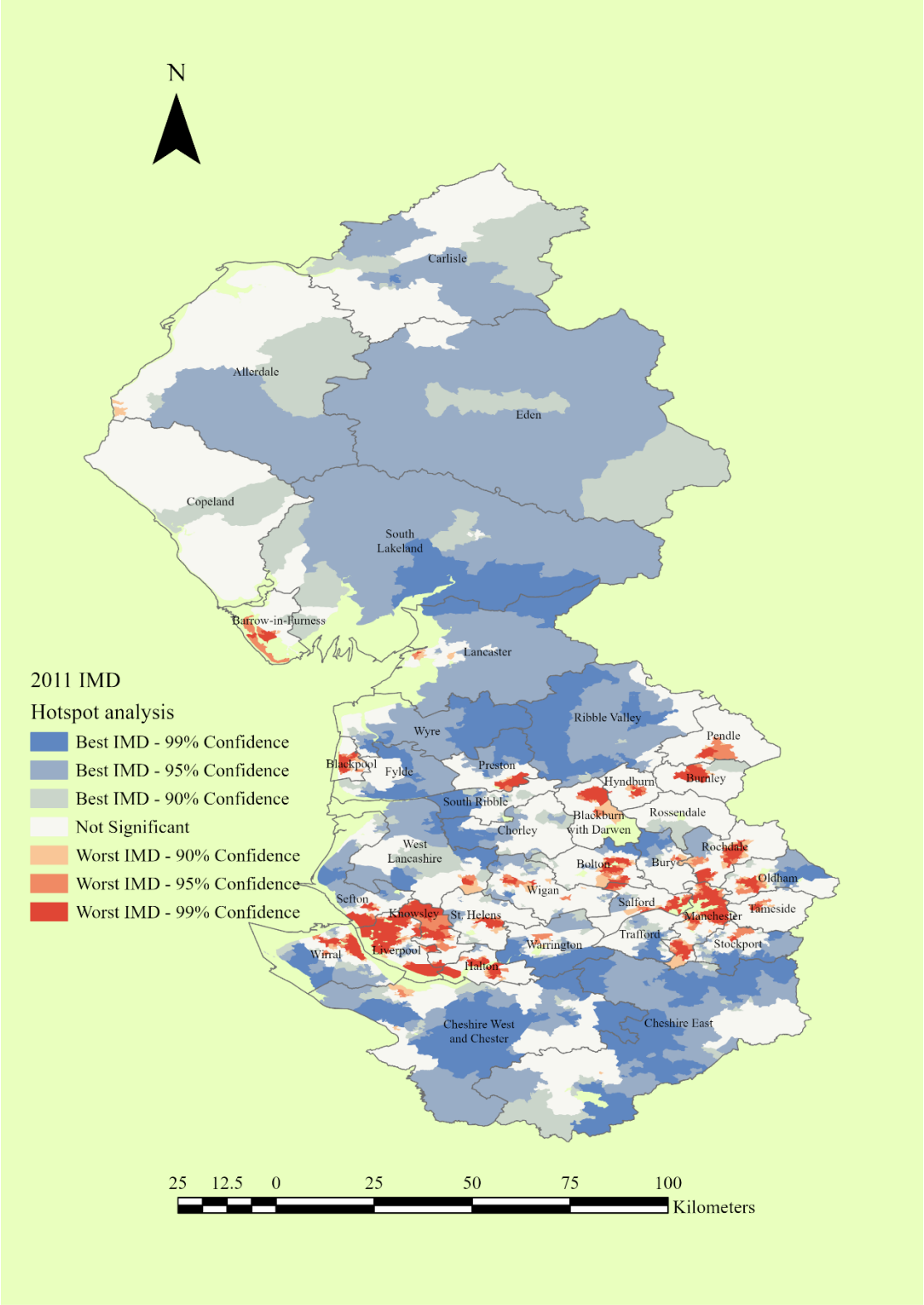


Figure 20: Hotspot analysis of 2011 Index of Multiple Deprivation



4.3 Comparison of the spatial relationships between the ICE and SRH with those of IMD and SRH

4.3.1 Distribution of SRH

Mapping the distribution of SRH values by LSOA shows a pattern consistent with established evidence in the health inequalities literature, with better health predominately located in rural areas and poorer health in urban areas. This can be seen in a band from Liverpool to Manchester and also in East Lancashire. This pattern of distribution for SRH was consistent from the 2001 to the 2011 census (see Figure 9 and Figure 10 respectively).

There is a decline in SRH in some urban areas, particularly around Liverpool, where several LSOAs shifted to the worse end of the SRH scale between 2001 and 2011 (Figure 21). Declining SRH is also apparent in several communities on the coasts of the Fylde in the Blackpool and Wyre areas (Figure 22) and in Cumbria, where is a decline in SRH on the Cumbrian coast from 2001 to 2011, with some LSOAs in the Maryport, Workington and Whitehaven areas that reported average levels of health in 2001 shifting to the poorer end of the rating scale in 2011 (Figure 23).

Cold spots of poor SRH in the 2011 data are typically very localised. Surrounding areas outside the scale of the cold spots do not show the same pattern, demonstrating the cold spots are localised (Figure 16). This shows high levels of segregation of cold spots in 2001 and a general absence of hotspots. In 2011 this heterogeneity is reduced with a much clear presence of large cold spots in rural areas and hotspots in and around urban areas.

Table 19 shows the change in total area of LSOAs occupied by residents with the best and worst SRH residents between 2001 and 2011.

Figure 21: SRH in the Liverpool area 2001 - 2011

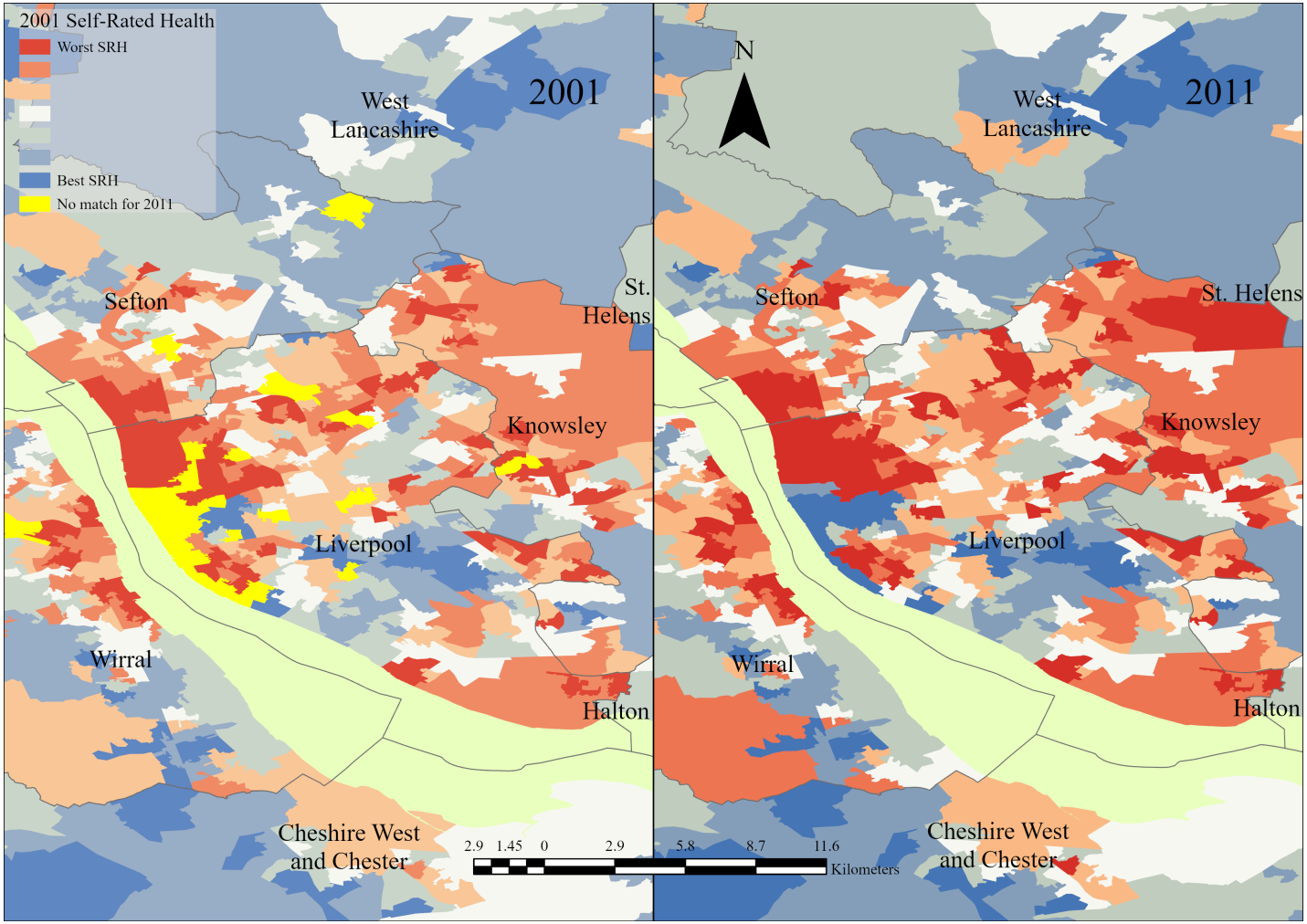


Figure 22: SRH on the Fylde Coast area 2001 - 2011

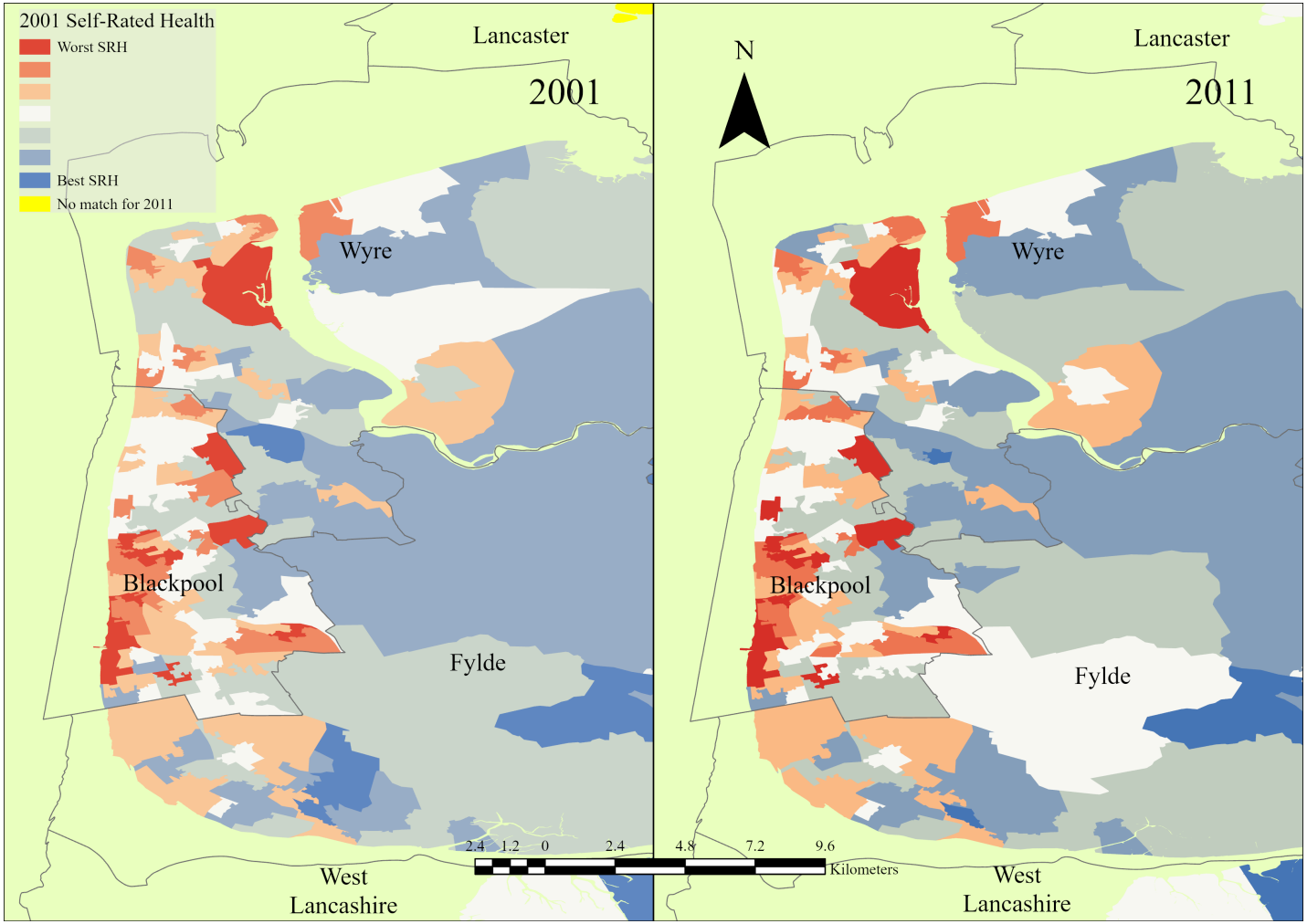
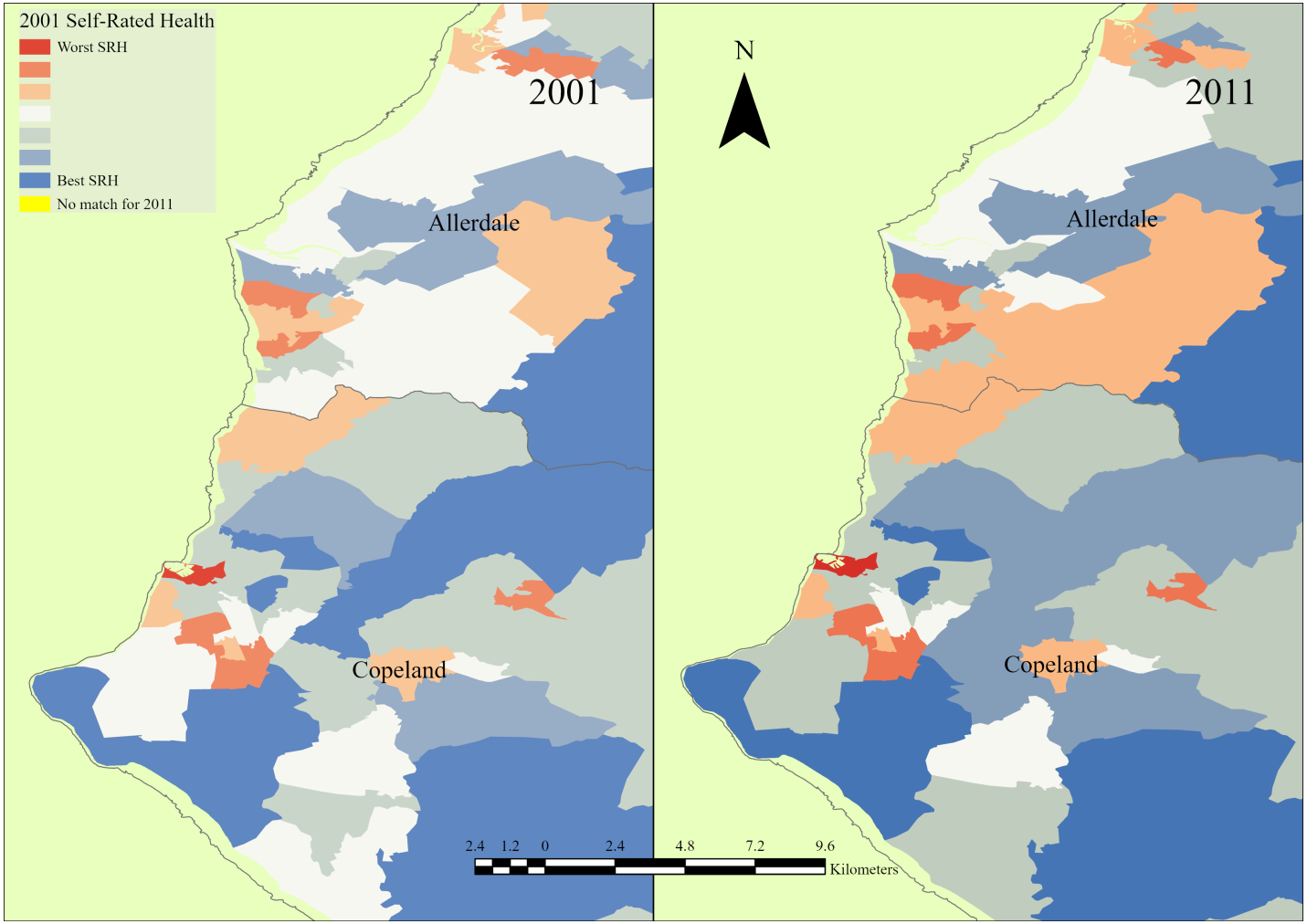


Figure 23: SRH on the Cumbria coast 2001 - 2011



4.3.2 Distribution of the ICE

Hotspot analysis of the ICE for salariat compared to working class occupations was configured to return cold spots in areas with significant concentrations of working-class occupancy such the Liverpool to Greater Manchester area, East Lancashire and coastal communities in Cumbria and the Fylde coast. Hotspots represent areas with significant concentrations of salariat occupancy, such as southern Cumbria, the Forest of Bowland and Cheshire (see Figure 17 and Figure 18). A slight reduction in the area of concentrated salariat was noted in north Lancashire.

Comparison of the maps for SRH and the IMD shows a consistent geographical association between deprivation and health (confirmed by the bivariate and GWR analyses results described below) and this is broadly replicated by the distribution of the salariat and working-class hotspots across the region. There are, however, some notable differences. Concentrated areas of predominately working-class residents on the ICE appear to be more widely dispersed across the region than concentrations of deprivation on the IMD and the pattern of association between adverse socioeconomic status and health is different. Although poorer SRH is mainly associated with concentrations of working-class residents, there are some significant concentrations of working-class residents located within wider areas of better SRH in the north of the region. For 2011, the hotspot analysis of the ICE also shows concentrations of disadvantaged working-class residents in several areas that are not apparent on the Index of Multiple Deprivation, particularly in North Cumbria (compare Figure 18 with Figure 20) although associated with small pockets of worse SRH (Figure 18). Table 19 shows the change in total area of LSOAs occupied by the highest concentrations of salariat and working-class residents between 2001 and 2011.

The ICE for salariat compared with working-class residents shows a slightly different pattern of distribution of socioeconomic disadvantage than the Index of Multiple Deprivation. The IMD shows isolated areas of greater deprivation surrounded by less deprived areas in northern central and coastal Cumbria for both 2001 and 2011 (Figure 13 and Figure 14, respectively). However, more extensive areas of LSOAs with higher concentrations of working-class residents on the ICE are visible around the same locations in Cumbria for both years (Figure 11 and Figure 12, respectively). Similarly, LSOAs with higher concentrations of working-class residents are more extensive and more widely distributed in the south of the region than the IMD would suggest, broadly in a band from Liverpool to Greater Manchester

4.3.3 Distribution of the IMD

Mapping the distribution of the IMD shows the most deprived LSOAs are generally to be found in a band between Liverpool and Manchester, in East Lancashire and in communities on the Fylde and Cumbria coasts (Figure 13).

Changes in the distribution of the IMD suggest an improvement in the socioeconomic circumstances of communities in the north of the region over the study period, with a greater number of LSOAs moving to the less deprived levels of the analysis from 2001 to 2011, which constitutes a reduced area of the North West region occupied by the most deprived residents (Table 19) represents area change in km^2; for maps see Figure 13 and Figure 14, respectively.

There was a slight increase in the area of affluence on the IMD, particularly in north Lancashire and Cumbria. Change in the area of occupied by more deprived residents was relatively minor, with a slight increase in the Preston area.

4.4 Changes in the relationships between ICE and SRH and IMD and SRH between 2001 and 2011

4.4.1 Change in areas of SRH and socioeconomic disadvantage

There is evidence of a decline in SRH across the region during the study period. The combined area of those LSOAs with the best SRH (>= 1 SD) declined slightly from 13,432km^2 in 2001 to 12,908 km^2 in 2011. Conversely, although the total area was considerably less, there was a substantial percentage increase in the area of LSOAs with the worst SRH (<= 1 SD), which increased from 191 km^2 in 2001 to 539 km^2 in 2011. Rather than reflecting an increase in the area of concentrated deprivation, this shift appears to be due to a reduction in the proportion of areas that were home to more advantaged residents. This is reflected by both indices, with the highest concentration of salariat residents on the ICE covering 5,304 km^2 in 2001 reduced to 4,776 km^2 in 2011 and the area with the highest concentration working class residents remaining relatively stable at 459 km^2 in 2001 and 454 km^2 in 2011. The IMD showed a similar pattern, with a reduction of the area occupied by the least deprived residents from 3,455 km^2 in 2001, to 2,481 km^2 in 2011. The area occupied by those most deprived actually increased slightly, from 430 km^2 in 2001 to 453 km^2 in 2011 (Table 19).

4.4.2 Quantifying changes within SRH, ICE and IMD

Mean values and standard deviations for SRH, the ICE and the IMD were calculated for 2001 and 2011 data. Those LSOAs above one standard deviation for each variable were categorised as having the best SRH, highest concentration of salariat residents and lowest deprivation on the IMD. Those below one standard deviation were categorised as having the worst SRH, highest concentration of working-class residents and highest deprivation on the IMD in each dataset. The total areas for best and worst health were obtained by the sum of the LSOA areas in the most and least advantaged categories for

each variable. It should be noted that the area of an LSOA is determined by its population and that LSOAs in more densely populated urban areas will necessarily account for a lesser area than those in less densely populated rural areas. It is instructive, however, to use the change in areas to inform a consideration of regional changes between 2001 and 2011.

Taken with the distribution and hotspot maps, there is evidence of shift towards poorer SRH across the region during the study period. It was found that the although the area with the best SRH had declined slightly from 2001 to 2011 (no significant change if considering 5% reduction; but significant if we consider a 1% reduction), the area occupied by those with the worst SRH had increased considerably, from 191km2 at the 2001 census, to 539km2 at the 2011 census (Table 19). Analysis of the ICE indicates a significant decrease in the area occupied by residents in the higher concentrations of the salariat, from 5,304km^2 in 2001 to 4,776km^2 in 2011. The total area of highest working-class concentrations on the ICE remained relatively stable, declining only slightly from 459km^2 in 2001 to 454km^2 in 2011. Results for the IMD also support the trend towards socioeconomic disadvantage across the region, with the area occupied by those least deprived on the IMD significantly declining from 3,455km^2 in 2001 to 2,481km^2 in 2011 (Table 19).

Proportional changes in the area covered by the best and worst LSOAs were tested via Pearson's chi-squared test statistic using as alternative change greater than 5%. The most significant changes were in: worsening SRH, decrease in highest salariat and least deprived IMD (This may indicate that SRH is more influenced by reductions in the affluent and less deprived categories than changes in other categories (Table 19).

Table 19: Change in area of best and worst SRH; salariat compared to working class and IMD, 2001-2011.

The last column shows the changes in % with their statistical significance compared to an absolute change of 5% (Pearson's chi-squared test).

	2001	2011	Change prop (%)
Best SRH	13,432km^2	12,908 km^2	-4
Worst SRH	191 km^2	539 km^2	65***
Highest Salariat	5,304 km^2	4,776 km^2	-10***
Highest working class	459 km^2	454 km^2	-1
Least deprived IMD	3,455 km^2	2,481 km^2	-29***
Most deprived IMD	430 km^2	453 km^2	5

Significance (* = 0.10; ** = 0.05; *** = 0.01)

4.4.3 Bivariate analysis of the IMD and SRH for 2001 and 2011

Similar to ICE/SRH, the analysis of the relationship between the IMD and SRH for 2001 shows extensive areas of positive linear association, such that lower deprivation is associated with better SRH. Large areas of both concave and non-significant relationships are seen, particularly in the Cumbria area. Isolated areas of undefined complex relationships are seen in the south of the region around Liverpool, Greater Manchester and in East Lancashire (Figure 26). The main difference with ICE is that IMD does not create any negative linear relationship with SRH.

As in ICE, the 2011 analysis indicates the extent of the area characterised by non-significant relationships had increased considerably in Cumbria since 2001 and the undefined complex areas were no longer present (Figure 27).

4.5 The effect of spatial concentration of occupational status on SRH

This section presents the results of bivariate analysis for the ICE for salariat compared to working-class residents and its association with the dependant variable of self-rated heath for the 2001 and 2011 census data. An analysis of the bivariate association between the IMD and SRH for 2001 and 2011 census data is also presented (see Figure

24 to Figure 27). The aim is to determine if SRH is dependent on or influenced by the concentrations of job classifications or deprivation and if those relationships vary over geographic space.

In accordance with the recommendations of the Office for National Statistics regarding the interpretation of composite deprivation scores, the bivariate analysis of the association between the IMD and SRH is based on the IMD rank order of LSOAs, where rank number 1 is the most deprived and progressively higher numerical rankings are associated with increasing affluence. For the ICE, positive values represent the concentration of the salariat and negative values represent the concentration of working class residents. The directions of these values determines the direction of association reported in the bivariate analysis charts, such that positive linear association represents better SRH being associated with an increasing concentrations of salariat residents and poorer SRH being associated with increasing concentrations of working class residents.

4.5.1 Bivariate analysis of the ICE and SRH for 2001 and 2011

The bivariate map for the 2001 ICE and SRH data shows extensive areas of positive linear associations across the region, such that better SRH is associated with increased concentrations of salariat residents covering most of Cumbria, northern Lancashire and Cheshire (Figure 24). There are also extensive areas across the region that are characterised by a concave relationship, where SRH increases as a concave curve as the concentration of salariat residents increases but, for the highest concentration of salariat, SRH decreases in Cumbria and the southern half of the region. This may due to high spatial heterogeneity effects over distance with the type of statistical association changing with greater area as for example higher salariat in pockets of deprived areas.

Areas of undefined complex relationships are seen in the south of the region where the ICE and SRH are significantly related, but the nature of the relationship

cannot be described reliably by any of the other relationship types. There are several smaller areas where the association is of the negative linear type, such that increasing concentrations of salariat are associated with poorer SRH, in the Liverpool, St. Helens and Greater Manchester areas (Figure 24).

The map for 2011 indicates a shift in the distribution of relationship types. Although extensive areas of positive linear and concave associations remain, these are reduced compared to 2001, with large areas in the north of the region now showing a non-significant relationship between the index and SRH. Those areas characterised by undefined complex relationships in 2001 have almost completely disappeared in 2011 (Figure 25).

Figure 24: Bivariate analysis of the ICE for salariat class compared to working class occupations and SRH for 2001

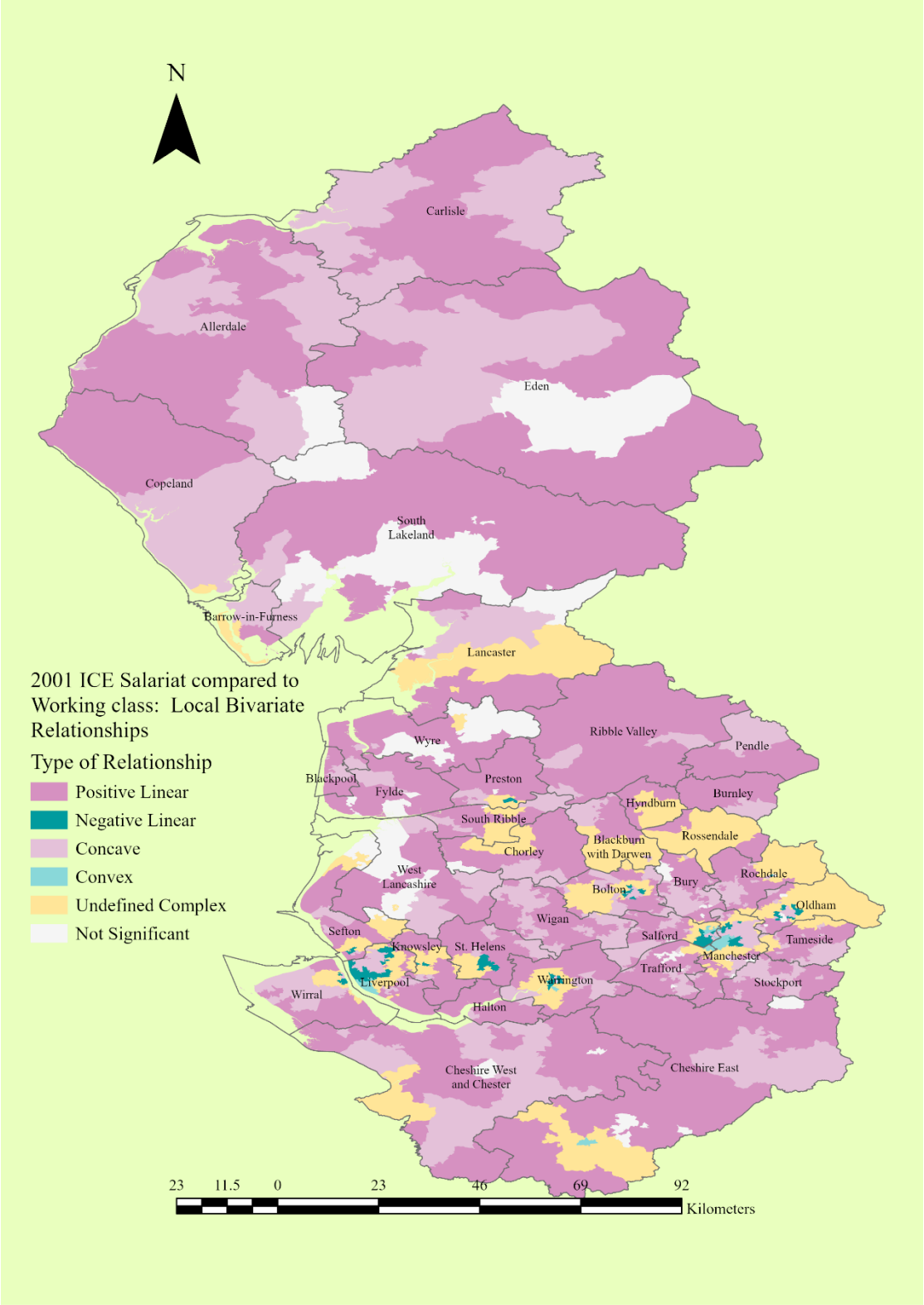


Figure 25: Bivariate analysis of the ICE for salariat class compared to working class occupations and SRH for 2011

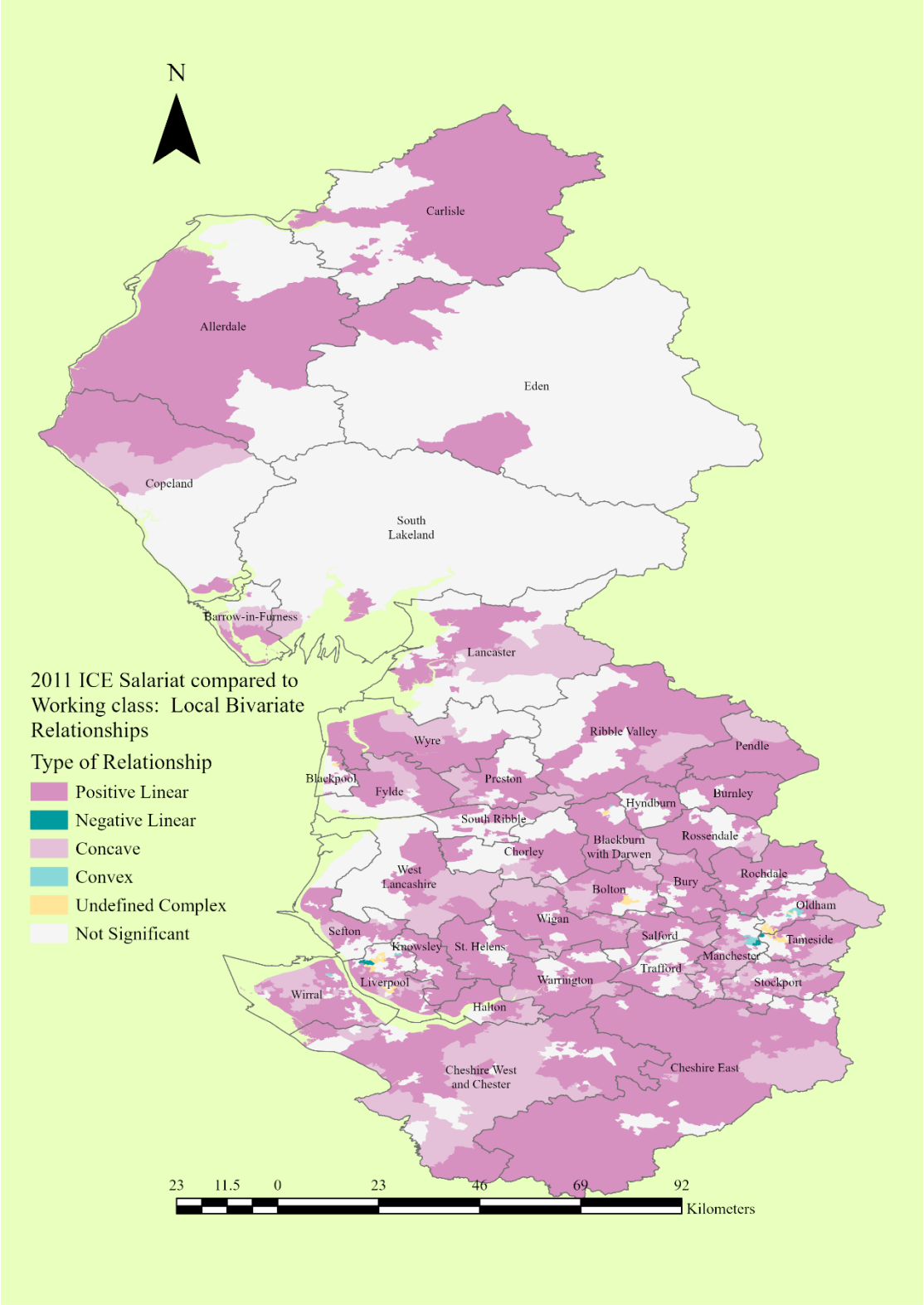


Figure 26: Bivariate analysis of the IMD and SRH for 2001

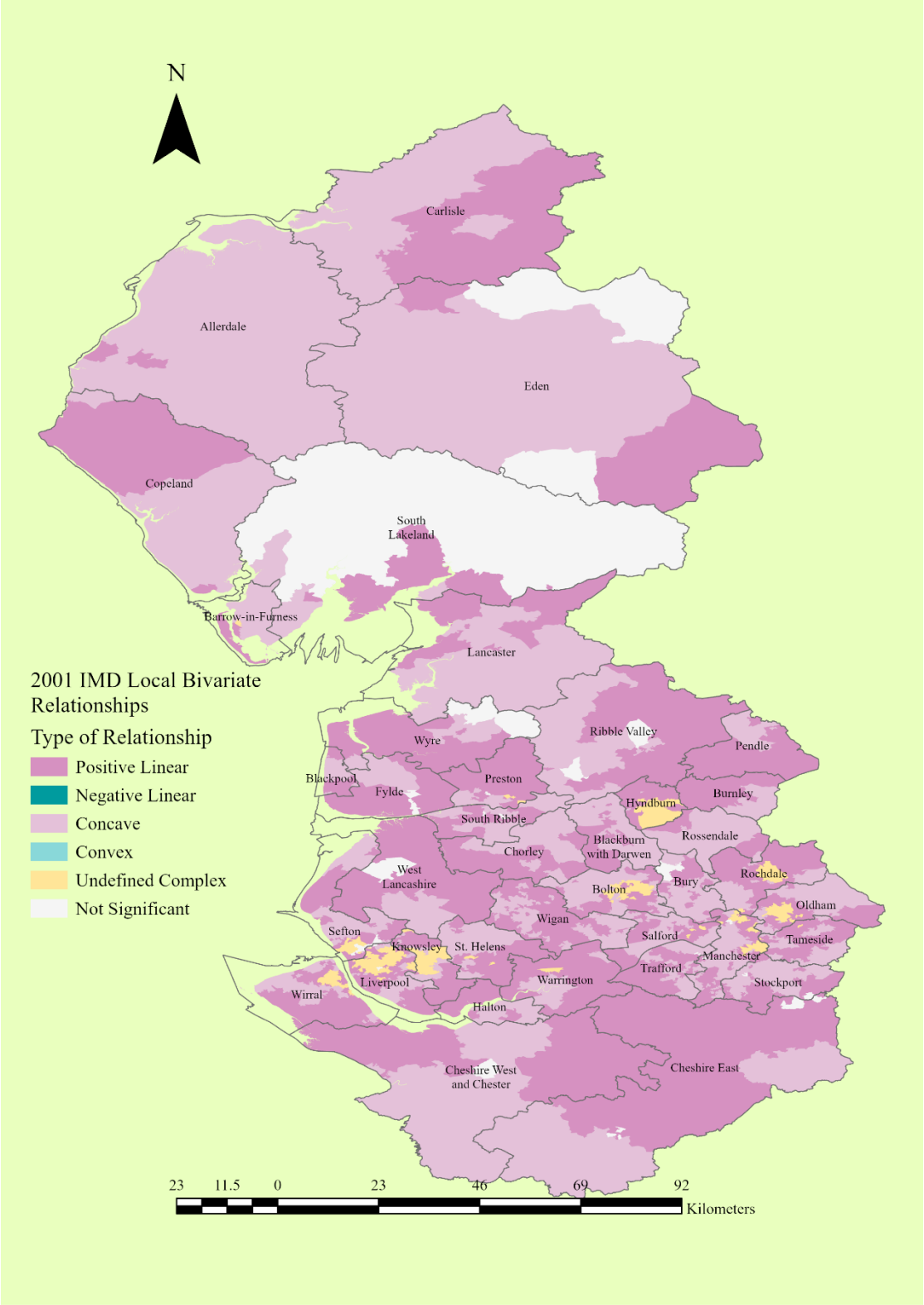
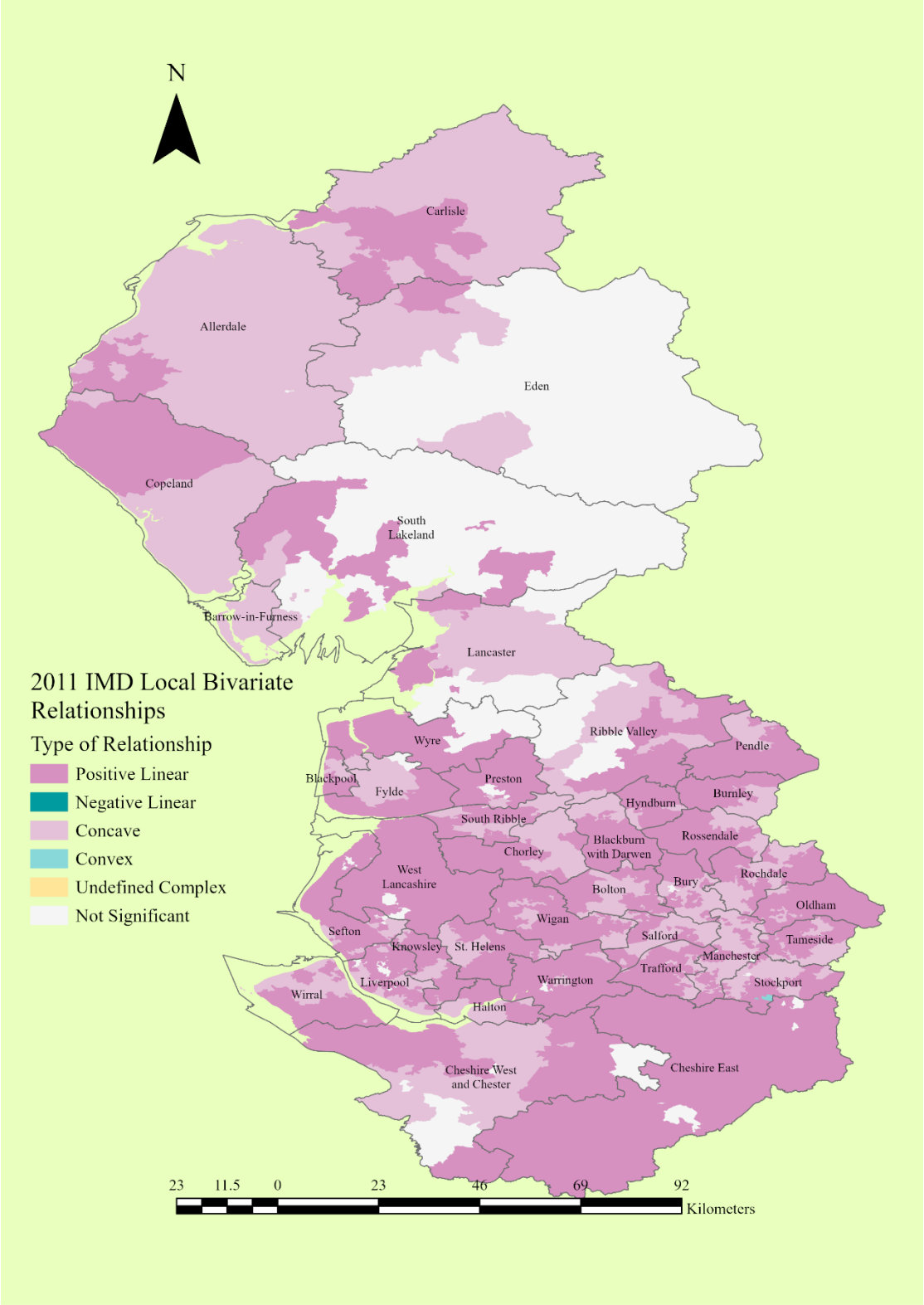


Figure 27: Bivariate analysis of the IMD and SRH for 2011



4.6 Summary

Across the region, the local bivariate relationships between the ICE, SRH and the IMD for both 2001 and 2011 were largely of the positive linear type, such that increased concentrations of salariat residents and lower levels of deprivation were both associated with better SRH. Extensive areas of concave relationships were also found for both predictive variables throughout the study period. However, there is evidence of a change in the pattern of association.

The analysis of the 2001 data for the ICE indicates a predominately positive linear association, with increasing concentrations of salariat residents being associated with better SRH across most of the region (Figure 24). However, there are several smaller areas where the association is of the negative linear type, such that increasing concentrations of salariat are associated with poorer SRH. These areas are mostly not present in the 2011 map, apart from a small area to the east of Greater Manchester (Figure 25).

Consistent with the findings for the ICE, the IMD also exhibits a shift to more extensive area of non-significant relationship in Cumbria between 2001 and 2011 and the transition of those areas characterised by undefined complex relationships to the positive linear or concave relationship types.

The GWR analysis found that the ICE is a better SRH predictor, along with age and ethnicity, than IMD, the latter selected in less than 95% of the models. Therefore, the ICE makes a useful contribution to understanding the association between socioeconomic disadvantage and SRH, albeit with some combinations showing counterintuitive associations. Two versions of the ICE were included in the model: salariat & intermediate occupations compared with working class occupations and salariat and intermediate occupations compared with working class occupations and

long-term unemployed. Of these, the former had a negative association with SRH such that increased concentrations of working-class residents were associated with better health. Including the long-term unemployed with working class residents reversed this effect, such that higher aggregate concentrations of salariat and intermediate residents experienced better SRH, whereas higher aggregate concentrations of working class and long-term unemployed residents experienced worse SRH. Although working class people tend to have worse health than their more affluent neighbours, the differences are probably less than for the long-term unemployed and it is likely that aggregating these residents resulted in a worse overall SRH value than if they had been treated separately.

CHAPTER 5: Discussion

The findings of the study are discussed in terms of the research questions, which were: what is the utility of using ICE metrics derived from employment relations compared to more traditional measures of deprivation represented by the IMD, for explaining relative spatial inequalities in SRH? Are employment relations as operationalised by occupational status better at explaining variations in SRH than more traditional measures of social deprivation? The chapter ends with a discussion of limitations that became apparent during the study and the implications of these for use of the ICE in future work.

5.1 The utility of the ICE

This study represents the first use of the ICE in the United Kingdom. Analysis of the ICE was broadly consistent with the IMD. However, the ability to construct novel indices using the ICE as demonstrated in this study offers prospective advantages for future research. The ICE is adaptable and novel indices may be derived from any combination of variables depending on the nature of the research question. The ICE measure of the concentration of employment relations showed a good degree of association with SRH and the findings of the literature review strongly suggest that this likely to be true of other markers of health status.

The introduction to the study observed that the employment environment in the UK has changed in recent years. Consistent with the established literature, a protective effect of higher status employment on SRH was found by the both the ICE and the IMD, but it is proposed that the ICE offers a means to develop more sensitive indicators of socioeconomic advantage than are captured by the major dimensions of deprivation in the IMD. Higher levels of income may in fact mask socioeconomic stresses that arise from adverse employment relations. The ICE provides an easily calculated tool to

examine these questions not only at a neighbourhood level, as demonstrated in this study, but its scalability also makes it a viable measure at regional and national levels of analysis. Unlike the IMD, which is primarily concerned with deprivation, the ICE includes measures of both advantage and disadvantage in a single index. The finding in this study that changes in regional SRH between the 2001 and 2011 censuses appear to reflect the proportion of residence and advantage and disadvantage circumstances, rather than just being associated with an absolute measure of deprivation, suggests that composite measures such as the ICE could be important in understanding social structures and health.

The ICE has also shown good construct validity in that it correlates with socioeconomic disadvantage (c.f. Polit & Beck, 2004) and has also been shown to be a reliable measure of spatial segregation at the LSOA level that has contributed to the study of health inequalities by allowing an understanding of the association between spatial concentrations of socioeconomic disadvantage and health.

This study supports the findings of studies in the US shown that show an association between concentrated disadvantage on the ICE and poorer health and in doing so in the context of the North West region it provides evidence that the ICE is a useful metric for health research in the UK. The ICE offers a single easily calculated measure of the spatial concentration of those socioeconomic relationships implicated in perpetuating health inequalities. Specifically, the study provides evidence that the ICE is in some instances better suited to studying SRH than conventional measures of socioeconomic disadvantage, as represented by the IMD. The ICE can bring into focus the range of concentrations of affluence and deprivation. Commonality between the two measures will be discussed, before a consideration of those findings that reflect the contribution of the ICE.

Results from both the ICE and the IMD show similar patterns of association with SRH and both appear to be sensitive to regional changes between the two censuses. The similar association with SRH suggests that both measures are useful in identifying disadvantaged areas of concern.

Although not present in the GWR best model for 2001, variants of the ICE were present to a significant degree in the variable selection. Two variants of the ICE were included in the 2011 model, both representing combinations of socioeconomic advantage and disadvantage at the extreme ends of the scale. Subsequent results from the GWR for 2011 found that worse SRH was generally associated with greater variation in the ICE. Examination of the distribution of standardised residuals for this analysis indicates that although the ICE generally made a reliable prediction of SRH, with low deviations across most of the region, the highest deviations were generally associated with areas of poorer SRH (Figure 8).

It is noted that the best model for 2001 did not include the ICE although ICE measures were selected during the variable selection process. It is possible that effects due to 2001 and 2011 census changes may have changed the relationships between outcome and predictors. In addition, the 2001 census recorded SRH as a dichotomous variable, with health being either good or not good. For the 2011 census this was changed to a five-point rating that captured degrees of ill-health.

Comparison of the regional distribution of relationship types for the bivariate correlation analysis reveals slightly different patterns for the ICE and IMD. Both indices show extensive areas of positive linear relationships across the region in 2001, but the ICE has notable areas of undefined complex relationships in the south. There are also isolated areas of negative linear relationships in Liverpool and Greater Manchester. By 2011, these areas have disappeared in both metrics, apart from a small

area of negative linear relationships in Greater Manchester (compare Figure 24 and Figure 25). The area characterised by non-significant relationships has expanded considerably by 2011. The IMD also has some areas of unidentified complex relationships in much the same locations in 2001, but these are much less extensive than the ICE and have disappeared by 2011. No areas of negative linear relationships were found for either year. It is possible that the changes in the ICE reflect the reduction in the area occupied by residents with salariat occupations between 2001 and 2011. This accounts for the emergence of an extensive area of no significant relationships between the ICE SRH and the in the north of the region in 2011 (Figure 25).

The hotspot analysis provided some evidence for a protective effect of concentrated working-class occupations on SRH in Cumbria (Macintyre et al., 2002). Clusters of LSOAs with higher concentrations of disadvantaged residents were found by the ICE in northern Cumbria, which is an area of better SRH (Figure 18). It may be that proximity to neighbourhoods with similar concentrations of working-class residents offers some protective effect (Pemberton et al., 2019).

Highly localised cold spots of poor SRH were found in the 2011 data in coastal communities on the Fylde and Cumbrian coasts, and also in Liverpool, Greater Manchester and parts of East Lancashire (Figure 16). These represent coastal and inner city communities, which are areas of socioeconomic challenge and are surrounded, or interspersed by, more affluent suburban neighbourhoods.

The findings of this study are broadly consistent with the literature examined in the systematic review. Spatial concentrations of socioeconomic disadvantage measured on both the ICE and IMD were associated with poorer SRH. Conversely, those areas with higher concentrations of advantage on both measures were associated with better SRH. Findings from both the ICE and IMD support established theory in the field, but

the results showed certain differences that might inform their use in future public health research.

The results reflect the diversity of the North West region of England, with a marked difference in the distribution of SRH between the urban, industrial and post-industrial areas in the south and the predominately rural areas in the north. This is supported by the distribution of the IMD and the ICE, which both follow the expected pattern of areas of poorer SRH being associated with adverse socioeconomic conditions (Giatti et al., 2010).

The choice of the LSOA as the unit of analysis representing these neighbourhood effects was based on the understanding that the effects of the physical environment on health depend on geographical proximity. Essentially, how closely individuals live to positive or negative influences in their neighbourhood. Proximity is largely determined by the interaction of the social environment, economic forces and institutional influences.

The infrastructure of neighbourhoods evolves in response to the arrival and departure of businesses and to decisions about the location of institutional services made by planners at local and national level (Northridge et al., 2003). The composition of the population may be determined by market forces that influence the movement of low-income groups into neighbourhoods characterised by low property values and adverse conditions such as higher pollution or crime. Some ethnic groups, especially new immigrants, may favour certain neighbourhoods regardless of their adverse environmental conditions in order to benefit from social networks and services already established there (Morello-Frosch, 2002).

Neighbourhoods therefore influence the health of their residents because they offer different and unequal access to resources arising from a physical domain regulated

by proximity, an economic domain regulated by markets and price mechanisms and an institutional domain regulated by local and national authorities and planning processes (King et al., 2005). The geographical distribution of resources, made differentially available by the influence of these three domains, determines the extent to which individuals and families can obtain the resources they need to maintain their health (Bernard et al., 2007).

5.2 Employment relations and SRH

The study has shown a strong association between Goldthorpe's schema of employment relations as captured by the NS-SeC categories and SRH. The UK labour market has changed substantially since the turn of the century. In the period from June to August 2019, before the COVID-19 epidemic affected the economy, the working age employment rate was 75.9% (Marmot et al., 2020). This is close to the record post-war employment rate, which dates to 1971 and is quite remarkable considering the severe recession that followed the financial collapse of 2008. However, this apparent success focuses on the quantity of jobs available and not on the quality of individuals' working lives and the effects this has on their health.

Good quality work is not easy to define and has proved difficult to measure. Questions of job quality and health have tended to focus on issues of material deprivation such as low pay, but much recent research has made it clear that the association between job quality and health involves a constellation of factors beyond those captured by the IMD, such as freedom to act and control one's own work. For example, political commitments to increasing the minimum wage have helped to improve low pay over the past several years, but most of the people currently living in poverty and at risk of poor health in the UK are in fact in employment. This suggests the need for alternative approaches to examine deprivation and health inequalities.

Current measures commonly used for making public policy such as the IMD are mainly used to assess measures of material deprivation and do not necessarily capture the prevalence of in-work poverty.

This study used an alternative approach in the form of the ICE to model the association between job quality and SRH using the conceptual framework of Goldthorpe's schema of employment relations. The employment relations schema captures several dimensions of work that are implicated in socioeconomic stress and its concomitant impact on health, such as job satisfaction and autonomy.

Neighbourhoods were characterised by the spatial concentration of residents in socioeconomically advantaged and disadvantaged occupations using a novel index derived from the ICE. The association between neighbourhood concentrations of different types of employment relations and SRH was compared with a conventional measure of local disadvantage in the form of the IMD. The study has demonstrated the utility of the ICE which, in conjunction with employment relations as a measure of socio-economic disadvantage, made an additional contribution to our understanding of health inequalities in the North West region than measures of deprivation alone. The following sections discuss the principal findings of the study.

5.3 Employment relations and the Goldthorpe schema

The typical rationale for the use of occupation-based socioeconomic measures such as the Goldthorpe schema is that they make reliable, parsimonious indicators of the social positions of individuals. This study supports the utility of Goldthorpe's construct of employee relations in understanding health inequalities. Use of the ICE demonstrated that spatial concentrations of salariat and working-class residents were predictive of SRH at the neighbourhood level. Further, the study has provided evidence that occupation-based socioeconomic measures do not serve as a mere proxy for income

data, but in fact contribute to the understanding of fundamental forms of social relations and inequalities to which income may in fact be incidental. Studies have shown that there is a high degree of income churn from year to year which makes income data unlikely to consistently represent individuals' positions in industrial economies, whereas occupation-based socioeconomic measures have been found to be more stable and are therefore better suited to describe the pattern of lifetime earnings (Goldthorpe et al., 2004; Rose & Pevalin, 2003).

The comparison of the IMD and the ICE derived from NS-SeC data addresses Goldthorpe's (2013) assertion that much social science research has become preoccupied with measures of income deprivation and poverty. In his critique of the reliance of much contemporary research on narrowly economic theories to explain socioeconomic disadvantage, Goldthorpe suggested that a focus on material deprivation might reflect the salience of economics within the social sciences and that this may have diverted researchers from considering significant dimensions of social inequality which are not captured by focusing on material deprivation alone.

The study found evidence that the quality of employment, as construed by the Goldthorpe schema, represents a useful adjunct to conventional constructs of material deprivation in understanding neighbourhood health inequalities. Evidence that characteristics of employment such as job control and insecurity are significant stressors suggests the conceptual model of employment relations that underlies the Goldthorpe schema captures an important dimension of socioeconomic distress that may not necessarily be apparent using conventional measures of material deprivation. The observation that over the past ten years more people experiencing poverty are actually in work, rather than being unemployed, suggests that conventional measures of material deprivation based on income and benefit claims might miss vulnerable communities.

The finding that the ICE for salariat compared to working-class residents disclosed localised hotspots of socioeconomic disadvantage in some areas where the IMD did not, suggests it is a useful tool for understanding the health implications of a rapidly shifting employment culture (see Figure 18 and Figure 20). This is consistent with the literature. However, the contribution of long-term unemployment to this effect should be acknowledged and this may be a useful subject for future research. Particularly, this should examine the specific reasons for unemployment, as the term current captures diverse medical and social reasons for unemployment.

5.4 Urban and rural communities

The analysis indicated a demarcation between urban and rural communities for all measures, with better SRH, better scores on the IMD and lower concentrations of working-class residents on the ICE being found in the northern, more rural parts of the region and in the south of the region, in Cheshire. Poorer SRH and adverse socioeconomic measures were generally found on the Cumbria and Fylde coasts, and the area between Liverpool and Manchester and also in East Lancashire. This is consistent with the evidence of the harmful effects of concentrated socioeconomic risks presented in the systematic review (see Badland et al. (2017); Badland et al. (2013)).

The results show that SRH is generally better in the region's more affluent rural communities and worse in urban communities. However, the socioeconomic profiles of rural areas can be highly diverse in relation to their level of affluence and health outcomes. Within all rural communities there will be pockets of deprivation and there are some apparently affluent areas of the region where there is in fact a high degree of deprivation, lower life expectancy and poorer health. Such areas include: Cumbrian coastal towns, small seaside towns with a 'bedsit economy', for example on the Fylde

coast, former industrial or mining communities, areas where there is a high degree of seasonal employment and areas with sparse or scattered populations

Both low population density and rurality appear to affect poverty levels. Sparsely populated areas that fall into the town and fringe or urban settlement types have the highest proportions of households below the poverty threshold (ONS, 2011). However, no area type is poverty free and there is often more variation within area types than there is between them.

5.5 The ICE compared to the IMD

Results from the ICE were consistent with established evidence on the geography of socioeconomic disadvantage and health, such that concentrations of occupations of lower socio-economic status on the Goldthorpe schema are associated with poorer SRH. Use of the ICE to model occupational relations data has given an insight into the distribution of socioeconomic disadvantage across the region that would not be afforded by reliance on the IMD alone.

The IMD has demonstrated considerable utility over the years, but it has some weaknesses. For example, the IMD was specifically designed to measure aspects of deprivation but not affluence (Deas et al., 2003). For example, the income deprivation dimension is concerned with those people on low incomes who are in receipt of benefits and tax credits. An area with a relatively small proportion of people on low income may also have relatively few people on high incomes. Such an area may be ranked among the least deprived in the country, but it is not necessarily among the most affluent. It may be the case that some highly deprived areas contain pockets of affluence; that is, the Index for an LSOA might represent a mixture of both deprived and affluent residents. It should also be noted that the methodology underlying the IMD was designed to reliably distinguish between areas at the most deprived end of the

distribution but not at the least deprived band. Differences at the less deprived end of the Index rankings will therefore be less well defined than those between areas at the more deprived and of the scale. Despite this, the IMD has shown good reliability as a predictor of health status (Abel et al., 2016).

5.5.1 Health status and the quality of work

The quality of work is a significant effect driver of health equity. Those in lower status jobs, younger people, those in lower paid jobs and non-white people are all more likely to experience the adverse health effects of poor quality work (UK working lives, 2018).

It may be that conventional measures such as the IMD serve to mask the presence of factors associated with health inequalities. For example, increasing rates of employment might appear to be associated with greater affluence on the income dimensions of the IMD. However, it is increasingly evident that work is not a guaranteed way out of poverty and the significant shift in numbers of people from unemployment benefits into work since the last census might simply have involved trading one stressful way of life for another, despite any apparent improvement in the Index.

5.6 Limitations of the study and implications for future work

The consistency of the ICE in this study with the findings of previous research into a range of health and socioeconomic factors suggests the ICE should generalise to other research questions. However, this study suggests that there are some methodological issues that need to be considered regarding the suitability of the ICE for future work.

Modelling depends on the scale and the number of neighbourhoods in GWR which means coefficient can change according to number of neighbourhoods selected. The study used the nearest neighbours approach in GWR, assuming that most of the

correlation is between contiguous neighbourhoods/LSOAs. Other combinations could be explored.

5.6.1 Variations between 2001 and 2011 census data

Historical comparisons between the 2001 and 2011 census were slightly affected by differences in their respective datasets. Measures used to compile the IMD were changed for the 2011 census to reflect changes in the benefits system since the 2001 census. It is noted that the scale for SRH was changed from a three-point 'good', 'fairly good', or 'not good' rating of health over the 12 months prior to census day 2001 to a five-point 'very good', 'good', 'fair', 'bad' or 'very bad' rating of current health on the day of the census in 2011. This might explain the finding of no significant clustering across almost all the region in the 2001 hotspot analysis of SRH (Figure 15).

5.6.2 Use of the Goldthorpe schema

The systematic review for this study found a diverse range of methodological approaches and it became clear that there is considerable inconsistency in the choice of measures of socioeconomic status: indeed, it has been claimed that there are over a thousand different measures in the literature (Connelly et al., 2016). Since the choice of measure will necessarily influence the outcome of the study, the following section will outline the conceptual and empirical considerations in the use of the Goldthorpe schema.

The Goldthorpe schema and its derivatives has been extensively used in the UK with evidence of satisfactory construct and criterion validity. However, the coherence and extent of the principal classes in the schema have been the subject of some debate. In particular, this has concerned the coherence and extent of the service class and the distinction between the service and intermediate classes. A study by Evans and Mills (2000) used data from the Office for National Statistics to examine the extent to which

measures of class-relevant job characteristics were discriminated by the categories of the schema; the structure of a 'contract type' dimension of employment relations construed as a latent variable; and the association between this latent variable and both the Goldthorpe class schema and a related measure–socio-economic group. It was found that the data were consistent with the existence of a three-factor latent 'contract type' variable largely corresponding to the dimensions of service, intermediate and wage-labour contracts in the conceptual basis of the Goldthorpe schema, with a substantial degree of fit between the latent 'contract types' and the schema. However, there was some evidence that the demarcation line between service and intermediate occupations might overestimate the number of service occupations.

Consideration should also be given to the age of those surveyed in the census. Goldthorpe and colleagues assert that most adults reach a point of 'occupational maturity', around about the age of 35 after which it is relatively unlikely they will experience major changes in their occupational position (Goldthorpe et al., 1987). Some studies, particularly in the field of social mobility, have been restricted to samples of adults over this age. More recently, Tampubolon and Savage (2012) found evidence that the appropriate age of occupational maturity may have risen slightly over time. The Office for National Statistics data used in this study was grouped into three categories: young people, working age adults and older adults. Stratification by narrower age bands is possible using ONS data, so it might be possible to weight the sample by an 'occupational maturity' factor in LSOAs with a higher proportion of residents over the age of thirty-five.

Finally, it is noted that the NS-SeC categories used in the census aggregate long-term unemployed with those residents who have never worked for whatever reason. Although this grouping effectively captures the overall dimension of 'worklessness', it

treats unemployed people as a homogenous grouping when there will almost certainly be a diverse range of lived experience among residents in this category that may affect their rating of their own health. Given the contribution of unemployment to the 2011 GWR model it may be that future research could examine the composition of this group in more detail to determine the relative health effects of long-term unemployment compared to never having worked.

5.6.3 'Superdiversity'

Much research into neighbourhood health has been framed in a context and composition dichotomy. This is concerned with the degree to which spatial variations in health arise from the people who live there or the characteristics of neighbourhood itself. Explanations for neighbourhood variations have been grouped into three principal types; compositional, contextual and collective. In addition to low socio-economic status, contextual effects include such factors as violence, noise, traffic, litter and poor air quality. Collective effects are concerned with social capital and are associated with protective effects such as ethnic density (Macintyre et al., 2002). Evidence from studies of neighbourhood 'superdiversity' suggests there is a need to understand how these various effects interact with each other to promote or diminish health (Pemberton et al., 2019). The results of this study suggest that the ICE is suited to examining such research questions as it can be used to examine combinations of factors.

Inclusion of minority ethnic status in the geographically waited regression model for the 2011 census data suggests that ethnicity would be a useful topic of further study. There is some evidence that a higher concentration of minority ethnic residents provides a buffering affect against ill-health at the neighbourhood level (see, for example, Bécares et al. (2009)). The ICE might usefully be used to examine the effects of concentrations of individual ethnic groups and also immigration status (Phillimore,

2015). Although this study found only partial evidence of a protective effect of neighbourhood concentration, the scalability of the ICE suggests a multi-scalar approach applying the ICE at local, regional or national geographical levels could be used to examine such 'extra-neighbourhood' effects on local health, consistent with the findings of health effects at neighbourhood and city-wide levels (Krieger, Feldman, et al., 2017; Krieger, Waterman, et al., 2017).

5.6.4 Task-based technological change and inequality

In the field of economics an increasing body of stratification research literature is concerned with the importance of job characteristics for explaining patterns of inequality. These studies, typified by the research of Autor and colleagues, focused on job tasks (Acemoglu & Autor, 2011; Autor & Handel, 2013).

As an alternative to the Goldthorpe model, which distinguishes between a service relationship and a labour contract based on asset specificity and monitoring difficulty, task-based research distinguishes between those occupations that can be replaced by technology and those which are complimented by it, based on task characteristics. Task-based technological change, as this concept is sometimes known, proposes that although technology threatens to replace routine tasks, it complements non-routine more analytically based tasks, making them more productive. Technological advances therefore have the effect of widening inequalities by reducing the demand for workers in routine occupations while at the same time increasing the demand for workers in non-routine and analytical occupations. This results in a deterioration in earnings and working conditions for those in routine occupations while improving pay and conditions for those in non-routine and analytical jobs (Autor, 2013).

Since data on task characteristics is not usually captured by social surveys, this field of research usually maps detailed information from specialised task databases onto

the occupational categories recorded in the census and similar surveys. A technology-based interpretation is then applied to aggregate occupational-level task scores to explain trends in employment and wages. It should be noted that similar limitations in obtaining occupational-level data on asset specificity and monitoring difficulty from social surveys was one of the drivers of the development of the NS-SeC categories (Mills, 2014).

Regarding this study, the rise of task-based technological change will have changed the characteristics of work for many residents in the region during the period between the 2001 and 2011 census.

CHAPTER 6: Conclusions

This chapter sets out the conclusions to be drawn from the study beginning with a recap of the research questions and study objectives, before setting out the value of the ICE in future public health research in the UK by considering its potential contribution to the principal challenges to public health set out in the Marmot review.

6.1 Research questions

The research questions were: what is the utility of using ICE metrics derived from employment relations compared to more traditional measures of deprivation represented by the IMD, for explaining relative spatial inequalities in SRH? Are employment relations as operationalised by occupational status better at explaining variations in SRH than more traditional measures of social deprivation?

The study found evidence of the utility of the ICE to derive measures of the spatial concentration of socioeconomic disadvantage from census data informed by the Goldthorpe schema. The study provided evidence that the ICE is a useful adjunct to traditional indices such as the IMD. This is considered below in terms of the four study objectives. The utility of the ICE for future research is considered in the context of future challenges for public health in the UK.

6.2 Conclusions from the study objectives

To recap from the introduction; the study had four principal objectives:

(i) To explore the spatial distributions of occupational status (using ICE), social deprivation (using IMD) and SRH.

The study found an association between groups of LSOAs with higher concentrations of salariat occupations using the ICE and better SRH. Conversely, ICE concentrations of working-class occupations were associated with poorer SRH across the region. This is consistent with the wider literature on socioeconomic status and

health and, more specifically, with studies that have used the IMD as a measure of socioeconomic disadvantage. However, the ICE has certain advantages over the IMD. The IMD was specifically designed to measure aspects of deprivation but not affluence, being concerned concerned with those people on low incomes who are in receipt of benefits and tax credits. The ICE is also designed to capture such aspects of deprivation, but it also explicitly includes measures of affluence in the index. This ability to include the dimension of relative inequality in the ICE offers certain advantages over measures of absolute deprivation such as the IMD.

It may be that the ICE is more sensitive to variations in advantage. The GWR analysis found that the ICE was a better SRH predictor, along with age and ethnicity, than IMD. However, the GWR analysis for 2011 found that worse SRH was generally associated with greater variation in the ICE. Examination of the distribution of standardised residuals for this analysis indicated that although the ICE generally made a reliable prediction of SRH, with low deviations across most of the region, the highest deviations were generally associated with areas of poorer SRH. Examining this result in more detail would be a useful topic for further study.

(i) To compare the spatial relationships between ICE and SRH with those of IMD and self-reported health.

Analysis of the ICE found a high degree of consistency with the conventional IMD measure that is widely used to assess deprivation at both the local and national government levels in the UK.

The study found evidence that the ICE measures derived from the Ns-SeC categories of employment add a useful extra dimension to the study of socioeconomic inequality and health. Employment relations, as construed by the Goldthorpe schema, represent a useful adjunct to conventional constructs of material deprivation in

understanding neighbourhood health inequalities. Evidence that characteristics of employment such as job control and insecurity are significant stressors suggests the conceptual model of employment relations that underlies the Goldthorpe schema captures an important dimension of socioeconomic distress that may not necessarily be apparent using conventional measures of material deprivation such as the IMD. The recent increase in in-work poverty suggests that conventional measures of material deprivation based on markers such as income and benefit claims might usefully supplement the IMD in identifying vulnerable communities. The finding that the ICE for salariat compared to working-class residents disclosed localised hotspots of socioeconomic disadvantage in some areas where the IMD did not, suggests it is a useful tool for understanding the health implications of a rapidly shifting employment culture.

(ii) To explore changes in the relationships between ICE and SRH and IMD and SRH between 2001 and 2011.

The distribution and hotspot maps provide evidence of shift towards poorer SRH across the North West region during the study period. It was found that the although the area with the best SRH had declined slightly from 2001 to 2011 (no significant change if considering 5% reduction; but significant if we consider a 1% reduction), the area occupied by those with the worst SRH had increased considerably between the 2001 and 2011 censuses. Analysis of the ICE found a significant decrease in the area covered by LSOAs with higher concentrations of residents in salariat occupations. The total area of highest working-class concentrations on the ICE remained relatively stable, declining only slightly between 2001 and 2011. Results for the IMD also support the trend towards socioeconomic disadvantage across the region, with the area occupied by those least deprived on the IMD declining significantly throughout the study period.

(iii) To investigate the effect of spatial concentration of occupational status on self-reported health.

The study was consistent with the existing literature, in that concentrations of socioeconomic advantage or disadvantage derived from the Goldthorpe schema of employment relations as operationalised in the UK census were associated with SRH. It was found that spatial concentrations of salariat occupations were associated with better SRH and concentrations of working class occupations or long-term unemployment were associated with poorer SRH. There remains the question of any protective effect on health of living in an area of concentrated disadvantage when it is surrounded by more affluent areas. The hotspot analysis provided some evidence for a protective effect of concentrated working-class occupations on SRH in northern Cumbria, where clusters of LSOAs with higher concentrations of disadvantaged residents were found by the ICE among areas or better SRH. It may be that proximity to neighbourhoods with similar concentrations of working-class residents has conferred some protective effect on health to these residents, however, this effect was not seen elsewhere in the region. Future studies might address this by developing a novel ICE that includes those variables found to be associated with any protective effect. There might also be an opportunity for a mixed methods approach that combines ICE socioeconomic measures with subjective perceptions of residents.

6.3 Use of the ICE in future studies

As part of the response to the COVID-19 pandemic the UK government has undertaken a major reorganisation of public health. At the time of writing (September 2021), Public Health England (PHE) is to be disbanded and its functions taken on by newly constituted agencies. This represents a division of PHE's remit into separate organisations, each with distinct health protection and health promotion responsibilities.

The National Institute for Health Protection (NIHP) will operate as an executive agency of the Department of Health and Social Care (DHSC), tasked to lead on the follow-up to the COVID-19 pandemic, monitor and control infectious diseases and respond to health protection incidents. The NIHP will be responsible for activities to protect people from 'infectious disease, incidents and outbreaks, and non-infectious environmental hazards such as chemicals and radiation' (UK Parliament, 2021).

The UK Health Security Agency (UKHSA) will bring together the current Joint Biosecurity Centre, NHS Test and Trace and some parts of Public Health England, such as the scientific laboratories and data surveillance teams, that have been responding to the pandemic. The UKHSA will be responsible for ensuring the UK is protected against infectious diseases and external health threats.

The health improvement remit of the former PHE will be taken over by the Office for Health Promotion (OHP), which will sit within DHSC to drive and support health improvement work. The government has said that the new organisation would 'lead national efforts to improve and level up the health of the nation by tackling obesity, improving mental health and promoting physical activity' (DHSC, 2021). It will also be responsible for other public health issues, including sexual health. The findings of this study suggest that the ICE would be best suited to the work of the OHP. The 'levelling up' agenda implies a concern with inequalities and the ICE has been used effectively to examine this both in the US work covered in the systematic review and also in this study.

The ICE can be used to improve population health and reduce health inequalities in two ways. Firstly, the index frames the problem of health inequalities in terms of inequitable relationships between socioeconomic economic groups, instead of focusing solely on the disadvantaged. Use of the index might address those problems that arise

from what has become known as the hollowing out of the middle, in which growing concentrations of affluence can simultaneously lead to growing concentrations of disadvantage and increasing health inequalities (Krieger, Waterman, et al., 2016). Secondly, the association between the index of concentration of the extremes and SRH suggests further research on the causal pathways linking extreme concentrations of affluence and deprivation both on health status and the degree of health inequalities. Research on the social determinants of health suggests that likely causal pathways might include the effect of spatial socioeconomic polarisation on educational attainment, economic opportunity and access to health care.

The application of the ICE at various geographical scales, in contrast to conventional measures of income inequality (the GINI index) and residential segregation (the index of dissimilarity), gives researchers a new methodology to examine the effect of small area socioeconomic spatial polarisation on health inequalities.

Finally, the introduction to this study in chapter 1 opened with the findings of the Marmot review (Marmot, 2010), which set out the challenges facing public health in the UK and proposed an agenda for future work. To close the study, the value of the ICE in understanding and promoting public health identified by this study will be considered in terms of the review's key evidence-based recommendations for a strategy to reduce health inequalities in England. This will provide a context for future studies by researchers and initiatives by public health managers based on the ICE and employment relations. Use of the ICE and the related methodology set out in this study would offer a set of powerful tools in support of policies to reduce health inequalities across all the categories set out by the Marmot review.

6.3.1 Health inequalities must be addressed in the interests of fairness and social justice

The study has demonstrated that the ICE provides an effective method for measuring inequalities between socioeconomic groups. This is not confined to Goldthorpe's salariat and working classes. Use of the ICE would allow comparisons of the spatial concentration of any groups of interest. Evidence from the systematic review shows that several US studies using the ICE to combine data on ethnicity with other personal characteristics have demonstrated the utility of this approach and this study supports these findings.

6.3.2 There exists a social gradient in health: health improves as social status improves

Use of the ICE for the Goldthorpe-derived categories of the NS-SeC adds an interesting dimension to the association between socioeconomic status and health. This study found that the ICE for increasing concentrations of advantage and disadvantage represented by salariat and working-class residents at the LSOA level were associated with better or worse SRH. It is apparent that it is not just the hierarchy of status that determines health, but concentrations of status may have a similar effect. The flexibility of the ICE allows the exploration of the effects of other individual categories, or combinations of categories of the NS-SeC.

6.3.3 Social inequalities result in health inequalities; therefore to reduce health inequalities we must consider all the social determinants of health

The ICE can be used with any combination of variables that may be geographically coded. This allows analysis of not just personal characteristics as in the present study, but also environmental risk factors, such as pollution or access to green spaces.

6.3.4 Health inequalities cannot be properly addressed by only targeting those worst off

Reducing the steepness of the social gradient in health requires universal actions concentrated according to levels of deprivation; what the Marmot review described as 'proportionate universalism'. Using the ICE to combine measures of deprivation and advantage in the same metric gives public health managers and researchers an effective method to examine the effects of combined advantage and disadvantage at the neighbourhood level. The ability of the ICE to place advantage and disadvantage on a continuum is useful. For example, from data analysed in this study it would be possible to identify those LSOAs where the ICE indicated a balance of concentration between the extremes and examine any associations with SRH.

6.3.5 Taking action to reduce health inequalities will have a positive effect on society

The Marmot review suggested several such positive effects, such as bringing economic benefits by reducing population illness and increasing productivity. Any of these factors can be modelled by the ICE, both individually and in combination to generate novel indices. The changes between 2001 and 2011 census data in this study demonstrate the value of the ICE in monitoring change over time.

6.3.6 A country's success is measured by more than economic growth

A fair distribution of health, wellbeing and sustainability are also important. The Marmot review proposed that climate change and social inequalities in health should be addressed simultaneously. Evidence presented in the systematic review for this study has demonstrated the utility of geographical information systems to examine environmental and socioeconomic dimensions of neighbourhood health (see the study of black carbon exposure by Krieger et al. (2015)). The use of such systems to model

ICE metrics in combination with environmental factors would allow researchers to assess sustainability as it relates to community health.

6.3.7 Give every child the best start in life and enable all children young people and adults to maximise their capabilities and have control over their lives

Although child development is beyond the scope of this study, the ICE offers a tool for analysing those social and environmental conditions known to affect children's health and life chances (see, for example, the studies by Carpiano et al. (2009) and (Dyson et al., 2009) reported above).

6.3.8 Create fair employment and good work for all

The study has demonstrated the effectiveness of the ICE in modelling NS-SeC employment categories derived from the Goldthorpe schema of employment relations and health status. Evidence that aspects of work captured by the Goldthorpe schema are associated with health outcomes means that the version of the ICE used in this study could be used for monitoring the employment market and population health.

6.3.9 Ensure healthy standard of living for all

The finding that the spatial concentration of non-white ethnic residents and aggregate age groups were part of the GWR model for 2011 suggests this requirement might be addressed by adapting the ICE to look at other aspects of neighbourhood composition. Census data allows specific ethic groups could be studied and age groups might usefully be reconsidered in terms of narrower age bands.

6.3.10 Create and develop healthy and sustainable places and communities

The systematic review for this study found evidence that considerable variations exist in the extreme spatial distributions of privilege and privation. It follows that if patterns of extreme social spatial concentrations are modifiable, then so are the excess burdens of adverse health that they create.

Unlike the IMD, the ICE combines measures of advantage and disadvantage in the same measure. Consistent with the comparative analysis of the 2001 and 2011 census maps in this study, the ICE should be used to identify and prioritise areas of change in the salariat or working-class concentrations at LSOA level.

6.3.11 Strengthen the role and impact of ill health prevention

Public health policy objectives can only be delivered through effective involvement of central and local government, the NHS, charitable and private sectors, individuals and communities. All of these agencies would benefit from a national ICE that expands the maps presented in this study to the rest of the UK. Linked ICE data tables could also be provided in the manner of the *Fingertips* resource currently hosted by Public Health England.

CHAPTER 7: References

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CHAPTER 8: Appendix

8.1 Appendix A: Canadian Effective Public Health Practice Project (EPHPP) evaluation scheme.

COMPONENT RATINGS

A) SELECTION BIAS

(Q1) Are the individuals selected to participate in the study likely to be representative of the target population?

1 Very likely
2 Somewhat likely
3 Not likely
4 Can't tell

(Q2) What percentage of selected individuals agreed to participate?

1 80 - 100% agreement
2 60 – 79% agreement
3 less than 60% agreement
4 Not applicable
5 Can't tell

RATE THIS SECTION	**STRONG**	**MODERATE**	**WEAK**
See dictionary	**1**	**2**	**3**

B) STUDY DESIGN

Indicate the study design

1 Randomized controlled trial
2 Controlled clinical trial
3 Cohort analytic (two group pre + post)
4 Case-control
5 Cohort (one group pre + post (before and after))
6 Interrupted time series
7 Other specify _____
8 Can't tell

Was the study described as randomized? If NO, go to Component C.

No Yes

If Yes, was the method of randomization described? (See dictionary)

No Yes

If Yes, was the method appropriate? (See dictionary)

No Yes

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	**1**	**2**	**3**

C) CONFOUNDERS

(Q1) Were there important differences between groups prior to the intervention?

1 Yes
2 No
3 Can't tell

The following are examples of confounders:

1 Race
2 Sex
3 Marital status/family
4 Age
5 SES (income or class)
6 Education
7 Health status
8 Pre-intervention score on outcome measure

(Q2) If yes, indicate the percentage of relevant confounders that were controlled (either in the design (e.g. stratification, matching) or analysis)?

1 80 – 100% (most)
2 60 – 79% (some)
3 Less than 60% (few or none)
4 Can't Tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	**1**	**2**	**3**

D) BLINDING

(Q1) Was (were) the outcome assessor(s) aware of the intervention or exposure status of participants?

1 Yes
2 No
3 Can't tell

(Q2) Were the study participants aware of the research question?

1 Yes
2 No
3 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	**1**	**2**	**3**

E) DATA COLLECTION METHODS

(Q1) Were data collection tools shown to be valid?

1 Yes
2 No
3 Can't tell

(Q2) Were data collection tools shown to be reliable?

1 Yes
2 No
3 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	**1**	**2**	**3**

F) WITHDRAWALS AND DROP-OUTS

(Q1) Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?

1 Yes
2 No
3 Can't tell
4 Not Applicable (i.e. one time surveys or interviews)

(Q2) Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).

1 80 -100%
2 60-79%
3 less than 60%
4 Can't tell
5 Not Applicable (i.e. Retrospective case-control)

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	**1**	**2**	**3**

G) INTERVENTION INTEGRITY

(Q1) What percentage of participants received the allocated intervention or exposure of interest?

1 80 -100%
2 60-79%
3 less than 60%
4 Can't tell

(Q2) Was the consistency of the intervention measured?

1 Yes
2 No
3 Can't tell

(Q3) Is it likely that subjects received an unintended intervention (contamination or co-intervention) that may influence the results?

4 Yes
5 No
6 Can't tell

H) ANALYSES

(Q1) Indicate the unit of allocation (circle one)

community organization/institution practice/office individual

(Q2) Indicate the unit of analysis (circle one)

community organization/institution practice/office individual

(Q3) Are the statistical methods appropriate for the study design?

1 Yes
2 No
3 Can't tell

(Q4) Is the analysis performed by intervention allocation status (i.e. intention to treat) rather than the actual intervention received?

1 Yes
2 No
3 Can't tell

GLOBAL RATING

COMPONENT RATINGS

Please transcribe the information from the gray boxes on pages 1-4 onto this page. See dictionary on how to rate this section.

A SELECTION BIAS	**STRONG**	**MODERATE**	**WEAK**
	1	2	3
B STUDY DESIGN	**STRONG**	**MODERATE**	**WEAK**
	1	2	3
C CONFOUNDERS	**STRONG**	**MODERATE**	**WEAK**
	1	2	3
D BLINDING	**STRONG**	**MODERATE**	**WEAK**
	1	2	3
E DATA COLLECTION METHOD	**STRONG**	**MODERATE**	**WEAK**
	1	2	3
F WITHDRAWALS AND DROPOUTS	**STRONG**	**MODERATE**	**WEAK**
	1	2	3

GLOBAL RATING FOR THIS PAPER (circle one):

1 STRONG (no WEAK ratings)
2 MODERATE (one WEAK rating)
3 WEAK (two or more WEAK ratings)

With both reviewers discussing the ratings:

Is there a discrepancy between the two reviewers with respect to the component (A-F) ratings?

No Yes

If yes, indicate the reason for the discrepancy

1 Oversight
2 Differences in interpretation of criteria
3 Differences in interpretation of study

Final decision of both reviewers (circle one):

1 STRONG
2 MODERATE
3 WEAK

Data Dictionary

Component Ratings of Study:

For each of the six components A – F, use the following descriptions as a roadmap.

A) SELECTION BIAS
Strong: The selected individuals are very likely to be representative of the target population (Q1 is 1) **and** there is greater than 80% participation (Q2 is 1).

Moderate: The selected individuals are at least somewhat likely to be representative of the target population (Q1 is 1 or 2); **and** there is 60 - 79% participation (Q2 is 2). 'Moderate' may also be assigned if Q1 is 1 or 2 and Q2 is 5 (can't tell).

Weak: The selected individuals are not likely to be representative of the target population (Q1 is 3); **or** there is less than 60% participation (Q2 is 3) **or** selection is not described (Q1 is 4); and the level of participation is not described (Q2 is 5).

B) DESIGN
Strong: will be assigned to those articles that described RCTs and CCTs.

Moderate: will be assigned to those that described a cohort analytic study, a case control study ,a cohort design, or an interrupted time series.

Weak: will be assigned to those that used any other method or did not state the method used.

C) CONFOUNDERS

Strong: will be assigned to those articles that controlled for at least 80% of relevant confounders (Q1 is 2); **or** (Q2 is 1).

Moderate: will be given to those studies that controlled for 60–79% of relevant confounders (Q1is1) **and** (Q2 is 2).

Weak: will be assigned when less than 60% of relevant confounders were controlled (Q1is1) **and** (Q2 is 3) **or** control of confounders was not described (Q1 is 3) **and** (Q2 is 4).

D) BLINDING
Strong: The outcome assessor is not aware of the intervention status of participants (Q1 is 2); **and t**he study participants are not aware of the research question (Q2 is 2).

Moderate: The outcome assessor is not aware of the intervention status of participants (Q1 is 2); **or** the study participants are not aware of the research question (Q2 is 2); **or b**linding is not described (Q1 is 3 and Q2 is 3).

Weak: The outcome assessor is aware of the intervention status of participants (Q1 is 1); **and** the study participants are aware of the research question (Q2 is 1).

E) DATA COLLECTION METHODS
Strong: The data collection tools have been shown to be valid (Q1 is 1); **and** the data collection tools have been shown to be reliable (Q2 is 1).

Moderate: The data collection tools have been shown to be valid (Q1 is 1); **and** the data collection tools have not been shown to be reliable (Q2 is 2) **or** reliability is not described (Q2 is 3).

Weak: The data collection tools have not been shown to be valid (Q1 is 2) **or** both reliability and validity described (Q1 is 3 and Q2 is 3).

F) WITHDRAWALS AND DROP-OUTS - a rating of:
Strong: will be assigned when the follow-up rate is 80% or greater (Q2 is 1).

Moderate: will be assigned when the follow-up rate is 60 – 79% (Q2 is 2) **OR** Q2 is 5 (N/A).

Weak: will be assigned when a follow-up rate is less than 60% (Q2 is 3) or if the withdrawals and drop-outs were not described (Q2 is 4).

8.2 Appendix B: Summary table of studies included in the literature review.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Hertzman, Power et al. (2001).	Using an interactive framework of society and life course to explain self-rated health in early adulthood.	England, Wales & Scotland UK.	All children born in England, Wales and Scotland during the 3–9 March 1958. 16,964 live births.	1958 British Birth Cohort.	Birth weight. Walking and talking. Height, emotional status and educational status at age 7. SRH at age 33.	Childhood social class by father's occupation. Social status at age 33.	Multiple linear regression models using SRH at age 33 as the dependent health outcome.	Both life-course and contemporary circumstances explained adult SRH.
Mindell, Knott et al. (2014).	Explanatory factors for health inequalities across different ethnic and gender groups: data from a national survey in England.	England UK	Ethnic minority population sample of 16,617 men, and 20,462 women.	Health Survey for England 2003-2006.	SRH and limiting long-term illness. Anxiety, depression and social support. Health behaviours including diet, smoking and exercise.	Educational attainment, household income & economic activity.	Regression.	Both SES and health behaviours were major predictors of ethnic health inequalities. Effects varied between ethnic groups.
Sacker, Worts et al. (2011).	Social influences on trajectories of self-rated health: evidence from Britain, Germany, Denmark and the USA.	UK, Germany, Denmark & USA	Working age respondents.	National household panel surveys 1995-2001.	SRH.	Educational attainment, occupational class, employment status, income, age, gender, minority status & marital status.	Latent growth curve models.	Social covariates predicted baseline health in all four countries. Trajectories of health for those in average and advantaged social circumstances were similar, but disadvantaged individuals had much poorer health trajectories than 'average' individuals.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Smith, Glazier et al. (2010).	The predictors of self-rated health and the relationship between self-rated health and health service needs are similar across socioeconomic groups in Canada.	Canada	Respondents aged between 24 and 64 years, living in Canada for more than 10 years (n=19,402).	Canadian Community Health Survey linked to the Ontario Health Insurance Plan 2000-2001.	SRH, physical health, mental health, health behaviours and health care utilisation.	Educational attainment and household income.	Fully adjusted probit regression models.	SRH assesses a broad variety of factors, including physical health status, mental health status, health utilization and health behaviours, relatively equally across socioeconomic groups, measured as either education or income. Level of SRH reflects expected health care utilization, including duration, severity, and aetiology of different diseases similarly across socioeconomic groups.
Badland, Foster et al.(2017).	Examining associations between area-level spatial measures of housing with selected health and wellbeing behaviours and outcomes in an urban context.	Melbourne, Australia.	7,753 adults.	Australian census collection undertaken in 2011 by the Australian Bureau of Statistics.	SRH.	Neighbourhood-level housing attributes; density, tenure; and affordable housing.	Multivariate multilevel logistic regression models.	Compared with reference groups, as dwelling density, proportion of rental properties, and housing unaffordability increased, the odds of reporting poorer SRH increased; however these associations did not always reach statistical significance.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Badland, Turrell et al. (2013).	Who does well where? Exploring how self-rated health differs across diverse people and neighbourhoods.	Brisbane, Australia	10,932 adults age 40-65.	HABITAT longitudinal study 2007–2011.	SRH.	Index of Relative Socioeconomic Disadvantage (IRSD) scores. Composite area-level measure including the proportion of low-income families, low educational attainment, and employment in unskilled occupations.	Multinomial unordered logistic regression.	Adjusted for demographics, those who lived in the most disadvantaged neighbourhoods were more likely to report poor SRH than those living in the least disadvantaged neighbourhoods. Those with the lowest SES in the most advantaged neighbourhoods had similar probability of reporting excellent SRH as those with the highest SES living in the most disadvantaged neighbourhoods.
Stafford, Martikainen et al. (2004).	Neighbourhoods and self rated health: a comparison of public sector employees in London and Helsinki.	London, UK and Helsinki, Finland.	London sample; n=5301 civil servants. Helsinki sample; n=4287 municipal employees	Whitehall II study (London, aged 39–63) and the Helsinki health study (aged 40– 60).	SRH.	SES by employment grade; managerial/administrative, professional and semi-professional, clerical, and manual workers.	Index of dissimilarity.	Neighbourhood socioeconomic context associated with health in both countries, with some evidence of greater neighbourhood effects in London. Greater socioeconomic segregation in London may have emergent effects at the neighbourhood level. Local and national social policies may reduce, or restrict, inequality and segregation between areas.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Popham and Bambra (2010).	Evidence from the 2001 English Census on the contribution of employment status to the social gradient in self-rated health.	England, UK.	349,699 women and 349,181 men aged 25-59.	UK census 2001	SRH.	Employment status and SES.	Generalised linear models.	Prevalence differences for poor health were reduced by 50% or over when adjusting for employment status. The social gradient in employment status contributes greatly to the social gradient in self-reported health.
Lahelma, Martikainen et al. (2004).	Pathways between socioeconomic determinants of health.	Helsinki, Finland.	6243 employees (80% female).	Helsinki health study 2000-2001.	SRH and limiting long term illness.	Education, occupational class, and household income.	Logistic regression.	Each socioeconomic indicator showed a clear gradient with health. However, parts of the effects of each socioeconomic indicator on health were either explained by or mediated through other socioeconomic indicators.
Rahkonen, Laaksonen et al. (2006).	Job control, job demands, or social class? The impact of working conditions on the relation between social class and health.	Helsinki, Finland.	40-60 year old employees working for the City of Helsinki (n = 8,970)	Helsinki health study 2000-2001.	SRH and limiting long term illness.	Social class, job control and job demands.	Multivariate logistic regression.	A substantial part of the relation between social class and health attributed to job control. However, job demands reinforced the relation. Although the effect of social class was mediated by psychosocial working conditions, both social class and working conditions were related to health after mutual adjustments.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Smith, Frank et al. (2008).	Examining the relationships between job control and health status: a path analysis approach.	Canada.	4,886 respondents aged 25-60.	Canadian National Population Health Study; 1994-2002.	SRH, health behaviours and psychological distress.	Educational attainment, job control and household income adequacy.	Path analysis.	Inclusion of other factors associated with lower socioeconomic status did not attenuate the direct and indirect effects of job control on health.
Sathyanarayanan, Brooks et al. (2012).	Multilevel Analysis of the Physical Health Perception of Employees: Community and Individual Factors	Michigan, USA.	22,012 active employees.	Health risk appraisal and census data 1999-2001.	SRH, health-related behaviours, medical history, and quality of life indicators.	Novel community deprivation index and racial segregation.	Multilevel modelling.	Community had a modest association with SRH. After adjusting for individual-level and demographic variables, employees living in less/ moderately deprived communities were more likely to report better physical SRH relative to those who live in highly deprived communities.
Pikhart, Bobak et al. (2001).	Psychosocial work characteristics and self-rated health in four post-communist countries.	Poland, Czech Republic, Lithuania and Hungary.	Working-age participants (n=3,941).	Random sample postal questionnaire and interview.	SRH.	Socioeconomic circumstances, perceived control over life, and the psychosocial work environment: job control, job demand, job variety, social support, and effort/reward ratio.	Logistic regression.	Effort/reward imbalance at work was a powerful determinant of SRH.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
de Castro, Rue et al. (2010).	Associations of Employment Frustration with Self-Rated Physical and Mental Health Among Asian American Immigrants in the U.S. Labor Force.	US national survey.	All Latino and Asian American adults in U.S. states and Washington, DC.	National Latino and Asian American Study 2002-2003.	SRH measures for mental (SRMH) and physical (SRPH) health.	Occupation, income, immigrated for employment, years in the US, language proficiency and educational attainment.	Ordered logistic regression.	Employment frustration was negatively associated with SRPH. This relationship was no longer significant in multivariate models including English proficiency. The negative association between employment frustration and SRMH persisted even when including all control variables.
D'Souza, Strazdins et al. (2003).	Work and health in a contemporary society: demands, control, and insecurity	South east Australia.	1,188 employed professionals, aged 40–44.	PATH 40+ (Personality and Total Health) Through Life Project cross sectional study of 40 to 44 year old adults.	Depression, anxiety, physical, and SRH.	Job insecurity, job strain, gender, education, marital status, employment status.	Multivariate logistic analyses	Adverse work conditions were associated with poor health, particularly mental health. Both job strain (high demands and low control) and job insecurity were independently associated with poor health. The health impact of work was independent of personality. Even in a relatively advantaged sample, fear of job loss and a sense of job insecurity may have potent health impacts.
Giatti, Barreto et al. (2008).	Household context and SRH: the effect of unemployment and informal work.	Brazil.	1998 (n = 85,384) 2003 (n = 89,063	Health Survey (PNAD) 1998 and 2003 by the Brazilian Institute for Geography and Statistics (IBGE).	SRH.	Educational attainment, labour market status and household material assets.	Multiple logistic regression.	Unemployment and/or informal work had a contextual impact on the SRH of household members.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Giatti, Barreto et al. (2010).	Unemployment and self-rated health: Neighborhood influence.	Brazil.	6,426 participants, ages ranged from 15 - 64 years.	2000 Brazilian Population Census	SRH.	Household income, residence in slum areas, employment status and behavioural risk factors.	Logistic regression.	Independent association between SRH and neighbourhood context. Low income and slum residence associated with poor SRH. However, the association was attenuated after adjustment for behavioural factors.
Carpiano, Lloyd et al. (2009).	Concentrated affluence, concentrated disadvantage, and children's readiness for school: A population-based, multi-level investigation.	British Columbia, Canada.	37,798 kindergarten children.	Human Early Learning Partnership (HELP).	Early Development Instrument (EDI).	ICE.	Hierarchical Linear Modelling.	Concentrated affluence may have diminishing rates of return on enhanced child development. Children in mixed-income neighbourhoods may benefit from the presence of affluent residents and the presence of services and institutions aimed at assisting lower-income residents.
Krieger et al. (2016).	Public Health Monitoring of Privilege and Deprivation With the Index of Concentration at the Extremes.	New York city, USA.	59 community districts, averaging 144,000 residents per district.	US Census American Community Survey (ACS) 2008-2012.	Infant mortality, diabetes mortality (all ages) & premature mortality (all cause).	ACS poverty levels & race/ethnicity.	ICE for measures at census tract and community district levels.	ICE a significant predictor for health measures in combination with SES factors.
Krieger, Waterman et al. (2017).	Measures of Local Segregation for Monitoring Health Inequities by Local Health Departments.	Boston, US.	667,137 grouped by census tract.	Boston birth and death data for 2010 to 2012 from the Massachusetts Department of Public Health. American Community Survey data for ICE.	Pre- term birth rate and premature mortality rate (age-adjusted deaths per 100,000 deaths among individuals younger than 65 years).	Household income and ethnicity.	ICE for deprivation and privilege.	ICE predicted preterm births and premature mortality with stronger associations than poverty alone.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Chambers, Baer et al. 2019).	Using Index of Concentration at the Extremes as Indicators of Structural Racism to Evaluate the Association with Preterm Birth and Infant Mortality—California, 2011–2012.	California, US.	Valid zip code of residence with at least 10 non-Hispanic Black women (n = 47,771).	California birth cohort files merged with American Community Survey by zip code (2011–2012).	Pre-term birth and infant mortality rates. Maternal characteristics: age, insurance status, parity, smoking, birthplace, BMI and any previous complications of pregnancy.	Race and income.	ICE for race, income and combined race and income measure.	Greater ICE extreme income, race, and race + income concentrations increased odds of preterm birth and infant mortality.
Wallace, Crear-Perry et al. (2017).	Privilege and Deprivation: Associations between the Index of Concentration at the Extremes and Birth Equity in Detroit.	Detroit, US.	All live births among non-Hispanic (NH) white and non-Hispanic black women in Wayne County, MI from 2010-20 (n=8,338).	U.C. Census and the California Health Interview Survey, 2011-2014.	Mental health.	Ethnicity, social capital and political participation.	Novel ICE measure of racial residential segregation (RRS) and ICE for social participation.	RRS ICE significantly associated with higher distress among Asian Americans. Higher levels of social capital resulted in lower distress scores.
Wallace, Crear-Perry et al. (2019).	Privilege and deprivation in Detroit: infant mortality and the Index of Concentration at the Extremes.	Michigan, US.	Non- Hispanic Black and White women in Wayne County, MI, from 2010 to 2013 (n=84,159),	Birth records and American Community Survey 2009–2013 data.	Infant mortality rates.	Prematurity, congenital abnormalities and external cause of death. Also, maternal ethnicity, age and insurance status.	ICE for income deprivation by federal definition of poverty.	ICE significantly predicted association between deprivation and infant mortality for non-Hispanic women.
Huynh, Spasojevic et al. (2018).	Spatial social polarization and birth outcomes: preterm birth and infant mortality – New York City, 2010–14	New York City, US.	Singleton births in New York City (2010–2014; n=532,806).	Birth and death data from the New York City Department of Health and Mental Hygiene.	Preterm birth and infant mortality.	Race/ethnicity, household income, educational attainment, insurance status and BMI.	ICE for income, race/ethnicity and a combined ICE for income with race/ethnicity.	Women in least privilege more likely to have preterm birth or infant mortality compared to women in areas with the most privilege. After adjusting for covariates, this association remained for preterm birth.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Shrimali, Pearl et al. (2020).	Neighborhood Privilege, Preterm Delivery, and Related Racial/Ethnic Disparities: An Intergenerational Application of the Index of Concentration at the Extremes.	California, US.	379,794 California-born primiparous mothers (born 1982–1997) and their infants (born 1997–2011).	Decennial census data for 1980, 1990, and 2000 and American Community Survey 5-year annualized estimates from 2007–2011.	Preterm delivery, defined as <37 completed weeks of gestation.	Maternal race/ethnicity, age, educational attainment, insurance status, and both early childhood and adult household income.	ICE for income, race/ethnicity and a combined ICE for income with race/ethnicity.	Analysis of ICE supported independent effects of early childhood and adulthood neighbourhood privilege on preterm delivery and related disparities.
Krieger, Kim et al. 2018).	Using the Index of Concentration at the Extremes at multiple geographical levels to monitor health inequities in an era of growing spatial social polarization: Massachusetts, USA (2010–14).	Massachusetts, US.	Data on deaths among all residents and decedents in Massachusetts (2010–14). (N=263,266).	American Community Survey 2010-2014.	Early death: all-cause child (< 5 years) and premature (< 65 years) mortality. Chronic disease mortality; cancer, cardiovascular disease, diabetes. Non-chronic disease mortality; suicide, HIV/AIDS and accidental poisoning (including drug overdoses). Deaths attributable to smoking	Gender, income and race/ethnicity. Urbanicity of census tract.	ICE for income, race/ethnicity and a combined ICE for income with race/ethnicity	rate ratios comparing the worst with the best quintile were typically greater at local level compared with city/town level, with the latter typically most attenuated in models employing both levels. Rate ratios were greater for the ICE measures (especially for racialized economic segregation) compared with poverty measures. No effect modification of these patterns was observed in relation to gender, but did occur for race/ethnicity. Rate ratios for city/town measures were strongest for populations of colour.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Krieger, Waterman et al. (2015).	Black carbon exposure, socioeconomic and racial/ethnic spatial polarization, and the Index of Concentration at the Extremes (ICE).	Boston, US.	757 urban working class white, black, and Latino adults (age 25–64) 2003–2004; 2008–2010.	United for Health (UFH) study (2003–2004) and My Body, My Story (MBMS) study (2008–2010).	Individual's 1-year cumulative average exposure to ambient black carbon exposure at their residential address in the year prior to study enrolment.	Occupation, educational attainment, household income.	ICE calculated for all SES measures.	CE measures, but not individual- and household-SEP, remained independently associated with black carbon exposure.
Bell, Zimmerman et al. (2006).	Birth outcomes among urban African-American women: A multilevel analysis of the role of racial residential segregation.	National, US.	34,376 singleton births to African-American women living in 225 US Metropolitan Statistical Areas.	National Center for Health Statistics 2002 and the 2000 US Census.	Prenatal care, parity, birthweight, prematurity and growth restriction.	Poverty, neighbourhood quality and segregation.	Multivariate regression,	Higher isolation associated with lower birthweight, higher rates of prematurity and higher rates of foetal growth restriction. In contrast, higher clustering was associated with more optimal outcomes.
Feldman et al, (2015).	Spatial social polarisation: using the Index of Concentration at the Extremes jointly for income and race/ethnicity to analyse risk of hypertension.	Boston metropolitan area, USA.	Multi-ethnic cohort of residents of Boston, Massachusetts n=2,145.	United for Health survey 2003 – 2004 (UFH) & My Body My Story survey (MBMS) 2008 – 2010.	Diastolic & systolic blood pressure.	Income distribution derived from 2010 US census data. Race/ethnicity.	ICE & logistic regression.	Higher spatial concentration of African American residents using ICE significantly associated with hypertension.

Author & Date	Title	Setting	Population	Data source	Health measures	Socioeconomic status	Methods	Outcomes
Krieger, Singh & Waterman, (2016).	Metrics for monitoring cancer inequities: residential segregation, the Index of Concentration at the Extremes (ICE), and breast cancer oestrogen receptor status (USA, 1992–2012	13 US states.	Women aged 25–84 (n = 516,382) in the 13 SEER registry databases with primary invasive breast cancer.	Data from US Surveillance, Epidemiology, and End Results (SEER) 1992 – 2012.	SEER data on breast tumour at time of diagnosis.	US census data on median household income. Race/ethnicity.	ICE & linear regression.	Prevalence of invasive breast tumours significantly associated with ICE for income and ethnicity significantly.
Do, Frank et al. (2017).	Black-white metropolitan segregation and self-rated health: Investigating the role of neighborhood poverty.	Minnesota, US.	31,780 African-American and 118,250 white residents in 214 metropolitan areas.	2008-2013 Integrated Health Interview Series (Minnesota Population Center, 2016). Also, 2000 and 2010 decennial censuses, and 2005-2009 American Community Survey (ACS).	SRH.	Neighbourhood poverty, ethnicity, educational attainment and employment status.	Logistic regression.	SRH of African-Americans suffers as a result of black-white segregation, both directly, and indirectly, through exposure to high poverty neighbourhoods. No consistent evidence of a direct relationship between segregation and poor health for whites..

8.3 Appendix C: Quality appraisal of studies included in the literature review

A) SELECTION BIAS	(Q1) Are the individuals selected to participate in the study likely to be representative of the target population?	(Q2) What percentage of selected individuals agreed to participate?	Section rating
Hertzman, Power et al. (2001).	1 Very likely	4 Not applicable	Strong
Mindell, Knott et al. (2014).	1 Very likely	2 60 – 79% agreement	Strong
Sacker, Worts et al. (2011).	1 Very likely	1 80 - 100% agreement	Strong
Smith, Glazier et al. (2010).	1 Very likely	1 80 - 100% agreement	Strong
Badland, Foster et al.(2017).	1 Very likely	1 80 - 100% agreement	Strong
Badland, Turrell et al. (2013).	1 Very likely	1 80 - 100% agreement	Strong
Stafford, Martikainen et al. (2004).	1 Very likely	2 60 – 79% agreement	Strong
Popham and Bambra (2010).	1 Very likely	1 80 - 100% agreement	Strong
Lahelma, Martikainen et al. (2004).	1 Very likely	2 60 – 79% agreement	Strong
Rahkonen, Laaksonen et al. (2006).	1 Very likely	2 60 – 79% agreement	Strong
Smith, Frank et al. (2008).	1 Very likely	1 80 - 100% agreement	Strong
Sathyanarayanan, Brooks et al. (2012).	1 Very likely	1 80 - 100% agreement	Strong
Pikhart, Bobak et al. (2001).	1 Very likely	2 60 – 79% agreement	Strong
de Castro, Rue et al. (2010).	1 Very likely	1 80 - 100% agreement	Strong
D'Souza, Strazdins et al. (2003).	1 Very likely	1 80 - 100% agreement	Strong
Giatti, Barreto et al. (2008).	1 Very likely	1 80 - 100% agreement	Strong
Giatti, Barreto et al. (2010).	1 Very likely	1 80 - 100% agreement	Strong
Carpiano, Lloyd et al. (2009).	1 Very likely	1 80 - 100% agreement	Strong
Krieger et al. (2016).	1 Very likely	1 80 - 100% agreement	Strong
Krieger, Waterman et al. (2017).	1 Very likely	1 80 - 100% agreement	Strong
Chambers, Baer et al. 2019).	1 Very likely	1 80 - 100% agreement	Strong
Wallace, Crear-Perry et al. (2017).	1 Very likely	1 80 - 100% agreement	Strong
Wallace, Crear-Perry et al. (2019).	1 Very likely	1 80 - 100% agreement	Strong
Huynh, Spasojevic et al. (2018).	1 Very likely	1 80 - 100% agreement	Strong
Shrimali, Pearl et al. (2020).	1 Very likely	1 80 - 100% agreement	Strong
Krieger, Kim et al. 2018).	1 Very likely	1 80 - 100% agreement	Strong
Krieger, Waterman et al. (2015).	1 Very likely	1 80 - 100% agreement	Strong
Bell, Zimmerman et al. (2006).	1 Very likely	1 80 - 100% agreement	Strong
Feldman et al, (2015).	1 Very likely	1 80 - 100% agreement	Strong
Krieger, Singh & Waterman, (2016)	1 Very likely	1 80 - 100% agreement	Strong
Do, Frank et al. (2017).	1 Very likely	1 80 - 100% agreement	Strong

B) STUDY DESIGN	Indicate the study design	Was the study described as randomized? If NO, go to Component C.	If Yes, was the method of randomization described?	If Yes, was the method appropriate?	Section rating
Hertzman, Power et al. (2001).	5 Cohort (one group pre + post (before and after))	No			Moderate
Mindell, Knott et al. (2014).	5 Cohort (one group pre + post (before and after))	Yes	Yes	Yes	Strong
Sacker, Worts et al. (2011).	6 Interrupted time series	No			Moderate
Smith, Glazier et al. (2010).	5 Cohort (one group pre + post (before and after))	No			Moderate
Badland, Foster et al.(2017).	5 Cohort (one group pre + post (before and after))	No			Moderate
Badland, Turrell et al. (2013).	5 Cohort (one group pre + post (before and after))	No			Moderate
Stafford, Martikainen et al. (2004).	5 Cohort (one group pre + post (before and after))	No			Moderate
Popham and Bambra (2010).	5 Cohort (one group pre + post (before and after))	No			Moderate
Lahelma, Martikainen et al. (2004).	5 Cohort (one group pre + post (before and after))	No			Moderate
Rahkonen, Laaksonen et al. (2006).	5 Cohort (one group pre + post (before and after))	No			Moderate
Smith, Frank et al. (2008).	5 Cohort (one group pre + post (before and after))	No			Moderate
Sathyanarayanan, Brooks et al. (2012).	5 Cohort (one group pre + post (before and after))	No			Moderate
Pikhart, Bobak et al. (2001).	5 Cohort (one group pre + post (before and after))	No			Moderate
de Castro, Rue et al. (2010).	5 Cohort (one group pre + post (before and after))	No			Moderate
D'Souza, Strazdins et al. (2003).	5 Cohort (one group pre + post (before and after))	No			Moderate
Giatti, Barreto et al. (2008).	5 Cohort (one group pre + post (before and after))	No			Moderate
Giatti, Barreto et al. (2010).	5 Cohort (one group pre + post (before and after))	No			Moderate
Carpiano, Lloyd et al. (2009).	5 Cohort (one group pre + post (before and after))	No			Moderate
Krieger et al. (2016).	5 Cohort (one group pre + post (before and after))	No			Moderate
Krieger, Waterman et al. (2017).	5 Cohort (one group pre + post (before and after))	No			Moderate
Chambers, Baer et al. 2019).	5 Cohort (one group pre + post (before and after))	No			Moderate
Wallace, Crear-Perry et al. (2017).	5 Cohort (one group pre + post (before and after))	No			Moderate
Wallace, Crear-Perry et al. (2019).	5 Cohort (one group pre + post (before and after))	No			Moderate
Huynh, Spasojevic et al. (2018).	5 Cohort (one group pre + post (before and after))	No			Moderate
Shrimali, Pearl et al. (2020).	5 Cohort (one group pre + post (before and after))	No			Moderate
Krieger, Kim et al. 2018).	5 Cohort (one group pre + post (before and after))	No			Moderate
Krieger, Waterman et al. (2015).	5 Cohort (one group pre + post (before and after))	No			Moderate
Bell, Zimmerman et al. (2006).	5 Cohort (one group pre + post (before and after))	No			Moderate
Feldman et al, (2015).	5 Cohort (one group pre + post (before and after))	No			Moderate
Krieger, Singh & Waterman, (2016)	5 Cohort (one group pre + post (before and after))	No			Moderate
Do, Frank et al. (2017).	5 Cohort (one group pre + post (before and after))	No			Moderate

C) CONFOUNDERS	(Q1) Were there important differences between groups prior to the intervention?	(Q2) If yes, indicate the percentage of relevant confounders that were controlled (either in the design (e.g. stratification, matching) or analysis)?	Section rating
Hertzman, Power et al. (2001).	1 Yes	1 80 – 100% (most)	Strong
Mindell, Knott et al. (2014).	1 Yes	1 80 – 100% (most)	Strong
Sacker, Worts et al. (2011).	1 Yes	1 80 – 100% (most)	Strong
Smith, Glazier et al. (2010).	1 Yes	1 80 – 100% (most)	Strong
Badland, Foster et al.(2017).	1 Yes	1 80 – 100% (most)	Strong
Badland, Turrell et al. (2013).	1 Yes	1 80 – 100% (most)	Strong
Stafford, Martikainen et al. (2004).	1 Yes	1 80 – 100% (most)	Strong
Popham and Bambra (2010).	1 Yes	1 80 – 100% (most)	Strong
Lahelma, Martikainen et al. (2004).	1 Yes	1 80 – 100% (most)	Strong
Rahkonen, Laaksonen et al. (2006).	1 Yes	1 80 – 100% (most)	Strong
Smith, Frank et al. (2008).	1 Yes	1 80 – 100% (most)	Strong
Sathyanarayanan, Brooks et al. (2012).	1 Yes	1 80 – 100% (most)	Strong
Pikhart, Bobak et al. (2001).	1 Yes	1 80 – 100% (most)	Strong
de Castro, Rue et al. (2010).	1 Yes	1 80 – 100% (most)	Strong
D'Souza, Strazdins et al. (2003).	1 Yes	1 80 – 100% (most)	Strong
Giatti, Barreto et al. (2008).	1 Yes	1 80 – 100% (most)	Strong
Giatti, Barreto et al. (2010).	1 Yes	1 80 – 100% (most)	Strong
Carpiano, Lloyd et al. (2009).	1 Yes	1 80 – 100% (most)	Strong
Krieger et al. (2016).	1 Yes	1 80 – 100% (most)	Strong
Krieger, Waterman et al. (2017).	1 Yes	1 80 – 100% (most)	Strong
Chambers, Baer et al. 2019).	1 Yes	1 80 – 100% (most)	Strong
Wallace, Crear-Perry et al. (2017).	1 Yes	1 80 – 100% (most)	Strong
Wallace, Crear-Perry et al. (2019).	1 Yes	1 80 – 100% (most)	Strong
Huynh, Spasojevic et al. (2018).	1 Yes	1 80 – 100% (most)	Strong
Shrimali, Pearl et al. (2020).	1 Yes	1 80 – 100% (most)	Strong
Krieger, Kim et al. 2018).	1 Yes	1 80 – 100% (most)	Strong
Krieger, Waterman et al. (2015).	1 Yes	1 80 – 100% (most)	Strong
Bell, Zimmerman et al. (2006).	1 Yes	1 80 – 100% (most)	Strong
Feldman et al, (2015).	1 Yes	1 80 – 100% (most)	Strong
Krieger, Singh & Waterman, (2016)	1 Yes	1 80 – 100% (most)	Strong
Do, Frank et al. (2017).	1 Yes	1 80 – 100% (most)	Strong

D) BLINDING	(Q1) Was (were) the outcome assessor(s) aware of the intervention or exposure status of participants?	(Q2) Were the study participants aware of the research question?	Section rating
Hertzman, Power et al. (2001).	1 Yes	2 No	Moderate
Mindell, Knott et al. (2014).	1 Yes	1 Yes	Strong
Sacker, Worts et al. (2011).	1 Yes	2 No	Moderate
Smith, Glazier et al. (2010).	1 Yes	2 No	Strong
Badland, Foster et al.(2017).	1 Yes	2 No	Moderate
Badland, Turrell et al. (2013).	1 Yes	2 No	Moderate
Stafford, Martikainen et al. (2004).	1 Yes	2 No	Moderate
Popham and Bambra (2010).	1 Yes	2 No	Moderate
Lahelma, Martikainen et al. (2004).	1 Yes	2 No	Moderate
Rahkonen, Laaksonen et al. (2006).	1 Yes	2 No	Moderate
Smith, Frank et al. (2008).	1 Yes	2 No	Moderate
Sathyanarayanan, Brooks et al. (2012).	1 Yes	2 No	Moderate
Pikhart, Bobak et al. (2001).	1 Yes	2 No	Moderate
de Castro, Rue et al. (2010).	1 Yes	2 No	Moderate
D'Souza, Strazdins et al. (2003).	1 Yes	2 No	Moderate
Giatti, Barreto et al. (2008).	1 Yes	2 No	Moderate
Giatti, Barreto et al. (2010).	1 Yes	2 No	Moderate
Carpiano, Lloyd et al. (2009).	1 Yes	2 No	Moderate
Krieger et al. (2016).	1 Yes	2 No	Moderate
Krieger, Waterman et al. (2017).	1 Yes	2 No	Moderate
Chambers, Baer et al. 2019).	1 Yes	2 No	Moderate
Wallace, Crear-Perry et al. (2017).	1 Yes	2 No	Moderate
Wallace, Crear-Perry et al. (2019).	1 Yes	2 No	Moderate
Huynh, Spasojevic et al. (2018).	1 Yes	2 No	Moderate
Shrimali, Pearl et al. (2020).	1 Yes	2 No	Moderate
Krieger, Kim et al. 2018).	1 Yes	2 No	Moderate
Krieger, Waterman et al. (2015).	1 Yes	2 No	Moderate
Bell, Zimmerman et al. (2006).	1 Yes	2 No	Moderate
Feldman et al, (2015).	1 Yes	2 No	Moderate
Krieger, Singh & Waterman, (2016)	1 Yes	2 No	Moderate
Do, Frank et al. (2017).	1 Yes	2 No	Moderate

E) DATA COLLECTION METHODS	(Q1) Were data collection tools shown to be valid?	(Q2) Were data collection tools shown to be reliable?	Section rating
Hertzman, Power et al. (2001).	1 Yes	1 Yes	Strong
Mindell, Knott et al. (2014).	1 Yes	1 Yes	Strong
Sacker, Worts et al. (2011).	1 Yes	1 Yes	Strong
Smith, Glazier et al. (2010).	1 Yes	1 Yes	Strong
Badland, Foster et al.(2017).	1 Yes	1 Yes	Strong
Badland, Turrell et al. (2013).	1 Yes	1 Yes	Strong
Stafford, Martikainen et al. (2004).	1 Yes	1 Yes	Strong
Popham and Bambra (2010).	1 Yes	1 Yes	Strong
Lahelma, Martikainen et al. (2004).	1 Yes	1 Yes	Strong
Rahkonen, Laaksonen et al. (2006).	1 Yes	1 Yes	Strong
Smith, Frank et al. (2008).	1 Yes	1 Yes	Strong
Sathyanarayanan, Brooks et al. (2012).	1 Yes	1 Yes	Strong
Pikhart, Bobak et al. (2001).	1 Yes	1 Yes	Strong
de Castro, Rue et al. (2010).	1 Yes	1 Yes	Strong
D'Souza, Strazdins et al. (2003).	1 Yes	1 Yes	Strong
Giatti, Barreto et al. (2008).	1 Yes	1 Yes	Strong
Giatti, Barreto et al. (2010).	1 Yes	1 Yes	Strong
Carpiano, Lloyd et al. (2009).	1 Yes	1 Yes	Strong
Krieger et al. (2016).	1 Yes	1 Yes	Strong
Krieger, Waterman et al. (2017).	1 Yes	1 Yes	Strong
Chambers, Baer et al. 2019).	1 Yes	1 Yes	Strong
Wallace, Crear-Perry et al. (2017).	1 Yes	1 Yes	Strong
Wallace, Crear-Perry et al. (2019).	1 Yes	1 Yes	Strong
Huynh, Spasojevic et al. (2018).	1 Yes	1 Yes	Strong
Shrimali, Pearl et al. (2020).	1 Yes	1 Yes	Strong
Krieger, Kim et al. 2018).	1 Yes	1 Yes	Strong
Krieger, Waterman et al. (2015).	1 Yes	1 Yes	Strong
Bell, Zimmerman et al. (2006).	1 Yes	1 Yes	Strong
Feldman et al, (2015).	1 Yes	1 Yes	Strong
Krieger, Singh & Waterman, (2016)	1 Yes	1 Yes	Strong
Do, Frank et al. (2017).	1 Yes	1 Yes	Strong

F) WITHDRAWALS AND DROP-OUTS	(Q1) Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?	(Q2) Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).	Section rating
Hertzman, Power et al. (2001).	4 Not Applicable (i.e. one time surveys or interviews)	5 Not Applicable (i.e. Retrospective case-control)	Strong
Mindell, Knott et al. (2014).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Sacker, Worts et al. (2011).	1 Yes	1 80 -100%	Strong
Smith, Glazier et al. (2010).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Badland, Foster et al.(2017).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Badland, Turrell et al. (2013).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Stafford, Martikainen et al. (2004).	1 Yes	1 80 -100%	Strong
Popham and Bambra (2010).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Lahelma, Martikainen et al. (2004).	1 Yes	2 60-79%	Moderate
Rahkonen, Laaksonen et al. (2006).	1 Yes	2 60-79%	Moderate
Smith, Frank et al. (2008).	1 Yes	1 80 -100%	Strong
Sathyanarayanan, Brooks et al. (2012).	1 Yes	1 80 -100%	Strong
Pikhart, Bobak et al. (2001).	1 Yes	2 60-79%	Moderate
de Castro, Rue et al. (2010).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
D'Souza, Strazdins et al. (2003).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Giatti, Barreto et al. (2008).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Giatti, Barreto et al. (2010).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Carpiano, Lloyd et al. (2009).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Krieger et al. (2016).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Krieger, Waterman et al. (2017).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Chambers, Baer et al. 2019).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Wallace, Crear-Perry et al. (2017).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Wallace, Crear-Perry et al. (2019).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Huynh, Spasojevic et al. (2018).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Shrimali, Pearl et al. (2020).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Krieger, Kim et al. 2018).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Krieger, Waterman et al. (2015).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Bell, Zimmerman et al. (2006).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Feldman et al, (2015).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Krieger, Singh & Waterman, (2016)	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong
Do, Frank et al. (2017).	4 Not Applicable (i.e. one time surveys or interviews)	1 80 -100%	Strong

G) INTERVENTION INTEGRITY	(Q1) What percentage of participants received the allocated intervention or exposure of interest?	(Q2) Was the consistency of the intervention measured?	(Q3) Is it likely influence that subjects received an unintended intervention (contamination or co-intervention) that may the results?	Section rating
Hertzman, Power et al. (2001).	1 80 – 100% (most)	2 No	2 No	Strong
Mindell, Knott et al. (2014).	1 80 – 100% (most)	3 Can't tell	2 No	Strong
Sacker, Worts et al. (2011).	1 80 – 100% (most)	1 Yes	2 No	Strong
Smith, Glazier et al. (2010).	1 80 – 100% (most)	1 Yes	2 No	Strong
Badland, Foster et al.(2017).	1 80 – 100% (most)	1 Yes	2 No	Strong
Badland, Turrell et al. (2013).	1 80 – 100% (most)	1 Yes	2 No	Strong
Stafford, Martikainen et al. (2004).	1 80 – 100% (most)	1 Yes	2 No	Strong
Popham and Bambra (2010).	1 80 – 100% (most)	1 Yes	2 No	Strong
Lahelma, Martikainen et al. (2004).	1 80 – 100% (most)	1 Yes	2 No	Strong
Rahkonen, Laaksonen et al. (2006).	1 80 – 100% (most)	1 Yes	2 No	Strong
Smith, Frank et al. (2008).	1 80 – 100% (most)	1 Yes	2 No	Strong
Sathyanarayanan, Brooks et al. (2012).	1 80 – 100% (most)	1 Yes	2 No	Strong
Pikhart, Bobak et al. (2001).	1 80 – 100% (most)	1 Yes	2 No	Strong
de Castro, Rue et al. (2010).	1 80 – 100% (most)	1 Yes	2 No	Strong
D'Souza, Strazdins et al. (2003).	1 80 – 100% (most)	1 Yes	2 No	strong
Giatti, Barreto et al. (2008).	1 80 – 100% (most)	1 Yes	2 No	Strong
Giatti, Barreto et al. (2010).	1 80 – 100% (most)	1 Yes	2 No	Strong
Carpiano, Lloyd et al. (2009).	1 80 – 100% (most)	1 Yes	2 No	Strong
Krieger et al. (2016).	1 80 – 100% (most)	1 Yes	2 No	Strong
Krieger, Waterman et al. (2017).	1 80 – 100% (most)	1 Yes	2 No	Strong
Chambers, Baer et al. 2019).	1 80 – 100% (most)	1 Yes	2 No	Strong
Wallace, Crear-Perry et al. (2017).	1 80 – 100% (most)	1 Yes	2 No	Strong
Wallace, Crear-Perry et al. (2019).	1 80 – 100% (most)	1 Yes	2 No	Strong
Huynh, Spasojevic et al. (2018).	1 80 – 100% (most)	1 Yes	2 No	Strong
Shrimali, Pearl et al. (2020).	1 80 – 100% (most)	1 Yes	2 No	Strong
Krieger, Kim et al. 2018).	1 80 – 100% (most)	1 Yes	2 No	Strong
Krieger, Waterman et al. (2015).	1 80 – 100% (most)	1 Yes	2 No	Strong
Bell, Zimmerman et al. (2006).	1 80 – 100% (most)	1 Yes	2 No	Strong
Feldman et al, (2015).	1 80 – 100% (most)	1 Yes	2 No	Strong
Krieger, Singh & Waterman, (2016)	1 80 – 100% (most)	1 Yes	2 No	Strong
Do, Frank et al. (2017).	1 80 – 100% (most)	1 Yes	2 No	Strong

H) ANALYSES	(Q1) Indicate the unit of Allocation (circle one)	(Q2) Indicate the unit of analysis (circle one)	(Q3) Are the statistical methods appropriate for the study design?	(Q4) Is the analysis performed by intervention allocation status (i.e. intention to treat) rather than the actual intervention received?	Section rating	Global rating
Hertzman, Power et al. (2001).	Community	Community	1 Yes	1 Yes	Strong	Strong
Mindell, Knott et al. (2014).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Sacker, Worts et al. (2011).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Smith, Glazier et al. (2010).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Badland, Foster et al.(2017).	Community	Community	1 Yes	1 Yes	Strong	Strong
Badland, Turrell et al. (2013).	Community	Community	1 Yes	1 Yes	Strong	Strong
Stafford, Martikainen et al. (2004).	Community	Community	1 Yes	1 Yes	Strong	Strong
Popham and Bambra (2010).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Lahelma, Martikainen et al. (2004).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Rahkonen, Laaksonen et al. (2006).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Smith, Frank et al. (2008).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Sathyanarayanan, Brooks et al. (2012).	Community	Community	1 Yes	1 Yes	Strong	Strong
Pikhart, Bobak et al. (2001).	Community	Community	1 Yes	1 Yes	Strong	Strong
de Castro, Rue et al. (2010).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
D'Souza, Strazdins et al. (2003).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Giatti, Barreto et al. (2008).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Giatti, Barreto et al. (2010).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Carpiano, Lloyd et al. (2009).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Krieger et al. (2016).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Krieger, Waterman et al. (2017).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Chambers, Baer et al. 2019).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Wallace, Crear-Perry et al. (2017).	Community	Community	1 Yes	1 Yes	Strong	Strong
Wallace, Crear-Perry et al. (2019).	Community	Community	1 Yes	1 Yes	Strong	Strong
Huynh, Spasojevic et al. (2018).	Community	Community	1 Yes	1 Yes	Strong	Strong
Shrimali, Pearl et al. (2020).	Community	Community	1 Yes	1 Yes	Strong	Strong
Krieger, Kim et al. 2018).	Community	Community	1 Yes	1 Yes	Strong	Strong
Krieger, Waterman et al. (2015).	Community	Community	1 Yes	1 Yes	Strong	Strong
Bell, Zimmerman et al. (2006).	Individual	Individual	1 Yes	1 Yes	Strong	Strong
Feldman et al, (2015).	Community	Community	1 Yes	1 Yes	Strong	Strong
Krieger, Singh & Waterman, (2016)	Community	Community	1 Yes	1 Yes	Strong	Strong
Do, Frank et al. (2017).	Community	Community	1 Yes	1 Yes	Strong	Strong